Annual Report 2019

Jožef Stefan Institute, Ljubljana, Slovenia

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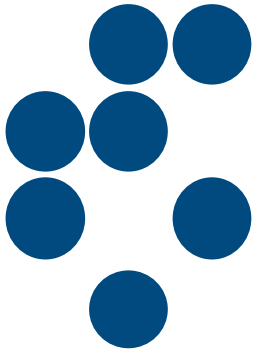
ANNUAL REPORT
JULY 2020

Annual Report 2019



Jožef Stefan Institute, Ljubljana, Slovenia

Annual Report 2019

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Ljubljana, July 2020

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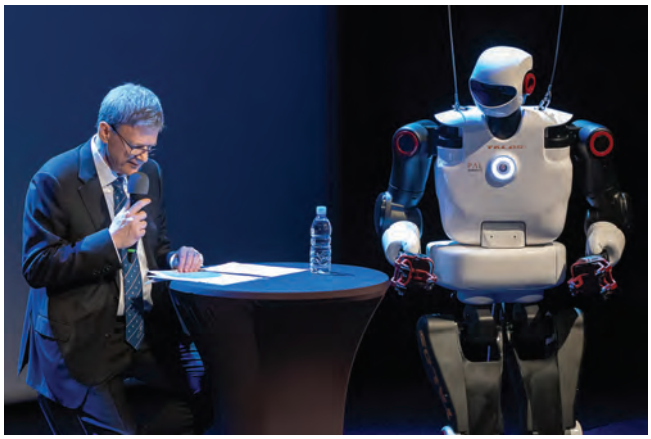
INTRODUCTION

The Jožef Stefan Institute dates back to the years after the Second World War. We believe that the Institute was formally established in 1949, but the development of the new institute took place over a long period of time in a rather complex social and political situation, at a time when educational and scientific policy in Slovenia was just being formed. The Institute started operating as the Physics Institute of the Slovenian Academy of Sciences and Arts. The primary aim of its first director, Anton Peterlin, was to create an environment to conduct high-quality physics research, with an emphasis on university teaching. However, the Institute soon became part of the federal nuclear program. In 1952, the Institute was named after the famous Slovenian physicist Jožef Stefan, who worked at the prestigious Vienna University in the Austro-Hungarian Empire during the 19th century.

The year 2019 thus marked the 70th anniversary of the Jožef Stefan Institute. We marked it with a series of events, with the main event taking place in the Linhart Hall of Cankarjev dom. The celebration of the 70th anniversary was not only about revisiting past events and listing the achievements in the history of our Institute, we also wanted to present to the Slovenian and international public the Institute as it is today, its importance for the development of Slovenia, as well as the Slovenian and international science that are conducted in our laboratories. I am happy to emphasize that the Institute is not only Slovenian, it is also a European institute, as its involvement in the European Research Area and its international cooperation and exchanges are crucial to its existence and operation. Last year, we added an agreement with the important Norwegian research organisation SINTEF to our many other agreements on bilateral cooperation.

In 2019, the Institute ended the year with 1061 employees, exceeding 1,000 employees for the first time. The situation in Slovenian science has improved in the past year, which is why we have been able to recruit more young doctoral students and postdoctoral associates. It is worth mentioning that most new employees come from abroad. The Institute's reputation in the international arena is great, which is also shown by the fact that among more than 8000 evaluated institutes from around the world, the Ranking Web of Research Centers put our institute as high as 102nd place. I also invite readers of this report to browse two publications published on the Institute's anniversary: the book "Inspired Searching", which presents the life of the Institute today with excellent images, and a short selection of photographs from the Institute's history "Utrinki 1949–2019" (Impressions 1949–2019).



Director Prof. Jadran Lenarčič in Cankarjev dom on the occasion of the 70th anniversary of the Jožef Stefan Institute.

Prof. Jadran Lenarčič
Director of the Jožef Stefan Institute

A BRIEF HISTORY OF THE JOŽEF STEFAN INSTITUTE

1946
~ Decision taken by the Slovenian Academy of Science and Arts to establish a Physics Institute

1949
~ Research connected to the peaceful use of atomic energy started, financed by the Federal Government

1952
~ Institute renamed the Jožef Stefan Physics Institute and moved to new laboratories on its present site

1954
~ The betatron and an electron microscope installed as the institute's first major pieces of equipment

1956
~ Van de Graaff accelerator, constructed at the institute, started operation

1958
~ Institute reorganised and new fields of activity defined: nuclear physics, solid-state physics, chemistry, and radiobiology

1959
~ Institute renamed the Jožef Stefan Nuclear Institute. The major source of income was provided by the Yugoslav Atomic Energy Commission

Mass spectrometer at the JSI (about 1960)

1962
~ One of the first compounds of a noble gas, XeF_6, synthesised at the institute
~ The first computer for research, ZUSE Z23, installed

1966
~ Nuclear research reactor TRIGA starts operation

1968
~ Yugoslav Atomic Energy Commission ceases to operate; The Republic of Slovenia becomes the institute's dominant source of research funding

1969
~ Institute is renamed as the Jožef Stefan Institute

1970
~ University of Ljubljana becomes a co-founder of the Jožef Stefan Institute, together with the Federal Executive Council

1971
~ A new unit, INOVA, established with the aim of applying the institute's expertise and output to productive use in the national economy

Institute buildings after the opening in 1953

1972
~ New computer Cyber 72 purchased, and the Republic Computer Centre established as an independent unit of the Jožef Stefan Institute

1974
~ Collaboration with the international centre CERN in the field of high-energy physics started
~ SEPO group for evaluating environmental interventions is established

1976
~ First Yugoslav 8-bit processor computer DARTA 80

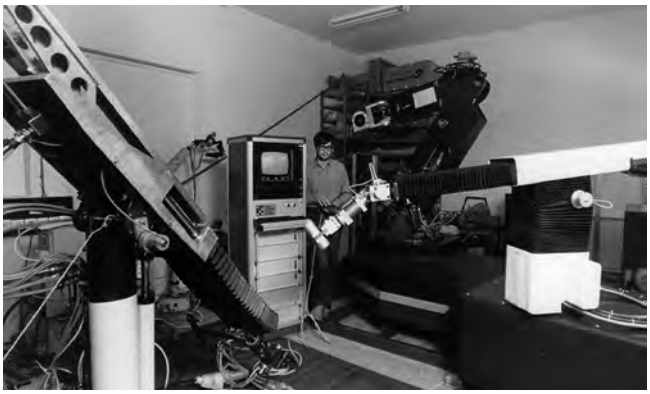
1979
~ Contract defining cooperation between the Jožef Stefan Institute and the Nuclear Power Plant Krško is signed
~ First robot in Slovenia is constructed

1982
~ Ecological Laboratory with Mobile Unit established as a special unit of the Slovenian Civil Protection Organisation

1983
~ Stefin, a cysteine proteinase inhibitor named after Jožef Stefan, isolated and its primary structure determined

The Reactor Centre, Podgorica, built in 1966

1985
~ "2000 New Young Researchers" project established by the Slovenian Research Council
~ Centre for Hard Coatings established by the Jožef Stefan Institute and the firm SMELT



The beginnings of robotics at the JSI, in 1985

1987
~ INEA established by the Jožef Stefan Institute as an independent company to promote technology transfer in the fields of cybernetics and energy management

1989
~ Milan Čopič Nuclear Training Centre established

1990
~ The first Slovenian supercomputer, CONVEX, installed at the Jožef Stefan Institute

1992
~ New technology centres established by the Ministry of Science and Technology
~ Jožef Stefan Institute restructured by the Slovenian Government as a public research institution
~ Jožef Stefan Technology Park founded, later to become the Ljubljana Technology Park

1995
~ Jožef Stefan Institute is a co-founder of the international postgraduate school for environmental sciences, the Nova Gorica Polytechnic
~ Research institutes in Velenje, ERICo and Valdoltra established by the Institute

1997
~ 3.5-MeV electrostatic accelerator, TANDETRON, installed

1999
~ Jožef Stefan Institute celebrates its 50th anniversary

2003
~ Jožef Stefan International Postgraduate School established

2004
~ Jožef Stefan Institute is chosen as the coordinator of four Research Centres of Excellence

2007
~ Nanomanipulation of single atoms using low-temperature scanning tunneling microscope
~ New ERDA/RBS beamline installed at the TANDETRON accelerator at the Microanalytical center

2015
~ New research infrastructure, including new and renovated laboratory and office space with high-tech instrumentation for environmental research

High-tech instrumentation for environmental research at the JSI in 2015

FORMER DIRECTORS

Prof. Anton Peterlin, first Director of the Jožef Stefan Institute

Prof. Anton Peterlin, Founder and first Director of the Jožef Stefan Institute, 1949–1955
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Prof. Milan Osredkar, 1963–1975
Prof. Boris Frlec, 1975–1984
Prof. Tomaž Kalin, 1984–1992
Prof. Danilo Zavrtanik, 1992–1996
Prof. Vito Turk, 1996–2005

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[1] since 1 July 2019 [2] until 31 October 2019 [3] since 1 November 2019

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University of Nova Gorica

Jožef Stefan International Postgraduate School

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Nanotesla Institute Ljubljana

Development Centre for Hydrogen Technologies

Technology Centre for Production Automation, Robotics and Informatics (ARI)

Centres of Excellence

Nanocenter - Center of Excellence in Nanoscience and Nanotechnology

Centre of Excellence for Integrated Approaches in Chemistry and Biology of Proteins (CIPKeBiP)

Centre of Excellence NAMASTE

Centre of Excellence for Polymer Materials and Technologies (PoliMaT)

EN-FIST Centre of Excellence

CEBIC Centre of Excellence for Biosensors, Instrumentation and Process Control

CO NOT: Centre of Excellence for Low-Carbon Technologies

Centre of Excellence for Space Sciences and Technologies SPACE-SI

[4] until 8 December 2019 [5] acting head since 9 December 2019

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Prof. Jadran Lenarčič

Assistant to the Director
Dr. Romana Jordan

Adviser
Marta Slokan, LL. B.

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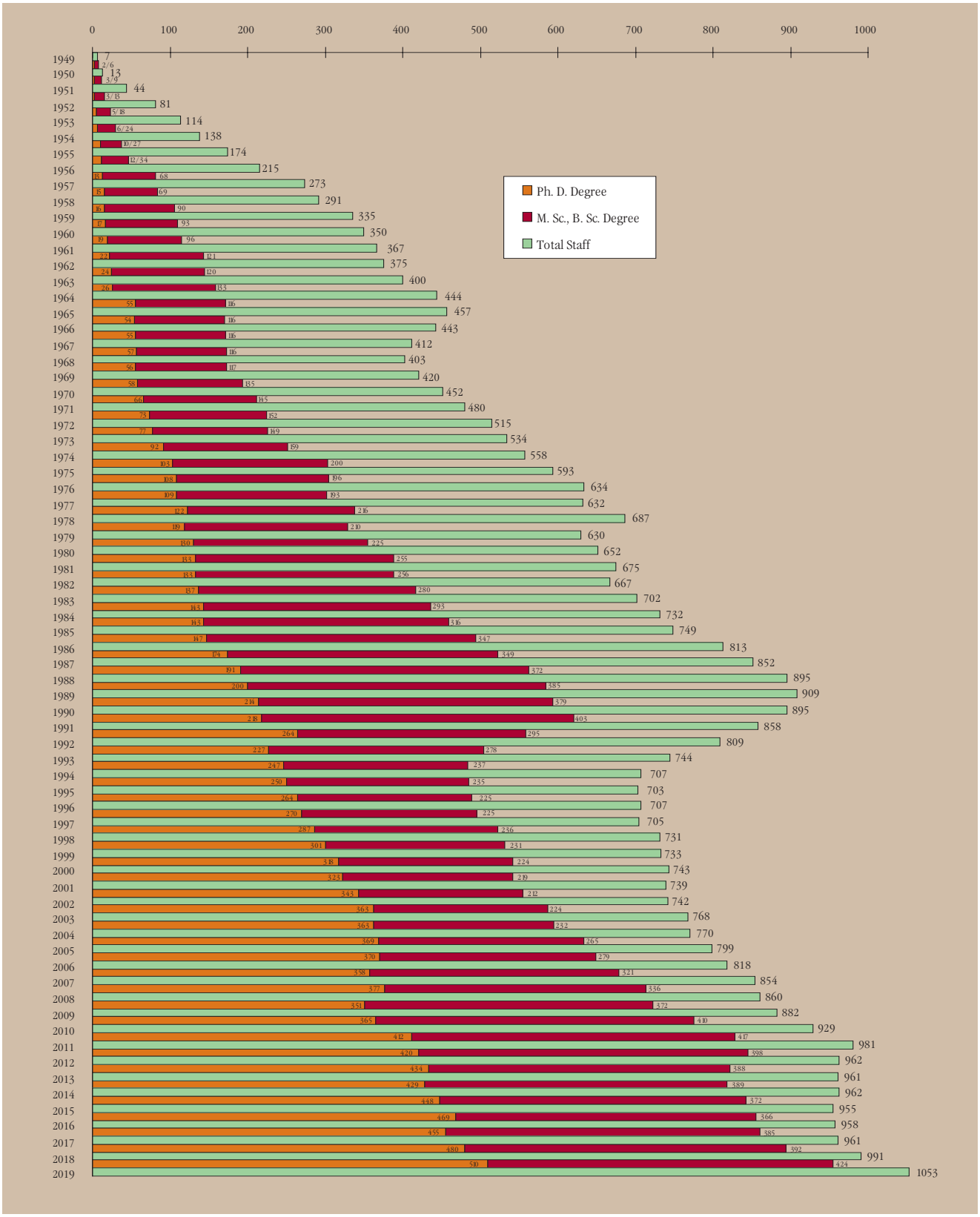
1949-2019



RECIPIENTS OF THE JSI AWARDS AND TITLES

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Prof. Robert Blinc†, President of the Scientific Council of the Jožef Stefan Institute from 1992 to 2007 (1933 - 2011)
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Prof. Boris Frlec, Director of the Jožef Stefan Institute from 1975 to 1984
Prof. Robert Huber, Nobel Prize Winner, Max-Planck-Institut für Biochemie, Munich, Germany
Prof. Milan Osredkar†, Director of the Jožef Stefan Institute from 1963 to 1975 (1919 - 2003)
Prof. Anton Peterlin†, Founder and First Director of the Jožef Stefan Institute from 1949 to 1955 (1908 - 1993)
Prof. Vito Turk, Director of the Jožef Stefan Institute from 1996 to 2005

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INTERNATIONAL COOPERATION

Multilateral international cooperation	No. of projects
H2020 (EUROPEAN INSTITUTE OF INNOVATION AND TECHNOLOGY, EXCELLENT SCIENCE, EURATOM, INDUSTRIAL LEADERSHIP, SOCIETAL CHALLENGES, SPREADING EXCELLENCE AND WIDENING PARTICIPATION, SCIENCE WITH AND FOR SOCIETY)	122
7. FP (COOPERATION: HEALTH, FOOD, AGRICULTURE/FISHERIES, BIOTECHNOLOGY, INFORMATION COMMUNICATION TECHNOLOGIES, NANOSCIENCES + NANOTECHNOLOGIES, MATERIALS + NEW PRODUCTION TECHNOLOGIES, ENERGY, ENVIRONMENT AND CLIMATE CHANGE, TRANSPORT (INCLUDING AERONAUTICS), SOCIO-ECONOMIC SCIENCES + THE HUMANITIES, SPACE, SECURITY; IDEAS: FRONTIER RESEARCH (EUROPEAN RESEARCH COUNCIL); PEOPLE: MARIE CURIE FELLOWSHIPS; CAPACITIES: RESEARCH INFRASTRUCTURES, SMEs, REGIONS OF KNOWLEDGE, RESEARCH POTENTIAL, SCIENCE AND SOCIETY, INCO (HORIZONTAL), DEVELOPMENT OF POLICIES) AND 7. FP - EURATOM	3
ESSR (INTERREG, KC, SRIP, SPS, KPP, RZ...)	41
OTHERS (COST, IAEA, JRC, ESA, CEF, EMPIR, ERASMUS+, LIFE+, ERA.NET, ARIMNET...)	210
TOTAL	**376**

Bilateral cooperation	No. of projects
Austria	4
Bosnia and Herzegovina	1
Germany	10
France	4
Croatia	6
Italy	3
Japan	3

Bilateral cooperation	No. of projects
Montenegro	1
Russia	1
Serbia	5
Turkey	1
USA	35
TOTAL	**94**

INTERNATIONAL COOPERATION AGREEMENTS

In 2019, international cooperation agreements were signed between the Jožef Stefan Institute and:

1. University of Montenegro, Podgorica, Montenegro (O2)
2. Open & Agile Smart Cities vzw, Brussels, Belgium (CSC&C)
3. Virginia Tech, Virginia, USA (F8)
4. SINTEF, Oslo, Norway (U1)

COOPERATION WITH HIGHER-EDUCATION ESTABLISHMENTS

FULL-TIME FACULTY MEMBERS

Professors

1. **Prof. Denis Arčon**, University of Ljubljana, Faculty of Mathematics and Physics
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33. **Prof. Žiga Šmit**, University of Ljubljana, Faculty of Mathematics and Physics
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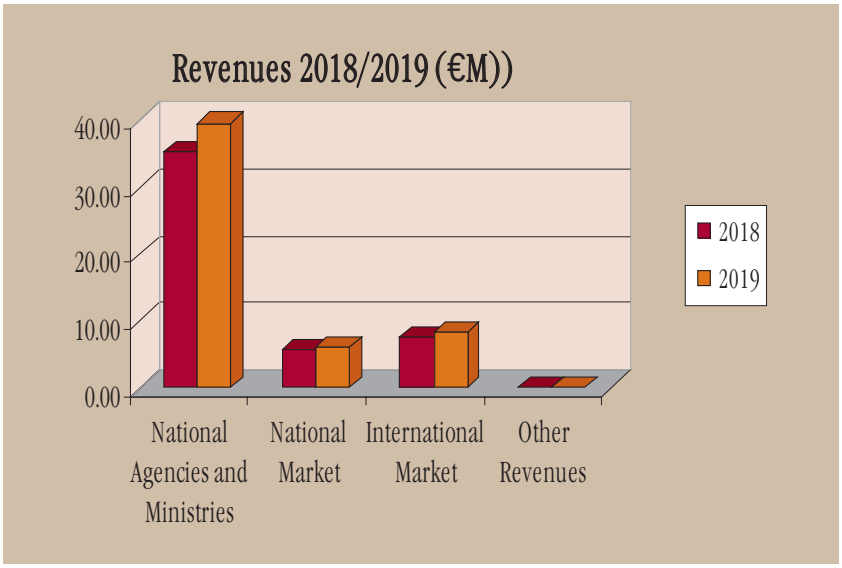
REVENUES JSI (€) AND NUMBER OF PROJECTS

	Contribution 2019	Contribution 2019	Contribution 2018	Contribution 2018	Index 2019/2018	No. of Projects in 2019
National Agencies and Ministries	39,744,499	73.0 %	35,471,296	72.4 %	112.0	364
National Market	6,104,020	11.2 %	5,820,996	11.9 %	104.9	430
International Market	8,501,438	15.6 %	7,533,096	15.4 %	112.9	330
Other Revenues	59,651	0.1 %	161,911	0.3 %	36.8	
TOTAL	**54,409,608**	**100.0 %**	**48,987,299**	**100.0 %**	**111.1**	**1124**



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1985-2019

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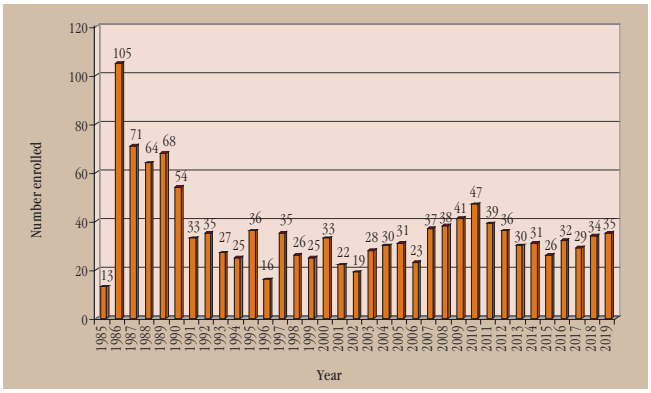

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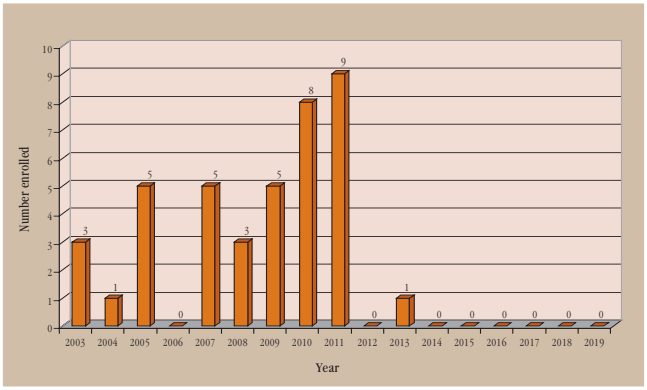

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1977-2019

Year	FMF		FKKT UNI LJ	FKKT UNI MB	NTF	FDV	FA	BF	FE and FRI	Other UNI LJ	FG and FERI	UNG	IPS	Total
	Physics	Mathematics												
... 1983	125	39	105						59	12	1			341
1984	11	3	7					1	12		1			35
1985	18	4	6					1	19		1			49
1986	16	8	4						22	2				52
1987	20	8	4						23	2				57
1988	26	7	8					1	27	2				71
1989	26	6	10					1	19	3	1			66
1990	26	5	11					2	25		1			70
1991	23	2	9					2	24	2	1			63
1992	22	3	16					3	17	1				62
1993	21	1	15					3	13	1				54
1994	7	1	8					3	6					25
1995	2		9					3	5					19
1996	2		9					3	5					19
1997	2		12					1	4		1			20
1998	1		6					1	7		1			16
1999	2		7					4	7					20
2000	1		5					3	9					18
2001	3		13					3	10					29
2002	4		20					3	10					37
2003	3		18					2	12	1				36
2004	4		17					1	15	1	2	2		42
2005	3		12			1		2	19		2	1		40
2006	2		12			1		1	17		2	2		37
2007	3		14			1		2	18		2	1		41
2008	2	1	13	3		1		2	15		1	1		39
2009	2	1	17	4		1		5	16		1	2		49
2010	2		11	5	2	1	1	3	10		1	2	5	43
2011	2	1	11	5	4	1	1	4	7		1		6	43
2012	2		10	6	3	1		3	6				5	36
2013	3	2	3	2	1		1		2	2			6	22
2014	14	6	3		2		1		3	2			1	32
2015	21	6	4		1				9	1			10	52
2016	16	2	5						7	1			15	46
2017	11	2	4					2	7				12	38
2018	**9**	**3**	**5**					**2**	**6**	**1**	**1**		**7**	**34**
2019	**16**	**1**	**5**						**7**		**1**		**12**	**42**
TOTAL	473	112	448	25	13	8	4	67	499	34	22	11	79	1795

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FKKT (Uni-Mb) Faculty of Chemistry and Chemical Technology, University of Maribor
NTF Faculty of Natural Sciences and Engineering, University of Ljubljana
FDV Faculty of Social Sciences, University of Ljubljana
FA Faculty of Administration, University of Ljubljana
BF Biotechnical Faculty, University of Ljubljana
FE Faculty of Electrical Engineering, University of Ljubljana
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FERI Faculty of Electrical Engineering and Computer Science, University of Maribor
UNG University of Nova Gorica
IPS Jožef Stefan International Postgraduate School
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PATENTS GRANTED

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4. Andraž Rešetič, Jerneja Milavec, Blaž Zupančič, Boštjan Zalar, Polymer dispersed liquid crystal elastomers (PDLCE), EP3119855 (B1), European Patent Office, 19. 06. 2019.
5. Nejc Lukač, Matjaž Lukač, Matija Jezeršek, Peter Gregorčič, Cleaning system, EP3127502 (B1), European Patent Office, 20. 03. 2019.
6. Gregor Primc, Miran Mozetič, Uroš Cvelbar, Alenka Vesel, Method and device for detection and measuring the density of neutral atoms of hydrogen, oxygen or nitrogen, EP3146327 (B1), European Patent Office, 06. 11. 2019.
7. Ita Junkar, Veronika Kralj-Iglič, Roman Štukelj, Rok Zaplotnik, Miran Mozetič, Method for treatment of tools and tools used for isolation of microvesicles, nanovescicles or exsomes, EP3185921 (B1), European Patent Office, 04. 09. 2019.
8. Tomaž Kompara, Igor Gornik, Peter Virtič, Rene Markovič, Miha Mlakar, Matjaž Gams, Danijel Jankovec, Jože Dermol, A smart home control system using artificial intelligence, SI 25667 (A), Urad RS za intelektualno lastnino, 31. 12. 2019.
9. Anton Umek, Boris Jerman, Mitja Gliha, Anton Kos, Iztok Špan, Link member for connection of a gripping assembly to a hydraulic crane arm with integrated dynamic weighing assembly, SI25473 (A), Urad RS za intelektualno lastnino, 31. 01. 2019.
10. Aleš Mrzel, Damjan Vengust, Method for the synthesis of metal molybdates and tungstates from molybdenum and tungsten carbides and nitrides, SI25549 (A), Urad RS za intelektualno lastnino, 31. 05. 2019.
11. Miha Glavan, Damir Vrančić, Dejan Gradišar, Iztok Humar, Mark Umberger, Satja Lumbar, System and procedure for managing the electrical power of the cooling system by regulating the product temperature and air temperature, SI25557 (A), Urad RS za intelektualno lastnino, 31. 05. 2019.
12. Rok Zaplotnik, Miran Mozetič, Gregor Primc, Alenka Vesel, Masaru Hori, Carbon nanostructured materials and methods for forming of these materials, SI25662 (A), Urad RS za intelektualno lastnino, 31. 12. 2019.

ART EXHIBITIONS AT THE JSI

Alenka Spacal, 14 January–14 February
Annamarie Saša Prah, 18 February–21 March
Utrinki 1949–2019, 18 March–31 December
IRWIN collective, 25 March–17 April
Klementina Golija, 23 April–8 May
Barbara Gregurič Silič, 13 May–29 May
Kiki Klimt, 3 June–19 June
Marjanca Prelog, 24 June–17 July
Primož Lampič, 22 July–5 September
Ivo Frbežar, 9 September–9 October
Jiři Bezlaj, 14 October–6 November
Cvetka Hojnik, 11 November–4 December
Katarina Spacal, 9 December–8 January 2020

Borut Pahor, President of the Republic of Slovenia, together with artists from the IRWIN collective, attending the opening of an IRWIN art exhibition at the Jožef Stefan Institute.

REVIEW OF PUBLICATIONS

FOR 2019

Department	Original Articles*	Books	Patent Appl. and Grants	Ph. D. Theses
Department of Theoretical Physics (F-1)	101	1		2
Department of Low and Medium Energy Physics (F-2)	71			
Department of Thin Films and Surfaces (F-3)	11			
Department of Surface Engineering and Optoelectronics (F-4)	50		3	1
Department of Solid State Physics (F-5)	126	5	2	3
Department of Gaseous Electronics (F-6)	36		3	1
Department for Complex Matter (F-7)	52	1	4	1
Department of Reactor Physics (F-8)	61	1	1	1
Department of Experimental Particle Physics (F-9)	145	3		
Department of Inorganic Chemistry and Technology (K-1)	32			
Department of Physical and Organic Chemistry (K-3)	14			2
Electronic Ceramics Department (K-5)	47		1	1
Department for Nanostructured Materials (K-7)	49		1	2
Department for Synthesis of Materials (K-8)	28			
Department for Advanced Materials (K-9)	42		3	
Department of Biochemistry, Molecular and Structural Biology (B-1)	23			
Department of Molecular and Biomedical sciences (B-2)	7			2
Department of Biotechnology (B-3)	32			1
Department of Environmental Sciences (O-2)	95	1		2
Department of Automation, Biocybernetics and Robotics (E-1)	46	1	1	2
Department of Systems and Control (E-2)	28		1	
Artificial Intelligence Laboratory (E-3)	53			
Laboratory for Open Systems and Networks (E-5)	19			
Department of Communication Systems (E-6)	53			1
Computer Systems Department (E-7)	40			
Department of Knowledge Technologies (E-8)	110	1	1	1
Department of Intelligent Systems (E-9)	60		1	
Department of Reactor Engineering (R-4)	53	1		2
Reactor Infrastructure Centre (RIC)	5			
Science Information Centre (SIC)	1			
Energy Efficiency Centre (EEC)	16			
Centre for Electron Microscopy and Microanalysis (CEMM)	5			
Centre for Knowledge Transfer in Information Technologies (CT-3)	1			1
Milan Čopič Nuclear Training Centre (ICJT)	7			
Radiation Protection Unit (SVPIS)	1			
Centre for Technology Transfer and Innovation (CTT)	3			
Center Factory of the Future (CFoF)	2		1	
Jožef Stefan Institute	1344	14	17	26

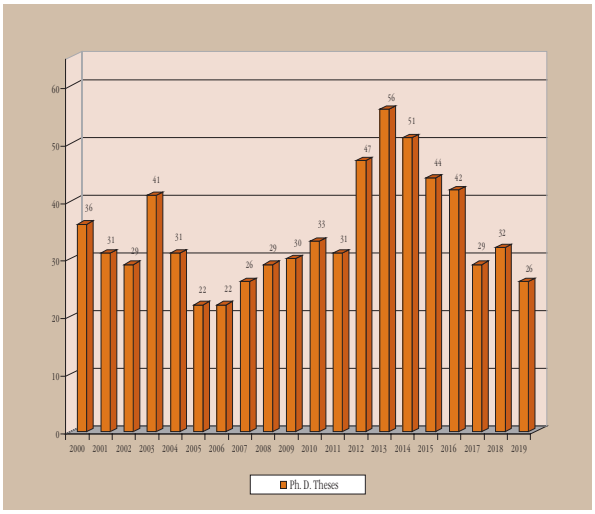
* Articles in Journals and Conference Proceedings, and Chapters in Books

COMPLETED THESES

UNTIL 2019

Year	Ph. D. Theses
...2000	560
2001	31
2002	29
2003	41
2004	31
2005	22
2006	22
2007	26
2008	29
2009	30

Year	Ph. D. Theses
2010	33
2011	31
2012	47
2013	56
2014	51
2015	44
2016	42
2017	29
2018	**32**
2019	**26**
TOTAL	1212



AWARDS AND APPOINTMENTS

AWARDS MADE TO JSI RESEARCHERS BY THE REPUBLIC OF SLOVENIA

Zois Award and Zois Certificate of Recognition

Denis Arčon

Presented with the Zois Award for outstanding scientific achievements in the field of quantum magnetism and unusual superconductivity

Nives Ogrinc

Presented with the Zois Award for outstanding achievements in the use of stable isotopes in interdisciplinary research

Miha Ravnik

Presented with the Zois Certificate of Recognition for outstanding achievements in the field of soft-matter physics

Boris Rogelj

Presented with the Zois Certificate of Recognition for outstanding achievements in the field of molecular basis of neurodegeneration

JSI AWARDS AND APPOINTMENTS

Emeritus Scientist

Gorazd Kandus

Emeritus Scientist: Prof. Gorazd Kandus

Blinc Award

Peter Prelovšek
Blinc Award for Lifetime Achievement in Physics

Martin Klanjšek
Blinc Award for Extraordinary One-time Achievements for proving the existence of unusual quasiparticles called anyons

Matjaž Perc
Blinc Award for physicist at the beginning of their career

The Jožef Stefan Golden Emblem Prize

presented to the following for doctoral theses with high impact :

Victor Vega Mayoral
Photophysics of transition-metal dichalcogenides obtained from liquid-phase exfoliation

Primož Koželj
Physical properties of high-entropy alloys and their comparison to complex intermetallics

JSI Director's fund

Blaž Alič, Mirela Dragomir, Kristian Radan, Matic Lozinšek
for the project entitled Extreme Conditions Chemistry Laboratory

OTHER SELECTED AWARDS TO JSI RESEARCHERS

Department of Intelligent Systems, Award for current work in the area of information society; Ljubljana; Information Society 2019 multiconference programme and organisation committee; recent success at scientific competitions

Department of Gaseous electronics, The paper "Towards universal plasma-enabled platform for the advanced nanofabrications: plasma physics level approach" was ranked in the top-3 papers of the publications in journal Reviews of Modern Plasma Physics.

The winners of Zois Awards and Zois Certificates of Recognition: Prof. Boris Rogelj, Prof. Nives Ogrinc, Prof. Denis Arčon and Prof. Miha Ravnik

Bojan Blažica, Barbara Koroušić Seljak, Peter Novak, Urban Škorc, Eva Valenčič, Information Strawberry, Ljubljana, 22nd International Multimedia Conference "Information Society". Award for the mobile app Know What You Eat - as the best achievement of the information society in 2018/19, 11. 10. 2019

Jasmin Bogatinovski, Dragi Kocev, The paper "Feature extraction for heartbeat classification in single-lead ECG" received an exceptional and outstanding paper award at the 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia, 25–29 May 2019

Andreja Bratovš, Highly Commended Poster Award, Barcelona, Spain, Perkin Elmer European In Vivo Optical Imaging User Group Meeting 2019, Stefin A-functionalized liposomes as a system for cathepsins S and L-targeted drug delivery.

Uroš Cvelbar became a fellow of the World Academy of Arts and Sciences (WAAS).

Božidara Cvetković, Robert Szeklicki, Vito Janko, Przemyslaw Lutomski, Mitja Luštrek, Excellent in science; Ljubljana; Slovenian Research Agency; human activity recognition with sensors

Mojca Čepič, Golden Award of the University of Ljubljana for successful research and pedagogical work, University of Ljubljana

Laura Drasler, Ula Dragman, Vič High School students, Krka Prize, "Coloidal silver in dental products", mentors: Anja Korent and Dr. Alenka Mozer (Vič High School).

Tome Eftimov, Best young scientist in North Macedonia for 2018, an award received from the president of North Macedonia Skopje, North Macedonia, 4. 4. 2019

Tome Eftimov, Extraordinary achievements in science, an award received from the mayor of Strumica, Strumica, North Macedonia, 11. 12. 2019

Darja Gačnik, Award for the best oral presentation in the young scientists' category, "Superconductivity in Ti–Zr–Hf–(Sn,Ni,Nb) high-entropy alloys", Dresden, Germany, European C-MetAC Days 2019

Lea Gašparič, 3. best poster prize at the 25th conference of the Slovenian Chemical Society

Hristijan Gjoreski, Simon Stankoski, Ivana Kiprijanovska, Stefan Kalabakov, Martin Gjoreski, Emteq Activity recognition challenge. 1st Place Award; Ubicomp 2019, London

Hristijan Gjoreski, Simon Stankoski, Ivana Kiprijanovska, Anastasija Nikolovska, Natasha Mladenovska, Marija Trajanoska, Bojana Velichkovska, Martin Gjoreski, Mitja Luštrek, Matjaž Gams, Challenge Up: Multimodal Fall Detection, 1st Place Award; International Joint Conference on Neural Networks (IJCNN) 2019.

Tanja Goričanec, Best Paper Award, 20 June 2019, Portorož, Slovenia, International Conference ANIMMA 2019 – Advancements in Nuclear Instrumentation Measurement Methods and their Applications, paper "Predicting Ex-Core Detector Response in a PWR with Monte Carlo Neutron Transport Methods"

Marko Grobelnik, Representative of Slovenia in Ad hoc Committee on Artificial Intelligence – CAHAI, Strasbourg, France, CAHAI

Marko Grobelnik, Head of subcommittee in OECD AI ONE for "AI Classification", Paris, France, OECD

James Hodson, honourable mention as the runner-up for the 2019 Hillcrest Behavioral Finance Award

Milena Horvat, ICMGP 2019 Life Achievement award - Kate Mahafy Life Achievement Award, Krakow, Poland, 8–13 September 2019

Hermina Hudelja, second place for her talk "Feather-light, cellulose-nanofiber-reinforced γ-Al_2O_3 foams", 27th International Conference on Materials and Technology (27th ICM&T), 16–18 October 2019, Portorož, Slovenia

Vito Janko, **Martin Gjoreski**, **Nina Reščič**, **Carlo Maria de Masi**, **Matjaž Gams**, **Mitja Luštrek**, SHL Challange – Sussex-Huawei Locomotion and Transportation Recognition Challenge, 1st Place Award; Ubicomp 2019, London.

The winners of the Jožef Stefan Golden Emblem Prize: Dr. Primož Koželj and Dr. Victor Vega Mayoral

Andreja Jelen, Award for the best poster, "Microstructure and magnetic properties of a single-crystalline FeCoCrMnAl high-entropy alloy", Kranjska Gora, The 14th International Conference on Quasicrystals (ICQ14)

Ita Junkar, Silver recognition of the Association for Technical Culture of Slovenia for the result achieved at the 53rd Meeting of young Researchers of Slovenia 2019 for supervising the research paper authored by Nika Špajzer and Nina Naprudnik

Marko Katrašnik, **Junoš Lukan**, **Mitja Luštrek**, **Vitomir Štruc**, Best paper award, Ljubljana, Program and organizing committee of Slovenian conference on artificial intelligence 2019 (International multiconference Information society), "Diarization procedure development using machine-learning algorithms"

Spomenka Kobe, Frey Award for Leadership in development new technologies that contribute to global sustainable development in the environment, economy, and social points of view, Paphos, Cyprus

Tajda Koblar, a Poljane High School student, Krka Prize, "Comparison of laser and water bath-based thawing process of frozen red blood cells", mentors: Dr Nina Kostevšek and Dr Ruka Rudež (Poljane High School).

Andraž Kocjan, "Young Scientist Award" given by the European Ceramic Society (ECerS) for outstanding contributions to the ceramic sciences, biannual 16th ECerS Conference, Turin, Italy

Barbara Koroušić Seljak, Supervisor of the Year 2018, Ljubljana, Young Academy of Slovenia, 19. 3. 2019

Nina Kostevšek, Best poster award at the H2020 COST Action training school in Trieste (CA17140 "Cancer nanomedicine - from bench to the bedside") for the presentation of her results on the development of multi-functional nanoparticles for medical applications. Dr Kostevšek is also a management committee member and representative for Slovenia in this COST Action, April 2019

Nina Kostevšek, Wüthrich International Young Star Award for the outstanding performance during the early career stages at Sustainable Industrial Processing Summit (SIPS 2019), Cyprus, 23–26 October 2019

Martin Košiček, The gold award for presentation in the section Young Scientists on Fundamentals and Applications of Dielectrics at 236th ECS Meeting in Atlanta 2019.

Janez Kovač, Recognition Congress Ambassador, Slovenian Convention Bureau for the organising the Joint Vacuum Conference JVC-16 and European Vacuum Conference EVC-14

Krajnc, **Bor**, **Nečemer**, **Marijan**, **Camin**, **Federica**, **Vogel-Mikuš**, **Katarina**, **Hamzić Gregorčič**, **Staša**, **Strojnik**, **Lidija**, **Ogrinc**, **Nives**, Best Poster Award, Characterization of truffles (Tuber sp.) in Slovenia using a stable isotope approach and elemental composition: 1st ISO-FOOD International Symposium on Isotopic and Other Techniques in Food Safety and Quality, Portorož, Slovenia, April 1–3, 2019.

Igor Križaj, Lapanje Award for outstanding scientific achievements in the field of biochemical sciences, Dobrna, 26. 9. 2019, Slovenian Biochemical Society.

Barbara Malič, Fellow of the European Ceramic Society

Barbara Malič, **Andrej Kitanovski** (UL FS), Excellent in Science ARRS 2019, ARRS, "Demo cooling device based on the electrocaloric effect"

Živa Marinko, presented a poster with the title "Connecting Metal Titanium Surface Properties and TiO_2 Nanotube Photocatalytic Activity: Top-Down Approach" and was awarded 3rd place at the Student Paper Contest as well as Environmental Science: Water Research & Technology Poster Prize, 6th European Conference on Environmental Applications of Advanced Oxidation Processes, 26–30 June 2019, Portorož, Slovenia

The winners of the JSI Director's fund award: Dr. Kristian Radan, Dr. Mirela Dragomir, Dr. Matic Lozinšek and Dr. Blaž Alič

Miran Mozetič, **Gregor Primc**, **Alenka Vesel**, Bronze medal ARCA 2019 at the 17th International Innovation Exhibition, Real Time Measurement of Radicals in Industrial Plasma Devices for Surface Modification, Zagreb, Croatia, 19 October 2019

Miran Mozetič, **Gregor Primc**, **Alenka Vesel**, **Rok Zaplotnik**, Recipients of the bronze medal ARCA 2019 at the 17th International Innovation Exhibition, Device and Method for Producing UV Radiation, Zagreb, Croatia, 19 October 2019

Nych Andriy, **Fukuda Jun-ichi**, **Ognysta Uliana**, **Slobodan Žumer**, **Igor Muševič**, Award for the best paper published in 2018 in the field of liquid crystals, "Spontaneous

formation and dynamics of half-skyrmions in a chiral liquid-crystal film", Tsukuba, Ibaraki, Japan, The Japanese Liquid Crystal Society

Nives Ogrinc, Nominated as a Congress Ambassador of Slovenia in 2019, Ljubljana, Slovenia,14 November 2019.

Panče Panov, received an award from the Faculty of Information Studies in Novo mesto for his contribution to raising the quality and outstanding achievements in the field of education for the year 2018.

Tadej Petrič, Leon Žlajpah, Best Student Paper Award, Kaiserslautern, Germany, RAAD 2019, KUKA LWR Robot Cartesian Stiffness Control Based on Kinematic Redundancy

Tadej Petrič, Leon Žlajpah, Second Best Application Paper Award, Kaiserslautern, Germany, RAAD 2019, On-line Adaption of Virtual Guides Through Physical Interaction.

Tadej Petrič, Leon Žlajpah, Best Paper Award, Srebrno Jezero, Serbia, IcETRAN 2019, End-effector cartesian stiffness optimization: sequential quadratic programming approach

Matic Poberžnik, best poster award at the "Quantum ESPRESSO Summer School on Advanced Materials and Molecular Modelling"

Chouhan, Raghuraj, Fajon, Vesna, Živković, Igor, Pavlin, Majda, Berisha, Sabina, Jerman, Ivan, Heath, David, Horvat, Milena, Best Poster Award, Development of an efficient passive sampler adsorbent for the detection of mercury in water via stratified nanostructured knitting, 1st ISO-FOOD International Symposium on Isotopic and Other Techniques in Food Safety and Quality, Portorož, Slovenia, April 1–3, 2019

Peter Rodič, Ingrid Milošev, Barbara Kapun, Damir Hamulić, Smart Coatings – from lab to commercial application, Road to market innovation as part of Innovation day, JUB, Dol pri Ljubljani, September 2019

Brigita Rožič, Fulbright grant for her excellent scientific and research work and congratulations of the President of the United States of America, Ljubljana, the US Embassy in Ljubljana as part of the Fulbright programme financed by the US government

Neelakandan M. Santosh, The best student presentation award at the conference PLATINUM 2019, Antibes, French Riviera, France

Gašper Stegnar, PhD Student award for outstanding and original contributions to research in the field of district heating and cooling at the 19th Eurheat & Power Congress, Nantes, France, the award was given by the DHC + Technology Platform

Strojnik, Lidija, Hladnik, Jože, Weber, Nika, Koron, Darinka, Stopar, Matej, Zlatić, Emil, Kokalj, Doris, Naglič Gril, Mateja, Grebenc, Tine, Perini, Matteo, Pianezze, Silvia, Camin, Federica, Ogrinc, Nives, Best Poster Award, Analytical technique sniffs out aroma, 11th Jožef Stefan International Postgraduate School Students' Conference and 13th Young Researchers' Day, 15–16 May 2019, Planica, Slovenia

Katja Škrlec, Krka Grand Prize for Research, Krka d.d., Novo mesto, Surface display of evasins and bepecin on bacteria *Lactococcus lactis* NZ9000 and *Lactobacillus salivarius* ATCC 11741 and evaluation of their anti-inflammatory action, Novo mesto, 18 October 2019

Iztok Tiselj, Gold plaque for outstanding merit in developing scientific, pedagogical or artistic creativity and for strengthening the university's reputation, University of Ljubljana, 3 December 2019

Mitja Uršič, Žan Kogovšek, Matjaž Leskovar, Matej Tekavčič, Best poster award (NENE2019 conference, Portorož, Slovenia, 9–12 September 2019), Nuclear Society of Slovenia, for the paper "Simulations of heat and mass transfer around circular core fragment in sodium coolant"

Eva Valenčič, Prešeren Award of the Biotechnical Faculty, Ljubljana, Award for the work "Optimization of the Slovene Food Basket Using the Linear Programming Method", 25. 11. 2019

Yevhenii Vaskivskyi, SPO-2019 prize for the best poster presentation "Investigation of metastable states in 1T-TaS2 by combining ultrafast spectroscopy with scanning tunneling microscopy", 20th International Young Scientists Conference Optics and High Technology Material Science (SPO 2019), 26–29 September 2019, Kyiv, Ukraine

Jaka Vodeb, SMEC Student Prize 2019 for an outstanding oral presentation "Correlated Configurational States and a Quantum Charge Liquid in Layered Metallic Dichalcogenides", International meeting Study of matter at extreme conditions (SMEC 2019), 30 March–6 April 2019, Miami – East Caribbean – Miami, USA

Vrzel Janja, Ogrinc Nives, Ludwig Ralf, Award for best presentation at the conference, A modelling framework for simulating groundwater and surface water dynamics and their interactions at the 2nd Atlas Georesources International Congress, Applied Geosciences for Groundwater, Hammamet, Tunisia in March 2019.

Abida Zahirović, Borut Štrukelj, Mojca Lunder (Faculty of Pharmacy, University of Ljubljana), **Ana Koren, Peter Kopač, Peter Korošec** (University Hospital, Golnik), Best research achievements in 2019, Ljubljana, University of Ljubljana, An important step towards more effective immunotherapy for allergy to bee venom, 18 December 2019

Abida Zahirović, Faculty of Pharmacy Dean´s Awards 2019, University of Ljubljana, Faculty of Pharmacy, Identification of epitopes of major bee venom allergen Api m 1 and characterisation of corresponding mimotopes for use in immunotherapy, 4 December 2019

Dolores Zimerl, best poster award at the 7th RSE-SEE conference ("Regional Symposium on Electrochemistry - South East Europe"), Split, Croatia, 27–30 May 2019

Martin Žnidaršič, Bernard Ženko, Aljaž Osojnik, Marko Bohanec, Panče Panov, The paper "Multi-criteria Modelling Approach for Ambient Assisted Coaching of Senior Adults", best paper award at the 11th International Conference on Knowledge Engineering and Ontology Development, Vienna, Austria, 17–19 September 2019

Slobodan Žumer, Frederiks medal for outstanding achievements in the theory of liquid crystals and related materials, Wroclaw, Poland, Russian Liquid Crystal Society

KNOWLEDGE TRANSFER

The JSI pays a lot of attention to furthering its links with industry. In keeping with European aims and the objectives of the Slovenian government, the JSI organized several important meetings on the subject of cooperation with enterprises and industry. In this way the JSI introduced a new method of cooperation, showing industry and the public that it is aware of its leading role, not only in research but also in the transfer of knowledge into practice.

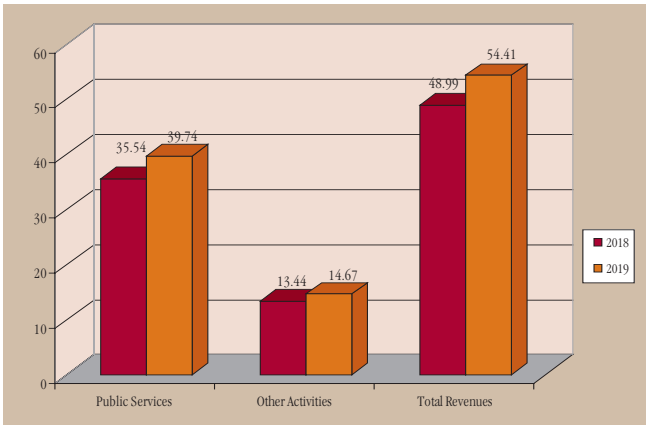
R & D PROJECT PARTNERS

1. 4Ocean Design, d. o. o., Ljubljana
2. Abc Accelerator, d. o. o., Ljubljana
3. Administration of the Republic of Slovenia for Food Safety, Veterinary and Plant Protection, Ljubljana
4. Adriaplin, d. o. o., Ljubljana
5. Aerosol, d. o. o., Ljubljana
6. Agency for Radwaste Management, Ljubljana
7. Akrapovič, d. d., Ivančna Gorica
8. Alma Mater Europaea, Maribor
9. Association of Urban Municipalities of Slovenia, Ljubljana
10. Atlantic Droga Kolinska, d. o. o., Ljubljana
11. Banka Intesa Sanpaolo, d. d., Koper
12. Biosistemika, d. o. o., Ljubljana
13. Brinox Process Systems, Medvode
14. Central Technical Library at the University of Ljubljana, Ljubljana
15. Chemcolor Sevnica, d. o. o., Sevnica
16. Comland, d. o. o., Ljubljana
17. Comsensus, d. o. o., Dob
18. Culmium, d. o. o., Kranj
19. Časnik Finance, d. o. o., Ljubljana
20. Dars, d. d., Celje
21. Društvo elektronikov Slovenije, Divača
22. Eles, d. o. o., Electricity Transmission System Operator, Ljubljana
23. Elestra, d. o. o., Ljubljana
24. Energetika Maribor, d. o. o., Maribor
25. Euro Plus, d. o. o., Šenčur
26. Eurofins Erico Slovenija, d. o. o., Velenje
27. Gen Energija, d. o. o., Krško
28. Generali Insurance, d. d., Ljubljana
29. Gentech, d. o. o., Ljubljana
30. Goap, d. o. o., Nova Gorica
31. Gorenje gospodinjski aparati, d. o. o., Velenje
32. Gostol - Gopan, d. o. o., Nova Gorica
33. Government Office for Development and European Cohesion Policy, Ljubljana
34. Helios, Domžale
35. Hidroelektrarne na Spodnji Savi, d. o. o., Brežice
36. Innovation Technology Cluster (ITC) Murska Sobota, Murska Sobota
37. InoVine, d. o. o., Ljubljana
38. Instrumentation Technologies, d. o. o., Solkan
39. Intersocks, d. o. o., Kočevje
40. Iskra, d. o. o., Ljubljana
41. Jernej Rančnik s. p., Laporje
42. KMZ - Zalar Miran s. p., Ljubljana
43. Knauf Insulation, d. o. o., Škofja Loka
44. Kolektor Group, d. o. o., Idrija
45. Krško Nuclear Power Plant, d. o. o., Krško
46. Lastinski, d. o. o., Novo mesto
47. Lek, d. d., Ljubljana
48. Lotrič Certificiranje, d. o. o., Železniki
49. LPKF Laser & Electronics, d. o. o., Naklo
50. Melamin, d. d., Kočevje
51. Microbium, d. o. o., Ljubljana
52. Milan Vidmar Electric Power Research Institute, Ljubljana
53. Ministry of Defence, Ljubljana
54. Ministry of Education, Science and Sport, Ljubljana
55. Ministry of Infrastructure, Ljubljana
56. Ministry of Justice, Ljubljana
57. Ministry of the Environment and Spatial Planning, Ljubljana
58. MK Team, d. o. o., Raka
59. MPT, d. o. o., Šmartno ob Paki
60. Nanos Scientificae, d. o. o., Ljubljana
61. National Institute of Biology, Ljubljana
62. National Institute of Chemistry, Ljubljana
63. Netis, d. o. o., Ljubljana
64. Odelo Slovenija, d. o. o., Prebold
65. Particulars, d. o. o., Domžale
66. Petrol, d. d., Ljubljana
67. Plamtex INT., d. o. o., Komenda
68. Plinovodi, d. o. o.
69. Podkrižnik, d. o. o., Ljubljana
70. Quintelligence, d. o. o., Ljubljana
71. Razvojni Center eNeM Novi Materiali, d. o. o., Zagorje ob Savi
72. Semantika, d. o. o., Maribor
73. SIJ Acroni, d. o. o., Jesenice
74. Slovenian Biochemical Society, Ljubljana
75. Slovenian National Building and Civil Engineering Institute, Ljubljana
76. Slovenian Radiation Protection Administration, Ljubljana
77. Slovenian Reserch Agency, Ljubljana
78. Slovensko društvo ljubiteljev kemije, Ljubljana
79. Statistical Office of the Republic of Slovenia, Ljubljana
80. Telekom Slovenije, d. d., Ljubljana
81. Trinet, d. o. o., Ljubljana
82. Unicredit Banka Slovenija, d. d., Ljubljana
83. University of Ljubljana, Ljubljana
84. University of Maribor, Maribor
85. University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies, Koper
86. Zdravstveni Dom Dr. Adolfa Drolca, Maribor

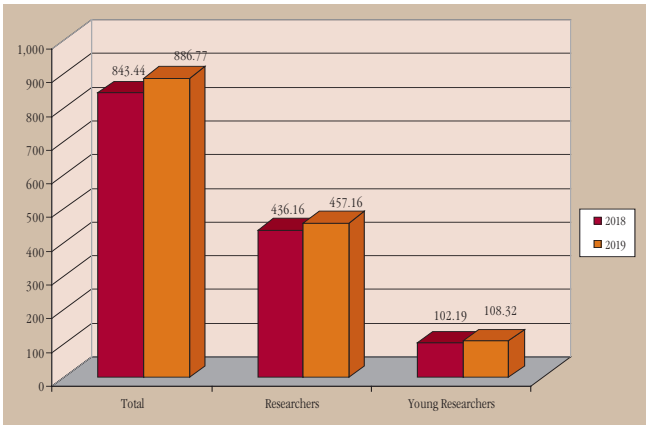
INSTITUTE IN NUMBERS

2018–2019

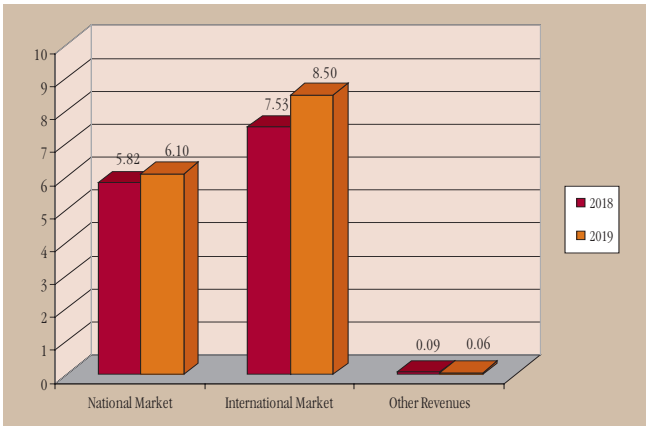
COMPARISON OF REVENUES (€M)



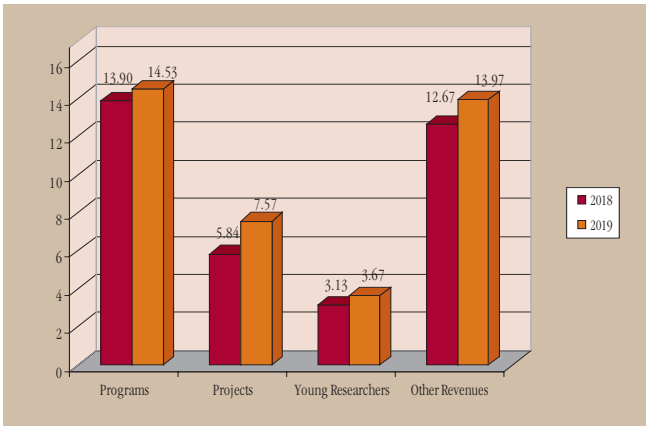
EMPLOYEES (FTE)



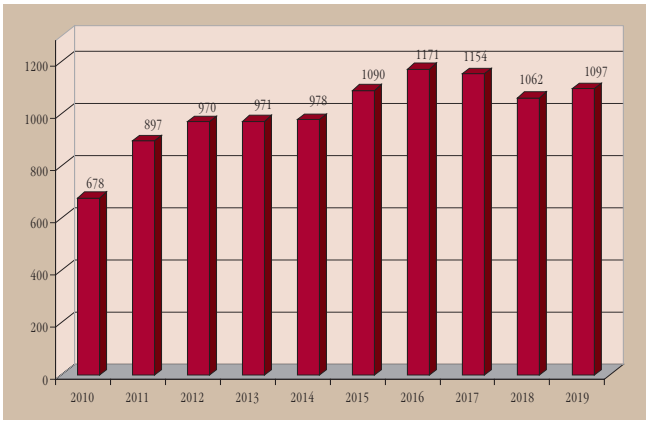
REVENUES FROM OTHER ACTIVITIES (€M)



REVENUES FROM PUBLIC SERVICES (€M)

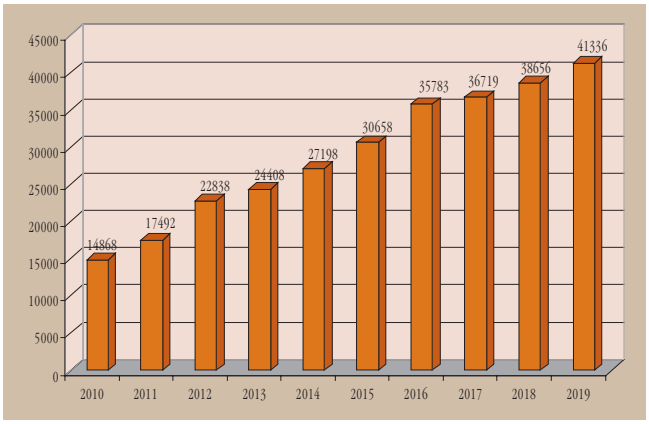


NUMBER OF PUBLICATIONS IN THE WEB OF SCIENCE*



* retrieved 6 July 2020

NUMBER OF CITATIONS IN THE WEB OF SCIENCE*



* retrieved 6 July 2020

RESEARCH DEPARTMENTS

DEPARTMENT OF THEORETICAL PHYSICS F-1

In 2019 members of the programme group THEORY OF NUCLEUS, ELEMENTARY PARTICLES AND FIELDS have continued with research in the area of hadronic physics, quantum chromodynamics, the effective field theory of electroweak decays of mrsons, unified theory and precise calculation in three-body systems

Head:
Prof. Jernej Fesel Kamenik

Using quantum chromodynamics on the lattice, we established that P_c pentaquarks do not appear in the one-channel scattering of a proton and J/ψ, which indicates that the coupling between the channels is crucial for their existence. Simulating the $D\bar{D}$ scattering, we determined the mass and the width of the charmonium vector resonance $\psi(3770)$ and the mass of the very recently discovered spin three resonance $X(3842)$, both in agreement with experiment. We calculated the energies and identified J^{PC} for numerous charmonia with spin up to $J \leq 3$, ignoring their strong decays. We identified a new approximate symmetry $SU(2)_{cs}$ of QCD in the extended temperature range $T \simeq 220–500$ MeV.

We proposed a new approach for computing tunnelling rates in quantum or thermal field theory with multiple scalar fields. It is based on exact analytical solutions of the piecewise linear potentials with many segments that describe any given potential to an arbitrary precision. The method was first developed for the single-field case in 3 and 4 space-time dimensions and demonstrated on examples of classic potentials as well as the calculation of quantum fluctuations. A systematic expansion of the potential beyond the linear order was considered, taking into account higher-order corrections, which paves the way for multiple scalar fields. We thereby provided a fast, semi-analytical tool for evaluating the bounce action for theories with an extended scalar sector.

We presented a prescription for using the a central charge to determine the flow of a strongly coupled supersymmetric theory from its weakly coupled dual. We classified all Kutasov-Seiberg-type dualities in large N_c SQCD with adjoints of rational R-charges by equating the superconformal index of the electric and magnetic theories: the obtained equation has a solution each time some product of cyclotomic polynomials has only positive coefficients.

Motivated by the existence of dark matter, we examined theoretical features of $U(1)_X$ extensions of the Standard Model, whose quantum anomalies are cancelled per generation. We considered experimental constraints in the MeV region. In particular, we focused on the model UV-completed by cold WIMPs. We derived the expressions for the full angular distributions of $B \to Dl\nu_l$ and $B \to D^* l\nu_l$ decays and discuss the spectra on each angle separately.

We proposed a novel strategy to test lepton-flavour universality (LFU) in top decays, applicable to top-pair production at colliders. We applied techniques from Bayesian generative statistical modelling to uncover hidden features in jet substructure observables that discriminate between different a-priori unknown underlying short-distance physical processes in multi-jet events. We also contributed to a community white paper on machine-learning approaches to top tagging as well as several CERN Yellow reports on the FCC-ee Lepton Collider, FCC-hh Hadron Collider as well as FCC Physics Opportunities; on the HE-LHC: The High-Energy Large Hadron Collider, including opportunities in flavour physics at the HL-LHC and HE-LHC and Higgs physics at the HL-LHC and HE-LHC. For a review article "GUT physics in the era of the LHC" we have prepared a review of phenomenology of leptoquarks.

- **We applied techniques from Bayesian generative statistical modelling to uncover hidden features in jet substructure observables that discriminate between different a-priori unknown underlying short-distance physical processes in multi-jet events.**
- **We constrained the parameter space of the $U(1)_X$ extension of the Standard Model that can accommodate the dark-matter model in the MeV region.**
- **We developed a fast and robust method to compute the probability of nucleating an energetically favourable bubble of vacuum, both in quantum and thermal field theories, which may control the production of gravitational waves, baryogenesis and primordial magnetic fields.**
- **We studied the RG flow of a supersymmetric theory through its dual and classified the dualities of a given type.**
- **We established that pentaquarks P_c do not appear in the one-channel scattering of a proton and J/ψ, which indicates that the coupling between channels is crucial for their existence.**

Some outstanding publications in the past year

1. Dillon, Barry M., Faroughy, Darius Alexander, Kamenik, Jernej. Uncovering latent jet substructure. Physical review. D, ISSN 2470-0010, 2019, vol. 100, no. 5, str. 056002-1-056002-8, doi: 10.1103/PhysRevD.100.056002. [COBISS.SI-ID 32686631]
2. Bečirević, Damir, Fajfer, Svjetlana, Nišandžić, Ivan, Tayduganov, Andrey. Angular distributions of $\bar{B}\to D(*)\ell\bar{\nu}_\ell$ decays and search of New Physics. Nuclear physics. Section B, ISSN 0550-3213. [Print ed.], Sep. 2019, vol. 946, art. no. 114707, 27 str., ilustr., doi: 10.1016/j.nuclphysb.2019.114707. [COBISS.SI-ID 3349860]
3. Guada, Victor, Maiezza, Alessio, Nemevšek, Miha. Multifield polygonal bounces. Physical review. D, ISSN 2470-0010, 2019, vol. 99, no. 5, str. 056020-1-056020-17, doi: 10.1103/PhysRevD.99.056020. [COBISS.SI-ID 32246055]

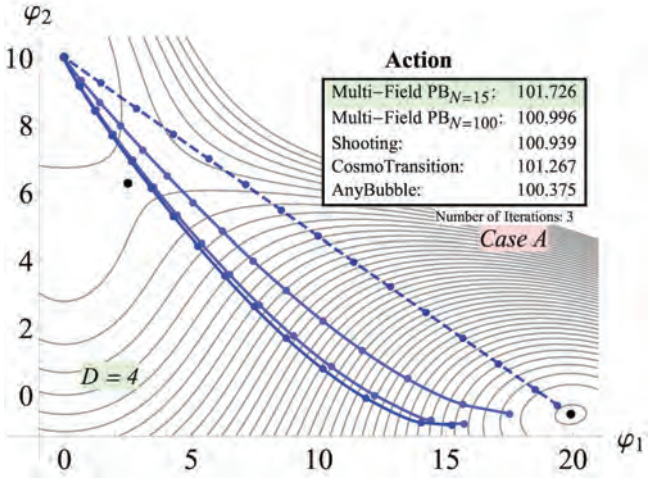


Figure 1: Multi-field polygonal bounce solution for two scalar fields. We use the fast polygonal method to evaluate within a couple of iterations the Euclidean action that controls the tunnelling probability in quantum and thermal field theory. The inset contains the resulting action compared to other approaches.

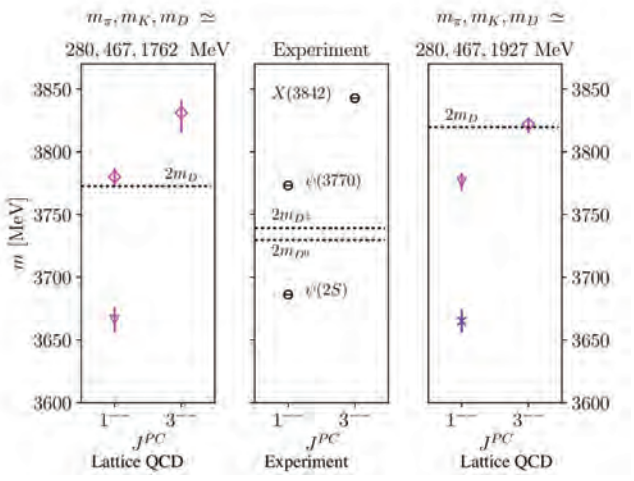


Figure 2: The masses $\bar{c}c$ charmonium resonances with J^{PC}= 1−− and 3−− obtained from our lattice QCD study at two values of the charm-quark mass, compared to experiment. X(3842) was discovered by LHCb in 2019 and is the first experimentally discovered $\bar{c}c$ with spin-three.

The group of SOLID-STATE THEORY AND STATISTICAL PHYSICS has been investigating the equilibrium and non-equilibrium properties of materials with strongly correlated electrons, nanosystems, as well as the properties of complex networks.

Within the theory of disordered many-body quantum models we continued the investigations of the one-dimensional Hubbard model with potential disorder. We showed that in the case of SU(2) spin symmetry and large disorder the spin dynamics remains sub-diffusive, while in contrast the energy as well as the charge transport exhibit marginal localization. Both these phenomena can be explained within an effective spin model with singular distribution of exchange coupling. When the SU(2) symmetry is broken, e.g., via the spin-dependent hopping, the many-body localization can be restored for both charge and spin degrees.

We have shown that a quantum particle propagates sub-diffusively in a strongly disordered chain when coupled to itinerant hard-core bosons. We have established a generalized Einstein relation that relates such a sub-diffusive spread to an unusual time-dependent drift velocity, which appears as a consequence of a constant electric field. We show that the Einstein relation remains valid well beyond the regime of the linear response.

Within the framework of the polaron theory we have computed the temperature-dependent spectral function of an electron, coupled to quantum Einstein dispersionless phonons. We have shown that with increasing temperature, additional spectral weight develops below the polaron band around the centre of the Brillouin zone. We have also derived exact frequency sum rules and used them to check the validity of the numerical approach.

- **We have established a generalized Einstein relation that relates sub-diffusive spread to an unusual time-dependent drift velocity, which appears as a consequence of a constant electric field.**
- **We showed that the Holstein polaron model represents a paradigmatic model to describe quantum chaos and ETH in many-body quantum systems.**
- **We explored how the Mott state collapses in a domain wall of a Mott insulator on triangular lattice 1T-TaS2.**
- **From human connectome to self-assembled nanonetworks, hidden structures like simplicial complexes might contain a geometric code to improve the network's performance.**

We studied a minimal model of electron-phonon coupling (the Holstein polaron model), viewed as a closed quantum system. We have investigated whether such a model exhibits thermalization of a perturbed nonequilibrium system and whether its eigenstates satisfy the eigenstate thermalization hypothesis (ETH).

We studied nonequilibrium states of the Chern insulator in the ribbon geometry produced during a slow quench from a trivial to a topological phase. We showed that the density of excitations in the edge states can be explained with the Kibble-Zurek mechanism. We also considered quenches in the Su-Schrieffer-Heeger model where the chiral symmetry is dynamically broken. To characterize nonequilibrium states generated in this way we introduced a generalized winding number. In the context of the development of magnesium batteries we studied the morphology evolution of different surface orientations of a magnesium crystal during deposition.

We performed studies of various lattice strongly-correlated problems using the dynamical mean-field methodology, with extensions to real-space dependence and to non-local correlations. Specifically, we studied the possibility of the metallization of domain-walls in the Mott insulator 1T-TaS_2, the magnetization curves in a Kondo lattice model with a finite concentration of magnetic impurities, and we investigated the role of vertex corrections in the Hubbard model on a square lattice. We also provided theoretical support to cold-atom experiments where bosonic jets were produced by the time-modulation of the interaction via Feshbach resonance.

We have investigated hidden geometries as topological substructures that influence the improved function of complex networks. For this purpose, we have developed models of self-organization of simplexes of a given size, by means of which we have generated different networks with hidden structures and at the same time controlled the spectral properties of the Laplace diffusion operator on these networks. We also studied the structure of simplicial complexes in human-brain networks, which are generated from experimental data collected through the Human Connectome Project. In disordered systems driven by an external magnetic field, we investigated changes in the critical fluctuations on the hysteresis loop in the transition from 2-dimensional to 3-dimensional structures by means of extensive numerical simulations and finite-size scaling and multi-fractal analyses of Barkhausen noise.

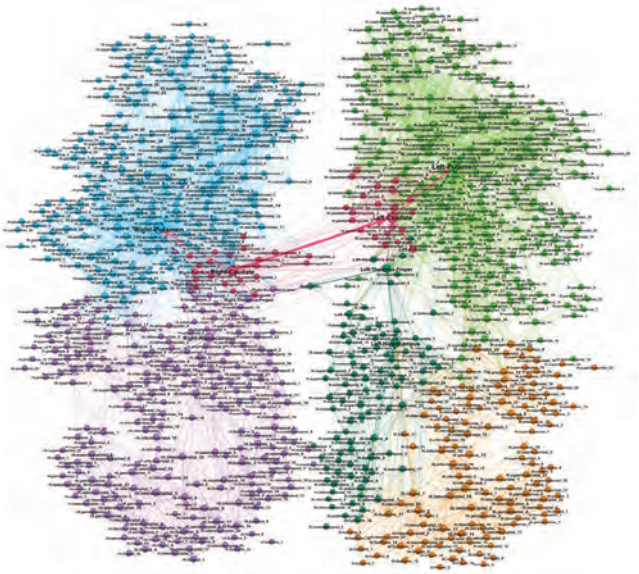


Figure 3: The human-brain network generated from HCP data; nodes represent named anatomical areas that have merged into functional modules marked in different colours.

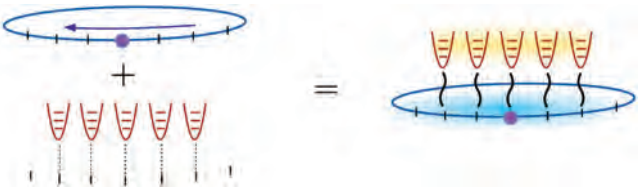


Figure 4: Quantum chaos and thermalization (right panel) emerging from coupling of a single electron (upper left) to independent local harmonic oscillators (lower left).

Some outstanding publications in the past year

1. Tadić, Bosiljka, Andjelković, Miroslav, Melnik, Roderick. Functional geometry of human connectomes. Scientific reports, ISSN 2045-2322, 2019, vol. 9, str. 12060-1-2060-12, doi: 10.1038/s41598-019-48568-5. [COBISS.SI-ID 32573735]D. Jansen, J. Stollp, L. Vidmar in F. Heidrich-Meisner, Physical Review B 99, 155130 (2019)
2. Skolimowski, Jan, Gerasimenko, Yaroslav, Žitko, Rok. Mottness collapse without metallization in the domain wall of the triangular-lattice Mott insulator 1T - TaS2. Physical review letters, ISSN 0031-9007. [Print ed.], 2019, vol. 122, no. 3, str. 036802-1-1-036802-6, doi: 10.1103/PhysRevLett.122.036802. [COBISS.SI-ID 32057895]
3. Mierzejewski, Marcin, Prelovšek, Peter, Bonča, Janez. Einstein relation for a driven disordered quantum chain in the subdiffusive regime. Physical review letters. [Print ed.]. 2019, vol. 122, iss. 20, str. 206601-1-206601-7, graf. prikazi. ISSN 0031-9007. DOI: 10.1103/PhysRevLett.122.206601. [COBISS.SI-ID 3313764]

The group for THEORETICAL BIOPHYSICS AND SOFT-MATTER PHYSICS investigated polyelectrolytes, liquid crystals, colloids, and phospholipid and biological membranes.

We studied molecular packing in continuous network liquid-crystalline phases. We proposed a new packing model of the phase, we used the resonant X-ray scattering to confirm two models of molecular packing in the phase, and we observed and described a new non-cubic continuous phase

We analysed the effects of chiral dopands on liquid-crystalline structures formed by chiral polar molecules

Figure 5: Cell-size pleomorphism drives aberrant dispersal in proliferating epithelia

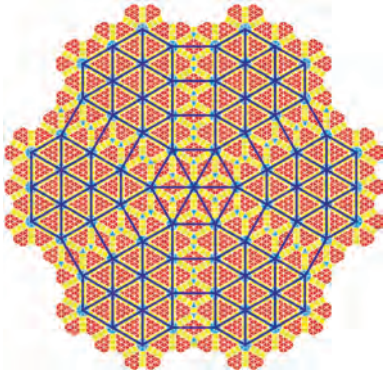


Figure 6: Second-generation quasicrystalline tiling with six-fold symmetry

with the symmetry. We theoretically showed that chiral dopants affect the structure of liquid-crystalline phases formed by achiral polar molecules, and that they modify the stability of the chiral domains and the phase itself. We discovered a two-parameter family of quasicrystalline tilings with six-fold symmetry that approach a hexagonal crystal in the limiting case and thus represent aperiodic approximants of periodic crystals. We generalized the concept of hyperuniformity from Euclidean space to the sphere, which can be used to describe the distributions of particles on the sphere and to detect order-disorder transitions in different systems.

Using computer simulations, we investigated the nature of the solvation properties of ions and charged molecules in thermo-responsive hydrogels, revealing the crucial role of the water interfacial potential in these processes. We studied the stability of biological fluids under negative pressure conditions, such as those occurring in plants. Our findings show that the presence of lipid aggregates imposes an upper limit for the magnitude of negative pressure, thereby restricting the height to which trees can grow. We explored the role of electrostatic interaction for morphological changes in viral capsids, which occur during their life cycle, and we studied how the stability of capsids is influenced by the encapsulated charged cargo.

We studied the phase diagram of limiting shapes of lipid vesicles confined to a spherical cavity, providing a basis for the understanding of complex vesicular formations such as the mitochondrion. Using a model where the structure of a simple epithelial tissue is represented by the vector of polygon classes seen on the apical side, we investigated the structure of proliferating tissues. We studied the in-plane cell arrangements in a fruit fly's wing disk during its growth. We found that small cells tend to disperse, whereas large cells prefer to maintain a compact squad. We studied the dynamics of nuclear packing at the surface of the fruit fly's embryo during its early development. We found that while the nuclei undergo synchronous divisions, the statistical-mechanical properties of their packing are preserved despite the 6-fold increase of density.

Some outstanding publications in the past year

1. Nakakura, Joichiro, Ziherl, Primož, Matsuzawa, Junichi, Dotera, Tomonari. Metallic-mean quasicrystals as aperiodic approximants of periodic crystals. Nature communications, ISSN 2041-1723, Sep. 2019, vol. 10, art. no. 4235, 8 str., ilustr., doi: 10.1038/s41467-019-12147-z. [COBISS.SI-ID 3365220]
2. Kanduč, Matej, Kim, Won Kyu, Roa, Rafael, Dzubiella, Joachim. Aqueous nanoclusters govern ion partitioning in dense polymer membranes. ACS nano, ISSN 1936-0851, 2019, vol. 13, no. 10, str. 11224-11234, doi: 10.1021/acsnano.9b04279. [COBISS.SI-ID 32800039]
3. Subramanian, Pazhayannur Ramanathan, Krajnc, Matej, Gibson, Matthew C. Cell-size pleomorphism drives aberrant clone dispersal in proliferating epithelia. Developmental cell, ISSN 1534-5807, [in press] 2019, str. 15, doi: 10.1016/j.devcel.2019.08.005. [COBISS.SI-ID 32748071]

Awards and appointments

1. Prof. Mojca Čepič: Golden Award of the University of Ljubljana for successful research and pedagogical work, University of Ljubljana
2. Prof. Peter Prelovšek: Blinc Award for Lifetime Achievement in Physics, FMF and JSI

Organization of conferences, congresses and meetings

1. Precision Era in High Energy Physics, Portorož, Slovenia, 15. – 19. 4. 2019
2. Selected topics in high energy physics, astrophysics, and cosmology, Belica, Slovenia, 9. – 11. 10. 2019
3. Nonequilibrium Dynamics In Correlated Systems And Quantum Materials, Krvavec, Slovenia, 15. – 18. 12. 2019

INTERNATIONAL PROJECTS

1. COST CA15108; Connecting Insights in Fundamental Physics (FUNDAMENTALCONNECTIONS)
   Prof. Jernej Fesel Kamenik
   Cost Office
2. COST CA16201; Unraveling New Physics at the LHC through the Precision Frontier
   Asst. Prof. Miha Nemevšek
   Cost Association Aisbl
3. COST CA17139; European Topology Interdisciplinary Action
   Dr. Anže Rapoš Božič
   Cost Association Aisbl
4. The Flavor of the Invisible Universe
   Asst. Prof. Nejc Košnik
   Slovenian Research Agency
5. New Searches for Physics Beyond the Standard Model
   Prof. Jernej Fesel Kamenik
   Slovenian Research Agency
6. Manifestation of Quantum Chaos in Quantum Many-Body Lattice Systems

Asst. Prof. Lev Vidmar
Slovenian Research Agency
7. The Flavor of Elementary Particles Beyond the Standard Model
Asst. Prof. Nejc Košnik
Slovenian Research Agency

RESEARCH PROGRAMMES

1. Theory of the condensed matter and statistical physics
Prof. Janez Bonča
2. Theoretical physics of nuclei, particles and fields
Prof. Jernej Fesel Kamenik
3. Biophysics of polymers, membranes, gels, colloids and cells
Prof. Primož Ziherl

R & D GRANTS AND CONTRACTS

1. Orientational Interactions in a Generalized Thomson Problem: Dipole-Stabilized Spherical Nanocontainers
Dr. Anže Rapoš Božič
2. New physics implications of scalar resonances at the LHC
Prof. Jernej Fesel Kamenik
3. High-resolution optical magnetometry with cold cesium atoms
Prof. Rok Žitko
4. Slow thermalization in quantum many-body systems
Prof. Peter Prelovšek
5. Diagnosing nonequilibrium quantum matter
Asst. Prof. Lev Vidmar
6. The influence of additives on nanoscopic wetting
Dr. Matej Kanduč
7. Financing of projects visits at the Slovenian higher education institutions - dr. Zupan
Asst. Prof. Jure Zupan
Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia
8. Financing of projects vistis at the Slovenian higer education institutions- dr. Mede
Dr. Timon Mede
Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia

VISITORS FROM ABROAD

1. Dr. Takeshi Kobayashi, ICTP, Trieste Italy, 16. – 18. 1. 2019
2. Prof. Jan Kalinowski University of Warsaw, Poland, 12. – 15. 2. 2019
3. Prof. Mikhail Kiselev ICTP, Trieste, Italy, 24. – 26. 2. 2019
4. Dr. Juan Herrero Garcia, SISSA, Trieste Italy, 13. – 15. 2. 2019
5. Prof. Juergen Schnack, University of Bielefeld, Germany, 25. – 27. 3. 2019
6. Dr. Federico Becca Department of Physics, University of Trieste, Trieste, Italy, 1. – 3. 4. 2019
7. Dr. Richard Ruiz, Université catholique de Louvain, Louvain, Belgium, 3. – 12. 4. 2019
8. Prof. Charles E. Creffield, Departamento de Física de Materiales, Universidad Complutense de Madrid, Spain 4. – 5. 4. 2019
9. Dr. Anna Gorczyca-Goraj, University of Silesia, Katowice, Poland, 8. – 10. 4. 2019
10. Prof. Pyungwon Ko, Korea Institute for Advance Study, Seoul, South Korea, 10. – 15. 4. 2019
11. Dr. Massimo Capone, Dr. Laura Fanfarillo in Dr. Adriano Amaricci, SISSA, Trieste, Italy, 17. 4. 2019
12. Manuel Szewc, International Center for Advanced Studies (ICAS) UNSAM, Buenos Aires, Argentina, 20. 4. – 18. 7. 2019
13. Dr. Kai Schmitz, University of Padova, Padova, Italy, 6. – 10. 5. 2019
14. Dr. Josu Hernandez Garcia, SISSA, Trieste, Italy, 8. – 12. 5. 2019
15. Dr. Federico Pobbe, University of Padova, Padova, Italy, 2. – 31. 5. 2019
16. Dr. Marija Mitrović Dankulov, Institute of Physics Belgrade, Serbia, 10. – 14. 5. 2019
17. Dr. Kim Won-Kyu, Freie Universität Berlin, Germany, 22. – 24. 5. 2019
18. Dr. Ranjan Modak, SISSA, Trieste, Italy, 28. – 30. 5. 2019
19. Prof. Tomonari Dotera, University of Kinki, Osaka, Japan, 31. 5. – 1. 6. 2019
20. Dr. Joichiro Nakakura, University of Tokyo, Japan, 31. 5. – 1. 6. 2019
21. Prof. Geoff J. Rodgers, Brunel University, London, United Kingdom, 10. – 15. 6. 2019
22. Michele Tammaro, University of Cincinnati, USA, 19. – 27. 6. 2019
23. Prof. Jesse Thaler, Massachusetts Institute of Technology, Cambridge, USA, 27. – 29. 6. 2019
24. Dr. Brijesh Kumar, School of Physical Sciences, New Delhi, India, 20. 6. 2019
25. Prof. Ezequiel Alvarez, International Centre for Advance Science, Buenos Aires, Argentina, 20. – 22. 6. 2019
26. Prof. Gholamereza Jafari, Physics Department, Shahid Beheshti University Teheran, Iran, 27. – 30. 6. 2019
27. Dr. Dario Rosa, Korea Institute for Advanced Study, Seul, South Korea, 1. – 3. 7. 2019
28. Dr. Wojciech De Roeck, KU Leuven, Belgium, 3. – 6. 7. 2019
29. Dr. Lorenzo Ubaldi, SISSA, Trieste, Italy, 16. – 19. 7. in 11. – 12. 12. 2019
30. Prof. Joern Kersten, University of Bergen, Bergen, Norway, 18. – 20. 7. 2019
31. Prof. Ilja Doršner, University of Split, Split, Croatia, 26. 7. – 10. 8. 2019
32. Dr. Miroslav Andjelković, Institute of Nuclear Sciences Vinca, Belgrade, Serbia, 8. – 15. 8. 2019
33. Dr. Marcos Rigol, The Pennsylvania State University, USA, 31. 8. – 3. 9. 2019
34. Michal Pacholski in Gal Lemut, Lorentz Institute, Leiden, Netherlands, 29. 9. – 5. 10. 2019
35. Prof. Matteo Rauzi z University Cote d´Azur, Nice, France, 17. – 18. 9. 2019
36. Dr. Alexander Wietek, Flatiron Institute, New York, USA, 23. – 27. 9. 2019
37. Prof. Marko Djordjević, University of Belgrade, Serbia, 02.10.2019
38. Dr. Christoph Schönle, University of Göttingen, Germany, 14. 10. – 7. 11. 2019
39. Prof. Jose Espinosa, Institute of Theoretical Physics, Madrid, Spain, 16. – 18. 10. 2019
40. Dr. Fabrizio Camerin z La Sapienza University of Rome, Rim, Italy, 13. – 26. 10. 2019
41. Dr. Zala Lenarčič, University of California, Berkeley, USA, 18. – 19. 10. 2019
42. Dr. Patrycia Lydzba, Wroclaw University of Science and Technology, Wroclaw, Poland, 11. – 25. 11. 2019
43. Dr. Julio Leite, Federal University of ABC, Santo André, Brazil, 14. – 17. 11. 2019
44. Dr. Frank Deppisch z University College, London, United Kingdom, 14. – 17. 11. 2019
45. Dr. Vedran Brdar, Max Planck Institute, Heidelberg, Germany, 17. – 22. 11. 2019
46. Prof. Michael Rappolt, School of Food Science & Nutrition, University of Leeds, Leeds, United Kingdom, 27. 11. 2019
47. Dr. Ivonne Ventura, z Universität Wien, Austria, 25. – 29. 11. 2019
48. Koya Kitagawa, Tohoku University, Tohoku, Japan, 3. – 31. 12. 2019
49. Prof. Jure Zupan, University of Cincinnati, USA, 22. – 24. 12. 2019
50. Prof. Gorazd Cvetić, Technical University Fed. S. Maria, Valparaiso, Chile, 23. 12. 2019

STAFF

Researchers

1. Prof. Borut Bajc
2. Dr. Damir Becirevic
3. Prof. Janez Bonča*
4. *Dr. Bojan Božič*, left 16.09.19*
5. Prof. Mojca Čepič*
6. *Daniele De Martino, B. Sc., left 16.10.19*
7. *Dr. Jure Derganc*, left 16.09.19*
8. Dr. Barry Michael Dillon
9. Dr. Ilja Doršner
10. Prof. Svjetlana Fajfer
11. **Prof. Jernej Fesel Kamenik, Head**
12. *Dr. Gregor Gomiščekˇ, left 16.09.19*
13. Dr. Matej Kanduč
14. Asst. Prof. Jure Kokalj*
15. Asst. Prof. Nejc Košnik
16. Dr. Rajmund Krivec
17. Asst. Prof. Jernej Mravlje
18. Asst. Prof. Miha Nemevšek
19. Dr. Mojca Pavlin
20. *Prof. Rudolf Podgornik*, retired 04.02.19*
21. Prof. Peter Prelovšek
22. Prof. Saša Prelovšek Komelj
23. Prof. Anton Ramšak*
24. Dr. Anže Rapoš Božič
25. Asst. Prof. Tomaž Rejec*
26. Fabio Staniscia, B. Sc.
27. Prof. Bosiljka Tadić
28. Horacio Andres Vargas Guzman, B. Sc.
29. Prof. Nataša Vaupotič*
30. Asst. Prof. Lev Vidmar
31. Prof. Primož Ziherl*
32. Prof. Rok Žitko

Postdoctoral associates

33. Dr. Tadej Emeršič
34. Dr. Matej Krajnc
35. Dr. Friedrich Johannes Krien
36. *Dr. Janja Majhenc, left 16.09.19*

37. *Dr. Mojca Mally*, left 16.09.19*
38. Dr. Timon Mede
39. Dr. Monalisa Patra
40. Clement Adrien Zankoc, B. Sc.
41. *Dr. Saša Ziherl*, left 16.09.19*

Postgraduates

42. *Dr. Darius Alexander Faroughy Carias, left 01.10.19*
43. Victor Francisco Guada Escalona, B. Sc.
44. Arman Korajac, B. Sc.
45. Luka Pavešić, B. Sc.
46. Jan Rozman, B. Sc.
47. Urša Skerbiš Štok, B. Sc.
48. Aleks Smolkovič, B. Sc.
49. Jan Šuntajs, B. Sc.
50. Martin Ulaga, B. Sc.
51. Lara Ulčakar, B. Sc.

Technical and administrative staff

52. Nevenka Hauschild

Note:

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1. Andreas-Kyriakos Doukas, *Liquid-drop model of polymer micelles:* doctoral dissertation, Ljubljana, 2019 (mentor Primož Ziherl).
2. Tadej Emeršič, *Optothermal manipulation of pressure-driven nematic liquid crystal microflows in microfluidic environment:* doctoral dissertation, Maribor, 2019 (mentor Uroš Tkalec).
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4. Alen Horvat, *Electronic correlations and transport in multi-orbital systems:* doctoral dissertation, Ljubljana, 2019 (mentor Jernej Mravlje).
5. Anja Kopač Lautar, *Theoretical study of processes on the solid electrolyte interface of rechargeable magnesium batteries:* doctoral dissertation, Ljubljana, 2019 (mentor Tomaž Rejec; co-mentor Marie-Liesse Doublet).

DEPARTMENT OF LOW AND MEDIUM ENERGY PHYSICS F-2

The Department of Low and Medium Energy Physics is engaged in research in the field of atomic and nuclear physics. Knowledge of atomic and nuclear physics is exploited in interdisciplinary research, including environmental radiological monitoring, material research, fusion, biology, energy storage, medicine, pharmacology, environment and archaeometry. Research is executed using our own experimental equipment, consisting of ion accelerator and beamlines, dedicated detectors of ionizing radiation, experimental setups for atomic physics and calibrated radiation fields. In addition, researchers from the department are using large research installations worldwide, either in the frame of self-initiated access applications or within international collaborations. In 2019 we visited accelerators, synchrotrons, free-electron lasers, fusion reactors and some other research facilities, which are not available in Slovenia. To balance the flow of researchers, we executed five projects within the Transnational Access Programme at the JSI tandem accelerator within the EU H2020 project "Radiate" of researchers from Czech Republic, Egypt, Germany, South Africa and Canada.

Head:
Prof. Primož Pelicon

We have continued our work at the three-spectrometer facility of the Mainz Microtron (MAMI) involving measurements of electron scattering with transversely polarized electrons, with production running on silicon nuclei. These studies represent an attempt to understand the fundamental symmetries of hadronic physics, exploiting observables sensitive to transverse polarization instead of the usual longitudinal polarization that probes the strangeness content of the nucleon. We have also concluded and published our quasi-elastic polarization transfer measurements on deuteron in anti-parallel kinematics (*Paul et al., Phys. Lett. B 795, 2019*) and studied the influence of Fermi motion on the comparison of the polarization transfer to a proton in elastic ep and elastic eA scattering (*Paul et al., Phys. Lett. B 792, 2019*). We completed our long-term study of the Q2-evolution of generalized proton polarizabilities (*Beričič et al., Phys. Rev. Lett. 2019*), as well as a related study in the resonance region (*Blomberg et al., Eur. Phys. A, 2019*). Further effort was invested in commissioning the gas-jet target intended for background-free measurements of nucleon form-factors both by means of the standard technique and by exploiting the method based on initial-state radiation (ISR): the latter depends on the virtually perfect knowledge of the radiative tail of the elastic peak to access the proton charge form factor at extremely small momentum transfers, and offers a distinct approach to addressing the famed "proton radius puzzle". The new multi-purpose neutron polarimeter has been constructed and commissioned, and preliminary data acquired.

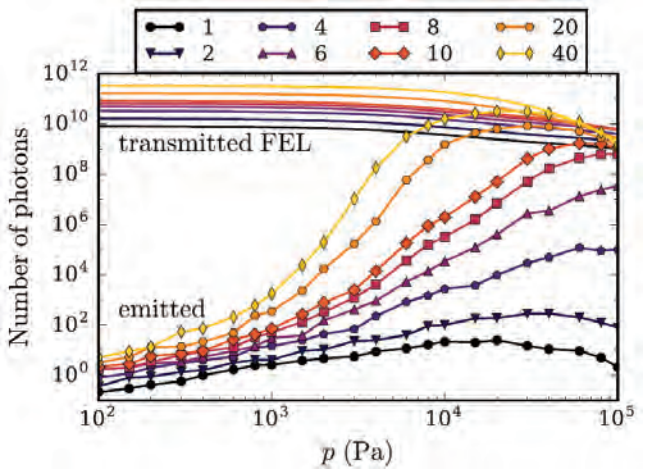

Figure 1: Calculated fluorescence intensity from 3a ^{1}P doubly excited state as a function of helium pressure in 1-mm-long gas cell and FEL light intensity (in 10^{12} W/cm^2 units) (Krušič et al., Phys. Rev. A 2019).

Our work at the Thomas Jefferson National Accelerator Facility (Jefferson Lab) has been focused on an analysis of the data from a comprehensive group of experiments using a tritium target. This effort gives us a unique opportunity to explore ^{3}H and its mirror nucleus of ^{3}He, and thereby impose severe constraints on state-of-the-art theories of nuclear many-body systems, in particular relating to the aspect of isospin symmetry. The first publication comparing proton momentum distributions in A=2 and A=3 nuclei is already available (*Cruz-Torres et al., Phys. Lett. B 2019*). Our analysis of data from the BigBite experiments has been concluded with a paper on the single-spin asymmetry Ay0 on transversely polarized 3He nuclei (*Long et al., Phys. Lett. B, 2019*) and on double-polarization asymmetries in the quasi-elastic 3He(e,e'p) process (*Mihovilovič et al., Phys. Lett. B, 2019*). We have published the results of a very first measurement of the Ar(e,e') inclusive cross-section (*Dai et al., Phys. Rev. C, 2019*), as well as those for inclusive scattering on aluminium, carbon, titanium and argon (*Murphy et al., Phys. Rev. C, 2019*).

We invest extensive efforts into the build-up and into the first phase-0 experiments at the new Facility for Antiproton and Ion Research in Europe FAIR, near Darmstadt in Germany, especially within the framework of the NUSTAR collaboration, dedicated to nuclear structure, reactions and astrophysics. We have constructed 36 detection

elements of the CALIFA scintillation detector for the experimental setup R3B, designed for calorimetry in reactions with relativistic ion beams. For the high-resolution spectroscopy setup DEGAS, we have developed and constructed the prototype of the signal readout chain for the BGO scintillator-based active background veto detector. We have also contributed to the multiple-reflection mass spectrometer at the FRS fragment separator by designing and constructing a system for the readout of the electrostatic ion lenses potentials, with a long-term stability of the order of 10^{-6}. We have actively participated in the first commissioning experiments of the DESPEC collaboration.

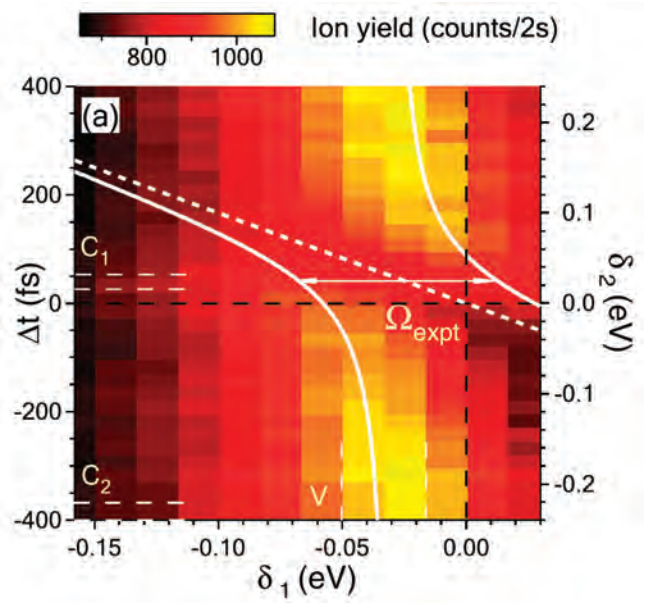

Figure 2: Spectral map of the Autler-Townes splitting due to the strong 2s2p $^1P^o$ - 2p^2 $^1S^e$ coupling in a He atom. Ion yield is shown as a function of photon energy detuning of the pump pulse and of delay between the pump and probe pulse. Because the coupling laser pulse is chirped, the delay is proportional to the photon energy of the laser pulse (Žitnik et al., Phys. Rev. A, 2019).

In 2019 the Nuclear Astrophysics Group performed measurements of nuclear reaction cross-sections at the JSI tandem accelerator, at Helmholz Zentrum Dresden Rosendorf, Germany and at the Max Planck Institute for Plasma Physics, Garching, Germany. We were focusing our attention on the differences between measurements in normal and inverse kinematics. The data analysis is in progress. The work is being conducted within the ERC complementary scheme project N1-0089 Electron Screening in Nuclear Reactions. We have published a new measurement of the nuclear reaction cross-section for the reaction between protons and deuterons in the energy range of the Big Bang (*Tišma et al., Eur. Phys. J., 2019*), where we discovered that the strong dipole angular distribution significantly affects the measurement. We also calculated the influence of the new measurement on the elemental abundances of the lightest elements that were produced during the Big Bang nucleosynthesis. We concluded that the new measurement impacts the abundances only slightly and certainly does not solve the too-low lithium abundance in the Universe.

Members of the Infrastructure Group for Ionizing Radiation Measurements were involved in research fields related to ionising radiation and nuclear physics. In addition, they were conducting activities in the environmental radioactivity monitoring of the living environment in Slovenia, regular Krško Nuclear Power Plant (KNPP) off-site environmental radioactivity monitoring, independent verification of the regular environmental radioactivity monitoring around KNPP, monitoring of radioactivity in fodder, central radioactive waste repository radiological monitoring, monitoring of the radioactivity in drinking water, material characterizations, calibrations of the radiation gauges and the measurements of the personal and environmental doses by thermoluminescent dosimeters. Those activities are accredited according the standard SIST EN ISO/IEC 17025.

In 2019 we continued intensive collaboration with the Metrology Institute of the Republic of Slovenia (MIRS). As a designated institution and as the holder of the national standard for the field of ionizing radiation, we continued the activities on projects from EU funding EMRP projects: "Preparedness – Metrology for mobile detection of ionising radiation following a nuclear or radiological incident". With the project "Preparedness", the JSI in collaboration with UPC, Barcelona, Spain, are developing and upgrading novel gamma-radiation hotspot locator available at the JSI and based on CsI detectors with an angular sensitivity, to be mountable on an unmanned helicopter. The members of the Group are executing the ENRAS project (full name of the project: ENsuring RAdiation Safety) in the framework of the Cooperation Programme Interreg V-A Slovenia-Croatia 2014-2020. The project involves the JSI (leading partner), the Institute for Medical Research and Occupational Health - IMI (project partner 1), Zagreb, Croatia and Firefighter Association of Slovenia - GZS (project partner 2). The aim of the project is to develop cross-border cooperation in the field of safety (civil protection) in the event of a nuclear or radiological emergency. In 2019, we individually trained 20 firefighting units, and with project partners from Croatia we took part in four joint exercises. Members of the department also took part in regular drills and special tasks with the radiological mobile unit ELME. In 2019 the members of ELME actively participated at the international exercise "Karavanke 2019" where we recovered radioactive sources that were scattered in the mountain area after a plane crash.

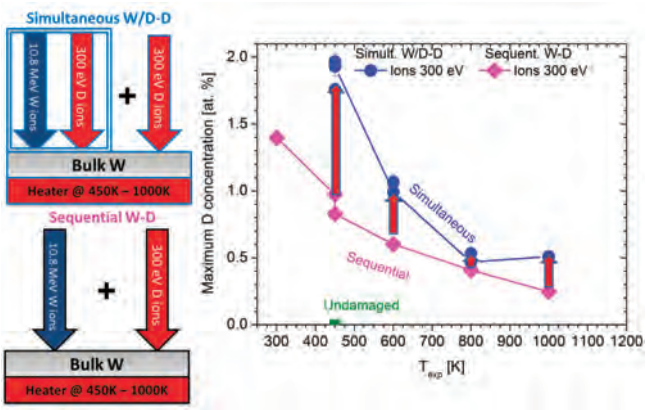

Figure 3: Left: schematic figures for the simultaneous W/D-D and sequential W-D exposure conditions. Right: maximum D concentrations obtained from the measured D depth profile at different exposure temperatures for the two exposure scenarios. Higher D concentration is observed for the simultaneous W/D-D ion exposure at all temperatures as compared to the sequential exposures. We have clearly shown that during the creation of defects the trapped D strongly increases the amount of the created defects (Markelj et al., Nucl. Fusion 59, 2019).

At the beginning of 2019 we published a theoretical study on self-amplified spontaneous emission from 3a ^{1}P doubly excited states in helium (*Krušič et al., Phys. Rev. A 2019*). We were interested in the amplification of fluorescence due to stimulation by the same fluorescence field as a function of the target length, the intensity of the free electron laser (FEL) light and the target pressure. The results were also submitted as a master work of Špela Krušič. The University of Ljubljana selected her work for the University Prešeren Prizes 2019. In the home laboratory we have recorded the first spectra of 1-keV electron scattering on argon with the electron driven magnetic bottle spectrometer. In collaboration with Laboratory for Quantum Optics at Nova Gorica University, we have developed a pump-probe method for measuring a complete frequency map of laser-dressed states with femtosecond lifetimes (Žitnik *et al., Phys. Rev. A, 2019*). The method is based on driving the selected transition with linearly chirped probe pulses and measuring the yields of decay products as a function of the frequency of the pump pulse and the pump-probe time delay. The method has been tested on the laser-coupled $2s2p\ ^1P^o$ and $2p^2\ ^1S^e$ autoionizing resonances in He using a high-order harmonic generation (HHG) pump in combination with an optical parametric amplifier probe laser. In 2019 we have also published a theoretical study on resonant and non-resonant Auger decay of the 2p vacancy in atomic chlorine (*Hrast et al., Phys. Rev. A, 2019*). The results are expected to help disentangle Auger spectra in the chlorine-containing molecules where fast dissociation often causes the spectra to originate from different fragments and less from the original molecule itself. In February 2019 we participated in experiments at Fermi FEL, where we were investigating whether the light with orbital angular momentum can transfer an extra angular momentum to quantum objects. To that purpose we have measured the angular distribution of photoelectrons, ejected from helium ground state due to the absorption of strong FEL and laser light. The laser light was prepared with different amounts of the orbital momentum by the passage through the holographic mask. In December 2019 we attended another two experiments at FEL Fermi. The first was proposed by us and performed in collaboration with French researchers from the LCPMR lab in Paris. We were trying to capture the interference effects of two different two-photon paths to the same doubly excited state in helium. The second experiment was conducted in collaboration with dr. A. LaForge from the USA. Looking for superfluorescence from helium clusters and gas we were trying to measure the temporal trace of 1s3p-1s2s fluorescence at 500 nm as a function of FEL intensity by using a streak camera with 10 ps temporal resolution. Instead of the exponential decay we saw the oscillatory time dependence of fluorescence due to the Zeeman level splitting in the strong magnetic field. With French colleagues we published a paper about $K^{-1}K^{-1}$ spectroscopy of benzene (*Carniato et al., J. Chem. Phys. 2019*) in the end of 2019.

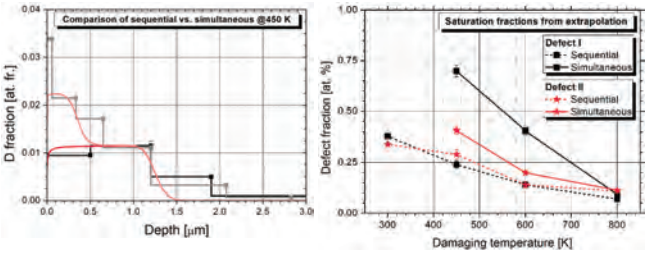

Figure 4: Left: Comparison of the measured simultaneous (grey symbol lines) and sequential (black symbol lines) D depth profiles at 450 K with the simulated profiles (red lines). The stepped depth profile for the simultaneous case is the consequence of slow diffusion of D inside the material during W irradiation indicating that the D stabilization takes place only where D is present. Right: Fraction of the created defects as a function of temperature for the simultaneous and sequential case, as obtained from the modelling. (Pečovnik et al., Nucl. Fusion, in press).

In 2019 we performed X-ray Raman spectroscopy (XRS) measurements to study the redox reaction mechanism of novel redox active organic materials. X-ray Raman spectroscopy represents inelastic X-ray scattering from core-electron excitations and is capable to extract soft-XAS information using hard X-ray probe, combining therefore the sensitivity of soft-XAS with experimental advantages of hard X-ray probe, especially its large penetration providing bulk sensitivity and also compatibility with in-situ cells. The experiment took place at the P01 beamline of the PETRA III synchrotron at DESY, Hamburg, in collaboration with the group for Modern Battery Systems from the National Institute for Chemistry. Ex-situ measurements on pre-cycled battery cathodes with different metal ions (Li, Al) stopped at several points along the discharge curve were performed and also operando measurements on an Al-PAQS battery during one discharge. Results of the experiment will provide identification of the basic electrochemistry mechanism of such redox active organic material in combination with different counter ions. Our work on x-ray spectroscopic characterization of novel energy storage materials also continued in our home laboratory. We have successfully recorded proton-induced high-energy-resolution sulphur Kα x-ray emission spectra on a working Li-S battery during discharge, which demonstrates the feasibility to characterize sulphur compounds build electrochemically within battery cathode also in a smaller laboratory using a laboratory excitation source. In the field of high-energy-resolution PIXE spectroscopy we have continued our collaboration with the group from the University of Guelph, Ontario, Canada, on the project of building the He induced multiple ionization satellites database which will be used to improve the accuracy of PIXE analysis using alpha particle beams, which is ongoing on the NASA Mars Curiosity rover. We have recorded $K\alpha L^n$

Figure 5: (left) Side view of the X-ray Raman Scattering (XRS) spectrometer at P01 beamline at PETRA III in DESY, Hamburg. (right) Experimental setup for the operando XRS measurements on battery cathode during discharge.

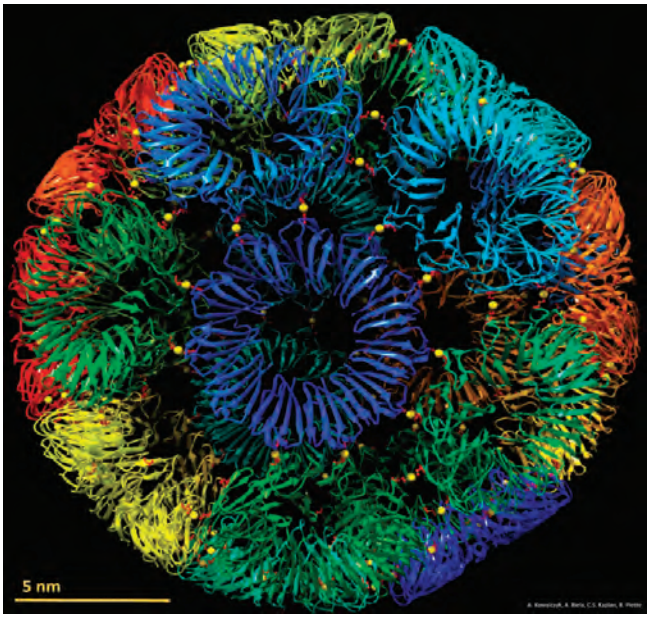

Figure 6: Model of mathematically "forbidden" protein cage with 22-nanometre diameter, presented in Nature (Malay et al., Nature, 2019). The cage is composed of 24 protein rings, interconnected by the gold atoms (presented in the figure as yellow spheres. The collaborators from the JSI determined the number of Au atoms, participating in the formation of the cage molecule

emission spectra from CaF_2, Cr, and Cr_2O_3 samples induced in collisions with 3-5 MeV He ions. We have published the results of resonant x-ray emission from Fe_2O_3 nanoparticles in an aqueous dispersion induced by stochastic x-ray pulses with energies around the Fe 1s ionization threshold (*Kayser et al., Nat. Commun., 2019*), and also the study of the influence of the solvent ionization with fast intense x-ray pulses on the electronic structure of the $Fe(CN)_6$ molecule in an aqueous solution (*Blachucki et al., Struct. Dyn., 2019*). Both measurements were performed at the LCLS free electron laser in Stanford in collaboration with the group from the PSI institute. We have also published measurements of the Kβ diagram (1s-3p), Kb^h hypersatellite ($1s^2$-1s3p) and valence to core (VtC) x-ray emission lines induced in metallic Cr by photon single and double K-shell ionization (*Zeeshan et al., X-Ray Spectrometry, 2019*) performed at the 6-2 beamline of the SSRL synchrotron in collaboration with the University of Fribourg.

Material properties were studied with measurements of the magnetic and electric hyperfine fields using Mössbauer spectroscopy. The properties of mixed-metal MOFs depend on the distribution of different metals within their frameworks. Because the ions of different metals in a mixed-metal MOF typically occupy crystallographically equivalent positions, diffraction techniques are able to provide only a limited insight into the distribution of the metals within the framework. Spectroscopic methods that rely on local probes, such as Mössbauer spectroscopy, tend to be more informative. Using an example of aluminum- and iron-containing MIL-100, we demonstrated that ^{27}Al NMR spectroscopy, when combined with first-principles calculations and magnetic, X-band electron paramagnetic resonance, Fe K-edge extended X-ray absorption fine structure, and Mössbauer measurements, makes it possible to accurately determine the arrangement of Al and Fe within the metal trimers, which are the basic building units of MIL-100. In this particular material, the incorporation of Fe and Al on the framework metal sites is random. (*Mali et al., The Journal of Physical Chemistry Letters, 2019*). Magnetic anisotropy in pentagonal bipyramidal complexes was studied using magnetic susceptibility measurements, powder X-band electron paramagnetic resonance (EPR) spectroscopy, Mössbauer spectroscopy, ab initio, and ligand-field density functional theory (LFDFT) calculations. The studied complexes display three distinct types of magnetic anisotropy (*Darmanović et al., The Journal of Physical Chemistry C, Nanomaterials and Interfaces, 2019*). The effect of the phase transformation of a $FePO_4$ catalyst material from the tridymite-like (tdm) $FePO_4$ to the α-domain (α-$Fe_3(P_2O_7)_2$) during the direct selective oxidation of methane to methanol was studied using oxidant species O_2, H_2O and N_2O. The results showed that the single-step non-syngas activation of CH_4 to oxygenate(s) on a solid $FePO_4$ phase-specific catalyst was influenced by the nature of the oxidizer used for the CH_4 turnover. The Mössbauer spectra revealed the change of the initial ferric orthophosphate, $FePO_4$ (tdm), to the divalent metal form, iron(II) pyrophosphate ($Fe_2P_2O_7$) (*Dasireddy et al., RSC Advances, 2019*).

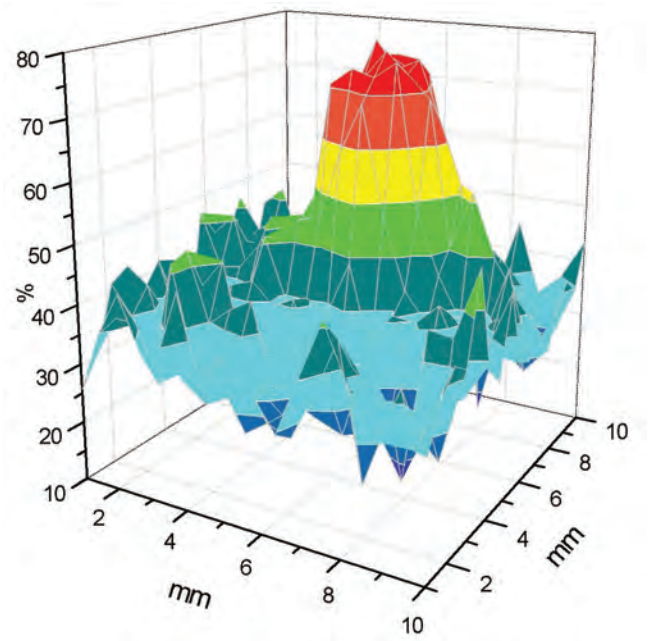

Figure 7: Copper profile of a hemi-spherical hole cut through a thick patina layer on archaeological bronze. The measurement is executed with the 3-MeV proton beam in air, directed through a 200-nanometre-thick Si_3N_4 membrane from vacuum into the air.

In 2019 we continued with fusion research, coordinated by EUROfusion Consortium and carried out within the Work Package on "Preparation of efficient Plasma-Facing Component (PFC) operation for ITER and DEMO". Our research is focused on hydrogen isotope (HI) retention in tungsten. Energetic neutrons from the deuterium-tritium (D-T) fusion reaction will create displacement damage in the crystal lattice throughout the bulk of the material in the amount of several displacements per atom (dpa) per year. The created lattice defects act as trapping sites for HIs with high de-trapping energy as compared to the energy of diffusion of hydrogen in tungsten. In order to study the influence of the neutron irradiation of materials on fuel retention, high-energy W ions produced by MV accelerators are used to produce displacement damage which mimics the damage created by neutrons very well. In real fusion devices the creation of displacement damage and hydrogen isotope and He irradiation will take place simultaneously. To be able to predict the influence of displacement damage on hydrogen transport and retention in a future nuclear environment we are studying the influence

of the conditions on damage creation, meaning at what temperature and with or without the presence of HI. In order to deduce the effect of D presence, a unique experimental set-up was developed for this purpose, where simultaneous 10.8-MeV W ion irradiation and 300-eV D ion exposure were performed together with sequential W-ion irradiation and D-ion exposure at elevated temperatures up to 1000 K (*Markelj et al., Nucl. Fusion 59, 2019*). At 450 K we observed a two-times-higher maximum D concentration for the simultaneous case than with the sequential case. At 600 K and 800 K the ratio between the simultaneous and sequential cases decreases to about 1.6 and 1.2, respectively, and increases again to a factor of 2 at 1000 K. We attribute this dependence on temperature to the change in the concentration of mobile and trapped D during the simultaneous exposures, which is in line with theoretical calculations predicting that trapped D in a vacancy prevents vacancy annihilation with self-interstitial atoms. In order to explain the obtained experimental results a new model was developed and included in a macroscopic rate equation code (*Pečovnik et al., Nucl. Fusion 60, 2020*). The new displacement damage creation and stabilization model is based on the spontaneous recombination of Frenkel pairs and the stabilization of defects that are occupied by D atoms. By using the new model, we could successfully replicate the measured D depth profiles and D thermal desorption data, where a higher defect concentration was observed when D was present during W irradiation, as compared to when no D was present. For this we utilized parameters, which include the number of distinct defect types, the de-trapping energies, their saturation concentrations and their probability for stabilization if they contain a D during the W-ion irradiation.

The tandem accelerator of the Jožef Stefan Institute provided 4432 beam hours to the users (in comparison: in the year 2017: 3991 beam hours, in 2018: 3050 beam hours delivered to the users). We carried out extensive measurements with the micro-PIXE method at the field of plant biology. In collaboration with co-workers from Tunisia we investigated the response of a halophyte *Sesuvium portulacastrum L.* to the increased presence of nickel in the soil (*Fourati et al., Chemosphere, 2019*). In collaboration with the University of Barcelona, we studied the distribution of aluminium in tea leaves (*Pongrac et al., Food and Chemical Toxicology, 2019*), and in collaboration with colleagues from Latvia the mineral composition of pine needles (*Pongrac et al., Trees, 2019*). In the frame of the national research project titled "Three-dimensional distribution of mineral nutrients in plant leaves" we measured the distribution of magnesium and calcium in the spinach leaves. For the applicative project "Locally grown buckwheat grain for the production of high-quality food products" we combined the elemental microscopy micro-PIXE with the imaging mass spectroscopy method MeV-SIMS, as well as with several other complementary imaging methods. Among others, buckwheat samples were measured at the helium ion microscope at the Helmholz Zentrum Dresden Rosendorf (HZDR) in the frame of Helmholtz European Partnering project "CROSSING", an ongoing bilateral project between JSI and HZDR involving five departments at the JSI and four institutes at HZDR.

The imaging mass spectroscopy method MeV-SIMS was upgraded within the national research project "Molecular Imaging inside the cell (MICE)". We achieved sub-micrometre lateral resolution with the application of continuous, low-current primary ion beam. In addition, the Time-Of-Flight (TOF) mass spectrometry is upgraded with reflectron stage, as well as with post-accelerating detector for secondary ions. This will contribute to the improvement of the mass resolution, as well as to the sensitivity for heavy secondary ions with masses exceeding 1000 Da.

In the EU project in the Marie Skłodowska-Curie Action "TissueMaps" we dedicated the micro-PIXE to measure the elemental distributions in the human tissue, removed during the replacement of failed hip prostheses, in order to improve understanding of the processes leading to the failures of the hip prostheses (*Punzon-Quijorna et al., Nucl. Instr. Meth. B, 2019*). After several years of work on the determination of metallic stoichiometry in large synthetic protein molecules with micro-PIXE, we managed to publish the results in the journal Nature (*Malay et al., Nature, 2019*). From the X-ray spectra, excited by 3 MeV protons, we managed to determine, how many gold atoms are participating in the formation of the spherically shaped protein molecule, composed of 24 rings. On the layer of dried protein, we directed the proton beam, and from the emitted X-rays we determined the stoichiometry ratio between the sulphur and gold. Sulphur is present in the proteins in two amino-acids: cysteine and methionine. In the proteomics, the presence of these amino acids is accurately determined with available methods and we may use sulphur as an internal standard. On the other hand, there is a lack of methods able to quantify the presence of metal atoms in protein molecules. The stoichiometry determination of the metalloid atoms in proteins with micro-PIXE has a great future potential, as we need only very small mass of the refined protein for the analysis in the order of 100 up to 5000 nanograms.

During 2019 we studied several archaeometry problems at the external ion beam. We completed a comprehensive analysis of prehistoric glass from Slovenia using the PIXE-PIGE method. The analysis involved the oldest glass from the transition between the Bronze and Early Iron Age until the examples of the Late Iron Age. For the oldest glass we

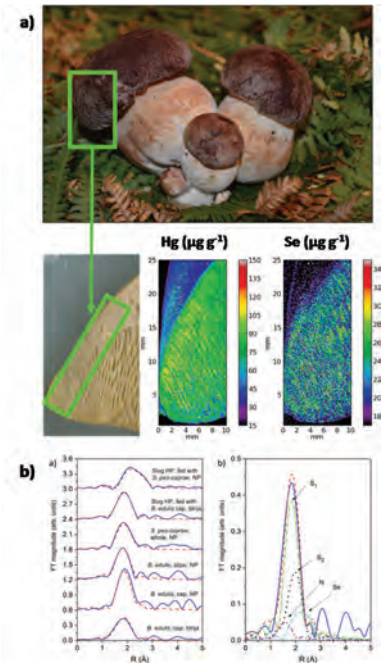

Figure 8: a) Localization of mercury and selenium in cap of a King bolete (Boletus edulis) by LA-ICPMS. b) Hg L_3EXAFS spectra recorded on different mushroom parts. The measurements were performed at ESRF and DESY.

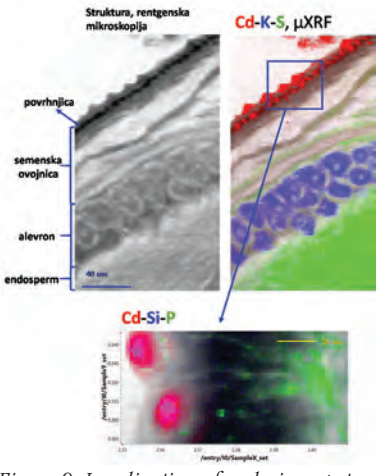

Figure 9: Localization of cadmium, potassium, sulphur, phosphorus and silicon in the cross-section of barley grain; measurements were performed at the I08 beamline of the Diamomd synchrotron in the UK.

noticed the use of different sources of alkalis and an influence of Egyptian glassmaking, but since the Mokronog-Slepšek horizon the glass is essentially natron-type, which is the property of Greek and Roman glassmaking. We found that the glass composition varies systematically with historic horizons, which point to a specialized workshop supplying the major part of the market. We further contributed to the analysis of medieval glass from Dalmatia and the Adriatic hinterland. We studied the composition of the pigments in the autobiographies of the Austrian diplomat Sigmund Herberstein printed in the 16th century. The method of XRF was used on the copy held in Prague. In order to execute a comparison with the data taken by PIXE in Ljubljana, we upgraded the physical model for the electron-induced bremsstrahlung radiation and transmission of the polycapillary optics for X-rays. We further deciphered the photographic technique of the recently discovered photo of Kranj – the present of silver suggested ambrotype. We further improved the in-air measuring line, so it is presently possible to execute mapping experiments with a resolution of about 0.2 mm.

Figure 10: In-field training of the radiological mobile unit members for the interventions in the case of radiological accidents within the project ENRAS (full name of the project: ENsuring RAdiation Safety) in the framework of the Cooperation Programme Interreg V-A Slovenia-Croatia 2014-2020.

Within the ARRS project entitled "Ionome of crop plants for safe and quality food production", we investigated the distribution and ligand environment of mercury in edible mushrooms *Boletus edulis* and *Scutiger pes-caprae* using LA-ICPMS and synchrotron-based techniques, micro-XRF at the synchrotron Elettra, Trieste, and XANES/ EXAFS (*Kavčič et al., Ecotoxicology and environmental safety, 2019*) at the synchrotrons ESRF, Grenoble and DESY, Hamburg, where we found that Hg accumulates mostly in the cap of the fungal sporocarp, more precisely in the hymenium, where spores are formed. Mercury binds in the di-thiol, tetra-thiol, diamino and HgSe complexes. It has been shown that the binding of Hg to Se reduces the bioavailability of Hg from fungi to higher trophic levels.

In collaboration with colleagues from the Izmir University of Economics, Turkey, we investigated the distribution of iron in seeds of dicotyledonous plants using synchrotron micro-XRF at the synchrotron Elettra. We found that iron is localized in perivascular and endodermal tissue and that iron localization correlates with the distribution of *VIT1* gene expression (*Ergolu et al., Frontiers in Plant Science, 2019*). Together with colleagues from I2BC, Gif-sur-Yvette, France, we continued the research of the ARIMNET BEST (Barley Stress Tolerance) project by performing measurements of cadmium localization in barley grains, at the I08 beamline at the Diamond synchrotron in the United Kingdom and at the Lucia beamline of the Soleil synchrotron. Cadmium was found to accumulate in the seed coat of barley grains, more precisely in silicified structures found on the surface of the seed coat.

In collaboration with colleagues from the University of Girona, Spain, we investigated the uptake and ligand environment of silver in lettuce exposed to different concentrations of Ag nanoparticles coated with different organic coatings (PVP, citrate, PEG). Ag L_3-edge XANES and EXAFS measurements were performed at the ALBA synchrotron in Spain. In cooperation with the Biotechnical Faculty and the Institute for Hop Research and Brewing in Žalec we continued the studies of the traceability of the origin of food and agricultural products combining X-ray fluorescence spectrometry and chemometric methods. Based on a combination of elemental fingerprinting and discriminant analysis, we presented an effective statistical model for monitoring the traceability and authenticity of hops (*Ocvirk et al., Food Chemistry, 2019*).

Organization of conferences, congresses and meetings

1. EMPIR Preparedness Meeting, 27–28 January 2019, Ljubljana
2. EURAMET TC-IR Annual Meeting 2019, 28–30 January 2019, Ljubljana
3. EMPIR DOSEtrace Meeting, 31 January 2019, Ljubljana
4. First Tritium School, Ljubljana, 25–28 March 2019, Ljubljana
5. CROSSING Meeting 2019, 10–12 April 2019, Ljubljana

INTERNATIONAL PROJECTS

1. FAIR Detectors
   Prof. Matej Lipoglavšek
   Gsi Helmholtzzentrum
2. CROSSING - Crossing Borders and Scales - An Interdisciplinary Approach
   Prof. Primož Pelicon
   Helmholtz-zentrum Dresden-Rossendorf E.v.
3. EMPIR; Preparedness - Metrology for Mobile Detection of Ionising Radiation Following a Nuclear or Radiological Incident
   Dr. Toni Petrovič
   Euramet E.v.
4. EMPIR; AEROMET - Aerosol Metrology for Atmospheric Science and Air Quality
   Prof. Matjaž Žitnik
   Euramet E.v.
5. EMPIR - 17RPT01 DOSEtrace; Research Capabilities for Radiation Protection Dosimeters
   Denis Glavič Cindro, M. Sc.
   Euramet E.v.
6. COST CA16117 - ChETEC; Chemical Elements as Tracers of the Evolution of the Cosmos
   Prof. Matej Lipoglavšek
   Cost Office

7. Training Fees for Mr. Andrii Kholodyuk, STEP
   Asst. Prof. Benjamin Zorko
   Ictp - Centro Internazionale di Fisica Teorica
8. Enhancing Nuclear Analytical Techniques to Meet the Needs of Forensic Sciences; Forensics with Nuclear Methods: Art and Food Forgery, Drugs in Hair
   Prof. Primož Pelicon
   IAEA - International Atomic Energy Agency
9. COST CA18130; European Network for Chemical Elemental Analysis by Total Reflection X-Ray Fluorescence
   Dr. Marijan Nečemer
   Cost Association Aisbl
10. Training Fees for Mr. Eyakifama Hazou, ICTP-IAEA Sandwich Training Educational Programme (STEP), from 8 July to 5 October 2019
    Asst. Prof. Benjamin Zorko
    Ictp - Centro Internazionale di Fisica Teorica
11. COST CA18222; Attosecond Chemistry
    Asst. Prof. Andrej Mihelič
    Cost Association Aisbl
12. COST CA18212; Molecular Dynamics in the GAS Phase
    Prof. Matjaž Žitnik
    Cost Association Aisbl
13. COST CA16117; Chemical Elements as Tracers of the Evolution of the Cosmos
    Prof. Matej Lipoglavšek
    Cost Association Aisbl
14. H2020 - CONCERT; European Joint Programme for the Integration of Radiation Protection Research
    Asst. Prof. Benjamin Zorko
    European Commission
15. H2020 - TRANSAT; TRANSversal Actions for Tritium
    Asst. Prof. Sabina Markelj
    European Commission
16. H2020 - RADIATE; Research and Development with Ion beams - Advancing Technology in Europe
    Asst. Prof. Matjaž Kavčič
    European Commission
17. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION
    Asst. Prof. Sabina Markelj
    European Commission
18. H2020 EUROfusion - Education-ED-FU
    Prof. Primož Pelicon
    European Commission
19. H2020 EUROfusion - Medium Size Tokamak Campaigns-MST1-FU
    Mitja Kelemen
    European Commission
20. H2020 - TissueMaps - Elemental Imaging of Human Tissue: Clinical Therapy Support and Development of New Diagnostics
    Prof. Primož Pelicon
    European Commission
21. Gamma Spectrometric Determination of Low Level Activity of Low-Energetic Radionuclides in Complexs Samples
    Asst. Prof. Benjamin Zorko
    Slovenian Research Agency
22. Study of Weak Charge Distributions with Precision Parity-Violating Measurements
    Asst. Prof. Miha Mihovilovič
    Slovenian Research Agency
23. Electrochemical Reactions in Organic-Metal Batteries Studied by X-Ray Raman Spectroscopy
    Asst. Prof. Matjaž Kavčič
    Slovenian Research Agency
24. Investigation of Helium Retention in Plasma Facing Materials Using Advanced Analytical Methods
    Asst. Prof. Sabina Markelj
    Slovenian Research Agency
25. IAEA WG3 MODARIA II, Fourth Technical Meeting of MODARIA II
    Asst. Prof. Benjamin Zorko
    Slovenian Research Agency
26. General Meeting ICRM
    Asst. Prof. Benjamin Zorko
    Slovenian Research Agency

RESEARCH PROGRAMMES

1. Archaeological and Archaeometric Research of Portable Archaeological Heritage
   Dr. Eva Menart
2. Object and Prestige; taste, status, power (Researches of the material culture in Slovenia)
   Dr. Marijan Nečemer
3. Structure of hadronic systems
   Prof. Simon Širca
4. Studies of atoms, molecules and structures by photons and particles
   Prof. Matjaž Žitnik
5. Fusion technologies
   Asst. Prof. Sabina Markelj

R & D GRANTS AND CONTRACTS

1. Triggering forbidden phenomena with twisted light and particles beams
   Prof. Matjaž Žitnik
2. Redox active organic materials for electrical energy storage
   Asst. Prof. Matjaž Kavčič
3. Ionom of crop plants for safe and quality food production
   Prof. Katarina Vogel-mikuš
4. Stable isotopes in the study of the impact of increasing CO2 levels on C and Hg cycling in coastal waters
   Prof. Katarina Vogel-mikuš
5. Three-dimensional distribution of mineral elements in plant leaves
   Asst. Prof. Paula Pongrac
6. Molecular imaging inside the cell
   Prof. Primož Pelicon
7. Catalysis of Nuclear Reactions by Electrons
   Prof. Matej Lipoglavšek
8. Molecular Imaging Inside the Cell
   Prof. Primož Pelicon
9. Spatial localization of elements and metabolits in plants
   Prof. Katarina Vogel-mikuš
10. Localy grown buckwheat grain for production of high quality food products
    Prof. Primož Pelicon
11. Selective plasma oxidation of FeCrAl alloys for extended-lifetime of glow plugs for diesel engines
    Dr. Tilen Brecelj
12. Innovative configuration of inductively coupled gaseous plasma sources for up-scaling to industrial-size reactors
    Dr. Romana Krištof
13. Innovative ECO plasma seed treatment (for sowing and for human and animal diet/ nutrition
    Prof. Primož Pelicon
    Ministry of Education, Science and Sport
14. ENRAS: Ensuring Radiation S afety for First Responder Teams in Case of Radiological or Nuclear Accidents
    Boštjan Črnič
    Government Office for Development and European Cohesion Policy
15. BEST: Barley stress tolerance
    Prof. Primož Pelicon
    Ministry of Education, Science and Sport
16. Calibrations
    Matjaž Mihelič, M. Sc.
17. Different Analyses
    Dr. Jasmina Kožar Logar
18. Support to the Quality Infrastructure in Serbia
    Denis Glavič Cindro, M. Sc.
    Physikalisch-technische Bundesanstalt (ptb)
19. EURAMET TC-Ionising Radiation (TC-IR) Annual Meeting 2019 and Working Meetings within EMPIR Projects Preparedness and DOSEtrace
    Denis Glavič Cindro, M. Sc.
20. TRANSAT First Tritium School, Ljubljana, 25-28 March 2019
    Asst. Prof. Sabina Markelj

NEW CONTRACTS

1. Measurements of gaseous effluents, specific analysis of H-3 and C-14 in year 2019
   Asst. Prof. Benjamin Zorko
   Nuklearna Elektrarna Krško d. o. o.
2. Off-site radiological monitoring of the HE Brežice 2019
   Asst. Prof. Benjamin Zorko
   Nuklearna Elektrarna Krško d. o. o.
3. Environmental radioactivity monitoring of living environment in Republic Slovenia in 2019
   Asst. Prof. Benjamin Zorko
   Ministry of the Environment and Spatial Planning
4. Determination of elemental composition and stable isotope composition of light elements in selected fruits and vegetables in 2019
   Dr. Marijan Nečemer
   Ministry of Agriculture, Forestry and Food
5. Maintenance of radiological emergency preparedness 2019
   Asst. Prof. Benjamin Zorko
   Nuklearna Elektrarna Krško d. o. o.

VISITORS FROM ABROAD

1. Dr Katja Magdić Košiček, IRB, Zagreb, Croatia, 1 January–15 November 2019
2. Prof. Dr Jechiel Lichtenstadt, Prof. Dr Eli Piasetzky and Dr Paul Sebouh, Tel Aviv University, Tel Aviv, Israel, 3–7 February 2019
3. Dr Tilo Reinert, Leipzig University, Leipzig, Germany, 17–23 February 2019
4. Sortiria Symeonidi, National Technical University of Athens, Athens, Greece, 1 March–31 August 2019
5. Prof. Dr Stephan Clemens, Bayreuth University, Bayreuth, Germany, 16–19 June 2019
6. Eyakifama Hazou, University of Lome, Lome, Togo, 8 July–5 October 2019
7. Dr Jurij Simčič, JPL, Pasadena, California, USA, 31 July 2019
8. Anna Stefanišin, UNIBL, Banja Luka, Bosnia and Herzegovina, 16 September–9 December 2019
9. Dr Igor Pasković, Institute of Agriculture and Tourism, Poreč, Croatia, 6–19 November 2019
10. Dr Carlotta Giusti, Pavia University, Pavia, Italy, 10–14 November 2019
11. Prof. Dr Jechiel Lichtenstadt and Dr Paul Sebouh, Tel Aviv University, Tel Aviv, Israel, 10–14 November 2019
12. Ms. Alaa Mohamed Elsaeed Hassan El-Minsy, NRC, Plant Nutrition Department, Dokki, Cairo Governorate, Egypt, 1–13 December 2019

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23. Dr. Aleksandra Cvetinović
24. Dr. Boštjan Jenčič
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26. Dr. Eva Menart*
27. Dr. Marko Petric
28. Dr. Jelena Vesić

Postgraduates

29. Žiga Barba, B. Sc.
30. Mateja Hrast, B. Sc.
31. Tim Kolar, B. Sc.
32. Špela Krušič, B. Sc.
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42. Dr. Primož Vavpetič
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44. Drago Brodnik
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47. Andrej Košiček, B. Sc.
48. Mirko Ribič, B. Sc.

Note:
* part-time JSI member

BIBLIOGRAPHY

Original Article

1. Mateja Grašič, Maja Dobravc, Aleksandra Golob, Katarina Vogel-Mikuš, Alenka Gaberščik, "Water shortage reduces silicon uptake in barley leaves", *Agricultural water management*, 2019, **217**, 47-56.
2. Dino Metarapi, Martin Šala, Katarina Vogel-Mikuš, Vid Simon Šelih, Johannes Teun van Elteren, "Nanoparticle analysis in biomaterials using laser ablation-single particle-inductively coupled plasma mass spectrometry", *Analytical chemistry*, 2019, **91**, 9, 6200-6205.
3. Drago Brodnik, Denis Glavič-Cindro, Matjaž Korun, Marijan Nečemer, Petra Maver, Toni Petrovič, Tim Vidmar, Branko Vodenik, Benjamin Zorko, "Negative correlation between the number of sunspots and the occurrence of ^{7}Be and ^{22}Na in the surface air and their contribution to radiation doses", *Arhiv za higijenu rada i toksikologiju*, 2019, **70**, 4, 290-295.
4. Mateja Grašič, Barbara Škoda, Aleksandra Golob, Katarina Vogel-Mikuš, Alenka Gaberščik, "Barley and spelt differ in leaf silicon content and other leaf traits", *Biologia*, 2019, **74**, 8, 929-939 pp..
5. Maja Pori, Iztok Arčon, Damjan Lašič Jurković, Marjan Marinšek, Goran Dražić, Blaž Likozar, Zorica Crnjak Orel, "Synthesis of a Cu/ZnO nanocomposite by electroless plating for the catalytic conversion of CO_2 to methanol", *Catalysis letters*, 2019, **149**, 5, 1427-1439.
6. Olena Pliekhova, Oleksii Pliekhov, Mattia Fanetti, Iztok Arčon, Nataša Novak Tušar, Urška Lavrenčič Štangar, "Cu and Zr surface sites in photocatalytic activity of TiO_2 nanoparticles: the effect of Zr distribution", *Catalysis today*, 2019, **328**, 105-110.
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8. Giacomo Lovat *et al.* (11 authors), "Determination of the structure and geometry of N-heterocyclic carbenes on Au(111) using high-resolution spectroscopy", *Chemical science*, 2019, **10**, 3, 930-935.
9. Mirela Dragomir, Paul A. Dube, Iztok Arčon, Chad Boyer, Meghan Rutherford, Christopher Wiebe, Graham King, Hanna Dabkowska, John E. Greedan, "Comparing magnetism in isostructural oxides $A_{0.8}La_{1.2}MnO_{4.1}$: anisotropic spin glass (A = Ba) versus long range order (A = Sr)", *Chemistry of materials*, 2019, **31**, 19, 7833-7844.
10. Sebastiano Tieuli, Franco Baldi, Iztok Arčon, Katarina Vogel-Mikuš, Michele Gallo, Laura Sperni, Oreste Piccolo, Stefano Paganelli, "Alternative recovery and valorization of metals from exhausted catalytic converters in a new smart polymetallic catalyst", *ChemistrySelect*, 2019, **4**, 15, 4624-4632.
11. Emna Fourati, Katarina Vogel-Mikuš, Taoufik Bettaieb, Anja Kavčič, Mitja Kelemen, Primož Vavpetič, Primož Pelicon, Chedly Abdelly, Tahar Ghnaya, "Physiological response and mineral elements accumulation pattern in Sesuvium portulacastrum L. subjected in vitro to nickel", *Chemosphere*, 2019, **219**, 463-471.

12. Alenka Ristić, Matjaž Mazaj, Iztok Arčon, Nina Daneu, Nataša Zabukovec Logar, Roger Gläser, Nataša Novak Tušar, "New insights into manganese local environment in MnS-1 nanocrystals", *Crystal growth & design*, 2019, **19**, 6, 3130-3138.
13. Anja Kavčič, Klemen Mikuš, Marta Debeljak, Johannes Teun van Elteren, Iztok Arčon, Alojz Kodre, Peter Kump, Andreas-Germanos Karydas, Alessandro Migliori, Mateusz Czyzycki, Katarina Vogel-Mikuš, "Localization, ligand environment, bioavailability and toxicity of mercury in Boletus spp. and Scutiger pes-caprae mushrooms", *Ecotoxicology and environmental safety*, 2019, **184**, 109623.
14. A. Blomberg *et al.* (28 authors), "Virtual Compton scattering measurements in the nucleon resonance region", *The european physical journal. A, Hadrons and nuclei*, 2019, **55**, 182.
15. Isabela Tišma, Matej Lipoglavšek, Miha Mihovilovič, Sabina Markelj, Matjaž Vencelj, Jelena Vesić, "Experimental cross section and angular distribution of the ^{2}H(p, γ)^{3}He reaction at Big-Bang nucleosynthesis energies", *The european physical journal. A, Hadrons and nuclei*, 2019, **55**, 137.
16. Karen Jacqueline Cloete, Žiga Šmit, Roya Minnis-Ndimba, Primož Vavpetič, Anton Du Plessis, Stephan G. le Roux, Primož Pelicon, "Physico-elemental analysis of roasted organic coffee beans from Ethiopia, Colombia, Honduras, and Mexico using X-ray micro-computed tomography and external beam particle induced X-ray emission", *Food chemistry. X.*, 2019, **2**, 100032.
17. Miha Ocvirk, Marijan Nečemer, Iztok Jože Košir, "The determination of the geographic origins of hops (Humulus lupulus L.) by multi-elemental fingerprinting", *Food chemistry*, 2019, **277**, 32-37.
18. Ana Miklavčič Višnjevec, Alenka Baruca Arbeiter, Matjaž Hladnik, Ajda Ota, Mihaela Skrt, Bojan Butinar, Marijan Nečemer, Marin Krapac, Dean Ban, Milena Bučar-Miklavčič, Nataša Poklar Ulrih, Dunja Bandelj, "An integrated characterization of jujube (Ziziphus jujuba Mill.) Grown in the North Adriatic Region", *Food technology and biotechnology: journal of the Faculty of Food Technology and Biotechnology University of Zagreb*, 2019, **57**, 1, 17-28.
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21. S. Carniato *et al.* (14 authors), "Double-core ionization photoelectron spectroscopy of C_6H_6: breakdown of the "intuitive" ortho-meta-para binding energy ordering of $K^{-1}K^{-1}$ states", *The Journal of chemical physics*, 2019, **151**, 21, 214303.
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23. Darinka Darmanović, Igor N. Shcherbakov, Carole Duboc, Vojislav Spasojević, Darko Hanžel, Katarina Anđelković, Dušanka Radanović, Iztok Turel, Milica Milenković, Maja Gruden-Pavlović, Božidar R. Čobeljić, Matija Zlatar, "Combined experimental and theoretical investigation of the origin of magnetic anisotropy in pentagonal bipyramidal isothiocyanato Co(II), Ni(II), and Fe(III) complexes with quaternary-ammonium-functionalized 2,6-diacetylpyridine bisacylhydrazone", *The journal of physical chemistry. C, Nanomaterials and interfaces*, 2019, **123**, 51, 31142-31155.
24. Boštjan Jenčič, Primož Vavpetič, Mitja Kelemen, Matjaž Vencelj, Katarina Vogel-Mikuš, Anja Kavčič, Primož Pelicon, "MeV-SIMS TOF imaging of organic tissue with continuous primary beam", *Journal of the American Society for Mass Spectrometry*, 2019, **30**, 9, 1801-1812.
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26. Jonathan Z. Low *et al.* (11 authors), "The environment-dependent behavior of the Blatter radical at the metal-molecule interface", *Nano letters*, 2019, **19**, 4, 2543-2548.
27. Ali D. Malay *et al.* (21 authors), "An ultra-stable gold-coordinated protein cage displaying reversible assembly", *Nature: the international weekly journal of science*, 2019, **569**, 438-442.
28. Yves Kayser *et al.* (18 authors), "Core-level nonlinear spectroscopy triggered by stochastic X-ray pulses", *Nature communications*, 2019, **10**, 4761.
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31. Boštjan Jenčič, Luka Šepec, Primož Vavpetič, Mitja Kelemen, Zdravko Rupnik, Matjaž Vencelj, Katarina Vogel-Mikuš, Nina Ogrinc Potočnik, Shane R. Ellis, Ron M. A. Heeren, Primož Pelicon, "Stigmatic imaging of secondary ions in MeV-SIMS spectrometry by linear Time-of-Flight mass spectrometer and the TimePix detecto", *Nuclear instruments & methods in physics research. Section B, Beam interactions with materials and atoms*, 2019, **452**, 1-6.
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33. Mateja Gračič, Urša Malovrh, Aleksandra Golob, Katarina Vogel-Mikuš, Alenka Gaberščik, "Effects of water availability and UV radiation on silicon accumulation in the C4 crop proso millet", *Photochemical & photobiological sciences*, 2019, **18**, 2, 375-386.
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38. Mateja Hrast, Andrej Mihelič, Klemen Bučar, Matjaž Žitnik, "Auger decay of the 2*p* vacancy in chlorine", *Physical review. A*, 2019, **100**, 2, 023408.
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40. Bojan Golli, H. Osmanović, Simon Širca, "Dynamical generation of resonances in the P33 partial wave", *Physical review. C*, 2019, **100**, 3, 035204.
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44. A1 Collaboration, S. Paul *et al.*, "Quasi-elastic polarization-transfer measurements on the deuteron in anti-parallel kinematics", *Physics letters. Section B*, 2019, **795**, 599-605.
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51. Benoit Charrasse *et al.* (15 authors), "Does the use of reference organisms in radiological impact assessments provide adequate protection of all the species within an environment?", *Science of the total environment*, 2019, **658**, 189-198.
52. W. Błachucki *et al.* (13 authors), "Inception of electronic damage of matter by photon-driven post-ionization mechanisms", *Structural dynamics*, 2019, **6**, 024901.
53. Riccarda Delfino, Matteo Biasotto, Riccardo Candido, Matteo Altissimo, Marco Stebel, Murielle Salomè, Johannes Teun van Elteren, Katarina Vogel-Mikuš, Cristina Zennaro, Martin Šala, Riccardo Addobbati, Giuliana Tromba, Lorella Pascolo, "Gadolinium tissue deposition in the periodontal ligament of mice with reduced renal function exposed to Gd-based contrast agents", *Toxicology letters*, 2019, **301**, 157-167.
54. Paula Pongrac, Edita Baltrenaite, Primož Vavpetič, Mitja Kelemen, Aleš Kladnik, Bojan Budič, Katarina Vogel-Mikuš, Marjana Regvar, Pranas Baltrenas, Primož Pelicon, "Tissue-specific element profiles in Scots pine (Pinus sylvestris L.) needles", *Trees*, 2019, **33**, 1, 91-101.
55. Nina Kacjan-Maršić, Marijan Nečemer, Robert Veberič, Nataša Poklar Ulrih, Mihaela Skrt, "Effect of cultivar and fertilization on garlic yield and allicin content in bulbs at harvest and during storage", *Turkish journal of agriculture and forestry*, 2019, **43**, 414-429..
56. Marko Černe, Igor Palčić, Igor Pasković, Nikola Major, Marija Romić, Vilim Filipović, Marina Diana Igrc, Aleksander Perčin, Smiljana Goreta Ban, Benjamin Zorko, Branko Vodenik, Denis Glavič-Cindro, Radmila Milačič, David John Heath, Dean Ban, "The effect of stabilization on the utilization of municipal sewage sludge as a soil amendment", *Waste management*, 2019, **94**, 27-38.
57. Mateja Grašič, Aleksandra Golob, Katarina Vogel-Mikuš, Alenka Gaberščik, "Severe water deficiency during the mid-vegetative and reproductive phase has little effect on proso millet performance", *Water*, 2019, **11**, 10, 2155.
58. Zeeshan Faisal *et al.* (13 authors), "Diagram, valence-to-core, and hypersatellite *K*β X-ray transitions in metallic chromium", *X-ray spectrometry*, 2019, **48**, 5, 351-359.

Published Conference Contribution (invited lecture)

1. Miha Mihovilovič, Harald Merkel, For the A1-Collaborion, "ISR experiment at A1-collaboration", In: *11th International Workshop on e^+e^- Collisions from Phi to Psi (PhiPsi 2017), June 26-29, 2017, Mainz, Gemany*, (EPJ web of conferences, **218)**, 2019, 04001.

Published Conference Contribution

1. Nataša Nemeček, Eva Menart, Domen Lavriha, Marko Jeran, Tomaž Lazar, Christian Degrigny, "Exploring suitable parameters for electrochemical cleaning/ consolidation of museum objects and practical use of the Pleco electrolytic pencil", In: *Metal 2019: the Interim Meeting of the ICOM-CC Metals Working Group, September 2-6, 2019, Neuchâtel, Switzerland*, Proceedings, International Council of Museums - Committee for Conservation (ICOM-CC), 2019, 472.
2. Eva Menart, Nataša Nemeček, Irena Kralj Cigić, Helena Pucelj Krajnc, "Study of preventive conservation procedure for paintings on iron plates", In: *Metal 2019: the Interim Meeting of the ICOM-CC Metals Working Group, September 2-6, 2019, Neuchâtel, Switzerland*, Proceedings, International Council of Museums - Committee for Conservation (ICOM-CC), 2019, 451.
3. Janvit Teržan, Petar Djinović, Janez Zavašnik, Iztok Arčon, Gregor Žerjav, Matjaž Spreitzer, Albin Pintar, "Direct propylene oxidation using molecular oxygen using mesoporous silica as the support", In: *Proceedings of the 8th Serbian-Croatian-Slovenian Symposium on Zeolites, Proceedings of the 8th Croatian-Slovenian-Serbian Symposium on Zeolites, Proceedings of the 8th Slovenian-Serbian-Croatian Symposium on Zeolites: [3 - 5 October 2019, Belgrade, Serbia]*, Serbian Zeolite Association, 2019, 29-32.
4. Simon Širca, "Measurement of G_A and the GDH sum rule at high energies at Jefferson Lab: two proposals", In: *Proceedings of the Mini-Workshop Electroweak Processes of Hadrons, Bled, Slovenia, July 15-19, 2019*, (Blejske delavnice iz fizike, **20** 1**)**, 2019, 93-102.
5. Sabina Markelj, Matic Pečovnik, Iztok Čadež, "Study of heavy ammonia production and hydrogen isotope exchange in ammonia on surfaces exposed to deuterium/nitrogen plasma", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 711.
6. Andreja Sironić, Ines Krajcar Bronić, Jasmina Kožar Logar, Romana Krištof, "Interlaboratorijske usporedbe aktivnosti organski vezanog tricija (OBT)", In: *Proceedings of the 12th Symposium of the Croatian Radiation Protection Association, Varaždin, Croatia, April 10.12. 2019: HDZZ - CRPA*, Hrvatsko društvo za zaščitu od zračenja, 2019, 364-369.
7. Ines Krajcar Bronić, Jasmina Kožar Logar, Romana Krištof, Jovana Nikolov, Nataša Todorović, Ivana Stojković, Jadranka Barešić, Andreja Sironić, Damir Borković, "Rezultati sudjelovanja u međunarodnoj usporednoj studiji za biogenu komponentu u tekućim gorivima", In: *Proceedings of the 12th Symposium of the Croatian Radiation Protection Association, Varaždin, Croatia, April 10.12. 2019: HDZZ - CRPA*, Hrvatsko društvo za zaščitu od zračenja, 2019, 355-363.

Independent Component Part or a Chapter in a Monograph

1. Jasmina Kožar Logar, "Radioaktivnost v pitni in podzemni vodi", In: *Obdelava podatkov meritev radioaktivnosti v okolju*, Institut Jožef Stefan, 2019, 21/106-35/106.
2. Toni Petrovič, "Radioaktivnost v padavinah in suhem usedu", In: *Obdelava podatkov meritev radioaktivnosti v okolju*, Institut Jožef Stefan, 2019, 37/106-49/106.
3. Katarina Vogel-Mikuš, Marijan Nečemer, "Radionuklidi v hrani", In: *Obdelava podatkov meritev radioaktivnosti v okolju*, Institut Jožef Stefan, 2019, 85/106-101/106.
4. Katarina Vogel-Mikuš, Johannes Teun van Elteren, Marjana Regvar, Jitrin Chaiprapa, Boštjan Jenčič, Iztok Arčon, Alojz Kodre, Peter Kump, Anja Kavčič, Mitja Kelemen, Dino Metarapi, Marijan Nečemer, Primož Vavpetič, Primož Pelicon, Paula Pongrac, "Recent advances in 2D imaging of element distribution in Plants by focused beam techniques", In: *Plant metallomics and functional omics: a system-wide perspective*, Springer, 2019, 169-207.

Theses and Mentoring

1. Anja Kavčič, *Effects of selenium on the uptake, ligand environment and bioavailability of mercury in selected plants and fungi:* doctoral dissertation, Ljubljana, 2019 (mentor Katarina Vogel-Mikuš).

DEPARTMENT OF THIN FILMS AND SURFACES F-3

The main research field of the department is the development, deposition and characterization of hard protective PVD coatings, while research is also conducted in other fields of thin films and surface physics. The basic research is concentrated on the study of the physical and chemical properties of various multicomponent, multilayer and nanostructured coatings. In the applied research, different coatings are developed for the protection of tools for various production processes in industry.

Head:
Prof. Miha Čekada

In the scope of our main research field of hard protective coatings, we have been active for several years in the work on growth defects in thin films deposited by magnetron sputtering. After the recent installation of a cathodic arc deposition unit we expanded the growth-defect research on this technique too; one of the method's characteristics is a large density of emitted microdroplets. We also gave emphasis to a known but otherwise less-explored effect of enhanced coating thickness on geometrically exposed spots. Preliminary results show interesting trends, which will be the topic of our research in the coming year too.

In the previous year we put a lot of our effort into analytics in the nanometre range. Our coworker Dr Aljaž Drnovšek recently returned from a post-doc; from Montanuniversität Leoben (Austria), University of Southampton (Great Britain) and University of California, Berkeley (USA), where he acquired knowledge on the measurement of coating fracture toughness, diamond high-temperature tip wear and basic science on crystal slip planes in various crystal structures. At these institutions he measured the nanomechanical properties of CrAlN and CrAlSiN coatings. In the previous year we successfully applied to the national call for co-financing of research equipment purchase; within this application we ordered an in-situ system for the measurement of physical properties at the nanolevel. This instrument will enable us to continue this research work at our home institution where we will analyse the nanomechanical properties of coatings deposited in our lab.

A somewhat different direction is the increasingly active collaboration with the Faculty of Mechanical Engineering at the University of Ljubljana. We have complementary equipment with their Laboratory for Machining, as our equipment enables the deposition of coatings and theirs the testing of coatings in semi-industrial conditions. Since last year we have had a young scientist who will perform his research on cryogenic machining at both institutions.

In addition to coating deposition and analytics the department is also active in understanding basic physical processes in plasma, which is used in the deposition. Magnetron sputtering is a technique that is commonly applied for the deposition of high-quality thin films and is a source of dense plasma. Research on magnetron discharge has recently shown that plasma is angularly inhomogeneous, which is in contradiction to common knowledge at the time. Work with a high-speed camera has proved that plasma is concentrated in areas having an arrow-like form, which form periodic or semi-periodic patterns. Such self-organized plasma has been found in both the classic DC and pulsed regimes of magnetron sputtering. In the previous year we were the first to show that self-organized plasma structures are also present in the oscillatory radio-frequency magnetron regime. This sputtering regime is predominantly used for the deposition of electrically non-conductive thin films. Our research has shown that plasma forms stable patterns in a wide range of discharge parameters.

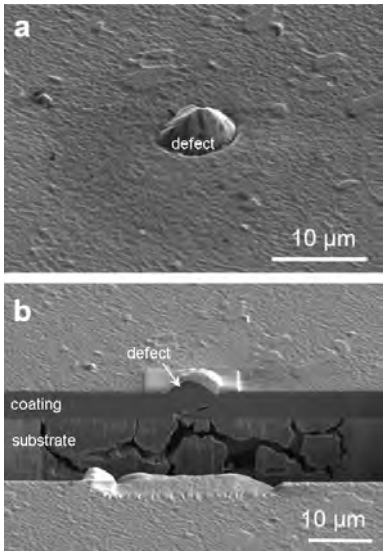

Figure 1: Growth defect on a TiAlN coating after exposure to a corrosion test: SEM image of the surface (a) and the image from the same perspective after construction of a cross-section using the FIB technique (b). Corrosion damage to the steel substrate is very apparent.

We have been active in nuclear fusion research for several years. This work is primarily conducted in collaboration with researchers from the Max-Planck Institut für Plasmaphysik from Garching (Germany). In the past we developed tungsten nitride thin films, which we deposited on test plates for the first wall of a fusion reactor. The plates were exposed to plasma in the ASDEX Upgrade tokamak. Using different surface techniques we analysed the wear tracks that had formed because of the high flux of ions and electrons towards the reactor wall.

To a minor extent the department is also active in some other fields of coating deposition and the analytics of surfaces and thin films. In most cases the materials investigated are chemically much different to the ones from our core competence; however, our contribution is useful for other research partners who do not have the relevant instruments for this type of research. In this way we collaborate with several departments of our institute, as well as with other research institutions, such as Faculties of

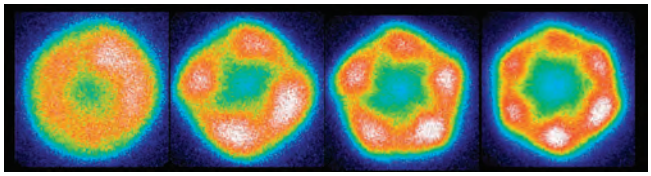

Figure 2: Self-organized plasma structures in the radio-frequency regime of magnetron sputtering at various discharge parameters. The images were acquired with a high-speed camera.

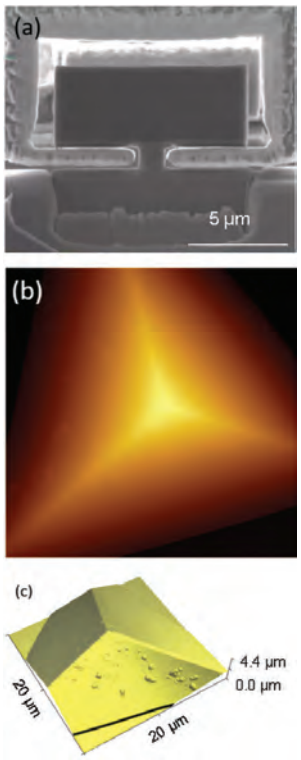

Figure 3: SEM image of in-situ tensile test of nickel (a); AFM image of a new Berkovich indenter (b) and corresponding 3D topography (c).

Mechanical Engineering in Ljubljana and Maribor, the Faculty for Natural Sciences and Technology at the University of Ljubljana, and Institute for Metals and Technologies. In collaboration with researchers from the Vinča Institute of Nuclear Sciences (Serbia) we investigate the magnetic properties of thin films and nanoparticles. We also collaborate with the Institute for Technical Physics and Materials Science (Hungarian Academy of Sciences). Our contribution is the deposition of Si/C multilayer structures.

Collaboration with Slovenian industry takes place on several levels. On one side there is multilateral participation in larger projects, such as the Gostop program within the smart specialization strategy. Within this project we evaluated the possibilities for the protection of aluminium die-casting tools using different coatings. The best results were achieved using a TiAlN-based nanolayer coating. There are also smaller targeted projects or informal cooperations, such as the study for the applicability of various coatings on laser sintered steel (in collaboration with the company Marsi). We often perform educational seminars, be it for a wider audience (organized by the Slovenian tool and die development centre, Tecos) or targeted for a particular company. Such a seminar can be an upgrade of previous collaboration or can serve as a baseline for further joint activities. In 2019 we had such seminars in the companies Krka, Gorenje, Odelo and Niko.

Companies also address us in the case of an issue connected to surfaces or thin films. This may require advanced analytics or a failure analysis. In the previous year, such analyses were performed for the companies: Cetis, Difa, Kovinos, Le-tehnika, Phos, Proarmis, SIQ Slovenia and Teroxal. Our industrial partners are also offered the service of depositing hard coatings on their tools, which we perform in the scope of our Hard Coatings Center. There are annually more than a hundred partners, which includes both large companies (e.g., Kolektor, Mahle, Unior, Hidria) as well as numerous small tool shops.

Some outstanding publications in the past year

1. P. Panjan, A. Drnovšek, P. Gselman, M. Čekada, P. Panjan, T. Bončina, D. Kek-Merl†, Influence of growth defects on the corrosion resistance of sputter-deposited TiAlN hard coatings, *Coatings*, 9 (2019) 8, 511
2. M. Panjan, Self-organizing plasma behavior in RF magnetron sputtering discharges, *Journal of applied physics*, 125 (2019) 20, 203303-1–203303-9

INTERNATIONAL PROJECTS

1. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION
   Dr. Matjaž Panjan
   European Commission
2. H2020 EUROfusion - Medium Size Tokamak Campaigns-MST1-FU
   Dr. Matjaž Panjan
   European Commission
3. High-Temperature Tribological Behavior of Novel Hard Nanocomposite Nitride Coatings
   Dr. Peter Panjan
   Slovenian Research Agency

RESEARCH PROGRAMME

1. Thin film structures and plasma surface engineering
   Prof. Miha Čekada

R & D GRANTS AND CONTRACTS

1. Initial stages in surface functionalization of polymers by plasma radicals
   Uroš Stele
2. Carbon nanowalls for future supercapacitors
   Prof. Miha Čekada
3. Central European SME Gateway to Key-enabling Technology Infrastructures - Sparking new Transnational KET Innovation Ecosystem
   Prof. Miha Čekada
   Bay Zoltan Alkalmazott Kutatasi Kozhasznu
4. Innovative ECO plasma seed treatment (for sowing and for human and animal diet/ nutrition
   Prof. Miha Čekada
   Ministry of Education, Science and Sport
5. Building blocks, tools and systems for the Factories of the Future – GOSTOP
   Prof. Miha Čekada
   Ministry of Education, Science and Sport
6. Irradiation and Analysis of Nano SiC Samples in the Year 2019
   Prof. Miha Čekada
   Institute of Radiation Problems of Azerbaijan National Academy of Sciences
7. Deposition of hard coatings
   Prof. Miha Čekada

VISITORS FROM ABROAD

1. Udo Stüber, KCS Europe GmbH, Monschau, Germany; Homare Namura, Kobe Steel, Japan, 1. 2. 2019
2. Aldo Conti, Sam Bort, Hiden Analytical, Milano, Italy; Warrington, United Kingdom, 19.–20. 2. 2019
3. Rainer Cremer, KCS Europe GmbH, Monschau, Germany, 5.–7. 3. 2019
4. Pal Terek, University of Novi Sad, Novi Sad, Serbia, 3.–14. 6. 2019
5. Marin Tadić, Vinča nuclear institute, Belgrade, Serbia, 20.–30. 6. 2019

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4. Dr. Aljaž Drnovšek

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Technical and administrative staff
8. Jožko Fišer
9. Damjan Matelič
10. Andrej Mohar
11. Tomaž Sirnik
12. Tadej Stele

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Original Article

1. Peter Panjan, Aljaž Drnovšek, Peter Gselman, Miha Čekada, Matjaž Panjan, Tonica Bončina, Darja Kek-Merl, "Influence of growth defects on the corrosion resistance of sputter-deposited TiAlN hard coatings", *Coatings*, 2019, **9**, 8, 511.
2. Marin Tadić, Djordje Trpkov, Lazar Kopanja, Sandra Vojnović, Matjaž Panjan, "Hydrothermal synthesis of hematite ($\alpha - Fe_2O_3$) nanoparticle forms: synthesis conditions, structure, particle shape analysis, cytotoxicity and magnetic propertie", *Journal of alloys and compounds*, **792**, 599-609.
3. Matjaž Panjan, "Self-organizing plasma behavior in RF magnetron sputtering discharges", *Journal of applied physics*, 2019, **125**, 20, 203303.
4. Juliane Moritz, Anže Abram, Miha Čekada, Urška Gabor, Maja Garvas, Irena Zdovc, Aleš Dakskobler, Jasna Cotič, Karolina Ivičak-Kocjan, Andraž Kocjan, "Nanoroughening of sandblasted 3Y-TZP surface byalumina coating deposition for improved osseointegration and bacteria reduction", *Journal of the European ceramic society*, 2019, **39**, 14, 4347-4357.
5. Dervis Ozkan, Peter Panjan, Mustafa Sabri Gök, Abdullah Cahit Karaoğlanli, "Investigation of machining parameters that affects surface roughness and cutting forces in milling of CFRPs with TiAlN and TiN coated carbide cutting tools", *Materials research express*, **6**, 9, 095616.
6. B. Labit *et al.* (466 authors), "Dependence on plasma shape and plasma fueling for small edge-localized mode regimes in TCV and ASDEX Upgrade", *Nuclear fusion*, 2019, **59**, 8, 086020.
7. Aljaž Drnovšek, Marisa Rebelo de Figueiredo, Hi Vo, Ao Xia, Shraddha J. Vachhani, Szilard Kolozsvári, Peter Hosemann, Robert Franz, "Correlating high temperature mechanical and tribological properties of CrAlN and CrAlSiN hard coatings", *Surface & coatings technology*, 2019, **372**, 361-368.
8. A. S. Racz, D. Zambo, Anelia G. Dobrikova, I. Lukas, Z. Zolnai, A. Németh, Peter Panjan, Ágota Deák, G. Battistig, Miklós Menyhárd, "Novel method for the production of SiC micro and nanopatterns", *Surface & coatings technology*, 2019, **372**, 427-433.

Published Conference Contribution

1. Pal Terek, Lazar Kovačević, Aleksandar Miletić, Dragan Kukuruzović, Branko Škorić, Aljaž Drnovšek, Peter Panjan, "Sticking and galling phenomena in ejection process of coated core pins from Al-SI-Cu- alloy casting", In: *Serbiatrib '19: 16th International Conference on Tribology, 15-17 May 2019, Kragujevac, Serbia,* (Proceedings on Engineering Sciences, **1**, 1), 2019, 246-251. [COBISS.SI-ID 33254695]
2. Dragan Kukuruzović, Pal Terek, Lazar Kovačević, Branko Škorić, Aleksandar Miletić, Peter Panjan, Miha Čekada, "Evaluation of soldering resistance of CrAiN coatings intended for application on high pressure die casting tools", In: *Serbiatrib '19: 16th International Conference on Tribology, 15-17 May 2019, Kragujevac, Serbia,* (Proceedings on Engineering Sciences, **1**, 1), 2019, 278-284. [COBISS.SI-ID 33254951]

DEPARTMENT OF SURFACE ENGINEERING AND OPTOELECTRONICS F-4

The Department of Surface Engineering conducts interdisciplinary research on designing the surface properties of various materials. We use advanced techniques for surface and thin-film characterization, in particular with our XPS, AES, SIMS and AFM instruments. The scientific activities are focused on surfaces and coatings, gaseous discharges, thermodynamically non-equilibrium plasma and the interaction of reactive plasma species with organic and inorganic materials. Patent applications protect innovative solutions for industry, medicine, biotechnology and agriculture.

Head:
Prof. Miran Mozetič

The research team has been deeply involved in the preparation of the Slovenian Strategy of Smart Specialization (S4). The document represents the roadmap for the transition to a modern society according to European Smart Specialisation Strategy (S3). Strategic Research and Innovation Partnerships (SRIPs) have been established. Among them, the most relevant for our department's activities are the SRIPs "Factories of Future" and "Food". Plasma technologies have been recognized as a key enabling technology by both SRIPs. Most currently used plasma technologies do not meet the standards of Industry 4.0, neither in conventional industries such as automotive and electrical, nor in agriculture. The research team of the Department of Surface Engineering prepared action plans for crossing the gap between current praxis and the demands of Industry 4.0. The team members are among the leading researchers in current large R&D projects, both in agriculture and the food industry.

The research team organized several topical workshops on plasma technologies that attracted attendance from both the commercial and academic spheres. The workshops represent unique opportunities for networking and the exchange of ideas. The organization of scientific meetings is recognized as a vital activity also by the Slovenian government. The high-profile events were awarded at a ceremony organized by Slovenian Convention Bureau. A member of our team, prof. Janez Kovač, was announced a Congress Ambassador of Slovenia for the organization of the European vacuum conference in Portorož. The conference gathered about 200 participants with good attendance by users as well as producers of vacuum equipment and large industrial vacuum systems. The photograph, Figure 1, was taken at the ceremony organized at Ljubljana Castle.

Figure 1: Prof. dr. Janez Kovač was announced as a Congress Ambassador of Slovenia for the organization of the Joint Vacuum Conference JVC-16 and European Vacuum Congress EVC-14.

Team members often serve as invited speakers at various scientific and professional meetings. Since we are renowned for activities related to Industry 4.0, the team members are frequently invited to lecture on the state of the art and demands in adopting plasma technologies to meet the criteria of Industry 4.0. The team leader, Prof. Miran Mozetič, served as a plenary speaker at the large conference of Asia-Pacific Physicists which was organized in Malaysia in autumn 2019. He explained the shortcomings of current plasma technologies and presented the roadmap, stressing the challenges for the plasma scientist, in particular for the adoption of plasma technologies to enable integration to smart production lines. The photograph, Figure 2, was taken at this conference, which was attended by about 500 participants.

Figure 2: The team leader was a plenary speaker at the 14th Asia-Pacific Physics Conference in Malaysia.

Current plasma reactors useful for the processing of materials suffer from a lack of reliable sensors for the real-time and spatially resolved monitoring of plasma parameters in industrial-size reactors. Many current reactors operate at a rather low power density, so the major reactants are neutral plasma radicals rather than charged particles. While the density of charged particles is often fairly homogeneous in industrial-size reactors, large gradients of neutral reactive species are often observed. The gradients, both spatial and temporal, are due to the variations in

The research team is deeply involved in industrial research within the Slovenian Strategy of Smart Specialization (S4).

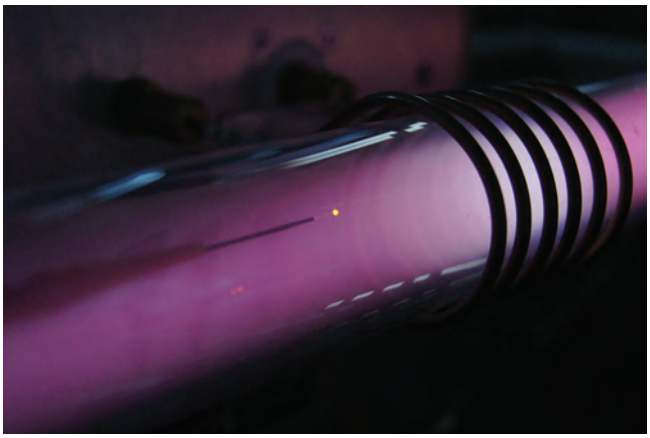

Figure 3: The tip of the patented catalytic probe is heated to about 1000 K by a laser connected to the other side of an optical fibre.

Figure 4: Dr Nina Recek is testing the decontamination and germination of plasma-treated seeds.

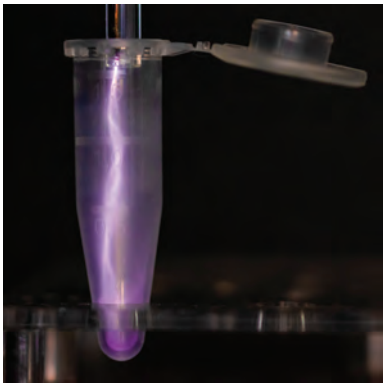

Figure 5: Treatment of Eppendorf tubes with gaseous plasma is useful for suppressing the adhesion of microvesicles and exosomes.

the probability of the heterogeneous surface recombination of radicals on the materials facing the plasma. There is a lack of reliable techniques for the determination of the radicals' density in low-pressure gaseous plasma. Different research groups have invented innovative techniques for measuring the densities with good space and time resolutions, and some are promising for applications in smart production lines. One solution employs a very reliable method – calorimetry. The research team has developed several solutions and the most sophisticated is the laser-driven catalytic probe. The original patent application was filed in 2014, and the EU patent was granted in 2019 [1]. The catalytic tip is kept continuously at high temperature, and the laser power needed to sustain such a constant temperature is inversely proportional to the flux of radicals onto the catalytic tip. A photograph of the tip immersed into an experimental plasma reactor is shown in Figure 3.

A large project "Innovative eco-friendly plasma technology for decontamination of seeds" was initiated in January 2019. The research team has ambitious plans to develop a technology for a plasma treatment to disinfect different seeds and suppress the concentration of toxins below the level prescribed by international standards. The technology will be developed up to Technological Readiness Level (TRL) 6: technology demonstrated in a relevant environment. Six partners are involved in the applied research and development of a prototype of a plasma reactor useful for seed treatment in the continuous mode. The consortium leader is the largest Slovenian producer of the seeds, while the scientific leadership was accepted by dr. Nina Recek (Figure 4). Researchers with different skills from several departments of the Jozef Stefan Institute are involved in this ambitious project.

The research team was also involved in another large project entitled "Food4Future". A novel technology was introduced for improving the properties of polyethylene (PE) and polypropylene (PP) foils suitable for applications in food packaging. The key innovative step was the optimization of plasma parameters for the treatment of these foils to achieve excellent adhesion of a chitosan-colloidal coating of superior antibacterial and antioxidant properties and low permeability for oxygen. First, a layer of chitosan macromolecular solution was deposited onto the plasma-treated surface, which enabled excellent antibacterial properties. Then, the second coating was deposited, containing a network of polyphenol resveratrol with embedded chitosan nanoparticles, which enabled antioxidant and antimicrobial properties simultaneously. X-ray photoelectron spectroscopy (XPS) and infrared spectroscopy (FTIR) showed successful binding of both coatings onto the foils. In addition, both layers enabled a reduced oxygen permeability and wetting contact angle of the foils; the latter indicates excellent anti-fog properties as well. Foils treated according to the methods of the invention exhibited over 90% reduction of bacteria as compared to the untreated foils and increased antioxidant activity by over a factor of 10. The technique is useful in different packagings, such as food (meat, vegetables, dairy and bakery products) and pharmaceutical packaging. An appropriate patent application was filed [2].

The bio-medical application of plasma technologies remains a hot topic of interdisciplinary research worldwide. The research team is among the most innovative in this scientific niche. A European patent disclosing a method for the modification of tools used for the isolation of microvesicles, nanovesicles or exosomes was granted in autumn 2019 [3]. A fruitful collaboration with researchers from the University of Ljubljana enabled the development of the method for the modification of the inner surface of Eppendorf tubes. The research on membrane nanostructures as a relevant factor influencing the cell-environment interactions was selected by the University of Ljubljana as one of the outstanding research achievements in 2019. The university announces such achievements annually to highlight outstanding researchers who have achieved particularly visible results in terms of international reputation as well as reverberation with the professional and general public. A photograph of plasma in an Eppendorf tube is shown in Figure 5.

Another interesting plasma application is the treatment of vascular stents. A couple of students were involved in these activities with the mentorship of Prof. Ita Junkar. The students Nika Špajzer and Nina Naprudnik prepared a report entitled "New generation of vascular stents" and their supervisor received the Silver Award at the 53rd Slovenian Young Researcher meeting for mentorship of this interdisciplinary research work. Furthermore, the report was granted a "Krka award" at the 49th

Competition of young researchers organized by the largest Slovenian pharmaceutical company Krka. The Silver Award is shown in Figure 6.

Nitinol (a nickel-titanium alloy) is used as the appropriate material in many medical applications; however, the possible release of toxic nickel from its surface and absorption in human tissue remains a significant concern. We developed a new route for suppressing the Ni release and thus improving the biocompatibility of this material. Our innovative procedure enables the formation of a thin titania film on the surface of this alloy. The oxide film represents a diffusion barrier for Ni ions from bulk material and thus prevents any release of Ni. The AES depth profile in Figure 7 reveals an immeasurably low concentration of nickel within the oxide film. The biocompatibility investigations, performed according to the ISO standard protocol using L929 human cells, showed the absence of any cytotoxic effects that might be due to the nickel's release. The investigation of nickel release of samples exposed to Hank's solution, measured by ICP-OES, also showed negligible Ni concentrations. The results were reported in a renowned journal [4]. This paper is the first report worldwide on a nickel-free titanium oxide film on the surface of any alloy containing Ni and Ti.

Multilayers play an important role in many scientific and technological fields and are most common in the fabrication and applications of semiconductor quantum-well structures. Therefore, there is a global demand for the reliable and quantitative characterization of the fabricated structures. Among the various methods, sputter depth profiling by ion bombardment in combination with secondary-ion mass spectrometry (SIMS) or electron spectroscopies (XPS, AES) has proved to be versatile and ubiquitously applicable. All three methods are available in our laboratories. The depth profiles of thin multilayer structures are, however, frequently distorted, mainly by sputtering-induced artefacts. A convenient means for the quantification of depth profiles with appropriate analysis and reconstruction of a measured depth profile is the Mixing-Roughness-Information (MRI) depth model, which takes into account three effects: atomic mixing, roughness and information depth. Recently, we improved the MRI model to take into account an additional artefact, i.e., the influence of preferential sputtering of different elements on depth resolution and profile shape in the sputter-depth profiling of multilayers. In our experimental and theoretical study of the preferential sputtering of very thin layers (thickness between 5 and 20 nm), we found how the interface width, interface location and layer thickness are affected by preferential sputtering in XPS, AES and SIMS depth profiling. The successful application of the MRI model expanded for the effect of preferential sputtering was used for fitting the as-measured AES depth profiles of Ag/Ni multilayers. These results were published in a leading journal for surface and thin-film characterization [5]. Figure 8 reveals applicability in the case of Ag/Ni structures.

The research team often participates in fusion-related projects either accomplished in our labs or at large tokamaks. The second-largest fusion experiment in Germany is tokamak ASDEX-U, located in Garching, Germany. In our experimental shifts, we evaluated the nitrogen concentration and ammonia production in N_2-seeded H-mode gaseous discharges [6]. We monitored the ammonia production using divertor spectroscopy and analysis of the exhaust gas (Figure 9). The amount of the detected ammonia increased continuously for five discharges with the same nitrogen seeding rate. The results show that the rate of ammonia formation exhibited the same trend as the nitrogen density in plasma. This density, in turn, was strongly influenced by the nitrogen wall inventory. The spatial distribution of the detected ammonia suggests that a significant contribution to the net ammonia formation occurs in plasma-shaded areas, through the surface reactions of neutral species. The results are important for designing the peculiarities of future fusion reactors, where it is supposed that nitrogen-seeding will be necessary for cooling the divertor plasma and thus prolonging the service time of the first-wall material.

Figure 6: Prof. dr. Ita Junkar was awarded for mentoring two students who prepared research on developing the new generation of vascular stents.

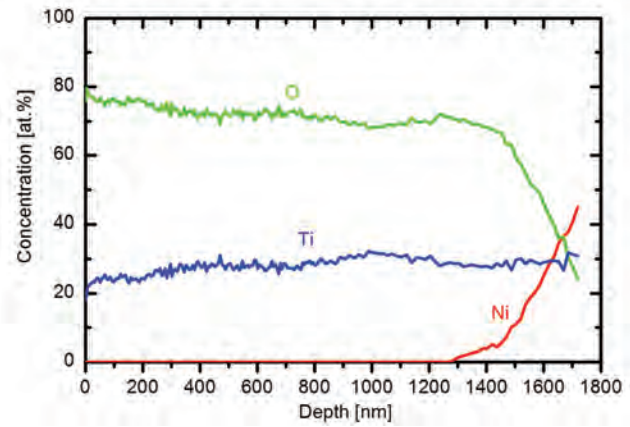

Figure 7: AES depth profile of the Nitinol sample oxidized according to our methods of invention based on treatment with hydrogen and oxygen plasma.

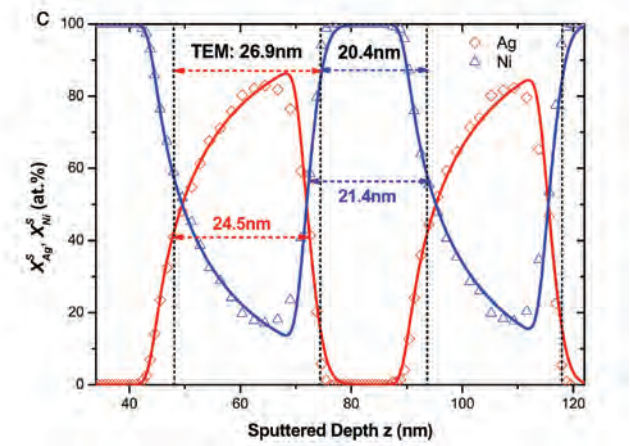

Figure 8: A region from the measured AES depth profile of multilayer structure Ag/Ni and modelling curves for Ag and Ni distribution obtained by the improved MRI model taking into account preferential ion sputtering rate.

Some outstanding publications in the past three years

[1] Gregor Primc, Miran Mozetič, Uroš Cvelbar, Alenka Vesel, Method and device for detecting and measuring the density of neutral atoms of hydrogen, oxygen or nitrogen, European patent EP 3146327B1, granted on 6th November 2019.

[2] Alenka Vesel, Miran Mozetič, Nives Ogrinc, Lidija Fras Zemljič, Tjaša Kraševec Glaser, Method for synthesizing impermeable foils for food packaging of superior antimicrobial and antioxidant properties with minimized oxygen permeability, patent application GB 1907793.2, filled on 31st May 2019.

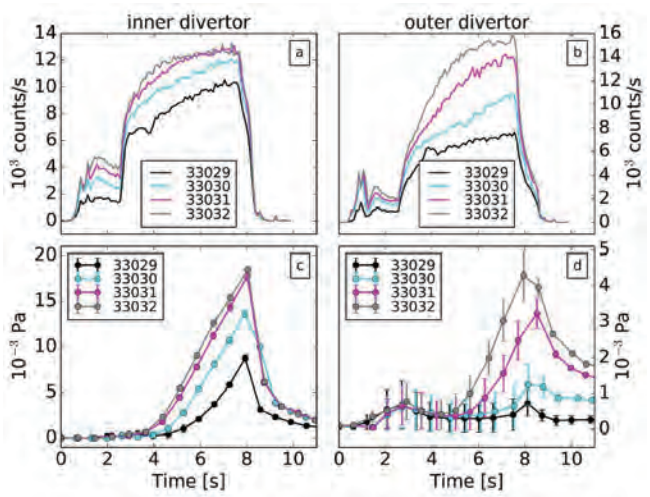

Figure 9: Time traces of the ND emission (a) and (b), and partial pressures of ammonia in the neutral gas (c) and (d), in the inner (a) and (c) and outer (b) and (d) divertor.

[3] Ita Junkar, Veronika Kralj-Iglič, Roman Štukelj, Rok Zaplotnik, Miran Mozetič, Method for treatment of tools and tools used for isolation of microvesicles, nanovesicles or exosomes, European Patent EP 3185921B1, granted on 4th September 2019.

[4] Monika Jenko, Matjaž Godec, Aleksandra Kocijan, Rebeka Rudolf, Drago Dolinar, Maja Ovsenik, Matevž Gorenšek, Rok Zaplotnik, Miran Mozetič. A new route to biocompatible Nitinol-based on a rapid treatment with H2/O2 gaseous plasma. Applied Surface Science (2019), vol. 473, p. 976-984.

[5] Siegfried Hoffman, Gang Zhou, Janez Kovač, Sandra Drev, SongYou Lian, Bin Lin, Yi Liu, Jiang Yong Wang, Preferential sputtering effects in depth-profiling of multilayers with SIMS, XPS and AES, Applied Surface Science (2019), vol. 483, p. 140-155.

[6] Aleksander Drenik, Jernej Kovačič, Natan Osterman, Matjaž Panjan, PRIMC, Gregor Primc, Matic Resnik, Rok Zaplotnik, The ASDEX-Upgrade team and the EUROfusion MST1 team, Evolution of nitrogen concentration and ammonia production in N2-seeded H-mode discharges at ASDEX Upgrade. Nuclear fusion (2019), vol. 59, p. 046010-1-18.

Awards and Appointments

1. Prof. Janez Kovač received the recognition Congress Ambassador from the Slovenian Convention Bureau for organising the Joint Vacuum Conference JVC-16 and European Vacuum Conference EVC-14
2. Asst. Prof. Ita Junkar received the silver recognition of the Association for Technical Culture of Slovenia for the result achieved at the 53rd Meeting of young Researchers of Slovenia 2019 for supervising the research paper authored by Nika Špajzer and Nina Naprudnik
3. Prof. Miran Mozetič, Asst. Prof. Gregor Primc and Prof. Alenka Vesel received the bronze medal ARCA 2019 at the 17th International Innovation Exhibition
4. Prof. Miran Mozetič, Asst. Prof. Gregor Primc, Prof. Alenka Vesel and Asst. Prof. Rok Zaplotnik were among the recipients of the bronze medal ARCA 2019 at the 17th International Innovation Exhibition

Patents granted

1. Rok Zaplotnik, Miran Mozetič, Gregor Primc, Alenka Vesel, Masaru Hori
   Carbon nanostructured materials and methods for forming of these materials
   SI25662 (A), Urad RS za intelektualno lastnino, 31. 12. 2019.
2. Gregor Primc, Miran Mozetič, Uroš Cvelbar, Alenka Vesel
   Method and device for detection and measuring the density of neutral atoms of hydrogen, oxygen or nitrogen
   EP3146327 (B1), European Patent Office, 06. 11. 2019.
3. Ita Junkar, Veronika Kralj-Iglič, Roman Štukelj, Rok Zaplotnik, Miran Mozetič
   Method for treatment of tools and tools used for isolation of microvesicles, nanovescicles or exsomes
   EP3185921 (B1), European Patent Office, 04. 09. 2019.

INTERNATIONAL PROJECTS

1. COST CA15114; Anti-Microbal Coating Innovations to prevent Infectious Diseases (AMICI)
   Prof. Uroš Cvelbar
   Cost Office
2. COST CA18113; Understanding and Exploiting the Impact of Low pH on Microorganisms
   Dr. Martina Modic
   Cost Association Aisbl
3. H2020 - PEGASUS; Plasma Enabled and Graphene Allowed Synthesis of Unique nano Structures
   Prof. Uroš Cvelbar
   European Commission
4. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION
   Asst. Prof. Rok Zaplotnik
   European Commission
5. H2020 EUROfusion - Education-ED-FU
   Prof. Miran Mozetič
   European Commission
6. H2020 EUROfusion - Medium Size Tokamak Campaigns-MST1-FU
   Asst. Prof. Rok Zaplotnik
   European Commission
7. H2020-EUROFUSION-WPPFC-PEX-FU, WPPFC-PEX-FU, EUROFUSION
   Asst. Prof. Rok Zaplotnik
   European Commission
8. Plasma-Assisted Design of Multifunctional Carbon Nanowalls Bio-Sensor
   Prof. Uroš Cvelbar
   Slovenian Research Agency
9. Innovative Coatings for Bare Metallic Vascular Stents for Reduction of Restenosis and Acceleration of Natural Endothelization
   Prof. Miran Mozetič
   Slovenian Research Agency
10. Transport and Field Emission Properties of Low-Dimensional Molybdenum and Tungsten Based Nanomaterials
    Dr. Vincenc Nemanič
    Slovenian Research Agency
11. Catalytic Probes for Characterization of Hydrogen Plasma
    Asst. Prof. Gregor Primc
    Slovenian Research Agency
12. Control of Chemical Composition of Thin Films by High Resolution Mass Spectrometry of Secondary Ions
    Prof. Janez Kovač
    Slovenian Research Agency
13. Advanced Catalysts based on Multilayered Vertically Oriented Graphene Nanostructures
    Prof. Alenka Vesel
    Slovenian Research Agency
14. Investigation of Helium Retention in Plasma Facing Materials Using Advanced Analytical Methods
    Dr. Gregor Filipič
    Slovenian Research Agency
15. Characterization of Oxygen Plasma Sustained with Powerful Gaseous Discharges
    Prof. Miran Mozetič
    Slovenian Research Agency
16. Consequences of electron emission from hot plasma-facing components in nuclear fusion reactors
    Prof. Miran Mozetič
    Slovenian Research Agency

RESEARCH PROGRAMMES

1. Vacuum technique and materials for electronics
   Dr. Vincenc Nemanič
2. Thin film structures and plasma surface engineering
   Prof. Miran Mozetič
3. Fusion technologies
   Asst. Prof. Rok Zaplotnik

R & D GRANTS AND CONTRACTS

1. Ecologically friendly in-situ synthesis of ZnO nanoparticles for the development of protective textiles
   Asst. Prof. Gregor Primc
2. Initial stages in surface functionalization of polymers by plasma radicals
   Prof. Janez Kovač
3. Plasma-assisted wound treatment and topical introduction of molecules
   Prof. Uroš Cvelbar
4. Novel higly sensitive and fast water qulity monitoring sensors
   Prof. Uroš Cvelbar
5. Advanced surface finishing technologies for antibacterial properties of patient specific 3D printed implantable materials
   Asst. Prof. Ita Junkar
6. Hybrid and Reengineered Nanocatalysts for New Purification Routes
   Prof. Uroš Cvelbar
7. New generation of superior creep resistant steels with nanoparticles modified microstructure
   Prof. Uroš Cvelbar
8. Development of new, environment-friendly approaches for plant and human virus inactivation in waters
   Asst. Prof. Gregor Primc
9. Innovative sensors for real-time monitoring of deposition rates in plasma-enhnced chemical vapour deposition (PECVD) systems
   Asst. Prof. Rok Zaplotnik
10. Advanced hydrodesulphurisation with catalyst nanomaterials
    Prof. Uroš Cvelbar
11. Advanced hemocompatible surfaces of vascular stents
    Asst. Prof. Ita Junkar
12. Evaluation of the range of plasma parameters suitable for nanostructuring of polymers on industrial scale
    Prof. Miran Mozetič
13. Selective plasma oxidation of FeCrAl alloys for extended-lifetime of glow plugs for diesel engines
    Prof. Janez Kovač
14. Innovative configuration of inductively coupled gaseous plasma sources for up-scaling to industrial-size reactors
    Prof. Miran Mozetič
15. Carbon nanowalls for future supercapacitors
    Prof. Alenka Vesel
16. Food for future - F4F
    Prof. Alenka Vesel
    Ministry of Education, Science and Sport
17. Potential of biomass for development of advanced materials and bio-based products
    Asst. Prof. Ita Junkar
    Ministry of Education, Science and Sport
18. Innovative ECO plasma seed treatment (for sowing and for human and animal diet/ nutrition
    Dr. Nina Recek
    Ministry of Education, Science and Sport
19. Building blocks, tools and systems for the Factories of the Future – GOSTOP
    Prof. Miran Mozetič
    Ministry of Education, Science and Sport
20. Development of nanostructured biosensors for diagnosis/treatment of cancer and surfaces with antibacterial
    Dr. Metka Benčina
    Ministry of Education, Science and Sport
21. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
    Prof. Miran Mozetič
    Ministry of Economic Development and Technology
22. Method for preparation of bacteriostatic surfaces on 3D printed medical implants
    Dr. Matic Resnik
    Ministry of Education, Science and Sport
23. Novel type of antibacterial coatings on textile materials and plastics with controllable release of antibacterial agent
    Prof. Uroš Cvelbar
    Ministry of Education, Science and Sport
24. Income from Coowners of Invention for Reimbursement of Costs for IP Protection in the Case of EVT140_Mozetič_Carbon Nanowall
    Prof. Miran Mozetič
    Nagoya University
25. EVT770_Mozetič_CNW2_Reimbursement of the Costs for Patent; Income from Coowners of Invention for Reimbursement of Costs for IP Protection in the Case of EVT770_Mozetič_CNW2
    Prof. Miran Mozetič
    Nagoya University

NEW CONTRACTS

1. Co-finanicing of L-project L2-1834 Carbon nanowalls for future supercapacitors
   Prof. Alenka Vesel
   Iskra, d. o. o.
2. Innovative sensors for real-time monitoring of deposition rates in plasma-enhanced chemical vapour deposition (PECVD) systems
   Asst. Prof. Rok Zaplotnik
   Iskra, d. o. o.

VISITORS FROM ABROAD

1. Dr. Francesco Mauro Ghezzi, Instituto di Fisica del Plasma – CNR, Milan, Italy, 14 January–4 February 2019
2. Hana Šourkova, Technical University of Liberec, Liberec, Czech Republic, 29–31 January 2019
3. B. Eng. Jaroslav Vozlab, Technical University of Liberec, Liberec, Czech Republic, 29–31 January 2019
4. Prof. Won Ho Choe, Korean Advanced Institute of Science and Technology, Daejeon, South Korea, 11–15 February 2019
5. Dr. Davor Peruško, Vinča Institute of Nuclear Science, Belgrade, Serbia, 5–10 May 2019
6. Dr. Suzana Petrović, Vinča Institute of Nuclear Science, Belgrade, Serbia, 5–10 May 2019
7. Dr. Maja Popović, Vinča Institute of Nuclear Science, Belgrade, Serbia, 5–10 May 2019
8. Dr. Lenka Zajičkova, Central European Institute of Technology (CEITEC), Brno, Czech Republic, 23–25 May 2019
9. Prof. Dr. Masaru Hori, Nagoya University, Nagoya, Japan, 25–26 May 2019
10. Prof. Dr. Radjeep Singh Rawat, Nanyang Technological University, Singapore, Singapore, 25–26 May 2019
11. Prof. Dr. David Neil Ruzic, University of Illinois, Illinois, USA, 25–26 May 2019
12. Prof. Dr. Jean-Paul Booth, Ecole Polytechnique, Palaiseau, France, 30 May–2 June 2019
13. Dr. Nuno Pinhao, Instituto Superior Technico, Lisbon, Portugal, 30 May–2 June 2019
14. Berke Karaman, Istanbul Technical University, Istanbul, Turkey, 23–28 June 2019
15. Prof. Dr. Mustafa Kamil Ürgen, Istanbul Technical University, Istanbul, Turkey, 23–28 June 2019
16. Cagatay Yelkarasi, Istanbul Technical University, Istanbul, Turkey, 23–28 June 2019
17. Prof. Dr. Petr Humpoliček, Tomas Bata University, Zlin, Czech Republic, 1–4 July 2019
18. Dr. Miomir Milosavljević, Vinča Institute of Nuclear Science, Belgrade, Serbia, 23–27 September 2019
19. Ana Grce, Vinča Institute of Nuclear Science, Belgrade, Serbia, 23–27 September 2019
20. Barbora Ptoskova, Tomas Bata University, Zlin, Czech Republic, 30 September–31 October 2019
21. Prof. Aleš Mraček, Tomas Bata University, Zlin, Czech Republic, 1 October 2019
22. Petr Smolka, Tomas Bata University, Zlin, Czech Republic, 1 October 2019
23. Prof. Slobodan Milošević, Institute of Physics, Zagreb, Croatia, 1 October 2019
24. Dr. Nikša Krstulović, Institute of Physics, Zagreb, Croatia,1 October 2019
25. Dr. Dejan Maletić, Institute of Physics, Belgrade, Serbia, 1 October 2019
26. Prof. Dr. Masaru Hori, Nagoya University, Nagoya, Japan, 3–5 December 2019
27. Atsushi Ozaki, Nagoya University, Nagoya, Japan, 1–8 December 2019

STAFF

Researchers

1. *Prof. Uroš Cvelbar, 01.05.19, transferred to Department F6*
2. *Dr. Aleksander Drenik, on leave 01.03.16*
3. Asst. Prof. Ita Junkar
4. Prof. Janez Kovač
5. **Prof. Miran Mozetič, Head**
6. *Dr. Vincenc Nemanič, 01.05.19, transferred to Department F6*
7. Prof. Alenka Vesel
8. Asst. Prof. Rok Zaplotnik
9. **Postdoctoral associates**
10. Dr. Metka Benčina
11. *Dr. Gregor Filipič, 01.05.19, transferred to Department F6*
12. Dr. Matej Holc
13. Dr. Petr Humpolíček
14. Dr. Kinga Kutasi
15. Dr. Marián Lehocký
16. *Dr. Martina Modic, 01.05.19, transferred to Department F6*
17. Asst. Prof. Gregor Primc
18. Dr. Nina Recek
19. Dr. Matic Resnik
20. **Postgraduates**
21. Jernej Ekar, B. Sc.
22. *Dr. Nataša Hojnik, 01.05.19, transferred to Department F6*
23. *Martin Košiček, B. Sc., 01.05.19, transferred to Department F6*
24. Dane Lojen, B. Sc.
25. Domen Paul, B. Sc.
26. Pia Starič, B. Sc.
27. *Petra Stražar, B. Sc., 01.05.19, transferred to Department F6*
28. *Marko Žumer, B. Sc., 01.05.19, transferred to Department F6*
29. **Technical officers**
30. Tatjana Filipič, B. Sc.
31. Eva Levičnik, B. Sc.
32. **Technical and administrative staff**
33. *Ula Groznik, B. Sc., 01.05.19, transferred to Department F6*
34. *Urška Kisovec, B. Sc., 01.05.19, transferred to Department F6*
35. Maja Šukarov, B. Sc.
36. Janez Trtnik

BIBLIOGRAPHY

Original Article

1. Aleksander Matavž, Andreja Benčan, Janez Kovač, Ching-Chang Chung, Jacob L. Jones, Susan Trolier-McKinstry, Barbara Malič, Vid Bobnar, "Additive manufacturing of ferroelectric-oxide thin-film multilayer devices", *ACS applied materials & interfaces*, 2019, **11**, 49, 45155-45160.
2. Tamilselvan Mohan, Alja Čas, Matej Bračič, Olivija Plohl, Alenka Vesel, Maja Rupnik, Lidija Fras Zemljič, Janez Rebol, "Highly protein repellent and antiadhesive polysaccharide biomaterial coating for urinary catheter applications", *ACS biomaterials science & engineering*, 2019, **5**, 11, 5825-5832.
3. Monika Jenko, Matjaž Godec, Aleksandra Kocijan, Rebeka Rudolf, Drago Dolinar, Maja Ovsenik, Matevž Gorenšek, Rok Zaplotnik, Miran Mozetič, "A new route to biocompatible Nitinol based on a rapid treatment with H_2/O_2 gaseous plasma", *Applied Surface Science*, 2019, **473**, 976-984.
4. Siegfried Hofmann, G. Zhou, Janez Kovač, Sandra Drev, S. Y. Lian, B. Lin, Y. Liu, Jiang Yong Wang, "Preferential sputtering effects in depth profiling of multilayers with SIMS, XPS and AES", *Applied Surface Science*, 2019, **483**, 140-155.
5. Martina Modic, Janez Kovač, John R. Nichols, Špela Kos, Gregor Serša, Uroš Cvelbar, James L. Walsh, "Targeted plasma functionalization of titanium inhibits polymicrobial biofilm recolonization and stimulates cell function", *Applied Surface Science*, 2019, **487**, 1176-1188.
6. Darja Božič, Simona Sitar, Ita Junkar, Roman Štukelj, Manca Pajnič, Ema Žagar, Veronika Kralj-Iglič, Ksenija Kogej, "Viscosity of plasma as a key factor in assessment of extracellular vesicles by light scattering", *Cells*, 2019, **8**, 9, 1046.
7. Danjela Kuščer, Andraž Kocjan, Maja Majcen, Anton Meden, Kristian Radan, Janez Kovač, Barbara Malič, "Evolution of phase composition and microstructure of sodium potassium niobate -based ceramic during pressure-less spark plasma sintering and post-annealing", *Ceramics international*, 2019, **45**, 8, 10429-10437.
8. Martin Minarik *et al.* (11 authors), "Preparation of hierarchically structured polystyrene surfaces with superhydrophobic properties by plasma-assisted fluorination", *Coatings*, 2019, **9**, 3, 201.
9. Tadeja Kosec, Andraž Legat, Janez Kovač, Damjan Klobčar, "Influence of laser colour marking on the corrosion properties of low alloyed Ti", *Coatings*, 2019, **9**, 6, 375.
10. Suzana Petrović, Davor Peruško, Evangelos Skoulas, Janez Kovač, Miodrag Mitrić, Jelena Potočnik, Zlatko Rakočević, Emmanuel Stratakis, "Laser-assisted surface texturing of Ti/Zr multilayers for mesenchymal stem cell response", *Coatings*, 2019, **9**, 12, 854.
11. Klemen Avsec, Monika Jenko, Marjetka Conradi, Aleksandra Kocijan, Alenka Vesel, Janez Kovač, Matjaž Godec, Igor Belič, Barbara Šetina, Črtomir Donik, Matevž Gorenšek, Boštjan Kocjančič, Drago Dolinar, "Surface properties of retrieved cementless femoral hip

endoprostheses produced from a Ti6Al7Nb alloy", *Coatings*, 2019, **9**, 12, 868.
12. Žiga Gosar, Janez Kovač, Miran Mozetič, Gregor Primc, Alenka Vesel, Rok Zaplotnik, "Deposition of $SiO_xC_yH_z$ protective coatings on polymer substrates in an industrial-scale PECVD reactor", *Coatings*, 2019, **9**, 4, 234.
13. Ladislav Vrsalović, Ivana Ivanić, Stjepan Kožuh, Borut Kosec, Milan Bizjak, Janez Kovač, Urška Gabor, Mirko Gojić, "Influence of heat treatment on the corrosion properties of CuAlMn shape memory alloys", *Corrosion reviews*, 2019, **37**, 6, 579-589.
14. Arijana Filipić, Gregor Primc, Rok Zaplotnik, Nataša Mehle, Ion Gutiérrez-Aguirre, Maja Ravnikar, Miran Mozetič, Jana Žel, David Dobnik, "Cold atmospheric plasma as a novel method for inactivation of potato virus Y in water samples", *Food and environmental virology*, 2019, **11**, 3, 220-228.
15. Rupert Kargl, Matej Bračič, Matic Resnik, Miran Mozetič, Wolfgang Bauer, Karin Stana-Kleinschek, Tamilselvan Mohan, "Affinity of serum albumin and fibrinogen to cellulose, its hydrophobic derivatives and blends", *Frontiers in chemistry*, 2019, **7**, 581.
16. Aleksander Drenik, Sebastijan Brezinšek, P. Carvalho, V. Huber, Natan Osterman, G. F. Matthews, Mitja Nemec, "Analysis of the outer divertor hot spot activity in the protection video camera recordings at JET", *Fusion engineering and design*, 2019, **139**, 115-123.
17. Igor Lengar, Andrej Žohar, P. Batistoni, Sergei Popovichev, S. Conroy, JET Contributors, "Characterization of JET neutron field in irradiation locations for DD, DT and TT plasmas", *Fusion engineering and design*, 2019, **146**B, 1967-1970.
18. Bor Kos, Scott W. Mosher, Ivan Aleksander Kodeli, Robert. E. Grove, Jonathan Naish, Barabara Obryk, Rosaria Villari, Paola Batistoni, JET Contributors, "Application of ADVANTG to the JET3 - NEXP streaming benchmark experiment", *Fusion engineering and design*, 2019, **147**, 111252.
19. Thomas Reichbauer, Aleksander Drenik, Rachael McDermott, Wolker Rohde, the ASDEX Upgrade Team, "Assessment of nitrogen fluence from the divertor plasma in nitrogen seeded discharges", *Fusion engineering and design*, 2019, **149**, 111325.
20. Anže Prašnikar, Andraž Pavlišič, Francisco Ruiz-Zepeda, Janez Kovač, Blaž Likozar, "Mechanisms of copper-based catalyst deactivation during CO_2 reduction to methanol", *Industrial & engineering chemistry research*, 2019, **58**, 29, 13021-13029.
21. Andrea Jurov, Dean Popović, Iva Šrut Rakić, Ida Delač Marion, Gregor Filipič, Janez Kovač, Uroš Cvelbar, Nikša Krstulović, "Atmospheric pressure plasma jet-assisted impregnation of gold nanoparticles into PVC polymer for various applications", *International journal of advanced manufacturing technology*, 2019, **101**, 3/4, 927-938.
22. Nikola Mikušová, Kateřina Nechvilová, Andréa Kalendová, Tereza Hájková, Zdenka Capáková, Ita Junkar, Marián Lehocký, Miran Mozetič, Petr Humpolíček, "The effect of composition of a polymeric coating on the biofilm formation of bacteria and filamentous fungi", *International journal of polymeric materials*, 2019, **68**, 4, 152-159.
23. Sandhya Gopalakrishnan, Indu Raj, T. Aby Mathews, Jiji Abraham, Hanna J. Maria, Miran Mozetič, Sabu Thomas, Nandakumar Kalarikkal, "Development of oral-fluid-impervious and fracture-resistant silver-poly(methyl methacrylate) nanoformulations for intra-oral/extra-oral rehabilitation", *Journal of applied polymer science*, 2019, **2019**, 47669.
24. Olivija Plohl, Urban Ajdnik, Sašo Gyergyek, Irena Ban, Alenka Vesel, Tjaša Kraševac Glaser, Lidija Fras Zemljič, "Superior stability and high biosorbent efficiency of carboxymethylchitosan covalently linked to silica-coated core-shell magnetic nanoparticles for application in copper removal", *Journal of environmental chemical engineering*, 2019, **7**, 1, 102913.
25. Stojana Veskovič Bukudur, Janez Kovač, Blaž Karpe, Polona Umek, Aleš Nagode, Romana Cerc Korošec, Milan Bizjak, "High temperature corrosion of commercial FeCrAl alloys (Kanthal AF) in nitrogen gas", *Journal of mining and metallurgy. Section B, Metallurgy*, 2019, **55**, 1, 55-63.
26. Vincenc Nemanič, Marko Žumer, Janez Kovač, "Hydrogen permeability of AISI 316 ITER grade stainless steel", *Journal of nuclear materials*, 2019, **521**, 38-44.
27. Lidija Androš-Dubraja, Damir Pajić, Martina Vrankić, Jure Dragović, Matjaž Valant, Metka Benčina, Marijana Jurić, "Single-step preparation of rutile-type $CrNbO_4$ and $CrTaO_4$ oxides from oxalate precursors-characterization and properties", *Journal of the American Ceramic Society*, 2019, **102**, 11, 6697-6704.
28. Roman Štukelj, Metka Benčina, Mattia Fanetti, Matjaž Valant, Mitja Drab, Aleš Iglič, Veronika Kralj-Iglič, "Synthesis of stable cannabidiol (CBD) nanoparticles in suspension", *Materiali in tehnologije*, 2019, **53**, 4, 543-549.
29. Metka Benčina, Ita Junkar, Tina Mavrič, Veronika Kralj-Iglič, Matjaž Valant, Aleš Iglič, "Performance of annealed TiO_2 nanotubes in interactions with blood platelets", *Materiali in tehnologije*, 2019, **53**, 6, 791-795.
30. A. Achour, S. Solaymani, Sorin Ionut Vizireanu, A. Baraket, Alenka Vesel, N. Zine, A. Errachid, Gheorghe Dinescu, Jean-Jacques Pireaux, "Effect of nitrogen configuration on carbon nanowall surface: towards the improvement of electrochemical transduction properties and the stabilization of gold nanoparticles", *Materials chemistry and physics*, 2019, **228**, 110-117.
31. Metka Benčina, Ita Junkar, Rok Zaplotnik, Matjaž Valant, Aleš Iglič, Miran Mozetič, "Plasma-Induced crystallization of TiO_2 nanotubes", *Materials*, 2019, **12**, 4, 626.
32. Tjaša Kraševac Glaser, Olivija Plohl, Alenka Vesel, Urban Ajdnik, Nataša Poklar Ulrih, Maša Knez Hrnčič, Urban Bren, Lidija Fras Zemljič, "Functionalization of polyethylene (PE) and polypropylene (PP) material using chitosan nanoparticles with incorporated resveratrol as potential active packaging", *Materials*, 2019, **12**, 13, 2118.
33. Žiga Gosar, Denis Đonlagić, Simon Pevec, Janez Kovač, Miran Mozetič, Gregor Primc, Alenka Vesel, Rok Zaplotnik, "Deposition kinetics of thin silica-like coatings in a large plasma reactor", *Materials*, 2019, **12**, 19, 3238.
34. Jelena Pavlović, Margarita Popova, Magdolna R. Mihályi, Matjaž Mazaj, Gregor Mali, Janez Kovač, Hristina Lazarova, Nevenka Rajić, "Catalytic activity of SnO_2- and SO_4/SnO_2-containing clinoptilolite in the esterification of levulinic acid", *Microporous and mesoporous materials: zeolites, clays, carbons and related materials*, 2019, **279**, 10-18.
35. The ASDEX-Upgrade team and the EUROfusion MST1 team, Aleksander Drenik *et al.* (15 authors), "Evolution of nitrogen concentration and ammonia production in N_2-seeded H-mode discharges at ASDEX Upgrade", *Nuclear fusion*, 2019, **59**, 4, 046010.
36. The ASDEX Upgrade Team and the EUROfusion MST1 team, L. Guimarais *et al.* (16 authors), "Link between divertor conditions and high-field-side/low-field-side midplane density profiles in H-mode plasmas at ASDEX upgrade", *Nuclear fusion*, 2019, **59**, 19, 126041.
37. B. Labit *et al.* (466 authors), "Dependence on plasma shape and plasma fueling for small edge-localized mode regimes in TCV and ASDEX Upgrade", *Nuclear fusion*, 2019, **59**, 8, 086020.
38. Matej Holc, Gregor Primc, Jernej Iskra, Primož Titan, Janez Kovač, Miran Mozetič, Ita Junkar, "Effect of oxygen plasma on sprout and root growth, surface morphology and yield of garlic", *Plants*, 2019, **8**, 11, 462.
39. Ilkay Karakurt, Kadir Ozaltin, Daniela Vesela, Marián Lehocký, Petr Humpolíček, Miran Mozetič, "Antibacterial activity and cytotoxicity of immobilized glucosamine/chondroitin sulfate on polylactic acid films", *Polymers*, 2019, **11**, 7, 1186.
40. Kateřina Skopalová, Zdenka Capáková, Patrycja Bober, Jana Pelková, Jaroslav Stejskal, Věra Kašpárková, Marián Lehocký, Ita Junkar, Miran Mozetič, Petr Humpolíček, "In-vitro hemocompatibility of polyaniline functionalized by bioactive molecules", *Polymers*, 2019, **11**, 1861.
41. Miroslav Mrlik, Marketa Ilcikova, Josef Osicka, Erika Kutalkova, Antonín Minařík, Alenka Vesel, Jaroslav Mosnacek, "Electrorheology of SI-ATRP-modified graphene oxide particles with poly(butyl methacrylate): effect of reduction and compatibility with silicone oil", *RSC advances*, 2019, **9**, 3, 1187-1198.
42. Tanja Zidarič, Nana Ivana Hrastnik, Ervin Šest, Janez Kovač, Vasko Jovanovski, Samo B. Hočevar, "A novel bismuth imidazolate-based sensor for detection of trace lead(II)", *Sensors and actuators. B, Chemical*, 2019, **291**, 354-361.
43. Raghuraj S. Chouhan, Gregor Žitko, Vesna Fajon, Igor Živković, Majda Pavlin, Sabina Berisha, Ivan Jerman, Alenka Vesel, Milena Horvat, "A unique interactive nanostructure knitting based passive sampler adsorbent for monitoring of Hg^{2+} in water", *Sensors*, 2019, **19**, 15, 3432.
44. Karthika Prasad, Nina Recek, Renwu Zhou, Rusen Zhou, Morteza Aramesh, Annalena Wolff, Robert E. Speight, Miran Mozetič, Kateryna Bazaka, Kostya Ostrikov, "Effect of multi-modal environmental stress on dose-dependent cytotoxicity of nanodiamonds in Saccharomyces cerevisiae cells", *Sustainable materials and technologies*, 2019, **22**, e00123.

Review Article

1. Miran Mozetič, "Surface modification to improve properties of materials", *Materials*, 2019, **12**, 4, 441.

2. Alenka Vesel, Rok Zaplotnik, Gregor Primc, Miran Mozetič, "Synthesis of vertically oriented graphene sheets or carbon nanowalls: review and challenges", *Materials*, 2019, **12**, 18, 2968.

Published Conference Contribution

1. Jelena Pavlović, Margarita Popova, Magdolna R. Mihályi, Matjaž Mazaj, Gregor Mali, Janez Kovač, Hristina Lazarova, Nevenka Rajić, "Catalytic activity of clinoptilolite-based catalysts in the esterification of levulinic acid", In: *Proceedings of the 8th Serbian-Croatian-Slovenian Symposium on Zeolites, Proceedings of the 8th Croatian-Slovenian-Serbian Symposium on Zeolites, Proceedings of the 8th Slovenian-Serbian-Croatian Symposium on Zeolites: [3 - 5 October 2019, Belgrade, Serbia]*, Serbian Zeolite Association, 2019, 89-92.
2. Jure Žigon, Marko Petrič, Sebastian Dahle, Ayata Ümit, Rok Zaplotnik, "The influence of artificial weathering and treatment with FE-DBD plasma in atmospheric conditions on wettability of wood surfaces", In: *Tagungsband: 3. Niedersächsisches Symposium Materialtechnik, 14 bis und 15. Februar 2019*, (Fortschrittsberichte der Materialforschung und Werkstofftechnik, **7)**, 2019.

Independent Component Part or a Chapter in a Monograph

1. Mitja Drab, Luka Mesarec, Roghayeh Imani, Marko Jeran, Ita Junkar, Veronika Kralj-Iglič, Samo Kralj, Aleš Iglič, "The role of membrane vesiculation and encapsulation in cancer diagnosis and therapy", In: *Advances in biomembranes and lipid self-assembly*, (Advances in biomembranes and lipid self-assembly, **29)**, Elsevier, 2019, 159-199.
2. Miran Mozetič, Alenka Vesel, Gregor Primc, Rok Zaplotnik, "Introduction to plasma and plasma diagnostics", In: *Non-thermal plasma technology for polymeric materials: applications in composites nanostructured materials, and biomedical fields*, Elsevier, 2019, 23-65.

Patent

1. Rok Zaplotnik, Miran Mozetič, Gregor Primc, Alenka Vesel, Masaru Hori, *Carbon nanostructured materials and methods for forming of these materials,* SI25662 (A), Urad RS za intelektualno lastnino, 31. 12. 2019.
2. Gregor Primc, Miran Mozetič, Uroš Cvelbar, Alenka Vesel, *Method and device for detection and measuring the density of neutral atoms of hydrogen, oxygen or nitrogen,* EP3146327 (B1), European Patent Office, 06. 11. 2019.
3. Ita Junkar, Veronika Kralj-Iglič, Roman Štukelj, Rok Zaplotnik, Miran Mozetič, *Method for treatment of tools and tools used for isolation of microvesicles, nanovescicles or exsomes,* EP3185921 (B1), European Patent Office, 04. 09. 2019.

Theses and Mentoring

1. Matej Holc, *Effects of highly reactive gaseous plasma treatment on the germination and growth of garlic:* doctoral dissertation, Ljubljana, 2019 (mentor Miran Mozetič; co-mentor Ita Junkar).

DEPARTMENT OF SOLID STATE PHYSICS F-5

Our research programme focuses on the study of the structure and dynamics of disordered and partially ordered condensed matter at the atomic and molecular levels, with a special emphasis on phase transitions. The purpose of these investigations is to discover the basic laws of physics governing the behaviour of these systems, which represent the link between perfectly ordered crystals, on one side, and amorphous matter, soft condensed matter and living systems, on the other. Such knowledge provides the key to our understanding of the macroscopic properties of these systems and is an important condition for the discovery and development of new multifunctional materials, nanomaterials and biomaterials for new applications. An important part of the research program is devoted to the development of new experimental methods and techniques in the field of cold atoms, quantum magnetism, quantum optics, biophotonics and super-resolution imaging.

Head:
Prof. Igor Muševič

The research programme of the Department of Solid State Physics at the Jožef Stefan Institute is performed in close collaboration with Department of Physics at the Faculty of Mathematics and Physics of the University of Ljubljana, Institute of Mathematics, Physics and Mechanics and the J. Stefan International Postgraduate School. In 2019, the research was performed within three research programmes:

- Magnetic Resonance and Dielectric Spectroscopy of Smart New Materials
- Physics of Soft Matter, Surfaces and Nanostructures
- Experimental Biophysics of Complex Systems

I. Research Programme "Magnetic Resonance and Dielectric Spectroscopy of Smart New Materials"

The research group presented the first experimental proof of existence of "anyone" particles (the particles that are simultaneously fermions and bozons) and discovered new quantum magnetic states in solid-state materials. It has found new multiferroic materials, revealed complex magnetism of high-entropy alloys, developed fully-printed thin-film capacitors and determined the physical-mechanical properties of liquid crystals and liquid-crystalline elastomers.

The research group has observed Kondo screening in a charge-insulating spinon metal, discovered additive manufacturing of ferroelectric-oxide thin-film multilayer devices, reported on the discovery of a giant electrocaloric response in smectic liquid crystals with a direct smectic-isotropic transition, reported on the existence of caesium bright matter-wave solitons and soliton trains in experiments with cold atoms and discovered a high-entropy alloy with excellent magnetic softness.

In 2019, the Research Programme *Magnetic Resonance and Dielectric Spectroscopy of Smart New Materials* focused on the study of physical phenomena in condensed matter at the atomic and molecular levels. The purpose of the research was to discover the basic laws of physics governing the behaviour of the investigated systems. The attained knowledge provides the key to the understanding of the microscopic and macroscopic properties of various types of solids. It is also an important condition for the discovery and development of new multifunctional materials and nanomaterials for novel technological applications.

In our research, we used the following experimental techniques:

- Nuclear magnetic resonance (NMR), electron paramagnetic resonance (EPR), and nuclear quadrupole resonance (NQR);
- Nuclear double resonance ^{17}O–H and ^{14}N–H;
- Fast field cycling NMR relaxometry;
- Linear and non-linear dielectric spectroscopy in the range 10^{-2} Hz to 10^{9} Hz;
- Frequency-dependent ac calorimetry;
- Measurement of electrical and thermal transport coefficients;
- Magnetic measurements;
- Methods of ultra-cold atoms.

The research programme worked in close collaboration with the Department of Physics at the Faculty of Mathematics and Physics of the University of Ljubljana, Institute of Mathematics, Physics and Mechanics, and the Jožef Stefan International Postgraduate School.

In 2019, members of the research programme published 42 original scientific papers in international peer-reviewed scientific journals. Among these, one paper was published in *Nature Physic* (IF = 21.8), one in *Angewandte*

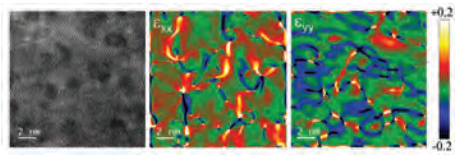

Figure 1: Maps of the ε_{xx} and ε_{yy} strain tensor components over the area of 1515 nm², where the highly stressed interfaces between the FeCoNi and the PdCu domains in the FeCoNiPdCu high-entropy alloys are visible.

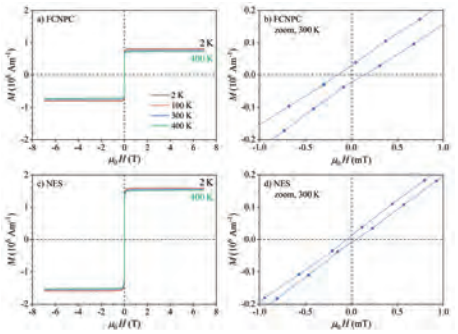

Figure 2: (a) M (H) curves of the FeCoNiPdCu (FCNPC) high-entropy alloy at selected temperatures between 400 and 2 K for a magnetic field sweep from –7 to 7 T. In (b)*, the curve at T = 300 K is zoomed in on the field axis about the origin. Panels (c) and (d) show the corresponding M (H) curves of the non-oriented electrical steel (NES) sample.*

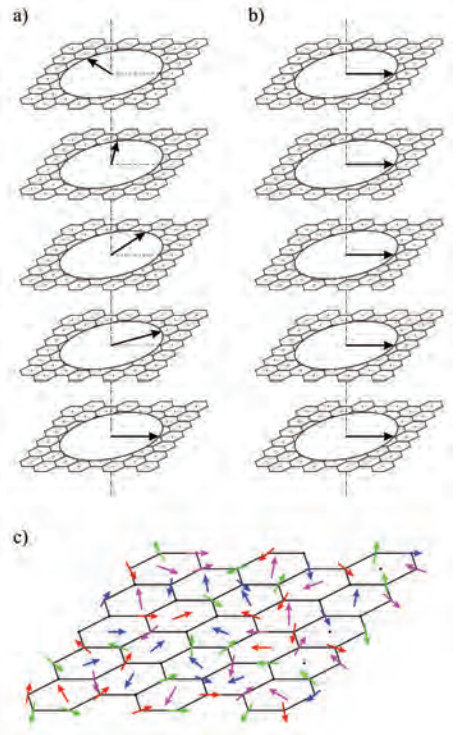

Figure 3: Schematic presentation of magnetic structures present in the Gd-Tb-Dy-Ho-Lu hexagonal high-entropy alloy: (a) basal-plane helical AFM structure; (b) basal-plane FM structure; (c) spin glass structure (magnetic moments of Gd, Tb, Dy and Ho ions are drawn with arrows of different colours and the length of the arrow is proportional to the size of the moment; nonmagnetic Lu ions are presented by black dots).

*Chemie, Intern. E*d. (IF = 12.3), one in *J. Mater. Chem.* (IF = 10.7), one in *ACS Appl. Mater. & Interf.* (IF = 8.5), one in *Appl. Mater. Today* (IF = 8.0), two in *Acta Mater.* (IF = 7.3), one in *J. Mater. Chem. C* (IF = 6.6), one in *Sensors and Actuators B* (IF = 6.3), and 15 papers in the journals with the IFs between 5 and 3.

The investigations focused on the following research fields:

High-entropy alloys

We have been investigating crystalline, multicomponent metallic alloys, known as high-entropy alloys, which are stabilized by the entropic term in the Gibbs free energy of mixing by the immense chemical (substitutional) disorder on the crystal lattice. In the paper "Discovery of a Feconipdcu High-Entropy Alloy with Excellent Magnetic Softness", P. Koželj *et al.*, *Adv. Eng. Mater.* 1801055 (2019), we report on the discovery of a magnetically soft high-entropy alloy with the composition FeCoNiPdCu, which performs comparably to the best commercial soft magnets for static and low-frequency applications. Properly heat-treated FeCoNiPdCu develops a nanostructure that can be viewed as a two-phase bulk nanocomposite of randomly intermixed FeCoNi magnetic domains and PdCu nonmagnetic "spacers", both of 2–5 nm cross dimensions (Figure 1). Due to the nanometric size, the FeCoNi domains are magnetically single-domain particles, and since the particles are exchange-coupled across the boundaries, exchange averaging of the magnetic anisotropy takes place, resulting in an almost vanishing coercive field and excellent magnetic softness (Figure 2). The formation of a two-phase nanostructure favourable for the exchange averaging of magnetic anisotropy is a consequence of specific values of the binary mixing enthalpies for the chosen elements. Experimentally, the magnetic properties of the FeCoNiPdCu high-entropy alloy are compared to the commercial, magnetically soft non-oriented silicon electrical steel (NES).

In the paper "Magnetic Phase Diagram and Magnetoresistance of Gd-Tb-Dy-Ho-Lu Hexagonal High-Entropy Alloy", S. Vrtnik *et al.*, *Intermetallics* **105**, 163–172 (2019), we present a study of the magnetic phase diagram and the magnetoresistance of a Gd-Tb-Dy-Ho-Lu "ideal" hexagonal high-entropy alloy (HEA), composed of the elements from the heavy half of the rare-earth series only. The phase diagram contains an antiferromagnetic (AFM) state, a field-induced ferromagnetic (FM) state above the AFM-to-FM spin-flop transition, and a low-temperature spin-glass state. The complex *(H, T)* phase diagram is a result of competition between the periodic potential arising from the electronic band structure that favours periodic magnetic ordering, the substitutional-disorder-induced random local potential that favors spin-glass-type spin freezing in random directions, the Zeeman interaction with the external magnetic field that favours spin alignment along the field direction, and the thermal agitation that opposes any spin ordering. The magnetoresistance reflects the complexity of the *(H, T)* phase diagram. Its temperature dependence can be explained by a continuous weakening and final disappearance of the periodic potential upon cooling that leads to the destruction of long-range-ordered periodic magnetic structures. The magnetoresistance is large only at temperatures where the AFM and field-induced FM structures are present and exhibits a maximum at the critical field of the AFM-to-FM transition. Within the AFM phase, the magnetoresistance is positive with a quadratic field dependence. Within the field-induced FM phase, it is negative with a logarithmic-like field dependence. At lower temperatures, the long-range periodic spin order "melts" and the magnetoresistance diminishes until it totally vanishes within the low-temperature spin glass phase. The magnetoresistance is asymmetric with respect to the field sweep direction, reflecting the non-ergodicity and frustration of the spin system.

A method for producing polymeric surface-modification layers

The surface properties of a substrate are among the most important parameters in the printing technology of functional materials, determining both the resolution and stability of the printed features. We have developed a method for the preparation of thin polymeric layers with large contact-angle hysteresis, which are used for adjustments of the wetting of arbitrary solid optical-grade substrates. The method is based on coating the surface with a mixture of polymers that undergo a phase separation and form an inhomogeneous, nano-textured surface upon deposition. The wetting is, in the second step, regulated by a surface treatment of the polymeric layer (O_2 plasma, UV/O_3). Our surface-adjustment layer is suitable for various printing applications (inkjet-, gravure-, spray- or screen-printing) or any other application that requires precisely

regulated wetting and large contact-angle hysteresis. The results were patented in A. Matavž, B. Malič, V. Bobnar, *A method for producing polymeric surface modification layers*, Patent application MKS/MP7501968, London: Intellectual Property Office, September 23, 2019.

Self-assembled porous ferroelectric thin films with a greatly enhanced piezoelectric response

In thin films, the electromechanical response is obstructed by the mechanical clamping of the substrate, resulting in a deterioration of the piezoelectric coefficients. By utilizing soft-chemistry techniques, we developed a simple and robust method based on the self-assembly of organometallic precursors in a polymer matrix for the deposition of nanostructured oxide thin films. The implemented macro-porosity leads to local elastic relaxations and greatly enhances the macroscopic electromechanical response. Exceptionally large measured piezoelectric coefficients, reaching the level of bulk ceramics, are associated with the increased elastic compliance of the nanostructured films and the highly mobile ferroelastic domain walls.

The results were published in A. Matavž, A. Bradeško, T. Rojac, B. Malič, V. Bobnar, "Self-assembled porous ferroelectric thin films with a greatly enhanced piezoelectric response" *Applied Materials Today* **16**, 83 (2019).

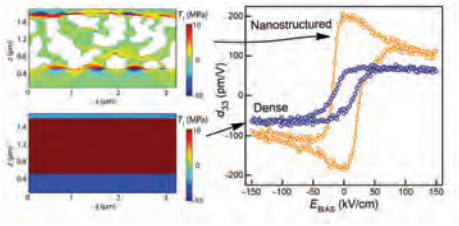

Figure 4: The finite-element-method simulation reveals that a strong tensile stress over the whole dense film thickness is released in a porous film (left), which greatly enhances its macroscopic electromechanical response (right).

Inkjet printing of ferroelectric thin-film multilayer devices

We designed a universal approach to the inkjet printing of metal oxides on arbitrary solid substrates. The full control over the wetting properties was achieved by introducing a few-nanometres-thick polymeric layer with textured topography. In combination with the specially designed ink formulation, it enabled a highly efficient deposition of flat structures with good lateral definition. The developed process is highly efficient and enables conformal stacking of functional oxide layers according to the user-defined geometry, sequence arrangement, and layer thickness – its large potential was demonstrated by the manufacturing of all-printed ferroelectric capacitors composed of as many as 16 individual layers. A detailed structural and electrical characterization revealed the excellent functional properties of the printed devices.

The results were published in A. Matavž, A. Benčan, J. Kovač, C.-C. Chung, J. L. Jones. S. Trolier-McKinstry, B. Malič, V. Bobnar, "Additive manufacturing of ferroelectric-oxide thin-film multilayer devices", *ACS Applied Materials & Interfaces* **11**, 45155 (2019).

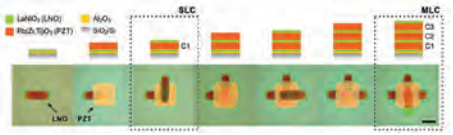

Figure 5: Optical images of sequentially printed LNO and PZT and a schematic of the corresponding cross-section. Alternating stacking was used to fabricate single-layer (SLC) and multilayer (MLC) capacitors with excellent functional properties.

The role of water in the transformation of $H_2Ti_3O_7$ nanoribbons in TiO_2 nanostructures

The investigation of the transformation of $H_2Ti_3O_7$ nanoribbons to anatase was motivated by three goals: (i) to determine the role of water in the transformation, (ii) to understand the behaviour of protonated tri-titanate nanoribbons under hydrothermal conditions over the whole pH range, and (iii) to explain the products' morphology in regard to reaction environments. The transformation reactions of protonated tri-titanate nanoribbons were conducted under various hydrothermal and solvothermal conditions, as well as with calcination in air. A deeper insight into the transformation process as well as the product formation was additionally ensured with the zeta-potential measurements of protonated tri-titanate nanoribbons and a detailed electronic microscopy study coupled with crystallography of the products. Protonated titanate nanoribbons are stable under basic conditions and their transformation to anatase nanoribbons depends on counter ions from the reaction mixture – for example, when ammonium ions acted as an exfoliating reagent. With decreasing pH of the reaction mixture both processes, topotactic transformation and dissolution-recrystallisation, are accelerated, where the nanoribbon is a substrate for the heterogeneous nucleation of anatase nanocrystals afterwards. Sodium titanate nanoribbons are suitable for the transformation to anatase nanoribbons under hydrothermal conditions as well. Water was revealed as being crucial for the transformation progress, since organic solvents served only as a thermal reaction medium and did not encourage catalysis.

The results were published in M. Sluban and P. Umek, "The role of water in the transformation of protonated titanate nanoribbons to anatase nanoribbons", *The journal of physical chemistry. C, Nanomaterials and interfaces* **123**, 23747–75 (2019).

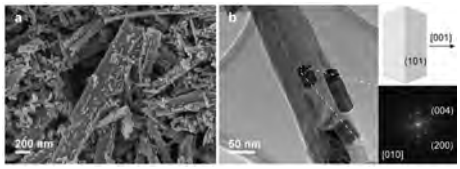

Figure 6: SEM (a) and TEM (b) images of the product formed at the transformation of $H_2Ti_3O_7$ nanoribbons under hydrothermal condition in 0.5-M NH_3 (aq). The FFT analysis of the anatase nanocrystal, oriented along the [010] zone axis, confirms its growth in the [001] direction. The dihedral angle between the marked facets reveals that the lateral facets belong to the {101} planes.

Donor-acceptor interaction in halogen-bonded complexes

Halogen-bonded complexes of *N*-iodosuccinimide (NIS) with the nitrogen atoms at the donor and acceptor positions have been investigated by ^{14}N nuclear quadrupole resonance (NQR) spectroscopy. The obtained data were analysed in terms of the correlation between the principal values of the quadrupole coupling tensor and show that the changes of the electron charge distribution at the XB donor and acceptor nitrogen positions are comparable to

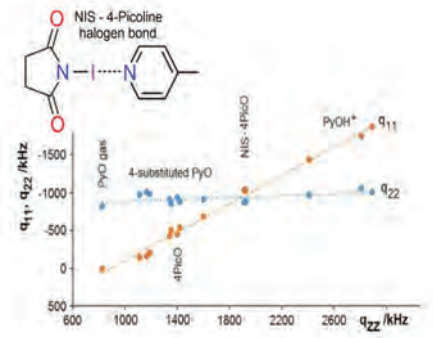

Figure 7: Correlation between the two smaller principal values q_{11} and q_{22} and the largest principal value q_{ZZ} of the quadrupole coupling tensor in PyO and related compounds.

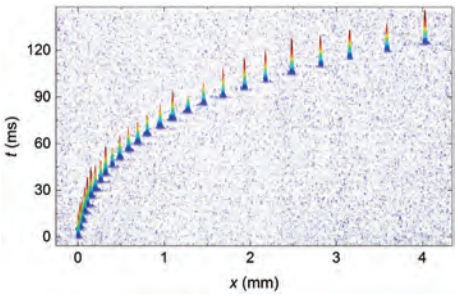

Figure 8: Density absorption images of a caesium soliton accelerating in a quasi-one-dimensional channel.

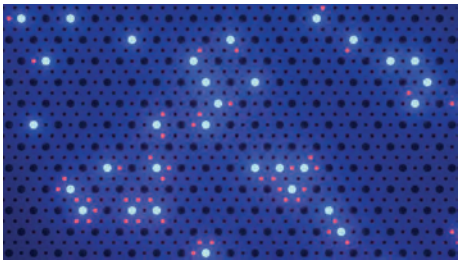

Figure 9: Quantum spin liquid on a kagome lattice.

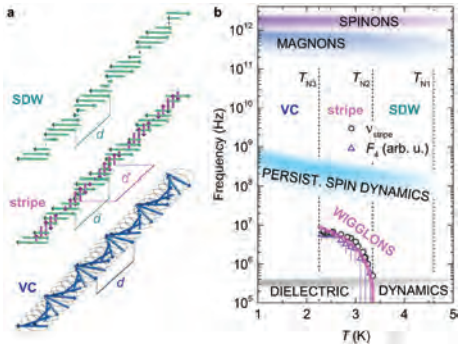

Figure 10: Magnetic structure models corresponding to the spin-density-wave (SDW), spin-stripe and vector-chiral (VC) phases in β-$TeVO_4$.

the changes of the electron charge distribution observed in strong hydrogen-bonded systems. We demonstrated that the deformation of the nitrogen electron orbitals, produced by halogen bond acceptor, is reflected on the principal value Q_{YY} of the ^{14}N quadrupole coupling tensor in NIS, which enables an estimation of the XB acceptor strength and the temperature dependence of the iodine atom displacements. The results were published in T. Apih, G. Gregorovič, V. Žagar, J. Seliger, "A study of donor-acceptor interaction in halogen bonded complexes of N-iodosuccinimide by ^{14}N NQR", *Chem. Phys.* **523**, 12–17 (2019).

Thermomechanical response of main-chain polymer-dispersed liquid-crystal elastomers

We have determined the thermomechanical response of main-chain polymer-dispersed liquid-crystal elastomers (PDLCE), optimized by controlling the concentration of crosslinker molecules. The resulting materials exhibit increased thermomechanical response, up to 25%, and higher elastic modulus, up to 300 kPa, as compared with sidechain PDLCEs. Alternative methods for orienting thermomechanically anisotropic LCE microparticles in isotropic polymer matrices have also been investigated. We have demonstrated that orientational order can be induced by the shear field of a laminar flow. This approach is advantageous with respect to the magnetic field alignment of microparticles, particularly in view of its application potential in additive-manufacturing technologies.

Production of caesium solitons and soliton trains in experiments with cold atoms

Tadej Mežnaršič, Tina Arh, Jaka Pišljar, Žiga Gosar, Erik Zupanič, and Peter Jeglič have demonstrated the production of cerium solitons and soliton trains to study their formation, fragmentation and collisions. When non-interacting Bose-Einstein condensate is confined to a quasi one-dimensional channel, it will spread due to dispersion as dictated by the Schrödinger equation. The spreading rate can be affected by changing the interaction between the atoms via the Feshbach resonance. If the interaction is set to just the right value, the attraction between atoms exactly compensates the dispersion and we get a bright matter-wave soliton. The results were published in T. Mežnaršič *et al.*, "Cesium bright matter-wave solitons and soliton trains", *Physical Review A* **99**, 033625 (2019).

Quantum magnetism

Matjaž Gomilšek, Martin Klanjšek, Matej Pregelj, and Andrej Zorko, in collaboration with partners from Slovenia, Switzerland and China, studied the magnetic state of impurities in a kagome quantum spin liquid Zn-brochantite. They discovered the first case of the Kondo effect in an electric insulator. Typically, conduction electrons screen the local moments of magnetic impurities in ordinary metals. However, in the investigated insulator an analogous phenomenon is possible due to its quantum-spin-liquid ground state, where magnetic spinon excitations forming a Fermi surface effectively replace the itinerant electrons in screening the magnetic moments of localized impurities. This discovery could be important for manipulating topologically protected spin-liquid states in quantum computing. The results were published in M. Gomilšek *et al.*, "Kondo screening in a charge-insulating spinon metal", *Nat. Phys.* **15**, 754 (2019).

Matej Pregelj, Andrej Zorko, Matjaž Gomilšek, Martin Klanjšek and Denis Arčon, in collaboration with partners from Switzerland, the United Kingdom and Croatia, discovered a new type of elementary excitations inherent to the spin-stripe order that emerge in the frustrated zigzag spin-1/2 chain compound β-$TeVO_4$. Employing muon spin relaxation, neutron diffraction and dielectric measurements, they found that these excitations are a bound state of two phason quasiparticles. The latter manifest as a wiggling-like motion of the magnetic moments, dubbed "wigglon", and give rise to unusual low-frequency spin dynamics. This result provides a new insight into the stripe physics of strongly correlated electron systems. The results were published in M. Pregelj *et al.* "Elementary excitation in the spin-stripe phase in quantum chains", *npj Quantum Mater* **4**, 22 (2019).

Matej Pregelj, Andrej Zorko, Martin Klanjšek and Denis Arčon, in collaboration with partners from Switzerland, Germany and Japan, studied magnetic phases in β-$TeVO_4$ in high-magnetic fields up to 25 Tesla. Based on magnetization and neutron-diffraction measurements they found that the transition from the helical ground state to the spin-density-wave state occurs at ~3 T for the magnetic field along the *a* and *c* crystal axes, while at ~9 T for the field along the *b* axis.

Moreover, they discovered that the high-field (HF) state, existing above ~18 T, is an incommensurate magnetically ordered state and not the spin-nematic state, as theoretically predicted. The HF state is likely driven by sizable interchain interactions and symmetric intrachain anisotropies uncovered in previous studies. The results were published in M. Pregelj *et al.* "Magnetic ground state of the frustrated spin-1/2 chain compound β-$TeVO_4$ at high magnetic fields", *Phys. Rev. B* **100**, 094433 (2019).

Andrej Zorko, Matej Pregelj, Martin Klanjšek and Matjaž Gomilšek, in collaboration with partners from Slovenia, United Kingdom, Switzerland and China, studied $YCu_3(OH)_6Cl_3$, which has been recently reported as the first geometrically perfect realization of the kagome lattice with negligible inter-site mixing and a possible quantum-spin-liquid ground state. However, by means of combining magnetization, heat-capacity, and muon-spin-relaxation measurements they found that below T_N = 15 K magnetic ordering is realized. The latter is rather unconventional, as first, a crossover regime where the ordered state coexists with the paramagnetic state extends down to $T_N/3$ and, second, the fluctuation crossover is shifted far below T_N. Moreover, persistent spin dynamics that is observed at temperatures as low as $T/T_N = 1/300$ could be a sign of emergent excitations of correlated spin loops or, alternatively, a sign of fragmentation of each magnetic moment into an ordered and a fluctuating part. The results were published in A. Zorko *et al.*, "Coexistence of magnetic order and persistent spin dynamics in a quantum kagome antiferromagnet with no intersite mixing", *Phys. Rev. B* **99**, 214441 (2019).

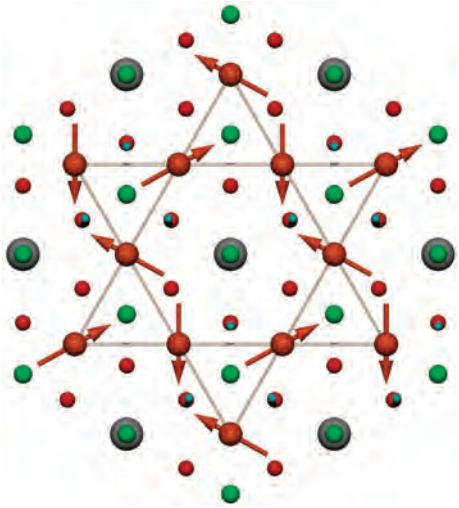

Figure 11: A perfect kagome lattice (lines) of Cu^{2+} spin-1/2 ions (orange) in the ab plane of the $YCu_3(OH)_6Cl_3$ compound. The Y^{3+}, O^{2-}, H^+, and Cl^- ions are shown in grey, red, turquoise, and green, respectively.

Andrej Zorko, Matej Pregelj, Matjaž Gomilšek and Martin Klanjšek, in collaboration with partners from Slovenia, Switzerland and China, studied the magnetic state of a new quantum kagome antiferromagnet $YCu_3(OH)_6Cl_3$. Even though it is one of the cleanest realizations of a 2D kagome spin lattice as it does not possess structural deformations nor detectable amounts of impurities, it still magnetically orders, which defies naive expectations. Researchers used elastic neutron scattering to show that the order arises from an unusually strong spin anisotropy of the Dzyaloshinskii–Moriya type, which is strong enough to push the system past its quantum critical from a disordered quantum-spin-liquid ground state to a ground state of a magnetically-ordered antiferromagnet with negative vector chirality. The results were published in A. Zorko *et al.*, "Negative-vector-chirality 120° spin structure in the defect- and distortion-free quantum kagome antiferromagnet $YCu_3(OH)_6Cl_3$", *Phys. Rev. B* **100**, 144420 (2019).

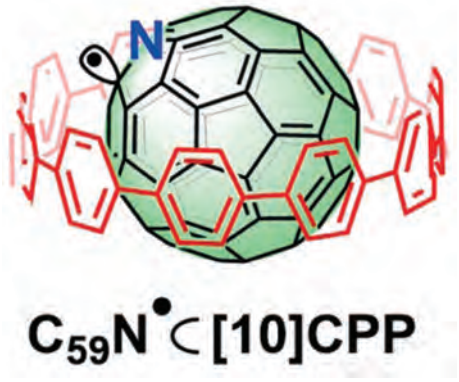

Figure 12: The CPP host and the $C_{59}N$ guest species.

In collaboration with colleagues from France, Germany and Greece, Denis Arčon studied the possibilities of the long-lived stabilization of the fullerene radical centres. A breakthrough in this area was achieved by trapping diamagnetic diamagnetic $(C_{59}N)_2$ in [10]cycloparaphenylene ([10]CPP). The dimer, under the influence of laser light, decomposed into two paramagnetic $C_{59}N$ radicals, while each individual radical was trapped in its own [10]CPP ring (Figure 12). Denis Arčon detected the $C_{59}N$ radicals and investigated them using the pulse electron paramagnetic resonance methods. The stabilization of such radicals can be an important step towards the realization of quantum qubits on a single fullerene molecule, since such complexes can also be properly arranged on the surface or in three dimensions. The results were published in A. Stergiu *et al.*, "A Long-Lived Azafullerenyl Radical Stabilized by Supramolecular Shielding with a [10]Cycloparaphenylene", *Angew. Chem. Int. Ed.* **58**, 17745–17750 (2019).

Study of multiferroic nanostructured materials and caloric effects for solid-state cooling applications

We showed, by direct measurements, the existence of large electrocaloric effect in soft materials like liquid crystals and in novel bulk composite lead-free materials. We demonstrated that liquid crystals can be used as active regenerators, thus replacing the current inactive regenerator materials and enhancing the efficiency of the new generation of cooling devices. We showed that perovskite ceramic materials can sustain more than 10^6 cycles without ageing, which is already sufficient for application. In addition, we showed how to avoid ageing and how to regenerate caloric materials. We also demonstrated how to stabilize liquid-crystal blue phases by the addition of specially decorated graphene nanoparticles. The above results have been published in 18 articles in international scientific journals. Recent works on multicalorics and soft materials have been cited more than 400 times in 2019 alone. The results were published in A. Bradeško, *et al.*, *Acta Materialia* **169** (2019) 275; E. Klemenčič, M. Trček, Z. Kutnjak, S. Kralj, *Scientific Reports* **9** (2019) 1721; U. Plaznik, M. Vrabelj, Z. Kutnjak, B. Malič, B. Rožič, A. Poredoš, A. Kitanovski, *Int. J. Refrig.* **98** (2019) 139; D. Črešnar, C. Kyrou, I. Lelidis, A. Drozd-Rzoska, S. Starzonek, S.J. Rzoska, Z. Kutnjak, S. Kralj, *Crystals* **9** (2019) 171; A. Kumar, A. Chauhan, S. Patel, N. Novak, R. Kumar, R. Vaish, *Scientific Reports* **9** (2019) 3922.

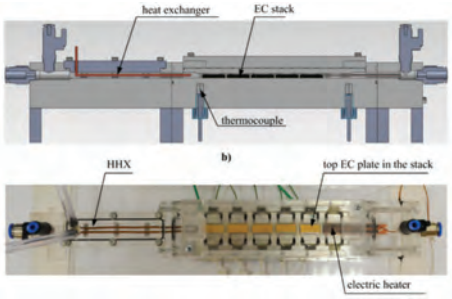

Figure 13: Electrocaloric cooling device with regenerator.

We performed the first numerical study of the topology of three-dimensional active nematic turbulence in a spherical confinement. We applied singularity theory to explain the nature of topological defects in chiral nematic droplets. We develop first high-order multipoles – as high as 64 and 128 poles – based on designed distortions in nematic fluids. We introduced routes for the accurate characterization of the surface morphology of microfilaments that form plants' tracheary systems and are crucial for their mechanical properties. We studied photoluminescence of individual MoS_2 tubes.

II. Research Programme "Physics of Soft Matter, Surfaces, and Nanostructures"

The investigations of the research programme *"Physics of Soft Matter, Surfaces, and Nanostructures"* focuses on novel complex soft-matter systems and surfaces with specific functional properties. The aim of the programme is to understand structural and dynamical properties of these systems, their interactions, their function at the molecular level, and self-assembly mechanisms in soft matter. The underlying idea is that it is possible to understand complex mechanisms, such as self-assembly, on a macroscopic level, using a simplified physical picture and models. In order to provide a comprehensive approach to the problem, the programme combines both experimental and theoretical investigations, supported by modelling and simulations. Special emphasis is given to the possible electro-optic and medical applications.

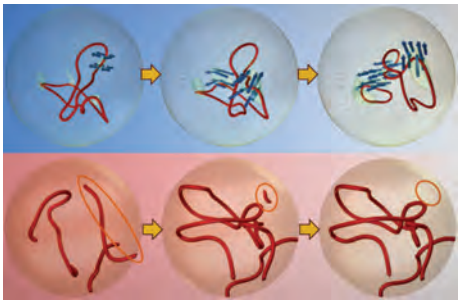

Figure 14: Active nematic topological defect transitions in spherical droplets with homeotropic surface alignment (left) and planar degenerate surface alignment (right).

Topology of Three-Dimensional Active Nematic Turbulence Confined to Droplets

In an active nematic droplet, we realized the first numerical study of the topology of three-dimensional active nematic turbulence. Simulations were performed using a mesoscopic model of active nematic fluids, which are most commonly used to describe biological systems driven by the internal conversion of stored energy (usually chemical) into motion. The chaotic motion in the active turbulence was explained by elementary topological events that affect defect lines appearing in such systems. Additionally, a coupling of surface and bulk dynamics through defects was demonstrated (*Physical Review X*, 2019, DOI: 10.1103/PhysRevX.9.031051).

Singularity theory explains topological defects in LC droplets

In a collaboration with researchers from the University of Warwick we provided a characterization of point defects in droplets of cholesteric liquid crystal, using a combination of experiment, simulation and theoretical analysis. We show that there are certain defects that are incompatible with a uniform sense of chiral twisting for topological reasons. Furthermore, those defects that are compatible with the twist of single handedness are shown to have the structure of the gradient field of an isolated critical point and, hence, are described by singularity theory. We show that the mathematical tools of singularity reproduce, with excellent agreement, the experimental observations of high charge defects and topological molecules. The results have implications beyond liquid-crystal droplets in characterizing chiral materials and their topology in general. (*Phys. Rev. X* 9, 021004, 2019).

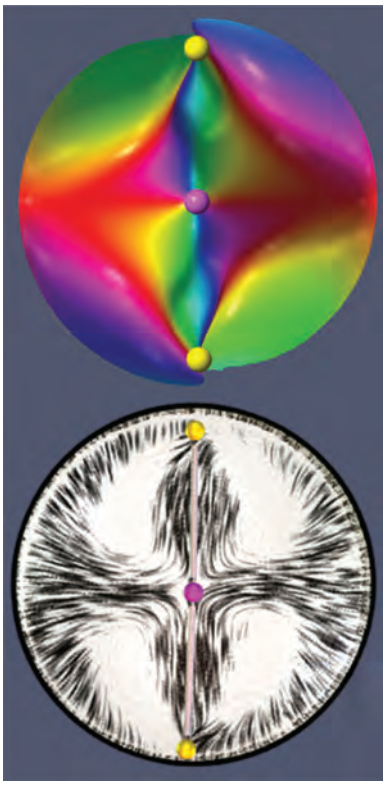

Figure 15: Numerical presentation (top) and experimental observation (bottom) of cholesteric droplet with one chiral and two achiral defects.

High-order elastic multipoles as colloidal atoms

Here we introduce physical design principles allowing us to define high-order elastic multipoles emerging when colloids with controlled shapes and surface alignment are introduced into a nematic host fluid. A combination of experiments and numerical modelling of equilibrium field configurations using a spherical harmonic expansion allow us to probe elastic multipole moments, bringing analogies with electromagnetism and the structure of atomic orbitals. We show that, at least in view of the symmetry of the "director wiggle wave functions," the diversity of elastic colloidal atoms can far exceed that of known chemical elements. The work was a collaboration with the experimental group at the University of Colorado Boulder (*Nature Comm.*, 2019, DOI: 10.1038/s41467-019-09777-8).

Spotting plants' microfilament morphologies and nanostructures

The tracheary systems of plants are crucial for the plants to survive. The curled-up microfilaments form left-handed helices that constitute the contours of tubes responsible for the transport of water and nutrients from the roots to the leaves. The microfilaments have mechanical properties that vary from plant to plant despite having similar polygonal-helical shapes and cellulose skeletons. In this research, that was done within a tight collaboration with the group of M. Godinho in Lisbon, we show that the surface morphology of the microfilaments, sensed by nematic liquid crystal droplets, is at the origin of entanglements, which are responsible for the mechanical behaviour of microfilaments (*PNAS* 2019, DOI: 10.1073/pnas.1901118116). This work introduces routes for the accurate characterization of plants' microfilaments and their potential use for bioinspired textiles.

Designed self-assembly of metamaterial split-ring colloidal particles in nematic fluids

In this work we demonstrate the self-assembly in a nematic fluid of a specific type of colloidal particle, split-ring resonators (SRRs), which are known in photonic metamaterials for their ability to obtain resonances in response to a magnetic field. Using free-energy minimisation calculations, we optimised the geometrical parameters of the SRR particles to reduce and prevent the formation of irregular metastable colloidal states, which in more general view corresponds to concepts of pre-designed self-assembly. Using the pre-designed particles, we then show self-assembly into two- and three-dimensional nematic colloidal crystals of split-ring particles. Our work is a contribution to the development of designed colloidal structures for possible use in photonic applications as tunable metamaterials (*Soft Matter* 2019, DOI: 10.1039/c9sm00842j).

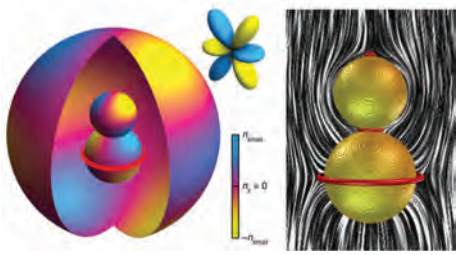

Figure 16: Elastic multipoles realized on specially shaped particles in the nematic liquid crystal.

Ray-based optical visualisation of complex birefringent structures including energy transport

We developed an efficient method to simulate light propagation in lossless and non-scattering uniaxial birefringent media, based on a standard ray-tracing technique supplemented by a newly derived transport equation for the electric field amplitude along a ray and a tailored interpolation algorithm for the reconstruction of the electromagnetic fields. We show that this algorithm is accurate in comparison to a full solution of Maxwell's equations when the permittivity tensor of the birefringent medium typically varies over a length much longer than the wavelength. We demonstrated the usefulness of our code for soft matter by comparing experimental images of liquid crystal droplets with simulated optical micrographs (*Soft Matter* 2019, DOI: 10.1039/c8sm02448k).

Moving the optical resolution limit in observations of liquid-crystal structures

We demonstrated that Stimulated Emission Depletion (STED) microscopy can be successfully used for high-resolution observations of structures formed in cholesteric liquid crystals (CLCs). Comparing the observations of optical microscopy operated in reflection mode with observations of confocal and STED microscopy, we have shown that the achievable resolution of the STED technique is below ~90 nm, improving on the best-achieved optical resolution of ~150 nm. A crucial step in making use of the fluorescent-probe-based STED technique in CLC possible, was the synthesis of custom fluorescent probes that mix well with LCs and are spectrally tailored to the STED microscope available at the JSI. (*Liquid Crystals,* DOI:10.1080/02678292.2019.1710870)

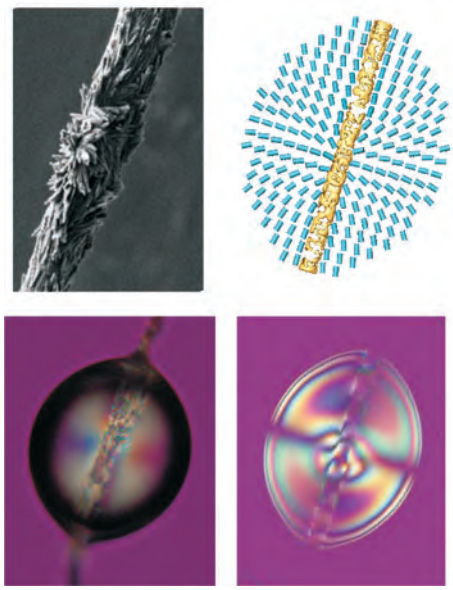

Figure 17: SEM picture of a rough nanofilament and polarization optical micrograph of a nematic droplet decorating the same filament (left) and simulated nematic ordering around such a filament with simulated polarization micrograph (right).

Tuneable ferroelectric liquid-crystal microlaser

We have studied the Whispering Gallery Mode (WGM) resonances in microdroplets of dye-doped ferroelectric liquid crystals. The emitted laser light of microdroplets exhibiting a ferroelectric Sm C*, excited using a pulsed laser, shows a multimode WGM spectrum. The WGM resonances are red-shifted upon the application of slowly varying electric field along the direction of the excitation light. This spectral shift is a consequence of a soliton-like deformation of the helical ferroelectric Sm C* structure due to the external electric field. It has a value of ~2.3 nm at 1 V/μm field, is fully reversible and quadratic in the applied field. (Liquid Crystals, DOI: 10.1080/02678292.2019.1700567)

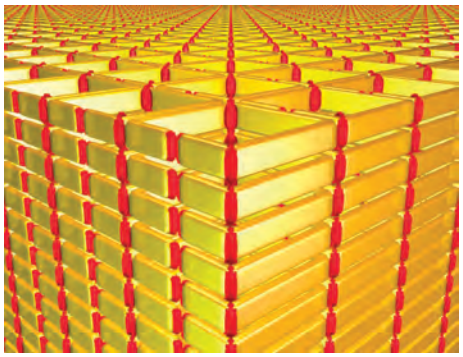

Figure 18: Three-dimensional horseshoe colloidal crystal.

Red Blood Cells' Shape Stabilized by Membrane's In-plane Ordering

Red blood cells (RBCs) are present in almost all vertebrates and their main function is to transport oxygen to the body tissues. The RBCs' shape plays a significant role in its functionality. In almost all mammals in normal conditions, RBCs adopt a disk-like (discocyte) shape, which optimizes their flow properties in vessels and capillaries. Experimentally measured values of the reduced volume (v) of stable discocyte shapes range in a relatively broad window between v~0.58 and 0.8. However, these observations are not supported by existing theoretical membrane-shape models, which predict that the discocytic RBC shape is stable only in a very narrow interval of v values, ranging between v~0.59 and 0.65. In our theoretical and numerical studies we demonstrate that this interval is broadened if a membrane's in-plane ordering and extrinsic curvature are taken into account. (*Scientific Reports,* DOI: 10.1038/s41598-019-561280)

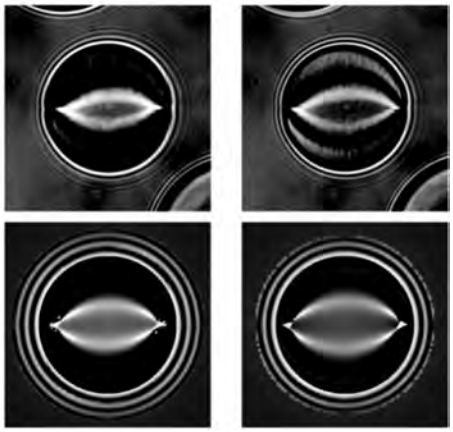

Figure 19: Bright-field micrograph of a nematic droplet before (left) and in (right) focus (top row) and corresponding simulations (bottom row).

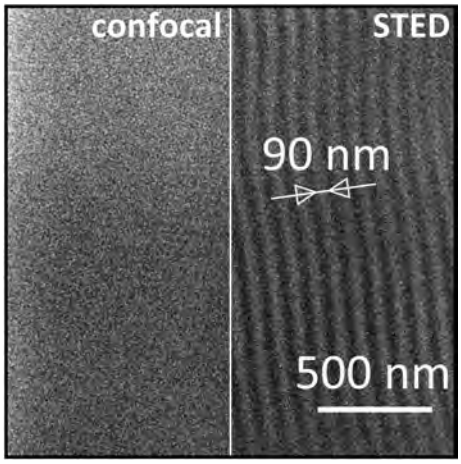

Figure 20: Comparison of structure images obtained using confocal (left) and STED microscopy (right).

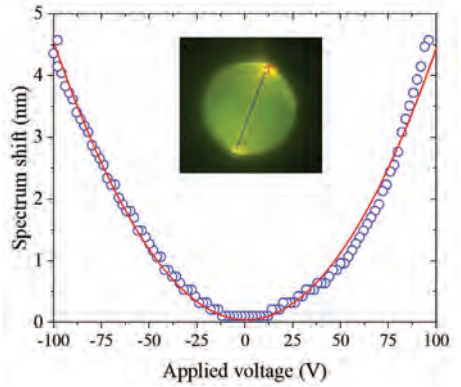

Figure 21: Ferroelectric microdoplet in Sm C exhibits multimode WGM spectrum which can be red-shifted with an applied electric field.*

Photoluminescence in MoS_2 microtubes

In collaboration with co-workers from Russia and France, we studied the photoluminescence of individual MoS_2 tubes *(Ann. Phys. (Berlin)* 2019, 1800415*)*. The emission form recombination of direct excitons was found to be strong despite the relatively large thickness of the walls of the tubes containing several dozens of monolayers. The spectra with strong "whispering gallery" mode peaks were recorded at room temperature with the Q-factor as high as several hundred. These results imply the application of these MoS_2 tubes as effective micro-resonators. These spectroscopy studies were included in the best 10 results in the report of the Ioffe Institute for the year 2019.

Quantum effects in MoS_2 nanotubes

In collaboration with Regensburg University, we reported on the first transport spectroscopy data on a quantum dot defined in a semiconducting multiwall MoS_2 nanotube. Low-temperature measurements performed at 300 mK are dominated by the Coulomb blockade, with regular Coulomb oscillations and features of quantum confinement. In a perpendicular magnetic field, we observed a clear indications of quantum state transitions (*Phys. Status Solidi RRL* 2019, 1900251).

MoS_2 nanotubes for the automotive industry

In collaboration with researchers from Austria and Poland, we investigated the feasibility of using MoS_2 nanotubes in the form tapping of zinc-coated automotive parts. The MoS_2 nanotubes are able to form a tribofilm on zinc-coated steel surfaces that results in torque reduction and the lowest sub-surface hardening. Sulfurized olefin polysulfide extreme pressure additive, which is currently widely spread in forming oils has a very good synergy with MoS_2 nanotubes in form tapping making them suitable candidates for being used in prospective formulations of the future nanofluid minimum quantity lubrication formulations (*Journal of Manufacturing Processes* **39**, 167–180 (2019)).

Configurational ordering of polarons in superconducting layered crystal 1T-TaSeS

Many two-dimensional metal dichalcogenides including 1T-TaSeS exhibit different irregularly ordered and even amorphous self-assembled electronic structures that can be created and manipulated by short light pulses or by charge injection in addition to periodic charge density waves. In collaboration with the Complex Matter department we explained this behaviour with a sparsely filled charged lattice gas model (*New J. Phys* **21**, 083001 (2019)). The computer simulations were supported by images of the surface of 1T-TaSeS taken using a Scanning Tunnelling Microscope. Moreover, we used Scanning Tunnelling Spectroscopy to show that the domain structure that spontaneously forms is not crucial for the existence of superconductivity in these samples.

Tuneable flat band in organic Kagome lattice

A Kagome lattice is expected to be a perfect platform for hosting exotic emergent phenomena such as negative magnetism and unconventional superconductivity. In this work we show how the geometrical frustration of a Kagome lattice leads to a zero probability for electrons to tunnel out of hexagons. When guest molecules are hosted in such a flat band, their states exhibit sharp features due to the localization of electron waves. These characteristics and the chemical tunability of organic Kagome offer a fertile playground to study emergent order in a well-defined system (*Physica Status Solidi* 2019, DOI: 10.1002/pssb.201900346).

Diffusive Memristive Switching on the Nanoscale

We studied the memristive action on the level of individual nanoparticles to find conditions for robust performance and unravel the underlying physical mechanism. Interestingly, we find that the application of alloy nanoparticles as a reservoir for mobile silver species effectively limits the formation of stable metallic filaments and results in reproducible diffusive switching characteristics. Notably, similar behaviour is encountered on macroscopic nanocomposite devices, which incorporate multiple stacks of nanoparticles and offer a high design versatility to tune switching properties and engineer scalable memristive devices with diffusive switching characteristics. No additional forming step is required for the memristive operation, which renders them very attractive for applications (*Sci Rep* **9**, 17367 (2019), DOI: 10.1038/s41598-019-53720-2).

III. Research programme "Experimental biophysics of complex systems and imaging in biomedicine"

Based on recent findings on the adverse outcome pathways following the exposure to nanoparticles, we have developed a completely new market idea and set up a spin-out company, Infinite Ltd., to develop cellular sensory systems for predicting lung diseases.

The research programme *Experimental biophysics of complex systems and imaging in biomedicine* combines research of the processes and structures of biological systems by developing new, advanced experimental techniques of super-resolution microscopies, microspectroscopies and nanoscopies as well as new imaging techniques. Our research is mainly focused on the response of molecular and supramolecular structures to interactions between materials and living cells as well as between light and living cells. We are interested in molecular events and the physical mechanisms with which these events are causally connected, time scales, conditions and applied value of the investigated mechanisms, especially for use in medicine and in the field of health care in general. With the development of new coupled super-resolution and spectroscopic techniques we want to open new possibilities to investigate biological systems and from there onwards to open new possibilities for designing medical materials and devices, for diagnostics, therapy and tissue regeneration, representing key challenges due to the population aging. The investment into the new super-resolution STED system opened up variety of fluorescence microscopy approaches: STED microscopy and two-photon (2PE) microscopy, multichannel spectrally resolved fluorescence lifetime imaging (spFLIM), fluorescence microspectroscopy (FMS). These, coupled with optical tweezers, can be used to examine interactions between materials, nanomaterials and cell lines and the phenomena involved, such as lipid wrapping and nanomaterial passivation, membrane disintegration, and cellular membrane translocation bypassing conventional signalling pathways. We also introduced a method that enables monitoring of the electric field in tumours in the treatment of cancer with electroporation, and further developed a method of multiparametric magnetic resonance imaging for the characterization of food and medicines and various industrial processes. High-resolution magnetic resonance imaging can monitor the effectiveness of surface treatments, the formation and dissolution of gels as well as measure diffusion in confined geometries with the use of modulated gradients.

In 2018 we published an article in Nano Letters demonstrating the use of STED microscopy to directly observe the lipid wrapping of TiO_2 nanotubes in living lung epithelium, for the first time. In collaboration with David Gomez's group at UCD (Dublin, Ireland), which performed proteomic analysis of these lipid wraps, we demonstrated that there are key enzymes in the wraps that could trigger blood clots. That is why in 2019 we identified key cells of an *in vitro* system capable of reproducing and explaining how blood-clot formation occurs *in vivo* in cooperation with the laboratory of Rinku Majumder of LSUHSC School of Medicine (New Orleans, USA). This is the basis for the development of a hypothetical adverse outcome signalling pathway (AOP) and an *in vitro* cell-based system that could predict which nanoparticles could trigger thrombosis.

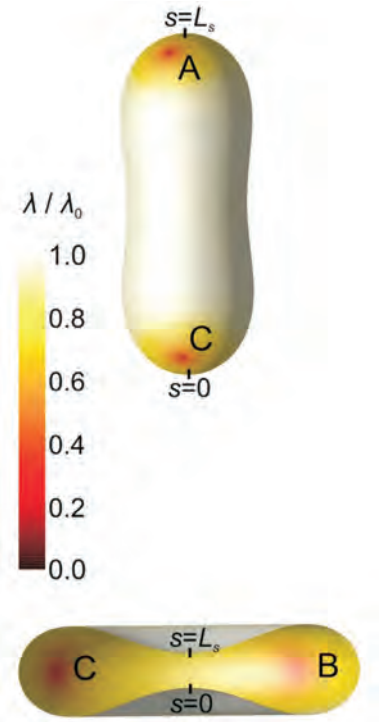

Figure 22: Prolate (top) and oblate (bottom) red-blood-cell shapes hosting topological defects.

A major breakthrough was made in 2019 with the discovery of a mechanism for triggering of chronic inflammation of the lung epithelium following single exposure to nanomaterials. STED and HIM microscopy (partly in collaboration with HZDR Dresden) revealed that epithelial cells passivate some nanomaterials on their surface, reducing the destructive effect of interactions between nanomaterials and various structures in cells (e.g., nucleus, actin networks, inner membranes; all observed by STED microscopy). Passivation can be achieved only by enhanced lipid synthesis (demonstrated by *in vitro* transcriptomics in collaboration with HGMU Munich and *in vivo* in collaboration with NRCWE Copenhagen and Health Canada) and excretion of nanomaterials-lipids agglomerates on the surface (demonstrated by STED microscopy). Unfortunately, immune cells, especially macrophages, recognize these aggregates as foreign matter and die while trying to degrade them. As a result, the material is again excreted into the space between the cells, which means that the circle closes - as the material is ready to be uptaken again by the epithelial cells. The circle repeats in a living system if dead macrophages are replaced by new ones, actually induced by the signalling of the epithelial cells. With modelling, we have shown that, in certain combinations of passivation, signalling and toxicity rates, a long-term (chronic) response to a single exposure is actually obtained. The paper is being prepared. At the same time, during the study of the mechanism, we identified certain techniques for detecting these events, based on which sensory systems can be made with the ability to predict disease states. We registered this knowledge with the IJS as hidden knowledge and founded a spin-out company Infinite Ltd.

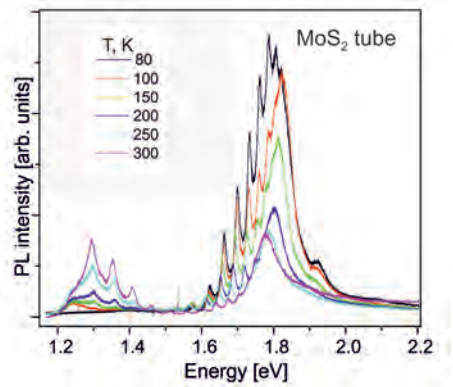

Figure 23: Temperature variation of micro photoluminescence spectra in MoS_2 tube of 2 μm in diameter.

In collaboration with the University of Oxford (UK), we have been developing advanced fluorescence microspectroscopic methods for the characterisation of local molecular environments. In particular, we greatly expanded the reliability and flexibility of super-resolution fluorescence

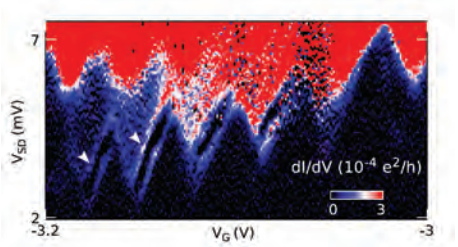

Figure 24: Discrete conductance resonances within the single-electron tunnelling regions. corresponding to an excitation energy of 500 μeV.

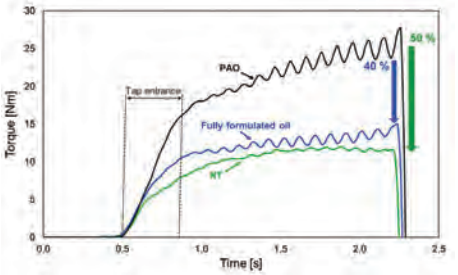

Figure 25: Torque as a function of time during tap entry for the threads formed using pure PAO oil, PAO with 5 wt.% MoS_2 nanotubes (NT) and reference fully formulated oil.

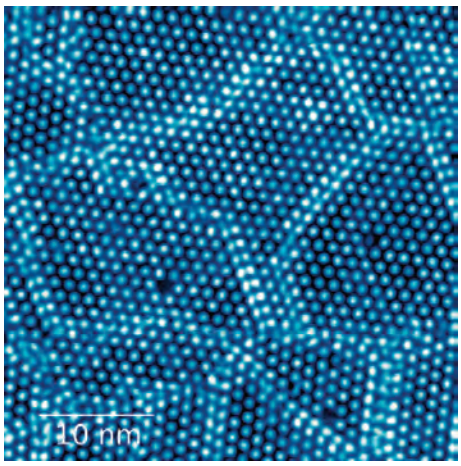

Figure 26: STM image of the surface of 1T-TaSeS exhibiting charge density wave domains separated by domain walls.

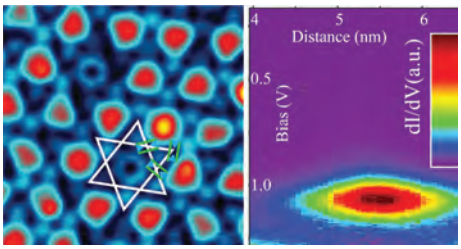

Figure 27: Molecular resolution STM image showing Kagome lattice of $(BETS)_2GaCl_4$. States of guest molecules are protected due to destructive interference on the frustrated lattice.

correlation spectroscopy (STED-FCS) by introducing adaptive optics to circumvent optical aberrations [1]. We shared our extensive expertise in STED-FCS in a comprehensive description of the method, published in *Nature Protocols* [2]. Using environment-sensitive dyes and other microspectroscopies, we also revealed that the molecular properties of biomembranes reflect their microscopic mechanical properties, which we reported in *Communications Biology* (by *Nature Publishing Group*) [3].

For efficient labelling we have investigated, synthesized and tested a series of new STED-able fluorophores where we specifically aim at very low bleaching rates to enable 3D time-lapse STED microscopy and tracking interactions in 3D. Few par-fluorophores for nano-temperature mapping have also been synthesized to allow temperature profiling in micro-boiling, an activity run in collaboration with prof. Golobič from the University of Ljubljana, Faculty of Mechanical Engineering.

Based on the experimental results achieved in the framework of the ARRS project (L7-7561) completed in 2019, we have developed a new methodology for the diagnosis of vascular leakage in ocular tissues and the detection of the pathological conditions on the retinal epithelium. For the purpose of the research, besides the concept, we developed and produced an advanced and cost-effective hyperspectral system based on the detection of tissue autofluorescence. In addition, part of the research aimed at hyperspectral detection of coagulation was summarized in a scientific paper (Podlipec *et al.*, *Journal of Biophotonics,* In submission).

As part of the another ongoing ARRS project (L2-9254), we conducted the first theranostics experiments with a time-based modular laser system developed at the Laboratory for Photonics and Laser Systems (FOLAS) on a real biological system. With the development of the laser system and its upgrade to our super-resolved STED microscope, we have successfully performed advanced diagnostics based on the detection of fluorescence lifetime on the ocular tissue, as well as therapeutics to the local target area. The essential results of the study were summarized in a scientific paper (Podlipec *et al.*, *Applied Physics A,* In submission).

Part of the research was also devoted to a new international project Crossing Borders and Scales (CROSSING) between the Jožef Stefan Institute (IJS) and the Helmholz-Zentrum Dresden Rossendorf (HZDR), where our group participates in the first of the four work packages covering the field of the correlative microscopy. We were able to acquire the first correlative images on the nanoscale combining optical super-resolution STED and helium-ion microscope (HIM) on the relevant biological sample of the nanoparticles interacting with the *in-vitro* pulmonary epithelium system. More results and publication of the results of the ongoing study is expected in 2020.

Use of magnetic resonance in the study of controlled-release polymer tablets

Controlled drug-delivery systems are widely used in the pharmaceutical industry because of their numerous advantages. For hydrophilic polymers, it is generally accepted that, once in contact with body fluids, they hydrate and swell, forming a gel layer that regulates the penetration of body fluids into the tablet and the dissolution of the incorporated drug. Therefore, the knowledge of the gel layer characteristics is of crucial importance for the use of controlled drug-delivery systems. Previous studies of xanthan tablets have shown the dependence of xanthan swelling and drug-release kinetics on the pH and ionic strength of the medium in which the tablet swells. The medium molecules and polymer-chain dynamics are very important for the drug release kinetics from hydrophilic matrix tablets, as these lead to constantly changing polymer-chain mesh sizes and distributions, which can change the diffusion pathways for the drug carried in the gel layers. The dynamic properties of the medium and the polymer molecules in xanthan gels at different xanthan concentrations were investigated by fast-field cycling NMR relaxometry. The study demonstrated faster medium dynamics in the more diluted xanthan gels than in those more concentrated. In addition, different media pHs also influenced the gel dynamics, with slower water and polymer-chain dynamics in the acid medium. The results were published in the article Urška Mikac, Ana Sepe, Anton Gradišek, Julijana Kristl, Tomaž Apih, "Dynamics of water and xanthan chains in hydrogels studied by NMR relaxometry and their influence on drug release", International journal of pharmaceutics, ISSN 0378-5173, 2019, 563, 373-383.

Measurement of cement-hydration dynamics by diffusion spectra

In the magnetic resonance imaging laboratory, we are examining different approaches to diffusion measurements in porous materials over a longer period of time. Our original contribution to science in this field is the

development of a method for the measurement of diffusion spectra by means of modulated magnetic field gradients. In this way, unlike other groups, we use a constant gradient. This, when used in a combination with a multi-spin echo sequence, becomes effectively oscillating and thus enables the measurement of the diffusion constant at the frequency determined by the oscillation of the effective gradient. The method also has technical constraints associated with the frequency bandwidth of radio-frequency pulses. A few years ago, we showed how to circumvent these restrictions and confirmed the method on test samples; however, we did not yet show the practical aspect of this method. In a recent study published in: SERŠA, Igor. Sequential diffusion spectra as a tool for studying time-dependent translational molecular dynamics: a cement hydration study. *Molecules*. 2020, vol. 25, no. 1, pp. 68-1-68-15 the use of this method was presented to monitor the hydration of white cement.

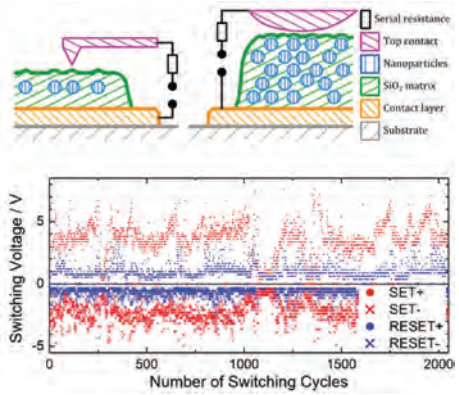

Figure 28: Measurements layout and the results of switching voltages as extracted from individual hysteresis loops for 2000 switching cycles in a $SiO_2/AgPt/SiO_2$ stack, measured by C-AFM on an individual AgPt nanoparticle.

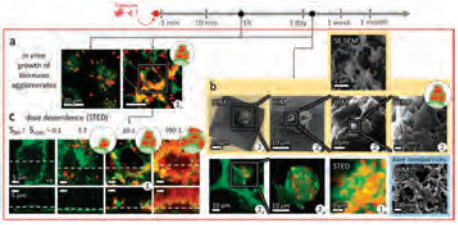

Figure 29: Passivation of TiO_2 nanotubes on the surface of lung epithelial cells. A) development of bionano agglomerates (left image 1h after nanoparticle exposure, right image 2 days after nanoparticle exposure, green and red colour code membranes and nanomaterial, respectively); B) different magnifications of bionano agglomerates on the surface of epithelial cells by STED (color coding same as for A), HIM and SEM microscopy; numbers 1 and 2 indicate two samples. C) dose dependence of bionano agglomerates formation - horizontal (upper row) and vertical (lower row) cross-sections obtained by STED microscopy, colour coding as in A.

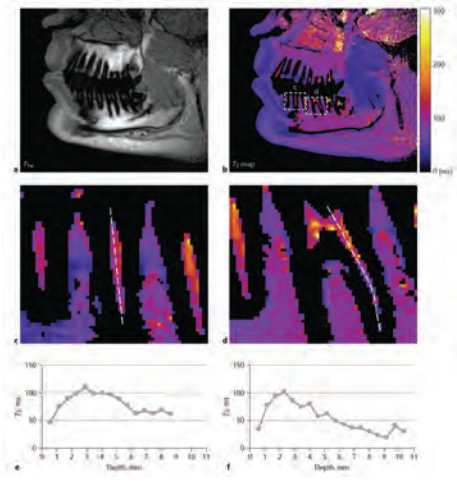

Figure 30: T1-weighted image (a) and the corresponding T2 map (b) of a representative patient's teeth in a sagittal slice. In the T2 map, two regions of interest (ROIs) are indicated by a dashed line, one is containing a single-rooted tooth and the other a molar. The magnified ROIs are shown in panels (c) and (d), respectively. (e), (f) Graphs of dental pulp T2 value depth profiles that were measured along a dashed line central to the dental pulp as indicated in the corresponding T2 maps of the ROIs.

Development of MRI methods for the diagnosis of malignant pleural mesothelioma

Diseases related to exposure to harmful asbestos are common in Slovenia. One of the worst forms of these is the pleural cancer known as malignant pleural mesothelioma. The treatment of patients with this disease is very demanding and good imaging diagnostic tools are needed to monitor its treatment. In this study, we have shown that magnetic resonance imaging using contrast agents can provide a good diagnostic tool. We analysed the dynamics of the accumulation of contrast agents using various existing pharmacokinetic models, determined their parameters, and then analysed their predicted value so that we compared the parameter values of the cancerous tissue with those of the healthy tissue. This study was also a doctoral thesis theme of the MPŠ PhD student Martina Vivoda Tomšič, who was successfully defended her PhD thesis in 2019 under the co-supervision of Prof. Dr. Igor Serša. Results of the study were published in a scientific article Martina Vivoda Tomšič, Sotirios Bisdas, Viljem Kovač, Igor Serša, Katarina Šurlan Popović, "Dynamic contrast-enhanced MRI of malignant pleural mesothelioma: a comparative study of pharmacokinetic models and correlation with mRECIST criteria", *Cancer imaging*. 2019, **19**, no. 1, 1-11.

Assessment of the caries of teeth *in vivo* by the use of T2 relaxation time mapping of dental pulps

Dental caries of patients is usually diagnosed by X-ray imaging. In a study on extracted teeth done a few years ago we demonstrated that magnetic resonance imaging (MRI) has a high potential for the evaluation of caries. This presence of caries can be detected by MRI in the demineralized region of the dentine and in dental pulp with changes in diffusion constants and T2 relaxational times. This study has now been repeated *in vivo* by measuring maps of T2 relaxation times in dental pulps of patients with caries and of healthy volunteers. We have shown that despite the low resolution of the obtained maps *in vivo* the method of T2 relaxation time mapping still enabled a good assessment of the degree of caries. These assessments gave comparable results with those obtained using the standard approach based on the international scale of caries (ICDAS). The results of this study were published in the article Ksenija Cankar, Jernej Vidmar, Lidija Nemeth, Igor Serša, "T2 mapping as a tool for assessment of dental pulp response to caries progression: in vivo MRI study", *Caries Research*, 2019, ISSN 0008-6568. DOI: 10.1159/000501901.

MR Microscopy of cerebral blood clots as a tool for the assessment of thrombectomy outcome

The treatment of ischemic stroke, similar to the treatment of myocardial infarction, is shifting from the use of thrombolysis to the mechanical removal approach by using catheter devices, i.e., thrombectomy. The performance of thrombectomy strongly depends on the blood clot, its length, composition, the degree of retraction, etc. Many of these parameters cannot be determined from CT scans that are recorded before the treatment of patients. In this study, that was done with retrieved cerebral blood clots, we have shown that much more information on blood clots can be obtained by MRI, especially if it includes different imaging methods such as T1, T2 and ADC mapping. We also showed that there is a weak correlation between the duration of the clot removal and some of the parameters obtained from MR images of the clots. The results of this study were published in the article Jernej Vidmar, Franci Bajd, Zoran Miloševič,

Igor Kocijančič, Miran Jeromel, Igor Serša, "Retrieved cerebral thrombi studied by T2 and ADC mapping preliminary results", *Radiology and oncology,* 2019, **53**, no. 4, 427-233.

The research of our department has been supported by a number of international projects financed by the European Union. It was also supported within many bilateral projects and other scientific cooperations. In 2019, the Department had cooperations with 113 partners from Slovenia and abroad. Among them were the following institutions:

1. BASF, Heidelberg, Germany
2. Ben Gurion University, Beersheba, Israel
3. Chalmers University of Technology, Physics Department, Göteborg, Sweden
4. Clarendon Laboratory, Oxford, UK
5. Centre national de la recherché scientifique, Laboratory de Marseille, Marseille, France
6. Centre national de la recherché scientifique, Laboratoire de Spectrochimie Infrarouge et Raman, Thiais, France
7. Department of Chemistry, College of Humanities and Sciences, Nihon University, Tokyo, Japan
8. Deutsches Krebsforschungszentrum, Heidelberg, Germany
9. Deutsches Elektronen-Synchrotron, Hamburg, Germany
10. École Polytechnique Fédérale de Lausanne, Lozana, Switzerland
11. Eidgenössische Technische Hochschule - ETH, Zürich, Switzerland
12. Elettra (Synchroton Light Laboratory), Basovizza (Bazovica), Italy
13. European Synchrotron Radiation Facility, Grenoble, France
14. Facultad de Ciencia y Technologia, Universidad del Pais Vasco UPV/EHU, Leioa, Spain
15. Faculty of Physics, Adam Mickiewicz University, Poznanj, Poland
16. Florida State University, Florida, USA
17. Forschungszentrum Dresden Rossendorf, Dresden, Germany
18. Gunma National College of Technology, Maebashi, Japan
19. High-Magnetic-Field Laboratory, Grenoble, France
20. High Magnetic Field Laboratory, Nijmegen, Netherlands
21. High Magnetic Field Laboratory, Tallahassee, Florida, USA
22. Humboldt Universität Berlin, Institut für Biologie/Biophysik, Berlin, Germany
23. Illie Murguescu Institute of Physical Chemistry of the Romanian Academy, Bucharest, Romania
24. International Human Frontier Science Program Organisation, Strasbourg, France
25. Institut Ruđer Bošković, Zagreb, Croatia
26. Institut za Teoretično fiziko univerze v Göttingenu, Göttingen, Germany
27. Institute of Molecular Physics, Polish Academy of Sciences, Poznanj, Poland
28. Institute of Electronic Materials Technology, Warsaw, Poland
29. Institut für Experimentalphysik der Universität Wien, Vienna, Austria
30. Institut für Biophysik und nanosystemforschung OAW, Graz, Austria
31. Institut za kristalografijo Ruske akademije znanosti, Moscow, Russia
32. Instituto Superior Tecnico, Departamento de Fisica, Lisbon, Portugal
33. International Center for Theoretical Physics, Trieste, Italy
34. ISIS, Rutherford Appleton Laboratory, Didcot, UK
35. A.F. Ioffe Physico-Technical Institute, Saint Petersburg, Russia
36. Kavli Institute for Theoretical Physics, Santa Barbara, USA
37. King's College, London, UK
38. University Medical Centre Ljubljana, Ljubljana, Slovenia
39. Korea Basic Science Institute, Daejeon, South Korea
40. Kyung Hee University of Suwon, Impedance Imaging Research Center, Seoul, South Korea
41. KTH Royal Institute of Technology, Stockholm, Sweden
42. KMZ - CNC obdelava kovin in drugih materialov Zalar Miran s.p., Ljubljana, Slovenia
43. Liquid Crystal Institute, Kent, Ohio, USA
44. Max Planck Institute, Dresden, Germany
45. Mayo Clinic, Rochester, Minnesota, USA
46. Merck KGaA, Darmstadt, Germany
47. MH Hannover, Hannover, Germany
48. National Academy of Sciences of Ukraine, Institute of Physics, Kiev, Ukraine
49. National Center for Scientific Research "Demokritos", Aghia Paraskevi Attikis, Greece
50. National Institute for Research in Inorganic materials, Tsukuba, Japan

51. Vinča Institute of Nuclear Sciences, Beograd, Serbia
52. Oxford University, Department of Physics, Department of Materials, Oxford, UK
53. Paul Scherrer Institut, Villigen, Switzerland
54. Politecnico di Torino, Dipartimento di Fisica, Torino, Italy
55. Radbound University Nijmegen, Research Institute for Materials, Nijmegen, Netherlands
56. Rwth Aachen University, Aachen, Germany
57. School of Physics, Hyderabad, Andhra Prades, India
58. SISSA, Trieste, Italy
59. State College, Pennsylvania, USA
60. Faculty of Medicine of the University of Rijeka, Rijeka, Croatia
61. University of Zagreb, Institute of Physics , Zagreb, Croatia
62. Technical University of Catalonia, Barcelona, Spain
63. Technical University Vienna, Vienna, Austria
64. The Geisel School of Medicine at Dartmouth, Hanover, USA
65. The Max Delbrück Center for Molecular Medicine in Berlin, Berlin, Germany
66. Tohoku University, Sendai, Japan
67. Tokyo University, Bunkyo, Tokyo, Japan
68. University of Aveiro, Aveiro, Portugal
69. Universita di Pisa, Dipartimento di Chimica e Chimica Industriale, Pisa, Italy
70. Université de Picardie Jules Verne, Amiens, France
71. Université de la Méditerranée, Marseille, France
72. University of Bristol, Bristol, UK
73. University of California at Irvine, Beckman Laster Institute and Medical Clinic, Irvine, California, USA
74. University of Durham, Durham, UK
75. University of Duisburg, Duisburg, Germany
76. University of Innsbruck, Innsbruck, Austria
77. Universität Freiburg, Institut für Makromolekulare Chemie, Freiburg, Germany
78. University of Linz, Institute of Chemistry, Department of Physical Chemistry & Linz Institute of Organic Solar Cells, Linz, Austria
79. University of Leeds, Leeds, UK
80. University of Loughborough, Loughborough, UK
81. Universität Mainz, Geowissenschaften, Mainz, Germany
82. Université de Nice, Nica, France
83. Université Paris Sud, Paris, France
84. University of Provence, Marseille, France
85. University of Tsukuba, Tsukuba, Ibaraki, Japan
86. University of Utah, Department of Physics, Salt Lake City, Utah, USA
87. University of Waterloo, Department of Physics, Waterloo, Ontario, Canada
88. Universität Regensburg, Regensburg, Germany
89. University of Zürich, Zürich, Switzerland
90. Univerza v Münchenu in MPQ, München, Germany
91. University of Mons, Mons, Belgium
92. Univerza v Pavii, Pavia, Italy
93. University of Maribor, Maribor, Slovenia
94. University of North Carolina, Chapel Hill, USA
95. University of Wisconsin, Madison, USA
96. Wagenigen University, Laboratory of Biopyhsics, Wageningen, Netherlands
97. Weizman Institute, Rehovot, Israel
98. Yonsei University, Seoul, South Korea

that made the reported studies possible.

Some outstanding publications in 2019

1. M. Gomilšek, R. Žitko, M. Klanjšek, M. Pregelj, C. Baines, L. Yuesheng, Q. Zhang, A. Zorko, *Kondo screening in a charge-insulating spinon metal.* Nature Physics **15** (2019) 754.
2. A. Matavž, A. Benčan, J. Kovač, C.C. Chung, J.L. Jones, S. Trolier-McKinstry, B. Malič, V. Bobnar, *Additive manufacturing of ferroelectric-oxide thin-film multilayer devices*. ACS Applied Materials & Interfaces **11** (2019) 45155.

3. B. Senyuk, J. Aplinc, M. Ravnik, I. I. Smalyukh, High-order elastic multipoles as colloidal atoms. Nature Communications **10** (2019) art. no. 1825, doi: 10.1038/s41467-019-09777-8.
4. S. Čopar, J. Aplinc, Ž. Kos, S. Žumer, M. Ravnik, Topology of three-dimensional active nematic turbulence confined to droplets. Physical Review X **9** (2019) 031051-1-031051-13,
5. J. Pollard, G. Posnjak, S. Čopar, I. Muševič, G. P. Alexander. Point defects, topological chirality and singularity theory in cholesteric liquid-crystal droplets. Physical Review X **9** (2019) 021004-1-021004-19,
6. A. P. Almeida, J. Canejo, U. Mur, S. Čopar, P. Almeida, S. Žumer. M. H. Godinho, Spotting plants´ microfilament morphologies and nanostructures. Proceedings of the National Academy of Sciences of the United States of America **116** (2019) 13188-13193.
7. T. Emeršič, R. Zhang, Ž. Kos, S. Čopar, N. Osterman, J. J. de Pablo, U. Tkalec, Sculpting stable structures in pure liquids. Science Advances **5** (2019) art. no. eaav4283.
8. E. Sezgin, F. Schneider, S. Galiani, I. Urbančič, D. Waithe, B. Lagerholm, B. Christoffer, Ch. Eggeling, Measuring nanoscale diffusion dynamics in cellular membranes with super-resolution STED-FCS, Nature protocols 14 (2019) 1054–1083.
9. J. Steinkühler, E. Sezgin, I. Urbančič, Ch. Eggeling, R. Dimova, Mechanical properties of plasma membrane vesicles correlate with lipid order, viscosity and cell density, Communications Biology 2 (2019) 337–1–337–8.

Some outstanding publications in 2018

1. N. Janša, A. Zorko, M. Gomilšek, M. Pregelj, K.W. Krämer, D. Biner, A. Biffin, C. Rüegg, M. Klanjšek. Observation of two types of fractional excitation in the Kitaev honeycomb magnet. *Nature Physics* **14**, (2018), 786-790.
2. P. Adler, P. Jeglič, T. Knaflič, M. Komelj, D. Arčon, et al. Verwey-type charge ordering transition in an open-shell p-electron compound. *Science Advances* **4**, (2018), eaap7581.
3. S. Gao, S. Vrtnik, J. Luzar, et al. Dipolar spin ice states with a fast monopole hopping rate in $CdEr_2X_4$ (X=Se, S). *Physical Review Letters* **120** (2018), 137201.
4. Yu.O. Zagorodniy, B. Zalar et al. Chemical disorder and ^{207}Pb hyperfine fields in the magnetoelectric multiferroic $Pb(Fe_{1/2}Sb_{1/2})O_3$ and its solid solution with $Pb(Fe_{1/2}Nb_{1/2})O_3$. *Physical Review Materials* **2** (2018), 014401.
5. J. Dolinšek. Electronic transport properties of complex intermetallics. *Crystal growth of intermetallics*, Eds. P. Gille, Yu. Grin (Berlin: De Gruyter, 2018), 260-278.
6. Pramanick, A., Dmowski, W., Egami, T.I, Setiadi Budisuharto, A., Weyland, F., Novak, N., Christianson, A., Borreguero, J. M., Abernathy, D., Jørgensen, M. R. V.. Stabilization of Polar Nanoregions in Pb-free Ferroelectrics. *Physical Review Letters* **120** (2018), 207603.
7. Guillamat, Pau, Kos, Žiga, Hardoüin, Jérôme, Ignés-Mullol, Jordi, Ravnik, Miha, Sagués, Francesc. Active nematic emulsions. *Science Advances* **4** (2018), 2375-2548.
8. Urbančič, Iztok, Garvas, Maja, Kokot, Boštjan, Majaron, Hana, Umek, Polona, Škarabot, Miha, Arsov, Zoran, Koklič, Tilen, Čeh, Miran, Muševič, Igor, Štrancar, Janez, et al. Nanoparticles can wrap epithelial cell membranes and relocate them across the epithelial cell laye. *Nano Letters* **18** (2018), 5294-5305.
9. Aničić, Nemanja, Vukomanović, Marija, Koklič, Tilen, Suvorov, Danilo. Fewer defects in the surface slows the hydrolysis rate, decreases the ROS generation potential, and improves the Non-ROS antimicrobial activity of MgO. *Small* **14** (2018), 1800205.
10. Santos, Ana Mafalda, Urbančič, Iztok, et al. Capturing resting T cells: the perils of PLL. *Nature Immunology* **19** (2018), 203-205.

Some outstanding publications in 2017

1. M. Klanjšek, A. Zorko, R. Žitko, J. Mravlje, Z. Jagličić, P.K. Biswas, P. Prelovšek, D. Mihailović, D. Arčon. A high-temperature quantum spin liquid with polaron spins. *Nature Physics* 13 (2017), 1130–1134.
2. Y. Takabayashi, M. Menelaou, H. Tamura, N. Takemori, T. Koretsune, A. Štefančič, G. Klupp, A.J.C. Buurma, Y. Nomura, R. Arita, D. Arčon, M.J. Rosseinsky, K. Prassides. π-electron $S = 1/2$ **quantum spin-liquid state in an ionic polyaromatic hydrocarbon.** *Nature Chemistry* 9 (2017), 635–643.
3. B. Rožič, J. Fresnais, C. Molinaro, J. Calixte, S. Umadevi, S. Lau-Truong, N. Felidj, T. Kraus, F. Charra, V. Dupuis, T. Hegmann, C. Fiorini-Debuisschert, B. Gallas, E. Lacaze. Oriented gold nanorods and gold nanorod chains within smectic liquid crystal topological defects. *ACS Nano* 11 (2017), 6728–6738.
4. A. Zorko, M. Herak, M. Gomilšek, J. van Tol, M. Velázquez, P. Khuntia, F. Bert, P. Mendels. Symmetry reduction in the quantum Kagome antiferromagnet Herbertsmithite. *Physical Review Letter* 118 (2017), 017202.

5. M. Gomilšek, M. Klanjšek, R. Žitko, M. Pregelj, F. Bert, P. Mendels, Y. Li, Q. M. Zhang, A. Zorko. Field-induced instability of a gapless spin liquid with a spinon Fermi surface. *Physical Review Letter* 119 (2017), 137205.
6. L. Giomi, Ž. Kos, M. Ravnik, and A. Sengupta. Cross-talk between topological defects in different fields revealed by nematic microfluidics. *Proceedings of the National Academy of Sciences of the United States of America* 114 (2017), E5771-E5777.
7. S. M. Hasheimi, U. Jagodič, M. R. Mozaffari, M. R. Ejtehadi, I. Muševič, and M. Ravnik, Fractal nematic colloids. *Nature Communications* 8 (2017), 12106.
8. G. Posnjak, S. Čopar and I. Muševič. Hidden topological constellations and polyvalent charges in chiral nematic droplets. *Nature Communications* 8 (2017), 14594.
9. A. Nych, Jun-ichi Fukuda, U. Ognysta, S. Žumer, I. Muševič. Spontaneous formation and dynamics of half-skyrmions in a chiral liquid-crystal film. *Nature Physics* 13 (2017), 1215.
10. E. Sezgin, F. Schneider, V. Zilles, I. Urbančič, E. Garcia, D. Waithe, A.S. Klymchenko, C. Eggeling. Polarity-Sensitive Probes for Superresolution Stimulated Emission Depletion Microscopy. *Biophysical Journal* 113 (2017), 1321-1330.
11. M. Kranjc, S. Kranjc,F. Bajd, G. Serša, I. Serša, D. Miklavčič. Predicting irreversible electroporation-induced tissue damage by means of magnetic resonance electrical impedance tomography. *Scientific Reports* 7 (2017*)*, 1-10.

Awards and Appointments

1. Dr Nych Andriy, Fukuda Jun-ichi, Ognysta Uliana, Prof. Žumer Slobodan, PhD, and Prof. Muševič Igor, PhD: award for the best paper published in 2018 in the field of liquid crystals, "Spontaneous formation and dynamics of half-skyrmions in a chiral liquid-crystal film", Tsukuba, Ibaraki , Japan, The Japanese Liquid Crystal Society
2. Prof. Arčon Denis, PhD: The Žiga Zois Prize for outstanding scientific achievements in the field of quantum magnetism and unusual superconductivity, Ljubljana, awarded by the Republic of Slovenia
3. Gačnik Darja, MPhys: the award for the best oral presentation in the young scientists' category, "Superconductivity in Ti–Zr–Hf–(Sn,Ni,Nb) high-entropy alloys", Dresden, Germany, European C-MetAC Days 2019
4. Dr Jelen Andreja: the award for the best poster, "Microstructure and magnetic properties of a single-crystalline FeCoCrMnAl high-entropy alloy", Kranjska Gora, The 14th International Conference on Quasicrystals (ICQ14)
5. Dr Klanjšek Martin: The Blinc Award for Extraordinary One-time Achievements for proving the existence of unusual quasiparticles called anyons, Ljubljana, Faculty of Mathematics and Physics, University of Ljubljana and Jožef Stefan Institute
6. Dr Koželj Primož: Golden Emblem Prize for his doctoral thesis with the highest impact in Slovenia and abroad, "Physical properties of high-entropy alloys and their Missing words
7. Assoc. Prof. Ravnik Miha: Žiga Zois Award for outstanding achievements in the field of soft-matter physics, Ljubljana, awarded by the Republic of Slovenia
8. Dr Rožič Brigita: Fulbright grant for her excellent scientific and research work and congratulations of the President of the United States of America, Ljubljana, the US Embassy in Ljubljana as part of the Fulbright programme financed by the US government
9. Prof. Žumer Slobodan, PhD: Frederiks medal for outstanding achievements in the theory of liquid crystals and related materials, Wrocslaw, Poland, Russian Liquid Crystal Society

Organization of conferences, congresses and meetings

1. Expert Meeting of Laboratory of Biophysics, Zelenica, 27–28 May 2019
2. The 14th International Conference on Quasicrystals (ICQ14), Kranjska Gora, 26–31 May 2019

Patent granted

1. Andraž Rešetič, Jerneja Milavec, Blaž Zupančič, Boštjan Zalar
   Polymer dispersed liquid crystal elastomers (PDLCE)
   EP3119855 (B1), European Patent Office, 19. 06. 2019.

INTERNATIONAL PROJECTS

1. MERCK - AFM Investigations
   Prof. Miha Škarabot
   Merck Kgaa
2. Double-Beam Laser Interferometer Measurement
   Prof. Vid Bobnar
   Tdk Electronics Gmbh & Co Og
3. CROSSING - Crossing Borders and Scales - An Interdisciplinary Approach
   Prof. Janez Štrancar
   Helmholtz-zentrum Dresden-rossendorf E.v.
4. Small Services
   Dr. Polona Umek
5. EPR Measurements
   Prof. Denis Arčon
6. Irradiation and Analysis of Nano SiC Samples in the Year 2019
   Prof. Vid Bobnar
   Institute of Radiation Problems of the Academy of Sciences of Azerbaijan
7. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Prof. Maja Remškar
   European Commission
8. COST CA15107; Multi-Functional Nano-Carbon Composite Materials Network
   Dr. Polona Umek
   Cost Office
9. COST CA15209; European Network on NMR Relaxometry
   Prof. Tomaž Apih
   Cost Office
10. COST CA16109; Chemical On-Line Composition and Source Apportionment of Fine Aerosol
    Asst. Prof. Griša Močnik
    Cost Office
11. COST CA16218; Nanoscale Coherent Hybrid Devices for Superconducting Quantum Technologies
    Dr. Abdelrahim Ibrahim Hassanien
    Cost Association Aisbl
12. COST CA16221; Quantum Technologies with Ultra-Cold Atoms
    Dr. Peter Jeglič
    Cost Association Aisbl
13. COST CA17121; Correlated Multimodal Imaging in Life Sciences
    Prof. Janez Štrancar
    Cost Association Aisbl
14. COST CA17139; European Topology Interdisciplinary Action
    Prof. Slobodan Žumer
    Cost Association Aisbl
15. COST CA16202; International Network to Encourage the Use of Monitoring and Forecasting Dust Products
    Asst. Prof. Griša Močnik
    Cost Association Aisbl
16. H2020 - SmartNanoTox; Smart Tools for Gauging Nano Hazards
    Prof. Janez Štrancar
    European Commission
17. H2020 - ENGIMA; Engineering of Nanostructures with Giant Magneto-Piezoelectric and Multicaloric Functionalities
    Prof. Zdravko Kutnjak
    European Commission
18. Superconductivity and Magnetism: Two Faces of Electron Correlations in Carbon- and Fe-Based Superconductors
    Prof. Denis Arčon
    Slovenian Research Agency
19. Transport and Field Emission Properties of Low-Dimensional Molybdenum and Tungsten Based Nanomaterials
    Prof. Maja Remškar
    Slovenian Research Agency
20. Testing Biocompatibility of Molybdenum and Tungsten based Nanoparticles: Measuring Cytotoxicity and Inflammatory Response in Human Cell Lines
    Prof. Maja Remškar
    Slovenian Research Agency
21. The Lipid-Peroxidation Inhibition Governed by Interactions between Nanocarried Flavonoids and Model Lipid Membranes
    Prof. Janez Štrancar
    Slovenian Research Agency
22. Dynamic Hysteresis in the Study of Magnetic Nanoparticle Efficacy for Hyperthermia Therapy
    Prof. Janez Dolinšek
    Slovenian Research Agency
23. Conservation of Cultural Heritage Indoors - The Case of Leonardo da Vinci's „Last Supper"
    Asst. Prof. Griša Močnik
    Slovenian Research Agency
24. Lipid Wrapped Nanoparticles and Activity of Factor Xa
    Dr. Tilen Koklič
    Slovenian Research Agency
25. Studies of Nanoporous Materials for Hydrogen Storage
    Prof. Janez Dolinšek
    Slovenian Research Agency
26. Magnetoresonance Study of Spin-Liquid Candidates
    Asst. Prof. Andrej Zorko
    Slovenian Research Agency
27. Advanced Organic and Inorganic Thin-Film Composites with Enhanced Dielectric and Electromechanical Response
    Prof. Zdravko Kutnjak
    Slovenian Research Agency

RESEARCH PROGRAMMES

1. Magnetic resonance and dielectric spectroscopy of „smart" new materials
   Prof. Janez Dolinšek
2. Physics of Soft Matter, Surfaces and Nanostructures
   Prof. Slobodan Žumer
3. Experimental Biophysics of Complex Systems
   Prof. Janez Štrancar

R & D GRANTS AND CONTRACTS

1. Sensor technologies in diagnostics and monitoring of cultural heritage buildings
   Prof. Janez Dolinšek
2. Electroporation-based treatments with new high-frequency electroporation pulses
   Prof. Igor Serša
3. Reconstruction of electrical conductivity of tissues by means of magnetic resonance techniques
   Prof. Igor Serša
4. Correlated electrons in cnofined molecular systems
   Prof. Denis Arčon
5. High-resolution optical magnetometry with cold cesium atoms
   Dr. Peter Jeglič
6. Integrated multi-channel artificial nose for vapor trace detection
   Prof. Igor Muševič
7. Probing spin states near the surface of quantum spin materials
   Prof. Denis Arčon
8. Advanced soft nematocaloric materials
   Dr. Brigita Rožič
9. Multicaloric cooling
   Prof. Zdravko Kutnjak
10. Optimization of MRI techniques for assessment of thrombolytic treatment outcome
    Prof. Igor Serša
11. Intracellular lasers: Coupling of optical resonances with biological processes
    Asst. Prof. Matjaž Humar
12. Study of intracellular forces by deformable photonic droplets
    Asst. Prof. Matjaž Humar
13. Electrocaloric elements for active cooling of electronic circuits
    Prof. Vid Bobnar
14. Advanced inorganic and organic thin films with enhanced electrically-induced response
    Prof. Vid Bobnar
15. Adverse outcome pathway leading to atherosclerosis
    Dr. Tilen Koklič
16. Performance of wood and lignocelolosic composites in outdoor applications
    Prof. Igor Serša
17. Advanced electrocaloric energij conversion
    Prof. Zdravko Kutnjak
18. Biopharmaceuticals: sensor for aggregation of protein particles based on liquid crystals
    Prof. Miha Ravnik
19. Spatial and temporal shaping of laser light for minimally invasive ophthalmic procedures
    Prof. Janez Štrancar
20. Microspectroscopy-based optimization of the effects of laser pulses on the retina
    Prof. Janez Štrancar
21. Domain engineered ferroelectric ceramic layer elements for efficient energy harvesting and energy conversion applications
    Prof. Zdravko Kutnjak
22. Building blocks, tools and systems for the Factories of the Future – GOSTOP
    Prof. Janez Štrancar
    Ministry of Education, Science and Sport
23. Conference ICQ14, International Conference on Quasicrystals, Kranjska Gora, Slovenia, 26. - 31. 05. 2019
    Prof. Janez Dolinšek

NEW CONTRACT

1. AerOrbi - Aerosol soft photo ionisation Orbitrap mass spectrometry
   Asst. Prof. Griša Močnik
   Aerosol d. o. o.

VISITORS FROM ABROAD

1. Prof. Tanigaki Katsumi, Tohoku University, Materials Physics & Nano Solid-State Physics, Sendai, Japan, 12–14 February 2019
2. Takuma T., Tohoku University, Materials Physics & Nano Solid-State Physics, Sendai, Japan, 12 February–23 March 2019
3. Prof. Stępień Ewa, Jagiellonian University, Medical Physics, Krakow, Poland, 18–23 February 2019
4. Dr Belhadi Jamal, Université de Picardie Jules Verne, Amiens, France, 21 February–1 March 2019
5. Prof. Sebastião Pedro, PhD, Instituto Superior de Ciências Sociais e Políticas, Lisbon, Portugal, 22. February–2 March 2019
6. Dr Salopek Branka, Institut Ruđer Bošković, Zagreb, Croatia, 4 March 2019
7. Dr Majhen Dragomira, Nestić Davor, Božinović Ksenija and De Bisschop Lenn, Institut Ruđer Bošković, Zagreb, Croatia, 18 March 2019
8. Prof. Rasing Theo, PhD, Radboud University, Nijmegen, The Netherlands, 19–30 March 2019
9. Miller Zachary, University of Missouri, Columbia, USA, 24–30 March 2019
10. Dr Hae Jin Kim, Korea Basic Science Institute, Daejeon, South Korea, 31 May–4 June 2019
11. Benyoussef Manal, Université de Picardie Jules Verne, Amiens, France, 7–28 June 2019
12. El Marssi Mimoun, Université de Picardie Jules Verne, Amiens, France, 29 June–12 July 2019
13. Nestić Davor, Institut Ruđer Bošković, Zagreb, Croatia, 1–5 July 2019
14. Dr Šegota Suzana and Sadžak Anja, Institut Ruđer Bošković, Zagreb, Croatia, 1–5 July 2019
15. Dr Majhen Dragomira, Institut Ruđer Bošković, Zagreb, Croatia, 9 July 2019
16. Zouhair Hanani, Cadi Ayyad University, Marrakesh, Morocco, 20 July–5 August 2019
17. Prof. Amjoud M'barek, PhD, Cadi Ayyad University, Marrakesh, Morocco, 15 July–13 August 2019
18. Prof. Mezzane Daoud, Cadi Ayyad University, Marrakesh, Morocco, 14 July–31 August 2019
19. Prof. Abdelhadi Alimousa, PhD, Cadi Ayyad University, Marrakesh, Morocco,14–28 July 2019
20. Ivanchenkov Serhii, Nanotechcenter Llc, Kiev, Ukraine, 1–31 August 2019 and 14 November–21 December 2019
21. Assist. Prof. Huettel Andreas K., University of Regensburg, Regensburg, Germany, 20 August 2019 and 14–18 November 2019
22. Merselmiz Soukaina, Cadi Ayyad University, Marrakesh, Morocco, 1–31 August 2019
23. Drożdż Anna, Smoluchowski Institute of Physics, Kracow, Poland, 1–30 September 2019
24. Xiaoxuan Wang, School of Biological Sciences & Medical Engineering, Southeast University, Nanjing, China, 1 September –30 November 2019
25. Acosta Selena, University of Mons, Mons, Belgium, 9–25 October 2019
26. Igarashi Mutsuo, Gunma National College of Technology, Maebashi, Japan, 2–7 November 2019
27. Lushnikov Sergey, Ioffe Physical Technical Institute, Saint Petersburg, Russia, 4 November–22 December 2019
28. Bakış Doğru, Koc University, Istanbul, Turkey, 3–16 November 2019
29. Ferrero Luca, Università degli Studi di Milano-Bicocca, Milan, Italy, 3–6 November 2019
30. El Marssi Mimoun, Université de Picardie Jules Verne, Amiens, France, 13–16 December 2019
31. Dr Spasojević Vojislav and Bošković Marko, Institut Ruđer Bošković, Zagreb, Croatia, 18–21 December 2019

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52. *Dr. Andraž Rešetič, on leave 08.07.19*
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Original Article

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2. Samra Hasanbašić, Ajda Taler-Verčič, Vida Puizdar, Veronika Stoka, Magda Tušek-Žnidarič, Andrej Vilfan, Selma Berbić, Eva Žerovnik, "Prolines affect the nucleation phase of amyloid fibrillation reaction; mutational analysis of human stefin B", *ACS chemical neuroscience*, 2019, **10**, 6, 2730-2740.
3. Stane Pajk, Maja Garvas, Janez Štrancar, "Fluorescent membrane probes based on a coumarin-thiazole scaffold", *Acta chimica slovenica*, 2019, **66**, 3, 668-674.
4. Ema Valentina Brovč, Stane Pajk, Roman Šink, Janez Mravljak, "Comparison of the NMR and the acid value determination methods for quality control of input polysorbates", *Acta chimica slovenica*, 2019, **66**, 4, 934-943.
5. Nikola Novak, Peter Keil, Till Frömling, Florian H. Schader, Alexander Martin, Kyle Grant Webber, Jürgen Rödel, "Influence of metal/semiconductor interface on attainable piezoelectric and energy harvesting properties of ZnO", *Acta materialia*, 2019, **162**, 277-283.
6. Andraž Bradeško, Lovro Fulanović, Marko Vrabelj, Mojca Otoničar, Hana Uršič Nemevšek, Alexandra Henriques, Ching-Chang Chung, Jacob L. Jones, Barbara Malič, Zdravko Kutnjak, Tadej Rojac, "Electrocaloric fatigue of lead magnesium niobate mediated by an electric-field-induced phase transformation", *Acta materialia*, 2019, **169**, 275-283.
7. Primož Koželj, Stanislav Vrtnik, Andreja Jelen, Mitja Krnel, Darja Gačnik, Goran Dražić, Anton Meden, Magdalena Wencka, David Jezeršek, Janez Leskovec, Soummyadipta Maiti, Walter Steurer, Janez Dolinšek, "Discovery of a FeCoNiPdCu high-entropy alloy with excellent magnetic softness", *Advanced engineering materials*, 2019, **21**, 5, 1801055.
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12. Andraž Bradeško, Ana Hedl, Lovro Fulanović, Nikola Novak, Tadej Rojac, "Self-heating of relaxor and ferroelectric ceramics during electrocaloric field cycling", *APL materials*, **7**, 2019, 071111.
13. Aleksander Matavž, Andraž Bradeško, Tadej Rojac, Barbara Malič, Vid Bobnar, "Self-assembled porous ferroelectric thin films with a greatly enhanced piezoelectric response", *Applied materials today*, 2019, **16**, 83-89.
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DEPARTMENT OF GASEOUS ELECTRONICS F-6

The research activities within the Department of Gaseous Electronics cover various research areas, ranging from the science of gases and gaseous discharges, plasma nanoscience, plasma biology and biomedicine, advanced sensors, surface electronics, and crystals to advanced vacuum science and technology. Within this scope, we are exploring different gaseous and plasma systems and their use in various fields important for the progress of humanity. The research activities are, therefore, quite diverse. The most important achievements and progress beyond the existing state of the art are described below.

Head:
Prof. Uroš Cvelbar

Department F6 is a new research unit at the JSI that was only established this year. The major activities in the department encompass interconnected fields of research, such as the science of gases and gaseous discharges, plasma nanoscience, processing and synthesis of nanomaterials, plasma chemistry, plasma electrochemistry and catalysis, plasma biomedicine and biotechnology, gas sensors, research on field emission in nanostructured materials, optoelectronics, vacuum science, design of vacuum systems, vacuum thermal insulation, and other emerging topics relevant to the manipulation of atoms and electrons. These topics of research are brought together to solve different problems and tackle grand challenges in science and technology as well as to support new emerging fields of research.

Revealing the growth mechanisms of nanostructures on surfaces exposed to reactive plasma – a step closer to a global model of nanostructure growth. In 2019 we improved the existing model of nanostructure growth for the special case of the growth of metal-oxide nanostructures directly on a metal source electrode with the use of gaseous plasma. This brings us one step closer to a global model of understanding the growth of all nanostructures in gaseous environments, including thermal growth. Our research aims at determining the growth mechanism of nanostructures, specifically nanowires, and then forecasting parameters that would enable the growth of targeted nanostructure morphologies without resorting to a trial-and-error approach. In recent years our research has focused on copper-oxide as a model, since it is a material in high demand, playing a pivotal role in many nanostructure-based emerging applications. These new-generation nanostructures are are potentially able to boost the characteristics of sophisticated modern electronic devices. However, the research is not limited to copper-oxide, but extends to all other metal-oxide nanostructures that follow the same principles. With experimental evidence and theoretical modelling, we succeeded in upgrading our model to include the role of plasma-ion bombardment of the surface and different layers of oxides. The results revealed that compared to thermal oxidation, plasma offers much faster growth and that the ion flux to the surface determines the saturation mode – the higher the ion flux, the smaller the copper-oxide nanowires at a fixed temperature of growth [*Plasma Sources Sci. Technol. 28 (2019) 084002*]. This behaviour differs greatly from the thermal growth of nanostructures, where the parabolic law determines the dependence of the oxide layers and nanowires on the time of growth, with a typical growth time of a few hours [*Nanomaterials 9 (2019) 1405*]. In addition, the experiments conducted on different metals confirmed that plasma can also be used to grow metal oxide nanowires other than copper, and that the technique has several advantages over thermal oxidation: i) plasma generates reactive oxygen radicals in the gas phase that eliminates the need to heat the surface to high temperatures when the dissociation of oxygen on the surface becomes effective; ii) plasma provides localised surface heating through a recombination of as-created oxygen atoms and also through ion bombardment and neutralisation, which can further increase the surface temperature; iii) plasma creates an electric field via the formation of a plasma sheath, with the electric field effectively guiding the nanowire growth and enabling the growth of vertically aligned nanostructures; and iv) plasma can also create localized nucleation spots via ion bombardment, as well as some other plasma-related effects, rendering the use of metal catalysts unnecessary.

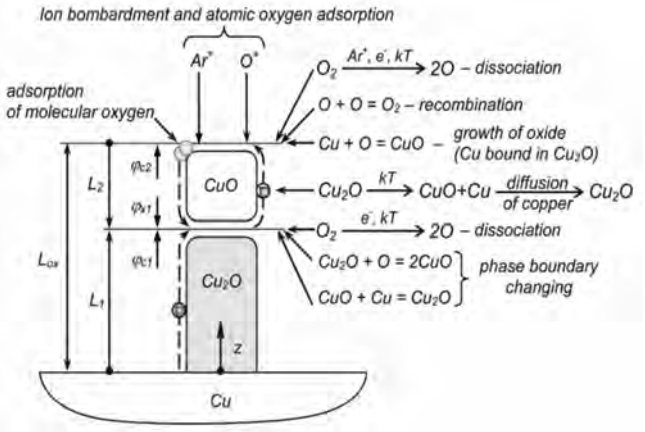

Figure 1: Schematics of all gaseous plasma particles interacting with a copper surface to create a copper-oxide layer, from which copper-oxide nanowires can be grown.

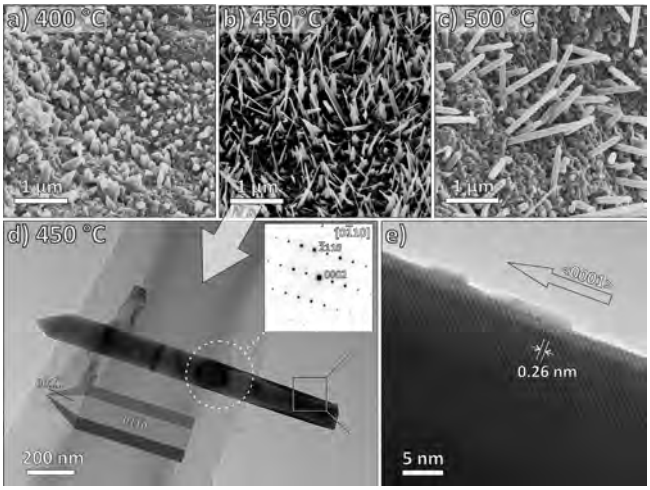

Figure 2: An example of ZnO nanowires grown under hybrid thermal-plasma conditions.

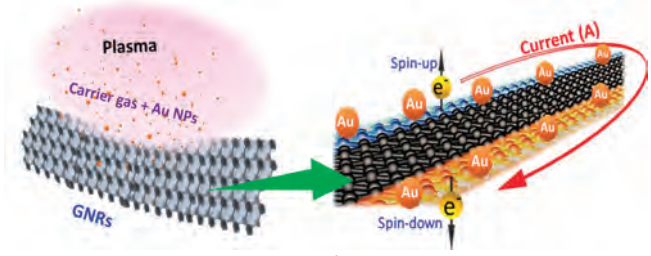

Figure 3: Schematic representation of graphene nanoribbon (GNR) edge tailoring with the assistance of plasma for 2D functionalisation electronics.

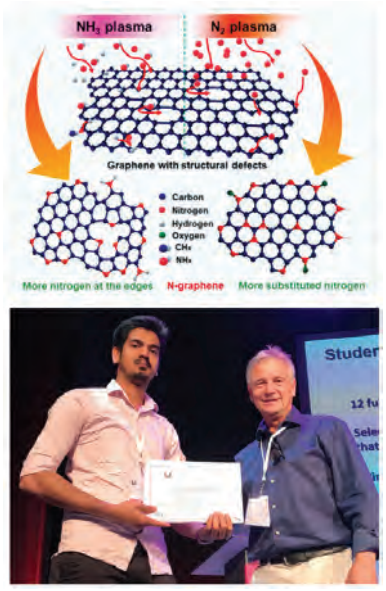

Figure 4: Schematics of different types of defects in graphene sheets, nitrogen atom interaction with structural defects, and the nitrogen incorporation mechanism. Based on these results our PhD student Neelakandan M. Santosh obtained the best student presentation award at the PLATHINIUM2019 conference in Antibes, France.

The targeted substitution of atoms in crystal networks, designing properties of nanomaterials and building N-graphene. Since graphene's discovery, 2D nanomaterials have attracted attention due to their promising tunable electronic properties. The possibility of tailoring electrical conductivity at the atomic level offers an opportunity to create new 2D structures for energy harvesting and sensing-related applications. For this purpose, one of the most successful ways to manipulate the physical properties of the aforementioned materials is surface modification employing plasma. Our research has demonstrated that plasma-gaseous chemical treatment can provide a controlled change in the bandgap, increase the sensitivity and significantly improve the material's structural stability to the environment as well. [*Front. Chem. Sci. Eng. 13 (2019) 427–443*] This has been demonstrated by our group for the generation of N-graphene from graphene. Incorporating nitrogen (N) atoms in graphene is considered a key technique for tuning the material's electrical properties. However, this was a great challenge, since it was unclear how to build N-graphene with the desired nitrogen configurations. Besides this, there was a lack of experimental evidence to explain the influence and mechanism of structural defects for nitrogen incorporation into graphene compared to the derived DFT theories. This knowledge gap was bridged through our systematic study of different nitrogencontaining gaseous plasma posttreatments on graphene nanowalls (CNWs) to produce N-CNWs with incorporated and substituted nitrogen [*Nanomicro Lett. 12 (2020) 53*]. Structural and morphological analyses reveal a remarkable difference in the plasma-surface interaction, nitrogen concentration and nitrogen-incorporation mechanism in CNWs by using different nitrogencontaining plasma. Electrical conductivity measurements revealed that the N-graphene conductivity is strongly influenced by the position and concentration of CN bonding configurations. These findings open up a new pathway for the synthesis of N-graphene using plasma posttreatment to control the concentration and configuration of incorporated nitrogen for application-specific properties. Our effort was supported by international collaboration in the frame of H2020 FET-Open project PEGASUS and Synchrotron BESSY II in Berlin. The exciting experimental results open a pathway in the new field of edge electronics that our group has started to explore. The field deals with 2D nanomaterials whose edge conductivity is tailored by different structure modifications. The obtained results were presented in an awarded student presentation titled "Effect of different nitrogen-containing plasma used for N-doping of graphene nanowalls" by our PhD student Neelakandan M. Santhosh at PLATHINIUM2019 (Plasma Thin film International Union Meeting) on 23–27 September 2019 in Antibes, French Riviera, France.

Practical implications of plasmas for the design of antibacterial surfaces or responses of medical implants. In 2019 our group also continued research in the plasma treatment of materials for use in medical applications. One of the studies that we performed was on the plasma treatment of textile materials for disinfection purposes. Surface disinfectants integrated with textile materials as disinfectant-impregnated wipes are the most common disinfection methods used in nosocomial environments, the food processing industry and other domestic situations due to their simple application and reliable performance. Typical disinfectants found in the market are quaternary ammonium compounds. In our research we demonstrated that plasma treatment of pure polyester commercial wiping materials before soaking them with quaternary ammonium compound doubles the shelflife in terms of antimicrobial efficacy and increases their elasticity. On the other hand, the elastic properties of cellulose/polyester and 100% cotton wiping materials are slightly reduced, and the increase of their shelf-life is not so drastic [*Polymers 11 (2019) 1769*]. A second study was made on a bio-compatible material for human implants, in this case a magnesium alloy. With oxygen-containing gaseous plasma treatment of this material, we were able to achieve surface modification to increase the corrosion resistance of the material, while still keeping its biocompatibility properties. The samples were tested in a simulated body fluid (SBF) solution in an electrochemical cell to create an artificial environment that would mimic the environment in a human body [*Surf. Coat. Technol. (2020) 125434*]. Furthermore, our results on titanium implants indicated that multiple benefits can be obtained from the use of reactive plasmas, like decontamination of biofilms as well as the stimulation of targeted cells. Biofilm contamination on an implanted medical

device represents a particularity resilient reservoir of infection that inevitably leads to device failure. In our studies, we demonstrated that an atmospheric-pressure air plasma treatment can simultaneously eradicate biofilm contamination while beneficially functionalising the underlying surface, creating long-lasting characteristics that inhibit microbial re-colonisation and promote fibroblast proliferation. By comparing two contrasting plasma treatments, the interplay between plasma-generated reactive species, biofilm contamination and the underlying surface was uncovered. It was found that the physicochemical characteristics of the treated surfaces strongly depend on the nature of the reactive species created within the plasma. Direct exposure to energetic plasma species led to the emergence of nanoscale surface features and the introduction of oxygen-containing functional groups, resulting in superhydrophilic surface characteristics. Using a polymicrobial biofilm model comprising *E. coli* and *S. epidermidis*, we showed that plasma can effectively eliminate biofilm contamination from the surface, achieving >4 log reduction, while simultaneously functionalising the surface to inhibit further colonisation, with a >2 log reduction in the number of colonies on treated surfaces compared to those untreated. To assess the biocompatibility of the treated surfaces, the adhesion and proliferation of murine fibroblasts was assessed using fluorescent microscopy, cell viability assays and flow cytometry. It was shown that surface functionalisation resulting from direct exposure to energetic plasma species led to surface characteristics that promote fibroblast adhesion and proliferation [*Appl. Surf. Sci. 487 (2019) 1178–1188*].

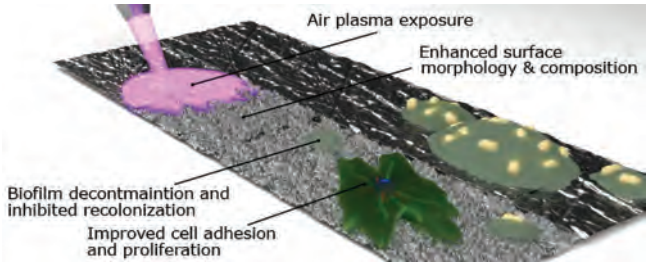

Figure 5: Improved biocompatible properties of a titanium surface after exposure to atmospheric-pressure air plasma.

Solving the problem of fungal and natural toxin pollution with a demonstration of a new solution. Another line of research connected to revealing the properties of atmospheric pressure plasmas is solving one of the most difficult tasks related to contamination of food by fungi and connected secondary metabolites – naturally occurring mycotoxins. This was the major subject of Dr. Nataša Honik's PhD research, which she finished in Spring 2019. The fungal contamination of surfaces is a global problem posing a major environmental and public-health challenge. A wide variety of antifungal chemical agents are available; however, using these disinfectants often results in the generation of toxic by-products and residues, raising major environmental concerns. Our research on atmospheric pressure air plasma generated by a surface barrier discharge (SBD) was demonstrated as a new and innovative green chemical method for fungal inactivation, with the potential to become an effective replacement for conventional chemical disinfection agents, such as Virkon®. Using *A. flavus* spores as a target organism, a comparison of plasma-based decontamination techniques was reported, highlighting their respective efficiencies and uncovering their underpinning inactivation pathways. Tests were performed using both direct gaseous plasma treatment and an indirect treatment using a plasma-activated aqueous broth solution. It was demonstrated that direct exposure to the gaseous plasma effluent exhibited superior decontamination efficiency and eliminated spores more effectively than Virkon®, a finding attributed to the synergistic production of a wide variety of reactive oxygen and nitrogen species within the plasma [*Environ. Sci. Technol. 53 (2019) 1893–1904*]. Furthermore, mycotoxins, the toxic secondary metabolites of mould species, are also a growing global concern, since almost 25% of all food produced is unfit for human or animal consumption, thus placing immense pressure on the food supply chain. Here, previously described cold atmospheric pressure plasma (CAP) represents a promising, low-cost and environmentally friendly means to degrade mycotoxins with a negligible effect on the quality of food products. To demonstrate this we explored the degradation of aflatoxins, trichothecenes, fumonisins and zearalenone using CAP generated in ambient air. The CAP treatment was found to reduce aflatoxins by 93%, trichothecenes by 90%, fumonisins by 93% and zearalenone by 100% after an 8-minute exposure. To evaluate the potential of CAP-mediated mycotoxin degradation against more conventional methods, its efficiency

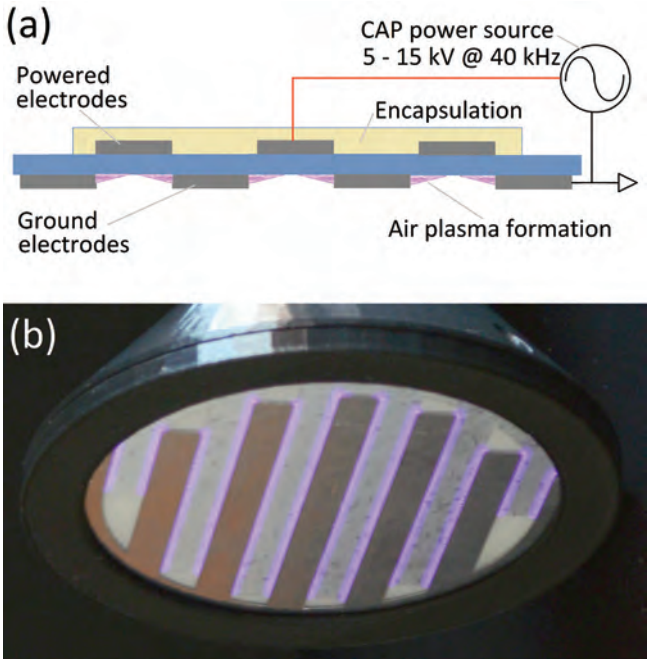

Figure 6: Cold atmospheric-pressure air plasma generated at surface electrodes.

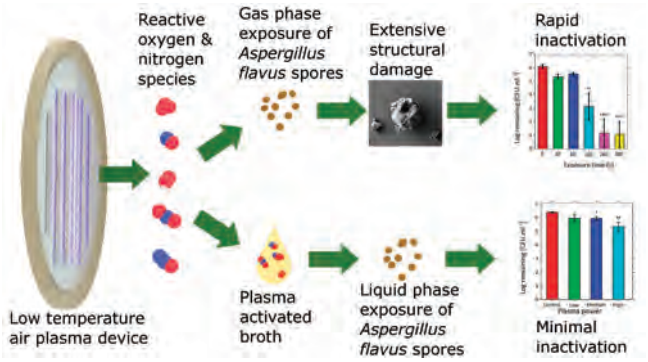

Figure 7: CAP used for decontamination of fungi and mycotoxins.

was compared to UVC light irradiation. In all cases, CAP was found to be considerably more efficient than UVC, with aflatoxin G_1 and zearalenone being completely degraded; levels that could not be achieved using UVC irradiation [*Toxins 11 (2019) 219*]. All these results have proved that the use of CAP is an efficient and new way to solve the fungi and mycotoxin contamination problem.

Fusion research and understanding interactions of fusion-relevant materials with reactor species. Members of the F6 Department are part of the EUROfusion consortium, working on fusion-related research activities in accordance with the current roadmap to the realisation of the first fusion device to produce net energy. The EUROfusion consortium involves 30 research organisations and universities from 26 European Union countries, Switzerland and the Ukraine, but the idea and its realisation involve thousands of scientists and engineers worldwide. Our ongoing research programme, starting in 2005, is focused on the interaction of hydrogen isotopes with several different fusion-relevant structural materials. When nuclear reactions are involved, the role of non-reacted fuel and reaction products needs to be analysed with care. Currently, tritium retention represents a serious safety threat as it can accumulate in materials or even permeate through the walls of the reactor. The accurate prediction of tritium retention was the motivation in our studies of hydrogen permeation through fusion-relevant materials: tungsten, beryllium, and ITER-grade stainless steel [*J. Nucl. Mater. 521 (2019) 38–44*]. In 2019 we focused on tritium retention in Be films, which are formed as deposits in fusion reactors, where we used thermal desorption spectroscopy [*Fus. Eng. Des. 150 (2020) 111365*]. Another activity was studying materials that could be used as tritium permeation barriers for the next generation of fusion reactors [*Nucl. Mater. Ener. 19 (2019) 451–457*]. These materials must be extremely impermeable, robust and compatible with Eurofer, which is selected as the low-activation structural material. Besides Eurofer, only a few materials have been recognised as potential candidates, e.g. selected oxides, like alumina and erbia and a few nitrides. Our investigations centred on various nitrides that were not studied as permeation barriers before: WN, CrWN, CrN, Cr_2N, AlCrN and ZrN. Experiments were realised at 400°C and at a hydrogen pressure of 1 bar. All the films exhibited interesting barrier properties, but ZrN was the most impermeable and should be investigated in detail in the future [*Fus. Eng. Des. 139 (2019) 74–80*].

Designing surfaces and exploring modifications of crystals on the atomic level. The exploitation of the properties of condensed matter, where atoms are arranged in a periodic crystal lattice, is the cornerstone of all modern electronic devices. Our research interest in this area is wide-ranging, and covers the synthesis, applications and modifications of materials for sensing, catalysis, biological applications, and the exploitation of semiconductor material properties. In this respect, our group explored two fundamental areas: (i) investigations of crystalline matter at the micro- and nano-scale, and (ii) investigations of surface electronic states resulting from a sharp transition from solid to vacuum, positioned only in a few atomic layers closest to the surface, having attenuated potential.

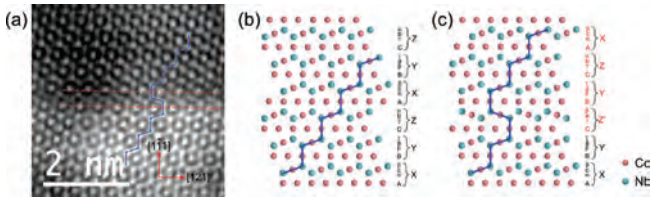

Figure 8: Probe-corrected HAADF-STEM micrograph and corresponding structure models of a stacking fault developed during a micropillar compression test in the C15 $NbCo_2$ Laves phase.

In a crystal, the atoms are arranged in periodic 3D unit cells, and their properties are determined primarily by the chemical bonds. External mechanical forces or chemically induced changes can cause drastic changes in the crystal structure; however, since all the material properties are derived from the crystal structure itself, the intrinsic properties of the material will also change. Investigations of the periodic and incommensurable crystal structures at the atomic level by means of X-ray diffraction, analytical scanning and transmission electron microscopy, and electron crystallography are giving us a unique insight into the very fundamental mechanisms of mechanical, magnetic, electrical, optical and thermal properties of metals, oxides, electronic ceramics and semiconductors. In addition to the investigations of ordered crystal structures and structural defects, our special focus is on an investigation of atypical surfaces and extrinsic states resulting from: i) defective surfaces where the translational symmetry of the surface is broken, ii) surfaces with adsorbed molecules, iii) contact between materials, e.g., semiconductor-oxide or semiconductor-metal, and iv) solid-liquid contact. Investigations of the above-described conditions and phenomena are possible using state-of-the-art research equipment available to researchers at the JSI, as well as other related institutes in the region and the broader international environment. Our results in the field of refractory metals encompass the research of Laves-phase defects in $NbCo_2$ developed during micropillar compression tests [*Acta Mater. 184 (2019) 151–163*], the development of co-produced tungsten and tungsten carbide composites [*J. Nucl. Mater. 524 (2019) 135-140*] and a dispersion-strengthening mechanism for strength-ductility trade-off via SiC nanoparticle dispersion in A356 Al matrix [*Mater. Sci. Eng. A (2019) 138639].* Besides metal-related research, a similar approach using nanostructured materials was used in sensorics, e.g., for a screen-printed carbon electrode modified with graphene nanoplatelets and gold nanoparticles towards simple and highly sensitive electrochemical biosensors [*Microchem. J.* 152 (2019) 104282], thermally reduced graphene oxide (rGO) as a graphene paste electrode for naptalam electro-

chemical sensors [*Anal. Chim. Acta 1035 (2019) 22–31*], and Ni-oxide based nanowire sensors for formaldehyde detection [*Electrochim. Acta 309 (2019) 346–353*].

Another major research area has been modifications of single crystals and their manipulation on the atomic level. Preliminary results of our group have already yielded significant international interest. Our work was recognised during a new symposium of the ECS Dielectric Science and Technology Division at the 236th ECS Meeting in Atlanta, Autumn 2019. Recognising the outstanding research achievements of Young Scientists on Fundamentals and Applications of Dielectrics, the first 'golden award' was shared between two young researchers; Thomas Kinsey from the University of Tennessee and Martin Košiček from the JSI. Their oral award presentations were titled "A Dielectric and Vibrational Spectroscopy Study of the Confinement Effects on Ion Dynamics in a Methacrylate Based Polymerized Ionic Liquid within Nanoporous Silica Membranes" and "Manipulation of a Single Crystal Nanowire on an Atomic Level", respectively. The awards were sponsored by Lam Research.

Figure 9: Martin Košiček shared the golden award with Thomas Kinsey in a competition of Young Scientists on Fundamentals and Applications of Dielectrics at the 236th ECS Meeting in Atlanta, Autumnå 2019. Left to right: Prof Dr Vimal H. Chaitanya, DS&T Chair; Thomas Kinsely; Martin Košiček; and Dr Yaw Obeng, past DS&T Chair.

Some outstanding publications in the past year

1. Nataša Hojnik, Martina Modic, Ni Yuan, Gregor Filipič, Uroš Cvelbar, James L. Walsh, "Effective fungal spore inactivation with an environmentally friendly approach based on atmospheric pressure air plasma", *Environ. sci. technol.*, vol. 53, no. 4, pp. 1893-1904, 2019.
2. Martina Modic, Janez Kovač, John R. Nichols, Špela Kos, Gregor Serša, Uroš Cvelbar, James L. Walsh, "Targeted plasma functionalization of titanium inhibits polymicrobial biofilm recolonization and stimulates cell function", *Appl. surf. sci.*, vol. 487, pp. 1176-1188, 2019.
3. Vincenc Nemanič, Marko Žumer, Janez Kovač, "Hydrogen permeability of AISI 316 ITER grade stainless steel", *J. nucl. mater.*, vol. 521, pp. 38-44, 2019.
4. B. B. Wang, X. X. Zhong, B. M. Ming, M. K. Zhu, Y. A. Chen, Uroš Cvelbar, Kostya Ostrikov, "Structure and photoluminescence properties of MoO_{3-x}/graphene nanoflake hybrid nanomaterials formed via surface growth", *Appl. surf. sci.*, vol. 480, pp. 1054-1062, 2019.
5. V. Nemanič. Hydrogen permeation barriers : basic requirements, materials selection, deposition methods and quality evaluation. *Nuclear materials and energy*, vol. 19, pp. 451-457, 2019.
6. Oleg B. Baranov, Gregor Filipič, Uroš Cvelbar, "Towards a highly-controllable synthesis of copper oxide nanowires in radio-frequency reactive plasma : fast saturation at the targeted size", *Plasma sources sci. technol.*, vol. 28, no. 8, art.no. 084002, 2019.
7. Nataša Hojnik, Martina Modic, Gabrijela Tavčar-Kalcher, Janja Babič, James L. Walsh, Uroš Cvelbar, "Mycotoxin decontamination efficacy of atmospheric pressure air plasma", *Toxins*, vol. 11, no. 4, pp. 219-1-219-12, 2019.
8. Klaus-Dieter Weltmann, Uroš Cvelbar, et al., "The future for plasma science and technology", *Plasma processes polym. (Print)*, vol. 16, no. 1, art. no. e1800118, 2019.

Awards and Appointments

1. Martin Košiček, The gold award for presentation in section Young Scientists on Fundamentals and Applications of Dielectrics at 236th ECS Meeting in Atlanta 2019.
2. Neelakandan M. Santosh, The best student presentation award at the conference PLATINUM 2019, Antibes, French Riviera, France
3. The paper "Towards universal plasma-enabled platform for the advanced nanofabrications: plasma physics level approach" was ranked in top 3 papers of the publications in journal Reviews of Modern Plasma Physics.
4. Prof. Uroš Cvelbar became fellow of the Wold Academy of Arts and Sciences (WAAS).

Organization of conferences, congresses and meetings

1. Organization of the workshop "Plasma tailored nanostructures and applications" (WOPTAN), Rogla, 14–17 January 2019

Patents granted

1. Wang Yongli, Boštjan Jančar, Hermann Grünbichler, Franz Rinner, Damjan Vengust, Danilo Suvorov
   Thermoelectric generator comprising a thermoelectric element
   EP2975659 (B1), European Patent Office, 16. 10. 2019.
2. Aleš Mrzel, Damjan Vengust
   Method for the synthesis of metal molybdates and tungstates from molybdenum and tungsten carbides and nitrides
   SI25549 (A), Urad RS za intelektualno lastnino, 31. 05. 2019.

INTERNATIONAL PROJECTS

1. COST CA15114; Anti-Microbal Coating Innovations to prevent Infectious Diseases (AMICI)
   Prof. Uroš Cvelbar
   Cost Office
2. COST CA18113; Understanding and Exploiting the Impact of Low pH on Microorganisms
   Dr. Martina Modic
   Cost Association Aisbl
3. COST CA18116; Aniridia: Mreženje za reševanje neizpolnjenih zdravstvenih, znanstvenih in družbenih izzivov
   Prof. Uroš Cvelbar
   Cost Association Aisbl
4. H2020 - PEGASUS; Plasma Enabled and Graphene Allowed Synthesis of Unique nano Structures
   Prof. Uroš Cvelbar
   European Commission
5. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION
   Dr. Vincenc Nemanič
   European Commission
6. H2020-EUROFUSION-WPPFC-PEX-FU, WPPFC-PEX-FU, EUROFUSION
   Dr. Vincenc Nemanič
   European Commission
7. Transport and Field Emission Properties of Low-Dimensional Molybdenum and Tungsten Based Nanomaterials
   Prof. Uroš Cvelbar
   Slovenian Research Agency
8. Investigation of Helium Retention in Plasma Facing Materials Using Advanced Analytical Methods
   Dr. Gregor Filipič
   Slovenian Research Agency
9. Oxidative Stress Responses of Microbial Biofilms Exposed to Cold Atmospheric Pressure Plasma Generated Reactive Species
   Dr. Martina Modic
   Slovenian Research Agency
10. Designing Catalytic Activity of Nanomaterials with Plasma
    Prof. Uroš Cvelbar
    Slovenian Research Agency
11. DST Secretary - e-Elections ECS - Division Dielectric Science and Technology DST
    Prof. Uroš Cvelbar
    Slovenian Research Agency

RESEARCH PROGRAMMES

1. Vacuum technique and materials for electronics
   Dr. Vincenc Nemanič
2. Thin film structures and plasma surface engineering
   Prof. Uroš Cvelbar

R & D GRANTS AND CONTRACTS

1. Plasma-assisted wound treatment and topical introduction of molecules
   Prof. Uroš Cvelbar
2. Novel higly sensitive and fast water qulity monitoring sensors
   Prof. Uroš Cvelbar
3. Plasma In-situ reactions and single crystal Transitions
   Prof. Uroš Cvelbar
4. Hybrid and Reengineered Nanocatalysts for New Purification Routes
   Prof. Uroš Cvelbar
5. Plasma decontamination of mycotoxins and inactivation of fungi in food industry
   Dr. Martina Modic
6. Selective plasma oxidation of FeCrAl alloys for extended-lifetime of glow plugs for diesel engines
   Dr. Vincenc Nemanič

NEW CONTRACT

1. Research of improved industrial dyeing of fibers by the use of plasma
   Prof. Uroš Cvelbar
   Beti Tekstilna Industrija d. d.

VISITORS FROM ABROAD

1. Prof. Dr Ibrahim Abdulhalim, Ben Gurion University of the Negev, Israel, 9–18 January 2019
2. Aaron Dickenson, University of Liverpool, Liverpool, United Kingdom, 12 January 2019
3. Brandon Harris, University of Liverpool, Liverpool, United Kingdom, 12 January 2019
4. Prof. James Walsh, University of Liverpool, Liverpool, United Kingdom, 8–19 January 2019
5. Prof. Hiroki Kondo, Nagoya University, Nagoya, Japan, 13–19 January 2019
6. Prof. Takeda, Nagoya University, Nagoya, Japan, 13–19 January 2019
7. Prof. Ohta, Nagoya University, Nagoya, Japan, 13–19 January 2019
8. Prof. Johannes Ernst Helmut, University of Orleans, GREMI, Orleans, France, 19–20 January 2019
9. Dr Julio Paulo dos Santos Duarte Vieira Henriques, Instituto Superior Tecnico Lisbon, Portugal, 1–5 April 2019
10. Aaron Dickenson, University of Liverpool, Liverpool, United Kingdom, 14 April–4 May 2019
11. Dr Petr Slobodian, Tomas Bata University, Zlin, Czech Republic, 22–25 May 2019
12. Aabha Bajaj, Ben Gurion University of the Negev, Israel 26–30 June 2019
13. Prof. Ibrahim Abdulhalim, Ben Gurion University of the Negev, Israel, 10–18 November 2019

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3. Dr. Janez Zavašnik

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5. Dr. Nataša Hojnik
6. Dr. Martina Modic

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8. Petra Stražar, B. Sc.
9. Marko Žumer, B. Sc.

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10. Damjan Vengust, B. Sc.

Technical and administrative staff
11. Ula Groznik, B. Sc.
12. Urška Kisovec, B. Sc.

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. B. B. Wang, X. X. Zhong, B. M. Ming, M. K. Zhu, Y. A. Chen, Uroš Cvelbar, Kostya Ostrikov, "Structure and photoluminescence properties of MoO_{3-x}/graphene nanoflake hybrid nanomaterials formed via surface growth", *Applied Surface Science*, 2019, **480**, 1054-1062.
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3. Xuan Xu, Sašo Šturm, Janez Zavašnik, Kristina Žužek Rožman, "Electrodeposition of a rare-earth iron alloy from an ionic-liquid electrolyte", *ChemElectroChem*, 2019, **6**, 11, 2860-2869.
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5. Ana Isabel Ribeiro *et al.* (13 authors), "Antimicrobial efficacy of low concentration PVP-silver nanoparticles deposited on DBD plasma-treated polyamide 6,6 fabric", *Coatings*, 2019, **9**, 9, 581.
6. Jakob Koenig, Vincenc Nemanič, Marko Žumer, Rasmus R. Petersen, Martin B. Østergaard, Yuanzheng Yue, Danilo Suvorov, "Evaluation of the contributions to the effective thermal conductivity of an open-porous-type foamed glass", *Construction & building materials*, 2019, **214**, 337-343.
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9. Jiří Matějíček, Jakub Veverka, Vincenc Nemanič, Ladislav Cvrček, František Lukáč, Vladimir Havránek, Ksenia Illková, "Characterization of less common nitrides as potential permeation barriers", *Fusion engineering and design*, 2019, **139**, 74-80.
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19. Ivana Zrinski, Kingkan Pungjunun, Sanja Martinez, Janez Zavašnik, Dalibor M. Stanković, Kurt Kalcher, Eda Mehmeti, "Evaluation of phenolic antioxidant capacity in beverages based on laccase immobilized on screen-printed carbon electrode modified with graphene nanoplatelets and gold nanoparticles", *Microchemical journal*, 2019, **152**, 104282.
20. Bin Guo, Martin Košiček, Junchi Fu, Yazhou Qu, Guanhua Lin, Oleg B. Baranov, Janez Zavašnik, Qijin Cheng, Kostya Ostrikov, Uroš Cvelbar, "Single-crystalline metal oxide nanostructures synthesized by plasma-enhanced thermal oxidation", *Nanomaterials*, 2019, **9**, 10, 1405.
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Theses and Mentoring

1. Nataša Hojnik, *Decontamination of mycotoxins with atmospheric pressure plasma:* doctoral dissertation, Ljubljana, 2019 (mentor Uroš Cvelbar; co-mentor Martina Modic).

DEPARTMENT FOR COMPLEX MATTER F-7

The research within the Department of Complex Matter encompasses a variety of fields, ranging from fundamental investigations of elementary excitations in quantum materials, nonequilibrium quantum matter, self-organizing behaviour adaptive functionality in complex systems and soft matter as well as nano-biosystems, biomolecules and various nanomaterials. The department's experimental activities are strongly complemented by theory on different levels and supported by diverse materials-synthesis techniques. Our research into ultrafast nonequilibrium transitions, investigations of new emergent hidden orders and ferromagnetic liquids are of significant interest worldwide and bear the trademark of our department and the Jožef Stefan Institute.

Head:
Prof. Dragan D. Mihailović

The experimental methods used at the department are suitably diverse, involving different types of femtosecond laser spectroscopy from THz to XUV, a variety of optical techniques, as well as synthetic chemistry and thin-film deposition methods such as MBE, ALD and EBE, laser biomedical studies, femtosecond STM and magnetometry.

The experimental research within the department is strongly supported by theory, with approaches ranging from analytical approaches to modelling with Monte-Carlo simulations and most recently quantum annealing on a D-wave quantum computer.

A number of spin-out research projects have recently gained importance, most recently ultrafast, low-energy cryo-memory devices based on our studies of ultrafast electronic transitions.

The research achievements are thus quite diverse, and we are able to report on important discoveries in a number of areas.

Ultrafast studies of nonequilibrium quantum matter.

A quantum traffic jam: The discovery of a new state of jammed quantum matter.

A paper recently published by a group of researchers from the F7 department entitled "The quantum jamming transition to a correlated electron glass in 1T-TaS_2"

reported on an unusual new state of quantum matter in which electrons are stuck in a quantum traffic jam. This is an entirely new form of matter, not reported before in quantum systems.

Electrons are probably the most important elementary particles in nature. For millennia, humans have been familiar with their manifestations in static electricity, lightning and magnetism. Their existence as particles is attributed to JJ Thomson in 1897. The motion of electrons within crystals in the form of waves was one of the successes of quantum physics in the 20th century. They are crucial in modern electronics and computing, and as such are a driving force in the global economy.

In experiments dedicated to the search for new forms of quantum materials under non-equilibrium conditions in crystals of tantalum disulphide, the group at the JSI used ultrashort laser pulses to create an unusually dense amorphous electronic state in which the electrons are jammed due to mutual interactions.

The reported phenomenon in crystals of tantalum disulphide can also have passible applications, since the jamming process can be controlled and greatly changes the electrical resistance of the crystal. The discovery is of fundamental importance as a completely new form of quantum matter and represents a challenge to modern quantum physics. Such quantum-jamming phenomena can also emerge in other systems whenever elementary quantum particles are compressed at high densities, such as in nuclei and neutron stars.

The research team succeeded in observing the new state with a special microscope, which is unique in allowing the observation of individual electrons after excitation of laser pulses less than 0.00000000000003 seconds long, while at the same time it allows the measurement of electrical resistance with electrodes only a few tens of nanometres apart.

A hyperuniform jammed state of electrons created through non-equilibrium conditions is a most unexpected and fundamentally important result. It has been known since a paper in 1934 by Eugene Wigner that at densities below a critical value, electrons in 2D can form an ordered crystal solely as a result of mutual Coulomb repulsion. Here we have shown that a related state – the hyperuniform jammed state – also exists, as a fundamentally new form of fermionic quantum matter.

European Research Council
Established by the European Commission

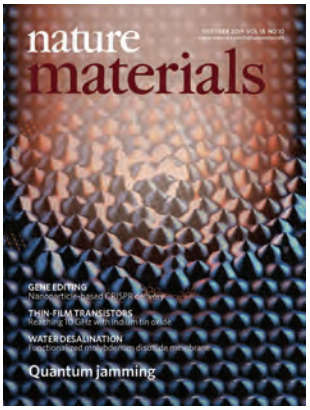

Figure 1: The work on quantum jamming, published in Nature Materials and featured on the cover page (see figure), was funded in part by the European Research Council (ERC). Since the first report of new hidden states of matter by our group in Science in 2014, similar research has been initiated by groups at MIT, Stanford, Duisburg, Harvard, Berkeley, and ETH and the Institute of Physics of the Chinese Academy of Science, among others. The US Department of Defence has published a research call in the field of hidden states of matter based on our group's findings. Now this has become a very active field of quantum physics, researching metastable states.

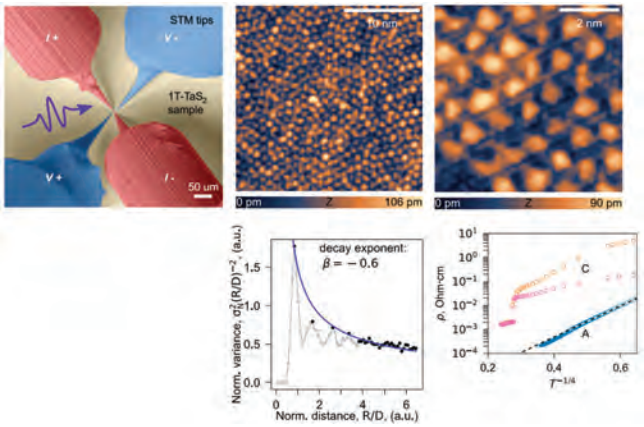

Figure 2: (a) schematic shown on a pseudo-colour SEM image; (b, c) large-scale and atomic-resolution images of the photo-induced metastable hyperuniform charge order at 5 K obtained with a single laser pulse of ~4mJ/cm² fluence in 1T-TaS_2; (d) radial dependence of the normalized polaron number variance (polaron density fluctuations); (e) the four-tip resistivity in the ground state and the photo-induced hyperuniform state measured with ohmic contacts.

In our paper we also report the first observation of the actual quantum-jamming transition, which is in a class of its own, bearing some resemblance to the glass transition which is – according to P.W. Anderson – "The deepest and most interesting unsolved problem in solid-state theory." In the paper we discuss the quantum-jamming transition in terms of the many-body-localization (MBL) problem, and showed how the jammed state in TaS_2 differs from the MBL state.

In fact, distinct many-body states can be created under non-equilibrium conditions through different ordering paths, even when their constituents are subjected to the same fundamental interactions. The phase-transition mechanism to such states remains poorly understood. We show that controlled optical or electromagnetic perturbations can lead to an amorphous metastable state of strongly correlated electrons in a quasi-two-dimensional dichalcogenide (Fig. 1). Scanning tunnelling microscopy (Fig. 1b,c) reveals a hyperuniform pattern of localized charges (Fig. 1d), whereas multi-tip surface nanoscale conductivity measurements (Fig. 1e) and tunnelling spectroscopy show an electronically gapless conducting state that is different from conventional Coulomb glasses and many-body localized systems. The state is stable up to room temperature and shows no signs of either local charge order or phase separation. The mechanism for its formation is attributed to a dynamic localization of electrons through mutual interactions. Theoretical calculations confirm the correlations between localized charges to be crucial for the state's unusual stability. The results were published in **Nature Materials 18, 1078-1083 (2019)**

Other ultrafast studies of electron and lattice dynamics in complex systems

Spectroscopic equilibrium and time-resolved studies of the electronic structure of the CDW molybdenum oxide Mo_8O_{23}.

Compounds from the family of MoO_{3-x} oxides have been recently recognized as promising battery and charge-storage materials, but also display intriguing fundamental physics with behaviour ranging from a wide-gap insulator (x = 0) to a metal (x = 1). Stoichiometric Mo_8O_{23} (x=1/8) is a low-dimensional, chemically robust, transition-metal oxide for which an unusual charge density wave transition has been suggested to occur above room temperature. Its low temperature behaviour is particularly enigmatic.

We studied single-particle relaxation dynamics by means of polarized transient reflection spectroscopy and found that besides a small, temperature-independent gap present already below the first structural transition, an additional temperature-dependent depletion of the density of states occurs below ~ 150 K. The coherent response dynamics as well is very unusual for a CDW compound, with anomalous mode softening at ~ 200 K, indicating possible competing orders or incipient transitions, as discussed in **Physical Review B, 99, 8, 085101 (2019)**.

We also performed a comprehensive experimental study of the electronic structure associated with various ordering phenomena in this compound, complemented by theory. Density-functional theory (DFT) calculations reveal a cross-over from a semi-metal with a vanishing band overlap to narrow-gap semiconductor behaviour with decreasing temperature. A buried Dirac crossing at the zone boundary is confirmed by angle-resolved photoemission spectroscopy (ARPES). Tunnelling spectroscopy (STS) reveals a gradual gap opening corresponding to a metal-to-insulator transition at 343 K in resistivity, consistent with the CDW formation and the DFT results, but with large non-thermal smearing of the spectra implying strong carrier scattering. At low temperatures, the CDW picture is negated by the observation of a metallic Hall contribution, a non-trivial gap structure in STS below ~170 K and ARPES spectra that together represent evidence for the onset of the correlated state at 70 K and the rapid increase of the gap size below ~30 K. The intricate interplay between electronic correlations

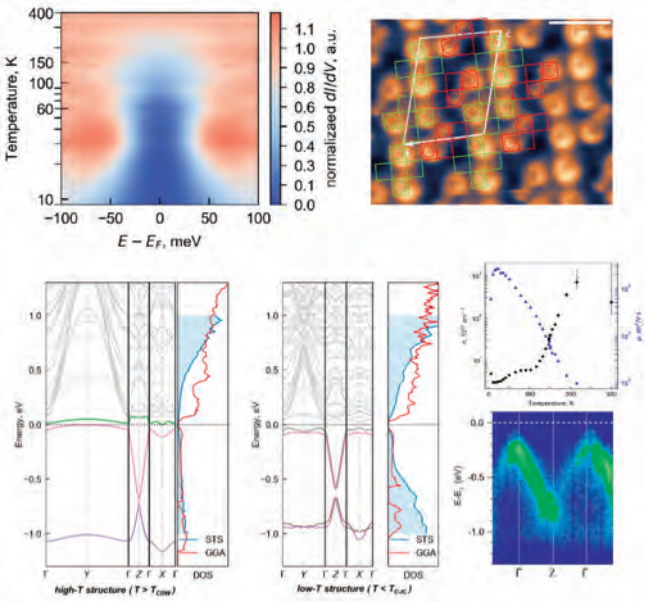

Figure 3: (top left) Normalized and symmetrized tunnelling spectra of Mo_8O_{23} single crystal. (top right) Pseudo-topographic scanning tunnelling microscopy image of (010) ac-plane of Mo_8O_{23} single crystal at 4.2 K with a low-temperature unit cell (white parallelogram) shown on top. Green and red squares represent the assignment of MoO_6 octahedra positions. (bottom left) Calculated band structure for the high-temperature atomic structure (T > TCDW) Different colours correspond to a different band. The right panel shows the comparison of the DFT GGA density of states with the dI/dV tunnelling spectrum at T = 403 K > TCDW. (bottom middle) Calculated band structure for the low-temperature atomic structure (T < TC-IC). Right panel shows the comparison of DFT GGA density of states with the dI=dV tunnelling spectrum at T = 4.2 K. (bottom right) Temperature dependencies of the Hall density (black circles, left axis) and Hall mobility (blue triangles, right axis). G-Z band structure cut measured with ARPES at T = 20 K.

and the presence of multiple narrow bands near the Fermi level set the stage for metastability and suggest suitability for memristor applications. The research is published in **Scientific Reports 9, 15959 (2019)**

We revealed the low-temperature electronic phase transitions in low-dimensional molybdenum oxide that are likely to be of a correlated nature. The intricate interplay between the electronic correlations and the presence of multiple narrow bands near the Fermi level set the stage for metastability and suggest suitability for memristor applications.

In this work, spectrally resolved optical pump-probe measurements were carried out on strongly correlated organic superconductor κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$] Br. We found two different types of carrier-relaxation dynamics, one of which appears at 1.82 eV and 1.94 eV, and another at 2.17 eV. The former is characterized by short decay time ~ 1–2 ps and appears below ~ 60 K. From a comparison with previous studies, the dynamics arises from the photo-induced pseudo-gap (PG) formation of the partially appearing Mott phase. The latter has a long relaxation time ~ 9 ps at 5 K and developed as the temperature decreases below 30 K. The slow dynamics is consistent with the appearance of a superconducting (SC) gap. Such a separate observation of PG and SC dynamics enables us to proceed with a further investigation of a relationship between them. The work was published in the **Journal of Superconductivity and Novel Magnetism 32, 1-5 (2019)**.

Ultrafast transient reflectivity across the unusual three-dimensional Peierls-like insulator-metal (IM) transition in $CuIr_2S_4$ was measured as a function of temperature and excitation fluence. The low-temperature insulating-phase transient response is dominated by broken-symmetry-induced coherent lattice oscillations that abruptly vanish at the IM transition. The insulating-phase lattice distortion is suppressed on a picosecond timescale at fluences above a threshold of ~4 mJ/cm² with 1.55-eV pump energy photons, while the electronic charge order shows signs of a transient suppression above a significantly lower fluence of ~0.3 mJ/cm². The insulating phase completely recovers before the arrival of the subsequent pump pulse after 4 μs. A quench induced by a single intense above-the-threshold pump pulse results in a multi-domain state with a domain structure that is relaxing on a timescale of minutes. The ultrafast transient reflectivity at 1.55-eV probe-photon does not show any detectable long-lived change after the quench in neither the relaxing multi-domain nor the completely relaxed state. The manuscript is under review at **Physical Review B**.

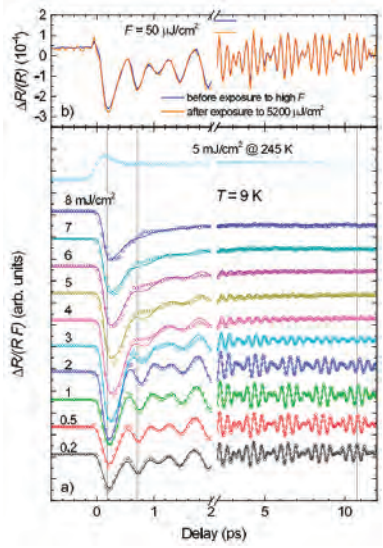

Figure 4: a) Normalized transient reflectivity as a function of the pump fluence in $CuIr_2S_4$. At high fluences a transient novel state is observed. The traces are vertically offset for clarity. b) The low pump-fluence transient reflectivity before and after exposure to the highest pump fluence indicates the reversibility of the transient novel state.

Ultrafast memory materials

Intertwined chiral charge orders and topological stabilization of the light-induced state of a prototypical transition metal dichalcogenide

The fundamental idea that the constituents of interacting many-body systems in complex quantum materials can self-organise into long-range order under highly non-equilibrium conditions leads to the notion that entirely new and unexpected functionalities might be artificially created. However, demonstrating new emergent order in highly non-equilibrium transitions has proven surprisingly difficult. In spite of huge recent advances in experimental, ultrafast, time-resolved techniques, methods that average over successive transition outcomes have so far proved incapable of elucidating the emerging spatial structure. Using scanning tunnelling microscopy, we report for the first time the charge order emerging after a single transition outcome in a prototypical two-dimensional dichalcogenide 1*T*-TaS_2 initiated by a single optical pulse. By mapping the vector field of charge displacements of the emergent state, we found surprisingly intricate, long-range, topologically non-trivial charge order in which chiral domain tiling is intertwined with unique unpaired dislocations that play a crucial role in enhancing the emergent states' remarkable stability. The discovery of the principles that lead to metastability in charge-ordered systems opens the way to designing novel emergent functionalities, particularly ultrafast all-electronic non-volatile cryo-memories. The results were published in **npj Quantum Materials 4, 1-9 (2019)**

We discovered a novel transient phase upon the ultrafast melting of the Peierls-like insulating state in $CuIr_2S_4$.

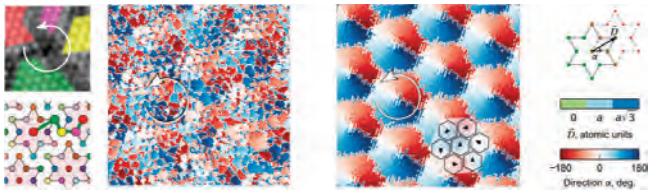

Figure 5: (a) exemplary unpaired dislocation in the photo-induced charge order; (b) spatial map and (c) model chiral vortex long-range photo-induced charge order in 1T-TaS_2; (d) colour legend for the panels b and c, showing the direction and amplitude of charge displacements.

Mottness collapse without metallization in the domain wall of the triangular-lattice Mott insulator 1T–TaS_2

Domain walls in insulating materials can be orders of magnitude more conducting than the bulk, allowing one to design the material functionality by their patterning. Studies of inhomogeneities such as domain walls in the presence of strong electronic interactions is a very challenging problem. A particularly interesting case is that of Mott insulators, where electrons are trapped solely by their mutual repulsion.

1*T*–TaS_2 is a charge-density-wave (CDW) compound with a Mott-insulating ground state. The metallic state obtained by doping, substitution, or pulsed charge injection is characterized by an emergent CDW domain-wall network, while single-domain walls can be found in the pristine Mott state. We studies whether and how the single

We were able to image the creation of topological defects in the photo-induced phase transition, thus uncovering the universal "topological metastability" mechanism responsible for the existence of the long-living photo-induced electronic states. The observation of the ultrafast topological transition in electronic ordering, that goes beyond the classic Ehrenfest classification, paves a new pathway to the design of photo-induced metastable states and is the first observation of emergent long-range quantum order created through a non-equilibrium transition.

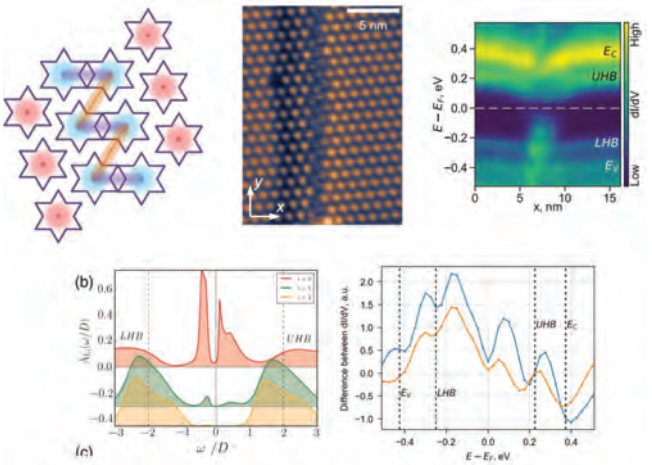

Figure 6: 5 (a, b) schematic representation and real-space topography of the domain wall in 1T-TaS_2; (c) averaged tunnelling spectra evolution across the wall in (b); d – difference between tunnelling spectra inside and outside the domain wall (blue and orange curves correspond to the left and right sides of the domain wall in (b)), emphasizing the existence of the in-gap states; e – DMFT spectral function inside the domain wall showing the collapse of Mott gap and formation of two dimerized in-gap levels, consistent with the observed experimental picture in (d).

We observed that strong electron-electron interactions can lead to the counterintuitive behaviour of a nanoscale object like domain walls, thus paving the way to tailoring material properties in complex systems via nanomodification with the help of electrical or optical pulses.

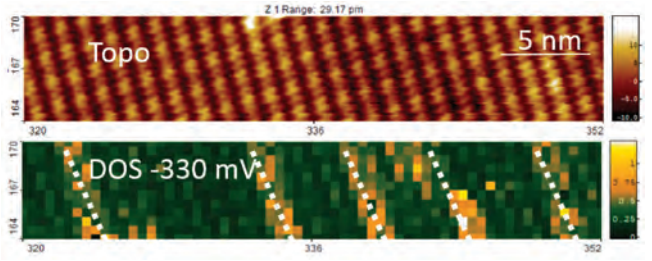

Figure 7: Top: Pseudo-topographic STM image of the metastable state of Mo_8O_{23} at T = 5.5 K. Bottom: the tunnelling spectral map cut at -330 mV of the same area taken simultaneously, demonstrating the electronic texture with the ribbon-like regions of enhanced density. White dashed lines correspond to the approximate ribbon direction.

walls (Fig. 3 a,b) become metallic. Tunnelling spectroscopy revealed the partial suppression of the Mott gap and the presence of in-gap states, strongly localized at the domain-wall sites (Fig. 3c). Using the real-space dynamical mean field theory description of the strongly correlated quantum-paramagnet ground state, we show that the local gap suppression follows from the increased hopping along the connected zigzag chain of lattice sites forming the domain wall. Furthermore, we show that full metallization is pre-empted by the splitting of the quasiparticle band into bonding and antibonding sub-bands (Fig. 3d), due to the structural dimerization of the wall, explaining the presence of the in-gap states and the low density of states at the Fermi level (Fig. 3e). The results were published in **Phys. Rev. Lett. 122, 036802 (2019)**

Super-stable photo-induced electronic textured phase in a correlated oxide.

The new metastable state found in the correlated oxide Mo_8O_{23} was studied microscopically, structurally and spectroscopically. Our spatially resolved scanning tunnelling spectroscopy (STS) studies demonstrate that the ground state of Mo_8O_{23} has an electronic texture that could be enhanced by ultrafast laser pulses. Our structural and optical studies show that after exposure to ultrafast laser pulses the low-temperature structure of Mo_8O_{23} is stabilized up to the room temperature and a switched metastable phase persists up to ~350 K. We are preparing an article on the above results, to be submitted in the first months of 2020.

Correlated nanomaterials

We report the first observation of superconductivity in a heterostructure consisting of an insulating ferroelectric film ($Ba_{0.8}Sr_{0.2}TiO_3$) grown on an insulating parent compound of La_2CuO_4 with [001] orientation. The heterostructure was prepared by magnetron sputtering on a non-atomically-flat surface with inhomogeneities of the order of 1–2 nm. The measured superconducting transition temperature T_c is about 30 K. We have shown that superconductivity is confined near the interface region. The application of a weak magnetic field perpendicular to the interface leads to the appearance of the finite resistance. That confirms the quasi-two-dimensional nature of the superconductive state. The proposed concept promises ferroelectrically controlled interface superconductivity, which offers the possibility for the novel design of electronic devices. **Physical Rev. Lett. 122, 237001 (2019).**

Theoretical studies on the nanoscale

Applying the symmetry arguments, we have shown that the symmetry-enforced Dirac points exist at some time-reversal symmetric momenta in the antiferromagnetic compound GdB_4. This fact is not trivial, because antiferromagnetic order breaks the time-reversal symmetry, but Dirac points can exist only in the case when this symmetry is present. These Dirac points can be controlled by an external magnetic field or by the deformation of the crystal. Application of the external magnetic field leads to splitting of these points into Weyl points or to the opening of a gap depending on the field direction. The application of the symmetry-breaking deformation also opens a gap in the spectrum. Suppression of the antiferromagnetic order leads to the formation of the nodal line instead of the Dirac points. This indicates that the symmetry-enforced Dirac semimetals can be effectively used in different spintronic devices. **Phys. Rev. B 99, 235154 (2019).)**

Mesoscopic irregularly ordered and even amorphous self-assembled electronic structures were recently reported in two-dimensional metallic dichalcogenides (TMDs), created and manipulated with short light pulses

or by charge injection. In the paper **Jaka Vodeb et al 2019 New J. Phys. 21 083001** we addressed the problem of metastable mesoscopic configurational charge ordering in TMDs with a sparsely filled charged lattice gas model in which electrons are subject only to screened Coulomb repulsion. The model correctly predicts the commensurate charge density wave states corresponding to different TMDs at magic filling fractions f_m = 1/3, 1/4, 1/9, 1/13, 1/16, ... as well as domain and amorphous states.

We revealed the electronic textured phase in the metastable state of a correlated oxide. Ultrafast laser optical pulses allow control and stabilization of the metastable state.

1T-TaS_2 is known for its remarkably complex phase diagram and its unique, long-lived, metastable hidden (H) state. Recently, a novel metastable state has been discovered using higher fluences for photo-excitation than in the case of the H state. The state has been dubbed as amorphous (A) due to its similarity to glass. Expanding on the work of Brazovskii and Karpov, in **Vodeb, J. et al. J Supercond Nov Magn (2019) 32: 3057** we show that the A state can be successfully modelled with classic interacting polarons on a two-dimensional hexagonal lattice. This type of calculation has been used in order to interpret experimental data on 1T-TaS_2 (**Gerasimenko, Y.A. et al. Nat. Mater. 18, 1078–1083 (2019).**).

Currently, we are dealing with simulating a relaxation sequence of the 1T-TaS_2 hidden state. We believe that quantum tunnelling between different configurations is responsible for the experimentally observed reconfigurations. In order to simulate this tunnelling process we are employing D-Wave's quantum computer.

Nanomaterials

Molybdenum nitrides, which are used as hard coatings or corrosion- and abrasion-resistant layers, are in general considered as having good chemical resistance. We find, however, that molybdenum nitride Mo_2N nanowires react with lead nitrate in water at room temperature, resulting in the formation of lead molybdate nanoparticles (Materials Chemistry and Physics). Depending on the initial concentrations, the resulting materials are either hybrid nanowires decorated with individual lead molybdate nanoparticles, or solely lead molybdate nanoparticles. The synthesised nanoparticles are fairly uniform in size, with diameters of up to a hundred nanometres. The performed one-step reaction, which is very fast and requires no additional reagents, clearly shows the unexpected chemical reactivity of molybdenum nitrides and opens up a new use for molybdenum nitrides as the starting materials in a variety of chemical reactions. At the same time, the demonstrated reaction presents a new method for the synthesis of lead molybdate nanoparticles or hybrid materials using molybdenum nitride nanowires as the starting material. We have protected the general method for the synthesis of metal (Mo, W, Fe, Ba.) molybdates and metal tungstates from molybdenum and tungsten carbides and nitrides with a **European patent application**, EP 18206299, and continue to protect the invention with the procedure for an international patent.

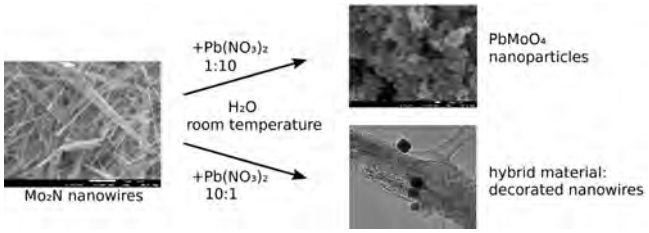

Figure 8: Lead molybdenum nitride nanoparticle decoration

Soft Matter

We continued to investigate tuneable optical diffraction structures based on liquid crystals that are introduced into periodic polymeric scaffolds. The scaffolds induce the planar alignment of liquid-crystalline (LC) materials and are fabricated by a direct laser-writing process based on two-photon polymerization. This method of LC alignment was recently patented in collaboration with the group from Nankai University (P.R. China) (CN103995394 (B), US2016291414 (A1), WO2015139353 (A1)) and provides micro-structured liquid-crystal configurations in oblique geometries, which opens up several possibilities for applications in liquid-crystalline optical modulators and spatial light filters, microfluidic units based on liquid crystals, etc. The invited review paper on this method was published in ***Liq. Cryst.*** **46, 2075 (2019).** In 2019 we demonstrated magnetically tuneable optical diffraction gratings composed of a ferromagnetic liquid crystal incorporated into a one-dimensional periodic scaffold. The results were reported in ***Opt. Express*** **27, 8900 (2019).**

In cooperation with Nankai University in China, we also continued investigations of calcium waves-based communication processes between microglial cells. In our experiments the cells are grown on special platforms with pre-determined spatial patterns and the intercellular signal transmission is analysed as a function of the distance between the stimulated central cell and the neighbouring cells. In 2019 the investigations were focused on intercellular communication over the intercellular bridge that is formed between the two daughter cells at the end stage of the cytokinesis process. The results of this work were recently accepted for publication in ***Biophys. J.*** We also extended our cooperation to investigations of the mechanical properties of biological cells exposed to a

liquid flow in patterned microfluidic assemblies. The results of those investigations were published in ***Biophys. Biochem. Res. Commun.*** 512, 303 (2019).

We investigated the mechanisms of the molecular recognition of lipophilic derivatives of guanosine in Langmuir films at the air-water interface. The research was based on measurements of modifications in the surface pressure of the film depending on its irradiation with light of two different wavelengths. In this analysis, photosensitive guanosine derivatives were used as sensors for the formation of base pairs. We also developed a theoretical model for describing the influence of illumination on molecular organization in the films. The results were reported in ***Langmuir*** 35, 6550 (2019).

In collaboration with the Department of Biotechnology (B3), we continued to investigate plasmid DNA containing extended G4C2 repeats. An increased number of G4C2 repeats within the C9orf72 gene is the most common mutation associated with neurological disorders amyotrophic lateral sclerosis (ALS) and frontotemporal dementia (FDT). We use atomic force microscopy to locate and visualize the G4C2 repeat regions based on the formation of G-quadruplex structures inside the plasmid DNA. In cooperation with the National Institute for Chemistry (KI) we started investigations of the relatively short DNA oligonucleotides containing different numbers of G4C2 sequences and of some other similar repeats. The results of the investigation of secondary and tertiary structures forming in aqueous solutions of such sequences were recently accepted for publication in ***Nucleic Acids Res.***

In cooperation with University of Vienna we continued to investigate synthetic magneto-active periodic media that might be suitable for application in magnetically tuneable neutron-optical devices. With Monte-Carlo simulations we analysed neutron transmission through nanocomposite materials. The results were published in ***Nulc. Instrum. Methods Phys. Res. A*** 916, 154 (2019).

We continued collaborative investigations of the surface properties of magneto-active elastomers (MAE) with the East-Bavarian Technical High School (OTH) in Regensburg. We analysed modifications of the surfaces roughness as a function of an applied external magnetic field in materials with different concentrations of magnetic microparticles and different softnesses of the elastomer network. We found that the magnetic tunability of the surface topography predominantly depends on the softness (shear modulus) of the material's structure. The work was reported in ***Polymers*** 11, 594 (2019).

A recent successful realization of ferromagnetic nematic liquid crystals at the JSI opened up the possibility to experimentally study a completely new set of fundamental physical phenomena that appear in such materials. In 2019 we started to explore, among others, also their nonlinear optical properties. The first measurements of optical second harmonic generation (SHG) in ferromagnetic liquid crystals were reported in **Soft Matter 15**, 8758(2019). In collaboration with researchers from Osaka University, we also showed that ferromagnetic liquid crystals can be used as magnetically controllable random lasers (***Optics express*** 27, 24426(2019)).

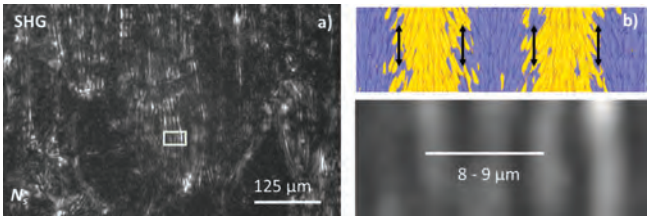

Figure 9: a) SHG image of the splay nematic phase just below the phase transition. b) a scheme of the structure of the splay nematic phase and an enlarged section of the SHG image from a) compared to the proposed structure.

We continued studies of suspensions of magnetic nanoplatelets in isotropic solvents, which at high enough concentrations exhibit ferromagnetic order. In particular, we focused on investigations of electrostatic interactions between magnetic platelets in different alcohols and found that it is possible to control the interaction by varying the amount of the surfactant or by changing the solvent (***The Journal of Physical Chemistry C*** 37, 23272 (2019)). We also studied the evolution of nematic and ferromagnetic ordering in these suspensions using small-angle neutron scattering (**Soft Matter 15**, 5412(2019)). In collaboration with researchers from Spain, we showed that magnetic nanoplatelets can be used for high-contrast cardiovascular imaging (***ChemPhotoChem*** 3, 529(2019).

In collaboration with researchers from the University of York, UK, we continued investigations of the recently designed splay nematic phase, which appears in materials made of polar wedge-shaped molecules. We used X-ray scattering experiments to measure the orientational order parameters in the nematic and the splay nematic phases and found that the degree of orientational order is somewhat larger in the splay nematic phase than in the preceding nematic phase. The method can be used to assist in the unambiguous identification of the splay-nematic phase (***Physical Chemistry Chemical Physics*** 21, 18759 (2019)). We also showed that the transition between the uniaxial and the splay nematic phase is a ferroelectric-ferroelastic phase transition, in which flexoelectric coupling causes the simultaneous occurrence of the diverging behaviour of electric susceptibility and of the instability towards splay deformation. By SHG imaging, we determined the period of modulated splay phase to be 5–10 microns. This study was published in ***Phys. Rev. Lett.*** 124, 037801(2020) and has been highlighted by the editors as an Editors' Suggestion.

We showed that the transition between the uniaxial and the splay nematic phase is a ferroelectric-ferroelastic phase transition.

Nonlinear optics

We studied new materials and their interaction with laser light. In cooperation with North Carolina State University, Raleigh, USA, where optical waveguides are produced with lithography on AlN thin films, we investigated several phase-matching possibilities for highest-efficiency second harmonic generation into the UV spectral region. The results were reported in *Appl. Phys. Lett* 114, 103504 (2019).

AlN waveguides on sapphire allow the use of the largest nonlinear optic coefficent in the UV range and promise high conversion efficiency for second harmonic generation. Optimized organic crystals for nonlinear optics are used for the generation and detection of broadband THz EM waves.

In collaboration with the company Rainbow Photonics and the Zurich University of Applied Sciences (Institute of Computational Physics) from Switzerland we studied the use of organic electro-optic crystals for the generation and detection of broadband THz radiation in the range from 1 to 20 THz.

Biomedical optics

We have continued with the development of novel biomedical applications based on photo–thermal radiometry (PPTR; time-resolved measurements of laser-induced infrared emission) and diffuse reflectance spectroscopy (DRS). By combining these experimental techniques and a dedicated numerical model of light transport in strongly scattering biological tissues, we have developed a unique approach for the non-invasive characterization of human skin in vivo in terms of several physiologically relevant parameters (e.g., the contents and oxygen saturation levels of dermal blood), scattering properties of the epidermis and dermis, etc. The technique was verified in controlled tests involving temporary obstruction of the peripheral blood circulation, acute and seasonal sun tanning, etc. Because the involved inverse analysis is numerically very intensive, we have constructed an efficient predictive model based on machine learning technology. (Collaboration with Department of Knowledge Technologies, JSI) **(Biomed. Opt. Express vol. 10, 2, 944-960, 2019)**

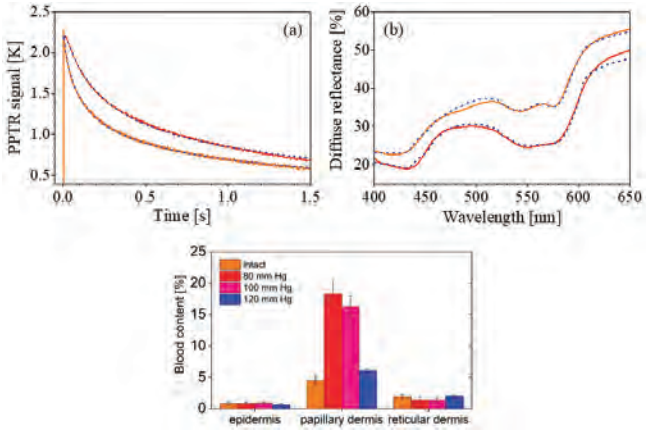

Figure 10: PPTR signals (a) and DRS spectra (b) as measured in intact and compressed human skin (orange and red solid lines, respectively), with the best-fitting model predictions (dashed), and the assessed volumetric blood contents at different values of the cuff pressure (c).

The described methodology was also applied to the characterization of hemodynamics in volunteers with incidentally obtained bruises (hematomas). The derived methodology and improved understanding of the bruise-healing dynamics could enable a more accurate determination of the time of injury in forensic investigations.

Using PPTR measurements we have determined temperature depth profiles induced in human skin in vivo by a pulsed 975-nm diode laser and compared them with those induced by the more common 532 nm (KTP) and 1064 nm (Nd:YAG) lasers. The results show that such diode lasers could be efficiently applied to the treatment of various dermatologic conditions, such as cutaneous lesions, photo aged skin, etc. (**Lasers Surg. Med., vol. 51, 774, 2019)**

We have developed a unique methodology for a non-invasive assessment of the structure and composition of human skin *in vivo*. The approach combines pulsed photothermal radiometry and diffuse reflectance spectroscopy in the visible part of the spectrum with numerical modelling of light transport in strongly scattering multi-layered structures (inverse Monte Carlo).

We have developed a numerical model of hyperthermic lipolysis in human subjects using an Nd:YAG laser (wavelength 1064 nm). The model enables the calculation of the temperature distribution and the resulting injury to subsurface adipocyte cells under different clinical treatment conditions. The results indicate that measurements of the skin-surface temperature might allow suitable control over the hyperthermic lipolysis effects deep within the skin. (Collaboration with Fotona d.o.o.) **(Lasers Surg. Med., vol. 51, 897, 2019)**

Microfluidics

Microfluidic research has been conducted in close collaboration with the Laboratory for Experimental Soft Matter at the Faculty of Mathematics and Physics and with the Condensed Matter Physics Department. We investigated the flow of nematic liquid crystals in microfluidic channels under the influence of local optothermal fields and observed the formation of topologically confined orientational domains. We studied nucleation, growth, shape and stabilisation of these domains as a function of fluid flow, confinement and laser pulses. Absorbed laser light was used to locally melt the liquid crystal into the isotropic phase, followed by quenching into the nematic phase when the laser was switched off. The defects coarsened into a single closed disclination loop, trapping a flow-aligned liquid crystal domain. Depending on the flow velocity, domains can either grow or shrink, or be additionally altered with optical tweezers, for example split into two parts. This approach enables the controlled manipulation of

orientational domains in liquid crystals. The experimental research was supported by a theoretical model as well as with simulations and published jointly in **Sci. Adv. 5, eaav4283, 2019**.

A second area of research was devoted to the development of passive two-point micro-rheology. The correlated motion of pairs of particles, immersed in a substance, was observed in order to determine the complex shear modulus of the given material. The method was tested on two examples: a viscous mixture of water and glycerol, and a viscoelastic agarose gel. The work was done as a master's thesis with the title *Measurement of viscoelastic properties of matter with two-point passive microrheology.*

We studied the formation, growth and stabilisation of topologically confined orientational domains in the microfluidic flow of nematic liquid crystals.

A part of our research was dedicated to the study of the hydrodynamic coupling of magnetically driven artificial cilia that we created in our laboratory. Experimental results indicate a high anisotropy in the coupling between neighbouring cilia and a different separation dependence for longitudinal and transverse coupling. This is consistent with the results of numerical simulations, which were conducted at the Condensed Matter Physics Department. The findings were presented at an international conference, while the article is still in preparation.

Some outstanding publications in the past year

1. Arko, Matej, Petelin, Andrej. Cross-differential dynamic microscopy. Soft matter, ISSN 1744-683X, 2019, vol. 15, no. 13, str. 2791-2797, doi: 10.1039/C9SM00121B. [COBISS.SI-ID 32334631]
2. Brence, Jure, Cmok, Luka, Sebastián Ugarteche, Nerea, Mertelj, Alenka, Lisjak, Darja, Drevenšek Olenik, Irena. Optical second harmonic generation in a ferromagnetic liquid crystal. Soft matter, ISSN 1744-683X, 2019, vol. 15, iss. 43, str. 8758-8765, ilustr., doi: 10.1039/C9SM01591D. [COBISS.SI-ID 3365476]
3. EMERŠIČ, Tadej, ZHANG, Rui, KOS, Žiga, ČOPAR, Simon, OSTERMAN, Natan, PABLO, Juan J. De, TKALEC, Uroš. Sculpting stable structures in pure liquids. Science advances, ISSN 2375-2548, Feb. 2019, vol. 5, art. no. eaav4283, 8 str., ilustr., doi: 10.1126/sciadv. aav4283. [COBISS.SI-ID 3291748]
4. Gerasimenko, Yaroslav, Karpov, Petr, Vaskivskyi, Igor, Brazovskii, Serguei, Mihailović, Dragan. Intertwined chiral charge orders and topological stabilization of the light-induced state of a prototypical transition metal dichalcogenide. npj quantum materials, ISSN 2397-4648, 2019, vol. 4, str. 32- 1-32-9, doi: 10.1038/s41535-019-0172-1. [COBISS.SI-ID 32480551]
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8. Ravnik, Jan, Vaskivskyi, Igor, Gerasimenko, Yaroslav, Diego, Michele, Vodeb, Jaka, Kabanov, Viktor V., Mihailović, Dragan. Strain-induced metastable topological networks in laser- fabricated TaS_2 polytype heterostructures for nanoscale devices. ACS applied nano materials, ISSN 2574-0970, 2019, vol. 2, no. 6, str. 3743-3751, doi: 10.1021/acsanm.9b00644. [COBISS.SI-ID 32649511]
9. Skolimowski, Jan, Gerasimenko, Yaroslav, Žitko, Rok. Mottness collapse without metallization in the domain wall of the triangular-lattice Mott insulator 1T - TaS_2. Physical review letters, ISSN 0031-9007. [Print ed.], 2019, vol. 122, no. 3, str. 036802-1-1-036802-6, doi: 10.1103/PhysRevLett.122.036802. [COBISS.SI-ID 32057895]
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Awards and Appointments

1. Yevhenii Vaskivskyi: SPO-2019 prize for the best poster presentation "Investigation of metastable states in 1T-TaS_2 by combining ultrafast spectroscopy with scanning tunnelling microscopy", 20th International Young Scientists Conference Optics and High Technology Material Science (SPO 2019), 26–29 September 2019, Kyiv, Ukraine
2. Jaka Vodeb: SMEC Student Prize 2019 for an outstanding oral presentation "Correlated Configurational States and a Quantum Charge Liquid in Layered Metallic Dichalcogenides", International meeting Study of matter at extreme conditions (SMEC 2019), 30 March to 6 April 2019, Miami – East Caribbean – Miami, USA

Organization of conferences, congresses and meetings

1. Nonequilibrium dynamics in correlated systems and quantum materials, Krvavec, Slovenija, 15–18. 12. 2019

Patents granted

1. Aleš Mrzel, Damjan Vengust
   Method for the synthesis of metal molybdates and tungstates from molybdenum and tungsten carbides and nitrides
   SI25549 (A), Urad RS za intelektualno lastnino, 31. 05. 2019.
2. Wang Yongli, Boštjan Jančar, Hermann Grünbichler, Franz Rinner, Damjan Vengust, Danilo Suvorov
   Thermoelectric generator comprising a thermoelectric element
   EP2975659 (B1), European Patent Office, 16. 10. 2019.
3. Nejc Lukač, Matjaž Lukač, Matija Jezeršek, Peter Gregorčič
   Cleaning system
   EP3127502 (B1), European Patent Office, 20. 03. 2019.

INTERNATIONAL PROJECTS

1. COST CA16101; MULTI-modal Imaging of FOREnsic SciEnce Evidence - tools for Forensic Science
   Prof. Boris Majaron
   Cost Office
2. COST CA16218; Nanoscale Coherent Hybrid Devices for Superconducting Quantum Technologies
   Prof. Viktor Kabanov
   Cost Association Aisbl
3. COST CA17123; MAGNETOFON; Ultrafast Opto-Magneto-Electronics for Non-Dissipative Information Technology
   Prof. Dragan Dragoljub Mihailović
   Cost Association Aisbl
4. COST CA17140 - Nano2Clinic; Cancer Nanomedicine - From the Bench to the Bedside
   Prof. Boris Majaron
   Cost Association Aisbl
5. Magnetically Reconfigurable Elastomeric Optical Surfaces
   Prof. Dragan Dragoljub Mihailović
   Slovenian Research Agency
6. The Development of a Nondestructive Analytical Method for the Screening of Upconverting Nanoparticles Surface Properties Based on Optical Characterization
   Prof. Boris Majaron
   Slovenian Research Agency
7. Design and Synthesis of Chemically Stable Luminescent Core-Shell Upconverting Nanoparticles for Bioimaging
   Prof. Boris Majaron
   Slovenian Research Agency
8. Liquid Crystalline Properties of Guanosine-Rich DNA and RNA Oligonucleotides
   Prof. Irena Drevenšek Olenik
   Slovenian Research Agency
9. Microstructuring of Liquid Crystals and Light Wave Manipulation by Photorefractive Materials
   Prof. Irena Drevenšek Olenik
   Slovenian Research Agency

RESEARCH PROGRAMMES

1. Medical physics
   Dr. Matija Milanič
2. Light and Matter
   Prof. Irena Drevenšek Olenik
3. Dynamics of complex nano-systems
   Prof. Dragan Dragoljub Mihailović

R & D GRANTS AND CONTRACTS

1. Femtosecond time-resolved scanning tunneling electron microscopy of complex materials
   Prof. Dragan Dragoljub Mihailović
2. Electrically tunable ferromagnetic liquids
   Asst. Prof. Alenka Mertelj
3. Probing spin states near the surface of quantum spin materials
   Petra Šutar
4. Phase transitions in systems of nucleotide repeat expansions associated with neurodegenerative diseases
   Prof. Irena Drevenšek Olenik
5. Mesoscopic Quantum Metastability
   Prof. Dragan Dragoljub Mihailović
6. Development of gradual optical shutter – OPTIGRAD
   Dr. Luka Cmok
   Ministry of Education, Science and Sport
7. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
   Prof. Dragan Dragoljub Mihailović
   Ministry of Economic Development and Technology
8. CMEM: Ultrafast all-electronic charge density wave memory for next generation computing
   Dr. Igor Vaskivskyi
   Ministry of Education, Science and Sport
9. Public call for reimbursement of costs for scientific publications in golden open access (for 2019)
   Prof. Dragan Dragoljub Mihailović
   Slovenian Research Agency
10. Advancing Charge Density Wave Memory Device Science and Technology
    Prof. Dragan Dragoljub Mihailović
    Nffa.eu
11. Small Services
    Dr. Aleš Mrzel

VISITORS FROM ABROAD

1. Dr Daniel Zabek, Institute of Heat Engineering, Warsaw University of Technology, Warsaw, Poland, 11 February to 12 August 2019
2. Dr Victor Vega Mayoral, CRANN & AMBER research centers, Trinity College Dublin; School of physics, Trinity College Dublin, Ireland, 26–30 March 2019
3. Héloïse Orihuel, Marseille University, Marseille, France, 3 April to 31 July 2019
4. Prof. Germano Montemezzani, University of Lorraine and Centrale Supelec, Metz, France, 14–17 April 2019
5. Dejan Bošnjaković, Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, Croatia, 10–21 June 2019
6. Prof. Duncan Haldane, Princeton University, New Jersey, USA, 10 June 2019
7. Jovana Stanojev, Biosense Institut, Novi Sad, Serbia, 7–10 July 2019
8. Barbara Adamiec, University of St Andrews, St. Andrews, Scotland, UK, 8 July to 25 August 2019
9. Dr Rinat Mamin, Zavoisky Physical-Technical Inst. of FIC KazanSC, Kazan, Russia, 2 July–1 August 2019
10. Anton Hromov, Taras Shevchenko National University of Kyiv, Department of Experimental Physics, Kyiv, Ukraine, 22–30 August 2019
11. Mathias Fleisch, Piezocryst Advanced Sensorics GmbH, Graz, Austria, 15–17 September 2019
12. Thomas Raistrick, School of Physics and Astronomy, University of Leeds, UK, 23 September to 15 October 2019
13. Prof. Helen F. Gleeson, School of Physics and Astronomy, University of Leeds, UK, 30 September to 2 October 2019
14. Prof. Ivan K. Schuller, Department of Physics and Center for Advanced Nanoscience, University of California, San Diego, USA, 30 September 2019
15. Prof. Ninel Kokanyan, Laboratory LMOPS University of Lorraine and CentraleSupelec, Metz, France, 13–26 October 2019
16. Rim Alrifai, Laboratory LMOPS University of Lorraine and CentraleSupelec, Metz, France, 13–26 October 2019
17. Héloïse Orihuel, Marseille University, Marseille, France, 26 October to 17 November 2019
18. Prof. Neven Barišić, Institute of Solid State Physics, TU Wien, Austria, Department of Physics and Faculty of Science, University of Zagreb, Croatia, 18. 10. –20. 10. 2019

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7. Asst. Prof. Tomaž Mertelj
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BIBLIOGRAPHY

Original Article

1. Jan Ravnik, Igor Vaskivskyi, Yaroslav Gerasimenko, Michele Diego, Jaka Vodeb, Viktor V. Kabanov, Dragan Mihailović, "Strain-induced metastable topological networks in laser-fabricated TaS_2 polytype heterostructures for nanoscale devices", *ACS applied nano materials*, 2019, **2**, 6, 3743-3751.
2. Luka Rogelj, Urban Pavlovčič, Jošt Stergar, Matija Jezeršek, Urban Simončič, Matija Milanič, "Curvature and height corrections of hyperspectral images using built-in 3D laser profilometry", *Applied optics*, 2019, **58**, 32, 9002-9012.
3. Dorian Alden, Tinkara Troha, Ronny Kirste, Seiji Mita, Qiang Guo, Axel Hoffmann, Marko Zgonik, Ramón Collazo, Zlatko Sitar, "Quasi-phase-matched second harmonic generation of UV light using AlN waveguides", *Applied physics letters*, 2019, **114**, 10, 103504.
4. Dragan Mihailović, "The importance of topological defects in photoexcited phase transitions including memory applications", *Applied sciences*, 2019, **9**, 5, 890.
5. Fulin Xing, Shuang Xun, Yanhan Zhu, Fen Hu, Irena Drevenšek Olenik, Xinzheng Zhang, Leiting Pan, Jingjun Xu, "Microfluidic assemblies designed for assessment of drug effects on deformability of human erythrocytes", *Biochemical and biophysical research communications*, 2019, **512**, 2, 303-309.
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7. Rok Dolenec, Elmar Laistler, Matija Milanič, "Assessing spectral imaging of the human finger for detection of arthritis", *Biomedical optics express*, 2019, **10**, 12, 6555-6568.
8. Mohamed Alaasar, Marko Prehm, Sebastian Belau, Nerea Sebastián Ugarteche, Martharyta Kurachkina, Alexey Eremin, Changlong Chen, Feng Liu, Carsten Tschierske, "Polar order, mirror symmetry breaking, and photoswitching of chirality and polarity in functional bent-core mesogens", *Chemistry: A European Journal*, 2019, **25**, 25, 6362-6377.
9. Jie Hu *et al.* (18 authors), "Magnetic nanoplatelets for high contrast cardiovascular imaging by magnetically modulated optical coherence tomography", *ChemPhotoChem*, 2019, **3**, 529-539.
10. Aleksander Drenik, Sebastijan Brezinšek, P. Carvalho, V. Huber, Natan Osterman, G. F. Matthews, Mitja Nemec, "Analysis of the outer divertor

hot spot activity in the protection video camera recordings at JET", *Fusion engineering and design*, 2019, **139**, 115-123.
11. Eduard Westphal, Hugo Gallardo, Nerea Sebastián Ugarteche, Alexey Eremin, Marko Prehm, Mohamed Alaasar, Carsten Tschierske, "Liquid crystalline self-assembly of 2,5-diphenyl-1,3,4-oxadiazole based bent-core molecules and the influence of carbosilane end-groups", *Journal of materials chemistry. C, Materials for optical and electronic devices*, 2019, **7**, 10, 3064-3081.
12. Yevhenii Vaskivskyi, Yelyzaveta Chernolevska, Antonina Vasylieva, Valeriy Pogorelov, Rasa Platakyte, Joana Stocka, Iryna Doroshenko, "1-Hexanol conformers in a nitrogen matrix: FTIR study and high-level ab initio calculations", *Journal of molecular liquids*, 2019, **278**, 356-362.
13. Patricija Hribar, Matija Tomšič, Andrej Jamnik, Darja Lisjak, Alenka Mertelj, "Electrostatic interactions between barium hexaferrite nanoplatelets in alcohol suspensions", *The journal of physical chemistry. C, Nanomaterials and interfaces*, 2019, **123**, 37, 23272-23279.
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Patent

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DEPARTMENT OF REACTOR PHYSICS F-8

During the past year we have been working mainly on:

- ***theoretical, experimental and applied reactor physics***
- ***plasma physics***
- ***neutron-transport calculations in fusion reactors***
- ***semiconductor physics***
- ***medical physics***

Head:
Asst. Prof. Luka Snoj

In the field of **reactor physics** our activities have been focused on the development of novel methods for research and power-reactor analyses.

In the framework of the international collaboration project E-SiCure - Engineering Silicon Carbide for Improved Border and Port Security, which is being carried out under the NATO Science for Peace and Security programme, we have continued the development of neutron detectors based on SiC aimed at the detection of fissile material. We produced several SiC detector prototypes with different converter layers made of ^{10}B and ^{6}Li which convert neutrons into ions (^{4}He and ^{3}H). Detector performance was tested a in dry chamber of the JSI TRIGA reactor and responses of individual detectors were clearly measurable. This is encouraging for future applications.

In 2019 a series of piezo-acoustic sensors manufactured by the companies Precision Acoustics and TWI were irradiated in the JSI TRIGA reactor under the supervision of the JSI and Sheffield University personell. The sensors were tested for radiation tolerance. Apart from the actual irradiations, JSI provided computational support by providing cumulative dose and dose rate calculations. Delayed radiation, contributing roughly 30 % was also included by an in-house developed and validated simulation code package JSIR2S.

We successfully finished several projects for IRSN (Institut de Radioprotection et de Sûreté Nucléaire) as part of a consortium with IDOM. The first such project was entitled DPA Cross-section Studies for PWR Vessel where the influence of various damage/DPA cross-sections and different methodologies for final DPA values calculations by means of three different computer programs was studied.

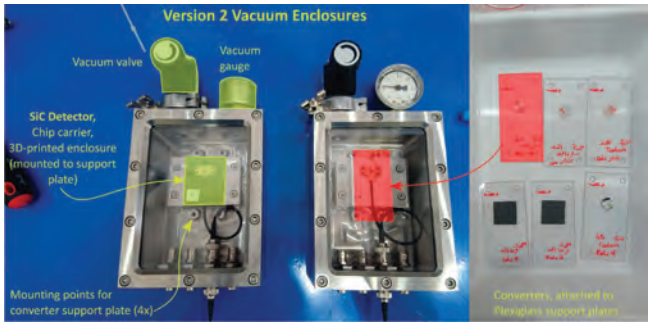

Figure 1: Prototype neutron detectors based on silicon carbide (SiC), developed in the E-SiCure project and tested in the JSI TRIGA reactor. The detectors operate in a vacuum environment and consist of SiC Schottky barrier diodes and neutron to charged particle converting films of 10B4C or 6LiF, around 2 μm in thickness, deposited onto aluminium substrate.

We have started a collaboration with the Rolls-Royce Civil Nuclear SAS company (Meylan, France) in which we perform experimental testing nuclear instrumentation at the JSI TRIGA reactor. In 2019 we have modified the tangential horizontal channel of the reactor piercing the thermal column for the needs of the testing activities, characterized the neutron field in the channel interior and performed two experimental campaigns.

In 2019, the European project EURAD was launched, where we contribute in sections WP3 CORI - Cement-Organic-Radionuclide-Interactions and WP8 SFC - Spent Fuel Characterization. In WP3 we have started conducting research on cement-organics-radionuclide interactions for the purpose of safe disposal of low and intermediate level radioactive waste within the framework of workpackage CORI of the EURAD H2020 European Joint Programme on Radioactive Waste Management. We have started conducting studies on radiolytic degradation of superplasticizers by irradiation with gamma rays at the TRIGA reactor. In WP8 we will contribute with detail calculation of the decay heat and photon/neutron source term of spent fuel assemblies originating from PWR and BWR reactors. We will focus on sensitivity and uncertainty analyses with the use of different codes and models.

In 2019 the ENEEP project - European Nuclear Experimental Educational Platform, funded by the EU, was launched. The aim of the project is the establishment of a platform at the EU level, for experimental nuclear education activities for students at every level and young professionals. The project is being carried out in partnership with the STU (Slovak Republic), CTU (Czech Republic), ATI (Austria) and BME (Hungary).

In 2019 we started investigations of the feasibility of using reactor pulse operation for specific applications, e.g., nuclear instrumentation testing at very high neutron flux levels, up to 10^{16} n cm^{-2} s^{-1}, which are attainable only during reactor pulses. For this purpose, the ability to monitor the absolute flux level, which varies by 6 – 7 orders of

magnitude within several ms, is mandatory. In 2020 we are planning an experimental campaign using miniature fission chambers and activation measurements.

In the field of neutron dosimetry, in collaboration with colleagues from CEA Cadarache and CEA Saclay, we are studying radiative neutron capture reactions, in themselves predominantly sensitive to the thermal and resonance neutron energy ranges, which would exhibit a sensitivity shift to epithermal neutron energies in conjunction with appropriate boron-based thermal neutron filters. In neutron dosimetry the epithermal energy range is very poorly covered on account of the small number of radiative capture reactions which have strong resonances at epithermal energies, or threshold reactions with a low energy threshold.

In collaboration with CEA Cadarache, planning of the ^{241}Am thermal neutron capture cross section measurements commenced. We performed test activation measurements of 242Am/242Cm using samples with low ^{241}Am activity, made at the JSI. We have determined the optimal starting 241Am activities for the experimental campaign which at the TRIGA reactor, which is expected to be performed in the first half of 2020.

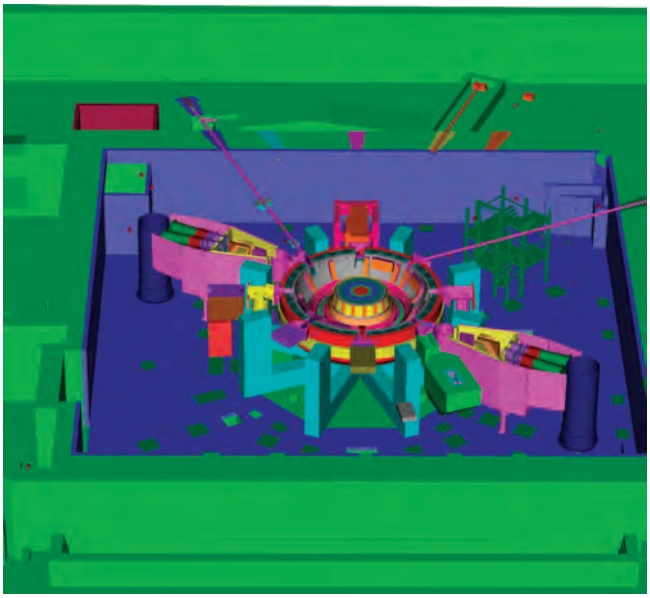

Figure 2: Cross section through the plasma center of the MCNP model used for transport simulations inside and outside of the JET tokamak hall. The model is visualized using the RADIANT tool.

Our team developed a two-step methodology code for calculation of the delayed gamma radiation field has been utilized for planning of neasurements of gamma heating using the calorimeteic method. The experimental campaign will be performed together with CEA Cadarache in 2020.

We continued to actively participate in the two OCED/NEA workgroups, namely the International Criticality Safety Benchmark Evaluation Project (ICSBEP) and International Reactor Physics Experiment Evaluation Project (IRPhEP), where we have contributed a new evaluation of a benchmark experiment with a UO_2F_2 solution in a spherical geometry. The experiment is crucial for the analysis of reprocessed fuel criticality measurements. We have taken part in the workgroup meetings and helped with the independent review of foreign benchmark experiment evaluations.

In 2019 a 4-year project SANDA was approved by European Comission, in which we will work on the preparation and validation of neutron data. The project is a continuation of the CHANDA and ANDES projects that have been successfully completed in the past.

We continued international collaboration lead by Swedish organizations Vattenfall, SKB and SSB in the field of spent PWR fuel characterization. In close collaboration with EC-JRC and SCK • CEN we have finished the calculations, where the decay heat from PWR fuel assemblies was determined. Further collaboration is foreseen under the NEA OECD.

Researchers of the Reactor Physics Department provided technical support for the safe operation of the Krško Nuclear Power Plant (NPP) also in 2019. We have independently performed nuclear core design calculations for the fuel cycle 31 and the start-up tests for the new fuel cycle. In addition, the expertise and calculational support for future dry storage of spent nuclear fuel was provided. In the framework of the applied project financed by the Slovenian Research Agency (sofinanced by the NPP Krško) McCord code has been further developed. The interface enables automatic transfer of the fuel characteristics from the CORD-2 system to the MCNP code for arbitrary operational state. Calibration and verification process of parameters has been performed at HZP and HFP conditions.

The work in the field of plasma physics in 2019 was oriented completely into nuclear fusion. Most of the work was done by particle-in-cell simulations and theoretical modelling. We were included in the EUROfusion Enabling Research project, where we are studying the possibility and consequences of the so-called “emissive divertor”. Our part consisted of theoretical modelling and simulations, which are strongly connected to our previous work on the phenomena aptly named “inverted-sheath”. We managed to derive the first theoretical quantitative model of the inverted sheath and developed a suitable simulation model for comparison. The most recent results show good agreement between both. We plan to continue the work on this subject also in the next year. We were again participating in the EUROfusion MST1 project on the filamentary transport studies. The experimental work included measurements in L- and H- mode on two tokamaks, namely AUG and TCV, with focus on different fuelling strategies. Our group was also the first to start the simulations of the parallel dynamic of the filamentary transport in the scrape-off-layer plasma. For that purpose we upgraded the particle-in-cell code BIT1 and developed a simulation model. The model is self-consistent and includes, a model of radial losses, complete atomic physics processes and recycling of the charged particles in parallel and radial direction. We will use the model to calculate heat loads and design new boundary condition for the scrape-off-layer of tokamaks. In the EUROfusion PFC project we have collaborated at the measurements in the WEST tokamak, with emphasis put on the data gathered from the Langmuir probes installed in the reactor wall. In the EUROfusion MST2 project we have contributed new thermal calculations

of the heat loads to the new probe head for the MST tokamaks and calculated the permittivity of the slits and grids in the retarding-field-analyser mounted in it.

In the field on neutron transport simulations for fusion reactors we continued our collaboration with several institutes/laboratories/universities on analyses of experimental data obtained during the calibration of JET's neutron detectors to neutrons from DD, DT and TT fusion reactions. For this purpose we simulated the detector responses to different plasma sources of neutrons inside the reactor. Calibration factors for both fission chambers (for time dependent neutron yield measurements) and the activation system (for time integrated neutron yield measurements) were determined. Computational support was crucial for achieving detector calibration uncertainties lower than the target uncertainty of 10 %. By the end of 2018 most of the DT calibration procedure was completed. However, the final confirmation will be performed during the experimental campaign. Calibration to TT neutrons is important for the pure tritium plasma phase of operation. Some additional analyses are still in progress to increase our understanding of the calibration procedure and reliability of the calculated correction parameters.

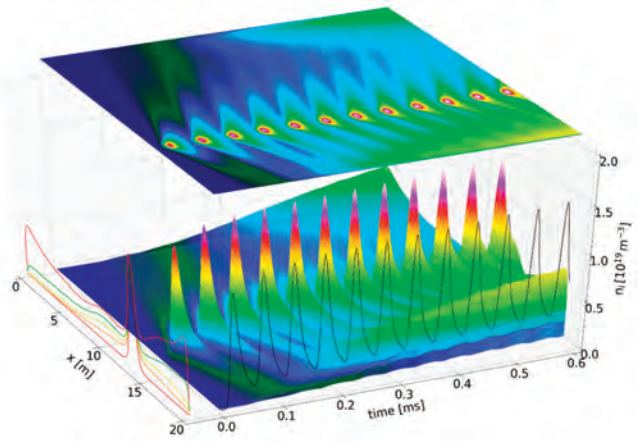

Figure 3: Ion density profile temporal development from self-consistent kinetic simulations of a tokamak plasma scrape-off-layer with filamentary transport within the EUROfusion MST-16 project 'Effects of filamentary transport on heat and particle loads'

In the scope of the European fusion programme (Fusion for Energy–F4E and EUROfusion) we continued international collabortation in the field of fusion neutronics that started 20 years ago. This research includes both experimental and teoretical work. Indeed, the Slovenian involvement in the European fusion programme started as part of this particular programme exactly 20 years ago, on March 21-22, 2000, with the EFDA Kick-off meeting on Fusion Technology in Garching. We performed the neutron transport, sensitivity and uncertainty analysis for the pre-design studies of the new fusion experiment to be performed at the FNG facility in Frascati, the Water Cooled Lithium Lead (WCLL) benchmark. XSUN-2017/SUSD3D package was used for the purpose of these analyses, which allow to optimise the design of the benchmark and evaluate the expected benefits of the measurements in terms of the basic nuclear data improvements.

At the OECD/NEA meetings (WPEC SG47, IRPhE/ICSBEP, EGRTS) we presented the evaluation of the benchmark experiment FNG-copper which was experimentally conducted in 2016-2017 for the validation of neutron cross-sections of copper.

In collaboration with CEA Cadarache we started bilateral project with main focus to determine with high accuracy radiation exposure of structure elements of fission and fusion nuclear reactors. Interest is in determination of dose and reaction rates, radiation damage, and activation of reactor vessel as well as other main components of the reactor. Due to the higher radiation field gradients, accurate transport calculations with uncertainties are needed. The latter is especially important from the standpoint of safety and economy.

The uncertainties connected to nuclear data are the main source of computational uncertainties, since the uncertainties in problem geometry and source of radiation are low due to the modern numerical methods (e.g. Monte Carlo method) and modern computer programs. Validation of such programs and methods is done with benchmark experiments (e.g. SINBAD base of experimental data). Measured uncertainties of such experiments are typically lower than the calculated ones, which offers an opportunity to obtain data regarding the nuclear data and also validate them. In the scope of the OECD/Nuclear Energy Agency the JSI and CEA institutes cooperate in a working group called "Working Party on International Nuclear Data Evaluation Co-operation" (WPEC) Subgroup 47 (WPEC SG47: Usage of the complete SINBAD base of experiments for nuclear data validation).

In June 2019 we organized the first meeting of the mentioned group WPEC SG47 in the scope of the 3 year mandate https://www.oecd-nea.org/science/wpec/sg47/. Coordinator of the group was I. Kodeli from the JSI.

In the scope of JSI and CEA cooperation we decided to focus on the analysis of benchmark experiments ASPIS, performed in the NESPOR/Winfrith reactor in the United Kingdom. Measured data of the mentioned experiment are already available in the SINBAD database. At the JSI we performed Monte Carlo calculation using the MCNP code with nuclear data libraries Cielo-62017, ENDF/B-VII, /B-VI, JENDL4.0u and JEFF3.3, while CEA (A. Hajji) used the Monte Carlo codes TRIPOLI4 and Serpent with nuclear data libraries JEFF-3.1.1, JEFF-3.2, ENDF/B-VIII, JENDL-4.0 and JEFF3.2, using angular dependant neutron scattering for ^{56}Fe from the nuclear data library JENDL. Main trends of the results for ASPIS Iron88 experiment are compliance between the both groups. A constant systematic difference of 10 % was observed. As the main differences were similarly observed in TRIPOLI-4 and SERPENT code, we can conclude that the differences are due to modelling. We investigated different aspects of modelling, such as fission spectrum, nuclear data connected to detector activation calculation, geometry details (1 mm gap between fission

plate and aluminium), and neutron multiplication in the fission plate. The mentioned factors affect the results, but do not explain the observed 10 % discrepancy between CEA and JSI results in its entirety.

Nevertheless, the mentioned main trends of the results, showed imperfections of modern nuclear data evaluations, both the ones done in the EU in the scope of JEFF-3.3 library, as well as the ones done in the US in the scope of the ENDF/B-VIII library. To our surprise, the older nuclear data libraries performed better in the mentioned analysis.

At OECD/NEA we also cooperated in the scope of the project Uncertainty Analysis in Modelling (UAM) in the group lead by G. Rimpault from CEA.

Researchers from the F8 division have performed simulations of neutron fields in various positions inside the JET tokamak, mainly as a support for neutron/gamma diagnostics for JET. Neutron spectra, neutron fluxes, reaction rates and neutron dose rates were calculated for several detector positions for the cases of DD, DT and TT plasmas. The majority of calculations have been performed in the view of preparation for the DT campaign at JET to be carried out in 2020/21 and in support of past experiments. Some of the results were needed to support experiments for commissioning of new neutron detection systems in view of DT operation. In case of the O-LTIS irradiation position, which is located behind the first wall of the JET tokamak, the neutron spectra and reaction rates were calculated for all materials in the holder. In the FOCS irradiation position additionally neutron dose rates and displacement per atom - DPA values in SiO2 were calculated for preparation to the upcoming DT campaign. Using special variance reduction methods we significantly increased the quality of the neutron flux calculation in the whole energy range and consequently improved calculations.

In 2019 researchers from the Reactor physics department have received the opportunity to contribute to the European DEMOnstrational fusion power plant project. Based on previous work performed in the field of Skyshine calculation we were assigned to do analysis of this phenomena for DEMO. In the scope of this project we will determine the Skyshine effect in the vicinity of the power plant during operation, shutdown and maintenance. During maintenance the highly activated breading blanket will be removed from the tokamak vacuum vessel and lifted in-to the maintenance hall. The analysis will be carried out with hybrid transport codes for neutral particles and programs developed at JSI.

We participated in the formation of the new program group - Fusion Technology, which started in January 2019. The newly formed program group, approved by ARRS, connected the leading Slovenian researchers in the field of fusion technologies and plasma physics, who originated from departments R4, F8, F2, F4 of the JSI and from the faculties of mechanical and electrical engineering of the University of Ljubljana. Four of the eleven researchers in the newly formed group originate from the F8 department.

Researchers from the F8 division and RIC collaborated in activities related to the preparation of a water activation experiment at the JET tokamak. The presence of the 16N isotope which is created via the threshold reaction $^{16}O(n,p)^{16}N$ in significant concentrations can represent an important operational constraint for fusion devices from the radiation protection standpoint. Current research shows that 16N can contribute significantly to nuclear heating in superconducting coils required for plasma confinement inside the vacuum vessel. The water activation experiment at JET will represent a unique opportunity to obtain fusion-relevant experimental data (especially in support of the ITER device, currently being built in Cadarache, France) and essential for the validation of computational methods and nuclear data in use for simulations. In 2019 we completed the analysis of the results of an experimental campaign in which we tested and calibrated two scintillation detectors present at the JET tokamak, which will be used in the water activation experiment. We used standard calibration gamma sources as well as a $^{244}Cm/^{13}C$ source, in essence a neutron source which also emits 6.13 MeV gamma rays, coinciding with the dominant gamma ray energy emitted by the ^{16}N isotope. The analysis led to the confirmation of the suitability of the detectors for the performance of the water activation experiment and the calibration of the detection efficiency. The results in addition to previous results obtained through the use of computational methods were submitted for publication as a scientific article.

In 2019 we continued with neutronic analyses in support of the DEMO (demonstrational fusion power plant) development process. This work is part of the EUROfusion Engineering Grant and in 2019 included work on different DEMO reactor configurations with emphasis on nuclear heating of superconducting magnets due to increased neutron and gamma fields caused by integration of various systems. Analyses showed some suitable configurations and useful shielding strategies that will be used in subsequent DEMO designs. These analyses were an important part of the preparation for the DEMO design review conducted at the end of the pre-conceptual design phase in the end of 2020.

Our active collaboration within the JET3-NEXP streaming benchmark experiment continued in 2019. This year a new experimental campaign was conducted, which will be used for validation of simulation of neutron fluence. The experiment was performed using thermoluminescent detector and activation foils. We contributed calculations of neutron fluences using Monte Carlo, deterministic and hybrid (Monte Carlo/deterministic) transport codes at several experimental locations inside the JET tokamak building. During this campaign additional measurement 6 additional measurement positions were added. This year the JSI also contributed results of a nuclear data uncer-

tainty propagation analysis which was performed using the newly developed ASUSD program package. ASUSD is currently the worlds most user friendly and efficient computes code system for such analyses.

In the year of 2019 the code package PLANET for detailed calculations of plasma neutron sources was being developed and applied in collaboration with the JET tokamak and PPPL (USA), Uppsala University (Sweden) and UNED (Spain). The code is based on a subroutine written in the programming language Fortran, which is coupled to the advanced Monte Carlo neutron transport code MCNP. The information on the plasma state is computed with the TRANSP plasma transport code, developed at the Princeton Plasma Physics Laboratory. Based on the plasma state description the neutron spectra are computed with the Swedish DRESS code. Obtaining data on neutron emissivity profile in the JET tokamak, neutron emission vector and energy one can commence the source random sampling procedure and calculation of a plasma neutron source description. The PLANET code package has been verified and validated using a simplified and detailed JET tokamak computational model. It was found that the neutron yield monitors that are positioned on the outside of the vacuum vessel are relatively insensitive to changes in the neutron source, while activation measurements can be used to record differences in the plasma state and the effects of plasma heating. Our collaboration with the Culham Centre for Fusion Energy in the UK has been strengthened by signing an agreement for appointing a post-doctoral researcher to a two year secondment abroad. He has taken up the position of responsible officer for the TRANSP code in 2019, additionally supporting the operation of the JET tokamak as the diagnostics coordinator in the control room.

In the field of medical physics, we have continued our research in the areas, which have been in our focus in the last few years: modelling, analysis of positron emission tomography (PET) images, and image-guided cancer therapy. We also continued with the newly established field of biomedical optics.

The computational model for simulating response of pre-clinical tumours to treatment with anti-PD-1 immunotherapy was verified with our own experiments on various types of cancer (melanoma, breast cancer, colon cancer). We found that the model predictions were in good agreement with the experiments. The model predicted that a complete response to immunotherapy was only possible in the case, when all tumour cells expressed major histocompatibility complex class I on their membranes. A paper describing the new results has already been written and submitted for review in a scientific journal.

In addition to modelling in oncology, we were also engaged in modelling thermal transport for the purpose of thermography in medicine. For this purpose, a finger model was developed where the exact structure was determined from the MR image of the finger (15 different structures) and the thermal properties were obtained from a public database (IT IS). With this model, we can simulate a static temperature distribution in the finger at given thermal sources, which is useful for simulating thermographic images of healthy and diseased fingers.

We completed a prospective immunotherapy study conducted in collaboration with the Institute of Oncology Ljubljana, where patients with metastatic lung cancer were treated with anti-PD-1 immunotherapy (pembrolizumab) and imaged with computed tomography (CT) and fluorodeoxyglucose (FDG) PET/CT before treatment, as well as 1, 4, 10, 16 and 20 months after the treatment. We found that pre-treatment radiomics analyses of FDG PET/CT images correctly predicted patients' response to immunotherapy with 80 % accuracy, which is much better than the current clinical standards. The manuscript with the results has been submitted for review in a scientific journal.

In the field of biomedical optics, we continued with building of the hypersoectral microscopy system. We performed first normalized measurements of histological samples. In collaboration with colleagues from University of Bologna we imaged fragments of old films from the 1950s with a goal to determine age affects, damage and possibility of restoration. We also collaborated with colleagues from University of Reka on applying machine learning algorithms for analysis of hyperspectral images.

As always in the recent years, we closely collaborated with the University of Wisconsin - Madison. The groups became even more organizationally integrated this year (regular Skype weekly meetings, internal reviews of papers, etc....)

Some outstanding publications in the past year

1. D. Kotnik et. al. Validation and evaluation of the ADVANTG code on the ICSBEP skyshine benchmark experiment. Annals of Nuclear Energy, 2019, vol. 125, pp. 249-260, doi: https://doi.org/10.1016/j.anucene.2018.11.025
2. Review paper: A. Žohar, L. Snoj, On the dose fields due to activated cooling water in nuclear facilities, Progress in Nuclear Energy, Volume 117, November 2019, 103042, DOI: https://doi.org/10.1016/j.pnucene.2019.103042
3. Ž. Štancar et. al. Multiphysics approach to plasma neutron source modelling at the JET tokamak, Nuclear Fusion, Volume 59, Number 9, DOI: https://doi.org/10.1088/1741-4326/ab2c8b

4. B. Kos, S.W. Mosher, I.A. Kodeli, R.E. Grove, J. Naish, B. Obryk, R. Villari, P. Batistoni and JET contributors, *Application of ADVANTG to the JET3 – NEXP streaming benchmark experiment*, Fusion Engineering and Design 147, 111252 (2019).
5. I.A. Kodeli, V. Radulovic, G. Veniger, D. Kavsek, T. Kuc, M. Ciechanowski, W. Pohorecki, *Activation of Mn, Li2O and LiF in JSI TRIGA reactor to study potential tritium production monitors for fusion applications*, Nuclear fusion, ISSN 0029-5515, 2019, no. 8, vol. 59
6. I. A. Kodeli, M. Angelone, FNG copper benchmark evaluation for the SINBAD database, *Fusion Engineering and Design* (2019) doi: /10.1016/j.fusengdes.2018.12.053.
7. L. Rogelj, U. Pavlovči, J. Stergar, M. Jezeršek, U. Simončič, M. Milanič, *Curvature and height corrections of hyperspectral images using built-in 3D laser profilometry*, Applied Optics. 2019 Nov 10;58(32):9002-12. https://doi.org/10.1364/AO.58.009002
8. M. Turk, U. Simoncic, A. Roth, D. Valentinuzzi, R. Jeraj, *Computational modelling of resistance and associated treatment response heterogeneity in metastatic cancers*, Physics in Medicine & Biology. 2019 May 23;64(11):115001. https://doi.org/10.1088/1361-6560/ab0924
9. D. Valentinuzzi, U. Simončič, K. Uršič, M. Vrankar, M. Turk, R. Jeraj, *Predicting tumour response to anti-PD-1 immunotherapy with computational modelling*, Physics in Medicine & Biology. 2019 Jan 16;64(2):025017. https://doi.org/10.1088/1361-6560/aaf96c
10. M. Milanic, A. Cenian, N. Verdel, W. Cenian, J. Stergar, B. Majaron, *Temperature Depth Profiles Induced in Human Skin In Vivo Using Pulsed 975 nm Irradiation*, Lasers in surgery and medicine. 2019 Nov;51(9):774-84. https://doi.org/10.1002/lsm.23108
11. M. Milanic, B.T. Muc, N. Lukac, M. Lukac, *Numerical Study of Hyper-Thermic Laser Lipolysis With 1,064 nm Nd: YAG Laser in Human Subjects*, Lasers in surgery and medicine. 2019 Dec;51(10):897-909. https://doi.org/10.1002/lsm.23124
12. T. Goricanec, et al., *Evaluation of the criticality and reaction rate benchmark experiments utilizing UO2F2 aqueous solution of intermediate enrichment in spherical geometry at ORNL*, Progress in Nuclear Energy, vol. 111, pp. 97-108, 2019.
13. B. S. Schneider, J. Kovacic, T. Gyergyek, B. Koncar,M. Draksler, S. Costea, et al. *New diagnostic tools for transport measurements in the Scrape-Off Layer (SOL) of medium-size tokamaks*. Plasma physics and controlled fusion, ISSN 0741-3335, [in press] 2019, 30 str., doi: 10.1088/1361-6587/ab0596.

Awards and Appointments

1. Tanja Goričanec: Best Paper Award, 20 June 2019, Portorož, Slovenia, International Conference ANIMMA 2019 – Advancements in Nuclear Instrumentation Measurement Methods and their Applications, paper "Predicting Ex-Core Detector Response in a PWR with Monte Carlo Neutron Transport Methods"

Organization of Conferences, Congresses and Meetings

1. ANIMMA 2019 - International Conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications, Portorož, Slovenia, 17–21 June 2019 (co-organizer together with CEA, France)

Patent granted

1. Robert Jeraj, Tyler J. Bradshaw, Timothy G. Perk
   Image enhancement system for bone disease evaluation
   US10445878 (B2), US Patent Office, 15. 10. 2019.

INTERNATIONAL PROJECTS

1. Experimental Testing of Self-Powered Neutron Detectors for the Thermocoax Company
   Dr. Vladimir Radulović
   Thermocoax Sas
2. Irradiation Services for the Rolls-Royce Civil Nuclear SAS Company
   Dr. Vladimir Radulović
   Rolls-royce Civil Nuclear Sas
3. Benchmarks of Computational Tools against Experimental Data on Fuel Burnup and Material Activation for Utilization, Operation and Safety Analysis of Research Reactors; Activation Rate Benchmark at the JSI TRIGA Mark-II Reactor
   Dr. Vladimir Radulović
   IAEA - International Atomic Energy Agency
4. E-SiCure - Engineering Silicon Carbide for Enhanced Border and Ports Security
   Prof. Luka Snoj
   Nato - North Atlantic Treaty Organisation
5. Kinetic Approach to Modelling and Measurements in SOL of Tokamak; Network of Small and Medium Size Magnetic Confinement Fusion Devices for Fusion Research
   Dr. Jernej Kovačič
   IAEA - International Atomic Energy Agency
6. Training Fees for Mr. Eyakifama Hazou, ICTP-IAEA Sandwich Training Educational Programme (STEP), from 16 February 2019 to 16 May 2019
   Prof. Luka Snoj
   Ictp - Centro Internazionale Di Fisica Teorica
7. H2020 - EURAD; European Joint Programme on Radioactive Waste Management
   Dr. Vladimir Radulović
   European Commission

8. H2020 - ENEEP; European Nuclear Experimental Educational Platform
   Dr. Vladimir Radulović
   European Commission
9. H2020 - SANDA; Supplying Accurate Nuclear Data for Energy and Non-Energy Applications
   Prof. Ivan Aleksander Kodeli
   European Commission
10. H2020 - ARIEL; Accelerator and Research Reactor Infrastructures for Education and Learning
    Prof. Ivan Aleksander Kodeli
    European Commission
11. H2020 EUROfusion - Research Unit - Administration and Services RU – FU
    Prof. Luka Snoj
    European Commission
12. H2020 EUROfusion - Enabling Research-2-FU
    Dr. Jernej Kovačič
    European Commission
13. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION
    Dr. Jernej Kovačič
    European Commission
14. H2020-EUROfusion; Exploatation of DT Operation for ITER-JET3-FU
    Prof. Luka Snoj
    European Commission
15. H2020 EUROfusion - Education-ED-FU
    Prof. Luka Snoj
    European Commission
16. H2020 EUROfusion - JET Campaigns-JET1-FU
    Dr. Žiga Štancar
    European Commission
17. H2020 EUROfusion - Medium Size Tokamak Campaigns-MST1-FU
    Dr. Jernej Kovačič
    European Commission
18. H2020 EUROfusion - JET Enhancements-JET4-FU, EUROFUSION
    Dr. Jernej Kovačič
    European Commission
19. H2020 EUROfusion - PMI-PPPT-2-FU: Nuclear data
    Prof. Ivan Aleksander Kodeli
    European Commission
20. H2020 EUROfusion - Engineering Grants: Fusion Plant Nuclear Analyst - The modelling of the proposed DEMO component designs, testing their performance under reactor conditions and development of new design solutions
    Dr. Aljaž Čufar
    European Commission
21. Accelerating Neutronics Analyses for Fusion and Fission Applications Using the ADVANTG Code
    Prof. Luka Snoj
    Slovenian Research Agency
22. Generation of a Plasma Neutron Source through the Coupling of Plasma Simulation Programs and Monte Carlo Neutron Transport Codes
    Prof. Igor Lengar
    Slovenian Research Agency
23. Experimental and Numerical Research in Support of Development of Plasma Potential Probes
    Dr. Jernej Kovačič
    Slovenian Research Agency
24. Multiphysics Validation of High Fidelity Modelling and Simulation for Nuclear Applications
    Dr. Vladimir Radulović
    Slovenian Research Agency
25. Use of Shielding Benchmarks for Nuclear Data Validation and Improvement
    Prof. Ivan Aleksander Kodeli
    Slovenian Research Agency
26. Optimization of Neutron Converting Components for Enhanced Performance of Silicon Carbide Based Neutron Detectors
    Prof. Luka Snoj
    Slovenian Research Agency
27. Steady-State and Transient Experimental Benchmark for Validation and Development of the TRAPID Neutronics Code Using the JSI TRIGA Mark-II Reactor
    Prof. Luka Snoj
    Slovenian Research Agency
28. Development of Multiphysics Tools for Plasma and Neutron Transport Calculations in Modern Fusion Devices
    Dr. Žiga Štancar
    Slovenian Research Agency
29. Steady-State and Transient Experimental Benchmark for Validation and Development of the TRAPID Neutronics Code Using the JSI TRIGA Mark-II Reactor
    Dr. Aljaž Čufar
    Slovenian Research Agency
30. Consequences of electron emission from hot plasma-facing components in nuclear fusion reactors
    Dr. Jernej Kovačič
    Slovenian Research Agency
31. Epithermal neutron flux determination and validation of nuclear cross-sections and through activation measurements employing neutron spectrum filters
    Prof. Andrej Trkov
    Slovenian Research Agency

RESEARCH PROGRAMMES

1. Medical physics
   Prof. Robert Jeraj
2. Reactor Physics
   Prof. Luka Snoj
3. Fusion technologies
   Prof. Igor Lengar

R&D GRANTS AND CONTRACTS

1. Analysis of nuclear heating in a reactor
   Prof. Luka Snoj
2. Determination of the Am-241 thermal neutron capture cross section by activation measurements at the JSI TRIGA reactor
   Dr. Gašper Žerovnik
3. Absolute radiation measurements at very high neutron flux levels in reactor pulse mode
   Prof. Igor Lengar
4. Electrocaloric elements for active cooling of electronic circuits
   Prof. Luka Snoj
5. Development of Computational Tools for the Determination of the Neutron Field in the Containment of a Pressurized Water Reactor
   Prof. Andrej Trkov
6. Član mednarodnega odbora - IGOR LENGAR - Upravni odbor «Fusion for Energy - F4E“
   Prof. Igor Lengar
   Ministry of Education, Science and Sport
7. ICERR Agreement for Receiving Affiliate Staff to CEA as a Designated International Center based on Research Reactors, through its Research Centres of Saclay and Cadarache
   Prof. Luka Snoj
   Cea - Commissariat A L“energie Atomique Et Aux
8. Irradiation of Glycol
   Prof. Luka Snoj
   Lancaster University
9. Irradiations on the TRIGA Reactor
   Prof. Luka Snoj
10. Experimental Testing of Self-Powered Neutron Detector Assemblies for CEA - INFINI Project
    Dr. Vladimir Radulović
    Cea List Institute, Dept. Of Metrology,
11. Neutron Transport and Criticality Calculations in Reactor Cores
    Dr. Vladimir Radulović
    Institut de Radioprotection et de Surete Nucleaire
12. Monte Carlo Simulation of Irradiation of Ultrasonic Sensors and Transducers in the JSI TRIGA Reactor
    Prof. Luka Snoj

NEW CONTRACTS

1. Independent Evaluation of the NPP Krško Cycle 31 Reload Safety Evaluation
   Asst. Prof. Marjan Kromar
   Nuklearna Elektrarna Krško d. o. o.
2. Reload Operational Core Analysis, Post Refuelling Nuclear Design Check Tests, PIS and KFSS Cycle Specific Data for Future Fuel Cycles (Cycle 31)
   Asst. Prof. Marjan Kromar
   Nuklearna Elektrarna Krško d. o. o.
3. Activities to support SFDS calculation and implementation
   Prof. Luka Snoj
   Nuklearna Elektrarna Krško d. o. o.

VISITORS FROM ABROAD

1. Valerio Mascolino, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, 1 January to 17 May 2019
2. Prof. Michael Österlund and Dr Ali Al-Adili, University Uppsala, Uppsala, Sweden, 3–4 January 2019
3. Prof. Alireza Haghighat, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, 7–18 January 2019
4. Dr Elchin Huseynov and Sahil Valiyev, National Nuclear Research Centre, Baku, Azerbaijan, 4–15 February 2019
5. Serhii Kupriianchuk, Institute for Safety Problems of NPPs, Ukraine's National Academy of Sciences, Kiev, Ukraine, 17 February to 16 May 2019
6. Prof. Tsviatko Popov, Faculty for Physics, St. Kliment Ohridski University, Sofia, Bulgaria; Prof. Svetlana Ratynskaia, Space & Plasma Physics, School of Electrical Engineering, Royal Institute of Technology (KTH), Stockholm, Sweden and Dr James P. Gunn, IRFM – CEA, Cadarache, France, 11–15 February 2019
7. Dr Stefan Costea, University of Innsbruck, Innsbruck, Austria, 24 March to 6 April 2019
8. Christophe Rome, ONET Technologies CN, Marseille, France, 17 April 2019
9. Walton Gusztav, Vysotsky V. Dmitry, Kuatbekov P. Ruslan, Mitinskaya V. Victoria, Rosatom Central Europe s.r.o., Prague, Czech Republic, 21 May 2019
10. Dr Henri Weisen, Swiss Plasma Center – EPFL, Lausanne, Switzerland, 8–11 June 2019
11. Dr Arnab Jyoti Deka, Institute for Plasma Research, Gandhinagar, Gujarat, India, 11–14 May 2019
12. Prof. Yuntao Song, ASIPP Institute, China Academy of Sciences, HeFei, Anhui Province, China, 10 June 2019
13. Dr Ivana Capan, Project leader of the international project E-SiCure, Zoran Ereš and Robert Bernat, Rudjer Bošković Institute, Zagreb, Croatia; Dr Željko Pastuović, Adam Sarbut, Dale Prokopovich, ANSTO (Australian Nuclear Science and Technology Organization), Lucas Heights, NSW, Australia; Dr Takeshi Ohshima, Takahiro Makino, Yuichi Yamazaki, National Institute for Quantum and Radiological Science and Technology, Chiba, Japan; Dr Jose Courtinho, Vitor Torres, University of Aveiro, Portugal, 10–14 June 2019
14. Florian Batard, École Nationale Supérieure d'Informatique pour l'Industrie et l'entreprise (ENSIIE), Évry, France, 16 June to 14 September 2019
15. Ryotaro Kimura, Faculty of Engineering, Energy and Environmental Systems, Hokkaido University, Hokkaido, Japan, 20 August to 31 October 2019
16. Dr Alireza Haghighat, Valerio Mascolino, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, 7–14 September 2019
17. Prof. Abdallah Lyoussi, Prof. Christophe Destouches, CEA, Cadarache, France, 9–12 September 2019
18. Loic Barbot, Gregoire De Izarra, CEA, Cadarache, France; Mathieu Trocme, Yoann Moline, CEA, Saclay, France; Manuel Cargnelutti, Danilo Bisiach, Aleš Bardorfer, Instrumentation Technologies, d.d., Solkan, Slovenia, 23–27 September 2019
19. Bergström Holm Johan, Bernroth Carl, Hendricks Mattias, Makronikos Asp Andreas, Rezai Abdullah, Prof. Ali Al Adili, Prof. Michael Österlund, Prof. Ane Håkansson, Prof. Andreas Solders, University of Uppsala, Uppsala, Sweden, 30 September to 2 October 2019
20. Prof. Roman Schrittwieser, University of Innsbruck, Innsbruck, Austria, 29 September to 2 October 2019
21. Dr Miroslav Konecny, Addsen s.r.o., Malacky, Slovakia, 23 October 2019
22. Dr Elchin Huseynov, National Nuclear Research Centre, Baku, Azerbaijan, 14–23 November 2019
23. Dr Ivana Capan, Project leader of the international project E-SiCure and Robert Bernat, Rudjer Bošković Institute, Zagreb, Croatia, 12 December 2019

STAFF

Researchers

1. Prof. Tomaž Gyergyek*
2. Prof. Robert Jeraj
3. Prof. Ivan Aleksander Kodeli
4. Asst. Prof. Marjan Kromar
5. Prof. Igor Lengar
6. Dr. Matija Milanič*
7. Dr. Urban Simončič*
8. **Prof. Luka Snoj, Head**
9. Prof. Andrej Trkov
10. Dr. Gašper Žerovnik

Postdoctoral associates

11. Stefan Costea, B. Sc.
12. Dr. Dušan Čalič*
13. Dr. Aljaž Čufar
14. Dr. Jernej Kovačič
15. Dr. Vid Merljak
16. Dr. Vladimir Radulović
17. Dr. Žiga Štancar

18. **Postgraduates**
19. Klemen Ambrožič, B. Sc.
20. Tanja Goričanec, B. Sc.
21. Bor Kos, B. Sc.
22. Domen Kotnik, B. Sc.
23. Anže Pungerčič, B. Sc.
24. Damijan Valentinuzzi, B. Sc.
25. Ingrid Vavtar, B. Sc.
26. Andrej Žohar, B. Sc.

Technical officers

27. Jan Malec, B. Sc.

Technical and administrative staff

28. Slavko Slavič, B. Sc.
29. Saša Škof, B. Sc.
30. *Uršula Turšič, B. Sc., retired 06.03.19*
31. Bojan Žefran

Note:
* part-time JSI member

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Original Article

1. Domen Kotnik, Bor Kos, Aljaž Čufar, Scott W. Mosher, R. E. Grove, Luka Snoj, "Validation and evaluation of the ADVANTG code on the ICSBEP skyshine benchmark experiment", *Annals of Nuclear Energy*, 2019, **125**, 249-260.
2. Luka Rogelj, Urban Pavlovčič, Jošt Stergar, Matija Jezeršek, Urban Simončič, Matija Milanič, "Curvature and height corrections of hyperspectral images using built-in 3D laser profilometry", *Applied optics*, 2019, **58**, 32, 9002-9012.
3. Elchin Huseynov, Anže Jazbec, Luka Snoj, "Temperature vs. impedance dependencies of neutron-irradiated nanocrystalline silicon carbide (3C-SiC)", *Applied physics. A, Materials science & processing*, 2019, **125**, 1, 9.
4. Nina Verdel, Ana Marin, Matija Milanič, Boris Majaron, "Physiological and structural characterization of human skin in vivo using combined photothermal radiometry and diffuse reflectance spectroscopy", *Biomedical optics express*, 2019, **10**, 2, 944-960.
5. Rok Dolenec, Elmar Laistler, Matija Milanič, "Assessing spectral imaging of the human finger for detection of arthritis", *Biomedical optics express*, 2019, **10**, 12, 6555-6568.
6. Song Chen, Stephanie A. Harmon, Timothy G. Perk, Xuena Li, Meijie Chen, Yaming Li, Robert Jeraj, "Using neighborhood gray tone difference matrix texture features on dual time point PET/CT images to differentiate malignant from benign FDG-avid solitary pulmonary nodules", *Cancer imaging*, 2019, **19**, 56.
7. Alison Roth, Stephanie A. Harmon, Timothy G. Perk, Jens C. Eickhoff, Peter L. Choyke, Karen A. Kurdziel, William L. Dahut, Andrea B. Apolo, Michael J. Morris, Scott Perlman, Glenn Liu, Robert Jeraj, "Impact of anatomic location of bone metastases on prognosis in metastatic castration-resistant prostate cancer", *Clinical genitourinary cancer*, 2019, **17**, 4, 306-314.
8. Marjan Kromar, Bojan Kurinčič, "Assessment of the photon and neutron source term for the NPP Krško spent fuel", *Energija*, 2019, **68**, 2-3, 184-198.

9. Igor Lengar, Andrej Žohar, P. Batistoni, Sergei Popovichev, S. Conroy, JET Contributors, "Characterization of JET neutron field in irradiation locations for DD, DT and TT plasmas", *Fusion engineering and design*, 2019, **146**B, 1967-1970.
10. Bor Kos, Scott W. Mosher, Ivan Aleksander Kodeli, Robert. E. Grove, Jonathan Naish, Barabara Obryk, Rosaria Villari, Paola Batistoni, JET Contributors, "Application of ADVANTG to the JET3 - NEXP streaming benchmark experiment", *Fusion engineering and design*, 2019, **147**, 111252.
11. Aljaž Čufar, Alessandro Bruschi, U. Fischer, Thomas Franke, G. Granucci, G. Grossetti, Ivan Aleksander Kodeli, D. Trombetta, R. Villari, "Equatorial electron cyclotron port plug neutronic analyses for the EU DEMO", *Fusion engineering and design*, 2019, **146**A, 336-340.
12. Ivan Aleksander Kodeli, M. Angelone, "FNG copper benchmark evaluation for the SINBAD database", *Fusion engineering and design*, 2019, **146**A, 312-315.
13. Matthew Scarpelli, Christopher Zahm, Scott Perlman, Douglas G. McNeel, Robert Jeraj, Glenn Liu, "FLT PET/CT imaging of metastatic prostate cancer patients treated with pTVG-HP DNA vaccine and pembrolizumab", *Journal for immunotherapy of cancer*, 2019, **7**, 23.
14. Lino Šalamon, B. Geslot, J. Heyse, S. Kopecky, Pierre Leconte, Gilles Noguere, C. Paradela, P. Schillebeeckx, Luka Snoj, "Neutron resonance transmission analysis of cylindrical samples used for reactivity worth measurements", *Journal of radioanalytical and nuclear chemistry: an international journal dealing with all aspects and applications of nuclear chemistry*, 2019, **321**, 2, 1519-1530.
15. Stephanie A. Harmon, Christopher W. Seder, Song Chen, Anne M. Traynor, Robert Jeraj, Justin D. Blasberg, "Quantitative FDG PET/CT may help risk-stratify early-stage non-small cell lung cancer patients at risk for recurrence following anatomic resection", *Journal of thoracic disease*, 2019, **11**, 4, 1106-1116.
16. Matija Milanič, Adam Cenian, Nina Verdel, Witold Cenian, Jošt Stergar, Boris Majaron, "Temperature depth profiles induced in human skin in vivo using pulsed 975nm irradiation", *Lasers in surgery and medicine*, 2019, **51**, 9, 774-784.
17. Matija Milanič, Blaž Tašič Muc, Nejc Lukač, Matjaž Lukač, "Numerical study of hyper-thermic laser lipolysis with 1,064 nm Nd:YAG laser in human subjects", *Lasers in surgery and medicine*, 2019, **51**, 10, 897-909.
18. A. Asuncion-Astronomo, Žiga Štancar, Tanja Goričanec, Luka Snoj, "Computational design and characterization of a subcritical reactor assembly with TRIGA fuel", *Nuclear Engineering and Technology*, 2019, **51**, 2, 337-344.
19. Ivan Aleksander Kodeli, Vladimir Radulović, Gregor Veniger, Darko Kavšek, T. Kuc, M. Ciechanowski, W. Pohorecki, "Activation of Mn, Li_2O and LiF in JSI TRIGA reactor to study potential tritium production monitors for fusion applications", *Nuclear fusion*, 2019, 8, vol. 59.
20. Žiga Štancar, Marina Gorelenkova, Sean Conroy, Patrick Sauvan, James Buchanan, Henri Weisen, Luka Snoj and JET Contributors, "Multiphysics approach to plasma neutron source modelling at the JET tokamak", *Nuclear fusion*, 2019, **59,** 9, 096020.
21. B. Labit *et al.* (466 authors), "Dependence on plasma shape and plasma fueling for small edge-localized mode regimes in TCV and ASDEX Upgrade", *Nuclear fusion*, 2019, **59**, 8, 086020.
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DEPARTMENT OF EXPERIMENTAL PARTICLE PHYSICS F-9

Departmental research is devoted to experimental studies of elementary particles, to reveal the ultimate building blocks of matter and the nature of the interactions between them. Experiments are carried out within large collaborative programmes at international centres for particle physics at CERN near Geneva and at KEK in Tsukuba. The department is also engaged in developing and applying the technologically advanced particle detectors that are demanded by such measurements. Astroparticle physics is an emerging field applying the experimental techniques of particle physics to solve astrophysical problems. Slovenian researchers are participating in measurements of ultra-high-energy cosmic rays with the Pierre Auger observatory spread over a surface of 3000 km² near Malargue in Argentina.

Head:
Prof. Marko Mikuž

In order to reveal the ultimate secrets of nature in the world of elementary particles, accelerators with higher and higher energies are needed. Their costs, both in terms of money and human resources, have grown to the level where they are affordable only as joint international enterprises. Thus, future accelerators will be unique facilities of their kind, the first being the Large Hadron Collider (LHC), just completed at the European Organization for Nuclear Research (CERN) near Geneva. Researchers will exploit this facility to perform experiments in presently inaccessible regions of energy, which, though pushed higher and higher, still remain minute compared to that of the vast blast of the Big Bang that led to the creation of the Universe.

Together with colleagues from the Physics Department of the Faculty of Mathematics and Physics and the Faculty of Electrical Engineering of the University of Ljubljana, and from the Faculty of Chemistry and Chemical Technology of the University of Maribor, we are performing measurements at CERN and the Japanese centre KEK in Tsukuba. We are taking part in two experiments, each conducted as an international collaboration:

- ATLAS at the Large Hadron Collider (LHC) at CERN (3000 researchers, 175 institutions from 38 countries),
- Belle II at the asymmetric electron-positron collider (KEK-B) at KEK (750 researchers, 101 institutions from 22 countries)

In the field of astroparticle physics we are part of the Pierre Auger collaboration (250 researchers, 94 institutions from 17 countries), which uses a giant scale (3000 km^2) observatory near Malargue in Argentina for detection of ultra-high-energy cosmic rays. This endeavour is carried out in collaboration with colleagues from the University of Nova Gorica.

A more detailed report on the 2019 activities follows, focused on the contributions of our researchers:

ATLAS experiment

The years 2015–2018 mark at CERN the data-taking period of the Large Hadron Collider (LHC) named "Run 2". In the year 2015 the upgraded Large Hadron Collider LHC began its operation at CERN and reached the record centre-of-mass energy of 13 TeV. The end of the "Run 2" of LHC operation subsequently finished at the end of 2018 with heavy-ion collisions (Pb-Pb) at the centre-of-mass energy of 5.02 TeV. In the current two-year period the detectors and colliders are being upgraded before the next re-start, which also gives us the much-needed time to analyse the data collected so far. The amount of the ATLAS experiment proton-proton collision data at 13 TeV in the years 2015–2018 reached the integrated luminosity of 150 fb^{-1} of exceptional data, whereby the LHC exceeded all expectations and facilitated the recording of the largest quantity of data at the ATLAS experiment so far. This set of unique data led to the most precise Run 2 searches of new physics beyond the Standard Model hitherto achieved. In the analysed data a considerable number of different theories were excluded and there are some indications of potential new discoveries in particle physics. However, for the confirming or refuting of these, the full set of recorded data needs to be analysed. Subsequently, the next year will still be full of challenges and expectations of pivotal events. In 2019 the ATLAS collaboration published more than 100 scientific papers in the most distinguished scientific journals [1], bringing the total number of scientific papers published by the collaboration to 900, with more than a hundred further papers in preparation.

In the analysed data a number of different theories were excluded and there are some indications for potential new discoveries in particle physics

The ATLAS Ljubljana group had a leading role in designing, building and operating several beam and radiation monitoring systems, namely: ATLAS Beam Condition Monitor (BCM), Beam Loss Monitor (BLM), Radiation

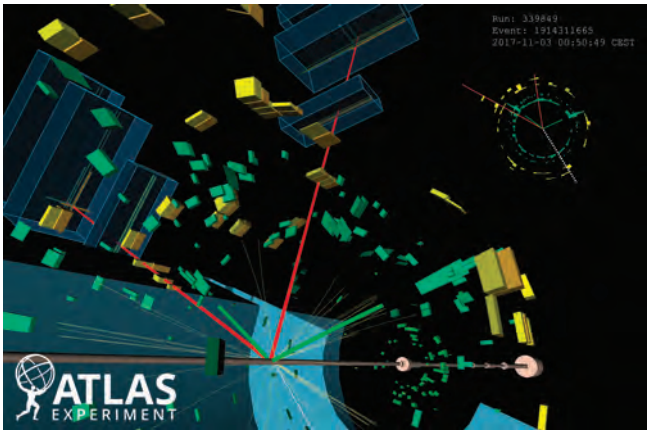

Figure 1: Event display of a 2μ2e ZH candidate in proton-proton collision at a centre-of-mass energy of 13 TeV. The red tracks are muons and the green tracks are electrons. This event is consistent with a VH candidate, with V=Z and Z→ νν or with V=W and W→ ℓν, where the charged lepton is outside the detector acceptance (or not reconstructed).

Monitor (RADMON) and Diamond Beam Monitor (DBM). BCM was built to monitor conditions of the LHC beams and issue warnings at unexpected and potentially dangerous situations. In the first part of LHC operation it served as the main luminosity monitor of ATLAS. BLM, on the other hand, is solely a safety system and protects the ATLAS Inner Detector from potential damage by LHC beams. It fired a few times and successfully extracted LHC beams and prevented potential damage to the detectors. RADMON records the doses received by different parts of the ATLAS Inner Detector. The newly built DBM was installed during the last shutdown and was used for the first time in 2015. It is built from a pCVD diamond sensor and a pixel readout chip with pixels of size 250×50 μm^2. It can provide luminosity measurements complementary to the BCM and other luminosity monitors in ATLAS. Its readout was first tested during the last operation with beams. For the High Luminosity upgrade we are developing yet another system to replace the current beam abort and luminosity monitors based on pCVD diamond sensors. A dedicated rad-hard ASIC readout chip for the new system has been developed, which will be used to amplify and discriminate the signals coming from the segmented pCVD diamond sensor

Belle detector at the asymmetric electron positron collider KEKB at K

Activities at the Belle and Belle II experiments, operating at the electron positron collider KEKB / SuperKEKB in Tsukuba, Japan, continued. The aim of experiments, belonging to the group of intensity frontier efforts, is a search for processes and particles, not included in the Standard Model (SM), commonly addressed as New Physics (NP); to do so, extremely precise measurement results are confronted to predictions of the SM. While the latter is considered as a very successful effective theory, it is believed that NP must exists and is responsible – among others – for the observed matter–antimatter asymmetry in the universe.

Activities at the Belle and Belle II experiments, operating at the electron-positron collider KEKB / SuperKEKB in Tsukuba, Japan, continued.

The Belle detector finished data taking in 2010, but analyses of several processes are still ongoing. Among the most noticeable results of the Belle collaboration in 2019 are the improved measurement of $B\rightarrow D^{*}\tau\nu$ decays [2] and a new measurement of $B\rightarrow K^{*}\ell^{+}\ell^{-}$ [3]. The former measurement tests the universality of various lepton flavours (e, μ, τ). The results do not point to significant deviations from the SM predictions. The latter measurement is a similar test in less abundant processes (the former decays proceed through a relatively frequent quark process $b\rightarrow c$, while the underlying process for the latter decay mode is a rare $b\rightarrow s$ transition). Also, here no deviations from theory predictions are observed within the experimental uncertainties.

In $B\rightarrow D^{*}\tau\nu$ measurement one of the B mesons created in $e^{+}e^{-}\rightarrow\Upsilon(4S)\rightarrow B\bar{B}$ is reconstructed through its semi-leptonic decay $B\rightarrow X_c\,\ell\nu$ (X_c denotes any system of hadrons composed of c quark). This enables energy and momentum determination for the other B meson (decaying into $D^{*}\tau\nu$ final state; note that because of τ decay there are at least two undetectable neutrinos in this final state). Despite the undetected neutrino it is hence possible to reconstruct the signal decays in order to compare their rate to those of $B\rightarrow D^{*}\mu\nu$ and $B\rightarrow D^{*}e\nu$. The ratio of these rates ($R(D^{(*)})=Br(B\rightarrow D^{(*)}\tau\nu)/Br(D^{(*)}\ell\nu)$, where $\ell = e$ ali μ) obtained from different Belle measurements is shown in 2.

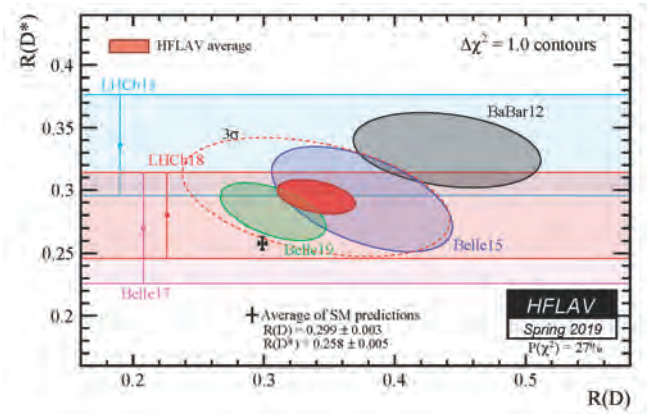

Figure 2: Average of R(D) and R(D) measurements (see text) compared to the SM prediction [2].*

The Belle II detector in 2019 continued taking data. The integrated luminosity is shown in Fig.3. The performance of the detector was good, with a few minor problems being dealt with as they appeared. In total, around 6 fb^{-1} of data was recorded in 2019. Using this data, the first publications were being prepared. Among those there is a search for potential dark-matter particles. Several models assume the existence of dark-matter constituents which, in rare cases, may be produced in electron-positron collisions at energies of the SuperKEKB collider. As an example, a dark gauge boson (Z'; a dark partner of the known Z^0 boson) with couplings to both SM and dark-matter particles might exist. It would be produced in $e^{+}e^{-}\rightarrow\mu^{+}\mu Z'$ and decay into dark-matter particles, which do not interact with ordinary matter and are hence undetected by the detector. The first

measurements using a partial set of data show that Belle II results will offer significantly tighter constraints on the coupling constant of *Z'* to SM particles than available from the existing measurements.

Pierre Auger observatory

The Pierre Auger Observatory is an international cosmic ray observatory in Argentina designed to detect ultra-high-energy cosmic rays: sub-atomic particles traveling nearly at the speed of light and each with energies beyond 10^{18} eV. In the Earth's atmosphere such particles interact with air nuclei and produce various other particles. Secondary particles forming the so-called "air shower" can be detected and measured in order to clarify the origin of the highest-energy primary particles and their properties, like energy, arrival direction and the particle type (photons, protons, atomic nuclei). But since these high-energy particles have an estimated arrival rate of just 1 per km^2 per century, the Auger Observatory has created a detection area of 3000 km^2 to be able to record a large number of these events. It is located in the western Mendoza Province, Argentina, near the Andes.

The Pierre Auger Observatory combines two complementary techniques to measure air showers. On their way through the atmosphere the secondary particles stimulate nitrogen molecules in the air to emit fluorescence light. This light is measured with large telescopes. In addition, secondary particles reaching ground level are registered in an array of particle detectors. The latter are water Cherenkov detectors, measuring the light emitted by relativistic particles passing through a water tank.

The Pierre Auger Collaboration had shown that the energy spectrum of cosmic rays exhibits a sharp drop around 10^{20} eV. This drop is compatible with the Greisen-ZatsepinKuz'min (GZK) cut-off caused by the universe becoming opaque due to resonant collisions between ultra-high-energy protons and the photons of the cosmic microwave 2.7 K background radiation. Past measurements by the Pierre Auger Collaboration have already cast some doubt on this explanation, and this year's results further established that the GZK cut-off cannot be the entire story and even the extent of its contribution to the cut-off remains unclear.

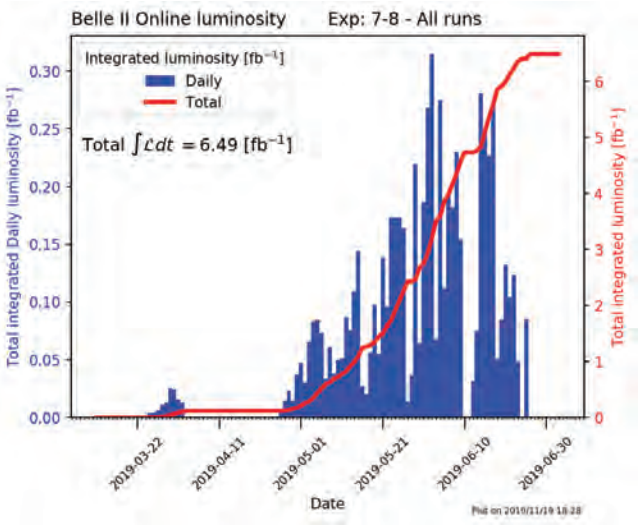

Figure 3: Integrated luminosity of SuperKEKB collider and Belle II detector in 2019.

Collisions of ultra-high-energy cosmic rays on atmospheric molecules provide hadronic interactions at an energy that exceeds the LHC centre-of-mass energy by one-to-two orders of magnitude. Although progress was made in incorporating LHC results, some mysteries were not solved. The number of muons in the Monte Carlo simulations is very significantly smaller than the number measured in the experimental data. Also, the depth at which most muons are produced that reach the Earth's surface cannot be described by Monte Carlo simulation for any reasonable compositional mix of cosmic rays.

The Pierre Auger observatory is currently upgrading its detection capabilities. The key element of the upgrade is the installation of a plastic scintillator on top of each existing surface-detector station. It will provide a complementary measurement of the showers, allowing the reconstruction of muons and electromagnetic particles. The surface scintillator detector stations (SSD) are being deployed over the full 3,000-km^2 area of the overall surface detector (SD). To enhance the capabilities of the surface detector, especially for composition measurements, it is being equipped with upgraded electronics with a larger sampling rate and a larger dynamic range.

Distributed computing

In 2019, the SiGNET Tier-2 center was running with 6600 CPU cores and 4.5 PB of storage space. The resources were mostly dedicated to the production and analyses of ATLAS data and Monte-Carlo simulation, and Belle II production. A smaller fraction was used by other departments at the Jožef Stefan Institute and external users in Slovenia. The general purpose NSC cluster at the Jožef Stefan Institute and the computing centre of ARNES are transparently included in the distributed computing infrastructure within the WLCG collaboration and the EGI infrastructure. In November, HPC.RIVR.UM, a new prototype HPC infrastructure at the University of Maribor was added to the grid and supercomputing infrastructure. The HPC was built from scratch and researchers from the F9 department helped to setup and configure the infrastructure. F9 was also participating in EuroHPC activities, preparing the procurement for the new Slovenian National HPC centre to be setup at IZUM, Maribor, one of the eight EuroHPC systems coming into operation late in 2020. F9 was also collaborating within the Leonardo consortium, one of the three pre-exascale HPC systems to be procured at Cineca, Bologna. SiGNET-T2 is a full member of the international organizations EGI/

Our department was also participating in EuroHPC activities, preparing the procurement for the new Slovenian National HPC centre

InSPIRE, wLCG and Nordugrid and participated in several joint projects related to the support, maintenance and planning of the computing infrastructure as well as the development, distribution and deployment of the distributed computing infrastructure.

Detector development

Most of the work on silicon detector development was performed in the framework of the ATLAS and CERN-RD50 collaborations. The group is also active in the development of diamond tracking detectors in the framework of the RD42 collaboration.

In the past year we continued the work on the development of High Granularity Timing Detector for ATLAS. We took the leading role in radiation studies of Low Gain Avalanche Detectors (LGAD), which are the choice for the sensor technology. We have evaluated thin LGADs from several producers and showed that the performance is similar for all. Extensive annealing studies were made during the last year. The dependence of gain on the fluence was precisely measured in the entire range of HL-LHC fluences and the measured time resolution (50-60 ps per sensor) was sufficient, also at the highest fluences providing <50-μm-thick sensors are used. At high fluences the multiplication takes place in silicon bulk as a consequence of the large space charge originating from the irradiation. The radiation tolerance of the LGAD is limited to fluences around ~1.5 10^{15} cm^{-2}, while at higher fluences the operation requires very close to break-down voltage. In order to avoid this, an alternative for LGADs was sought in small-cell-size 3D detectors, which were shown to be radiation hard in the whole HL-LHC range. We showed that these detectors when used with dedicated electronics can reach a time resolution similar to that of the LGADs.

Our group is active in the investigation of silicon detectors for the next generation of hadron colliders (e.g., FCC – Future Circular Collider).

In 2019 we continued the development of a multichannel system for the readout of different dosimetric sensors for medicine and nuclear technology. Extensive irradiation studies were performed with RadFETs. These are sensors suitable for remote online micro-dosimetry in medicine and for radiation monitoring in ATLAS ITk. Our group is leading the development of a radiation monitoring system for ATLAS ITk. ITk is the tracking system in ATLAS after the upgrade to HL-LHC.

We continued the studies of depleted CMOS detectors, the technology of monolithic detectors for highly radioactive environments. Our work was concentrated on the measurements of radiation-damage effects on the charge-collection properties of CMOS detectors from different producers [4]. We established the universal relation between the irradiation fluence and the effective doping concentration and made comprehensive studies of the initial dopant removal both with reactor neutron and 24 GeV protons. In 2019 we took part in test beam measurements with CMOS detectors.

Our group is active in the investigation of silicon detectors for the next generation of hadron colliders (e.g., the FCC – Future Circular Collider). Work in this field includes measurements of the silicon detector's response after exposure to neutron fluences beyond 10^{17} n/cm^2. In 2019 we made systematic measurements of the charge collection with planar detectors irradiated up to 10^{17} n/cm^2.

Our group collaborated in the development of diamond detectors, more precisely in studies of the effects of irradiation with protons or neutrons on detectors made from poly-crystal or single-crystal artificial diamond. Interesting measurements were made with 3D diamond detectors. Similarly, as in silicon, in 3D detectors electrodes are made in holes drilled through the diamond. This shortens the drift distance of the charge carriers and improves the charge-collection efficiency. With TCT measurements exploring two photon-absorption processes, three-dimensional mapping of the diamond detectors was measured.

In 2019 we began a new phase of the development of novel Cherenkov Ring Detectors (RICH). For the upgrade of the Belle II detector in the forward region and for the upgrade of the Cherenkov ring detectors of the LHCb spectrometer, we are developing a single photon sensor that will be very fast, will have fine granulation, will be sensitive to light with long wavelengths and will also withstand large radiation levels, mainly due to neutrons. As a part of this activity, we have also intensified our collaboration with the LHCb experiment by becoming its associated technical members. In the field of the development of detectors for medical imaging, we have continued to develop ultra-fast detectors for time-of-flight positron emission tomography (TOFPET) using Cherenkov radiation. We measured the efficiency for the detection of annihilation gamma rays using a matrix of PbF_2 crystals and silicon photomultipliers as light sensors, and have shown that it would allow a successful application in the TOFPET scanner [5]. We also explored the possibilities of a scanner that would use three layers of shorter crystals with SiPM sensors for each of the layers, instead of a single layer of crystals and light sensors, a combination of quick response and excellent efficiency. The encouraging results have received considerable attention, and a report of the study has already been published in one of the central journals of the field.

Within the framework of the European project AIDA 2020 (Advanced European Infrastructures for Detectors at Accelerators) more than 150 irradiations by neutrons were performed at the reactor centre at the request of 15

different institutions. The focus was on the development of components for planned upgrades of the ATLAS, CMS and Belle detectors.

Some outstanding publications in the past year

1. ATLAS Collaboration, "Combination of Searches for Invisible Higgs Boson Decays with the ATLAS Experiment", Phys. Rev. Lett. 122, 231801 (2019).
2. Hiti et al., *Charge collection in irradiated HV-CMOS detectors.,* Nucl. Instr. and Meth. A924 (2019) 214-218

Organization of Conferences, Congresses and Meetings

1. "RECFA visit to Slovenia - Open Session", Jožef Stefan Institute, Ljubljana, Slovenia, 5–6 April 2019
2. Workflow Management Software Technical Interchange Meeting, Jožef Stefan Institute, Ljubljana, Slovenia, 13–15 May 2019

INTERNATIONAL PROJECTS

1. COST CA16108 - VBSCan; Vector Boson Scattering Coordination and Action Framework
   Prof. Borut Paul Kerševan
   Cost Office
2. COST VBSCan; Vector Boson Scattering Coordination and Action Framework
   Prof. Borut Paul Kerševan
   Cost Association Aisbl
3. H2020 - JENNIFER; Japan and Europe Network for Neutrino and Intensity Frontier Experimental Research
   Prof. Peter Križan
   European Commission
4. H2020 - AIDA-2020; Advanced European Infrastructures for Detectors at Accelerators
   Prof. Marko Mikuž
   European Commission
5. H2020 - JENNIFER2; Japan and Europe Network for Neutrino and Intensity Frontier Experimental Research 2
   Prof. Rok Pestotnik
   European Commission
6. H2020 - ATTRACT; Real-time Flourescence Lifetime Acquisition System (RfLAS)
   Dr. Rok Dolenec
   Embl - European Molecular Biology Laboratory
7. Fabrication and Qualification of NürFETs Dosimeters for use at Nuclear Reactors
   Dr. Gregor Kramberger
   Slovenian Research Agency
8. Development of Segmented Silicon and Diamond Radiation Sensors and Readout Electronics for Particle Physics and Medical Diagnostics
   Asst. Prof. Igor Mandić
   Slovenian Research Agency
9. Study of Portion and Spatial Resolution of High-Resolution Events on Image Quality in Hybrid Resolution PET Systems
   Prof. Vladimir Cindro
   Slovenian Research Agency

RESEARCH PROGRAMMES

1. Astroparticle Physics
   Prof. Marko Zavrtanik
2. Experimental Particle Physics
   Prof. Marko Mikuž

R & D GRANTS AND CONTRACTS

1. New atmospheric monitoring devices and techniques for Imaging Atmospheric Cherenkov Telescopes
   Prof. Marko Zavrtanik
2. Advanced detector for Time-of-Flight PET based on Cherenkov radiation
   Prof. Samo Korpar
3. Depleted CMOS Sensors for the ATLAS Tracker Upgrade and Future Collider Experiments
   Prof. Marko Mikuž
4. Advanced hadron identification methods for Belle II
   Prof. Peter Križan
5. Development of High Granularity Timing Detector for ATLAS experiment
   Dr. Gregor Kramberger
6. Collaboration CERN RD-39
   Prof. Marko Mikuž
   Cern
7. Collaboration CERN RD-50
   Prof. Marko Mikuž
   Cern
8. Member of Resources review board at ATLAS experiment (CERN)
   Prof. Marko Mikuž
   Ministry of Education, Science and Sport
9. Member of Restricted European Committe for Future Accelerators (RECFA) and Plenary ECFA (PECFA)
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   Ministry of Education, Science and Sport
10. Collaboration DELPHI
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11. Collaboration ATLAS
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12. Collaboration CERN RD-42
    Prof. Marko Mikuž
    Cern
13. Collaborations Belle in Belle II
    Prof. Peter Križan
    Kek - High Energy Accelerator Research
14. Design, Procurement and QA of Flex-rigid Hybrids
    Prof. Marko Mikuž
    European Organization For Nuclear Research
15. Irradiations in TRIGA Nuclear Reactor
    Prof. Vladimir Cindro

VISITORS FROM ABROAD

1. Prof Shohei Nishida, KEK, Tsukuba, Japan, 9 January – 11 January 2019
2. Dr Marko Milovanović, DESY, Hamburg, Germany, 1 March – 3 March 2019
3. Prof Aire Ruzin, School of Electrical Engineering, Tel Aviv University, Tel Aviv, Israel, 12 September 2019
4. Dr Roy Wastie, Oxford University Oxford, Great Britain, 19–28 September 2019
5. Prof Neville Harnew, Oxford University Oxford, Great Britain, 30 September 2019
6. Dr Maxim Titov, CEA, Saclay, Gif sur Yvette Cedex, France, 14 –15 October 2019
7. Ozan Yilmaz, Abant Izzet Baysal University, Bolu, Turkey, 2 –9 November 2019
8. Umutcan Gürer, Abant Izzet Baysal University, Bolu, Turkey, 2 –9 November 2019
9. Hüseyin Karaçali, Abant Izzet Baysal University, Bolu, Turkey, 4–9 November 2019
10. Ercan Yilmaz, Abant Izzet Baysal University, Bolu, Turkey, 4–9 November 2019
11. Raffaele Giordano, University of Naples Federico II, Naples, Italy, 6 December 2019
12. Dr Ezio Torassa, INFN, Padova, Italy, 12–13 December 2019

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Original Article

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3. A. Acharyya *et al.* (470 authors), "Monte Carlo studies for the optimisation of the Cherenkov Telescope Array layout", *Astroparticle Physics*, 2019, **111**, 35-53.
4. Rok Dolenec, Elmar Laistler, Matija Milanič, "Assessing spectral imaging of the human finger for detection of arthritis", *Biomedical optics express*, 2019, **10**, 12, 6555-6568.
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19. ATLAS Collaboration, G. Aad *et al.,* "Measurement of the inclusive cross-section for the production of jets in association with a Z boson in proton-proton collisions at 8 TeV using the ATLAS detector", *The European physical journal. C*, 2019, **79**, 10, 847.
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Theses and Mentoring

1. Gašper Kukec Mezek, *Mass composition of ultra-high energy cosmic rays at the Pierre Auger Observatory:* doctoral dissertation, Nova Gorica, 2019 (mentor Andrej Filipčič).
2. Marta Trini, *Search for neutrinos at extreme energies with the Pierre Auger Observatory:* doctoral dissertation, Nova Gorica, 2019 (mentors Danilo Zavrtanik, Jaime Alvarez-Muñiz).

DEPARTMENT OF INORGANIC CHEMISTRY AND TECHNOLOGY K-1

The Department of Inorganic Chemistry and Technology is one of the leading groups in the world for the synthesis of new inorganic compounds containing fluorine. The main research fields are the synthesis of new coordination compounds with different ligands, the chemistry of noble gases, the chemistry of elements of the main groups, the synthesis of new hybrid materials and inorganic materials with special properties. A great deal of the activity of the group has been devoted to technological, ecological and process safety issues in Slovenia. The group has already been cooperating closely with Slovenian industry for more than 30 years. It is also active in the field of education and in the field of the promotion of natural sciences among students at colleges and elementary schools.

Head:
Asst. Prof. Gašper Tavčar

In the field of noble-gas/fluorine chemistry, new compounds were synthesized and characterized. Single crystals of $[Xe_2F_{11}]_2[SnF_6]$, $[Xe_2F_{11}]_2[PbF_6]$, and $[XeF_5]_4[Sn_5F_{24}]$ were grown from saturated aHF solutions upon crystallization. The crystal structures of isotypic $[Xe_2F_{11}]_2[SnF_6]$ and $[Xe_2F_{11}]_2[PbF_6]$ consist of $[Xe_2F_{11}]^+$ cations and $[MF_6]^{2-}$ anions (M = Sn, Pb) that interact by means of fluorine bridge contacts. The single-crystal structure determination of $[XeF_5]_4[Sn_5F_{24}]$ reveals that it is built of two-dimensional $([Sn_5F_{24}]^{4-})_\infty$ grids and $[XeF_5]^+$ cations located between them. The 2D grids have a wave-like conformation. The $([Sn_5F_{24}]^{4-})_\infty$ layer contains both six- and seven-coordinated Sn(IV) interconnected by bridging fluorine atoms. The crystal-structure determination of $[XeF_5]_4[Sn_5F_{24}]$ revealed the first example of a structurally characterized Sn(IV) fluoride compound which does not consist just of $[SnF_6]^{2-}$ anions.

The $([Sn_5F_{24}]^{4-})_\infty$ layer contains both six- and unique seven-coordinated Sn(IV) interconnected by bridging fluorine atoms.

Our research also focused on the use of a boron-doped diamond electrode as a sufficiently stable electrode for electrochemical measurements/synthesis in a liquid anhydrous hydrogen fluoride medium. The electrooxidation of silver(I) was studied in this solvent by using classic transient electrochemical methods and impedance spectroscopy. It was found that faradaic currents related to silver(I) oxidation and the fluorine evolution reaction are reasonably separated on the potential scale that allows for the efficient electrosynthesis of $Ag(II)F_2$, a powerful oxidizer. Impedance spectroscopy measurements provide an insight into the complex mechanism of AgF_2 formation. The procedure for electrosynthesis is provided for the first time in both galvanostatic and potentiostatic conditions.

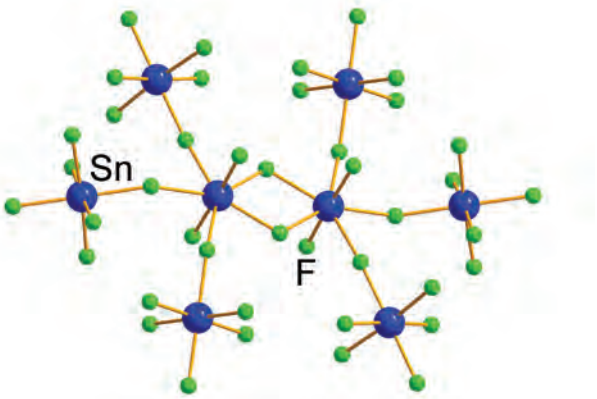

Figure 1: Part of the layer in the crystal structure $(XeF_5)_4(Sn_5F_{24})$

In the scope of on-going research of high-surface-area materials, we have reported the preparation of amorphous CrF_3-based materials with exceptionally high specific surface areas in the range 180–420 $m^2\,g^{-1}$ (HS-CrF_3). This novel class of fluoride materials was obtained by the reaction of the $[N_2H_6][CrF_5]\cdot H_2O$ precursor with fluorine (F_2) in an anhydrous hydrogen fluoride (aHF) medium at room temperature. It was found that the stepwise reaction starts with the oxidative decomposition of the cationic part of the precursor with F_2, in which a CrF_3 intermediate with a low surface area is formed. In the following steps, part of the Cr^{3+} is oxidized to $Cr^{>3+}$, and in the presence of residual $H_2O/[H_3O]^+$ species $Cr^{>3+}$ fluoride oxides are formed. The formation of volatile chromium compounds, mainly CrO_2F_2, is apparently the key step that leads to the formation of HS-CrF_3. The HS-CrF_3 materials are Lewis acids and exhibit a high reactivity towards some F/Cl exchange reactions. These features are ascribed to the nanoscopic nature, exceptionally high surface area, and low levels of residual impurities exhibited by these new materials.

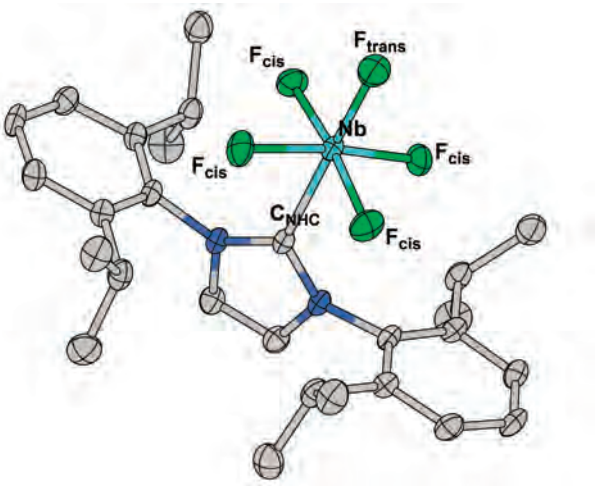

Figure 2: Structure of $[(L^{Dipp})NbF_5]$

The first-known copper(I) cyanate pi-complex which was synthesized and characterized in cooperation with the Ivan Franko University from

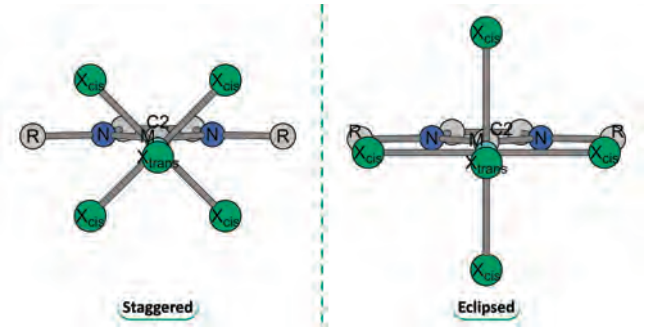

Figure 3: View on the staggered and eclipsed conformations of N-heterocyclic carbene (NHC) with MX_5 complexes

Uncontrolled release of gasseous fluoride can be detected in different plant species

Figure 4: Acta Chimica Slovenica, Issue No. 2, 2019, cover page presenting the review article Fluoride in human health and nutrition by authors Dona Štepec and Maja Ponikva-Svet

Lviv. A number of copper(I) pi-complexes with heterocyclic ligands were also synthesized and explored.

Our work in the field of carbene chemistry continued with reactions of niobium(V) and tantalum(V) fluoride (NbF_5, TaF_5) with N-heterocyclic carbene (NHC) ligand and led to the formation and isolation of the corresponding $[(L^{Dipp})MF_5]$ (M = Nb, Ta) complexes. While related chloride complexes were structurally characterized before, there were no known structurally characterized transition-metal pentafluoride complexes. Despite the expected similarity in the structure, fluorides behave differently to the corresponding chlorides in terms of the orientation of the MF_5 unit in relation to the NHC ring. In cooperation with the Department of Physical and Organic Chemistry at Jožef Stefan Institute we analysed, by means of DFT calculations, MX_5 (M = Nb, Ta; X = F, Cl) complexes with different substituents on the NHC ("wingtips"). We showed that as soon as the groups are sufficiently small the equatorial halide atoms orient themselves in a staggered position. As the groups on the NHC ring, become larger the smaller MF_5 remains in staggered conformation, whereas the MCl_5 unit changes orientation toward the eclipsed conformation.

The work of the department in the field of environmental science was based on total fluorine determination in certain samples of vegetation like spruce needles and leaves of bean, peach, hornbeam and grape wine we managed to prove the uncontrolled release of gaseous fluorides from Rogaška Slatina glassworks and to determine the dispersion pattern. In this study, we employed our recently developed procedure for a measurement-uncertainty evaluation for the determination of the total fluorine in vegetation, which also enabled an examination of compliance with the regulations. Possible positive and adverse effects of fluoride on human health were described in a review article. This article was presented on the cover of the Acta Chimica Slovenica journal. We contributed a chapter to an edited book dealing with the chemistry of hypervalent halogen compounds.

Within the topic of the process safety, in 2018 we researched and published work on the topics of the introduction of safe use of the liquefied natural gas (LNG) for ships' propulsion (European project SUPER-LNG and consultation services for Port of Koper), the relationship between leadership styled and safety management systems in industrial organizations, and the resilience and protection of sensitive industrial sites and plants (critical infrastructure) against physical, cybernetic, technology hazards and extreme natural phenomena (European project InfraStress).

We continued with our activity in the field of education and the promotion of sciences should be mentioned. Members of the department were actively engaged in the work of the Jožef Stefan International Postgraduate School as lecturers and as mentors to M.Sc. and Ph.D. students. In addition, the School of Experimental Chemistry maintained its very important relations with elementary, secondary schools

Figure 5: School of Experimental Chemistry at Researchers Night 2019 (Photo: Marjan Verč)

and even kindergartens through experimental courses performed in a specialized laboratory or through direct demonstrations at the schools. With demonstrations of chemical experiments, we participated at the Hokus pokus festival, Znanstival, Slovenian Science Festival, and others. Some of the activities of the School of Experimental Chemistry were carried out within a project that is funded by the JSI and the City of Ljubljana.

Promotion of science, research, and non-formal education is also linked to the European Action Researcher's night under the Horizon 2020 program. At the end of September 2019, we organized and carried out a series of activities in the frame of this H2020 project. The workshops of the School of Experimental Chemistry were presented at primary and secondary schools, senior citizens' homes, the library and in the centre of Ljubljana. In the evening, in cooperation with the research departments and centres of the Jožef Stefan Institute, we opened the doors of the institute in Ljubljana and Podgorica. Visitors were able to see some of the departments and centres, visit the nuclear reactor TRIGA and participate in various workshops.

Some outstanding publications in the past year

1. Z. Mazej, E. A. Gorehnik, Crystal structures of photochemically prepared $(Xe_2F_{11})_2(MF_6)$ (M = Sn, Pb) and $(XeF_5)_4(Sn_5F_{24})$ containing six- and seven-coordinated Tin(IV), *European Journal of Inorganic Chemistry*, (2019), 1265-1272
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4. G. Tavčar, T. Skapin, High surface area chromium(III) fluoride: preparation and some properties,*Journal of fluorine chemistry*, 222/223 (2019) 81-89
5. D. Štepec, G. Tavčar, M. Ponikvar-Svet, Fluorine in vegetation due to an uncontrolled release of gaseous fluorides from a glassworks : a case study of measurement uncertainty, dispersion pattern and compliance with regulation, *Environmental pollution*, 248 (2019) 958-964
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Awards and Appointments

1. Blaž Alič, Matic Lozinšek, Mirela Dragomir, Kristian Radan, Director's fund project for 2019, Jožef Stefan Institute, for the project entitled Extreme Conditions Chemistry Laboratory

Organization of conferences, congresses and meetings

1. Matic Lozinšek, Member of the organizing committee, Slovenian Chemistry Days 2019, 25.–27. 9. 2019, Maribor, Slovenia

INTERNATIONAL PROJECTS

1. Extraction of Tantalum and Niobium from Ores
   Asst. Prof. Gašper Tavčar
   Prg Ltd.
2. H2020 - NOCMOC; European Researchers' Night (NIGHT)
   Dr. Melita Tramšek
   European Commission
3. H2020 - InfraStress; Improving Resilience of Sensitive Industrial Plants & Infrastructures Exposed to Cyber-Physical Threats, by Means of an Open Testbed Stress-Testing System
   Prof. Marko Gerbec
   European Commission
4. The Development of a Nondestructive Analytical Method for the Screening of Upconverting Nanoparticles Surface Properties Based on Optical Characterization
   Prof. Maja Ponikvar-svet
   Slovenian Research Agency
5. High-Pressure Structural Study of Hydrated Metal Salts of Superweak (B12F12)2- Anion
   Dr. Matic Lozinšek
   Slovenian Research Agency

RESEARCH PROGRAMME

1. Inorganic Chemistry and Technology
   Asst. Prof. Gašper Tavčar

R & D GRANTS AND CONTRACTS

1. Evaluation of greenhouse gasses mitigation measures in industry
   Dr. Robert Kocjančič
2. SUstainability PERformance of LNG-basedmaritime mobility
   Prof. Marko Gerbec
   Rhe Emillia-romagna Region
3. Innovative ECO plasma seed treatment (for sowing and for human and animal diet/

nutrition
Asst. Prof. Gašper Tavčar
Ministry of Education, Science and Sport

4. Evaluation of greenhouse gasses mitigation measures in industry
Dr. Robert Kocjančič
Ministry of the Environment and Spatial Planning

NEW CONTRACT

1. The aspect of safety for the ships bunkering operation with Liquefied Natural Gas (LNG) in the port of Koper
Prof. Marko Gerbec
University of Ljubljana

VISITOR FROM ABROAD

1. Agnieszka Starobrat, Wojciech Wagner; training and work in the laboratory, Center of New Technologies, University of Warsaw, Warsaw, Poland, 27.5.2019 - 14.6.2019
2. Dr Rafał Jurczakowski, Dr Piotr Połczyński; CNBCh, University of Warsaw, Warsaw, Poland, 4.8.2019 - 15.8.2019
3. Prof. dr. Judith A. K. Howard; Institute colloquium and SKD 2019, Durham University, Department of Chemistry, Durham, United Kingdom, 23.9.2019 - 25.9.2019
4. Malina Jop; Working practice IAESTE at IJS, Montanuniverstiy Leoben Austria, Graz, Austria, 2.9.2019 - 11.10.2019

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Independent Component Part or a Chapter in a Monograph

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DEPARTMENT OF PHYSICAL AND ORGANIC CHEMISTRY K-3

The department is focused on investigating the physicochemical processes on the surfaces of solids, such as corrosion and heterogeneous catalysis, as well as the synthesis of new compounds. The synergy of these two fields is created in the studies of corrosion protection and functionalization of materials.

Head:
Prof. Ingrid Milošev

Our experimental and theoretical investigations of elementary physicochemical processes on solid surfaces are focused on the field of corrosion, corrosion protection and catalysis. Corrosion is a widespread phenomenon with significant economic and environmental impacts. Because of the enormous costs, the protection of metals and alloys is essential. In-depth basic knowledge of surface processes is needed to design effective corrosion protection, since understanding the mechanism of the inhibition of corrosion at the atomic level is still extremely limited. To overcome this, we introduced a synergistic iterative process into the research, combining the synthesis of new compounds, electrochemical and surface analytical techniques, and modelling and simulation of processes based on first principles. Such a newly established research strategy is expected to boost the innovative design of advanced sustainable solutions in the protection of materials.

We are focused on alloys based on aluminium and copper, as well as steel and other technologically important materials. Lightweight aluminium alloys are used in various applications, especially in the transport industry, where there is a great need to reduce the weight of vehicles and consequently reduce emissions into the environment. Steel and alloys based on copper are indispensable materials in the field of infrastructure, construction, etc. Traditional ways of corrosion protection such as conversion chromate coatings can no longer be used due to ecological restrictions. Over the past decade, various alternatives have been explored, among which the most important are sol-gel coatings, conversion coatings, superhydrophobic coatings and various inorganic and organic inhibitors. The needs of industry, in particular, transport, construction, machine and electronics, require the development of efficient, sustainable and environmentally friendly coatings, which at the same time exhibit additional functional characteristics. In our laboratory we investigate all of the above-mentioned alternatives and even combine them with each other, e.g., sol-gel coatings and inhibitors, in order to achieve not only barrier protection, but also active protection, where the coating after corrosion damage is able to self-heal. We also introduce modern methodologies, such as the atomic-layer deposition, in corrosion protection. Review papers that summarize contemporary modes of corrosion protection developed in our laboratory were published in the journal *Acta Chimica Slovenica* (Figure 1).

In the presence of sulphate ions, a coating is formed in the solution of sodium chloride and cerium (III) acetate on the surface of the aluminium alloys, which is homogeneous and free from cracks and defects. Its dense structure and low solubility contribute to an inhibitory effect that lasts much longer than in the absence of sulphate ions. A cerium coating formulation containing acetate and sulphate ions is a good candidate for modern anti-corrosion protection.

Figure 1: Front page of the journal Acta Chimica Slovenica, year 2019, volume 66, number 3, featuring the review paper "Contemporary modes of corrosion protection and functionalization of materials" by Ingrid Milošev.

Conversion coatings can be defined as coatings formed by conversion from a soluble salt to a slightly soluble or insoluble oxide and/or hydroxide, which precipitates either throughout the metal surface, or at intermetallic particles that are electrochemically more noble with respect to the surrounding matrix and where oxygen reduction takes place. Conversion coatings based on the salts of rare earths, zirconium or titanium are an important research direction in the search for novel corrosion protection. Our previous studies on conversion coatings based on rare earths (cerium and lanthanum) were continued, aiming to investigate whether it is possible to achieve a synergistic effect between different salts.

Cerium(III) acetate was taken as the basic formulation, since it was proven to be the salt with best performing inhibition characteristics in our previous studies. We investigated the formation of protective layers on the surface of the aluminium alloy 7075-T6 in NaCl and in NaCl containing a corrosion inhibitor Ce(III) acetate, $Ce(OAc)_3$, and various sodium salts (NaOAc, $NaNO_3$ and Na_2SO_4) aiming to evaluate the synergism between cerium cations and acetate, nitrate and sulphate anions. When added to NaCl solution alone, $NaNO_3$ and Na_2SO_4 act as corrosion inhibitors, and NaOAc acts as corrosion accelerator. $Ce(OAc)_3$ cathodically protects the AA7075-T6 in the NaCl solution only at neutral pH by the formation of cerium-based deposits, mainly at cathodic sites. The addition of $Ce(OAc)_3$ to NaCl produces a buffering effect, maintaining the solution pH at 8.3 up to ratio $n_{OH^-}/n_{Ce^{3+}}$ of 1.42.

The addition of $NaNO_3$ or NaOAc has an adverse effect on the $Ce(OAc)_3$ action as worse electrochemical values were obtained compared to a solution containing only $Ce(OAc)_3$. This may be due to surface passivation with nitrate anions, which decreases the inhibition efficiency of cerium hydroxide precipitation, and the acceleration of dissolution in the presence of acetate anions, respectively.

The addition of Na_2SO_4 has a synergistic effect on the action of $Ce(OAc)_3$. The buffer region is narrower and cerium hydroxide precipitates at lower pH, which also affects the stoichiometry of the precipitated cerium hydroxide/oxide. Sulphate ions are incorporated in the precipitated product, $Ce(OH)_a(SO_4)_b$, which has very low solubility in water. In the presence of SO_4^{2-}, the formation of insoluble Ce(IV) species is favoured, which may be the reason for the improvement in layer protectiveness. Therefore, when combining $Ce(OAc)_3$ and Na_2SO_4 in NaCl, acetate anions provide the buffering capacity of solution, cerium cations are essential for the deposition of insoluble hydroxide deposits, while sulphate anions lower the pH required for precipitation of deposits and incorporate in the deposited product.

We showed by means of an integrative approach, consisting of electrochemical testing, surface science experiments and molecular modelling, that linear carboxylic acids have the ability to make aluminium superhydrophobic and to enhance its corrosion resistance, provided that their alkyl chains are long enough to make the protective organic film sufficiently stable.

A long-term, 1-month immersion test on scribed samples was used to follow the efficiency of combinations of different anions added to a NaCl solution. The morphology of the precipitated products was dependent on the type of anion. The best inhibition efficiency was achieved when $Ce(OAc)_3$ and Na_2SO_4 were added to NaCl solution. Samples of AA7075-T6 were able to self-heal, as confirmed by surface analysis methods. Therefore, under such conditions, active corrosion protection on the damaged sites was achieved.

Synergy between acetate and sulphate anions was further investigated for the aluminium alloy 2024-T3, which contains copper as the main alloying element. The effect of the addition of various amounts of Na_2SO_4 in a NaCl+$Ce(OAc)_3$ solution on the corrosion performance of AA2024-T3 was investigated. Several important findings could be summarised. The presence of 30-mM Na_2SO_4 was found to be optimal, resulting in more than 5 weeks of stable inhibition. Sulphate ions primarily affect the morphology of the formed cerium-based precipitates. Atomic force microscopy (AFM) and scanning Kelvin probe force microscopy (SKPFM) techniques confirm that after immersion in NaCl+$Ce(OAc)_3$ and NaCl+$Ce(OAc)_3$+ Na_2SO_4 solutions, the galvanic difference between the cathodic/anodic intermetallic particles and the matrix is reduced, thus leading to a diminished susceptibility to localised corrosion. The reduction of the magnitude of the Volta potential is related to the formation of the cerium film, starting from the intermetallics and covering progressively the surrounding matrix. In the presence of sulphate ions in solution a more homogeneous, crack- and defect-free cerium film is formed. Its dense structure contributes to the inhibition effect, which lasts much longer than in its absence. The overall corrosion protection of the formed film is better than other Ce-based studied systems, which makes it a good candidate for a conversion coating (Figure 2).

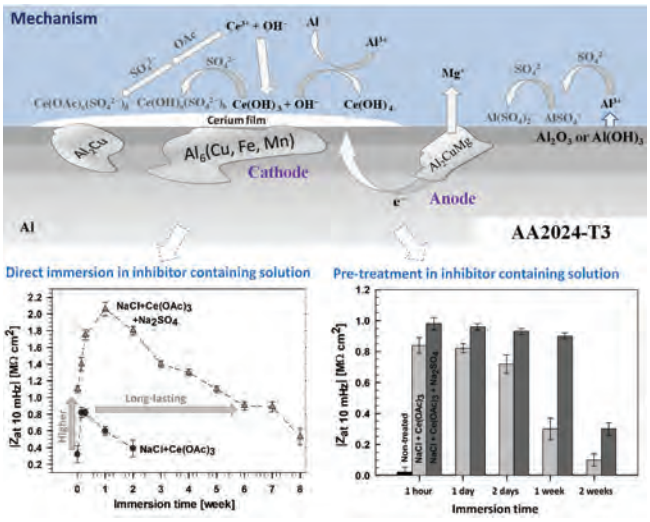

Figure 2: Upper row: Schematically presented precipitation of cerium species mainly on the cathodic sites ($Al_6(Cu,Fe,Mn)$, Al_2Cu) and aluminium surface, meanwhile the Mg is slowly dissolved from anodic sites (Al_2CuMg). The adsorption of sulphate ions on the aluminium surface and the incorporation in the coordinated compounds with the cerium ions is also presented, Lower row left: Impedance magnitude at 10 mHz for the alloy AA2024-T3 as a function of immersion time up to eight weeks in NaCl+$Ce(OAc)_3$ solution without and with added different concentrations of Na_2SO_4. Lower row right: Impedance magnitude at 10 mHz for the alloy AA2024-T3 as a function of immersion time up to four weeks in NaCl, NaCl+$Ce(OAc)_3$ and NaCl+$Ce(OAc)_3$+Na_2SO_4 solutions.

Among conversion coatings we also investigated commercial hexafluoro-zirconate trivalent chromium coatings (SurTec® 650) deposited on a chemically cleaned aluminium alloy 3003. The morphology, composition and corrosion properties were studied. Coatings were deposited at room temperature using different concentrations of SurTec 650 (10, 25 and 50 vol. %) and different conversion times (90 s, 11 min and 18 min). Scanning electron microscopy with energy-dispersive X-ray spectrometry (SEM-EDS), X-ray photoelectron spectroscopy (XPS) and time-of-flight secondary ion mass spectrometry (ToF-SIMS) were employed to investigate the surface morphology, composition and thickness of uncoated and coated AA3003 samples. The morphology of the coating varied from uniform nodular to non-uniform and cracked; coatings were deposited at intermetallic particles and at the alloy matrix. The main constituents of the conversion coatings are Zr(IV) and Cr(III) oxides; in addition to oxides, fluorides are also formed. The corrosion properties were investigated in two solutions: more-aggressive sodium NaCl and less-aggressive simulated acid rain. These commercial conversion coatings exhibited good corrosion resistance but only after longer immersion in solution, i.e., 24 h. The results reveal an interesting behaviour of zirconate-based coatings on aluminium-manganese alloy, which was then investigated in more details in our further studies.

An especially important part of our research comprises various hybrid sol-gel coatings designed to protect aluminium alloys or steel in a chloride environment. We are currently investigating four types of coatings in

our laboratory, which are designated as GTS and GTS-Ce, TMZ, TMM and ZG. For the preparation of hybrid, i.e., inorganic-organic, silicon sol-gel GTS coatings, precursors tetraethyl orthosilicate (TEOS) and organically modified silane precursor 3-glycidoxypropyl trimethoxysilane (GPTMS) are used. The sol also contains particles of silicon dioxide to achieve the barrier properties of the coating. To achieve the inhibition properties, cerium(III) nitrate is added to sol (GTS-Ce label). Coatings TMZ are prepared from TEOS and an organically modified silane precursor of 3-methacryloxy propyltrimethoxysilane (MAPTMS), which was then mixed with different amounts of zirconium(IV) propoxide, chelated with methacrylic acid (MMA). Polysiloxane coatings TMM is also acrylate-based combining MAPTMS copolymerized with methyl methacrylate, and hydrolysed TEOS. Coatings ZG are prepared from ZTP and GPTMS precursors, whereas as-catalysed acetic acid was used. All these coatings offer good corrosion protection of aluminium alloys. In addition to their protection properties, we also studied the mechanism of synthesis and their physical and chemical properties. More details are given for the GTS+Ce coating. As mentioned above, it contains Ce(III) nitrate. However, it is not clear whether the protection results from the corrosion inhibition effect alone or from the cerium effect on the sol-gel network. Thus, the role of cerium addition as well as of the curing temperature on the network structure was studied by several techniques. Liquid-state nuclear magnetic resonance spectroscopy (^{29}Si NMR) and solid-state magic angle spinning nuclear magnetic resonance spectroscopy (^{29}Si MAS/NMR) were used to study the chemical composition and degree of polycondensation of inorganic and organic networks as a function of the curing temperature and cerium content. The addition of cerium leads to a higher degree of inorganic and organic polymerisation in the hybrid sol-gel coatings, especially at lower temperature. This facilitates the production of more compact coating while curing already at room or lower temperatures. Cerium act as a Lewis acid and thus can facilitate the reaction of hydrolysis of the inorganic part and the opening of the epoxy rings of the organic phase of the network.

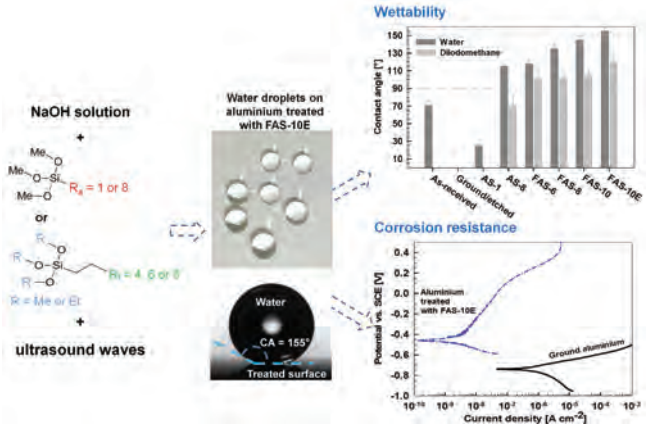

Figure 3: Schematic presentation of synthesis of alkyl- and perfluorsilane coatings on aluminium surface. Hydrophobic and superhydrophobic coatings exhibit corrosion protection properties, as well as self-cleaning and anti-icing abilities.

The sol-gel methodology offers many possibilities for the synthesis of coatings with various functional properties. One of them is hydrophobicity, which is then the basis for applications such as self-cleaning and anti-icing. A study aimed to fabricate a highly hydrophobic aluminium surface in a one-step ultrasound process in a sodium hydroxide solution containing various alkoxysilanes. The latter were based on the trimethoxysilane of various type and length of the introducing group at the silyl bond (Si–C): R_a-Si(OMe)$_3$ and R_f-(CH$_2$)$_2$-Si(OMe)$_3$, where R_a and R_f are alkyl and perfluoroalkyl introducing groups, respectively, and OMe is the methoxy group. The effect of methoxy and ethoxy groups at the siloxy (Si–O–Si) bond was additionally investigated for perfluorodecyl silanes. The corrosion performance was studied using potentiodynamic electrochemical techniques. The wettability, morphology, surface topography and surface composition of the treated aluminium surfaces were characterised using an optical tensiometer, a scanning electron microscope coupled with an energy-dispersive X-ray spectrometry system, a contact profilometer and a Fourier-transform infrared spectroscopy system. Micro-/nanostructures formed on the treated aluminium surfaces led to an increase in the water contact angle from 71° for ground surface, up to 115° for the surface treated with alkyl silanes and up to 155° for that treated with fluoroalkyl silanes with a long chain. The superhydrophobic coatings show corrosion-resistant behaviour in a chloride solution, while the durability in slightly acidic/alkaline solutions indicates the excellent water-repellent nature of the coatings, the self-cleaning ability for different types of pollutants and improved anti-icing properties with freezing and melting delay (Figure 3).

We showed with aid of molecular modelling that a silanol unit can form at most one strong SiO–Al bond with the surface of oxidized aluminium, thus making the silanol–surface bonding scheme, where the monomeric silanol unit in the polymer is bonded to the surface via two SiO–Al bonds, questionable.

We continued to work on the project COR_ID within M-Era.Net (European Research Area, an EU funded network). The main aim of the project *"Design of corrosion resistant coatings targeted for versatile applications" (COR_ID)* is to design and engineer new coatings for aluminium alloys with targeted properties of increased corrosion resistance, specific hydrophobic properties, prolonged service life-time and reduced ecological impact. Project consortium comprised researchers from Slovenia, France and Hungary: Department of Physical and Organic Chemistry of the Jožef Stefan Institute, Talum d.d. Kidričevo, Chimie ParisTech (CNRS) from Paris and Eötvös Loránd University from Budapest. In the field of computational modelling we extended our density functional theory (DFT) based study on the interactions of silanols–key components in the synthesis of siloxane-based sol-gel coatings–with hydroxylated oxidized aluminium surfaces. We studied the adsorption of a model silanol molecule, $CH_3Si(OH)_3$, on four chemically and structurally diverse surface models, i.e., (i) hydroxylated ultra-thin oxide film supported on Al(111), (ii) boehmite γ-AlOOH, (iii)

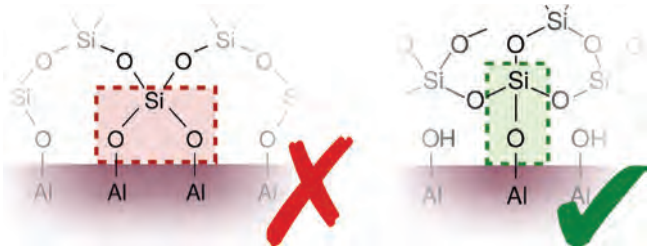

Figure 4: A scheme of bonding of siloxane-based films on oxidized aluminium surfaces. Each monomeric silanol subunit forms at most one SiO–Al bond.

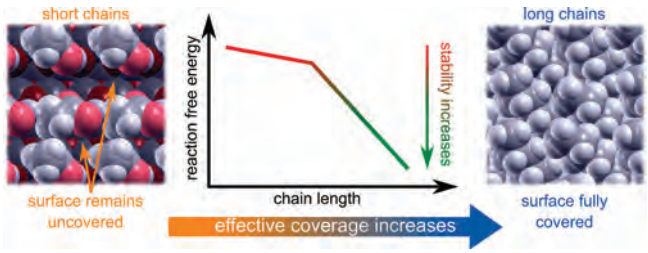

Figure 5: An increase in alkyl chain length leads to a more stable inhibitor film on the surface and a greater effective coverage.

hydroxylated α-Al_2O_3, and (iv) gibbsite $Al(OH)_3$(010). We demonstrated that a silanol unit can form at most one strong SiO–Al bond with the surface via the condensation mechanism, whereas the formation of a second such bond was found to be endothermic (and endergonic) on all the considered surface models. We attributed the inferiority of the second bond formation to the strained configuration of the structure in the bidentate bonding mode. In particular, the distance between the two oxygen atoms in the two SiO–Al bonds is much smaller than the distance between the oxygen atoms in the two OH groups on the pristine substrate. Our results thus clearly demonstrated that the occasionally used scheme of silanol–surface bonding, where a monomeric silanol subunit in a polymer binds to the surface via two SiO–Al bonds, needs to be reconsidered (Figure 4).

In the context of a systematic study of the efficiency of carboxylic acids (CA) in inhibiting the corrosion of aluminum in chloride solution, we addressed with molecular modelling the roles of adsorption mode, molecular coverage, alkyl chain tilt-angle, and alkyl chain length on the stability of the formed CA monolayers. Adsorption was modelled on two models of the hydroxylated ultrathin-oxide film supported on aluminium. We considered two adsorption modes: (i) plain adsorption and (ii) adsorption via condensation. While on a fully hydroxylated surface only the monodentate carboxylate bonding mode was identified, the bidentate mode was found to be viable near OH vacancies. We showed that the adsorption energy can be decomposed into the headgroup–surface and lateral interchain components. While the headgroup–surface interaction is largely independent on alkyl chain length, lateral intermolecular interactions are proportional to the number of C atoms in the alkyl chain. Consequently, adsorption is stabilized by about 1 eV/molecule at the full monolayer coverage when the alkyl chain length increases from 2 to 18 C atoms (Figure 5).

We continued to work on the M-Era.Net project entitled "*COIN DESC: Corrosion inhibition and dealloying descriptors*". The project consortium consists of four partners from Slovenia, Belgium, Spain, and Netherlands (Department of Physical and Organic Chemistry of Jožef Stefan Institute, Institute for Materials Research of Hasselt University, Department of Physics at Universitat Politècnica de Catalunya, and Materials Science and Engineering at Delft University of Technology). We have tested about two dozen different azole molecules as potential corrosion inhibitors for copper and zinc in NaCl solution by electrochemical methods, such as polarization resistance and electrochemical impedance spectroscopy. The interfacial bonding of the inhibitors was investigated by FTIR, XPS, and AFM techniques as well as by explicit inhibitor–surface DFT calculations. We aimed at integrating high-throughput oriented experimental testing of a larger number of corrosion inhibitors with insights provided by more detailed mechanistic analyses (experimental and computational) with the specific objective to identify physically-sound corrosion inhibition descriptors. In this context, we investigated the dissociative adsorption of imidazole on the oxidized surface of copper and showed that it proceeds via the cleavage of the C2–H bond (Figure 6), whereas for triazole and tetrazole, dissociative adsorption proceeds via the dissociation of the N–H bond. We also investigated co-adsorption effects, i.e., how the adsorption of corrosion-relevant species, such as $O_{(ads)}$, $H_{(ads)}$, $OH_{(ads)}$ and $Cl_{(ads)}$, affects the intermolecular interactions and the adsorption of inhibitor molecules on the surface. Calculations show that the presence of chemisorbed oxygen enhances the interaction between the inhibitors and the surface and also promotes the dissociation of the N–H bond of the azole corrosion inhibitors, which in turn leads to even more stable inhibitor structures on the surface.

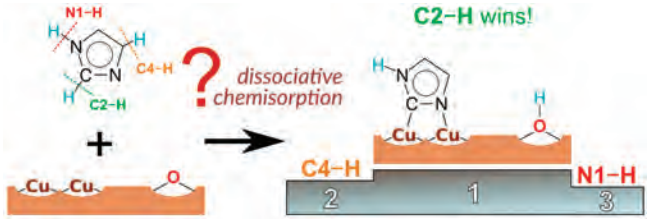

Figure 6: The most favourable dissociative adsorption of imidazole on oxidized copper surfaces proceeds through the cleavage of C2–H bonds.

We also organized an international summer school entitled "*Quantum ESPRESSO Summer School on Advanced Materials and Molecular Modelling*", that took place from September 15 to 20 at the Jožef Stefan Institute. More than 70 participants, tutors and lecturers from around the world attended the school (Figure 7). The main goal of the school was to introduce students, postdocs, and other researchers to materials and molecular modelling with the "Quantum ESPRESSO" software package. The school covered basic concepts as well as recent advances and developments, with the emphasis on density-functional-theory based methods and high-performance computing.

In the framework of Laboratory for Organic and Bioorganic Chemistry we continued the investigation on the application of principles of green chemistry to the transformations of organic compounds. We studied a mechanism of the reaction of direct esterification of carbocyclic acids mediated by 1,3-dibromo-5,5-dimetil hidantoin (DBDMH)

and established that DBDMH plays a role of pre-catalyst, thus forming active catalytic species: hydrogen hipobromide (HOBr), hydrobromide (HBr) or molecular bromine.

We developed a new synthetic method for the introduction of nitrogen functionality into organic molecules. Benzyl alcohols and alkyl or aril amines gave in the presence of sub stoichiometric amounts (5-7 mol %) of N-bromosuccinimide benzyl alkyl amines, while a Ritter-type reaction between benzyl alcohols and alkyl nitriles under the same reaction conditions gave benzyl alkylamides.

In the framework of the joint project with Faculty for Biotechnology, University of Ljubljana, and in collaboration with the company Alkimica we prepared a series of N-acetylcysteamine thioesters of 1,3-keto carbocyclic acids in order to use them as precursors in the biosynthesic of tetracyclines. Ordinary corresponding malenate derivatives are used in this process, but we hope that micro-organisms developed in the Faculty for Biotechnology could transform our alternative precursors into tetracyclines.

Figure 7: Participants of the "Quantum ESPRESSO Summer School on Advanced Materials and Molecular Modelling", that took place at the Jožef Stefan Institute from 15 to 20 September, 2019.

Some outstanding publications in the past year

1. I. Milošev, T. Bakarič, S. Zanna, A. Seyeux, P. Rodič, M. Poberžnik, P. Cornette, D. Costa, A. Kokalj, P. Marcus, Electrochemical, Surface-Analytical, and Computational DFT Study of Alkaline Etched Aluminum Modified by Carboxylic Acids for Corrosion Protection and Hydrophobicity, J. Electrochem. Soc. 166 (2019) C3131–C3146.
2. M. Poberžnik, A. Kokalj, Implausibility of bidentate bonding of the silanol headgroup to oxidized aluminum surfaces, Appl. Surf. Sci. 492 (2019) 909–918.
3. K. Čebular, B.Đ. Božić, S. Stavber, 1,3-dibromo-5,5-dimethylhydantoin as a precatalyst for activation of carbonyl functionality, Molecules, 24 (2019) 2608-1–2608-16
4. P. Rodič, I. Milošev, M. Lekka, F. Andreatta, L. Fedrizzi, Study of the synergistic effect of cerium acetate and sodium sulphate on the corrosion inhibition of AA2024-T3, Electrochim. Acta, 308 (2019) 337–349.
5. U. Tiringer, B. Mušič, D. Zimerl, G. Šekularac, S. Stavber, I. Milošev, The effects of cerium ions on the curing, polymerisation and condensation of hybrid sol-gel coatings. J. Non-Cryst. Solids, 510 (2019) 93–100.

Awards and Appointments

1. Dolores Zimerl, best poster award at the 7th RSE-SEE conference ("Regional Symposium on Electrochemistry - South East Europe"), Split, Croatia, 27–30 May 2019
2. Matic Poberžnik, best poster award at the "Quantum ESPRESSO Summer School on Advanced Materials and Molecular Modelling"
3. Lea Gašparič, 3rd best poster prize at the 25th conference of the Slovenian Chemical Society
4. Peter Rodič, Ingrid Milošev, Damir Hamulić, Barbara Kapun: Best Idea on the conference "Road to Market Innovation" within the Innovation Day of the company JUB.

Organization of conferences, congresses and meetings

1. Fundamentals of corrosion protection and coatings production: mCBEEs ("Advanced integrative solutions to corrosion problems beyond micro-scale: towards long-term durability of miniaturized biomedical, electronic and energy systems", H2020 MSCA - ITN - 2017-764977), Ljubljana, Slovenia, 24. – 29. 6. 2019
2. Quantum ESPRESSO Summer School on Advanced Materials and Molecular Modelling, Ljubljana, Slovenia, 15. – 20. 9. 2019

INTERNATIONAL PROJECTS

1. Micro Grant of KET4CP (Key Enabling Technology for Clean Production), Hydrophobic TOP COAT for marine application
   Prof. Ingrid Milošev
   Chemitek - QuÍmica AvanÇada
2. COST CA17126: Towards Understanding and Modelling Intense Electronic Excitation
   Asst. Prof. Anton Kokalj
   Cost Association Aisbl
3. H2020 - mCBEEs; Advanced Integrative Solutions to Corrosion Problems Beyond Micro-Scale: Towards Long-Term Durability of Miniaturized Biomedical, Electronic and Energy Systems
   Prof. Ingrid Milošev
   European Commission
4. H2020 - MAMI; Magnetics and Microhydrodynamics - From Guided Transport to Delivery
   Prof. Ingrid Milošev
   European Commission

5. INCOR: INterfaces relevant for CORrosion and its inhibition
   Prof. Ingrid Milošev
   Slovenian Research Agency
6. Fundamental Insights Into Fuel Cell Electrocatalysis – Combination of Modelling and Experiment
   Asst. Prof. Anton Kokalj
   Slovenian Research Agency

RESEARCH PROGRAMMES

1. Chemistry for sustainable development
   Dr. Peter Rodič
2. Advanced materials for low-carbon and sustainable society
   Prof. Ingrid Milošev

R & D GRANTS AND CONTRACTS

1. Multidisciplinary approach towards development of a novel multifunctional heterogeneous catalyst for efficient conversion of H_2 and CO_2 gas mixtures into fuel additives and surrogates
   Asst. Prof. Anton Kokalj
2. Photocatalytic water treatment - development of immobilized catalysts and compact reactor systems
   Dr. Peter Rodič
3. COR_ID: Design of corrosion resistant coatings targeted for versatile applications
   Prof. Ingrid Milošev
   Ministry of Education, Science and Sport
4. COIN DESC: Corrosion inhibition and dealloying descriptors
   Asst. Prof. Anton Kokalj
   Ministry of Education, Science and Sport

NEW CONTRACTS

1. Micro Grant of KET4CP (Key Enabling Technology for Clean Production), Developing isocyanate-free polyurethane-based coatings used for corrosion protection
   Dr. Peter Rodič
   Chemcolor Sevnica d. o. o.

VISITORS FROM ABROAD

1. dr. Dominique Costa, Chimie ParisTech, PSL University, CNRS, Institut de Recherche de Chimie Paris, Paris, France, 24. 4. – 26. 4. 2019
2. dr. Dominique Costa, Chimie ParisTech, PSL University, CNRS, Institut de Recherche de Chimie Paris, Paris, France, 3. 6. – 6. 6. 2019
3. dr. Dominique Costa, Chimie ParisTech, PSL University, CNRS, Institut de Recherche de Chimie Paris, Paris, France, 12. 7. – 20. 7. 2019
4. Aleksandar Jovanović, Faculty of physical chemistry, University of Belgrade, Belgrade, Serbia 3. 8. – 16. 8. 2019
5. Aleksandar Jovanović, Faculty of physical chemistry, University of Belgrade, Belgrade, Serbia 14. 9. – 22. 9. 2019
6. Ana Dobrota, Faculty of physical chemistry, University of Belgrade, Belgrade, Serbia 14. 9. – 22. 9. 2019
7. Emilie Gaudry, Institut Jean Lamuor & Universite de Lorraine, Nancy, France, 31. 5. 2019
8. Bruno Ribeiro, Lima Corporate S.p.A., Udine, Italy, 1. 5. – 31. 7. 2019
9. Ana Damjanović, Kolektor Group, Idrija, 15. 9. – 15. 12. 2019
10. dr. Njomza Ajvazi, College of Medical Sciences "Rezonanca", Priština, Republic of Kosovo, 9. 7. – 28. 9. 2019

STAFF

Researchers
1. Asst. Prof. Anton Kokalj
2. **Prof. Ingrid Milošev, Head**
3. *Prof. Stojan Stavber, left 01.05.19*

Postdoctoral associates
4. Dr. Matic Poberžnik
5. Dr. Peter Rodič
6. Dr. Urša Tiringer

Postgraduates
7. *Dr. Klara Čebular, left 01.09.19*
8. Matjaž Dlouhy, B. Sc.
9. Damir Hamulić, B. Sc.
10. Ana Kraš, B. Sc.
11. Nikolina Lešić, B. Sc.
12. Ivan Spajić, B. Sc.
13. Gavrilo Šekularac, B. Sc.

Technical officers
14. Barbara Kapun, B. Sc.
15. *Dolores Zimerl, B. Sc., left 11.11.19*

BIBLIOGRAPHY

Original Article

1. Matjaž Dlouhy, Antonija Lesar, "Characterization and atmospheric implication of hydrotrioxy radical-water-methylamine-formic acid-sulphuric acid complexes", *Acta Chimica Slovenica*, 2019, **66**, 1, 229-238.
2. Anton Kokalj, Dunja Gustinčič, Matic Poberžnik, Matic Lozinšek, "New insights into adsorption bonding of imidazole: a viable C2-H bond cleavage on copper surfaces", *Applied Surface Science*, 2019, **479**, 463-468.
3. Matic Poberžnik, Anton Kokalj, "Implausibility of bidentate bonding of the silanol headgroup to oxidized aluminum surfaces", *Applied Surface Science*, 2019, **492**, 909-918.
4. Maja Mujdrica Kim, Barbara Kapun, Urša Tiringer, Gavrilo Šekularac, Ingrid Milošev, "Protection of aluminum alloy 3003 in sodium chloride and simulated acid rain solutions by commercial conversion coatings containing Zr and Cr", *Coatings*, 2019, **9**, 9, 563.
5. Peter Rodič, Ingrid Milošev, "The influence of additional salts on corrosion inhibition by cerium(III) acetate in the protection of AA7075-T6 in chloride solution", *Corrosion Science*, 2019, **149**, 108-122.
6. Peter Rodič, Ingrid Milošev, Maria Lekka, Francesco Andreatta, Lorenzo Fedrizzi, "Study of the synergistic effect of cerium acetate and sodium sulphate on the corrosion inhibition of AA2024-T3", *Electrochimica Acta*, 2019, **308**, 337-349.
7. Yolanda S. Hedberg, Monika Žnidaršič, Gunilla Herting, Ingrid Milošev, Inger Odnevall Wallinder, "Mechanistic insight on the combined effect of albumin and hydrogen peroxide on surface oxide composition and extent of metal release from Ti6Al4V", *Journal of Biomedical Materials Research. Part B, Applied Biomaterials.*, 2019, **107**B, 3, 858-867.
8. Žiga Zupanek, Melita Tramšek, Anton Kokalj, Gašper Tavčar, "The peculiar case of conformations in coordination compounds of group V

pentahalides with N-heterocyclic carbene and synthesis of their imidazolium salts", *Journal of Fluorine Chemistry*, 2019, **227**, 109373.
9. Urša Tiringer, Branka Mušič, Dolores Zimerl, Gavrilo Šekularac, Stojan Stavber, Ingrid Milošev, "The effects of cerium ions on the curing, polymerisation and condensation of hybrid sol-gel coatings", *Journal of Non-crystalline Solids*, 2019, **510**, 93-100.
10. Ingrid Milošev *et al.* (11 authors), "Electrochemical, surface-analytical, and computational DFT study of alkaline etched aluminum modified by carboxylic acids for corrosion protection and hydrophobicity", *Journal of The Electrochemical Society*, 2019, **166**, 11, c3131-c3146.
11. Klara Čebular, Bojan Đ. Božić, Stojan Stavber, "1,3-dibromo-5,5-dimethylhydantoin as a precatalyst for activation of carbonyl functionality", *Molecules*, 2019, **24**, 14, 2608.
12. Peter Rodič, Ingrid Milošev, "One-step ultrasound fabrication of corrosion resistant, self-cleaning and anti-icing coatings on aluminium", *Surface & Coatings Technology*, 2019, **369**, 175-185.

Review Article

1. Ingrid Milošev, "Contemporary modes of corrosion protection and functionalization of materials", *Acta Chimica Slovenica*, 2019, **66**, 3, 511-533.

Independent Component Part or a Chapter in a Monograph

1. Gavrilo Šekularac, Sanja Eraković, Srečko Stopić, "Innovative approaches toward the synthesis of electroactive RuO_2-based materials of intrinsic structure", In: *Metals and metal-based electrocatalytic materials for alternative energy sources and electronics*, (Chemical engineering methods and technology), Nova Science Publishers, 2019, 67-119.

Theses and Mentoring

1. Klara Čebular, *Transformations of oxygen functional groups in organic molecules mediated by molecular iodine or/and N-halo compounds:* doctoral dissertation, Ljubljana, 2019 (mentor Stojan Stavber).
2. Dunja Gustinčič, *Adsorption of azole molecules on oxidized copper surface and their inhibition of copper corrosion:* doctoral dissertation, Ljubljana, 2019 (mentor Anton Kokalj; co-mentor Ksenija Kogej).
3. Matic Poberžnik, *Quantum mechanical modeling of the oxidation of aluminum surfaces and their interactions with corrosion inhibitors:* doctoral dissertation, Ljubljana, 2019 (mentor Anton Kokalj; co-mentor Tomaž Urbič).

ELECTRONIC CERAMICS DEPARTMENT

K-5

The Electronic Ceramics Department is active in researching the synthesis, properties and applications of materials for electronics and energetics, mainly complex multifunctional materials and structures that can perform multiple functions (multifunctional materials). The materials of interest include ceramic piezoelectrics, ferroelectrics, relaxors, multiferroics and conductive oxides. The emphasis is on the creation of the properties by the synthesis and structure on the nano-, micro- and macro-levels. The group also works on principles of basic technologies of ceramic pressure sensors, ceramic MEMS and flexible electronics.

Head:
Prof. Barbara Malič

In the framework of **lead-free piezoelectric ceramics** we continued our research of sodium potassium niobate ($K_{0.5}Na_{0.5}NbO_3$, KNN)-based materials, which could replace the efficient lead-based piezoelectrics. Using a multi-scale approach, by combining electron microscopy together with analytical tools, we analysed the representative multiple-element-modified ceramic material (K,Na,Li)(Nb,Ta)O_3-CaZrO_3 for which MnO_2 was added either before, or after the calcination step. We proved that the functional properties are, to a large degree, sensitive to minor modifications of the synthesis route, and consequently to different material properties on all scales. We showed that all the features, defects and segregation from the micro to the atomic level could be the basis for the challenging reproducibility of modified KNN. (Figure 1)

In collaboration with the Department for Nanostructured Materials, Department of Surface Engineering and Optoelectronics, JSI and Faculty of Chemistry and Chemical Technology, Ljubljana we prepared KNN-based ceramics by pressure-less spark plasma sintering in vacuum. After sintering the ceramic was electrically conductive due to the partial reduction of Nb^{5+} to Nb^{4+}. After post-annealing in oxygen, which results in the re-oxidation of Nb^{4+}, we obtained a material with piezoelectric properties comparable to those of a conventionally sintered ceramic, while better dielectric properties are attributed to the homogeneous microstructure with sub-micrometre-sized grains as a result of the rapid heating rate and the short dwell times of the sintering.

In collaboration with colleagues from the Advanced Materials Department, JSI, spark-plasma sintered Na(Nb,Ta)O_3 ceramics were produced and their structural behaviour with increasing Ta doping was studied, with the aim to find optimum energy storage properties of these materials. It was revealed that the doping pushes the material through various phase transitions that change the character of the materials from antiferroelectric (AFE) to ferroelectric (FE) to paraelectric. The highest energy density was obtained for the materials with 40–60 mole % Ta concentration (~0.9 J/cm3 with breakdown strength of 160 kV/cm and ~87% efficiency), which was at the boundary between the AFE/FE phases.

We continued with the work on **polycrystalline $BiFeO_3$**. Dopants with multiple oxidation states, such as Co and Mn, are often used in perovskites to control the defect chemistry and thus the electrical and electromechanical properties. In particular, doping with Co is efficient in tailoring the conductivity of multiferroic $BiFeO_3$. We studied in detail the surface defect states in undoped and Co-doped thin-film and ceramic $BiFeO_3$ using X-ray photoelectron spectroscopy (XPS) performed by our colleagues from the Technical University of Darmstadt in Germany. In particular, it was shown that Co is an excellent inhibitor of the surface reduction of $BiFeO_3$ to Fe^{2+} cations and metallic Bi when samples are exposed to water or by heat treatment in a low partial pressure of oxygen. The reason is the change of the oxidation state of Co from 3+ to 2+ upon reduction, which limits the upward shift of the Fermi energy above the reduction potential of $BiFeO_3$.

The Demo Cooling Device Based on the Electrocaloric Effect was among the achievements 'Excellent in Science 2019' selected by Slovenian Research Agency. It is the result of the collaboration of researchers from the Electronic Ceramics Department, Condensed Matter Physics Department, JSI, and Laboratory for Refrigeration and District Energy, Faculty of Mechanical Engineering, University of Ljubljana. The invention has been patented in the EU, USA and China.

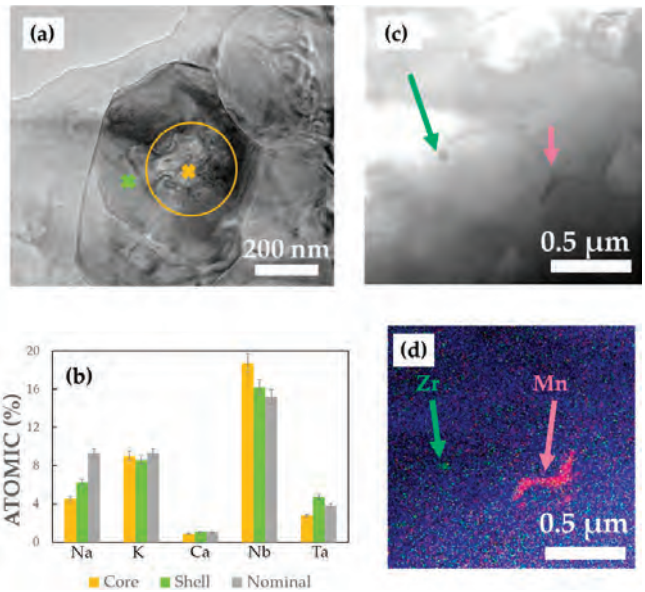

Figure 1:Nano-scale chemical inhomogeneity in multiple-elements modified potassium sodium niobate-based ceramics; a) SEM micrograph of a core-shell grain with b) corresponding EDXS analysis showing Nb-rich core and Ta-rich shell; c) STEM image with d) corresponding EDXS mapping showing nano-scale segregations of Zr-rich and Mn-rich phases.

Upon invitation from the journal Nature Materials, Mojca Otoničar and Brahim Dkhil, from Centrale Supelec, University of Paris-Seclay, wrote an opinion Electrocalorics Hit the Top for the News & Views section (published October 24, 2019). They commented on an article in which a team of researchers from the University of Cambridge, in collaboration with partners from Murata, Japan, reported on multilayer capacitors that exhibit an extremely high electrocaloric response, forecasting a breakthrough in this alternative cooling technology.

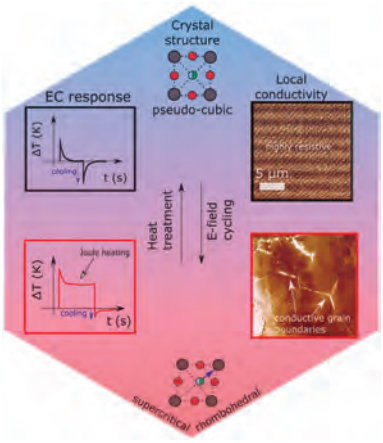

Figure 2: Electric-field cycling of electrocaloric material $Pb(Mg_{1/3}Nb_{2/3})O_3$ (PMN) leads to a transition from the pseudo-cubic to the supercritical-rhombohedral phase. This transition introduces a redistribution of charged point defects in the material, resulting in an increased electrical conductivity at the grain boundaries and, consequently, decreased cooling capacity. The transition is reversible with a heat treatment. In the paper we propose a novel approach to avoid the fatigue of PMN by controlling the field-cycling conditions using the electric-field–temperature phase diagram of PMN.

The results are important for applications of $BiFeO_3$ in photocatalytic water splitting, corrosion and gas sensing.

While promising for high-temperature applications, $BiFeO_3$ solid-solution-based piezoceramics are difficult to synthesize due to the persistence of secondary phases, known to be stabilized in $BiFeO_3$ due to a complicated interplay between kinetic and thermodynamic aspects of the system. To explore this processing problem, we used the $BiFeO_3$-$SrTiO_3$ (BFO–STO) ceramic system and performed a comparative study using three different synthesis approaches: i) conventional solid state from mixed oxides, ii) synthesis from pre-synthesized BFO and STO binaries and iii) mechanochemical activation. We found that the key element for the synthesis of homogeneous ceramics is to prevent the formation of Bi-rich phases during the diffusion reaction, which typically have low melting temperatures. We showed that this can be achieved either by using binaries as precursors, in which case pure Bi_2O_3 is avoided in the initial mixture, or by mechanochemical activation, which increases the homogeneity of the powder mixture, leading to a reaction between the activated constituents that is completed at lower temperatures.

In collaboration with researchers from Friedrich-Alexander-Universität, Erlangen, Germany, we studied the piezoelectric and ferroelectric properties of lead-free $(Na_{0.5}Bi_{0.5})TiO_3$-based ceramics using piezoresponse force microscopy (PFM). We were among the first to report ferroelectric domains in mechanically loaded relaxor ferroelectrics. In collaboration with the Advanced Materials Department, JSI, we continued with the PFM study of the piezoelectric and ferroelectric properties of micrometre-to-nanometre-sized $BaTiO_3$-based plates.

Research on **lead-based ferroic materials** continued with studies of the fatigue behaviour in the **electrocaloric (EC) response** of the prototypic relaxor lead magnesium niobate, $Pb(Mg_{1/3}Nb_{2/3})O_3$ (PMN). While still not fully addressed, fatigue resistance is the key aspect for future EC cooling devices considering that the active materials are expected to sustain not only large electric fields (several tens of kV/cm) but also a large number of such field cycles. Fatigue tests on PMN ceramics revealed the onset of Joule heating during continuous field cycling, originating from the increased grain-boundary conductivity, as found by conductive atomic-force microscopy analysis. A combination of multiscale characterization techniques clarified the mechanism of fatigue and showed that it is related to an unusual field-induced transformation of the relaxor to the ferroelectric phase in the ergodic PMN. We showed that the fatigue can be avoided by controlling this transformation using the electric-field-temperature phase diagram of PMN. (Figure 2)

One of the main problems in selecting efficient materials for EC applications is the emergence of self-heating during the electric field's application, often referred to as the Joule heating. Motivated to understand more about self-heating effects in ceramics, we performed a study focusing on the contribution to self-heating during EC cycling in different compositions, i.e., relaxor PMN and ferroelectric Pb(Zr,Ti)O_3 (PZT) in its "hard" and "soft" variant. The results showed that the self-heating effects have origins not only in the elevated electrical conductivity, as mostly discussed, but can also be extensive due to ferroelectric domain switching. The key parameter is the hysteresis loss, which should be more prominently considered in the selection and engineering of materials for future EC cooling devices.

We proceeded with an investigation of the **multicaloric effect in $Pb(Fe_{0.5}Nb_{0.5})O_3$** (PFN) ceramics. Ceramics were prepared by the mechanochemical activation of constituent oxides, followed by a thermal treatment. We investigated the influence of sintering conditions and doping with manganese on the functional properties of ceramics (Figure 3). In addition to multicaloric properties, we also investigated the piezoelectric response and ferroelectric domain structure of the prepared PFN ceramic samples.

Popularization of science: Hana Uršič, in collaboration with Emmanuel Defay from Luxembourg and Magdalena Wencka from Poland, organized a symposium titled Calorific Materials for Efficient Use of Heat: Progress and Challenges at the E-MRS Fall Meeting 2019 in Warsaw. Kristian Radan and Matic Lozinšek from the Department of Inorganic Chemistry and Technology attended in Genoa the "17th Festival of Science 2019" with an experimental show entitled "Kitchen Experiments". (Figure 5)

Studies of relaxor **ferroelectric $Pb(Mg_{1/3}Nb_{2/3})O_3$–$PbTiO_3$ (PMN-PT) ceramics** continued this year, strengthening the ideas on the nonlinearities and hysteresis of the monoclinic compositions with specific nano-to-mesoscale structure. The studies were partly performed at the National Institute of Chemistry in Ljubljana, and in collaboration with prof. Jacob Jones from North Carolina State University, USA and prof. Dragan Damjanović from École polytechnique fédérale de Lausanne, Switzerland.

We studied **sodium niobate thin films** doped with manganese (NN), and their solid solutions with 5 or 10 mol % calcium zirconate (CZ) on platinized silicon substrates prepared by chemical solution deposition. The NN thin films exhibited well-shaped ferroelectric loops with a remanent polarization and coercive field of ~10 μC/cm² and ~100 kV/cm, respectively.

The modification with CZ strongly influenced the ferroelectric response of the films: the remanent polarization progressively decreased to around 2.5 μC/cm^2. The absence of an anti-ferroelectric response, characteristic for bulk NN and NN-CZ ceramics, was attributed to the nanoscale microstructure and residual thermal stresses. All the studied films exhibited a piezoelectric response with the highest piezoelectric d_{33} coefficient of 35 pm/V at 300 kV/cm bias field for the NN modified films with 5 mol % CZ.

Using **inkjet printing technology** we patterned multilayer **ferroelectric thin-film** capacitors consisting of layers of conducting lanthanum nickelate as top/bottom/internal electrodes and of ferroelectric layers of $Pb(Zr,Ti)O_3$ (PZT). The capacitors were successfully patterned on different substrates: silicon wafers, polycrystalline alumina and nickel foils. Compared to single-layer capacitors the multilayer components exhibit much larger capacitance density and the electromechanical response. The research was performed in collaboration with colleagues from the Departments of Condensed Matter Physics and Surface Engineering and Optoelectronics, and The Pennsylvania State University in the frame of a bilateral project. (Figure 4).

With colleagues from the Condensed Matter Physics Department, JSI, we employed a soft-chemistry approach to deposit **PZT thin films** with engineered macroporosity on platinized silicon **by spin-coating**. The presence of pores within the bulk of the films enabled local elastic relaxations, thus contributing to an enhanced electromechanical response. The value of the piezoelectric coefficient approached that of its bulk counterpart, which was attributed to both increased elastic compliance of the film and enhanced mobility of ferroelastic domain walls.

We continued the research of the **electrophoretic deposition of thick films** of environmentally benign piezoelectrics based on KNN on metallized corundum substrates for energy-harvesting applications in collaboration with researchers from the University of Tours, Tours, France.

We proceeded with the preparation of **thick films by the aerosol deposition method**. The aerosol deposition system is a part of the Laboratory for the Ultracool Preparation of Complex Oxides, for short **ULTRACOOL**, for which the financial support was granted by the Director's fund 2017 project. In collaboration with Faculty of Mechanical Engineering, University of Ljubljana, we prepared protective alumina coatings on magnetocaloric gadolinium elements. Together with researchers from Friedrich-Alexander-Universität, Erlangen, Germany we prepared porous lead-free $BaTiO_3$-based piezoelectric thick films. Current research is focused on the optimization of processing parameters for the preparation of functional PMN-PT thick films on metal and polymer substrates.

In the scope of the Ultracool laboratory, the equipment for '**Cold sintering**' was set-up, enabling the conducting of preliminary tests on real samples (i.e., pressing of wetted powders at pressures up to 600 MPa and temperatures up to 300 °C). Furthermore, systematic sintering experiments were launched first on lead-based perovskite ferroelectrics, then on multiferroic $BiFeO_3$ ceramics and also on composites of these two perovskite compounds. The obtained samples had high dielectric breakdown strength and high density, nevertheless, further analyses are needed to fully understand the mechanisms underpinning the cold-sintering technique. However, to the best of our knowledge, we were the first to successfully cold-sinter BFO ceramics with the help of molten hydroxide flux. The work on cold sintering is also performed in collaboration with colleagues from Penn State University (prof. Clive Randall), as well as with the group of Advanced Ferroics at Centrale Supelec, Paris (prof. Brahim Dkhil).

The "**Extreme Conditions Chemistry Laboratory**" **project** (ECCL, http://eccl.ijs.si/), led by Matic Lozinšek and Blaž Alič from the Inorganic

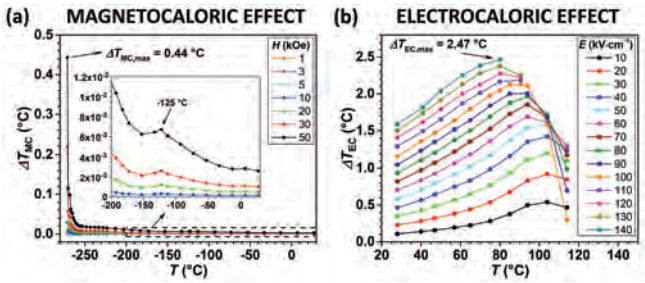

Figure 3: (a) Magnetocaloric and (b) electrocaloric effects of Mn-doped $Pb(Fe_{0.5}Nb_{0.5})O_3$ ceramics.

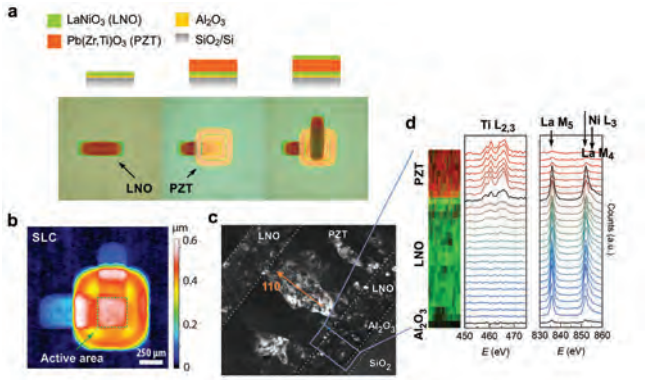

Figure 4: Inkjet printing of ferroelectric thin-film capacitors. (a) Optical images of sequentially printed LNO and PZT structures and a schematic of a corresponding cross section. (b) Contact profilometry 2-D scans of the printed capacitor. (c) Dark-field TEM image of the LNO/PZT/LNO capacitor cross section. (d) EELS map of a 100 × 170 nm^2 region across the Al_2O_3/LNO/PZT interface.

Barbara Malič was made a Fellow of the European Ceramic Society in recognition of her research of ferro- and piezoelectric ceramics and thin films.

Figure 5: "17. Festival of Science 2019" in Genoa "Kitchen Experiments" by Kristian Radan from the Electronic Ceramics Department and Matic Lozinšek from the Department of Inorganic Chemistry and Technology and the Faculty of Chemistry and Chemical Technology, University of Ljubljana.

Chemistry and Technology Department, and Mirela Dragomir and Kristian Radan from Electronic Ceramics Department was granted financial support from the **Director's fund for 2019**. Our colleagues proposed to set up a new laboratory with specialized equipment that would allow them to perform synthesis and characterization of new compounds and materials under extreme conditions, i.e., low temperatures or very high pressures. The project could provide completely new insights into the chemistry of materials.

Research and development work on **LTCC** (Low Temperature Co-fired Ceramics) technology has focused on the design and fabrication of three-dimensional ceramic structures for the packaging of microelectronic components and systems in cooperation with CoE NAMASTE, and the companies HIPOT-RR and KEKO Equipment.

Some outstanding publications in the past year

1. Bradeško, Andraž, Fulanović, Lovro, Vrabelj, Marko, Otoničar, Mojca, Uršič, Hana, Henriques, Alexandra, Chung, Ching-Chang, Jones, Jacob L., Malič, Barbara, Kutnjak, Zdravko, Rojac, Tadej. Electrocaloric fatigue of lead magnesium niobate mediated by an electric-field-induced phase transformation. **Acta materialia**, ISSN 1359-6454. [Print ed.], 2019, vol. 169, str. 275-283, doi: 10.1016/j.actamat.2019.03.017. [COBISS.SI-ID32250151]
2. Prah, Uroš, Rojac, Tadej, Wencka, Magdalena, Dragomir, Mirela, Bradeško, Andraž, Benčan, Andreja, Sherbondy, Rachel, Brennecka, Geof, Kutnjak, Zdravko, Malič, Barbara, Uršič Nemevšek, Hana. Improving the multicaloric properties of Pb(Fe0.5Nb0.5)O3 by controlling the sintering conditions and doping with manganese. **Journal of the European ceramic society**, ISSN 0955-2219. [Print ed.], 2019, vol. 39, no. 14, str. 4122-4130, doi: 10.1016/j.jeurceramsoc.2019.05.062. [COBISS.SI-ID 32459303]
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4. Nicole Bein, Pamela Machado, Mariona Coll, Feng Cheng, Maja Makarovič, Tadej Rojac, Andreas Klein, "Electrochemical reduction of undoped and cobalt-doped induced by water exposure : quantitative determination of reduction potentials and defect energy levels using photoelectron spectroscopy", **J. phys. chem. lett.**, vol. 10, no. 21, str. 7071-7076, 2019, doi: 10.1021/acs.jpclett.9b02706. [COBISS.SI-ID 32828199]
5. Condurache, Oana, Radan, Kristian, Prah, Uroš, Otoničar, Mojca, Kmet, Brigita, Kapun, Gregor, Dražić, Goran, Malič, Barbara, Benčan, Andreja. Heterogeneity challenges in multiple-element-modified lead-free piezoelectric ceramics. **Materials**, ISSN 1996-1944, 2019, vol. 12, no. 24, str. 4049-1-4049-12, doi: 10.3390/ma12244049. [COBISS.SI-ID 32977959]

Awards and Appointments

1. Barbara Malič: Fellow of the European Ceramic Society
2. Barbara Malič, Andrej Kitanovski (UL FS): Excellent in Science ARRS 2019, ARRS, "Demo cooling device based on the electrocaloric effect"
3. Mirela Dragomir, Kristian Radan, Blaž Alič (K1), Matic Lozinšek (K1): Director's Fund, Jožef Stefan Institute, "Extreme Conditions Chemistry Laboratory"

Organization of Conferences, Congresses and Meetings

1. E-MRS 2019 Fall Meeting: European Materials Research Society, Warsaw, Poland, September 16–19, 2019
2. MIDEM 2019: 55th International Conference on Microelectronics, Devices and Materials with the Workshop on Laser Systems and Photonics, Bled, Slovenia, September 25–27, 2019

INTERNATIONAL PROJECTS

1. EPCOS - Laboratory Measurements
   Asst. Prof. Hana Uršič Nemevšek
   Epcos Ohg
2. Laboratory Measurements
   Prof. Barbara Malič
   Tdk Electronics Gmbh & Co Og
3. Electric Measurements
   Prof. Tadej Rojac
   Tdk Electronics Gmbh & Co Og
4. Laboratory Measurements
   Prof. Andreja Benčan Golob
   Tdk Electronics Gmbh & Co Og
5. Electrocaloric Measurements of Ceramic Samples
   Prof. Barbara Malič
   Tdk Electronics Gmbh & Co Og
6. Atomic Force Microscope Measurements
   Asst. Prof. Hana Uršič Nemevšek
   Tdk Electronics Gmbh & Co Og
7. Environment Friendly Ferroelectric Materials in Bulk and Thin-Film Forms and Low-Temperature Processing Thereof
   Prof. Barbara Malič
   Slovenian Research Agency
8. Processing of Piezoelectric Thick Films by Aerosol Deposition Technique

Asst. Prof. Hana Uršič Nemevšek
Slovenian Research Agency
9. Novel Hardening Mechanisms in Lead-Free Piezoceramics
Prof. Tadej Rojac
Slovenian Research Agency
10. Cold Sintering of Complex Oxide Materials
Dr. Mojca Otoničar
Slovenian Research Agency
11. Low Bandgap Ferroelectric Solar Cell Absorbers: Synthesis and Characterization
Asst. Prof. Hana Uršič Nemevšek
Slovenian Research Agency
12. Interface Stability of Piezoelectric Ceramic Oxides
Prof. Tadej Rojac
Slovenian Research Agency
13. Environmental Benign Sodium Potassium Niobate-based Thick Films for Piezoelectric Energy Harvesting Applications
Prof. Danjela Kuščer Hrovatin
Slovenian Research Agency
14. Understanding Size Effects in Antiferroelectric Materials
Dr. Mojca Otoničar
Slovenian Research Agency
15. Multiferroics for Solid-State Cooling Applications
Asst. Prof. Hana Uršič Nemevšek
Slovenian Research Agency
16. Processing – Structure - Properties Study of Environmentally Friendly Piezoelectric Nanoparticles of Tailored Surface Morphology
Prof. Andreja Benčan Golob
Slovenian Research Agency
17. High-Pressure Synthesis and Characterization of Selected Ferroics
Dr. Kristian Radan
Slovenian Research Agency
18. Crystal Growth and Magnetic Properties of Double Perovskites
Dr. Mirela Dragomir
Slovenian Research Agency

RESEARCH PROGRAMME

1. Electronic Ceramics, Nano-, 2D and 3D Structures
Prof. Barbara Malič

R & D GRANTS AND CONTRACTS

1. Multicaloric cooling
Asst. Prof. Hana Uršič Nemevšek
2. Electrocaloric elements for active cooling of electronic circuits
Prof. Barbara Malič
3. Advanced inorganic and organic thin films with enhanced electrically-induced response
Prof. Barbara Malič
4. Advanced electrocaloric energij conversion
Prof. Barbara Malič
5. Domain engineered ferroelectric ceramic layer elements for efficient energy harvesting and energy conversion applications
Prof. Barbara Malič
6. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
Prof. Barbara Malič
Ministry of Economic Development and Technology
7. Public call for reimbursement of costs for scientific publications in golden open access (for 2019)
Prof. Barbara Malič
Slovenian Research Agency
8. Stay of Maja Makarovič in Trondheim - Interactions between Charged Defects and Domain Walls in Lead-Free BiFeO3
Maja Makarovič
Jecs Trust
9. Sample Preparation
Prof. Andreja Benčan Golob
Cern
10. Stay of Oana Andreea Condurache in AI CUZA Iasi, Romania - Functional Characterisation of Potassium Sodium Niobate-Based and Bismuth Ferrite-Based Ceramics
Oana Andreea Condurache
Jecs Trust
11. Stay of Kristian Radan in Leoben, Austria - Ramanska študija izbranih feroelektričnih perovskitov brez svinca
Dr. Kristian Radan
Jecs Trust

VISITORS FROM ABROAD

1. Yuji Matsushita, Osaka Prefecture University – Graduate School of Engineering, Department of physics and electronics, Osaka, Japan, October 10, 2018 – January 6, 2019
2. Prof. Raul Bermejo, Montanuniversität Leoben, Leoben, Austria, January 17, 2019
3. Ibrahim Gökdemir, Yildiz Technical University, Istanbul, Turkey, February 4–March 25, 2019
4. Dr Marco Deluca, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria, February 13, 2019
5. George Markou, University of Ioannina, Ioannina, Greece, March 1 – April 30, 2019
6. Chrisanthi Ikonomidi, University of Ioannina, Ioannina, Greece, March 1 – May 31, 2019
7. Dr Julian Walker, Norwegian University of Science and Technology (NTNU), Trondheim, Norway, March 16 – 21, 2019
8. Mathis Lechable, Université François-Rabelais Tours, Tours, France, April 1 – June 21, 2019
9. Rémy Lecomte, Université François-Rabelais Tours, Tours, France, April 1 –June 21, 2019
10. Valentin Roulaud, Université François-Rabelais Tours, Tours, France, April 2 – June 21, 2019
11. Marko Mudri, Bjelovar University of Applied Sciences, Department of Mechatronics, Bjelovar, Croatia, April 23 – October 22, 2019
12. Nicole Bein, Technische Universität Darmstadt (TUDa), Darmstadt, Germany, May 6–24, 2019
13. Hugo Mercier, Université François-Rabelais Tours, Greman CNRS, Tours, France, May 27 – June 8, 2019
14. Yao Minghai, Centrale Supélec, Université Paris-Saclay, Paris, France, June 1 – 30, 2019
15. Prof. Brahim Dkhil, Centrale Supélec, Université Paris-Saclay, Paris, France, June 3–5, 2019
16. Prof. Franck Levassort, Université François-Rabelais Tours, Greman CNRS, Tours, France, June 3 – 6, 2019
17. Prof. Dr. Angus I. Kingon, Brown University, Providence, Rhode Island, USA, June 10–11, 2019
18. Prof. Nava Setter, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, June 10 – 11, 2019
19. Prof. Hisao Suzuki, Shizuoka University, Hamamatsu, Japan, July 19 – 22, 2019
20. Dr Magdalena Wencka, Institute of Molecular Physics, Polish Academy of Sciences, Poznań, Poland, July 23 – August 2, 2019
21. Prof. Mariya Gancheva, Institute of General and Inorganic Chemistry, Sofia, Bulgaria, August 19 – 23, 2019
22. Udo Eckstein, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany, August 25 – September 15, 2019
23. Kristijan Kovačić, Bjelovar University of Applied Sciences, Department of Mechatronics, Bjelovar, Croatia, September 16, 2019 – May 21, 2020
24. Nicole Bein, Technische Universität Darmstadt (TUDa), Darmstadt, Germany, September 23 – October 17, 2019
25. Dr Marco Deluca, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria, September 30, 2019
26. Prof. Dr Andreas Klein, Technische Universität Darmstadt (TUDa), Darmstadt, Germany, October 10, 2019
27. Dr Marko Vrabelj, TDK Electronics GmhH & Co OG, Deutschlandsberg, Austria, October 21 – 22, 2019
28. Dr Kerstin Schmoltner, TDK Electronics GmhH & Co OG, Deutschlandsberg, Austria, October 21 – 22, 2019
29. Dr Marcus Albrecher, TDK Electronics GmhH & Co OG, Deutschlandsberg, Austria, October 21 – 22, 2019
30. Astita Dubey, Institute for Materials Science – Universität Duisburg-Essen, Essen, Germany, October 21 – December 8, 2019
31. Yao Minghai, Centrale Supélec, Université Paris-Saclay, Paris, France, November 3 – December 1, 2019
32. Mateo Miličević, Bjelovar University of Applied Sciences, Department of Mechatronics, Bjelovar, Croatia, November 4, 2019 – January 3, 2020
33. Federica Benes, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria, November 10 – 30, 2019
34. Prof. Brahim Dkhil, Centrale Supélec, Université Paris-Saclay, Paris, France, December 1–6, 2019
35. Marion Höfling, Technische Universität Darmstadt (TUDa), Darmstadt, Germany, December 9 – 13, 2019
36. Mihail Slabki, Technische Universität Darmstadt (TUDa), Darmstadt, Germany, December 9 – 13, 2019
37. Prof. Brahim Dkhil, Centrale Supélec, Université Paris-Saclay, Paris, France, December 19 – 21, 2019

STAFF

Researchers
1. Prof. Andreja Benčan Golob
2. Prof. Goran Dražić*
3. Prof. Danjela Kuščer Hrovatin
4. **Prof. Barbara Malič, Head**
5. Dr. Mojca Otoničar
6. Prof. Tadej Rojac
7. Asst. Prof. Hana Uršič Nemevšek

Postdoctoral associates
8. Dr. Mirela Dragomir
9. Dr. Kostja Makarovič*
10. Dr. Kristian Radan
11. *Dr. Tanja Vrabelj, left 01.02.19*

Postgraduates
12. Dr. Andraž Bradeško
13. Oana Andreea Condurache, B. Sc.
14. *Lovro Fulanović, B. Sc., left 01.02.19*
15. Sabi William Konsago, B. Sc.
16. Maja Makarovič, B. Sc.
17. Uroš Prah, B. Sc.
18. Samir Salmanov, B. Sc.
19. Matej Šadl, B. Sc.

Technical officers
20. *Darko Belavič, B. Sc., left 01.02.19*
21. Silvo Drnovšek, B. Sc.
22. Brigita Kmet, B. Sc.
23. Marija Šebjan Pušenjak, B. Sc.

Technical and administrative staff
24. Tina Ručigaj Korošec, B. Sc.

Note:
* part-time JSI member

BIBLIOGRAPHY

Original Article

1. Boštjan Genorio, Katharine L. Harrison, Justin Grant Connell, Goran Dražić, Kevin R. Zavadil, Nenad M. Markovic, Dušan Strmčnik, "Tuning the selectivity and activity of electrochemical interfaces with defective graphene oxide and reduced graphene oxide", *ACS applied materials & interfaces*, 2019, **11**, 37, 34517-34525.
2. Aleksander Matavž, Andreja Benčan, Janez Kovač, Ching-Chang Chung, Jacob L. Jones, Susan Trolier-McKinstry, Barbara Malič, Vid Bobnar, "Additive manufacturing of ferroelectric-oxide thin-film multilayer devices", *ACS applied materials & interfaces*, 2019, **11**, 49, 45155-45160.
3. Andraž Bradeško, Lovro Fulanović, Marko Vrabelj, Mojca Otoničar, Hana Uršič Nemevšek, Alexandra Henriques, Ching-Chang Chung, Jacob L. Jones, Barbara Malič, Zdravko Kutnjak, Tadej Rojac, "Electrocaloric fatigue of lead magnesium niobate mediated by an electric-field-induced phase transformation", *Acta materialia*, 2019, **169**, 275-283.
4. Darko Makovec, Matej Komelj, Goran Dražić, Blaž Belec, Tanja Goršak, Sašo Gyergyek, Darja Lisjak, "Incorporation of Sc into the structure of barium-hexaferrite nanoplatelets and its extraordinary finite-size effect on the magnetic properties", *Acta materialia*, 2019, **172**, 84-91.
5. Primož Koželj, Stanislav Vrtnik, Andreja Jelen, Mitja Krnel, Darja Gačnik, Goran Dražić, Anton Meden, Magdalena Wencka, David Jezeršek, Janez Leskovec, Soummyadipta Maiti, Walter Steurer, Janez Dolinšek, "Discovery of a FeCoNiPdCu high-entropy alloy with excellent magnetic softness", *Advanced engineering materials*, 2019, **21**, 5, 1801055.
6. Tomaž Kos, Tadej Rojac, Janko Petrovčič, Damir Vrančić, "Control system for automated drift compensation of the stand-alone charge amplifier used for low-frequency measurement", *AIP advances*, 2019, **9**, 3, 035133.
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9. Andraž Bradeško, Ana Hedl, Lovro Fulanović, Nikola Novak, Tadej Rojac, "Self-heating of relaxor and ferroelectric ceramics during electrocaloric field cycling", *APL materials*, **7**, 2019, 071111.
10. Aleksander Matavž, Andraž Bradeško, Tadej Rojac, Barbara Malič, Vid Bobnar, "Self-assembled porous ferroelectric thin films with a greatly enhanced piezoelectric response", *Applied materials today*, 2019, **16**, 83-89.
11. Alexander Martin, Hana Uršič Nemevšek, Tadej Rojac, Kyle Grant Webber, "Direct observation of the stress induced domain structure in lead-free $(Na_{1/2}Bi_{1/2})TiO_3$-based ceramics", *Applied physics letters*, 2019, **114**, 5, 052901.
12. Marta Pedrosa, Marija J. Sampaio, Tajana Horvat, Olga C. Nunes, Goran Dražić, Alírio E. Rodrigues, José Luís Figueiredo, Cláudia G. Silva, Adrián M. T. Silva, Joaquim Luís Faria, "Visible-light-induced self-cleaning functional fabrics using graphene oxide/carbon nitride materials", *Applied Surface Science*, 2019, **497**, 143757.
13. Katja Bezek, Damijan Nipič, Karmen Godič Torkar, Martina Oder, Goran Dražić, Anže Abram, Janez Žibert, Peter Raspor, Klemen Bohinc, "Biofouling of stainless steel surfaces by four common pathogens: the effects of glucose concentration, temperature and surface roughness", *Biofouling*, 2019, **35**, 3, 273-282.
14. Maja Pori, Iztok Arčon, Damjan Lašič Jurković, Marjan Marinšek, Goran Dražić, Blaž Likozar, Zorica Crnjak Orel, "Synthesis of a Cu/ZnO nanocomposite by electroless plating for the catalytic conversion of CO_2 to methanol", *Catalysis letters*, 2019, **149**, 5, 1427-1439.
15. Jingkun Li, Qingying Jia, Sanjeev Mukerjee, Moulay Tahar Sougrati, Goran Dražić, Andrea Zitolo, Frédéric Jaouen, "The challenge of achieving a high density of Fe-based active sites in a highly graphitic carbon matrix", *Catalysts*, 2019, **9**, 2, 144.
16. Danjela Kuščer, Andraž Kocjan, Maja Majcen, Anton Meden, Kristian Radan, Janez Kovač, Barbara Malič, "Evolution of phase composition and microstructure of sodium potassium niobate -based ceramic during pressure-less spark plasma sintering and post-annealing", *Ceramics international*, 2019, **45**, 8, 10429-10437.
17. Marjan Bele, Kevin Stojanovski, Primož Jovanovič, Leonard Moriau, Gorazd Koderman Podboršek, Jože Moškon, Polona Umek, Melita Sluban, Goran Dražić, Nejc Hodnik, Miran Gaberščck, "Towards stable and conductive titanium oxynitride high-surface-area support for iridium nanoparticles as oxygen evolution reaction electrocatalyst", *ChemCatChem*, 2019, **11**, 20, 5038-5044.
18. Marta Pedrosa, Goran Dražić, Pedro B. Tavares, José Luís Figueiredo, Adrián M. T. Silva, "Metal-free graphene-based catalytic membrane for degradation of organic contaminants by persulfate activation", *Chemical engineering journal*, 2019, **369**, 223-232.
19. Mirela Dragomir, Paul A. Dube, Iztok Arčon, Chad Boyer, Meghan Rutherford, Christopher Wiebe, Graham King, Hanna Dabkowska, John E. Greedan, "Comparing magnetism in isostructural oxides $A_{0.8}La_{1.2}MnO_{4.1}$: anisotropic spin glass (A = Ba) versus long range order (A = Sr)", *Chemistry of materials*, 2019, **31**, 19, 7833-7844.
20. Andreja Erman, Gregor Kapun, Sara Novak, Mojca Pavlin, Goran Dražić, Damjana Drobne, Peter Veranič, "How cancer cells attach to urinary bladder epithelium in vivo: study of the early stages of tumorigenesis in an orthotopic mouse bladder tumor model", *Histochemistry and cell biology*, 2019, **151**, 3, 263-273.
21. Kristijan Brecl, Chiara Barretta, Gernot Oreski, Barbara Malič, Marko Topič, "The influence of the EVA film aging on the degradation behavior of PV modules under high voltage bias in wet conditions followed by electroluminescence", *IEEE journal of photovoltaics*, 2019, **9**, 1, 259-265.
22. Matej Šadl, Urban Tomc, Uroš Prah, Hana Uršič Nemevšek, "Protective alumina coatings prepared by aerosol deposition on magnetocaloric

gadolinium elements", *Informacije MIDEM: časopis za mikroelektroniko, elektronske sestavne dele in materiale*, 2019, **49**, 3, 177-182.
23. Mario Bieringer, J. Rose Stewart, Andrew P. Grosvenor, Mirela Dragomir, John E. Greedan, "Quenching of long range order and the Mn^{3+} ordered moment in the layered antiferromagnet, $Ba_xSr_{1-x}LaMnO_4$: a polarized neutron scattering study", *Inorganic chemistry*, 2019, **58**, 7, 4300-4309.
24. Uroš Plaznik, Marko Vrabelj, Zdravko Kutnjak, Barbara Malič, Brigita Rožič, Alojz Poredoš, Andrej Kitanovski, "Numerical modelling and experimental validation of a regenerative electrocaloric cooler", *International journal of refrigeration*, 2019, **98**, 139-149.
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29. Mirela Dragomir, Mojca Otoničar, Marko Vrabelj, Lovro Fulanović, Silvo Drnovšek, Tadej Rojac, Barbara Malič, "Seeding effects on the mechanochemical synthesis of $0.9Pb(Mg_{1/3}Nb_{2/3})O_3 0.1PbTiO_3$", *Journal of the European ceramic society*, 2019, **39**, 5, 1837-1845.
30. Tanja Vrabelj, Aleksander Matavž, Hana Uršič Nemevšek, Vid Bobnar, Barbara Malič, "The effect of calcium zirconate modifications on the microstructure and functional properties of sodium niobate thin films prepared by chemical solution deposition", *Journal of the European ceramic society*, 2019, **39**, 7, 2325-2330.
31. Uroš Prah, Tadej Rojac, Magdalena Wencka, Mirela Dragomir, Andraž Bradeško, Andreja Benčan, Rachel Sherbondy, Geof Brennecka, Zdravko Kutnjak, Barbara Malič, Hana Uršič Nemevšek, "Improving the multicaloric properties of $Pb(Fe_{0.5}Nb_{0.5})O_3$ by controlling the sintering conditions and doping with manganese", *Journal of the European ceramic society*, 2019, **39**, 14, 4122-4130.
32. Hana Uršič Nemevšek, Andreja Benčan, Uroš Prah, Mirela Dragomir, Barbara Malič, "Structure and dynamics of ferroelectric domains in polycrystalline $Pb(Fe_{1/2}Nb_{1/2})O_3$", *Materials*, 2019, **12**, 8, 1327.
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1. Damjana Drobne, Sara Novak, Andreja Erman, Goran Dražić, "New opportunities for FIB/SEM EDX in nanomedicine: cancerogenesis research", In: *Biological field emission scanning electron microscopy*, Wiley, 2019, 533-543.

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1. Andraž Bradeško, *Coupling of electrocaloric and electromechanical responses in relaxor ferroelectrics for dielectric cooling:* doctoral dissertation, Ljubljana, 2019 (mentor Tadej Rojac; co-mentor Zdravko Kutnjak).
2. Aleksander Matavž, *Inkjet printing and structure-property relations of ferroelectric thin-film structures:* doctoral dissertation, Ljubljana, 2019 (mentor Vid Bobnar; co-mentor Barbara Malič).
3. Maja Pori, *Influence of the synthesis parameters on the performance of copper and zinc oxide-based catalysts for methanol synthesis reactions:* doctoral dissertation, Ljubljana, 2019 (mentor Marjan Marinšek; co-mentor Goran Dražić).

DEPARTMENT FOR NANOSTRUCTURED MATERIALS K-7

The R&D at the Department for Nanostructured Materials is focused on the areas of nanotechnology and advanced materials to address the most difficult societal challenges that Europe and the world are currently facing. This includes clean and efficient energy, health, environment remediation and critical-raw-materials resource efficiency. A versatile team with synergies across a variety of complementary basic and applied expertise in combination with state-of-the-art research methods enables us to respond promptly to various emerging societal challenges. The basic and applied research of the Department for Nanostructured Materials includes magnets and intermetallic alloys, engineering and functional ceramics, minerals, sensors, materials for a sustainable and ecologically built environment, biomimetic- and bio-materials.

Head:
Prof. Sašo Šturm

Magnetic Materials

In the frame of H2020 MSCA ITN **Marie Skłodowska-Curie European Training Network (DEMETER)** we are focusing on the **recycling and reprocessing of critical raw materials, i.e., rare-earth-based permanent magnets.** We successfully produced novel permanent magnets based on the recycled end-of-life Nd-Fe-B and Sm-Co systems. With the implementation of the spark plasma sintering (SPS) technique, we produced Nd-Fe-B permanent magnets from recycled powders obtained after HDDR (hydrogenation-disproportionation-decrepitation-recombination) processing. The recycling scheme of the HDDR route has been established by relating the magnetic properties' variations with particle size and oxygen content to help industry retain control of microstructure and quality in the recycled Nd-Fe-B powders (**Published in Journal of Rare Earths**). Likewise, the hot-deformation experiments in the SPS on the recycled HDDR Nd-Fe-B system yielded a 12% improvement in remanence, improving it from 0.9 T in the recycled powder to 1.01 T in the hot-deformed magnet, with the coercivity retained better than the recycled feedstock. SPS was used to consolidate the recycled Nd-Fe-B powder blends containing 1, 2 and 5 wt. % of DyF_3. About ~2 wt. % DyF_3 dopant in the HDDR Nd-Fe-B powder was sufficient to develop a uniform core-shell microstructure, with Dy-rich shells resulting in the coercivity increment. The obtained coercivity values of the blended magnets were 41% higher than the starting recycled HDDR powder and 17.5% higher than the SPS-ed magnet without the Dy addition **(Published in Materials).**

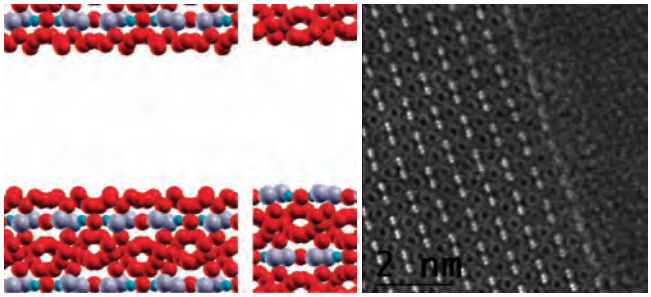

Figure 1: Reconstruction of the Fe- (left) and Nd- (middle) terminated Nd-Fe-B surface, obtained by means of ab-initio calculations, with the corresponding HAADF-STEM image of the Nd-Fe-B grain boundary.

With the aim of understanding the role of the grain boundaries with respect to the properties of Nd-Fe-B-based permanent magnets either from raw materials or from recycled feedstocks, we applied, in addition to various experimental activities, the density-functional theory (DFT). In this manner we performed ab-initio calculations simulating the atomic-scale structural properties at the surface, and at different interfaces of the ideal $Nd_2Fe_{14}B$ crystalline phase, which is the source of the strong ferromagnetism in the magnets (Figure 1). According to extensive experimental evidence the boundary effects prevent us from exploiting the full potential of the material. The DFT simulations, in synergy with the electron-microscopy imaging, will contribute to understanding these effects in detail, and hence to tailoring the respective microstructures, resulting in optimum magnet performance.

In DEMETER we evaluated the electrodeposition of Nd and Fe from ionic liquids based on 1-ethyl-3-methylimidazole dicyamide (Figure 2). We found that Nd can be reduced only in the presence of Fe, which catalyses the further reduction of Nd, and we also proposed an appropriate mechanism (**published in ChemElectroChem**). Furthermore, a novel recycling concept for sintered Nd-Fe-B magnets was developed based on selective anodic etching, where single-crystalline hard magnetic matrix grains of $Nd_2Fe_{14}B$ can be obtained for novel magnet fabrication, thus significantly reducing the energy and environmental impact. (**published in ChemSusChem, IF = 7.804**). The procedure is the subject of a patent application at the European patent office (**Application EP 18 2018 508.4**).

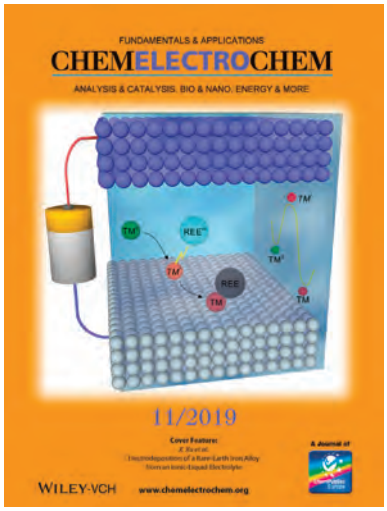

Figure 2: Awarded front cover of the ChemElectroChem journal. Art work illustrating the induced co-deposition mechanism for the rare earth (Nd) and transition metal (Fe).

We continued with the European project **MaXycle**, a transnational collaborative research and innovation project, funded from the ERA-NET Cofund on Raw Materials (ERA-MIN 2) instrument under Horizon 2020. Already, the first results showed that recycling EoL magnets will be a challenging task, as

the difference in composition and coatings makes it impossible to develop a uniform recycling route. EoL magnets with no history are the most problematic as they have to be analyzed before recycling. That is why MaXycle is proposing a uniform marking system for magnets for easy recyclability.

By implementing electrochemistry we have developed a facile method for rare-earth elements recovery and Fe deposition from sintered Nd-Fe-B magnets using total magnet oxidation on the anode and Fe deposition on the cathode. The leached rare earths from the magnets are obtained via a precipitation technique (published in Green Chemistry, and patented at the European Patent Office, Application EP 19197716.4). This new, closed-loop technology of continuous magnet leaching and Fe deposition with rare-earth recovery surpasses the current state-of-the-art method of hydrometallurgy in relation to the use of chemicals, the production of waste and the total cost.

In 2019 we started with the European project **Susmagpro**, which stands for Sustainable Recovery, Reprocessing and Reuse of Rare Earth Magnets in a European Circular Economy. The project aims to develop a recycling supply chain for rare-earth magnets in the European Union and to demonstrate the effective reuse of recycled rare-earth materials within several industries. The multidisciplinary SUSMAGPRO consortium are 20 of Europe's industry and academic leaders in REEs, sustainable processing, reuse, recycling, and recovery schemes, and cover the whole value chain from the collectors of magnet-containing scrap, to the producers of high-tech products.

In work for a Swiss industrial partner we demonstrated that we can design a novel form of permanent magnet, called a multicomponent magnet, where the surface region of the magnet has a high coercivity, while the central part is characterized by high remanence. The magnetic field around the Dy-free inner part is higher than in the Dy-rich surface part of the magnets. The interaction at the interface of two different magnetic phases in such a geometry has been uncovered by theoretical modelling. Our study shows that it is possible to arrange multiple phases of permanent magnets in one magnetic net-shaped body, therefore increasing the overall magnetic performance in spatially confined areas. This new finding opens up possibilities for more complex designs of permanent magnets that are currently gaining momentum related to electric mobility. In addition, such a multicomponent-magnet approach reduces the total cost of the electric motors from two perspectives: it requires a significantly lower amount of expensive Dy, which is also regarded as a critical raw material, and it lowers the amount of other materials used to construct the electric motor, which can now be realized in more compact geometry due to the higher overall remanent magnetization (Br) of the multicomponent magnet. From the economic perspective, we estimated that the increase of the production costs of such a magnet compared to the existing technology is minor. This could enable much faster growth of wind turbine generators' installation, and the use of electrical vehicles that are powered by permanent-magnet motors. The results of this work were published in the **Journal of Magnetism and Magnetic Materials**.

As part of the research work for Slovenian industrial partners, we focused on: (i) the improvement of coercivity of melt-spun powders used for bonded magnets, and (ii) the development of a coating procedure using different coating materials to prevent corrosion in aggressive conditions. Already in the first year of the two projects, we successfully increased the coercivity by more than 15%, and we established the most effective solution to protect sensitive Nd-Fe-B powders by using alumina as a thin protective layer. The improvement of coercivity was achieved by the addition of a Nd-Cu low-melting-point alloy, which was subsequently subjected to the optimized thermal treatment procedure. The next step in this research is to upscale the powder mixtures for the pilot production. The required quantity of the final powder for pilot plant production is 6 kg. In the second project, we established the most effective solution to protect the sensitive Nd-Fe-B powders by using alumina as a thin protective layer and prepared a quantity of 6 kg of coated powder for the pilot production test. The results are excellent and will be further transferred to large-scale production. The final analyses showed that the alumina-coated magnetic powder had almost no loss of magnetic properties after 2 months of a corrosion test. The corrosion resistance in demineralized water at 85 0C of the compressed bonded magnets was significantly improved, and the surface hardness of the alumina-coated magnetic powders is lower than that of the uncoated samples. This implies that the proposed powder-protection technology will not significantly change the existing tool wear used for the fabrication of the final bonded magnets.

We continued with the national project (L2-9213) in collaboration with company Magneti Ljubljana, where we are investigating novel ways of recycling magnetic swarf based on Sm-Co. We found that the magnetic swarf can be partially recycled by a re-melting procedure where the metal part (Co-rich) can be efficiently separated from the slurry (Sm-oxide-rich).

In 2019 we initiated research related to **additive manufacturing**, which is based on a state-of-the-art fused-deposition modeling (FDM) printer from the company Hage and an extruder machine for the production of metal- and ceramic-filed filaments. This technology will facilitate the production of complex net-shaped metallic and ceramic parts for new, emerging technologies. One of the fields where 3D printed parts have a high potential are complex-shaped magnets for new, electric motor design platforms, which theoretically surpass the current motor efficiencies and show great promise in relation to electric mobility and transfer to a carbon-free economy.

The additive-manufacturing technologies make it possible to produce magnets of arbitrary shapes and magnetization distributions. In order to design a magnet as the source of a given magnetic-flux field, expressed in terms of

the lines-of-force pattern, it is necessary to solve the so-called magnetostatic inverse problem. This requires solving the respective Maxwell equations. Which we performed in the framework of the finite-element method.

We continued with research in the framework of European project **AMPHIBIAN**, which stands for AnisoMetric Permanent HybrId magnets Based on Inexpensive And Non-critical materials. The goal of the project is to prepare hybrid ferrite-based magnets with energy product, BH_{max}, higher than 50 kJ/m^3. The upper limit so far is 45 kJ/m^3. The hybrid anisotropic magnets with enhanced magnetic performance prepared in the AMPHIBIAN project were installed in a demonstration flywheel (electric energy storage device – Figure 3). Until now, we systematically studied the influence of various processing methods on the magnetic properties of Sr-hexaferrite and determined the most suitable densification method. In the past year we were also investigating possibilities for an increase in the recycling rate of the scrape material produced during the injection moulding of ferrite magnets.

Figure 3: Flywheel prototype in which Nd-Fe-B magnets were replaced by ferrite magnets.

Complex Intermetallic Alloys

We successfully renewed the unique research project **International Associated Laboratory (LIA) PACS2**, which connects CNRS and JSI research teams for the period between 2019-2022. In the frame of joint activities we concluded our studies of the Al–V–Sn ternary system on a new ternary phase with the composition $Al_{1+x}V_2Sn_{2-x}$ (x = 0.19). Single-crystal X-ray diffraction measurements reveal that this ternary phase crystallizes with an orthorhombic structure, isostructural to the GaV_2Sn_2 structure type, showing a layered structure composed of vanadium cluster bands formed with pentagonal faces intercalated by Sn atom layers, which are exchanging with layers composed of Al columns. The time-sequenced atomically resolved HAADF-STEM imaging confirmed the orthorhombic structure and, in addition, the nonperiodic and anomalously large intensity variations at the Al sites (Figure 4). We confirmed that the anomalous image-intensity variations at the Al sites remain constant during the acquisition of the image series, which supports the idea that Al atoms are partially substituted with foreign Ga atoms, introduced during the Ga ion-milling (**published in Inorganic Chemistry**).

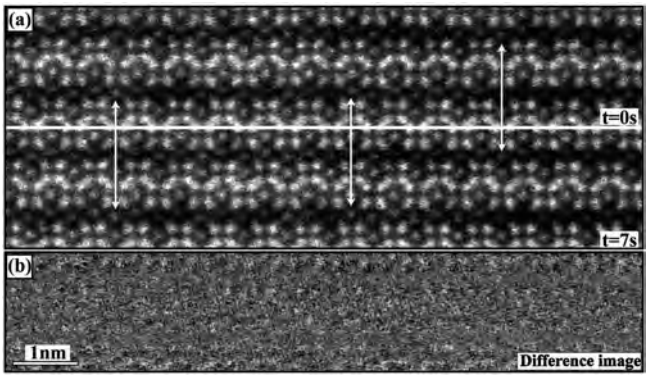

Figure 4. (a) Series of drift-corrected subsequently acquired images (Δt = 7 s) with the indicated equivalent atomic column positions (arrow marks). (b) Difference image confirming the minimized drift image region.

Sensors

We have fabricated KOH-modified Ni-nanowire-based electrodes (i.e., catalysts) for formaldehyde (HCHO) electro-oxidation in alkaline media. The catalysts based on Ni nanowires were synthesised via template-assisted electrodeposition, followed by a modification process in an alkaline solution (potential cycling in KOH), which produced a catalytically active NiOOH/$Ni(OH)_2$ redox couple on the surface. We demonstrated that the morphological and chemical changes introduced in the KOH-modification process play a crucial role in the electrocatalysis of the HCHO oxidation in alkaline media. We have been able to produce the catalyst, which is not only fundamentally interesting, but also very much applicable for the catalysis industry, as it ranged among the best catalytic performance (i.e. low overpotential of 0.4V) in comparison with the Ni-based catalysts disclosed in the literature. It also exhibits excellent sensor properties: a low detection limit of (0.8 μmol L^{-1}), a fast response time, a high sensitivity, good reproducibility and selectivity to other organic compounds **(published in Electrochimica Acta)**. Furthermore, the Ni nanowires were successfully integrated into commercially screen-printed electrodes (SPE) that results in the development of new low-cost devices for the in-situ analysis of HCHO that are currently being developed together with the Institute for Pulp and Paper and Faculty of Electrical Engineering and Computer Science University Maribor (FERI UM).

We are developing modified printed electrodes via the nanostructuring of the receptor elements based on transition metal (oxide)hydroxides and conductive polymers that serve as the base for an autonomic sensor platform for toxic organic compounds such as formaldehyde (national project L2-8182) and acrylamide (national project J2-1739) suitable for an in-situ detection system.

In the frame of developing a sensory platform for the acrylamide we investigated the use of polymers. Polyaniline is a conductive polymer with chemi-resistive properties, which makes it a widely used material for sensors. We are

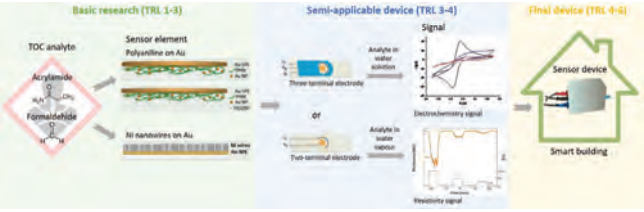

Figure 5: Research scheme towards the commercialization of TOC sensors.

preparing polyaniline via electrochemical synthesis on commercial screen-printed electrodes. Polyaniline is studied for the potential resistivity sensing of gases (ammonia) or liquids, and as a polymer for molecular imprinting (acrylamide sensing). We supplemented our fundamental electrochemical deposition studies by in-situ dynamic correlative approaches combining UV-vis spectroscopy and electrochemistry (spectro-electrochemistry) to understand the polymerisation mechanism in details. The acquired knowledge presents the base for an efficient realization of polyaniline as a material for the sensing of toxic organic compounds, such as acrylamide. In collaboration with FERI UM we are developing a sensory platform, designed as a two-terminal electrode device sensitive to ammonia in gas and acrylamide in water vapour (Figure 5).

Materials for a Clean Environment and Health

In the field of **photo-electro-catalytic decomposition of organic substances**, we were engaged in the degradation of volatile organic compounds (VOCs) in air and persistent organic pollutants in water. Air purification was focused on the design and assembly of a photocatalytic reactor and the preparation of an active photocatalyst by the anodic oxidation of titanium foil. We were able to eliminate key problems associated with the anodization of a flexible titanium foil. The prepared TiO_2 nanotube catalyst is strongly attached to the substrate, which is important for the safe operation of the cleaning system, without polluting the environment with detached nanoparticles. The designed air reactor was mainly used for the decomposition of formaldehyde, which is one of the main indoor VOC pollutants. Photocatalytic degradation has proven to be a very effective and promising approach for technology transfer to a larger scale. In the field of water purification, we investigated the suitability of substrates in the form of immobilized 2D nanostructures for the immobilization of metal catalysts. TiO_2 nanotubes were enhanced by annealing them in an ammonia atmosphere. The prepared TiOxNy films were tested for electrochemical, morphological and structural properties. Degradation studies were performed on phenol and textile dye. We elucidated the kinetics and the mechanism of phenol degradation. The results of this study were published in a highly ranked journal ***Applied catalysis B, Environmental*** (IF = 14.229). In addition, the TiO_2 photocatalyst was used for the photocatalytic degradation of microplastics, which has proved to be successful, but the studies are still in the first phase of research. (Figure 6)

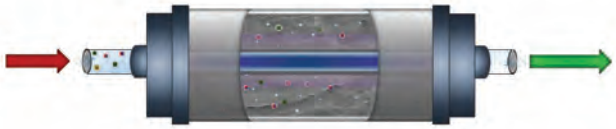

Figure 6: Schematic presentation of VOC air purification filter based on nanostructured TiO_2.

Biomaterials

In collaboration with the Queen's University Belfast, United Kingdom, and the Faculty of Medicine, University of Ljubljana, we have developed **pH-sensitive liposomes** with encapsulated anticancer drug doxorubicin conjugated to a prostate-specific antigen (PSA)-cleavable peptide that can be selectively activated by secreted PSA at the tumour site. Our results demonstrated the superior activity of Dox-PSA loaded pH-responsive liposomes in tumour spheroids, due to deeper penetration, compared to a free drug. Moreover, such a system enables enhanced safety due to a dual safety mechanism, i.e., the pH-sensitivity of liposomes that release prodrug only in the acidic tumour micro-environment and the enzymatic cleavage of a prodrug that occurs only inside of the PSA-expressing cancer cells. This study was published in **Molecular Pharmaceutics**.

We are developing theranostic nanosystems based on liposomes that are assumed to be one of the safest drug-delivery systems developed so far.

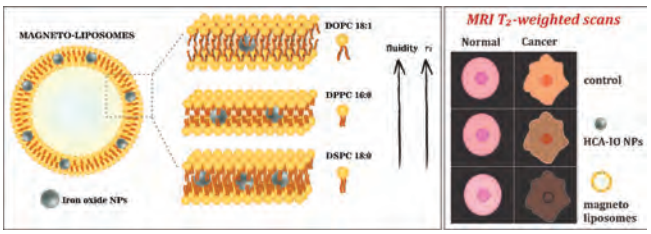

Figure 7: Left: Graphical representation of the structure of magnetic liposomes with different lipid bilayer compositions, which affects the fluidity of the bilayer and, consequently, the relaxivity, which is a measure of the effectiveness of the contrast agent for MRI. Right: In-vitro results have shown that due to the preferential internalization of magnetic liposomes into cancer cells, these in the MRI image have a much darker contrast than those exposed to free nanoparticles or as untreated. Therefore, they can be clearly distinguished from healthy cells that maintain a brighter contrast in the image.

Important results were also achieved in diagnostics. The majority of the clinically approved iron oxide nanoparticles (IO NPs) used as contrast agents for **magnetic resonance imaging (MRI)** have been withdrawn from the market, either due to safety concerns or lack of profits. Therefore, there is a need for novel IO NPs-based imaging agents with a high safety margin and superior MRI properties. Thus, we investigated magnetic-liposomes with different formulations and tested their contrast performance for MRI. We found that the encapsulation of NPs into liposomes dramatically improves their contrast performance (up to 42-fold) due to the favourable interactions between water visualized in MRI and the lipid coating. Importantly, an in vitro study showed improved the selectivity of the magnetic-liposomes compared to the free nanoparticles. The cancer cells

internalized a high concentration of liposomes, while their content was minimal in the normal cells, which led to an improvement in the contrast and an easier distinction between the healthy and the cancerous cells (Figure 7). In the case of free nanoparticles, the rate of internalization in both types of cell lines is similar and thus the diagnostics is limited.

As part of the project, which is being carried out in collaboration with the Faculty of Veterinary Medicine, UL, we continued our research on the silk fibroin carrier for pharmaceutical ingredients. We successfully incorporated estradiol into the fibroin film, and by using a surfactant we also achieved a significant increase in the release of estradiol over a longer period of time. The results of fibroin degradation studies have shown that controlling the rate of crystallization can affect the rate of estradiol release from the fibroin carrier.

In 2019, a patent (US 10,322,001) was granted to protect the process of preparing a multilayer bioactive coating in porous surface of Ti-based bone implants. The main component of the multilayer coating is nanoparticulate bioactive glass, introduced in the implant surface layer. In a biological environment, bioactive glass dissolves and helps to form bone, thereby improving the osteointegration of a titanium-based implant.

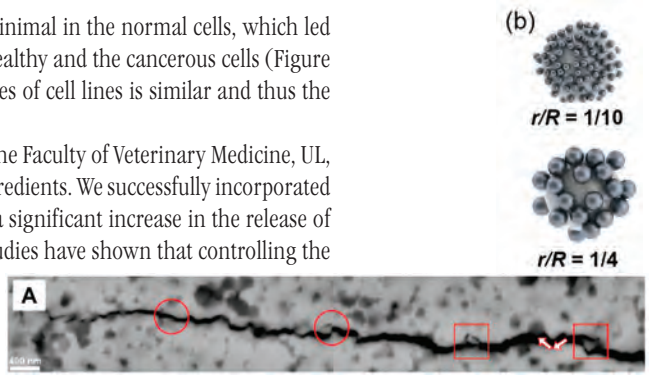

Figure 8: (a) SEM micrograph showing an arrested crack propagated from a Vickers indent. Circles, squares, and arrows indicate the crack branching, crack bridging, and crack deflection mechanisms, respectively, all contributing to a tougher ceramic nanocomposite. (b) Different sphere ratios between larger non-conducting matrix particles and the surrounding smaller, electrically conductive ones.

Asst. Prof. Andraž Kocjan has received the prestigious, early career "Young Scientist Award" given by the European Ceramic Society (ECerS) for outstanding contributions to the ceramic sciences given at the biannual 16th ECerS Conference held in Turin, Italy.

Engineering Ceramics

A fabrication route for the processing of tough and electrically conductive ZrO_2–TiN ceramic nanocomposite was established (Figure 8), enabling its electro-discharge machining (EDM) in a fully densified state. The TiN nanoparticles were incorporated into the zirconia matrix by admixing nanopowders or via the wet-synthesis approach. The powder precursors were rapidly sintered in a spark plasma sintering (SPS) furnace. We showed that the addition of 15 vol.% of TiN nanoparticles was already a sufficient amount to provide electrical percolation. These findings were coupled with theoretical simulations made using the Metropolis method for electrical conductivity of a binary system of electrically insulating and conducting spheres showing the influence of the ratio between bigger non-conducting matrix particles and the surrounding smaller, electrically conductive ones (Figure 8), yielding a roadmap for electrically conductive ceramic composites. The works were published in **Materials** and **Journal of the European Ceramic Society.**

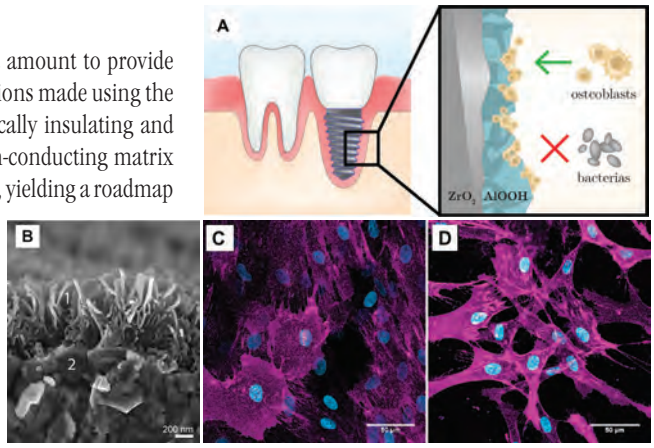

Figure 9: (a) Schematic representation of the surface-modification concept of a dental implant using nanostructured coating making a dental implant osseoconductive while repelling bacterial adhesion. (b) Nanostructured alumina coating residing on 3Y-TZP surface. Fluorescence micrographs of 3Y-TZP surfaces with adhered osteoblasts after 9 days in culture: (c) on sandblasted and (d) coated 3Y-TZP surface.

In the field of dental ceramics, we have been traditionally involved in the research on zirconia (3Y-TZP). In an interdisciplinary study, we have demonstrated a simple, viable, and effective solution for the modification of the 3Y-TZP dental implant surfaces by a combination of micro- and nano-roughening. To achieve both roughening types, gentle sandblasting was followed by nanostructured alumina coating deposition, improving 3Y-TZP`s osseointegration and antibacterial properties (Figure 9). Such an approach was successful for the adhesion and differentiation of human osteoblasts, while also minimising the attachment of Staphylococcus aureus bacteria. The work was published in the **Journal of the European Ceramic Society**. The same nanostructured coating can be used in an everyday dental laboratory procedure of 3Y-TZP surface preparation for improving the bonding of dental cements to 3Y-TZP. In collaboration with the Department for Prosthetic Dentistry, Medical Faculty, University of Ljubljana, an in-vitro study evaluating different laboratory firing protocols affecting the bond strength to 3Y-TZP was performed. The work was published in **Advances in Applied Ceramics**.

Genuine Technologies d.o.o., a start-up company, co-founded by dr. Nataša Drnovšek and Asst. prof. Andraž Kocjan, is using JSI`s licensed knowledge for the manufacture of Ca-silicate-based cement for endodontic treatment of teeth. The company has received a **CE mark** for its product **RS+™** – a medical device (Figure 10), and has acquired an **ISO 13485** standard, which specifies requirements for a quality-management system, where an organization needs to demonstrate its ability to provide medical devices and related services that consistently meet customer and applicable regulatory requirements.

Figure 10: Glass vials containing RS+™ powder cement.

Structural Materials

As part of EUROfusion's European fusion program, we continued our research on W-W_2C composites for the DEMO demonstration fusion power plant, while expanding our research to include binder-less tungsten carbide (WC), based on the encouraging results of the completed Enabling research project. In the first part, the composition and the process of the preparation of the W-W_2C composites were optimized based on a study of the relationship between the initial and final compositions of the material and the mechanical and thermal properties in the temperature range from room temperature to 1000 °C. The main criterion for selecting the optimal composition was the resistance of the material to thermal shocks during laser testing in high heat fluxes. The composite with 11% W_2C showed the best performance. In a similar way, the analysis of WC samples was carried out. The results revealed that the particle size had a crucial influence on the thermal conductivity and thus the resistance to thermal shocks. We therefore focused primarily on increasing the thermal conductivity.

Functional ceramics: semiconducting ZnO-based ceramics (varistors, thermoelectrics)

In the field of oxide thermoelectric materials of the n-type, our results obtained in cooperation with the "Shanghai Institute of Ceramics, the Chinese Academy of Science - SICCAS" showed that classic sintering in a reducing atmosphere and also spark plasma sintering (SPS) in a vacuum strongly enhance the thermoelectric characteristics of ZnO-based ceramics by increasing the electrical conductivity (σ) for several orders of magnitude in comparison to sintering in air due to strongly increased charge carrier concentration and mobility. We found that such sintering conditions increase the otherwise limited solid solubility of the donor dopants in ZnO and also prevent the formation of the intrinsic acceptor states (zinc vacancies, V_{Zn}, and oxygen interstitials, Oi) and hence electrostatic Schottky barriers at the grain boundaries. However, for the application of such thermoelectric ZnO-based ceramics their stability under oxidising atmosphere (i.e., air) is questionable. Therefore, we studied the effect of annealing in air on the thermoelectric characteristics of the ZnO-based ceramics prepared by sintering in at reducing atmosphere. It showed that annealing in air strongly reduced thw electrical conductivity and hence the power factor, PF (PF = σS^2; S = Seebeck coefficient) of ceramics in comparison to the original one, nevertheless their PF is still 8-times higher than in ceramics prepared by sintering in air. Results indicate that despite property degradation in air the preparation of thermoelectric ZnO-based ceramics by sintering in a reducing atmosphere or vacuum has advantages for their applications.

Recently it was discovered that some magnetic semiconductors have better thermoelectric properties than expected and that also the incorporation of a magnetic element in some otherwise nonmagnetic semiconducting compounds enhances their thermoelectric characteristics due to coupling between the magnetic moment and the charge carriers. Hence, we study in collaboration with National Institute for Materials Science – NIMS (Tsukuba, Japan) the influence of Co on the structural, microstructural and thermoelectric properties of the Al-doped ZnO ceramics with the compositions $Zn_{0.98-x}Al_{0.02}Co_xO$ (x = 0; 0.001; 0.0025; 0.005; 0.01; 0.05; 0.10). We analyse the possible effects of adding Co on the magnetism of ceramics and consequently the density and the mobility of the charge carriers, the electrical conductivity and the Seebeck coefficient. In collaboration with NIMS we also studied the influence of using fine nano-powders of ZnO prepared by the double-emulsion method on the microstructure development and the thermoelectric characteristics of undoped and Al-doped ZnO ceramics processed by the SPS method.

In the field of ZnO-based varistor ceramics we continued our research, in collaboration with the Shanghai Institute of Ceramics, the Chinese Academy of Science – SICCAS, on the development of a novel type of varistor ceramics. Standard ZnO-based varistor ceramics, which strongly dominate in the field of overvoltage protection applications, have a complex chemical composition with typically about 7 to 10 wt.% of oxides of Bi, Sb, Co, Mn, Ni and Cr added to ZnO and hence the microstructure. Because Bi_2O_3 results in the formation of a liquid phase during sintering and also evaporates, this causes various difficulties and higher costs in the mass production of varistors. The new type of ZnO-based varistor ceramics has an excellent current-voltage (I-U) nonlinearity, despite a very simple chemical composition with only three easily available dopants added to ZnO in amount of about 3.5 wt.%, none of them forming a liquid phase or being volatile during the sintering. Our research was focused on the mechanism of the formation of the Schottky barriers to explain the nature of the I-U nonlinearity in this new type of varistor ceramic in the absence of standard dopants inducing nonlinearity, like oxides of Bi and Pr.

We continued on the microstructure evolution and electrical properties of SnO_2-based varistor ceramics. Promising dielectric and varistor properties were obtained by the dual doping of SnO_2 with CoO and Ta_2O_5. Unlike in the SnO_2–CoO–Nb_2O_5 system, we find that more CoO is needed to obtain fully dense microstructures with optimal electrical properties. **This is due to the difference in the charge-compensation mechanism where no Sn^{2+} is incorporated into the structure and Co^{2+} takes the role of the acceptor**. Already, 0.05 mol% Ta_2O_5 effectively reduces the porosity, improves densification and dielectric permittivity and triggers a 3-fold increase in the SnO_2 growth rate. With larger additions, however, Ta_2O_5 segregates to the grain boundaries and hinders SnO_2 grain growth, which in turn improves the electrical properties. The **non-linear coefficient α reaches a value of 40**

and a threshold voltage of 272 ± 2 V/mm at a low leakage current I_L = 1.2 μA with the addition of 1 mol% Ta_2O_5. The lowest content of Ta_2O_5 results in a **high dielectric permittivity, reaching 6525** for a doping level of 0.10 mol%. The study was published in ***J Eur Ceram Soc*** .

Mineralogy

In collaboration with the Department for Litospheric Research of Vienna University we started two research projects that involve the **atomic-resolution electron microscopy of petrological samples**. The first is FWF-ARRS International Project GInA: 'Mineral inclusions in garnets from macroscopic to atomic scale – opening the petrogenetic archive'. Another project that we take part is FWF-RFBR International Joint Project MiMa: 'Fe-Ti oxide inclusions and magnetism of oceanic gabbro'. Within the project we receive one PhD student and one post-doc for specialization in atomic-scale electron microscopy methods. From our collaboration with the University in Novosibirsk and Tairus we published atomic-scale studies of the internal structure of leucosapphire, and high-temperature in-situ transmission electron microscopy and an X-ray study of twinning in natural aragonite (Figure 11). The work was published in **CrysEngComm**.

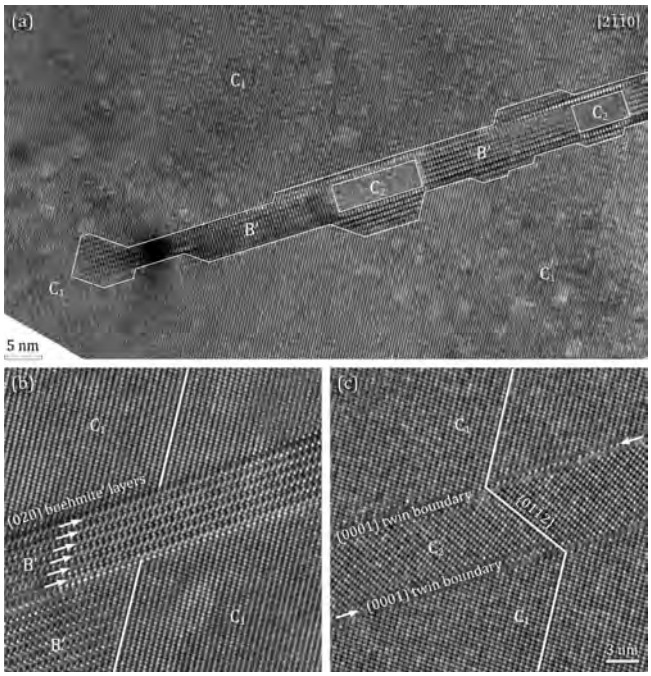

Figure 11: High-resolution TEM of Al–O–H lamellae in leucosapphire. (a) Segment of the lamella embedded in the corundum (C1) matrix. Boehmite-like layers (B') are faceted towards the host corundum matrix (C1). Within B' layers domains of corundum are in a twin (C2) orientation with respect to the host (C1). (b) Close-up of the boehmite-like layer (B') within the host corundum (C1). (c) Segment of the lamella with corundum in a twin orientation (C2). [Thomas et al. CrystEngComm 2019]

Self-assembly: We continued fundamental studies on the self-assembly TiO2 rutile mesostructures. Grown on a single-crystal substrate, rutile fibres show unusual displacements that could not be explained by simple epitaxial growth. The shifts between the fibres are systematic and show the presence of some strong, yet unknown, ligand interaction that compresses the adjacent rutile structure. Ab-initio theoretical calculations of the TiO_2-water-TiO_2 interface result in increased acidity when the interface includes the observed shift, and neutral in the absence of the shift. **This is the first theoretical proof that acidic conditions directly control the translation state between the rutile fibers**. Rutile crystals decorated with mesostructured rutile fibres show enhanced photocatalytic properties. To extend our studies of self-assembly we submitted an FET-open project in collaboration with University of Barcelona and Fraunhofer Institute in Freiburg as of September 2019.

In collaboration with the Institute for Multidisciplinary Research in Belgrade we selected inversion boundaries (IBs) in **ZnO as a model system for quantum chemical investigation of the stability and formation of chemically induced planar defects in crystals**. Our studies are based on modeling IB structures and involve atomic-scale investigations of IBs with selected dopants, and experimental in-situ studies of their formation mechanisms. Five possible IB structures were addressed, out of which three were already experimentally confirmed. The theoretical part of the investigations was made in collaboration with the Department of Physical and Organic Chemistry of the JSI. The main goal of these fundamental studies is to obtain an understanding of the formation and stability of chemically induced defects in crystals and to predict how they modify the material's physical properties.

Advanced Electron Microscopy

For the microscopic examinations of materials, we use advanced **correlative microstructural characterization**, for a combined and optimal use of several analytical microscopic methods including: scanning electron microscopy (**FEGSEM**), qualitative and quantitative elemental analysis by electron-probe microanalysis (**EPMA**) using energy-dispersive and wavelength-dispersive X-ray spectroscopy (**EDS, WDS**), electron-backscatter diffraction (**EBSD**) and complementary atomic force microscopy (**AFM**).

We have successfully demonstrated how Liquid-Cell Transmission Electron Microscopy can be implemented for the in-situ dynamic observation of nucleation and growth processes taking place in nanoscale materials that are in a solvated environment.

By using **optimized correlative microanalysis**, we have studied various materials such as: thermoelectric ceramics, complex metallic alloys, magnetic materials based on Nd-Fe-B and Sm-Fe-Co, abrasives, piezoelectric perovskite ceramics. By performing the **expert-level quantitative WDS microanalysis** we have accurately measured trace concentrations of the dopants Eu and Dy in phosphorescent ceramics based on $Sr_4Al_{14}O_{25}$. We have determined the exact chemical composition of submicrometric ceramic thin films that were made from 67PMN33PT complex perovskite. With the micro-crystallographic **EBSD** analyses we investigated and directly determined the **crystallographic twin**

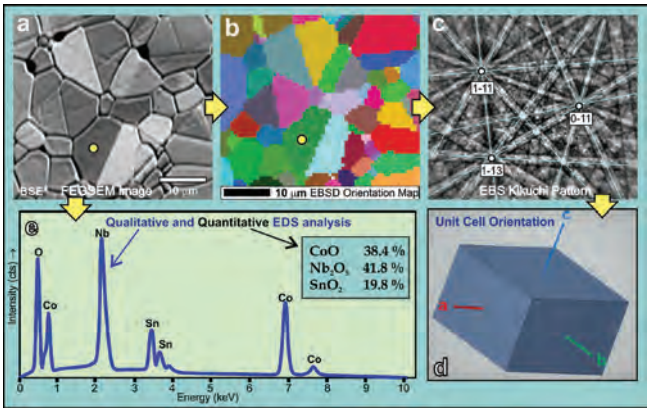

*Figure 12: **Correlative microstructural characterization of SnO_2-CoO-Nb_2O_5 ceramics**: (a) FEGSEM micrograph of the microstructure; (b) EBSD orientation map revealing the random crystallographic orientations of the grains; (c) individual Kikuchi EBSD pattern from a selected grain; (d) reconstruction of the orientation of the tetragonal unit cell in a selected grain; (e) qualitative and quantitative EDS analysis of chemical composition of the material.*

ESTEEM3 consortium, which was successfully granted in 2019, has a status of EU Advanced Community. A member of our department is the scientific coordinator of the consortium.

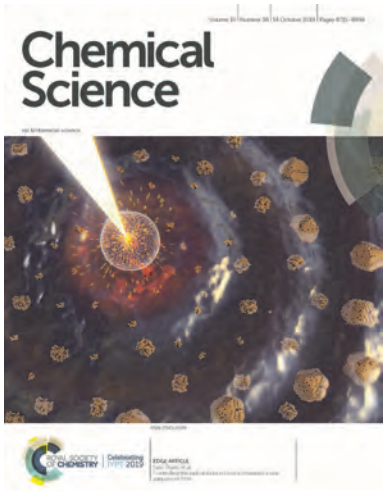

Figure 13 Awarded front cover of Chemical Science journal. Art work representing the radical-induced redox chemistry inside the LCTEM.

types in **cassiterite** SnO_2 ceramics (Figure 12), we studied the texture in conventionally and SPS sintered $Nd_2Fe_{14}B$ magnets.

To bridge the gap between conventional (high-vacuum) and in-situ liquid TEM we have recently implemented an interdisciplinary research platform for dynamic TEM studies in liquid environments, Liquid-Cell Transmission Electron Microscopy (LCTEM), that are overcoming the static limitations of conventional analysis techniques. This ground-breaking approach opens up a wide range of possibilities in high-resolution in-situ dynamic studies where case-by-case specialized experiments can be performed by the proper redesign of liquid chambers, allowing us to perform direct nucleation and growth studies of nanoparticles either from solutions or during the electrodeposition, at the nanoscale and in real time. However, the beam-driven solvent radiolysis, which results from the microscope's high-energy electron beam, can dramatically influence the dynamics of the system (Figure 13). Recent research suggests that radical-induced redox chemistry can be used to investigate the various redox-driven dynamics for a wide range of functional nanomaterials. We proposed a holistic approach to the processes in the radical-induced redox chemistry in LCTEM, including the complex kinetics of the radiolysis species and their influence on the redox chemistry of the materials under investigation. The results of this study were published in a highly ranked journal ***Chemical Science*** (IF = 9.5).

The ESTEEM3 consortium (Enabling Science and Technology through European Electron Microscopy) continued its activities in the field of materials characterization using state-of-the-art techniques of transmission electron microscopy, such as electron energy-loss spectroscopy (EELS), high-resolution scanning transmission electron microscopy (STEM, HAADF-STEM), in situ TEM and mechanical preparation of the TEM samples.

The research group of the Department for Nanostructured Materials is very strongly connected with the activities within the **Center for Electron Microscopy and Microanalysis (CEMM)**, mainly through the implementation of various electron microscopy analytical techniques and the possibility for the researchers to access research infrastructure for electron microscopy.

Industrial partners

Within the project "Microstructural investigations of abrasive materials" with industrial partner Weiler Abrasives (SwatyComet) we have investigated innovative composite abrasives, intended to develop and manufacture improved cutting and grinding tools with a prolonged lifetime.

Education and outreach activities

For the seventh year, the members of the department participated in science promotion activities within the framework of the Science on the Street project. In 2019 there were 16 popular science lectures. The Scientific slam was organized in collaboration with the Cutting Edge conference, which is organized by FKKT-UL. On the ZnC website we have published 13 blogs of researchers and 3 contests. At the invitation of the EIT "Raw Materials" and JA Slovenia (Institute for the Promotion of Youth Entrepreneurship), we co-organised the Innovation Camp 2019 in Zreče. 100 students from 20 high schools from all over Slovenia participated in the Innovation Camp.

SRIP ToP activities, vertical value chain (VVV) New materials

Within the SRIP ToP VVV New Materials activities, we prepared new action plan for the III. phase of SRIP ToP for the period 2020-2023, which is following the successful ending of II. phase. We participated in the preparation of the brochure, which will represent the main focus areas of SRIP ToP. In collaboration with the Horizontal network (HOM) of Modern technology for materials, we organized two workshops, namely, "Modern characterization techniques" and "Chemical and structural analysis of materials". They were intended to educate and connect industry with research organizations in research and development fields. Further, we have prepared a brochure "Examples of good practice", which presents application topics, services and examples of collaboration with industry.

Awards and appointments

1. In April 2019 **Dr Nina Kostevšek** received a Best poster award at the H2020 COST Action training school in Trieste (CA17140 "Cancer nanomedicine - from bench to the bedside") for the presentation of her results on the development of multi-functional nanoparticles for medical applications. Dr Kostevšek is also a management committee member and representative for Slovenia in this COST Action.
2. The 27th International Conference on Materials and Technology (27th ICM&T) took place in Portorož from 16 to 18 October 2019. In the scope of the conference Young researchers' competition was organized. The six-member international committee awarded **Hermina Hudelja** with the second place for her talk "Feather-light, cellulose-nanofiber-reinforced γ-Al_2O_3 foams".
3. At the 6th European Conference on Environmental Applications of Advanced Oxidation Processes which was held from 26 to 30 June 2019 in Portorož, Slovenia, **Živa Marinko** presented a poster with the title "Connecting Metal Titanium Surface Properties and TiO_2 Nanotube Photocatalytic Activity: Top-Down Approach" and was awarded 3rd place at the Student Paper Contest as well as Environmental Science: Water Research & Technology Poster Prize.
4. **Asst. Prof. Andraž Kocjan**, a senior research fellow at the Department for Nanostructured Materials of Jožef Stefan Institute, has received prestigious, early career award "Young Scientist Award" given by the European Ceramic Society (ECerS) for outstanding contributions to the ceramic sciences. Dr Kocjan has published 44 scientific papers (~1000 citations), 2 professional papers and 3 non-technical articles (and held 7 invited talks and 7 interviews). He is an author of an EU and Slovenian patent, GB patent application, technical invention and has co-founded a spin-out company based on JSI's licensed knowledge (producing bioactive fillers for endodontic treatment of teeth receiving ISO 13485 and CE mark for manufacturing and marketing of medical devices). The award was given at the biannual 16th ECerS Conference held in Turin, Italy. At the ceremony Dr Kocjan gave a talk entitled "From unusual to innovative and sustainable processing of ceramics.
5. Tajda Koblar, a Poljane High School student, designed a research study entitled "Comparison of laser and water bath-based thawing process of frozen red blood cells" under the mentorship of **Dr Nina Kostevšek** (JSI, K7) and Dr Ruka Rudež (Poljane High School). Her work was selected for this year's Krka Prize.
6. Laura Drasler and Ula Dragman, Vič High School students, created a research study entitled "Coloidal silver in dental products" under the mentorship of **Anja Korent** (Drame at the time, JSI, K7), and Dr Alenka Mozer (Vič High School). Their work was selected for this year's Krka Prize.
7. **Dr Nina Kostevšek** was awarded the Wüthrich International Young Star Award for the outstanding performance during the early career stages at Sustainable Industrial Processing Summit (SIPS 2019) which was in Cyprus from 23 to 26 October 2019. This award has been established in honour of the distinguished work and lifetime achievements of 2002 Nobel Laureate in Chemistry, Prof. Kurt Wüthrich, who is known for developing the NMR method for studying macrobiological molecules. Dr Nina Kostevšek presented work on the development of new nanoparticle-based contrast agents for magnetic resonance imaging.
8. **Prof. Spomenka Kobe** is the recipient of the prestigious "Frey Award for Leadership in development new technologies that contribute to global sustainable development in the environment, economy, and social points of view." The summit honoured the 2019 STARS of sustainable science, technology, and innovation and was divided into ten parallel Symposia devoted to the awardees. One of them was the "Kobe International Symposium on Science of Innovative and Sustainable Alloys and Magnets (SISAM)," Paphos, Cyprus, where the world-leading scientists from the field of magnets and complex alloys presented their latest achievements in the field. Frey Award is granted to scientists, economists, and politicians. So far, the only awarded Slovenian was Dr Janez Potočnik, European Commissioner for Science and later for Environment.

Organization of conferences, congresses and meetings

1. The 27th International Conference on Materials and Technology – 27. ICM&T, 16–18 October 2019, Portorož, Slovenia (co-organisers)
2. Annual meeting of LIA PACS2: International Associated Laboratory; Push-Pull Alloys and Complex Compounds: from bulk properties to surface functions, 16–19 December 2018, Nancy, France
3. The 11th Jožef Stefan International Postgraduate School Students' Conference and 13th CMBE day, 15–16 April 2019, Rateče, Slovenia (co-organisers)
4. Workshop on "Chemical and structural analysis of materials"; SRIP ToP, "New materials" value chains and the horizontal network "Modern Production Technology for Materials", Podgorica, Slovenia, 28 November (co-organisers)
5. Workshop "EIT Raw materials", 23–24 September 2019, Zreče, Slovenia (co-organisers)
6. Midterm meeting of the H2020 project AMPHIBIAN: AnisoMetric Permanent HybrId magnets Based on Inexpensive And Non-critical materials, 10–12 June 2019, Ljubljana, Slovenia

Patent granted

1. Saša Novak, Nataša Drnovšek, Gregor Murn
   Implant having a multilayered coating and a process for preparing thereof
   US10322001 (B2), US Patent Office, 18. 06. 2019.

INTERNATIONAL PROJECTS

1. Spark Plasma Sintering (SPS) of Cost Effective and High Performance Rare-Earth Based Permanent Magnets for Electrical Machines
   Prof. Spomenka Kobe
   Abb Switzerland Ltd
2. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Prof. Saša Novak Krmpotič
   European Commission
3. COST MP1407 - e-MINDS; Electrochemical Processing Methodologies and Corrosion Protection for Device and Systems Miniaturization
   Prof. Kristina Žužek Rožman
   Cost Office
4. COST CA17140 - Nano2Clinic; Cancer Nanomedicine - From the Bench to the Bedside
   Dr. Nina Kostevšek
   Cost Association Aisbl
5. A novel ciruclar economy for sustainable RE-based magnets
   Prof. Spomenka Kobe
   Ministry of Education, Science and Sport
6. H2020 - DEMETER; Training Network for the Design and Recycling of Rare-Earth Permanent Magnet Motors and Generators in Hybrid and Full Electric Vehicles
   Prof. Kristina Žužek Rožman
   European Commission
7. H2020 - AMPHIBIAN; Antisometric Permanent Hybrid Magnets based on Inexpensive and Non-Critical Materials
   Dr. Petra Jenuš
   European Commission
8. H2020 - ESTEEM3; Enabling Science and Technology through European Electron Microscopy
   Prof. Miran Čeh
   European Commission
9. H2020 - SUSMAGPRO; Sustainable Recovery, Reprocessing and Reuse of Rare-Earth Magnets in a Circular Economy
   Prof. Spomenka Kobe
   Sennheiser Electronic Gmbh & Co Kg
10. H2020-EUROfusion-Plasma Facing Components-1-IPH-FU, EUROFUSION
    Prof. Saša Novak Krmpotič
    European Commission
11. H2020 EUROfusion - Materials-PPPT-FU
    Prof. Saša Novak Krmpotič
    European Commission
12. H2020 EUROfusion - Education-ED-FU
    Prof. Saša Novak Krmpotič
    European Commission
13. RECEMENT: Re-generating (raw) materials and end-of-life products for re-use in Cement/Concrete, ERA.MIN2
    Prof. Sašo Šturm
    University of Ljubljana (UNI-LJ), University POLITEHNICA of Bucharest (UPB), Sabanci University (SU)
14. Atomic-Scale Investigations of Twinning and Polytypism in Natural Diamonds
    Prof. Aleksander Rečnik
    Slovenian Research Agency
15. Properties of Monolithic and Composite Advanced Ceramics obtained by Conventional and Non-Conventional Sintering Methods
    Dr. Petra Jenuš
    Slovenian Research Agency
16. Functionalized TiO2 Nanostructures for Application in Photo-Catalysis and Sensors
    Prof. Miran Čeh
    Slovenian Research Agency
17. Stability via Doping: Experimental and Theoretical Design of Functional Oxide Ceramics
    Prof. Aleksander Rečnik
    Slovenian Research Agency
18. Micro-to Nanoscale Textures of Ore Minerals: Methods of Study and Significance
    Dr. Janez Zavašnik
    Slovenian Research Agency
19. Investigation of Helium Retention in Plasma Facing Materials Using Advanced Analytical Methods
    Dr. Janez Zavašnik
    Slovenian Research Agency

RESEARCH PROGRAMMES

1. Nanostructured Materials
   Prof. Sašo Šturm
2. Ceramics and complementary materials for advanced engineering and biomedical applications
   Asst. Prof. Andraž Kocjan
3. Fusion technologies
   Prof. Saša Novak Krmpotič

R & D GRANTS AND CONTRACTS

1. W- and WC-based composites for high thermally loaded parts in the fusion demonstration power plant DEMO
   Prof. Saša Novak Krmpotič
2. Catalytically-assisted high efficiency and low-cost nanostructured sensors based on modified screen printed electrodes for analytical chemistry
   Prof. Kristina Žužek Rožman
3. Towards reliable implementation of monolithic zirconia dental restorations
   Asst. Prof. Andraž Kocjan
4. Mineral inclusions in garnet from macroscopic to atomic scale: Opening the petrogenetic archive
   Prof. Aleksander Rečnik
5. High performance nanostructured acrylamide sensors
   Dr. Kristina Žagar Soderžnik
6. Nanoscale investigations of diffusion controlled topotaxial phase transformations in rutile-corundum host systems
   Prof. Aleksander Rečnik
7. Characterization of fractal structures and scale-up parameters in their synthesis
   Dr. Matejka Podlogar
8. Development of a new reactor concept for microkinetic studies and its use for selective oxidative dehydrogenation of alkanes and methane coupling
   Dr. Luka Suhadolnik
9. Role of estrogens in active brain feminisation? and development of a novel hormone implant, mimicking estrous cycle
   Prof. Saša Novak Krmpotič
10. Selective extraction of high value molecules from forest products processing residues in the speciality chemicals sector
    Dr. Petra Jenuš
11. UV sensors nanoparticles embedded into PA fibres
    Prof. Spomenka Kobe
12. Effective recycling of abrasive sludge in the production of Sm2Co17 magnets for a waste-free economy
    Prof. Kristina Žužek Rožman
13. Development of complex shape multicomponent permanent magnets with the use of advanced 3D printing technology
    Prof. Spomenka Kobe
14. Degradation of textile microplastic for domestic wastewater treatment
    Dr. Matejka Podlogar
15. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
    Dr. Kristina Žagar Soderžnik
    Ministry of Economic Development and Technology
16. Services for the Exports
    Dr. Zoran Samardžija
17. External Services
    Asst. Prof. Andraž Kocjan

NEW CONTRACTS

1. Degradation of textile microplastic for domestic wastewater treatment
   Dr. Matejka Podlogar
   Gorenje Gospodinjski Aparati,d.d.
2. Development of complex shape multicomponent permanent magnets with the use of advanced 3D printing technology
   Prof. Spomenka Kobe
   Kolektor Group d. o. o.
3. Corrosion protection of magnetic powders to improve their resistivity to liquids at higher temperatures
   Prof. Spomenka Kobe
   Kolektor Group d. o. o.

4. Implementation of surface modification of Nd-Fe-B powders to increase the coercivity of bonded magnets
   Prof. Spomenka Kobe
   Kolektor Group d. o. o.
5. Microstructural analyses of abrasive materials
   Dr. Zoran Samardžija
   Swatycomet, WEILER Abrasives d.o.o.
6. Effective recycling of abrasive sludge in the production of Sm2Co17 magnets for a waste-free economy
   Prof. Kristina Žužek Rožman
   Magneti d.d.
7. Development of a new magnetic powder
   Prof. Sašo Šturm
   RLS Merilna tehnika d.o.o.
8. NextGenHVEC: Advanced materials, technologies and prototypes for cost effective hybrid varistor electronic components with improved thermal stability
   Prof. Sašo Šturm
   Kekon keramični Kondenzatorji, d.o.o.
9. Coating of Nd-Fe-B powders for corrosion protection - transfer to pilot production
   Prof. Spomenka Kobe
   Sieva, podjetje za razvoj in trženje v avtomobilski industriji d.o.o.
10. Development of complex shape multicomponent permanent magnets with the use of advanced 3D printing technology
    Prof. Spomenka Kobe
    Kolektor Group d. o. o.
11. Carrying out a study of the possibility of galvanic deposition of nickel on magnetic dust and improving the corrosion protection of magnetic dust
    Prof. Spomenka Kobe
    Kolektor Group d. o. o.
12. Implementation of VSM, XRD, TEM and CoNiP measurements
    Prof. Sašo Šturm
    RLS Merilna tehnika d.o.o.

VISITORS FROM ABROAD

1. Dr Melike Mercan Yildizhan Özyar, Linköping University, Linköping, Sweden, 20 January – 3 February 2019
2. Dr Lavinia Scherf, Dr Jaćim Jaćimović and Dr Reto Kessler, ABB Switzerland Ltd., Baden, Switzerland, 22–23 January 2019
3. Hans Willemsen, 3D-CAT, Additively manufactured chemical processing units, Epe, Netherlands, 25 January 2019
4. Prof. Takao Mori, National Institute for Materials Science (NIMS), Tsukuba, Japan, 25–27 January 2019
5. Dr Blaž Belec, Institute of materials for electronics and magnetism, CNR, Parma, Italy, 4–13 February 2019
6. Ana Damnjanović, Kolektor Group, d.o.o., Idrija, Slovenia, 1 March – 31 May 2019
7. Dr Andrasz Kovacs, Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Institute for Microstructure Research, Research Centre Jülich, Germany, 5–8 March 2019
8. Dr Ismail Özgür Özer in Ertuğrul İşlek, Anadolu University, Eskişehir, Turkey, 11–14 March 2019
9. Vesna Ribić, University of Belgrade, Belgrade, Serbia, 21 March – 7 April 2019
10. Prof. Jean-Claude André, CNRS - L'institut des sciences et de l'ingénierie des systèmes, Nancy, France, 27–28 March 2019
11. Dr Andreja Gajović and Ivana Panžić, Institut Ruđer Bošković, Zagreb, Croatia, 15–18 April 2019
12. Prof. Dragoljub Mirjanić, Academy of Sciences and Arts of the Republika Srpska, Banja Luka, Bosnia and Herzegovina, 29–30 April 2019
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14. Dr Andreja Gajović, Institut Ruđer Bošković, Zagreb, Croatia, 27–31 May 2019
15. Prof. Cleva Ow-Yang and Prof. Mehmet Ali Gülgün, Sabanci University, Faculty of Engineering & Natural Science, Istanbul, Turkey, 22–25 May 2019
16. Vesna Ribić, University of Belgrade, Belgrade, Serbia, 1 July – 1 October 2019
17. Dr Blaž Belec, Institute of materials for electronics and magnetism, CNR, Parma, Italy, 3–9 July 2019
18. Dr Andreja Gajović and Dr Tihana Čižmar, Institut Ruđer Bošković, Zagreb, Croatia, 19 July 2019
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21. Dr Melike Mercan Yildizhan Özyar, Linköping University, Linköping, Sweden, 11–31 August 2019
22. Dr María Jazmin Duarte Correa and Dr Aleksander Kostka, Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf, Germany, 30 August – 2 September 2019
23. Sergio Floriano Toribio, Sergio Haro Murcia and Jose Maria Cantarero Alonso, Rey Juan Carlos University, Madrid, Spain, 9 September – 9 December 2019
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25. Dr Daniel Meljanac, Institut Ruđer Bošković, Zagreb, Croatia, 15–21 September 2019
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27. Prof. Bojana Obradović, University of Belgrade, Belgrade, Serbia, 14 October 2019
28. Dr Masato Sagawa, Dr Yutaka Yoshida and Dr T. Iiriyama, Daido Steel Co., Ltd., Higashi-ku, Nagoya, Aichi, Japan, 21 October 2019
29. Dr Michael Cattell, Institute of Dentistry, London, Great Britain, 21–22 October 2019
30. Ivana Jelić, University of Belgrade, Belgrade, Serbia, 21–27 October 2019
31. Dr Richard Wheeler, Edinburgh Scientific, Edinburgh, Scotland, 30 October 2019
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33. Dr María Jazmin Duarte Correa, Prof. Gerhard Dehm, Dr Subin Lee and Dr Aleksander Kostka, Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf, Germany, 27 November – 1 December 2019
34. Dr Melike Mercan Yildizhan Özyar, Linköping University, Linköping, Sweden, 1–21 December 2019
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36. Prof. Gerald Kothleitner, FELMI-ZFE Institut für Elektronenmikroskopie und Nanoanalytik, Graz, Austria, 5 December 2019
37. Dr Milan Vukšić and Martina Kocijan, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia, 8–14 December 2019
38. Dr Richard Wheeler, Edinburgh Scientific, Edinburgh, Scotland, 2–6 December 2019
39. Dr Andreja Gajović and Ivana Grčić, Institut Ruđer Bošković, Zagreb, Croatia, 23 December 2019
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Original Article

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Patent

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Theses and Mentoring

1. Anas Eldosouky, *Hydrogen decrepitation and reprocessing of Sm-Co magnets:* doctoral dissertation, Ljubljana, 2019 (mentor Irena Škulj; co-mentor Kristina Žužek Rožman).
2. Awais Ikram, *Reprocessing of recycled Nd-Fe-B and Sm-Co-based magnets with contemporary sintering technique:* doctoral dissertation, Ljubljana, 2019 (mentor Kristina Žužek Rožman; co-mentor Spomenka Kobe).
3. Xuan Xu, *Recycling and reprocessing of Nd-Fe-B permanent magnets via electrochemical methods:* doctoral dissertation, Ljubljana, 2019 (mentor Kristina Žužek Rožman).

DEPARTMENT FOR MATERIALS SYNTHESIS K-8

The research of the Department for Materials Synthesis is mainly related to the synthesis of various advanced materials, especially magnetic materials, semiconducting oxides, and optical materials. Special attention is given to nanostructured materials, such as ferrofluids, functionalized nanoparticles for use in biomedicine, multifunctional nanocomposites, magnetic coatings, and fluorescent nanoparticles.

Head:
Prof. Darko Makovec

For the applications of nanoparticles, as well as for their assembly into composite materials, the engineering of their surface properties is of key importance. The surface properties are usually engineered by bonding different functionalization molecules onto the nanoparticles' surfaces. This layer of molecules has to be bonded by forming stable covalent bonds, not to be desorbed or exchanged with other ligands from the medium. Since irreversible covalent bonding is not possible between ionic inorganic surfaces and organics, an alternative coordinative bonding is often exploited for the surface functionalisation. Very strong coordinative bonding can be achieved between surface metal ions and some organic moieties (e.g., carboxylates, sulfonates, phosphonates). Among these, the phosphonates are known to form the strongest coordinative bonds, especially with trivalent metals like Fe^{3+} and the lanthanides. Our study was focused on a specific tetraphosphonate, ethylenediamine tetra(methylene phosphonic acid), shortly EDTMP, for coating the surfaces of barium hexaferrite nanoplatelets. Few-nanometre-thick amorphous coatings formed under various synthesis conditions (ligand concentration, temperature, pH, time). Surprisingly, the coatings were thicker than calculated from the possible surface coverage, determined with a thermogravimetric analysis. A more detailed STEM study revealed the depletion of the nanoplatelets' surface Fe^{3+} ions and their incorporation into an amorphous coating. This suggested that a metal-phosphonate framework was formed on the nanoplatelets' surface. Moreover, the coatings were highly porous with a specific surface area of 600–700 m^2/g, which is comparable to known highly porous materials, like metal-organic frameworks (MOFs). Similar to the EDTMP, diphosphonic acids also formed porous coatings at the nanoplatelets, but monophosphonic acids formed a dense bilayer without any evidence for the surface dissolution of barium hexaferrite. The new porous hybrid materials composed of an anisotropic magnetic core hybridized with a porous framework with many active sites (e.g., -OH, P=O, P–O, $=NH^+$) are candidates for new recyclable magnetic catalysts or chemical reactors with the possibility for simultaneous magneto-optical monitoring of the processes. The study continues in cooperation with the Department for Complex Matter (Dr. Alenka Mertelj and Patricija Hribar Boštjanjčič), Department for Nanostructured Materials (Dr. Andraž Kocjan and Hermina Hudelja), Department of Surface Engineering and Optoelectronics (Dr. Janez Kovač), Department of Physical and Organic Chemistry (Dr. Anton Kokalj), and the University of Nova Gorica (Prof. Iztok Arčon, Prof. Matjaž Valant and Dr. Andraž Mavrič).

Actuation of magnetic nanoclusters with an AC magnetic field was applied to selectively heat the surface of a catalyst.

We continued the research related to ferromagnetic suspensions of barium hexaferrite nanoplatelets in liquid crystals (in cooperation with the Department for Complex Matter in the frame of the national research project, leader Dr. Alenka Mertelj). We were involved in rheological studies of ferromagnetic liquid-crystal suspensions. Other studies were focused on understanding the colloidal interactions in suspensions of hexaferrite nanoplatelets in isotropic solvents. In parallel, we were involved (with the Department for Complex Matter and Osaka University) in magneto-optical studies of ferromagnetic nematic liquid crystals.

An important part of the research at the department remains devoted to clusters of superparamagnetic iron-oxide nanoparticles (nanoclusters). The nanoclusters are developed for applications that require manipulation with an applied magnetic field. The applications range from magnetic drug delivery to the magnetic separation of poisonous heavy metals from water or (bio)catalysts from a reaction mixture after the completion of a catalytic process. In cooperation with researchers from the Faculty of Pharmacy, University of Ljubljana (Prof Petra Kocbek) we developed novel one-pot methods for the preparation of nanoclusters based on the hot ultrasonication homogenization of a hydrophobic phase containing nonpolar surfactant into an aqueous phase. In another study we cooperated on the development of magnetic delivery nanosystems. The nanochains containing around five nanoclusters per chain were coated using silica with large, radially oriented pores (Figure 1). The pores in the silica enable loading of an active pharmaceutical substance, while the magnetic core provides magnetic guidance.

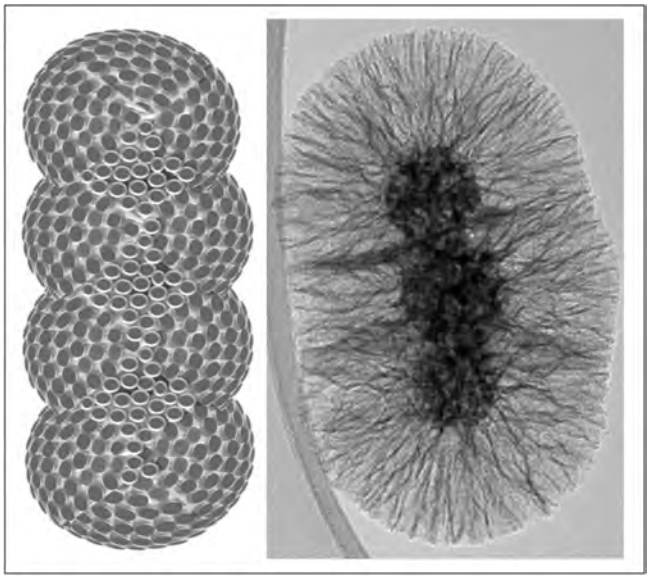

Figure 1: Nanochain coated with silica with large, radially aligned pores, which enable loading of an active pharmaceutical substance for magnetic drug delivery.

Development of magnetic nanostructures, nanoclusters and nanochains with highly porous silica shells for targeted drug delivery.

In 2019 we completed the investigation of PDA-coated magnetic nanoclusters for catalysis in collaboration with researchers from the University of Trieste, Italy (Prof Maurizio Prato and Prof Paulo Fornasiero). We demonstrated the role of the support used for oxygen reduction reaction (ORR) catalysts based on N-, O-doped nanocarbons. The materials can drastically change the selectivity of the reduction process, favouring either H_2O or H_2O_2 as the main product. The work highlighted the key parameters that tailor the selectivity for the future design of catalysts for ORR applications.

We also continued the research on applications of the AC-heating of carbon- and alumina-coated magnetic nanoclusters in the synthesis of catalysts and in catalysis. Both types of magnetic nanoclusters were prepared by the thermal transformation of precursor materials. The precursors were synthesized by i.) hydrothermal carbonization of carbohydrate (for carbon-coated nanoclusters) or ii.) hydrolysis of AlN (alumina-coated) in the colloidal suspension of superparamagnetic iron-oxide nanoparticles.

As a proof-of-concept a Ru-bearing nanocatalyst was synthesized using an AC-field as a heat source for the reduction of Ru^{3+}. The suspension of carbon-coated magnetic nanoclusters in an isopropanol solution of $Ru(acac)_3$ was exposed to the AC magnetic field. The locally delivered heat led to the homogeneous deposition of Ru nanoparticles with a diameter of 1.6 nm, exclusively on the surfaces of carbon-coated magnetic nanoclusters. Compared to conventional heating, the time for the nanocatalyst synthesis was significantly shortened; the magnetically mediated heating-up period was practically immediate, the time to quantitatively deposit Ru was significantly decreased, and the cooling-down period was immediate, since the bulk of the liquid medium remains at a significantly lower temperature than the surfaces of the nanoclusters. In collaboration with the Department of Catalysis and Chemical Reactions Engineering, National Institute of Chemistry (Dr Blaž Likozar and Dr Miha Grilc) we tested the synthesized nanocatalyst in the hydrogenation of furfural. The nanocatalyst showed high activity in the hydrogenation of furfural to furfuryl alcohol. After four recycling cycles the conversion remains 100 %, while the selectivity is steadily increased from 80 % in the first run to >99 % in the last.

In collaboration with the same research group from the National Institute of Chemistry, we also studied the AC-mediated catalysis using Ru-bearing carbon and alumina-coated nanoclusters. Both catalysts exhibited a large surface area and were homogenously decorated with small Ru nanoparticles, approximately 2 nm in size. The carbon-coated nanoclusters were used in hydrogenation of levulinic acid. The relatively small amplitude of the AC field was sufficient for the hydrogenation to occur. Within 2 hours the conversion of levulinic acid reached almost 100 % and the selectivity for gamma-valerolactone was as high as 90 %. After four recycling cycles the conversion and selectivity remained practically unchanged, suggesting good stability of the catalyst. When conventional heating was used to provide thermal energy for the hydrogenation the rate of reaction was significantly lower, which indicates that the surface of the catalyst reaches very high temperatures when exposed to the AC field. A similar result was obtained in the hydrogenation of furfural over an alumina-coated catalyst (Figure 2). Both examples demonstrate that the AC heating of the catalysts can be successfully applied to the batch hydrogenation of biomass-based platform chemicals to value-added chemicals in a slurry-type reactor.

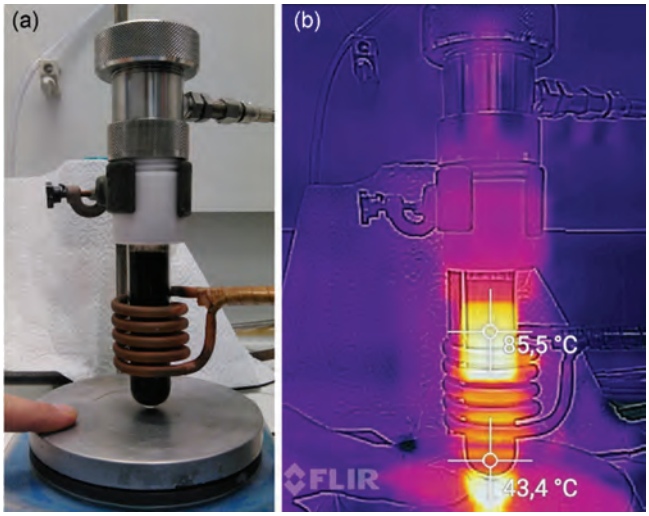

Figure 2. Image (a) and thermogram (b) of the AC-field-mediated hydrogenation of furfural in a batch-slurry-type reactor.

Frustrated Lewis pairs are compounds where a Lewis acid and base cannot form a classic adduct because of the steric hindrance. There are well-known molecular examples and a few solid-state ones. Compounds are interesting because the energy of frustration can activate small molecules, such as H_2, CO and CO_2, which are typically activated by precious, or on rare occasions, by transition metals. In collaboration with the University of Bern (Prof Ulrich Ashauer), Department of Nanostructured Materials (Dr Andraž Kocjan), Department of Inorganic Chemistry and Technology (Dr Gašper Tavčar and Dr Tomaž Skapin) and with the Department of Catalysis and Chemical Reactions Engineering, National Institute of Chemistry (Dr Blaž Likozar and Dr Miha Grilc) we are

investigating the influence of the surface acidity of aluminium oxide/fluoride and the structure of the adsorbed Lewis base on the potential for the formation of surface-frustrated Lewis pairs and their hydrogenation activity.

An important part of the research was devoted to our new concepts of biomedical applications, which are based on the transformation of low-frequency (1–200 Hz) alternating magnetic-field (AMF) energy to mechanical energy, mediated with anisotropic magnetic nanoparticles. In our project devoted to magneto-mechanical cancer treatment we cooperate with the Faculty for Electrical Engineering (Laboratory for Biophysics - FEE-Biophysics), Laboratory for Bioelectromagnetics - FEE-Magnetics), Faculty of Health Sciences (Laboratory for Clinical Biophysics - FHS), University of Ljubljana, and the Department of Molecular and Biomedical Sciences (B2-JSI). For the magneto-mechanical treatment the anisotropic magnetic nanoparticles are internalized into the cancer cells. When exposed to a magnetic field, the anisotropic magnetic nanoparticle inside the cell directs according to the applied field. The nanoparticle's rotation under the influence of the AMF results in a transfer of the force, which is applied to damage the cell interior. We investigated the two types of magnetic nanoparticles, where different mechanisms of transfer from the magnetic energy to mechanical energy are expected: (i.) hard-magnetic nanoplatelets (from 50 nm wide, ~ 3 nm thick), and (ii.) one-dimensional superparamagnetic (SPM) nanochains (600 nm long, ~ 90 nm thick). The efficiency of the nanoparticles was tested *in vitro* on giant unilamellar vesicles (GUVs) and different cells, including blood cells (erythrocytes) and different types of cancer cells. For the testing, we had to develop new procedures for the preparation of test suspensions. Maintaining colloidal stability of the suspensions of permanently magnetic nanoplatelets, such as hexaferrite nanoplatelets, is very challenging, because they tend to agglomerate due to magnetic dipole-dipole interactions. We developed a new method for the covalent grafting of dextran molecules onto the surfaces of silica-coated nanoplatelets. For tracking of the nanoparticles with fluorescence microscopy a fluorescent dye was incorporated into the silica shells of the nanoplatelets. In 2019 we completed the test of the magneto-mechanical effect of the nanoplatelets' GUVs in cooperation with the FEE. The GUVs represent the simplest model of a cell membrane, which comes into a contact with nanoparticles first. When the nanoplatelets electrostatically adhered onto the GUV's surfaces, exposure to the AMF resulted in cyclic fluctuations of the GUV's shape at a low nanoplatelet concentration (1 μg/ml), corresponding to the field frequency. The higher nanoplatelet concentrations, above 10 μg/ml, caused disruption of the GUV's phospholipid-bilayer membrane, resulting in bursting of the GUVs. To evaluate the influence of the magnetic field parameters on the efficiency of the nanoplatelets' actuation the number of GUVs was estimated from videos recorded before and after the treatment of the GUVs with AMF and normalized to the number of GUVs in the untreated GUV suspensions. As expected, the number of GUVs decreased in proportion to the nanoplatelet concentration and the magnetic-field amplitude and the frequency. Interestingly, the measurements of the GUV size distribution before and after the treatment showed no differences, suggesting that the GUVs' bursting is not a collective effect of all the nanoplatelets adsorbed on the individual GUV. Theoretical calculations (cooperation with Dr. Mitja Drab form FEE and Dr. Simon Čopar from the Faculty of Mathematics and Physics, University of Ljubljana) suggested that the individual nanoplatelet could not be responsible for triggering the disruption of the phospholipid bilayer either. It seems that the GUVs burst due to local rupture of the bilayer as a consequence of forces produced by the assembly of several NPLs. In parallel we continued our *in vitro* assessment of the magneto-mechanical effect of the anisotropic nanoparticles on highly invasive breast adenocarcinoma (MDA-MB-231) and cervical adenocarcinoma (HeLa) cancer cells (cooperation with B2-JSI). The viability of the cells was assessed with fluorescence microscopy and flow cytometry. Cells were incubated with different concentrations of the nanoplatelets and treated with the AMF for a short period of time. The AMF of different amplitude (1 mT, 10 mT) and frequency (3–100 Hz) was tested. After the treatment with AMF the cell viability decreased significantly, but the effect was relatively small. However, the relative effect was very large when analysed against the amount of internalized NPLs. Namely, a very small amount of the NPLs was internalized in the cells, as shown by transmission electron microscopy analysis (cooperation with Institute of Cell Biology, University of Ljubljana, Prof Mateja Erdani Kreft). The small amount of nanoplatelets internalized by the cells was ascribed to the excellent colloidal stability of the nanoplatelet suspension. Namely, the cells exposed to stable suspensions uptake nanoparticles to a much lesser extent compared to nanoparticles that show some agglomeration. We tried to improve the uptake of nanoplatelets by the

Magneto-mechanical effect of anisotropic magnetic nanoparticles exposed to a low-frequency magnetic field was tested for the destruction of cancer cells *in vitro*.

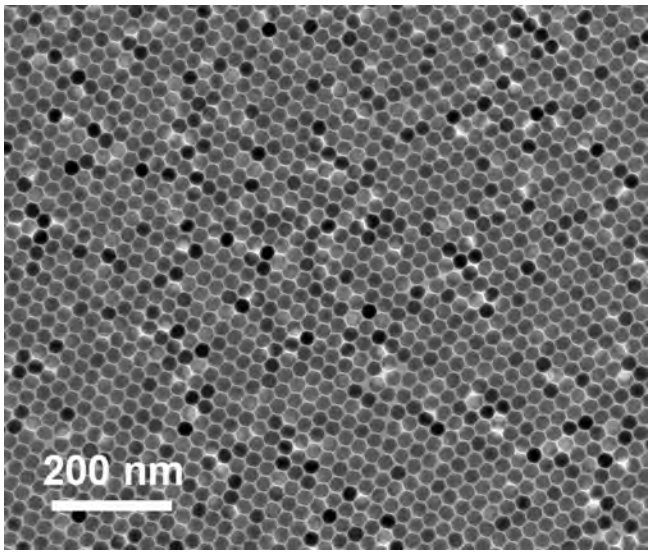

Figure 3: Lanthanide-doped fluoride ($NaYF_4$) up-converting fluorescent nanoparticles.

cells by their attraction to their surfaces using permanent magnets placed below the culture. The efficiency of the method was limited: the internalization of the nanoplatelets improved; however, many technical problems arose.

In 2019 we completed an investigation confirming photothermal effects, extracellular matrix disruption potential, and cancer cells eradication potential of magnetic nanochains. The investigation was carried out in collaboration with CNRS-IPBS, Toulouse, France (Dr Jelena Kolosnjaj-Tabi). We developed conjugated nanochains, which can disrupt the extracellular matrix by combined magneto-mechanical and photo-thermal effects. The role of the extracellular matrix is to provide structural and biochemical support to the surrounding cells. The magneto-mechanical and thermal approaches involving prospective anisotropic magnetic particles could thus represent a methodological alternative to manage highly desmoplastic tumours or antibiotic-resistant bacterial infections.

We also completed the investigation on cellulose acetate electrospun fibres decorated with magnetic nanoparticles for multifunctional gas and pH fluorescent sensors in collaboration with Prof T. Krasia Christoforou from the University of Cyprus and Prof C. Riziotis from the National Hellenic Research Foundation, Theoretical and Physical Chemistry Institute, Athens, Greece. The encapsulation of the nanoparticles within the fibres and the covalent anchoring of the fluorophore onto the nanoparticle surfaces prevented the fluorophore's leakage from the fibrous mat, thus enabling stable fluorescence-based operation of the developed materials. These materials were further evaluated as dual fluorescent sensors. The results were published in Scientific Reports.

We continued with the research of fluorescent optical materials. Fluorescent nanoparticles with upconversion emission can be applied in various optical elements and are also proposed as alternative bio-markers in imaging diagnostic techniques for medicine. Based on our previous discovery of the significant dissolution of fluoride-based upconversion nanoparticles (e.g., Ln-doped LnF_3 and $NaYF_4$) we focused on the prevention/minimization of their dissolution. The most significant dissolution of the Ln-doped fluorides was detected in the presence of phosphate ions due to the strong interaction between the Ln^{3+} and Y^{3+} ions resulting in insoluble Ln(Y)-phosphates. We studied the efficiency of some phosphonate coatings to prevent the dissolution of the upconverting nanoparticles. We tested tetraphosphonate, ethylenediamine tetra(methylene phosphonic acid) (EDTMP), a bisphosphonate (sodium alendronate) and a dendrimeric PEGylated phosphonate. The most efficient protection against the dissolution of UCNPs was provided by the EDTMP. The dissolution of the upconversion nanoparticles in a phosphate-rich medium was decreased down to 10-times with respect to the bare nanoparticles. The dissolution studies were made in cooperation with the Department of Inorganic Chemistry and Technology (Dr Maja Ponikvar-Svet) and with the Faculty of Medicine at University of Ljubljana (Dr Lovro Žiberna and Prof Mojca Kržan). All the studies were accompanied with precise optical characterization in cooperation with the Department of Complex Matter (Prof Boris Majaron).

We also continued our research of materials exhibiting a positive temperature coefficient of resistivity (PTCR). The focus was on composite materials containing a mixture of a conducting phase (metal) and non-conducting phase ($BaTiO_3$ ceramics). Due to dimensional changes during a phase transformation in the non-conducting phase disconnections occur in the conductive phase that lead to the PTCR anomaly. Using this principle, we prepared a magnetic Ni-$BaTiO_3$ composite with a jump-like PTCR effect. This is the first example of PTC thermistors with relatively high magnetization, i.e., a magnetic PTCR composite.

Some outstanding publications in the past year

1. Makovec, Darko, Komelj, Matej, Dražić, Goran, Belec, Blaž, Goršak, Tanja, Gyergyek, Sašo, Lisjak, Darja. Incorporation of Sc into the structure of barium-hexaferrite nanoplatelets and its extraordinary finite-size effect on the magnetic properties. Acta materialia, ISSN 1359-6454. [Print ed.], Jun. 2019, vol. 172, str. 84-91.
2. Hu, Jie, Goršak, Tanja, Mertelj, Alenka, Makovec, Darko, Lisjak, Darja, et al. Magnetic nanoplatelets for high contrast cardiovascular imaging by magnetically modulated optical coherence tomography. ChemPhotoChem, ISSN 2367-0932, 2019, vol. 3, str. 529-539.
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INTERNATIONAL PROJECTS

1. COST CA18132; Functional Glyconanamaterials for the Development of Diagnostics and Targeted Therapeutic Probes
   Asst. Prof. Slavko Kralj
   Cost Association Aisbl
2. H2020 - BeMAGIC; Magnetoelectrics Beyond 2020: A Training Programme on Energy-Efficient Magnetoelectric Nanomaterials for Advanced Information and Healthcare Technologies
   Prof. Darja Lisjak
   European Commission
3. The Development of a Nondestructive Analytical Method for the Screening of Upconverting Nanoparticles Surface Properties Based on Optical Characterization
   Prof. Darja Lisjak
   Slovenian Research Agency
4. Dynamic Hysteresis in the Study of Magnetic Nanoparticle Efficacy for Hyperthermia Therapy
   Asst. Prof. Sašo Gyergyek
   Slovenian Research Agency
5. Design and Synthesis of Chemically Stable Luminescent Core-Shell Upconverting

Nanoparticles for Bioimaging
Prof. Darja Lisjak
Slovenian Research Agency

RESEARCH PROGRAMME

1. Advanced inorganic magnetic and semiconducting materials
   Prof. Darko Makovec

R&D GRANTS AND CONTRACTS

1. Anisotropic magnetic nanoparticles for the magneto-mechanical therapy of cancer
   Prof. Darko Makovec
2. Electrically tunable ferromagnetic liquids
   Prof. Darja Lisjak
3. Multifunctional Janus Nanoplatelets
   Jelena Papan
4. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
   Prof. Darko Makovec
   Ministry of Economic Development and Technology
5. JSI's equipment and working space rental by a company
   Asst. Prof. Sašo Gyergyek
   Inovine d. o. o.
6. Equipment lease ali Contract on equipment use
   Asst. Prof. Sašo Gyergyek
   Inovine d. o. o.
7. Different Services
   Prof. Darko Makovec

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8. Sebastjan Nemec, B. Sc.

Technical and administrative staff
9. Bernarda Anželak, B. Sc.
10. Tamara Matevc, B. Sc.

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Review Article

1. Helena Oliveira *et al.* (11 authors), "Critical considerations on the clinical translation of Upconversion Nanoparticles (UCNPs): recommendations from the European Upconversion Network (COST Action CM1403)", *Advanced healthcare materials*, 2019, **8**, 24, 1801233.

DEPARTMENT FOR ADVANCED MATERIALS K-9

At the Advanced Materials Department, we investigate novel materials through an understanding of the mutual dependence of their structural, microstructural and functional characteristics. Modern technologies that enable the synthesis of materials with atomic- and microscale precision are used to prepare pre-designed structural 3D materials, thin films and nanoparticles with the desired crystal structure, chemical composition, microstructure and morphology. Among our important objectives is the development of i) novel functional oxides for electronic applications and energy conversion, ii) antibacterial and piezoelectrical biocompatible materials and iii) heat-insulation materials with improved properties and sustainability.

Head:
Asst. Prof. Matjaž Spreitzer

Novel functional oxides

In the scope of the HarvEnPiez M-era-Net Project and the studies of ferroelectric perovskite particles with defined morphologies for piezoelectric applications, the research was focused on the elucidation of experimental conditions for controlling the composition, crystal structure and preferential orientation to obtain $Ba_{1-x}Ca_xTiO_3$-based platelets with improved ferroelectric/piezoelectric characteristics. In the topochemical microcrystal conversion (TMC) from $Bi_4Ti_3O_{12}$ to the target $Ba_{1-x}Ca_xTiO_3$ perovskite platelets the incorporation of Ca was found to be limited (≤1.5 at.% at nominal x=0.1) and accompanied by considerable Bi remains (up to 2 at.%). Both types of cations are incorporated at the A-site of the single crystalline complex $Ba(Ca,Bi)TiO_3$ perovskite structure of the platelets. Additionally, defects such as dislocations enriched with Ca (Figure 1) and inclusions containing Bi are also present in the crystal. It was found that the general principles for the formation of $BaTiO_3$-based platelets with high tetragonality and high (001) preferential orientation already changed for low Ca substitutions (i.e. x=0.01). While for $BaTiO_3$ platelets, prolonged annealing times at 600–900 °C (12 hours) and a slow cooling rate (1 °C/min) favoured high (001) preferential orientation. These conditions led to a pseudocubic structure for the composition with x=0.01. Shorter annealing times (2 hours at 900 °C) and fast cooling rates (>10 °C/min) enabled a long-range-ordered tetragonal structure for the Ca, Bi-containing platelets (x=0⇒$Ba_{0.96}Bi_{0.07}Ti_{0.97}O_3$, x=0.01⇒$Ba_{0.92}Ca_{0.016}Bi_{0.09}Ti_{0.97}O_3$ and x=0.05⇒ $Ba_{0.89}Ca_{0.056}Bi_{0.09}Ti_{0.96}O_3$). For these platelets piezo-response force microscopy (PFM) revealed the presence of ~500-nm-sized ferroelectric domains and local d_{33} values of 20–80 pm/V. A low-temperature X-ray diffraction examination of $Ba(Ca,Bi)TiO_3$-based perovskite platelets revealed that small contents of Bi (1.4 at.%) and Ca (0.3 at.%) inhibit the low-temperature tetragonal-to-orthorhombic phase transition (present in pure $BaTiO_3$ at 5–10 °C), while these substitutions do not significantly influence the tetragonal-to-cubic phase transition at 125–135 °C. Broadening of the temperature range of tetragonal phase stability down to very low temperatures (≤ -120 °C) implies less-temperature-dependent ferroelectric/piezoelectric properties in the temperature range – 120 °C≤T≤100 °C.

We found that the minor incorporation of both Ca and Bi in $(Ba,Ca,Bi)TiO_3$ perovskite platelets significantly broadened the temperature range of the tetragonal phase with ferroelectric properties stability (from below -120 to 135°C), compared to that of pure $BaTiO_3$ (5 to 125 °C).

We studied the epitaxial growth of $SrTiO_3$ and $Bi_4Ti_3O_{12}$ nanoplatelets under hydrothermal conditions to prepare the $SrTiO_3$ and heterostructural $Bi_4Ti_3O_{12}/SrTiO_3$ nanoplatelets with different ratios of $SrTiO_3$ and $Bi_4Ti_3O_{12}$. The processes that accompany this topochemical conversion (TC) and its mechanism were explained. The epitaxially grown layers of $SrTiO_3$ protect the template against premature and uncontrolled dissolution, thus presumably decisively influencing the retention of the platelet after the completion of the conversion. Consequently, the finished $SrTiO_3$ platelets after the conversion, as well as partially converted $Bi_4Ti_3O_{12}/SrTiO_3$ composites, acquire the mesocrystalline structure. According to the literature, mesocrystalline and hetero-structures can enhance the photocatalytic activity of the $SrTiO_3$ particles for H_2 evolution from water splitting. The prepared mesocrystalline nanoplatelets were tested for photocatalytic H_2 production without the use of co-catalysts and confirmed the positive influence of the heterostructure on the efficiency of the photocatalytic reaction. The study of epitaxial growth and TC mechanism was broadened to the conversion of $Bi_4Ti_3O_{12}$ to other $MTiO_3$ (M=Ba,

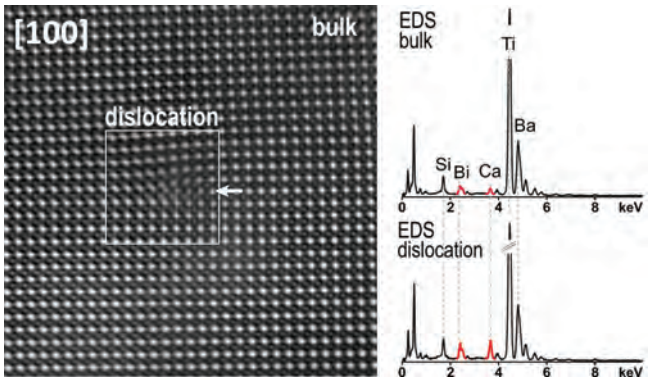

Figure 1: HR-STEM image of the $Ba_{1-x}Ca_xTiO_3$ platelet cross-section with the Ca-rich dislocation in single crystalline bulk (left) and EDS spectra of bulk (top-right) and dislocation (bottom-right).

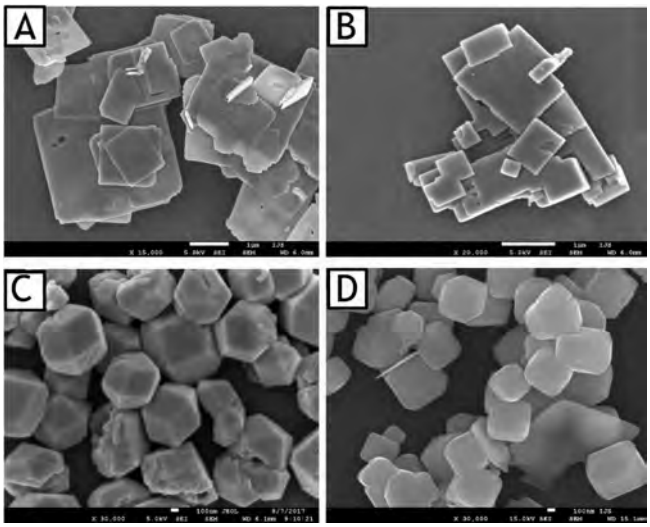

Figure 2: From the $Bi_4Ti_3O_{12}$ (BIT) templates, $SrTiO_3$ (A), $CaTiO_3$ (B) and $BaTiO_3$ (C and D) particles were prepared under hydrothermal conditions. In the latter, the anisotropic shape of the template was not preserved.

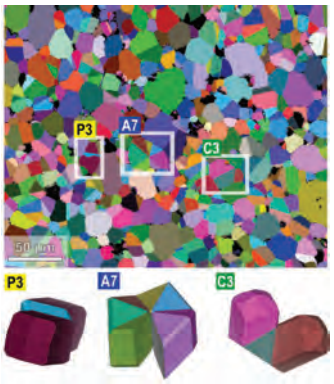

Figure 3: EBSD image of SnO_2-based ceramics with many cassiterite twins. The analysis revealed the presence of crystallographically different types of multiple twins: polysynthetic, alternating and coplanar; schematic models of the twins with a different number of twin domains are shown below the microstructure.

Ca). The mechanism proceeds on the same principle, but for the case of $BaTiO_3$ we were unable to determine such conditions that would allow the preservation of the anisotropic shape (plate-like shape). It is assumed that the reason is a larger ionic radius of Ba^{2+}. In this case, the growth on the surface of the template occurs in the form of island formation and does not completely cover and thereby protect the entire surface of the template. The template therefore dissolves in the reaction and the plate-like shape in this case is diminished (Figure 2).

In the frame of the national research project J1-9177 we studied the microstructure development and electrical properties of SnO_2-based ceramics doped with oxides of cobalt and niobium. Characteristic for this system is the development of a dense microstructure that contains a high fraction of contact and multiple twins of cassiterite SnO_2. In collaboration with Géosciences Montpellier (France) we analysed the microstructures using electron-backscatter diffraction (EBSD) to reveal the crystallography of multiple twins. We identified three types of twins with different crystallographic settings: polysynthetic or lamellar twins and two types of cyclic twins, coplanar and alternating (Figure 3). Based on phase-equilibrium studies of the SnO_2-Co_3O_4-Nb_2O_5 system we found that the formation of twins is related to the oriented growth of cassiterite on structurally related Co-Nb-oxides with the columbite- and corundum-type structures. In addition to these crystallographic characteristics, the ceramic also exhibits interesting functional properties. At low doping levels, it has promising dielectric properties, while at higher doping levels, it shows nonlinear current-voltage dependency, which is excellent for varistor applications. The results are published in the Journal of the European Ceramic Society.

We continued to study the growth and properties of $Pb(Mg_{1/3}Nb_{2/3})O_3$–$PbTiO_3$ (PMN-PT) thin films. Previous analyzes have shown that films prepared by pulsed laser deposition (PLD) using Pb-rich targets exhibit a surplus of Pb and Mg deficiency. Therefore, we prepared targets with different excess amounts of Pb and Mg. The chemical composition of the films at the macroscopic level was examined by wavelength-dispersive X-ray spectroscopy. The composition of the sample prepared from the target with 20 mol.% PbO excess and 20 mol.% MgO excess, was the closest to stoichiometric, but the sample in question did not exhibit superior functional properties. Based on the results of the microscopic analysis and on literature data, we assume that the main reason for this is a different local stoichiometry of the films resulting from extended PbO defects and/or a different local chemical environment affecting the response of individual species in the material upon the application of an electrical field. The structure of the PMN-PT thin films with different concentrations of the PT component around the morphotropic phase boundary was also studied. The structure of the epitaxial thin films was found to differ strongly from that of bulk PMN-PT, with the tetragonal phase being stabilized on $SrTiO_3$ substrates. We found that the composition with the highest piezoelectric response is shifted towards higher PT contents in the thin films.

A large part of research was focused on the integration of $SrTiO_3$ with graphene oxide-buffered silicon surfaces. We investigated the interface reactions between silicon and $SrTiO_3$, with and without a graphene oxide buffer layer. Also, the key parameters for the PLD growth of $SrTiO_3$ were optimized. $SrTiO_3$ of optimum quality was used as a pseudo-substrate for the growth of piezoelectric $Pb(Zr_{0.52}Ti_{0.48})O_3$ (PZT) thin film. The characterization of the functional properties revealed d_{33} values comparable to PZT grown on $SrTiO_3$ prepared by molecular beam epitaxy method. The results demonstrate the high applicative potential of the studied integration method.

We stabilized single-phase and stochiometric thin films of piezoelectric PMN-PT, epitaxially aligned with various oxide single crystals.

We collaborate with Institute of Geotechnics, Slovak Academy of Sciences (Košice, Slovakia) and CRISMAT-CNRS Laboratory (Caen, France) on the topic of next-generation thermoelectric materials based on copper-rich sulphides. We have shown that an efficient, ecologically safe and scalable approach using a combination of high-energy milling and spark plasma sintering (SPS) can be used for the synthesis of thermoelectric sulphides with complex crystal structures, like tetrahedrite ($Cu_{12}Sb_4S_{13}$) and colusite ($Cu_{26}V_2Sn_6S_{32}$), compounds that exhibit excellent thermoelectric performance. In our recent work we studied phase changes during milling and the SPS of elemental precursors for the synthesis of tetrahedrite. We found that the formation of targeted compound proceeds via several intermediate phases and that only under certain conditions, the product is single-phase tetrahedrite with an excellent figure of merit (ZT of 0.67@700K), as a consequence of a high power factor (1.07 $mWm^{-1}K^{-2}$) and a low thermal conductivity (1.12 $Wm^{-1}K^{-1}$). The excellent performance of the samples was interpreted based on the results of microstructural and nanoscale characterisation. The results are published in Journal of the European Ceramic Society.

Organic pollutants such as azo dyes and phenolic compounds in wastewater pose a serious environmental problem, as they are difficult to decompose with traditional water-treatment methods. However, the photocatalytic degradation process of these pollutants could achieve reductions in their harmful effects in a clean and sustainable manner. Therefore, within the framework of nano-structured materials, we focused on the synthesis and photocatalytic activity of the hollow TiO_2 sphere (Ti-HS). In a typical Ti-HS synthesis, carbon spheres (CSs) were added to a solution of Ti (OBu) 4 and ethanol under vigorous stirring. The obtained Ti @ CS product was calcined at various temperatures between 450 and 800 °C to form Ti-HS, which were about 800 nm in size and a shell thickness of about 100 nm. The samples fired <725 °C retained the anatase structure, while firing of samples at > 725 °C produces a mixture of anatase and rutile. Measurements of the band gap of the Ti-HS showed that its value decreased from 3.2 eV for samples with anatase (450-650 °C) to 3.1 eV for the sample fired at 725 °C. However, the samples fired at 750 °C and 800 °C showed values of about 3.0 eV, which are typical of the rutile structure. The photocatalytic activities of Ti-HS were monitored by the decomposition of methyl blue under the influence of UV light in an aqueous solution. A pronounced photocatalytic effect was detected for Ti-HS, which were calcined between 650 and 725 °C and was better or comparable to the commercial nano-powder of Deguss P25 (Figure 4).

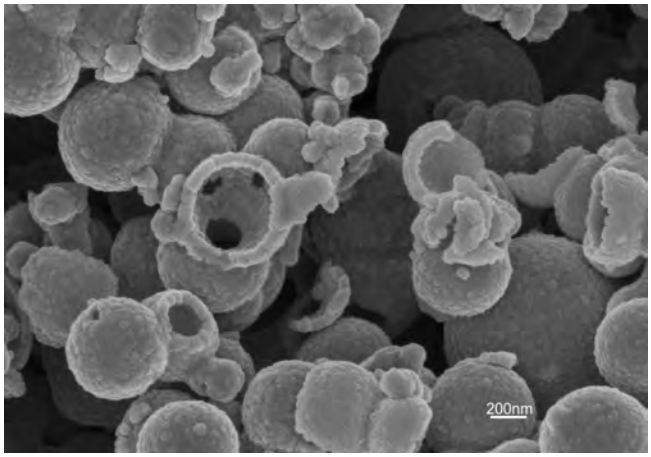

Figure 4: Hollow TiO_2 spheres after firing at 725 °C, with photocatalytic properties better than Degussa P25.

In the scope of investigation of the phase relations in ternary metallic systems that can be found in technically very important materials such as strong magnets, based on $Nd_2Fe_{14}B$, we investigated high-temperature phase relations in the Nd-Dy-Cu system. During the recycling process of $Nd_2Fe_{14}B$-based magnets, some particular elements are added in order to improve their magnetic properties, such as Dy and Cu. The added elements can incorporate into the crystal structure of the $Nd_2Fe_{14}B$ compound or are located at the grain boundary and thus form new phases. Our investigations showed that in the investigated system the intermetallic compounds based on Nd-Cu and Dy-Cu systems form solid solutions over an extended concentration range.

We have developed innovative antimicrobial materials (in form of organic piezoelectric films and ion-doped magnetic nanoparticles) and confirmed their ability to effectively decompose and destroy bacterial formations.

Antibacterial and piezoelectric biocompatible materials

Within the project "Piezoelectric biomaterials for electrostimulated regeneration" we investigated the influence of electrostimulation to bacteria. In contrast to the ultrasonic stimulation of planktonic bacteria which did not significantly affected bacterial growth using selected ultrasonic parameters, the presence of piezo-PLLA films during stimulation provided a strong bactericidal effect. Similarly, bacteria in biofilms grown on the top of piezo-PLLA films also confirmed the strong bactericidal effect (Figure 5). This was not the case for biofilms grown on non-piezoelectric PLLA films (with DR 1). The same processing procedure using an external ultrasonic field repeated in red blood cells showed the absence of signs of toxicity. Morphologically cells had the normal discoid shape, without detectable changes in the membrane and without a tendency to aggregate. The study demonstrated the ability to design biomaterials and to use electro-mechanical stimulation as a tool for obtaining antimicrobial properties. The strategy is an antibiotic- and nanoparticle-free solution. It excludes any releasing components and could be extremely important when antibiotic-resistant strains are concerned.

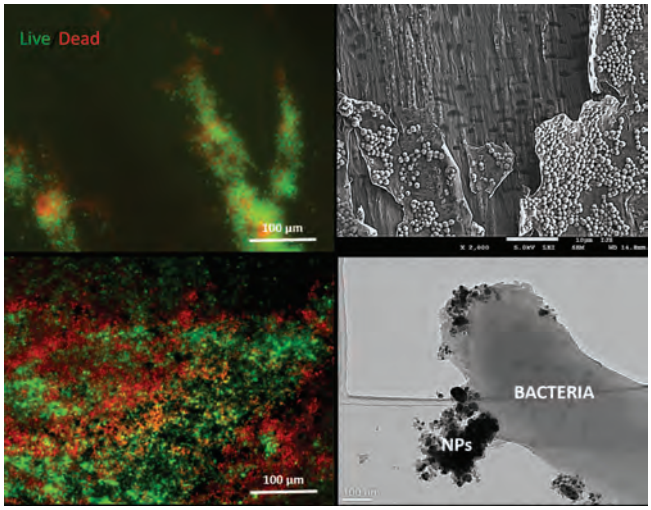

Figure 5: Bacterial viability (Live Dead® assay) and their morphology (SEM images) after interaction with sonicated piezo-PLLA films (a,b) and CFO NPs (c,d).

In the field of designing magnetic antimicrobilas within the structure of cobalt-ferrite (CFO) we performed partial substitution of Fe^{3+} with Ga^{3+} ions. The samples were phase pure with a cubic spinel structure and contained sphere-like nanoparticles with a mean diameter of ~6±1 nm and 25–27 wt.% of absorbed oleic acid, indicating the formation of a complete monolayer on the surface. By adding gallium in the CFO structure the Me–O stretching mode of the tetrahedral sites moved towards higher values, indicating a gradual substitution of the iron ions by gallium ones. The change in the spinel structure was also confirmed by Raman spectroscopy. Magnetic measurements revealed the influence of heteroatoms on the saturation magnetization and magnetic anisotropy, showing for all the samples superparamagnetic behaviour at room temperature. Mössbauer spectra evidenced the modification of the inversion degree, with iron in

the tetrahedral site, which decreases with the increase of the Ga content. The substitution of Fe^{3+} ions with Ga^{3+} leads to a change in the chemical composition and cationic distribution of CFO and consequently to a variation of its magnetic properties that can be tuned for different applications. The nanoparticles were confirmed to destroy the bacterial membrane producing strong bactericidal effect.

Materials for heat-insulation applications

Glass waste is recognized as a clean inorganic waste that could be implemented in several new industrial products, a model of the circular economy. One of the potential applications of the contaminated glass waste is production of foamed glass, a high added-value product. A major disadvantage of the production is high costs related to the need to adjust its composition to enable the production of a product with superior properties. The foaming mechanism is heavily influenced by the composition of the used glass, is often hindered by the crystallization process, which is detrimental to the quality of the final product. By adding specific foaming additives, we were able to tune the composition and foaming process of flat glass to avoid crystallization and prepare a foamed glass sample with closed porosity, a small pore size and a low thermal conductivity of 45 mW/(m·K). On the other hand, bottle glass with only minor differences in the composition proved to be much more prone to crystallization. To develop an effective foaming process for bottle glass we are looking for alternative foaming additives to tune the glass stability and surface tension.

We showed that good thermal insulation properties can be obtained by preventing the crystallization of the glass and controlling the composition of the gases in the closed pores.

We studied the crystallization behavior of the container glass cullet supplied by industry in the industrially relevant foaming process, which includes relevant batch compositions and conditions. Usually, surfaces of the milled glass particles act as nucleation centers supporting the crystallization process, so we analyzed waste glass using the DSC and XRD techniques. From the DSC results thermal properties, the glass transformation and glass crystallization temperatures, and crystallization behavior of the glass were determined. Also, different additives, inhibitors of the crystallization were tested. XRD analysis gave an insight into the phase compositions and content of the crystalline phases in the obtained samples. The phase composition was not so much influenced with the additives, the main crystalline phases, quartz and cristobalite only varied in the content. The important properties of the foamed glass are the density and thermal conductivity, so for the sintered samples density, porosity and thermal conductivity were determined.

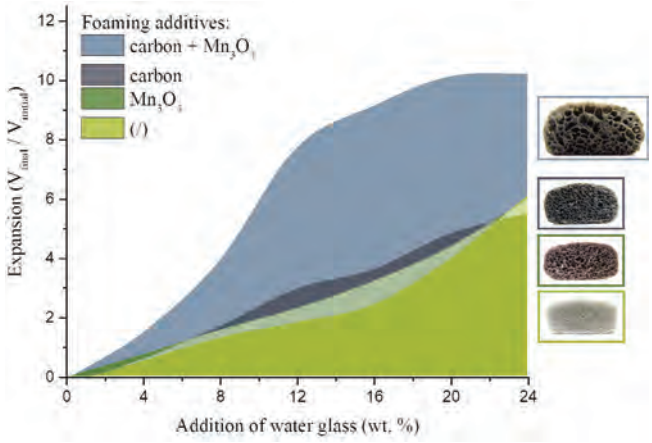

Figure 6: Expansions of compositions with different combinations of foaming additives depending on the addition of water glass. Expansions of the compositions without one or both additives are very similar and significantly smaller than the expansion of the composition with two additives. The result suggests that the major contribution to the expansion comes from two sources: water glass and the reaction between carbon and Mn_3O_4.

In addition to the research on the thermal insulation and mechanical properties of foamed glass, attention was paid to the environmental impact of the required processing conditions. In the study of modified foaming mechanisms that allow foaming in a less-energy-expensive process, we focused on the foaming mixtures that contain water glass. Using water glass, we were able to prepare low-density foamed glass in an air atmosphere. The resulting material has a low thermal conductivity, comparable to products prepared in energy-intensive processes. By comparing the expansions of the samples prepared with different combinations of foaming additives, we determined that two mechanisms mainly contribute to foaming (Figure 6). During the heat treatment, water vapor is released from the water glass up to ~ 600 °C, which locally creates a less oxidizing atmosphere and inhibits the oxidation of the carbonaceous foaming agent. Furthermore, the addition of water glass lowers the optimum sintering and foaming temperature of the foaming mixture, which favorably affects both the foaming and the energy balance of the process. Due to the apparent usefulness of the water glass, we intend to investigate the possibilities of its use for the preparation of foamed glass from other types of waste glass.

Characterization of electrical properties

In 2019 we made improvements to a number of characterization procedures used at our department. The most outstanding was the complete implementation of a Van der Pauw style system for measuring the sheet resistance of thin samples, which allowed us to measure the electrical conductivity of materials such as graphene and thin films of various conductive oxides. Notable improvements were also made to our setup for determining the d_{31} piezoelectric component of PLLA based polymers. We also upgraded our methods of modeling and measuring the thermal properties of materials, with special emphasis on foamed glass as well as various mineral-wool composites.

PROJECTS

In the scope of the **M-ERA.NET project HarvEnPiez** we investigated the synthesis of various defined-shape ferroelectric particles with an anisotropic shape (plates, rods) that have controlled preferential orientation. Their self-assembled structures are meant for energy-harvesting applications. Since the $MTiO_3$-type perovskite particles do not show the tendency for anisotropic growth in the shape of plates and rods, we used the topochemical transformation for their preparation. The main focus is on studying the reaction mechanism of topochemical conversion from $Bi_4Ti_3O_{12}$ to $MTiO_3$ (M = Ba, Ca, Sr) and their solid solutions in molten salt and under hydrothermal conditions. The project is a cooperation between Slovenia, Latvia and Romania. The Latvian group is involved in *ab initio* calculations and the modeling of piezoelectric properties, whereas the role of Romanian group relates to designing and fabricating of a piezoelectric device. Funding agency: M-ERA.NET European Transnational Agency. Coordinator: dr. Marjeta Maček Kržmanc.

Project **CleanTechBlock Basics**, "**Sustainable Multi-functional Building Block Basics**", addressed heat-transfer in foamed glass and demonstrated the adaptability of the CTB wall solution to different climates. Work was focused on the quantification of the different contributions to the effective thermal conductivity in the foamed glass for which we performed detailed characterization of the microstructure, pore size, open and closed porosity, glass and gas composition, thermal conductivity and developed a vacuum cell for probing the thermal conductivity of the prepared open-porous foamed glass. The testing revealed the contributions of solid conduction, gaseous conduction and the radiation contribution to the effective thermal conductivity in foamed glass. The results were used for the validation of the theoretical calculations, estimating the lower theoretical limit and guidance for new procedures focused on minimizing the thermal conductivity in foamed glasses. Funding agency: M-ERA.NET European Transnational Agency. Coordinator: dr. Jakob König.

Applied project "**Mineral wool composites with improved insulation properties**" is focused on the development of an innovative new preparation procedure for mineral-wool composites with decreased thermal conductivity. Initially, theoretical calculations on the thermal conductivity of the composites were made, followed by experimental validation of the model by measurements performed on test composite samples. The results provided the boundary compositions for the product with targeted insulation properties. In the next stage, the mechanical properties are being addressed by adding a suitable binder through dry and/or wet application process. Funding agency: Slovenian Research Agency. Coordinator: dr. Jakob König.

Project **SIOX** aims to exploit the rich functionalities of oxides and their heterostructures, which show great promise within the emerging field of oxide electronics. For their implementation, the epitaxial integration of oxides with silicon platforms using industrially appropriate technology is urgently needed, and its development represents the main goal of SIOX. Funding agency: M-ERA.NET European Transnational Agency. Coordinator and principal investigator: Asst. Prof. Matjaž Spreitzer.

BI-RS/18-19-050: With Nuclear Institute Vinća (Belgrade, Serbia) we collaborate in the frame of bilateral project "**Synthesis of R_2MoO_6:REE luminescent nanopowders and their structural characterization by electron microscopy**", where we develop novel luminescent nanomaterials for advanced applications. Using cost-effective self-initiated and self-sustained synthesis approach we developed thermally and chemically stable Eu^{3+} activated yttrium molibdate, which can efficiently absorb energy in the near-UV region (324–425 nm) and emit in the red region of the spectrum (611 nm). Funding agency: Slovenian Research Agency. Principal investigator: Asst. Prof. Nina Daneu.

BI-RS/18-19-042: Project "**Nanostructured and mesoporous functional materials with accentuated photocatalytic properties under the influence of sunlight**" aims to synthesise new functional materials that exhibis solar-light-driven photocatalytic activity in water-pollutant degradation. The synthesis of the following materials is planned: nanostructured ZnO, ZnO/PEO composites, ZnO/SnO_2 particles, hierarchically structured TiO_2 particles with mesoporous nanostructure and large specific surface area, as well as $BaTi_{0.9}Sn_{0.1}O_3$ particles/ceramics. Funding agency: Slovenian Research Agency. Principal investigator: Asst. Prof. Srečo Škapin.

Organization of conferences, congresses and meetings

1. Workshop Contemporary characterization techniques for materials within SRIP Factories of the Future & SKD – Section for ceramics, Ljubljana, 18. 4. 2019
2. Workshop on international project M.ERA-NET "SunToChem: Engineering of perovskite photocatalysts for sunlight-driven hydrogen evolution from water splitting", Ljubljana, 1.–2. 9. 2019
3. Organization of symposium "Ion-related phenomena in nanoscale oxide systems", E-MRS Fall Meeting 2019, Warsaw, Poland, 16.–19. 9. 2019
4. Workshop on international project M.ERA-NET "SIOX: Engineering of silicon-oxide interface using the pulsed-laser deposition technique", Goriška Brda, 21.–22. 10. 2019
5. Workshop Chemical and Structural Analysis for Materials, within SRIP Factories of the Future & SKD – Section for ceramics, Dol pri Ljubljani, 28. 11. 2019

Patents granted

1. Wang Yongli, Boštjan Jančar, Hermann Grünbichler, Franz Rinner, Damjan Vengust, Danilo Suvorov
   Thermoelectric generator comprising a thermoelectric element
   EP2975659 (B1), European Patent Office, 16. 10. 2019.
2. Aleš Mrzel, Damjan Vengust
   Method for the synthesis of metal molybdates and tungstates from molybdenum and tungsten carbides and nitrides
   SI25549 (A), Urad RS za intelektualno lastnino, 31. 05. 2019.

INTERNATIONAL PROJECTS

1. Investigation of NdDyCoCuFe Rare Earth Alloys Alloys and Related Compounds
   Asst. Prof. Matjaž Spreitzer
   Urban Mining Company
2. Investigation of NdDyCoCuFe Rare Earth Alloys Alloys and Related Compounds
   Asst. Prof. Matjaž Spreitzer
   Urban Mining Company
3. COST CA 17140; Cancer Nanomedicine - From the Bench to the Bedside (NANO2CL)
   Dr. Marija Vukomanović
   Cost Association Aisbl
4. Synthesis of Luminescent Nanopowders of Type R2MoO6:REE and Their Structural Characterization by Means of Electron Microscopy
   Asst. Prof. Nina Daneu
   Slovenian Research Agency
5. Nanostructured and Mesoporous Functional Materials with Enhanced Solar Light Driven Photocatalytic Activity
   Asst. Prof. Srečo Davor Škapin
   Slovenian Research Agency
6. Stoichiometry Engineering of Epitaxial PMN-PT Thin Films
   Asst. Prof. Matjaž Spreitzer
   Slovenian Research Agency

RESEARCH PROGRAMME

1. Contemporary Inorganic Materials and Nanotechnologies
   Asst. Prof. Matjaž Spreitzer

R & D GRANTS AND CONTRACTS

1. Synthesis and characterization of alkali activated foams based on different waste
   Asst. Prof. Srečo Davor Škapin
2. Piezoelectric Biomaterials for Electro-stimulated Regeneration
   Dr. Marija Vukomanović
3. Nanoscale investigations of diffusion controlled topotaxial phase transformations in rutile-corundum host systems
   Asst. Prof. Nina Daneu
4. Engineering of oxides on silicon for future electronics
   Asst. Prof. Matjaž Spreitzer
5. Mineral inclusions in garnet from macroscopic to atomic scale: Opening the petrogenetic archive
   Asst. Prof. Nina Daneu
6. Mineral wool composite with improved insulation properties
   Dr. Jakob König
7. Central European SME Gateway zo Key-enabling Technology Infrastructures - Sparking new Transnational KET Innovation Ecosystem
   Asst. Prof. Matjaž Spreitzer
   Bay Zoltan Alkalmazott Kutatasi Kozhasznu
8. Innovative ECO plasma seed treatment (for sowing and for human and animal diet/ nutrition
   Dr. Marija Vukomanović
   Ministry of Education, Science and Sport
9. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
   Asst. Prof. Matjaž Spreitzer
   Ministry of Economic Development and Technology
10. Control of crystallization in glass materials for thermal insulation
    Dr. Sonja Smiljanić
    Ministry of Education, Science and Sport
11. HarvEnPiez: Innovative nano-materials and architectures for integratedpiezoelectric energy harvesting applications
    Dr. Marjeta Maček Kržmanc
    Ministry of Education, Science and Sport
12. CTB Basics: CleanTechBlock-Sustainable Multi-functional Building Block Basics
    Dr. Jakob König
    Ministry of Education, Science and Sport
13. SIOX: Engineering of silicon-oxide interface using the pulsed-laser deposition technique
    Asst. Prof. Matjaž Spreitzer
    Ministry of Education, Science and Sport
14. SunToChem: Engineering of perovskite photocatalysts for sunlight-driven hydrogen evolution from water splitting
    Dr. Marjeta Maček Kržmanc
    Ministry of Education, Science and Sport
15. XRD Analysis
    Asst. Prof. Matjaž Spreitzer

NEW CONTRACTS

1. Determination of potential structural changes of proteins using the following analytical techniques: UV-Vis-NIR spectrometry, fluorescence spectrometry, X-ray diffraction and circular dichroism
   Asst. Prof. Matjaž Spreitzer
   Lek d. d.
2. Mineral wool composite with improved insulation properties
   Dr. Jakob König
   Knauf Insulation, d.o.o., Škofja Loka

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1. Dr José-Alberto Padron Navarta, Géosciences Montpellier, CNRS, Montpellier, France, 1. 1.–8. 1. 2019.
2. Prof. Gertjan Koster, University of Twente, Enshede, Netherlands, 22.–25. 4. 2019.
3. Dr Nadežda Stanković, Dr Jelena Luković, Dr Branko Matović, Vinča Nuclear Institute, Belgrade, Serbia, 19.–25. 5. 2019.
4. Prof. Davide Peddis, University of Cagliari, Monserrato, Italy, 5.–8. 6. 2019.
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9. Dr Leonid Rusevich, Institute of Solid State Physics, University of Latvia, Riga, Latvia, Dr C.S. Jeffrey Wu, Dr Wen Yueh Yu, Department of Chemical Engineering, National Taiwan University, Taipei, Taiwan, 1.–2.9. 2019.
10. Dr Sarah Risquez, Dr Adrien Piot, Dr Jaka Pribošek, Dr Heimo Müller, Silicon Austria Labs GmbH, Graz, Austria, 12. 9. 2019.
11. Prof. Heli Jantunen, University of Oulu, Oulu, Finland, 11.–15. 11. 2019.
12. prof. Dr Eric Bousquet, Dr Wen Yi, University of Liège, Liège, Belgium, Dr Bin-Bin Chen, Fudan University, China, 21. 10. 2019.
13. Dr Vladislav Rac, prof. Dr Vesna Rakić, Poljoprivredni fakultet Beograd, Belgrade, Serbia, 1.–3. 12. 2019.

Visiting Researcher

14. Dr Jamal Belhadi, Laboratoire de Physique de la Matière Condensée (LPMC), Amiens, France, 1. 3. 2019–29. 2. 2020.

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Original Article

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2. Nuria Blanco-Cabra, Karina Vega-Granados, Laura Moya-Andérico, Marija Vukomanović, Andrés Parra, Luis Álvarez de Cienfuegos, Eduard Torrents, "Novel oleanolic and maslinic acids derivatives as a promising treatment against bacterial biofilm innosocomial infections: an in vitro and in vivo study", *ACS infectious diseases*, 2019, **5**, 9, 1581-1589.
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4. Mark Huijben *et al.* (19 authors), "Defect engineering in oxide heterostructures by enhanced oxygen surface exchange", *Advanced functional materials*, 2019, **23**, 13, 5240-5248.
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Published Conference Contribution

1. Vasyl Shvalya, Gregor Filipič, Damjan Vengust, Janez Zavašnik, Martina Modic, Ibrahim Abdulhalim, Uroš Cvelbar, "Reusable copper oxides based plasmonic templates for improved SERS detection", In: *55th International Conference on Microelectronics, Devices and Materials & the Workshop on Laser Systems and Photonics, September 25 - September 27 2019, Bled Slovenia*, Conference proceedings, MIDEM, 2019, 14.
2. Janvit Teržan, Petar Djinović, Janez Zavašnik, Iztok Arčon, Gregor Žerjav, Matjaž Spreitzer, Albin Pintar, "Direct propylene oxidation using molecular oxygen using mesoporous silica as the support", In: *Proceedings of the 8th Serbian-Croatian-Slovenian Symposium on Zeolites, Proceedings of the 8th Croatian-Slovenian-Serbian Symposium on Zeolites, Proceedings of the 8th Slovenian-Serbian-Croatian Symposium on Zeolites: [3 - 5 October 2019, Belgrade, Serbia]*, Serbian Zeolite Association, 2019, 29-32.
3. Maruša Borštnar, Sabina Kramar, Nina Daneu, "Potek hidratacije in nastanek hidratacijskih produktov belitno-kalcijevo sulfoaluminatnega cementa pri različnih temperaturah", In: *24th Meeting of Slovenian Geologists, Ljubljana, november 2019*, Treatises, reports, (Geološki zbornik, **25)**, 2019, 13-15.

Patent Application

1. Aleš Mrzel, Damjan Vengust, *Method for the synthesis of metal molybdates and tungstates from molybdenum and tungsten carbides and nitrides,* EP3486218 (A1), European Patent Office, 22. 05. 2019.

Patent

1. Wang Yongli, Boštjan Jančar, Hermann Grünbichler, Franz Rinner, Damjan Vengust, Danilo Suvorov, *Thermoelectric generator comprising a thermoelectric element,* EP2975659 (B1), European Patent Office, 16. 10. 2019.
2. Aleš Mrzel, Damjan Vengust, *Method for the synthesis of metal molybdates and tungstates from molybdenum and tungsten carbides and nitrides,* SI25549 (A), Urad RS za intelektualno lastnino, 31. 05. 2019.

DEPARTMENT OF BIOCHEMISTRY, MOLECULAR AND STRUCTURAL BIOLOGY B-1

The research activities of the members of the department are largely focused on studies of the physiological role of proteases in normal and pathological conditions, the mechanism of their action and regulation, as well as their properties and structures. Part of the activities is devoted to the development of tools that allow us to understand the properties of proteases and other enzymes, as well as to enable their monitoring and manipulation in in-vivo conditions.

Head:
Prof. Boris Turk

Protease research has undergone a major expansion in the past decade, largely due to the extremely rapid development of new technologies, such as quantitative proteomics and in-vivo imaging, as well as the extensive use of in-vivo models. These have led to the identification of physiological substrates and resulted in a paradigm shift from the concept of proteases as protein-degrading enzymes to proteases as key signalling molecules. Their catalytic activities are precisely regulated, the most important ways being zymogen activation and inhibition by their endogenous protein inhibitors. Any imbalance in this regulation can lead to pathologies such as autoimmune, neurological and cardiovascular disorders, cancer and osteoporosis. However, the molecular mechanisms of protease action are only partially understood, since only a minor subset of physiological substrates for a limited number of proteases has been identified. The role of proteases in various physiological processes is therefore still poorly understood.

One such example is the role of proteases in oxidative stress, which can be described as an increased level of reactive oxygen species (ROS) affecting a wide variety of cellular components, causing various abnormalities. For a long time, oxidative stress was associated with cell death, especially classic necrosis; however, its role in other cell-death pathways was less clear. In the article published in Biological Chemistry, we evaluated the effect of four different ROS scavengers, N-acetyl-L-cysteine (NAC), α-tocopherol (α-TOC) and two SOD mimetics, Mn(III)tetrakis(4-benzoic acid)porphyrin chloride (MnTBAP) and Tempol. We focused on four different cell-death models, including menadione (MD)-triggered necrosis, staurosporine (STS)-induced apoptosis and tumour necrosis factor (TNF)-induced apoptosis or necroptosis. We observed that while the classic ROS scavenger NAC entirely prevented MD-triggered necrosis, other ROS scavengers were less efficient. Even more, ROS were found to have a marginal effect on other studied cell-death pathways. Despite that, we found that Tempol was able to substantially prevent TNF-induced apoptosis and also TNF-induced necroptosis to a lesser extent. However, the effect was likely not associated with its ROS-scavenging function, but compound-specific and the mechanism of action remains to be revealed. In our other study, we found that impaired redox homeostasis could also be the molecular mechanism behind the stefin-B mediated progression of Unverricht-Lundborg disease, which is a form of myoclonic epilepsy. Stefin B (cystatin B) is an intracellular inhibitor of cysteine cathepsins and stefin B-deficient mice were found to be more sensitive to lipopolysaccharide (LPS)-induced sepsis as a consequence of the increased expression of caspase-11 and Nucleotide-binding oligomerization domain, Leucine rich Repeat and Pyrin domain containing (NLRP) inflammasome activation and higher levels of mitochondrial reactive oxygen species (ROS). In our study, we investigated whether LPS-triggered oxidative stress affected the protein levels and redox status of redox sensitive proteins (thioredoxin, peroxiredoxins, and superoxide dismutases) in the macrophages and spleen of LPS-injected mice. The LPS challenge was found to result in a marked elevation in mitochondrial peroxiredoxin 3 (Prx3), sulfiredoxin, and superoxide dismutase 2 (Sod2) in stefin B-deficient macrophages and spleen. We determined that sulfiredoxin is targeted to mitochondria after the LPS challenge and that the upregulation of mitochondrial redox-sensitive proteins Prx3 and Sod2 in stefin B-deficient cells implies a protective role of stefin B in mitochondrial function. Besides studying the physiological functions of stefins, we also tried to apply them to the development of targeted drug-delivery systems. Stefins are general endogenous inhibitors of cysteine cathepsins and their specific inhibitory affinity can be utilized for targeted drug delivery in pathological conditions such as cancer, where cysteine cathepsins are abundantly overexpressed. Cathepsins S and L are also known to be secreted into the tumour micro-environment by tumour and/or immune cells, which makes them promising drug-delivery targets. We tested this hypothesis by developing a new system for cathepsin S/L, targeting using a liposomal drug-carrier system functionalized with the endogenous cysteine cathepsin inhibitor stefin A. We confirmed the selective targeting of cathepsins by stefin A-conjugated liposomes in vitro and in vivo and demonstrated the potential of this approach for cancer diagnosis and treatment.

As a continuation of our protease-specificity studies, we performed a proteomic characterization of the degradome of cysteine protease legumain, which confirmed its narrow proteolytic specificity. We have shown that legumain has a high preference for protein cleavages outside of secondary structure elements.

Besides developing our own projects, we also collaborated with research groups from Slovenia and other countries (Hungary, Croatia, Poland, Netherlands and USA), which resulted in publications in prestigious journals such as JACS, PNAS and Chemical Science. Due to our extensive expertise in proteolysis, we were invited to prepare two review papers describing the role of cysteine cathepsins on extracellular proteolysis and extracellular matrix remodelling and we also prepared an extensive review of the use of degradomics in biomarker discovery.

Some outstanding publications in the past year

1. Bratovš A, Kramer L, Mikhaylov G, Vasiljeva O, Turk B. (2019) Stefin A-functionalized liposomes as a system for cathepsins S and L-targeted drug delivery. Biochimie. Nov; 166:94-102. doi: 10.1016/j.biochi.2019.05.018.
2. Trstenjak Prebanda M, Završnik J, Turk B, Kopitar Jerala N. (2019) Upregulation of Mitochondrial Redox Sensitive Proteins in LPS-Treated Stefin B-Deficient Macrophages. Cells. Nov 21;8(12):1476. doi: 10.3390/cells8121476.
3. Vizovišek M, Fonović M, Turk B. (2019) Cysteine cathepsins in extracellular matrix remodeling: Extracellular matrix degradation and beyond. Matrix Biol. Jan;75-76:141-159. doi: 10.1016/j.matbio.2018.01.024.
4. Kavčič N, Pegan K, Vandenabeele P, Turk B. (2019) Comparative study of the differential cell death protecting effect of various ROS scavengers. Biol Chem. Jan 28;400(2):149-160. doi: 10.1515/hsz-2017-0317

Awards and Appointments

1. Andreja Bratovš: Highly Commended Poster Award, Barcelona, Spain, Perkin Elmer European In Vivo Optical Imaging User Group Meeting 2019, Stefin A-functionalized liposomes as a system for cathepsins S and L-targeted drug delivery.

Organisation of conferences, congresses and meetings

1. 36th Winter School on Proteinases and Inhibitors 2019, Tiers, Italy, 13-17 March 2019, co-organizers

INTERNATIONAL PROJECTS

1. COST CA 15203; Mitochondrial Mapping: Evolution-Age-Gender-Lifestyle-Environment
   Asst. Prof. Nataša Kopitar – Jerala
   Cost Office
2. COST CA15124; NEUBIAS - A New Network of European Bioimage Analysts to Advance Life Science Imaging
   Asst. Prof. Tina Zavašnik Bergant
   Cost Office
3. COST CA15214; An Integrative Action for Multidisciplinary Studies on Cellular Structural Networks
   Asst. Prof. Nataša Kopitar – Jerala
   Cost Office
4. The Role of Cystatins in Neuroinflamamtion
   Asst. Prof. Nataša Kopitar – Jerala
   Slovenian Research Agency
5. Cancer management with cathepsin-targeting protein-drug conjugates: application to brain tumor therapies
   Prof. Boris Turk
   Slovenian Research Agency

RESEARCH PROGRAMMES

1. Structural biology
   Prof. Dušan Turk
2. Proteolysis and its regulation
   Prof. Boris Turk

R & D GRANTS AND CONTRACTS

1. Cathepsin X inhibitors impair the resistence of tumor cells to antiprotease therapy
   Prof. Boris Turk
2. Molecular genetic biomarkers and mechanisms of unresponsiveness to biological therapyanti-TNF in patients with chronic immune diseases
   Prof. Boris Turk
3. Structural insight into the mechanism of Clostridium difficle surface formation
   Prof. Dušan Turk
4. Inhibition of Staphylococcus aureus cell wall remodeling
   Prof. Dušan Turk
5. Role of legumain in infection and inflammation
   Prof. Marko Fonović
6. Role of cysteine cathepsins in complement activation in cancer
   Prof. Boris Turk
7. Improvement of immunotherapeutic potential of NK cells through modulation of cystatin F
   Dr. Miha Butinar
8. Mineral inclusions in garnet from macroscopic to atomic scale: Opening the petrogenetic archive
   Prof. Boris Turk
9. Cathepsin-based non-invasive diagnostics and theranostics of cancer
   Prof. Boris Turk
10. Innovative ECO plasma seed treatment (for sowing and for human and animal diet/nutrition
    Prof. Boris Turk
11. Lyposomal Proteases in Semaphorin Signaling and Cell Polarity
    Prof. Boris Turk
    Icgeb - International Centre For Genetic

VISITORS FROM ABROAD

1. Prof. Kazuo Umezawa, Aichi Medical University, Nagakute, Japan, 4-6 March 2019
2. Dr Jakub Ptáček, Institute of Biotechnology CAS, Prague, Czech Republic, 9-11 July 2019
3. Michał Kanoza, Jagiellonian University, Kraków, Poland, 27 July to 30 September 2019
4. Alma Jahić, University of Tuzla, Bosnia & Herzegovina, 29 September to 11 October 2019

STAFF

Researchers
1. Dr. Iztok Dolenc
2. Prof. Marko Fonović
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4. Prof. Brigita Lenarčič*
5. *Abelardo Manuel Silva, B. Sc., left 15.06.19*
6. Prof. Veronika Stoka
7. Andrej Šali, B. Sc.
8. **Prof. Boris Turk, Head**
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10. Asst. Prof. Livija Tušar
11. Prof. Olga Vasiljeva
12. Prof. Eva Žerovnik

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15. Dr. Nežka Kavčič
16. *Dr. Jasna Lalić, left 16.10.19*
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18. Dr. Georgy Mikhaylov
19. Dr. Sara Pintar
20. Dr. Jure Pražnikar*
21. Dr. Vida Puizdar
22. *Dr. Ajda Taler-Verčič, left 04.11.19*
23. Dr. Aleksandra Usenik
24. Dr. Robert Vidmar

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25. Monika Biasizzo, B. Sc.
26. Andreja Bratovš, B. Sc.
27. *Marija Grozdanić, B. Sc., left 01.10.19*
28. Urban Javoršek, B. Sc.
29. Jure Loboda, B. Sc.
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34. Eva Vidak, B. Sc.
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40. Polonca Pirš Kovačič

Note:
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BIBLIOGRAPHY

Original Article

1. Samra Hasanbašić, Ajda Taler-Verčič, Vida Puizdar, Veronika Stoka, Magda Tušek-Žnidarič, Andrej Vilfan, Selma Berbić, Eva Žerovnik, "Prolines affect the nucleation phase of amyloid fibrillation reaction; mutational analysis of human stefin B", *ACS chemical neuroscience*, 2019, **10**, 6, 2730-2740.
2. Urša Pečar Fonović, Milica Perišić, Nace Zidar, Brigita Lenarčič, Janko Kos, "The carboxypeptidase activity of cathepsin X is not controlled by endogenous inhibitors", *Acta chimica slovenica*, 2019, **65**, 1, 58-61.
3. Robert Vidmar, Matej Vizovišek, Dušan Turk, Boris Turk, Marko Fonović, "Characterization of legumain degradome confirms narrow cleavage specificity", *Acta chimica slovenica*, 2019, **66**, 1, 50-57.
4. Janja Božič, Iztok Dolenc, "Feedback regulation of cathepsin C by the Propeptide dipeptides of Granzymes A and B", *Acta chimica slovenica*, 2019, **66**, 2, 501-509.
5. Junjun Ni, Zhou Wu, Veronika Stoka, Jie Meng, Yoshinori Hayashi, Christoph Peters, Hong Qing, Vito Turk, Hiroshi Nakanishi, "Increased expression and altered subcellular distribution of cathepsin B in microglia induce cognitive impairment through oxidative stress and inflammatory response in mice", *Aging cell*, 2019, **18**, 1, e12856.
6. Andreja Bratovš, Lovro Kramer, Georgy Mikhaylov, Olga Vasiljeva, Boris Turk, "Stefin A-functionalized liposomes as a system for cathepsins S and L-targeted drug delivery", *Biochimie*, 2019, **199**, 94-102.
7. Katarina Korenčan, Jan Potempa, Boris Turk, "Host cell-surface proteins as substrates of gingipains, the main proteases of Porphyromonas gingivalis", *Biological chemistry*, 2019, **399**, 12, 1353-1361.
8. Nežka Kavčič, Katarina Pegan, Peter Vandenabeele, Boris Turk, "Comparative study of the differential cell death protecting effect of various ROS scavengers", *Biological chemistry*, 2019, **400**, 2, 149-160.
9. Eva Žerovnik, "Possible mechanisms by which Stefin B could regulate proteostasis and oxidative stress", *Cells*, 2019, **8**, 1, 70.
10. Mojca Trstenjak-Prebanda, Janja Završnik, Boris Turk, Nataša Kopitar-Jerala, "Upregulation of mitochondrial redox sensitive proteins in lps-treated stefin B-deficient macrophages", *Cells*, 2019, **8**, 12, 1476.
11. Ana Bajc Česnik, Simona Darovic, Sonja Prpar Mihevc, Maja Štalekar, Mirjana Malnar, Helena Motaln, Youn-Bok Lee, Julija Mazej, Jure Pohleven, Markus Grosch, Miha Modic, Marko Fonović, Boris Turk, Micha Drukker, Christopher E. Shaw, Boris Rogelj, "Nuclear RNA foci from C9ORF72 expansion mutation form paraspeckle-like bodies", *Journal of cell science*, 2019, **132**, 5, jcs224303.
12. Janja Božič, Katja Bidovec, Matej Vizovišek, Iztok Dolenc, Veronika Stoka, "Menadione-induced apoptosis in U937 cells involves Bid cleavage and stefin B degradation", *Journal of cellular biochemistry*, 2019, **120**, 6, 10662-10669.
13. Elma Mons *et al.* (11 authors), "The alkyne moiety as a latent electrophile in irreversible covalent small molecule inhibitors of cathepsin K", *Journal of the American Chemical Society*, 2019, **141**, 8, 3507-3514.
14. Tamara Marić *et al.* (12 authors), "Bioluminescent-based imaging and quantification of glucose uptake in vivo", *Nature methods*, 2019, **16**, 6, 526-532.
15. Maja Marinović Guić, Lucija Mijanović, Marko Šoštar, Matej Vizovišek, Alexander Junemann, Marko Fonović, Boris Turk, Igor Weber, Jan Faix, Vedrana Filić, "IQGAP-related protein IqgC suppresses Ras signaling during large-scale endocytosis", *Proceedings of the National Academy of Sciences of the United States of America*, 2019, **116**, 4, 1289-1298.
16. Mateja Rebernik, Brigita Lenarčič, Marko Novinec, "The catalytic domain of cathepsin C (dipeptidyl-peptidase I) alone is a fully functional endoprotease", *Protein expression and purification*, 2019, **157**, 21-27.
17. Jure Pražnikar, Miloš Tomić, Dušan Turk, "Validation and quality assessment of macromolecular structures using complex network analysis", *Scientific reports*, 2019, **9**, 1678.
18. Anastasija Panevska, Vesna Hodnik, Matej Skočaj, Maruša Novak, Špela Modic, Ivana Pavlic, Sara Podržaj, Miki Zarić, Nataša Resnik, Peter Maček, Peter Veranič, Jaka Razinger, Kristina Sepčić, "Pore-forming protein complexes from Pleurotus mushrooms kill western corn rootworm and Colorado potato beetle through targeting membrane ceramide phosphoethanolamine", *Scientific reports*, 2019, **9**, 5073.

Review Article

1. Vito Turk, Dušan Turk, Iztok Dolenc, Veronika Stoka, "Characteristics, structure, and biological role of stefins (type-1 cystatins) of human, mammal, and parasite origin", *Acta chimica slovenica*, 2019, **66**, 1, 5-17.
2. Eva Vidak, Urban Javoršek, Matej Vizovišek, Boris Turk, "Cysteine cathepsins and their extracellular roles: shaping the microenvironment", *Cells*, 2019, **8**, 3, 264.
3. Matej Vizovišek, Marko Fonović, Boris Turk, "Cysteine cathepsins in extracellular matrix remodeling: extracellular matrix degradation and beyond", *Matrix biology*, 2019, **75/76**, 141-159.

4. Marija Grozdanić, Robert Vidmar, Matej Vizovišek, Marko Fonović, "Degradomics in biomarker discovery", *Proteomics. Clinical applications.*, 2019, **13**, 6, 1800138.

Independent Component Part or a Chapter in a Monograph

1. Livija Tušar, Marjana Novič, Marjan Tušar, Jure Zupan, "Structural elucidation", In: *Encyclopedia of analytical science*, Elsevier, 2019, 278-289.

DEPARTMENT OF MOLECULAR AND BIOMEDICAL SCIENCES B-2

The research programme of the Department of Molecular and Biomedical Sciences is focused on basic research in protein biochemistry, molecular and cellular biology, and genetics. The primary goal of our investigations is the acquisition of a new understanding of mammalian pathophysiology, with the aim of improving human and animal health.

Head:
Prof. Igor Križaj

Toxinology

One of our traditional research topics in the field of toxinology is the study of molecular mechanisms of toxic action of secreted phospholipases A_2 ($sPLA_2$s) from animal venoms. In particular, we are focused on those endowed with presynaptic neurotoxicity (β-neurotoxins). The knowledge that we are gaining by studying toxic $sPLA_2$s is helping us to discover the pathophysiological roles of orthologous mammalian $sPLA_2$s, for example, their role in the development of neurodegenerative diseases such as Alzheimer's disease (AD).

In this year we published a very important paper on the molecular identification of a mitochondrial receptor for ammodytoxin (Atx), a neurotoxic $sPLA_2$ from the venom of the nose-horned viper (*Vipera a. ammodytes*, *Vaa*) (J. Šribar et al., *Sci. Rep.*, 9 (2019), 293). This finding is crucial, not only to deepen our understanding of the motoneuron poisoning by Atx on the molecular level, but also to unravel the role of a mammalian $sPLA_2$, an orthologue of Atx, in AD. In the paper we described the purification of an Atx receptor from neuronal mitochondria and its identification as the subunit II of cytochrome c oxidase (CCOX), an essential constituent of the respiratory chain complex. We demonstrated that Atx inhibits the activity of CCOX, which explains the hindering of ATP production by this toxin in a poisoned nerve terminal. Studies are underway to confirm similar activity also in the case of the endogenous $sPLA_2$. Endogenous $sPLA_2$ is present in mitochondria; therefore, we are testing the hypothesis of its involvement in physiological regulation of ATP production by the organelle in normal conditions. In pathological conditions, for example in AD, the activity of the endogenous enzyme is largely increased, and damage inflicted to neuronal mitochondria very similar to the one observed in the Atx-poisoned nerve endings. We are trying to confirm a functional link between the endogenous $sPLA_2$, CCOX binding and THE degeneration of mitochondria, and Atx may serve as an excellent tool to this end.

In the area of $sPLA_2$ research, we concluded the first year of a bilateral project with our Russian partners from the Laboratory of Molecular Toxinology at Shemyakin and Ovchinnikov Institute of Bioorganic Chemistry, Russian Academy of Sciences, Moscow (BI-RU/19-20-029). In this context, we are studying how the endogenous $sPLA_2$s modulate the functions of the nicotinic acetylcholine receptor (nAChR). The new young researcher involved in these studies is preparing recombinant mammalian $sPLA_2$s (GII, GV and GX isoforms) and their enzymatically inactive forms to probe their effects on nAChR in the Russian laboratory. In the scope of this collaboration, I. Križaj also presented an invited talk at the II. Life Sciences Forum (joint VI. Congress on Biochemistry and IX. Russian Symposium "Proteins and Peptides") in Sochi, Russia.

In 2019 we were also intensively studying the *Vaa* venom proteins that affect the blood coagulation process–haemostasis, in particular a serine protease with procoagulant, FVIIa-like activity, named VaaSP-VX, the first procoagulant snake venom serine protease with dual, blood coagulation factor V- and X-activating activity. The experimental part is finished and the paper is drafted (Z. Latinović et al., in preparation).

We also published a review paper entitled "Venomous snakes in Slovenia–composition and action of their venoms" in the Slovenian journal Medicinski razgledi (V. Leban et al., *Med. razgl.*, 58 (2019), 55–74).

A new ambitious international network emerged in 2019, focusing on the improvement of snakebite therapy and the development of advanced tools to degrade vessel-occlusive thrombi, aiming to drastically reduce mortality and morbidity due to snake envenoming and thrombosis. Both aims of this consortium of 13 research groups from Europe and Latin America

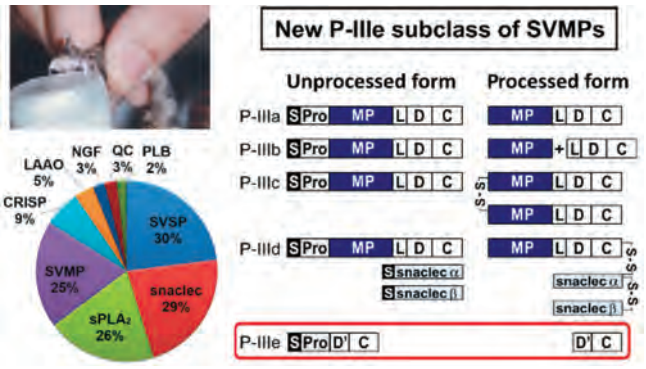

Figure 1: Comprehensive analysis of the proteome and transcriptome of the nose-horned viper (Vipera a. ammodytes, Vaa) venom. The pie diagram shows relative amounts of the main protein families in the venom: snake C-type lectin-like protein (snaclec), secreted phospholipase A_2 ($sPLA_2$), snake venom serine protease (SVSP), snake venom metalloproteinase (SVMP), Cys-rich secretory protein (CRISP), L-amino acid oxidase (LAAO), nerve growth factor (NGF), glutaminyl cyclase (QC) and phospholipase B (PLB). A transcript coding for a protein similar to P-III SVMPs but lacking the MP domain was also found at the protein level in the venom. The existence of such a protein has been demonstrated for the first time. We proposed the introduction of a new P-IIIe subclass of SVMP precursor-derived proteins. The figure is adapted from A. Leonardi et al. (J. Proteome Res., 18 (2019), 2287–2309).

focus on highly effective snake-venom proteinases, metallo- and serine proteinases. Our group has been invited to join and was involved in the preparation of an MCSA-ITN application entitled: "Converting Viper venoms into Public and Private health ESsentials (CoViPPES)" to raise money for the recruitment and training of early-stage researchers.

In 2019 we concluded a systematic analysis of the venoms of two European snakes: the medically very relevant nose-horned viper (*Vaa*) and one of the rarest Croatian karst vipers (*Vipera ursinii macrops, Vum*).

The local and systemic clinical manifestations of poisoning with the venom of *Vaa* are the result of the pathophysiological effects inflicted by enzymatic and non-enzymatic venom components acting, most prominently, on blood, cardiovascular and nerve systems. To help improve the current antivenom therapy towards higher specificity and efficiency, and to assist drug discovery, we have constructed, by combining transcriptomic and proteomic analyses, the most comprehensive library yet of the *Vaa* venom proteins and peptides (Figure 1). Sequence analysis of the venom gland cDNA library has revealed the presence of messages encoding 12 types of polypeptide precursors. At the protein level, 57 venom proteins belonging to 16 different protein families have been identified, four of which, serine proteases (SVSPs), $sPLA_2$s, snaclecs and metalloproteinases (SVMPs), comprise about 80% of all venom proteins. Peptides detected in the venom include natriuretic peptides, bradykinin-potentiating peptides and inhibitors of SVSPs and SVMPs. Of particular interest, a transcript coding for a protein similar to P-III metalloproteinases but lacking the metalloproteinase domain was also found at the protein level in the venom. The existence of such proteins has been demonstrated for the first time, justifying the proposal of a new P-IIIe subclass of ancestral SVMP precursor-derived proteins (A. Leonardi et al., *J. Proteome Res.*, 18 (2019), 2287–2309).

Animal venoms are rich sources of new substances and molecular tools to improve human and animal health.

We also studied the toxic activities of the *Vum* venom and comprehensively described the proteomic profile of this venom in collaboration with colleagues from the University of Zagreb (UZ). This snake is not medically important; however, its ecology is very special, and it is threatened with extinction. Our data opened the way to unravel a unique insecticidal activity of the venom, potentially leading to new pesticides. Comparing the pathological properties of the *Vum* venom with those of the *Vaa* venom, and the proteomes of both venoms, we indicated the existence of neurotoxins in viperid venoms structurally unrelated to $sPLA_2$s (M. Lang Balija et al., in preparation).

In collaboration with colleagues from the Centre for Clinical Toxicology and Pharmacology, University Medical Centre Ljubljana (UMCL), we investigated an interesting clinical effect, a profound, transient and reversible thrombocytopenia of functional platelets in patients envenomed by the nose-horned viper venom. In thromboembolic diseases, such as myocardial infarction and ischemic stroke, platelets play a pivotal role. The currently used antiplatelet drugs have one common side effect—a decreased count of platelets with inhibited function. Such a condition represents a high risk of life-threatening haemorrhage, especially in interventional cardiology and angiology employing an antithrombotic approach. Our findings may pave the way to the development of a new group of antiplatelet agents, which will minimize the risk of life-threatening bleeding in the antithrombotic approach in interventional cardiology and angiology, and increase the effectiveness of vessel dilatation and emboli aspiration. As we have demonstrated, reversible thrombocytopenia in patients poisoned by the *Vaa* venom is caused by snake C-type lectin-like proteins (snaclecs). In 2019 we isolated a pool of these proteins from the venom and purified them to different extents.

Figure 2: Professor I. Križaj receives the Lapanje award. At the 13th Meeting of the Slovenian Biochemical Society in Dobrna on September 26th, 2019, I. Križaj received the Lapanje award, the highest award of the Slovenian Biochemical Society, for his scientific achievements. The justification for his decoration is available at http://www.sbd.si/sl/nagrajenci/40/lapanjetova-nagrada/igor-krizaj.

The network, including experts from UMCL, immunologists from UZ and our group, continues to collect and analyse samples from patients who have been envenomed by the nose-horned viper venom and treated with different antivenoms or not, in order to generate new directives for efficient immunotherapy.

The year 2019 was the last one of the Slovenian-Serbian bilateral project (BI-RS/18-19-005). In the scope of this project, our Serbian partners from the Institute of Molecular Genetics and Genetic Engineering, Belgrade, prepared vectors to express snake venom CRISP and new P-IIIe subclass SVMP, and we started to produce these proteins in bacterial system.

At the end of 2018 we initiated a large research project with the collaboration of two foreign groups, the Department of Biotechnology and Biomedicine from the Technical University of Denmark and the Beijing Genomics Institute from Hong Kong. The major aim of the project is to sequence, assemble *de novo*, annotate and thoroughly analyse the complete *Vaa* genome. From an adult male specimen of this snake, captured in the wild in the north-western part of Slovenia, the liver was dissected and deep frozen. High-molecular-mass genomic DNA (>100 kilobases)

was isolated from this tissue, purified and submitted to combined nucleotide sequencing. The second-generation sequencing resulted in 129 gigabases (Gb), and that of the third generation in 161.5 Gb. These data were subjected to a *de novo* assembly process resulting in the final scaffold set with a total length of 1.56 Gb and an N50 contig of 3.38 megabases. In 2020 the first draft genome of *Vaa* is expected to be roughly annotated.

Our scientific achievements in the field of toxinology were very well recognised in 2019. We have been invited as lecturers at expert meetings and scientific conferences. Most worthy of mention is the invitation to I. Križaj to organise the section and to deliver a keynote lecture at the 20th World Congress of the International Society on Toxinology, Buenos Aires, Argentina, 8–13 September 2019. Further, I. Križaj was invited to participate in writing a book chapter for an esteemed publishing house (B. Lomonte & I. Križaj (2019): Snake Venom Phospholipase A_2 Toxins. Handbook of Venoms and Toxins of Reptiles, 2nd Edn. (Stephen P. Mackessy, Ed.), CRC Press, Taylor & Francis Group, Boca Raton, Florida, USA, in preparation). And last but not least, the very good work of Križaj's team was also acknowledged at home, in Slovenia, when the Slovenian Biochemical Society awarded I. Križaj with the Lapanje Award, the highest distinction of the society, for the outstanding scientific achievements that made an important contribution to the development of biochemical sciences in Slovenia (Figure 2).

Lipid metabolism and signalling

Our work in the field of "Lipid metabolism and signalling" is focused on the identification of cellular pathways of lipid acquisition, trafficking and utilization that can be targeted to reduce the resistance of cancer cells to stress. The survival of cancer cells during severe stress depends on the availability of extracellular lipids and on their capacity to synthesize, mobilise or recycle their own intracellular lipids. By studying the ways in which cancer cells use lipids, we aim to reduce their remarkable ability to adapt to the inhospitable tumour micro-environment and thus reduce the tumour growth, metastasis and resistance to therapy.

Targeting the ways in which cancer cells use lipids is a promising strategy to reduce their resilience.

The paper titled "Lipid Droplets and the Management of Cellular Stress", by E. Jarc Jovičić and T. Petan, was published in the *Yale Journal of Biology and Medicine*, a journal that has been continuously published since 1928 and is edited by Yale medical and graduate students. This invited review paper was prepared for the September 2019 special issue of the journal entitled "Organelles" and was selected as an editor's pick upon publication. In this review, we discuss the emerging roles of lipid droplets as fat storage organelles and major regulators of cellular metabolism. One of the hallmark characteristics of lipid droplets is their capacity to buffer excess lipids and to finely tune their subsequent release based on specific cellular requirements. This simple feature of lipid droplet biology, buffering and the delayed release of lipids, forms the basis for their pleiotropic roles in the cellular stress response. In each cell, lipid droplets support the homeostasis of membrane lipid composition and dynamics, take care of damaged proteins and lipids and patrol the cell to form dynamic contacts with other organelles. They provide protection against excess dietary fat, but also enable optimal energy production in the muscle and heart, complement autophagy during starvation (Figure 3), and regulate inflammatory and immune responses. In each cell, they modulate membrane lipid composition and dynamics, take care of damaged proteins and lipids, patrol the cell to form dynamic contacts with mitochondria and stimulate the oxidative metabolism. Lipid droplets are even formed in the nucleus to orchestrate gene expression and nuclear function. These and other ways in which lipid droplets help cells fight against various forms of stress were the focus of this work.

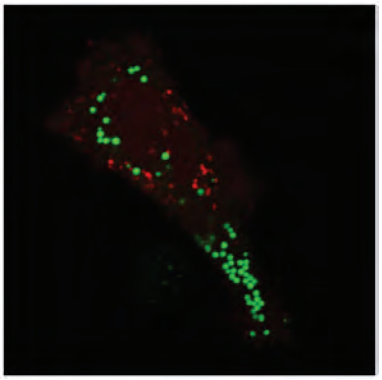

Figure 3: Lipid droplets accumulate in cancer cells exposed to stress. HeLa cervical-cancer cells were exposed to short-term nutrient starvation. Lipid droplet biogenesis and autophagy are activated under these conditions. Lipid droplets and autophagosomes were visualized with live-cell confocal fluorescent imaging. Lipid droplets were stained with the neutral lipid dye BODIPY 493/503 (green), whereas autophagosomes are coloured red due to the presence of a genetically inserted autophagosomal marker protein LC3, fused with red fluorescent protein (RFP) (authors: M. Jusović & T. Petan).

The paper "A twist of FATe: lipid droplets and inflammatory lipid mediators", by E. Jarc Jovičić and T. Petan, was published upon invitation in a special issue of *Biochimie* entitled "Biogenesis and fate of lipid droplets". *Biochimie* is a journal published by Elsevier on behalf of the Société Française de Biochimie et Biologie Moléculaire and we were delighted to have the opportunity to contribute to this issue. In this review, we discuss the principal ways in which lipid droplets regulate the availability of fatty acids for the production of lipid mediators and the activation of inflammatory signalling pathways. On the one hand, lipid droplets sequester polyunsaturated fatty acids (PUFAs), thereby limiting their availability for participation in the signalling pathways. On the other hand, lipids derived from the neutral lipid core or the phospholipid monolayer of lipid droplets directly act as signalling mediators or are converted into ones. Most notably, we now have evidence in immune cells and adipocytes that lipid droplet-derived PUFAs may oxidized by cyclo-oxygenase and lipoxygenase enzyme to produce a plethora of lipid mediators, such as those from the eicosanoid family, that regulate the inflammatory process and also affect tumorigenesis. Lipid droplets thus act as signalling hubs that integrate metabolic and inflammatory processes. Traditionally, the hydrolysis of glycerophospholipids in cellular membranes by various PLA_2 enzymes has been considered the main source and stimulus for lipid mediator synthesis. Here we expand this view by discussing novel evidence that identifies lipid droplets as sources for lipid mediator production, thereby challenging the dogmatic view of

phospholipase-driven inflammatory lipid mediator synthesis. Understanding the connections between these emerging topics may in turn lead us to the discovery of important missing links between nutrition, lipid overload and inflammation in some major modern diseases, such as cancer, metabolic diseases and neurodegeneration.

Our recent work in the field of lipid droplets was well accepted in the scientific community, as judged by several invited lectures, most notably at the 13th Meeting of the Slovenian Biochemical Society, held in Dobrna, Slovenia, where Dr Petan was invited to present his work. E. Guštin, our former master's student from the Faculty of Chemistry and Chemical Technology at the University of Ljubljana, was awarded the Krka Prize for her master's thesis titled "Lipid droplets and fatty acid trafficking in breast cancer cells". M. Jusović received an Ad Futura Postgraduate Scholarship for her PhD studies at the Jožef Stefan International Postgraduate School and joined our group this year. Belen Vilanova Baeza, a master's student from the Edinburgh Napier University, UK, joined our department for a 3-month research visit via the Erasmus+ mobility programme.

Genetics and genomics of yeasts for the development of biotechnology.

High-throughput genetics and functional genomics in yeast *Saccharomyces cerevisiae*

Polygenic trait analysis and genome-editing methods are among the fastest-developing fields in genetics. We developed a method for the iterative crossing of yeast strains with diverse genetic backgrounds, with which we were able to prepare a strain with an extremely high level of acidotolerance (D. Slokar & U. Petrovič, unpublished). The method has great potential in the field of biotechnology. We have developed a CRISPR-Cas9 multiplex method, which can simultaneously make up to five specific changes in the yeast genome (G. Žun et al., unpublished). With a combination of these approaches, new industrial yeast strains can be prepared even more effectively.

Figure 4: Cover of the Yeast journal's Special Issue on Yeast Lipids. The issue's editor was U. Petrovič, principal investigator of the yeast genetics and biotechnology group. He was also the head of the organizing and scientific committees of the YLC 2019 – 14th Yeast Lipid Conference.

In collaboration with the group of Prof. Blaž Zupan from the Faculty of Computer and Information Sciences at the University of Ljubljana, we published an article describing a freely available method for the analysis of large numbers of images acquired by microscopic analysis (P. Godec et al., *Nat. Commun.*, 10 (2019), 4551). This method enables us to be even more competitive in investigating inter-organelle interactions and other cell-biological phenomena in yeast.

In May 2019 our group organised and hosted the 14th Yeast Lipid Conference, a bi-annual event bringing together researchers from the field of yeast lipid research from the whole world. Uroš Petrovič was also a guest co-editor of the Special Issue on Yeast Lipids of the Yeast journal (Figure 4).

Evolutionary genomics

The origin and evolution of large multigene families of pore-forming proteins (aerolysins and actinoporins) in lampreys have been investigated (N. Marondini et al., in preparation). The origin and evolution of lysozyme families in eukaryotes were investigated using the phylogenomic analysis. Large amount of novel data has been obtained for the oldest lineages of animals and enabled us to clarify the origin of metazoa-specific lysozyme families (S. Štrukelj et al., in preparation).

In the scope of the bilateral project with Croatia (BI-HR/18-19-030: "Gene-modulatory role of human alpha satellite DNA: physiological and evolutionary implications"), we investigated the association of alpha satellite DNA with transposable elements. Analysis of primate genome data has enabled us to clarify the mechanisms how the alpha satellite DNA inserts into the introns of different genes. The mobility and insertion of alpha satellite DNA into the introns has been enabled by various transposable elements. We have found that alpha satellite DNA in euchromatin genes is associated with various transposable mobile elements, e.g. with different Alu and L1 repeat families, different LTRs from endogenous retroviruses, and with different molecular fossils of DNA transposons. Analysis of the distribution of alpha satellite DNA in the introns of orthologous genes in primates revealed several distribution patterns (absence in the prosimians; presence in Simiiformes, Catarrhini, Hominoidea, Hominidae and Homininae) and different insertion times (10, 18, 20, 30 and 45 million years ago) of this repetitive DNA into the analysed euchromatic genes. Gene ontological analysis of genes associated with alpha satellite DNA revealed that these genes are involved into the specific biological processes and have specific molecular functions (D. Kordiš et al., in preparation).

Evolutionary, genomic and structure-function analysis of an unusual fungal lipid droplet-associated protein.

The diversity and evolution of RNA viruses has been well studied in arthropods and especially in insects. However, the diversity of RNA viruses in the basal hexapods has not been analysed yet. To better understand their diversity, evolutionary histories and genome organizations, we searched for RNA viruses in transcriptome and genome databases of basal hexapods. We discovered 40 novel RNA viruses, some of which are also present as endogenous viral elements derived from RNA viruses (Figure 5). We demonstrated that basal hexapods host 14 RNA viral clades that have been recently identified in invertebrates. The following RNA viral clades are associated with basal hexapods: Reo, Partiti-Picobirna,

Toti-Chryso, Mono-Chu, Bunya-Arena, Orthomyxo, Qinvirus, Picorna-Calici, Hepe-Virga, Narna-Levi, Tombus-Noda, Luteo-Sobemo, Permutotetra and Flavi. We have found representatives of the nine RNA viral clades that are present as endogenous genomic copies in the genomes of Machilis (Monocondylia) and Catajapyx (Diplura). Our study provided a first insight into the diversity of RNA viruses in basal hexapods and demonstrated that the basal hexapods possess quite high diversity of RNA viral clades (S. Ott & D. Kordiš, *PeerJ*, (2019), in press).

The diversity and evolution of RNA viruses has also been well studied in vertebrates and invertebrates. However, the diversity of RNA viruses in non-bilaterians and their role in viral origins and evolution is unclear. To understand their diversity better, evolutionary histories and genome organizations, we searched for RNA viruses in numerous transcriptome and genome databases of non-bilaterians. Here, we demonstrate that non-bilaterians possess 18 out of 24 RNA viral clades, which are the following: Birna, Partiti-Picobirna, Toti-Chryso, Reo, Mono-Chu, Bunya-Arena, Orthomyxo, Ophio, Yuevirus, Qinvirus, Hepe-Virga, Luteo-Sobemo, Narna-Levi, Nido, Picorna-Calici, Tombus-Noda, Astro-Poty and Weivirus. Such RNA virome diversity is similar to that of insects, crustaceans and molluscs, but is higher than in platyhelminthes, nematodes, chelicerates or vertebrates. Our study shows that non-bilaterians might be the important reservoir of numerous RNA viruses. The discovery of rich and diverse RNA viromes in the non-bilaterians has important implications for inferring the ancestral metazoan virome, explaining the origin and the timing of appearance of Metazoa-specific RNA viral clades and families, as well as inferring the age and distribution of RNA viral clades and demonstrating that rich RNA viromes are typical for all invertebrate lineages (S. Ott & D. Kordiš, *PeerJ*, (2019), under revision).

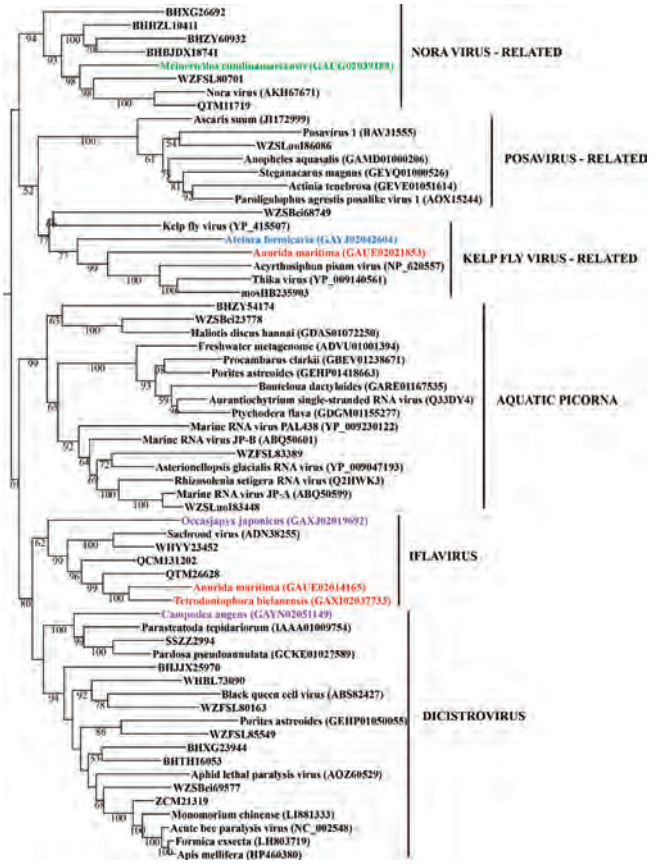

Figure 5. Maximum-likelihood phylogeny of the "Picorna-Calici" clade of RNA viruses in basal hexapods. Phylogeny is based on the analysis of the viral RdRP domain. The names of the viruses are marked with different colours based on their host taxonomy; springtails (Collembola) are red, Diplura are violet, Monocondylia are green, and Zygentoma are blue. The best-fit model of amino acid substitution for this data set was determined as Blosum62+I+G4 according to the Bayesian information criterion. Most sequences were obtained from the GenBank; species names and accession numbers are included. The figure is adapted from S. Ott & D. Kordiš (PeerJ, (2019), in press).

Other subjects

We also participated in several research projects out of the thematic scope of our department. Two collaborative projects resulted in publications in 2019.

As partners in the Slovenian Research Agency (SRA) project J4-7162, led by colleagues from the Biotechnical Faculty of the University of Ljubljana (BF/UL), we participated in preparing an invited review paper on ceramide phosphoethanolamine (CPE), the major sphingolipid in invertebrates and in some bacterial species (A. Panevska et al., *Biochim. Biophys. Acta - Biomembranes*, 9 (2019), 1284–1292). CPE has also been detected in trace amounts in mammalian cells. Understanding the biophysical and physiological relevance of CPE is still elusive. It is apparent, however, that it differs in the biosynthetic mechanisms of sphingomyelin, due to the specific CPE synthase in invertebrates. In contrast to well-established sphingomyelin/cholesterol interactions that result in the formation of ordered membrane domains, the formation of ordered CPE/cholesterol domains is not favoured. CPE may be crucial for the early development of *Drosophila melanogaster*, and it might be involved in the developmental stages of *Trypanosoma brucei*. As a Bacteroidetes-associated sphingolipid, CPE might also be involved in the maintenance of these bacteria in their ecological niches. An efficient detection of CPE in biological systems is needed to better define its distribution and biological role(s).

In collaboration with another research group from the BF/UL we were analysing vitellogenin (Vtg), a female-specific protein and its potential as a molecular marker for sex identification of the European blind cave salamander or proteus (*Proteus anguinus*). In this endangered animal, sexes are indistinguishable based on external morphology, which hinders the establishment of an efficient captive breeding program. Most importantly, we identified Vtg in the plasma of vitellogenic proteus female with visible oocytes and showed that simultaneously with the degradation of oocytes also the Vtg concentration was decreasing until it dropped under the detection level. Thus, we exposed Vtg as a promising molecular marker for sex identification in proteus, advancing the reproductive programme of this unique species (T. Gredar et al., *Comp. Biochem. Physiol. – Part B: Biochem. & Mol. Biol.*, 235 (2019), 30–37).

As partners in the study of glioblastoma multiforme (GBM), the most common and lethal form of brain tumour, in a project led by colleagues from the Medical Faculty of the UL, we participated with the confocal microscopy analysis. To improve the therapy of this tumour and the patient outcome, sustained drug delivery to glioma cells is

needed, while minimising toxicity to adjacent neurons and glia cells. This may be achieved through an anti-proteomic approach based on nanobodies, the single-domain antigen-binding fragments of heavy-chain antibodies of the camelid adaptive immune system. In the work submitted for publication, we report that anti-vimentin, anti-TUFM, anti-NAP1L1 and anti-DPYSL2 nanobodies display a cytotoxic effect and reduce glioblastoma cell migration (A. Zottel et al., *Therap. Adv. Med. Oncol.*, submitted).

As partners in the SRA project J7-7424, led by colleagues from the Faculty of Electrical Engineering of the UL, we participated with the analysis of nanoparticles' protein corona composition to explain their cytotoxicity and induction of cytokine secretion in THP-1 macrophages. The paper is in the final stage of preparation (K. Strojan et al., in preparation).

Also in the field of nanoparticles research, this time in collaboration with our partners from the Ruđer Bošković Institute in Zagreb, we participated in establishing the mechanism of formation and morphogenesis of *Arca noae* shell's nanoscale biomineral structures. We accomplished the mass-spectrometric identification of protein components of the shell, potentially involved in the process of biomineralization, i.e., initiation of the extracellular nucleation of aragonite nanocrystals. The experimental part of the work is concluded, and the paper is in preparation (V. Čadež et al., in preparation).

Some outstanding publications in the past year

1. Šribar, J., Kovačič, L., Oberčkal, J., Ivanušec, A., Petan, T., Fox, J.W. and Križaj, I.: The neurotoxic secreted phospholipase A_2 from the *Vipera a. ammodytes* venom targets cytochrome c oxidase in neuronal mitochondria. Sci. Rep., 9 (2019), 283
2. Leonardi, A., Sajevic, T., Pungerčar, J. and Križaj, I.: A comprehensive study of the proteome and transcriptome of the venom of the most venomous European viper: Discovery of a new subclass of ancestral snake venom metalloproteinase precursor-derived proteins. J. Proteome Res., 18 (2019), 2287–2309
3. Godec, P., Pančur, M., Ilenič, N., Čopar, A., Stražar, M., Erjavec, A., Pretnar, A., Demšar, J., Starič, A., Toplak, M., Žagar, L., Hartman, J., Wang, H., Bellazzi, R., Petrovič, U., Garagna, S., Zuccotti, M., Park, D., Shaulsky, G. and Zupan, B.: Democratized image analytics by visual programming through integration of deep models and small-scale machine learning. Nat. Commun., 10 (2019), 4551
4. Panevska, A., Skočaj, M., Križaj, I., Maček, P. and Sepčić, K.: Ceramide phosphoethanolamine, an enigmatic cellular membrane sphingolipid. Biochim. Biophys. Acta – Biomembranes, 1861 (2019), 1284–1292
5. Jarc, E. and Petan, T.: Lipid droplets and the management of cellular stress. Yale J. Biol. Med., 92 (2019), 435–452

Awards and appointments

1. Igor Križaj: Lapanje Award for outstanding scientific achievements in the field of biochemical sciences, Dobrna, 26. 9. 2019, Slovenian Biochemical Society.

Organization of conferences and meetings

1. 16th World Hematology Congress, Rome, Italy, 18–19 March (co-organisers)
2. 20th World Congress of the International Society on Toxinology, Buenos Aires, Argentina, 8–13 September 2019 (co-organisers)
3. 13th Meeting of the Slovenian Biochemical Society with International Participation, Dobrna, 24– 29 September 2019 (co-organisers)

INTERNATIONAL PROJECTS

1. Gene-Modulatory Role of Human Alpha Satellite DNA: Physiological and Evolutionary Implications
   Prof. Dušan Kordiš
   Slovenian Research Agency
2. Characterization of New Bacterial Enzymes to Ameliorate Food Quality and Human Health
   Prof. Igor Križaj
   Slovenian Research Agency
3. Do Endogenous Secreted Phospholipases A2 Modulate Nicotinic Acetylcholine Receptor Functions?
   Prof. Igor Križaj
   Slovenian Research Agency

RESEARCH PROGRAMME

1. Toxins and biomembranes
   Prof. Igor Križaj

R&D GRANTS AND CONTRACTS

1. DNA sampling II: a method for identification of directly or indirectly bound proteins at specific loci on bacterial chromosomes
   Prof. Igor Križaj
2. Neurotoxicity or neuroprotection of nanomaterials: the rele of biocorona
   Prof. Igor Križaj
3. Development of medical chestnut honey quality control and technology
   Prof. Igor Križaj

4. Bisphenol A alternatives: transfer from food contact material, fate and human exposure
   Asst. Prof. Toni Petan
5. Anisotropic magnetic nanoparticles for the magneto-mechanical therapy of cancer
   Prof. Igor Križaj
6. Neuropsychological dysfunctions caused by low level exposure to selected environmental pollutants in susceptible population – NEURODYS
   Prof. Igor Križaj
7. Protein complexes from the fungal genus Pleurotus, new biopesicides for controlling Colorado potato beetle and western corn rootworm
   Prof. Igor Križaj
8. Exploitation of a virus-borne small protein to combat antibiotic resistance in Staphylococcus aureus
   Prof. Igor Križaj
9. Targeting lipid droplets to reduce cancer cell resistance to stress
   Asst. Prof. Toni Petan
10. Improved treatment and monitoring of Water Framework Directive priority pollutants
    Prof. Igor Križaj

VISITORS FROM ABROAD

1. Dr. Nemanja Stanisavljević, Institute of Molecular Genetics and Genetic Engineering, University of Belgrade, Serbia, 4–15 March 2019
2. Prof. Mike Richardson, Leiden University, Leiden, Netherlands, 5–6 June 2019
3. Prof. Manjunatha Kini, National University of Singapore, Republic of Singapore, 5–8 June 2019
4. Dr. Klementina Fon Tacer, St. Jude's Children Research Hospital, Memphis, USA, 1 July 2019
5. Prof. dr. Klaus Natter, Karl-Franzens-Universität, Graz, Austria, 16–18 September 2019
6. Klavdija Pačnik, B. Sc., Karl-Franzens-Universität, Graz, Austria, 16–18 September 2019
7. Matthias Diepold, M: Sc., Karl-Franzens-Universität, Graz, Austria, 16–18 September 2019
8. Prof. Đurđica Ugarković, Ruđer Bošković Institute, Zagreb, Republic of Croatia, 21– 22 October 2019
9. Dr. Isidoro Feliciello, Ruđer Bošković Institute, Zagreb, Republic of Croatia, 21– 22 October 2019
10. Dr. Željka Pezer Sekač, Ruđer Bošković Institute, Zagreb, Republic of Croatia, 21– 22 October 2019

STAFF

Researchers

1. Prof. Dušan Kordiš
2. **Prof. Igor Križaj, Head**
3. Asst. Prof. Adrijana Leonardi
4. Asst. Prof. Toni Petan
5. Prof. Uroš Petrovič*
6. Prof. Jože Pungerčar
7. Dr. Jernej Šribar

Postgraduates

8. Tadeja Bele, B. Sc.
9. Adrijan Ivanušec, B. Sc.
10. Eva Jarc Jovičić, B. Sc.
11. *Ana Kump, B. Sc., left 01.11.19*
12. Dr. Mojca Ogrizović

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13. Igor Koprivec
14. Maja Šimaga, M. Sc.

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BIBLIOGRAPHY

Original Article

1. Tajda Gredar, Adrijana Leonardi, Maruša Novak, Kristina Sepčić, Lilijana Bizjak-Mali, Igor Križaj, Rok Kostanjšek, "Vitellogenin in the European cave salamander, Proteus anguinus: its characterization and dynamics in a captive female as a basis for non-destructive sex identification", *Comparative biochemistry and physiology. Part B, Biochemistry & molecular biology*, 2019, **235**, 30-37.
2. Adrijana Leonardi, Tamara Sajevic, Jože Pungerčar, Igor Križaj, "Comprehensive study of the proteome and transcriptome of the venom of the most venomous European viper: discovery of a new subclass of ancestral snake venom metalloproteinase precursor-derived proteins", *Journal of proteome research*, 2019, **18**, 5, 2287-2309.
3. Primož Godec, Matjaž Pančur, Nejc Ilenič, Andrej Čopar, Martin Stražar, Aleš Erjavec, Ajda Pretnar, Janez Demšar, Anže Starič, Marko Toplak, Lan Žagar, Jan Hartman, Wang Hamilton, Riccardo Bellazzi, Uroš Petrovič, Silvia Garagna, Maurizio Zuccotti, Dongsu Park, Gad Shaulsky, Blaž Zupan, "Democratized image analytics by visual programming through integration of deep models and small-scale machine learning", *Nature communications*, 2019, **10**, 4551.
4. Jernej Šribar, Lidija Kovačič, Jernej Oberčkal, Adrijan Ivanušec, Toni Petan, Jay W. Fox, Igor Križaj, "The neurotoxic secreted phospholipase A_2 from the Vipera a. ammodytes venom targets cytochrome c oxidase in neuronal mitochondria", *Scientific reports*, 2019, **9**, 283.

Review Article

1. Anastasija Panevska, Matej Skočaj, Igor Križaj, Peter Maček, Kristina Sepčić, "Ceramide phosphoethanolamine, an enigmatic cellular membrane sphingolipid", *Biochimica et biophysica acta. Biomembranes*, 2019, **1861**, 7, 1284-1292.
2. Vid Leban, Miran Brvar, Igor Križaj, Adrijana Leonardi, Katarina Černe, "Venomous snakes in Slovenia - composition and action of their venoms", *Medicinski razgledi*, 2019, **58**, 1, 55-74.
3. Eva Jarc, Toni Petan, "Lipid droplets and the management of cellular stress", *The Yale journal of biology and medicine*, 2019, **92**, 3, 435-452.

Theses and Mentoring

1. Eva Jarc, *The role of lipid droplets in cancer cell stress resistance:* doctoral dissertation, Ljubljana, 2019 (mentor Toni Petan).
2. Mojca Ogrizović, *Role of gene PEX11 and identification of novel genes affecting lipid metabolism in yeast Saccharomyces cerevisiae:* doctoral dissertation, Ljubljana, 2019 (mentor Uroš Petrovič).

DEPARTMENT OF BIOTECHNOLOGY B-3

At the Department of Biotechnology we investigate biological molecules of microbiological, fungal, plant and animal origin using modern biotechnological methods. We would like to apply them for diagnostic and therapeutic purposes in human and veterinary medicine, for plant protection, the preparation of quality and safe food and for the protection of the environment, contributing to an improvement of peoples' health and the environment in which we live. Our research work is focused on the processes of cancer progression and immune response, neurodegenerative processes, the biology of fungi, plant stress response and in search for new biotechnological approaches and products.

Head (until 31. 10. 2019):
Prof. Janko Kos

Head (since 1. 11. 2019):
Prof. Boris Rogelj

In the field of research on bioactive proteins from mushrooms, we continued in 2019 to characterize L-amino acid oxidases (LAO) with antibacterial activity. These enzymes are widely distributed in various organisms and play a wide variety of biological functions, either in basal amino acid catabolism or in reactions related to hydrogen peroxide formation. The most studied are those from snake venoms, as LAOs in some represent the major toxic ingredient. We discovered an incredible diversity of LAOs in mushrooms that showed different substrate specificity, pH optima and molecular masses. We used model Gram-positive and Gram-negative bacteria to show the antimicrobial potential of LAOs from mushrooms and discovered that they completely inhibited the growth of *Escherichia coli*, while *Lactococcus lactis* had a longer lag phase. Higher fungi have been shown to represent a novel and readily available source of versatile enzymes with L-amino acid oxidase activity.

In the field of glycobiology, in 2019 we continued our research into active substances that influence the formation of biofilms of food-borne pathogenic and food-spoilage bacteria in collaboration with the Biotechnical Faculty of the University of Ljubljana. Bacterial biofilms enable the bacteria to survive even under adverse conditions, since the bacteria in them are hidden in the matrix of extracellular material. The prevention of biofilm formation can contribute to the reduced use of antibiotics.

The glycosylation profile is an important issue of cysteine peptidases inhibitor cystatin F, which was, in the previous year, one of the main targets we investigated in the field of antitumor immune response. Cystatin F can enter the lysosomes and cytotoxic granules of cytotoxic T lymphocytes and NK cells and inhibits cathepsins C and H, which are the main convertases of progranzymes, the triggers of cell death. In previous years, by using different cystatin F mutants, we have shown that the internalization of both dimeric and monomeric form of cystatin F leads to a reduction of the activity of cathepsins C and H in NK cells and consequently lower cytotoxicity in particular in NK cells. Last year we also demonstrated the same mechanism for cytotoxic T lymphocytes.

The studies of cystatin F and other effector molecules of anti-tumour immune response we extended to the tumour microenvironment. In this case tissue sections obtained from human brain tumours were used. Additionally, we developed a cell model of the tumour microenvironment with the interplay between cytotoxic cells and other immune cells, tumour stem cells and differentiated tumour cells. In this model cystatin F appeared as an important mediator, causing anergy of the cytotoxic cells and consequently a lower cancer-cell killing. On the other hand, cystatin F can increase the differentiation of cancer stem cells, which become more sensitive to convenient cancer therapy.

Tumour-cell invasion is impaired by organo-ruthenated nitroxoline derivatives through the inhibition of cathepsin-B activity

Besides the cystatin F exogenous synthetic peptidase inhibitors have been studied as potential anti-tumor compounds. In collaboration with the Faculty of Chemistry and Chemical technology at the University of Ljubljana we published a study on organo-ruthenated nitroxoline derivatives as promising inhibitors of cathepsin B.

In the field of neurobiology we continued investigations of the molecular mechanisms of frontotemporal dementia (FTD) and amyotrophic lateral sclerosis (ALS) with four published articles. We have shown that the RNA from the GGGGCC expanded repeat mutation has properties of paraspeckles, which has important consequences for the regulation of this RNA. We show that the accumulation of GGGGCC RNA can be regulated with a paraspeckle protein SFPQ. In collaboration with the Francis Crick Institute in London and the Helmholtz Center Munich we have shown that Neat1 is also regulated with TDP-43 and vice versa, and that the cross-regulation has important implications for the transition from pluripotency to differentiation. Cytoplasmic accumulation and the aggregation of TDP-43 is the main pathological sign of ALS and FTD. Thus, the involvement of TDP-43 in embryonal development also has a significant impact for neurodegeneration. In collaboration with the King's College London we published a study

Cross-regulation between TDP-43 and Neat1, the non-coding RNA scaffold of paraspeckles, promotes transition from pluripotency to differentiation

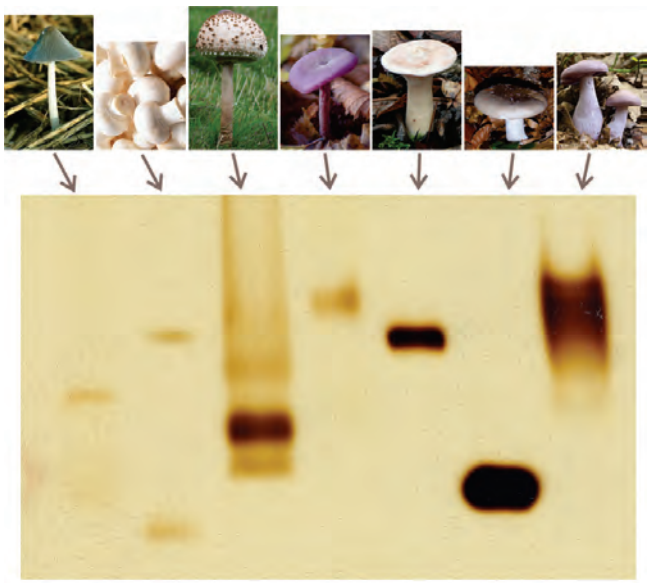

Figure 1: L-amino acid oxidase activity (LAO) in mushrooms: from left: grey shag (Coprinopsis cinerea), portobello mushroom (Agaricus bisporus), parasol mushroom (Macrolepiota procera), amethyst deceiver (Laccaria amtethystina), trooping funnel (Infundibulicybe geotropa), clouded agaric (Clitocybe nebularis) and wood blewit (Lepista nuda).

Development of electrospun poly(ethylene oxide) nanofibres that enable the long-term viability and high loading of probiotics, such as lactic acid bacteria.

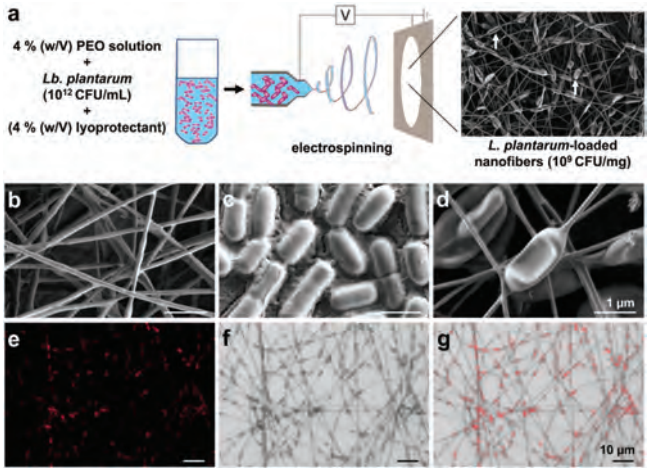

Figure 2: Schematic representation of electrospinning for the preparation of L. plantarum-loaded nanofibres. Scanning electron microscopy images are shown for (b) pure PEO nanofibres, (c) L. plantarum cells and (d) L. plantarum-loaded PEO nanofibres. Confocal microscopy images are also shown for PEO nanofibres with incorporated L. plantarum cells that express mCherry, as (e) fluorescence, (f) bright-field, and (g) merged images.

showing that the heterogeneous nuclear ribonucleoprotein E2 (hnRNP E2) is a component of TDP-43 aggregates in the A and C pathological subtypes of frontotemporal lobar degeneration. This interaction with TDP-43 in specific FTLD subtypes suggests different underlying neurodegenerative pathways. As a part of the MinE consortium for the determination of genetic causes of ALS we published about the project MinE databrowser, which brings large-scale whole-genome sequencing in ALS to researchers and the public and allows users to query a transcript and immediately access a unique combination of detailed data, annotations and association statistics that would otherwise require analytic expertise and visits to scattered resources. We also published a review of noncanonical functions of snoRNAs in the reputable journal Nucleic Acids Research (IF=11.1).

At the department we continued our work on probiotic lactic acid bacteria. In collaboration with the Chair of Pharmaceutical Technology from the Faculty of Pharmacy, we were among the first to develop a procedure for the incorporation of model lactic acid bacterium Lactobacillus plantarum ATCC 8014 into nanofibres by using the electrospinning technique. Nanofibres are considered an innovative delivery system, appropriate for local topical administration, e.g., for vaginal probiotic delivery. The incorporation of probiotic bacteria in nanofibres merges two technological steps into one by concomitant drying of the bacteria and the formation of dosage form. Bacteria were incorporated into poly(ethylene oxide) polymer, and high loading of L. plantarum cells (up to 7.6 × 108 CFU/mg) was achieved. The long-term storage (6 months) of nanofibres was tested, and the viability of L. plantarum was improved considerably when amorphous lyoprotectant trehalose was included in the formulation. The release of bacteria from the nanofibres was relatively fast, with almost all of the L. plantarum cells released over 30 min, which is advantageous for some applications. In a further study, we expanded this work by effective incorporation of ten species of lactic acid bacteria with markedly different properties (morphology, zeta-potential, hydrophobicity, average cell mass, growth characteristics) into nanofibres. Again, all the species were viable upon release from nanofibres and the viability was shown to correlate with cell hydrophobicity.

We also continued our work on the genetic engineering of lactic acid bacteria. Subject to invitation, we prepared a thorough review of applications of engineered lactic acid bacteria for the delivery of proteins and therapeutic peptides for Applied Microbiology & Biotechnology. We developed new anti-inflammatory lactic acid bacteria capable of targeting the IL-23 receptor, and assessed TNF -binding lactococci in inflammatory disease patients' mucosa, with both cytokine pathways important for the disease pathogenesis. To improve the technique of surface display that is crucial in this process, we screened a collection of lactococcal and phage surface anchoring domains. We have identified a new ChW-containing anchoring domain in AM12 phage endolysin that is capable of surface display comparable to the currently established approach using the cAcmA anchor. However, its mode of anchoring was shown to be different, which enabled the concomitant use of both anchors, suggesting considerable biotechnological potential.

The results of the research at the Department of Biotechnology in 2019 were published in 34 scientific papers in journals with an impact factor. We received two new research grants from the Slovenian Research Agency. Prof. Boris Rogelj received the national Zois recognition for scientific achievements in molecular basis of neurodegeneration, Nika Kruljec and Katja Škrlec received Krka awards and Abida Zahirović received the Deans award from the Faculty of Pharmacy. Members of the department were also very active in pedagogical work as lecturers and mentors to students

preparing diploma and doctoral thesis at the universities in Slovenia and abroad. In 2019 two doctoral theses were completed at the department.

Some outstanding publications in the past year

1. Modic, Miha, Rot, Gregor, Lepko, Tjaša, Rogelj, Boris, Ule, Jernej, et al. Cross-regulation between TDP-43 and paraspeckles promotes pluripotency- differentiation transition. *Molecular cell*, ISSN 1097-2765. [Print ed.], 2019, vol. 74, no. 5, str. 951-965, IF 14.5
2. Schmieder, Stefanie S., Stanley, Claire E., Rzepiela, Andrzej, Swaay, Dirk Van, Sabotič, Jerica, Nørrelykke, Simon F., Demello, Andrew J., Aebi, Markus, Künzler, Markus. Bidirectional propagation of signals and nutrients in fungal networks via specialized hyphae. *Current biology*, ISSN 0960-9822. [Print ed.], 2019, vol. 29, issue 2, str. 217-228, IF 9.2

Awards and Appointments

1. Prof. Boris Rogelj, Presented with the Zois Certificate of Recognition for outstanding achievements in the field of Molecular basis of neurodegeneration
2. Katja Škrlec: Krka Grand Prize for Research, Krka d.d., Novo mesto, Surface display of evasins and bepecin on bacteria *Lactococcus lactis* NZ9000 and *Lactobacillus salivarius* ATCC 11741 and evaluation of their anti-inflammatory action, Novo mesto, 18 October 2019
3. Abida Zahirović, Borut Štrukelj, Mojca Lunder (Faculty of Pharmacy, University of Ljubljana), Ana Koren, Peter Kopač, Peter Korošec (University Hospital, Golnik): Best research achievements in 2019, Ljubljana, University in Ljubljana, An important step towards more effective immunotherapy for allergy to bee venom, 18 December 2019
4. Abida Zahirović: Faculty of Pharmacy Dean´s Awards 2019, Ljubljana, Faculty of Pharmacy, Identification of epitopes of major bee venom allergen Api m 1 and characterisation of corresponding mimotopes for use in immunotherapy, 4 December 2019

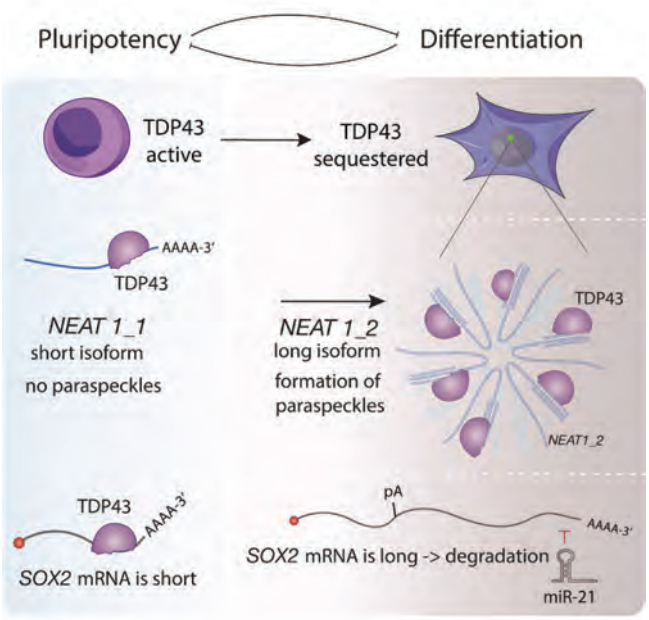

Figure 3: Reciprocal cross-regulation and activity of TDP-43 and the long isoform of the lncRNA Neat1 in pluripotent and differentiated cells. In pluripotent cells, TDP-43 represses the formation of paraspeckles, which form on the scaffold of long isoform of Neat1 by enhancing the polyadenylated short isoform of Neat1. TDP-43 also promotes pluripotency by regulating alternative polyadenylation of transcripts encoding pluripotency factors. One example is Sox2, where TDP-43 partially protects SOX2's 3' UTR from miR-21-mediated degradation. On the other hand, long isoform of Neat1 sequester TDP-43 and other RNA binding proteins and promote exit from pluripotency. (Modic et al., Molecular Cell 2019)

Organization of conferences and meetings

1. Minisymposium Tumor microenvironment: tumor-immune cell interactions, Jožef Stefan Institute and Nacional Institute of Biology, 24 September 2019
2. NanoTemper Workshop: Measure binding affinities and protein stability with NanoTemper Technologies, 15 October 2019
3. Annual meeting of co-workers of the research programme Pharmaceutical Biotechnology: Knowledge for Health, from the Department of Biotechnology at the Jožef Stefan Institute and the Chair of Pharmaceutical Biology, Faculty of Pharmacy, University of Ljubljana, Ljubljana, 21 November 2019

INTERNATIONAL PROJECTS

1. De-regulated expression of CodY controlled proteins in L. lactis for enhancing nisin production
   Prof. Aleš Berlec
   Fermentech Gsv Pvt Ltd.
2. COST CA18238; Ocean4Biotech - European Transdisciplinary Networking Platform for Marine Biotechnology
   Dr. Jerica Sabotič
   Cost Association Aisbl
3. Regulation of Cytotoxicity of „Super Charged" Natural Killer Cells with Cystatin F
   Prof. Janko Kos
   Slovenian Research Agency
4. ALS and FTD Relevant Characterization of In Vivo Protein Interactors of FUS
   Prof. Boris Rogelj
   Slovenian Research Agency

RESEARCH PROGRAMME

1. Pharmaceutical Biotechnology: Knowledge for Health
   Prof. Janko Kos

R & D GRANTS AND CONTRACTS

1. Nucleart transport defect in neurodegenerative diseases
   Prof. Boris Rogelj
2. Cathepsin X inhibitors impair the resistence of tumor cells to antiprotease therapy
   Prof. Janko Kos
3. Pathogenic role of paraspeckle-like nuclear bodies in neurodegenerative diseases ALS and FTD
   Prof. Boris Rogelj
4. Inhibition of cathepsin X activity as a novel strategy for the treatment of Parkinson's

disease
Prof. Janko Kos
5. Targeting Campylobacter adhesion in the fight against antimicrobial resistance
Dr. Jerica Sabotič
6. Advanced surface finishing technologies for antibacterial properties of patient specific 3D printed implantable materials
Asst. Prof. Helena Motaln
7. Phase transitions in systems of nucleotide repeat expansions associated with neurodegenerative diseases
Prof. Boris Rogelj
8. New antimicrobial strategies in prevention of biofilm formation by using lectins that inhibit bacterial adhesion
Dr. Jerica Sabotič
9. Improvement of immunotherapeutic potential of NK cells through modulation of cystatin F
Prof. Janko Kos
10. Development of new, environment-friendly approaches for plant and human virus inactivation in waters
Asst. Prof. Helena Motaln
11. Innovative ECO plasma seed treatment (for sowing and for human and animal diet/nutrition)
Prof. Boris Rogelj
Ministry of Education, Science and Sport

VISITORS FROM ABROAD

1. Dr. Luc Dupuis, French Institute of Health and Medical Research, INSERM, University of Strasbourg, Strasbourg, France, 19 September – 22 September 2019
2. Prof. Jürgen Dittmer, Martin Luther University, Halle – Wittenberg, Halle (Saale), Germany, 23 September – 27 September 2019
3. Jakub Nowak, Nanotemper Technologies GmbH, Munich, Germany, 15 October 2019

STAFF

Researchers
1. Prof. Aleš Berlec
2. **Prof. Janko Kos*, Head, until 31. 10. 2019**
3. Asst. Prof. Helena Motaln
4. **Prof. Boris Rogelj, Head, since 1. 11. 2019**
5. Dr. Jerica Sabotič
6. Prof. Borut Štrukelj*

Postdoctoral associates
7. Dr. Janja Božič
8. Dr. Nikolaja Janež
9. Dr. Ana Mitrović
10. Dr. Milica Perišić Nanut
11. Dr. Mateja Prunk
12. Dr. Anja Pucer Janež
13. Dr. Katja Rebolj
14. *Dr. Petra Zadravec, left 06.05.19*

Postgraduates
15. *Ana Bajc Česnik, B. Sc., left 01.05.19*
16. Mirjana Malnar, B. Sc.
17. Tina Vida Plavec, B. Sc.
18. Emanuela Senjor, B. Sc.
19. Abida Zahirović, B. Sc.

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20. Eva Erzar, B. Sc.

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Note:

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BIBLIOGRAPHY

Original Article

1. Urša Pečar Fonović, Milica Perišić, Nace Zidar, Brigita Lenarčič, Janko Kos, "The carboxypeptidase activity of cathepsin X is not controlled by endogenous inhibitors", *Acta chimica slovenica*, 2019, **65**, 1, 58-61.
2. Tina Vida Plavec, Aleš Berlec, "Surface anchoring on Lactococcus lactis by covalent isopeptide bond", *Acta chimica slovenica*, 2019, **66**, 1, 18-27.
3. Jerica Sabotič, Miha Renko, Janko Kos, "Beta - trefoil protease inhibitors unique to higher fungi", *Acta chimica slovenica*, 2019, **66**, 1, 28-36.
4. Abida Zahirović, Borut Štrukelj, Peter Korošec, Mojca Lunder, "Epitope mapping of major ragweed allergen Amb a 1", *Acta chimica slovenica*, 2019, **66**, 1, 37-44.
5. Janja Božič, Iztok Dolenc, "Feedback regulation of cathepsin C by the Propeptide dipeptides of Granzymes A and B", *Acta chimica slovenica*, 2019, **66**, 2, 501-509.
6. Anže Meden, Damijan Knez, Marko Jukič, Xavier Brazzolotto, Marija Gršič, Anja Pišlar, Abida Zahirović, Janko Kos, Florian Nachon, Jurij Svete, Stanislav Gobec, Uroš Grošelj, "Tryptophan-derived butyrylcholinesterase inhibitors as promising leads against Alzheimer's disease", *Chemical communications*, 2019, **55**, 26, 3765-3768.
7. Damijan Knez, Izidor Sosič, Anja Pišlar, Ana Mitrović, Marko Jukič, Janko Kos, Stanislav Gobec, "Biological evaluation of 8-Hydroxyquinolines as multi-target directed ligands for treating Alzheimer's disease", *Current Alzheimer research*, 2019, **16**, 9, 801-814.
8. Stefanie S. Schmieder, Claire E. Stanley, Andrzej Rzepiela, Dirk van Swaay, Jerica Sabotič, Simon F. Nørrelykke, Andrew J. deMello, Markus Aebi, Markus Künzler, "Bidirectional propagation of signals and nutrients in fungal networks via specialized hyphae", *Current biology*, 2019, **29**, 2, 217-228.
9. Katja Škrlec, Špela Zupančič, Sonja Prpar Mihevc, Petra Kocbek, Julijana Kristl, Aleš Berlec, "Development of electrospun nanofibers that enable high loading and long-term viability of probiotics", *European journal of pharmaceutics and biopharmaceutics*, 2019, **136**, 108-119.
10. Tina Vida Plavec, Borut Štrukelj, Aleš Berlec, "Screening for new surface anchoring domains for Lactococcus lactis", *Frontiers in microbiology*, 2019, **10**, 1879.
11. W. Kattuah, Boris Rogelj, R. Andrew King, Christopher E. Shaw, Tibor Hortobágyi, Claire Troakes, "Heterogeneous nuclear ribonucleoprotein E2 (hnRNP E2) is a component of TDP-43 aggregates specifically in the A and C pathological subtypes of frontotemporal lobar degeneration", *Frontiers in neuroscience*, 2019, **13**, 551.
12. Ana Mitrović, Jakob Kljun, Izidor Sosič, Matija Uršič, Anton Meden, Stanislav Gobec, Janko Kos, Iztok Turel, "Organoruthenated nitroxoline derivatives impair tumor cell invasion through inhibition of cathepsin B activity", *Inorganic chemistry*, 2019, **58**, 18, 12334-12347.
13. Bogdan Zdravković, Tanja Prunk Zdravković, Marko Zdravković, Borut Štrukelj, Polonca Ferk, "The influence of nano-TiO_2 on metabolic activity, cytotoxicity and ABCB5 mRNA expression in WM-266-4 human metastatic melanoma cell line", *JBUON*, 2019, **24**, 1, 338-346.
14. Ana Bajc Česnik, Simona Darovic, Sonja Prpar Mihevc, Maja Štalekar, Mirjana Malnar, Helena Motaln, Youn-Bok Lee, Julija Mazej, Jure Pohleven, Markus Grosch, Miha Modic, Marko Fonović, Boris Turk, Micha Drukker, Christopher E. Shaw, Boris Rogelj, "Nuclear RNA foci from C9ORF72 expansion mutation form paraspeckle-like bodies", *Journal of cell science*, 2019, **132**, 5, 1-14.
15. Janja Božič, Katja Bidovec, Matej Vizovišek, Iztok Dolenc, Veronika Stoka, "Menadione-induced apoptosis in U937 cells involves Bid

cleavage and stefin B degradation", *Journal of cellular biochemistry*, 2019, **120**, 6, 10662-10669.
16. Biljana Božić, Goran Lončar, Tjaša Vižin, Zoran Radojičić, Vera Popović Brkić, Janko Kos, "Relationship of high circulating cystatin C to biochemical markers of bone turnover and bone mineral density in elderly males with a chronic heart failure", *Journal of Medical Biochemistry*, 2019, **38**, 1, 53-62.
17. Bosa Mirjanić-Azarić, Novak Vasic, Darko Černe, Janko Kos, Nataša Bogavac-Stanojević, "Plasma cathepsin S is associated with high-density lipoprotein cholesterol and bilirubin in patients with abdominal aortic aneurysms", *Journal of Medical Biochemistry*, 2019, **38**, 3, 268-275.
18. Mirjana Malnar, Tadeja Režen, "Factors affecting RNA quantification from tissue long-term stored in formalin", *Journal of pharmacological and toxicological methods*, 2019, **96**, 61-66.
19. Tina Vida Plavec, Milan Kuchař, Anja Benko, Veronika Lišková, Jiří Černý, Aleš Berlec, Petr Malý, "Engineered lactococcus lactis secreting IL23 receptor-targeted rex protein blockers for modulation of IL-23/Th17-mediated inflammation", *Microorganisms*, 2019, **7**, 5, 152.
20. Miha Modic *et al.* (20 authors), "Cross-regulation between TDP-43 and paraspeckles promotes pluripotency- differentiation transition", *Molecular cell*, 2019, **74**, 5, 951-965.
21. Camila Ramaho Bonturi *et al.* (10 authors), "A bifunctional molecule with lectin and protease inhibitor activities isolated from Crataeva tapia bark significantly affects cocultures of mesenchymal stem cells and glioblastoma cells", *Molecules*, 2019, **24**, 11, 2109.
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23. Mojca Lunder, Irena Roškar, Jan Hošek, Borut Štrukelj, "Silver fir (Abies alba) extracts inhibit enzymes involved in blood glucose management and protect against oxidative stress in high glucose environment", *Plant foods for human nutrition*, 2019, **74**, 1, 47-53.
24. Kristina Sepčić, Jerica Sabotič, Robin Ohm, Damjana Drobne, Anita Jemec Kokalj, "First evidence of cholinesterase-like activity in Basidiomycota", *PloS one*, 2019, **14**, 4, e0216077.
25. Mateja Prunk, Milica Perišić, Jerica Sabotič, Urban Švajger, Janko Kos, "Increased cystatin F levels correlate with decreased cytotoxicity of cytotoxic T cells", *Radiology and oncology*, 2019, **53**, 1, 57-68.
26. Saša Simčič, Aleš Berlec, Sanja Stopinšek, Borut Štrukelj, Rok Orel, "Engineered and wild-type L. lactis promote anti-inflammatory cytokine signalling in inflammatory bowel disease patient's mucosa", *World journal of microbiology & biotechnology*, 2019, **35**, 3, 45.

Review Article

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2. Tina Vida Plavec, Aleš Berlec, "Engineering of lactic acid bacteria for delivery of therapeutic proteins and peptides", *Applied microbiology and biotechnology*, 2019, **103**, 2053–2066.
3. Barbara Breznik, Ana Mitrović, Tamara Lah Turnšek, Janko Kos, "Cystatins in cancer progression: more than just cathepsin inhibitors", *Biochimie*, 2019, **166**, 233-250.
4. Tanja Jakoš, Anja Pišlar, Anahid Jewett, Janko Kos, "Cysteine cathepsins in tumor-associated immune cells", *Frontiers in immunology*, 2019, **10**, 2037.
5. Jerica Sabotič, Janko Kos, "CNL- *Clitocybe Nebularis* Lectin - the fungal GalNAcβ1-4GlcNAc-Binding Lectin", *Molecules*, 2109, **24**, 23, 4204.

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1. Clemens Peterbauer, Stefan Heinl, Aleš Berlec, Reingard Grabherr, "Recombinant gene expression in lactobacilli: strategies and applications", In: *Lactobacillus genomics and metabolic engineering*, Caister Academic Press, 2019, 169-186.

Theses and Mentoring

1. Janko Ignjatović, *Detection and immunigenicity evaluation of recombinant monoclonal antibodies' structural variants:* doctoral dissertation, Ljubljana, 2019 (mentor Borut Štrukelj; co-mentor Urban Švajger).
2. Mateja Prunk, Role of cystatin F and cysteine cathepsins in the function of cytotoxic T lymphocytes: doctoral dissertation, Ljubljana, 2019 (mentor Janko Kos).

DEPARTMENT OF ENVIRONMENTAL SCIENCES O-2

The Department of Environmental Sciences focuses on the interweaving of the physical, chemical and biological processes that shape our environment, humans and their activities. Our research is interdisciplinary and multidisciplinary and takes place in several areas, such as environmental analytical chemistry, biogeochemical cycles, microbial ecology, environment and health, environmental technologies, risk and environmental assessment, and environmental monitoring. We also work on the development of technical solutions for environmental problems and environmental management. The department hosts the "ISO-FOOD" ERA Chair for isotope techniques in food safety, quality and traceability, the infrastructure Centre of Mass Spectrometry (CMS) and the Mobile Ecological Laboratory Unit (ELMU).

Head:
Prof. Milena Horvat

Environmental analytical chemistry

The role of trace elements and their impact on the environment and living organisms depend not only on their total concentration, but also on the chemical forms in which they are present. Our research is oriented to the development of new analytical procedures for the speciation of elements, like Al, As, Cr, Se, Sn, Br, Pt, Ru, Ni, V, Zn etc. in environmental, food and biological samples.

In the field of ***elemental speciation***, the analytical performance of the low-pressure and high-pressure conjoint liquid chromatography (CLC) monolithic columns, assembling one convective interaction medium (CIM) protein G and one weak anion-exchange diethylamino (DEAE) disks, which enable two-dimensional separation in a single chromatographic run, were evaluated by comparing their robustness, selectivity, repeatability and reproducibility in the speciation of Pt-based chemotherapeutics in human serum. Analyses of the serum samples of cancer patients treated with cisplatin or carboplatin showed that Pt chemotherapeutics were bound preferentially to HSA.

A novel, robust, rapid, sensitive and reliable analytical method based on monolithic chromatography (4 CIM DEAE disks, assembled into a column) coupled to UV and ICP-MS detectors was developed for Cr speciation in human serum and the investigation of the kinetics of the interaction of Cr(VI) and Cr(III) with serum constituents. The rate of Cr(VI) reduction in serum was slow. With the method developed it was for the first time possible to perform the speciation of Cr in human serum at physiological concentration levels. The results revealed that Cr in serum of unexposed individuals is bound to Tf.

Within the framework of the SRA project "Non-traditional isotopes as identifiers of authigenic carbonates" we developed and optimised analytical methods for the determination of $\delta^{26/24}$Mg and $\delta^{88/86}$Sr in surface water and soil by MC-ICP-MS. The optimised procedures were tested on water and soil samples from the karst aquifer of the Ljubljanica River. New methods for Sr isotope ratio determination in milk and olive-oil samples were developed and optimised and applied for the geographical discrimination of Slovenian milk. We also optimised the analytical procedure for $^{87}Sr/^{86}Sr$ isotope ratio determination by MC-ICP-MS in olive oil and tested them on Tunisian and Croatian olive oils for their geographical discrimination.

Within the framework of the Targeted Research Programme (CRP), Identification of Pb sources in the upper Mežiška valley based on Pb isotope composition, different Pb selective resins (Sr-resin, Pb-resin and Dowex 1-X8) for Pb isolation from water, plant, soil and sediment matrices were evaluated in terms of their efficiency of recovery and Pb isotope fractionation. The one with the best results will be further used for the source identification of Pb in dust particles in the upper Mežiška valley.

The Infrastructure for promoting Metrology in Food and Nutrition (METROFOOD-RI) that was successfully included as a Research Infrastructure on the ESFRI Roadmap in 2018, is now proceeding to obtain ERIC status (METROFOOD-PP). The JSI coordinates the Slovenian Joint Research Unit.

In the framework of the EMPIR MercOx project, we developed a new procedure for the calibration of instruments for the measurements of oxidized Hg in air using low-temperature plasma and validated a newly developed calibrator based on the dispersion of $HgCl_2$ solution. A highly specific radioactive 196-Hg tracer was used to allow validation at very low atmospheric concentrations.

Ultralight interwoven graphitic carbon nitride (g-CN) nanosheets for use as a potential adsorbent in a passive sampler (PAS) designed to bind Hg^{2+} ions have developed and successfully tested (Figure 1a). A lightweight aerogel with a porous 3D structure, which accommodates and provides a large surface area for the binding of gaseous elemental mercury (GEM) was also developed. The trials and testing are underway on a laboratory scale (Figure

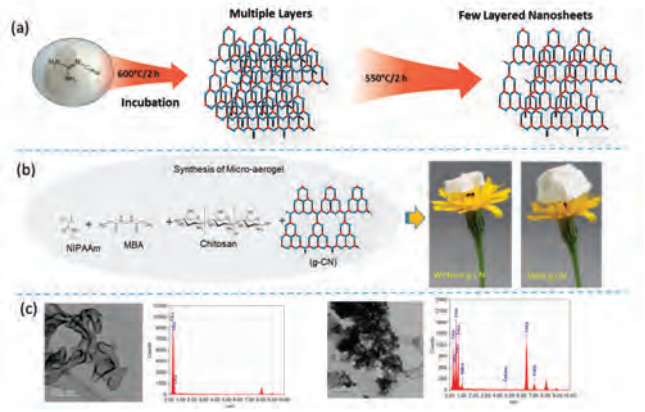

Figure 1. Synthesis route adopted for the preparation of different nanostructure material. (a) Synthesis of g-CN nanosheets via hydrothermal method; (b) Aerogel crosslinking chemistry and finished product and (c) Magnetic g-CN particles TEM images.

2b). Magnetic graphitic carbon nitride, Fe@g-CN, has been synthesized by adorning a graphitic carbon nitride (g-CN) support with iron oxide via a hydrothermal method. Characterization results confirm the intact structure, functionalities and magnetic properties of the as-synthesized material (Figure 1c).

The metrology-related activities in the field of traditional stable isotopes included (i) the evaluation of the uncertainty of the stable isotope composition of C and O in a newly developed reference CO_2 gas that is a part of the EMIR SIRS project Metrology for Stable Isotope Reference Standards; (ii) the preparation of the new EMPIR project STELLAR, Stable Isotope Metrology to Enable Climate Action and Regulation, that was selected for funding in November 2019; and (iii) the development of new food matrix reference materials for hydrogen, carbon, nitrogen, oxygen, and sulphur stable isotope-ratio measurements: collagens, flours, honeys, and vegetable oils. The latest is a result of a joint collaboration performed with Indiana University and Fulbright financial support.

The official nomination for the official analysis of stable isotopes in food samples by the Administration of the Republic of Slovenia for Food Safety, Veterinary and Plant Protection, Ministry of Agriculture, Forestry and Food was obtained in September 2019. It comes on the back of the laboratory receiving accreditation certificate No. LP-090 in April 2019 with the new extended scope for methods in the field of stable isotope analysis of light elements using mass spectrometry.

As a Designated Institute (DI) for "Amount of Substance: Trace elements in inorganic and organic materials", we participated in the following studies in 2019:

- APMP.QM-S10 Elements and Food Supplement,
- CCQM-K145 Bovine Liver and SIM.QM-S10 Trace elements and skimmed-milk powder, organized by National Metrology Institutes of Hong Kong (GLHK), China (NIM), Canada (NRC) and Argentina (INTI)
- the second, third and fourth Interlaboratory Comparison Investigation (ICI) on Cr in whole blood, serum and urine.
- the stability testing of the reference materials ERM-BB185 Bovine liver-trace elements by ICP-MS, ERM-CE477 Tributyltin, dibutyltin and monobutyltin in mussel tissue Mussle tissue, BCR-462 Tributyltin and dibutyltin in coastal sediment and BCR-646 Butyltin and phenyltin compounds in freshwater sediment by GC-ICP-MS. All the materials were prepared by the Joint Research Centre in Geel (JRC-Geel), Belgium.

Participation in such studies enables the entry of new CMCs (calibration and measurement capabilities) into the BIPM database of key comparisons (KCDB).

The Group of ***organic analysis*** has continued to research the occurrence and cycling of contaminants of emerging concern (CECs), namely pharmaceutical and personal care products, and industrial compounds that have an endocrine-disrupting effect in environmental, health and food-related research. Our research related to environment and wastewater treatment has continued to address industrial chemicals including Bisphenol A (BPA) and its alternatives. We have also focused on their stability, as well as biological (conventional with activated sludge and in algal ponds) and photo treatment. Besides target analyses, we also employed non-target screening of biodegradation and photodegradation transformation products of three Bisphenols and identified over ten novel transformation products. We also focused on the development of advanced extraction techniques, where we synthesised and tested molecularly imprinted polymers for the determination of pharmaceutical residues (e.g., sertraline and its degradation products). In addition, we examined the degradation of sertraline in surface water under the influence of real and simulated solar light and developed a LC-MS-based workflow for the determination of sertraline transformation products in surface water. We also determined the occurrence of these compounds in Slovenian rivers.

In the field of ***food studies***, we developed an analytical method for the determination of neonicotinoids in different food matrices, including honey and propolis and applied it to a series of commercially available products. Results showed that only low contamination with selected neonicotinoids was present in real samples. We also addressed variations in phytoestrogen content between organically and conventionally produced beer and hops using a LC-MS/MS. Our research included the determination of three selected prenylflavonoids in hops and beer and was after optimisation and validation tested on real samples. Results showed that measuring the level of the selected compounds could not serve as an organic fraud technique, while the $\delta^{15}N$ values were significantly higher in beers declared as organic compared to those declared

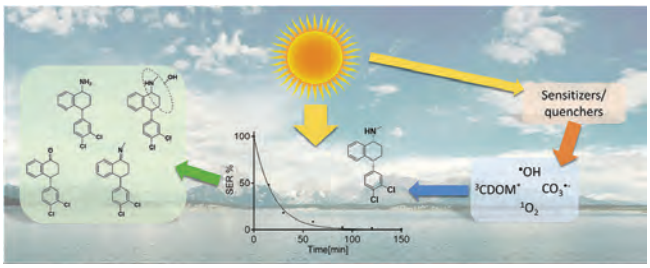

Figure 2: Photodegradation of sertraline in surface water

as conventional, indicating that $\delta^{15}N$ values could be a suitable marker to differentiate between organically and conventionally produced beer.

The group of ***radiochemistry*** developed, in the framework of the CROSSING project with the Helmholtz Zentrum Dresden Rosendorf, a dual radiolabel procedure for CeO_2 nanoparticles (NPs). ^{141}Ce was produced during neutron irradiation in a nuclear reactor. The ^{139}Ce produced with a cyclotron was in-diffused into the CeO_2 NP. In-diffused ^{139}Ce was bound labile close to the surface, whereas ^{141}Ce was uniformly distributed within the NP. This procedure makes it possible to study the dissolution of CeO_2 NPs by measuring the radiolabelled Ce isotopes using gamma spectrometry and discrimination between dissolution close to the surface and dissolution of the whole nanoparticle. The radiolabelled NPs were used for the study of their solubility under acidic and reducing conditions with and without the presence of phosphates. It was found that the presence of phosphate substantially reduces the solubility of Ce nanoparticles under reducing conditions, while this was not so pronounced under acidic conditions.

Biogeochemical cycles and climate change

Biogeochemical cycles of nutrients and other elements (metals and metalloids) couple the biosphere with the hydrosphere, lithosphere and atmosphere, connecting them in a complex nexus with multiple interdependencies and interactions.

As a part of the COST Action OceanGov.into, we analysed the CO_2 cycling in estuarine and coastal marine environments. The Adriatic Sea is currently a CO_2 sink with an annual flux of approximately -1.2 to -3 mol C m^{-2} yr^{-1}, which is smaller than in the NW Mediterranean (-4 to -5 molC m^{-2} yr^{-1}), but nevertheless a considerable contribution of the overall Mediterranean CO_2 sink. The computed Revelle factor for the Adriatic Sea (~ 10) indicates that the waters should not be particularly exposed to acidification. The inflow of rivers draining carbonate terrains results in a high input of alkalinity, therefore the Adriatic is supersaturated with respect to $CaCO_3$ throughout the year. Nevertheless, significant effects on calcifying organisms and phytoplankton can be expected with progressing ocean acidification, while the effects on microbially driven processes are not definite yet.

In collaboration with the National Institute of Biology, we participated in a study on modelling the influence of multiple stressors on the respiration and microbial biomass in the hyporheic zone of the upper Sava River catchment using decision trees. It was shown that the temperature, land use and water quality are the predictors that mostly govern the response of the analysed parameters.

We collaborated with researchers from Niš University (Serbia) in the investigations of toxicity of cerium oxide nanoparticles (CeO_2NPs) in non-biting midges. The results indicated that exposure to CeO_2NPs contaminated freshwater sediments does not pose a risk to chironomids in environmentally relevant concentrations. However, the significant accumulation of CeO_2NPs by chironomid larvae may pose a risk through trophic transfer to organisms further up the food chain.

For the needs of a study of food partitioning of conflict bears in Slovenia in the field of ***isotope ecology***, we explored in collaboration with the Biotechnical Faculty of the University in Ljubljana the influence of prolonged ethanol storage and defatting of brown bear (Ursus arctos) tissues on the isotopic composition of carbon, nitrogen and sulphur and the accuracy of the partitioning of food sources based on C, N and S stable isotopes. It turned out that ethanol storage and defatting had only minor influences on the $\delta^{13}C$ values of tissues of bear liver, while other treatments had no significant effect on measured isotope ratios of any element and matrix. Moreover, the observed differences did not affect the food source estimate significantly.

In collaboration with the Slovenian Academy of Sciences and Arts we investigated the vegetation history and sedimentary processes in the catchment area of Lake Bohinj (Julian Alps, Slovenia), where a 12-m-long sediment core was collected and analysed for mineral composition, grain size and pollen distribution, geochemical and isotope characteristics. In the top 4.4 m covering the last 6600 years, we reconstructed environmental changes and interactions of people (agriculture, grazing, mining) with the environment and climate.

Figure 3: Sampling of tufa in the Krka River for the analysis of the behaviour of metal isotopes in terrestrial carbonate cycle

Water cycle: The usability of novel tracers based on non-traditional isotopes of metals (U, Sr, Mg, Mo) in hydrogeological processes was tested in karstic aquifers of the Ljubljanica and Krka rivers in Slovenia. The U, Sr and Mg isotopes were determined in water and rock samples and used as tracers of water masses and identifiers of authigenic carbonate. The preliminary results show a substantial variability in $^{238/234}U$ isotope ratios, pointing to different origins of uranium, which makes it useful for tracing sources, mixing and biogeochemical processes in

groundwater. The isotope ratios of $^{88/86}$Sr and $^{26/24}$Mg were proven to be a powerful tool for the study of the carbonate cycle in karst aquifers, which can act as a powerful terrestrial sink of CO_2. These isotopes enable a quantitative estimate of the precipitation or dissolution of carbonate within the aquifer, and in the case of dissolution, also the identification of the origin of dissolved inorganic carbon (bedrock *vs.* secondary carbonate incrustations in fissures and conduits).

In the Velenje Coal Mine, we analysed groundwater in Pliocene and Triassic aquifers and traced the age of water and the origin of dissolved inorganic carbon using water and C isotopes. We ruled out coal as a primary source of dissolved inorganic carbon in the groundwater. The isotopic composition of carbon and hydrogen in dissolved methane pointed towards the microbial processes as the dominant methanogenic pathway. The measured range of values of 3H activity concentrations in groundwater confirmed that the Pliocene aquifers contain mainly modern (< 50 yr old) water, while the absence of ^{3}H in Triassic aquifer together with the stable O and H isotope composition of water indicated the Pleistocene age of the water.

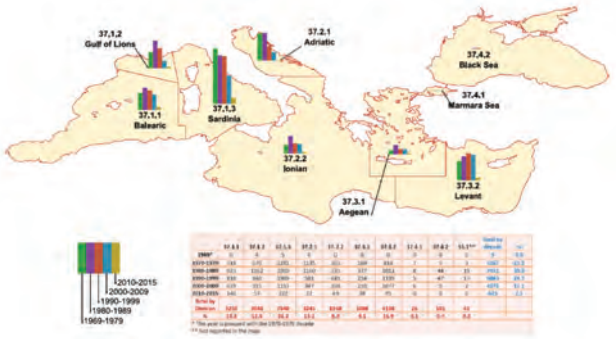

Figure 4: In the journal Nature Scientific Data the results of 24,465 records from the 539 sources have been summarized and now included in the M2B mercury database in the biota of the Mediterranean. The M2B database is intended to support the implementation of the Minamata Mercury Convention.

In collaboration with the Faculty of Civil and Geodetic Engineering of the University of Ljubljana and the Karst Research Institute we determined the mean transit time and the fraction of young water in the karst aquifer of the Ljubljanica River, which are important parameters for sustainable groundwater management. Using a stable isotope composition of O and H in precipitation and sources and sinks of karst rivers in the northern part of the aquifer, we determined the mean transit times of 0.4 to 0.8 years and the fraction of young water (< 2.3 months), on average 28 %.

In the framework of the IAEA project "Use of Isotope Techniques for the Evaluation of Water Sources for Domestic Supply in Urban Areas" we used isotopes as tools (δ^{18}O, δ^{2}H, $^{87/86}$Sr ratios) and multi-elemental analyses for tracing the distribution of water from different wells and pumping stations in the water-supply system of the VOKA Snaga Public Utility. It turned out, however, that the chemical fingerprint has a better prediction value for water-source appointment than stable isotopes.

In collaboration with colleagues from the Hungarian Academy of Science and Arts we finalised the study on the variability of isotopic composition of precipitation on the Adriatic–Pannonian transect. We evaluated the altitude, temperature and continental effects in the area. Currently in progress is the publication of a special issue in the open-access journal MDPI Water entitled "Use of Water Stable Isotopes in Hydrological Process", where both coordinators of the bilateral projects are acting as guest editors.

Atmosphere research: We used radon (^{222}Rn) in ambient air as an indicator of the vertical mixing of air in the lower atmosphere in Ljubljana (SA, sub-Alpine basin) and in Ajdovščina (SM, sub-Mediterranean valley, Fig. x), with contrasting topographical and geological settings. In a comparative study, outdoor radon concentrations have been used for the summer period (June–August 2018) and four radon-based stability classes have been determined for each site. We have found that radon is trustworthily tracking the mixing of air in both cases, and explained the factors that lead to differences between the two locations. A model for the identification of persistent temperature inversion, using radon-based stability classes in winter (December 2016 - February 2017 and December 2017 - February 2018) in Ljubljana, has been tested on selected pollutants (NO_2, CO, PM_{10}, BC, SO_2, O_3). The research was performed within the STRAP project (Sources, TRAnsport and fate of persistent air Pollutants in the environment of Slovenia).

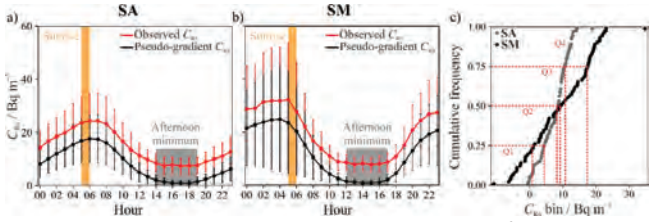

Figure5: Summertime mean hourly diurnal composites of observed radon and the local contribution to radon (pseudo-gradient) in a) Ljubljana (SA), b) Ajdovščina (SM) and c) cumulative distribution of the mean of pseudo-gradient radon at the SA and SM, with indicated quartiles ranges

Microbial system ecology

In 2019, research was carried out in two European projects: Applause (Allien Plant Species - from harmful to useful with citizens' ice activities) and Greener (InteGRated Systems for Effective ENvironmEntal Remediation), where we developed methods for combining cells into aggregates as well as methods for gluing cells onto different surfaces to form layers of different composition and thickness. A patent is pending for this innovative approach. Moreover, based on these methods, we were the first to demonstrate that bacterial cell adhesion to the surface can regulate the attachment of cells from the environment and biofilm succession, which was published in the prestigious journal Advanced Science (Figure 5).

The possibilities of the metabolic coupling of different cells with each other were investigated for the purposes of the transformation of nitrite into nitrogen, lignin to vanillin, cellulose into polyhydroxyalkanoates, and the

degradation of polycyclic aromatic hydrocarbons by cell aggregation. For combining different bacterial cells, we also enriched a microbial collection with strains that break down lignin, cellulose and starch. Within the frame of the research work on the Applause project, we have also developed various prototypes of alternative paper production processes using waste wood and polymer waste materials.

In national projects, we have primarily collected microbes from the oral cavity that are probiotic and integrated the sequencing and annotation processes of the genomes of these isolated bacteria.

In cooperation with the company VOKA – Snaga d.o.o. and the Geological Survey of Slovenia, we have been developing measures for cleaning the contaminated part of the Ljubljana Marsh and for clearing the soil upon the accidental spillage of kerosene in the Kozina area (SW Slovenia).

In the CROSSING project we analysed the interactions between bacteria and nanoparticles and examined the possibilities of dissolving CeO_2 nanoparticles through the action of ubiquitous bacteria of the genus *Pseudomonas*.

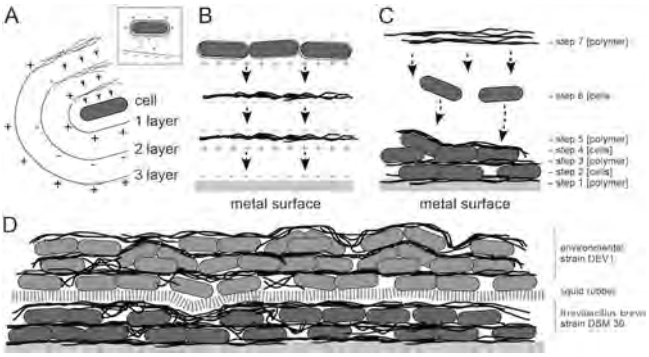

Figure 6: Preparation of artificial biofilms: Two types of bacterial cells have been used in the process, which have previously altered the surface potential (A). The living cells were arranged in layers (B) and covered with layers of natural polymers (C). Finally, they obtained a spatially arranged structure containing both types of microbes in separate spaces (D).

In the framework of international cooperation, we participated in the experiments and a student exchange with the University of Tomsk, Russia, where we studied the antimicrobial activity of differently treated surfaces of materials used in prosthetics. For these purposes, we have also developed a special method that allows the observation of the effects of different surfaces on microbial cells in real time and in microliter volumes.

Environment and health

We started with the implementation of the national human biomonitoring program (HBM), which was approved by the Office for Chemicals at the Ministry of Health of the Republic of Slovenia. The areas with which we started extensive sampling of the population of children and adolescents included Koroška, Celje, Vrhnika and Jesenice. We completed a pilot study of HBM in Prekmurje and organized a series of consultations with the Slovenian profession on the use of HBM data in risk assessments. In addition to trace elements, we determined three bisphenols (BPA, BPF and BPZ), triclosan and parabens in over 1000 samples and continued to develop non-target analytical procedures for urine. We also evaluated for the first time, the exposure of the Slovenian population to organophosphorus pesticides and polycyclic aromatic hydrocarbons (PAHs), glyphosate, and a wider range of phthalates and DINCH. The results revealed that exposure of the Slovenian population is comparable to the rest of Europe and shows lifestyle and dietary characteristics that make a key contribution to the exposure to the chemicals under investigation.

Within the framework of the project Neuropsychological Dysfunction caused by the low level of exposure of selected pollutants from the environment in a sensitive population (NEURODYS), we continued to use available data from previous and current studies (PHIME, CROME, HEALS) and supplemented chemical, biochemical and molecular analyses missing data gaps. The main objective of the proposed project is to establish a link between exposure to chemicals in the environment, human (epi) genomes and neuropsychological performance, taking into account the microbiome. With regard to the new study population, we have started integrating obstetricians at the Celje Maternity Hospital in collaboration with the General Hospital Celje. Moreover, sequencing methods for DNA and RNA using third-generation sequencers were introduced. Protocols for the analysis of the human microbiome on excreta samples from adult volunteers and infants were established. A special DNA isolation method was prepared for microbiome analyses and all bioinformatic procedures were established: methods for determining the quality of sequences, filtering procedures for the highest-quality sequences, determining sequences based on BLAST algorithms, and statistically informative analysis of the proportions of representatives of alpha, beta, and gamma diversity. We also introduced informatics methods for predicting the function of microorganisms based on the sequence of 16S rRNA genes, which allows us to evaluate the metabolic potential of a particular microbial community, in this case, the functioning of the human microbiome.

Figure 7: Within the HBM, urine in the Slovenian population was evaluated for the presence of pesticides belonging to the group of organophosphorus (OP) compounds and pyrethroids (PYR). It is a very rare study that reports results on the prevalence of these compounds under family circumstances by analysing maternal and infant urine samples. By analysing the metabolic products of these compounds, we have found that the presence of metabolic products of parathion and pyrethroids is positively correlated between mother and child, suggesting a pathway of exposure through food and lifestyle. The chlorpyrifos abundance, however, was characteristic only for mothers. At present, the concentration of measured pesticides in children and mothers does not pose a health risk.

In the field of mercury research, we have shown that the uptake and distribution of selenium, inorganic and methylmercury are also influenced by the presence of ApoE ε4. Mothers who had at least one ε4 allele had higher selenium values in their plasma compared to non-carriers (62.6 and 54.9 ng/mL). Children who were ε4 carriers had significantly higher Hg levels in umbilical cord blood. We also observed an Hg-related decrease in the cognitive abilities of ε4-bearing children. The negative association between fine motor skills and Hg, however, was independent of genotype.

The importance of Hg speciation was reiterated, as only by clearly defining exposure to various Hg specimens can we reduce the chances of inappropriately evaluating the associations between prenatal exposure to low Hg values and its negative effects on child development. The speciation of Hg in meconium has shown that meconium is a suitable biomarker of prenatal exposure to MeHg and Hg0. In addition, higher levels of selenium in mothers carrying the ApoE ε4 allele could be associated with the positive effects of apolipoprotein E. It can be concluded that children who are ε4 carriers are more susceptible to the negative effects of Hg on the neuropsychological development of children, but to confirm this hypothesis further studies are needed.

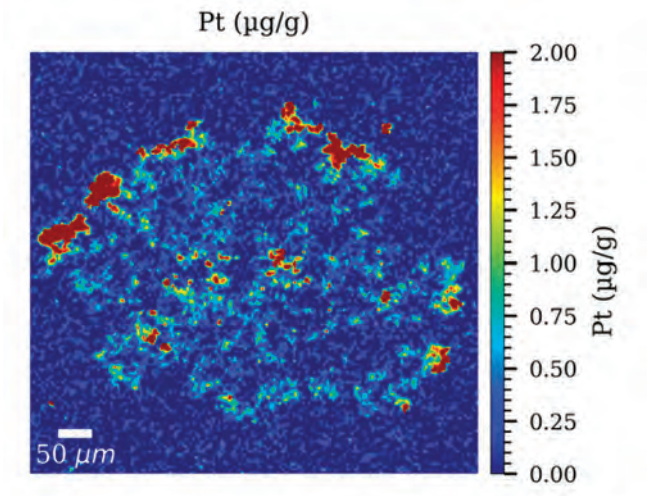

Figure 8: Pt quantification via isotope dilution of a tumorous spheroid treated with cisplatin by LA-ICP-MS. We used 2D LA bioimaging via ID for the quantification of Pt in tumorous spheroids threated with cisplatin (Figure XY). We optimized parameters for the laser ablation (LA) and quantification of the ablated sample by ICP-MS. Currently, we are developing several analytical methods for the bio-imaging of biological tissues, e.g., tumorous spheroids and cells that comprise quantification by matrix matched standards and the isotope dilution (ID) technique.

In the field of wastewater-based epidemiology we joined the international WBE community and jointly published an article in the renowned journal Addiction, providing a spatiotemporal assessment of illicit drug use on a large-scale using evidence from a 7-year international wastewater monitoring campaign. We included data for Ljubljana for 2017 and five Slovenian municipalities, in order to compare the drug use between Slovenian and international cities. We also performed wastewater sampling of 48 elementary, secondary and higher education bodies in Slovenia to compare drug consumption based on weighted student population data according to geographical location (urban vs. rural) and educational level (primary, secondary, higher education). Once we have evaluated the data, we will, in collaboration with National Institute of Health Protection, compare them with data from the European School Survey Project on Alcohol and Other Drugs (ESPAD) and the Health Behaviour in School-Aged Children (HBSC) project. To the best of our knowledge, this research is novel and provides essential information on drug use among Slovenian schoolchildren and students.

We also studied the migration of twelve bisphenols (BPs) from beverage cans and reusable steel and plastic sports bottles using a validated GC-MS/MS method with ng L-1 LOQ and showed that human exposure to BPs is higher from cans, where levels of BPA exceed specific migration limits. For the national human biomonitoring programme, we analysed 750 urine samples for the presence of three BPs (BPA; BPF and BPZ), triclosan and parabens and continued with developing a non-target workflow for urine analysis.

Food

In the framework of the ***ERA Chair ISO-FOOD*** Elemental and stable isotope composition was used to establish a database of authentic samples and develop appropriate models for origin identification. The approach was applied to different food commodities, including algae dietary supplements from Spirulina, Chlorella, Brown algae, truffles and honey. Further, the preliminary expert task of checking the origin of selected fruits (strawberries, cherries) and vegetables (asparagus, garlic) was performed for the Administration of the Republic of Slovenia for Food Safety, Veterinary and Plant Protection. The study confirms that the models created based on authentic samples for each selected fruit and vegetable represent a solid foundation for distinguishing between authentic and market samples with a certain percentage of reliability and for establishing an appropriate traceability system. The database formation and development of appropriate models are in line with the new EU project FNS-Cloud, starting in October 2019.

In addition, in Spirulina dietary supplement samples from the Slovenian market fatty acid and amino acid composition was determined. The distribution of the fatty acids following their concentrations was as follows: palmitic acid > linoleic acid > γ-linolenic acid > stearic acid > oleic acid > palmitoleic acid. Omega-3 fatty acids were found only in small concentrations. Large deviations in fatty acid composition in some samples suggested the possibility of adulterations of some Spirulina dietary supplements. Combining the use of stable-isotope ratios of light elements and elemental composition with total fatty- and amino acid composition using Discriminant Analysis (DA) enabled us to achieve a better characterization of the samples' geographical origin and possible adulterations.

A new method for a determination of Sr stable-isotope analysis was applied to milk and truffle samples in order to obtain better separation according to the geographical origin. The measured $^{87}Sr/^{86}Sr$ ratios in milk from different locations revealed a complex underlying lithology and region-specific variability. Besides a different lithology, the source of the feed also affects the Sr fingerprint of milk; therefore, the provenance of Slovenian milk continues to be a subject of investigation.

Within the REALMed project and smart specialization program "Food for Future" we developed new analytical methods and analysed isotope profiles for the authenticity study of new commodiries (e.g. argan and truffles) from different Mediterranean countries. A dynamic headspace solid-phase microextraction (HS-SPME) methodology used with gas chromatography-mass spectrometry (GC-MS) and gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS) analysis was developed for compound identification and stable-isotope analysis of volatile organic compounds (VOCs). The first stable-isotope databases for apple, strawberry, vanillin, and truffle aroma compounds were established. Pure synthetically derived characteristic aroma compounds and nature-identical vanillin samples were also characterised. Additional types of fruits were tested, and the apple and strawberry database was expanded to include the analysis of raw fruit and fruit juices. For most of the selected aroma compounds, good discrimination was obtained between the natural and synthetic authentic range of isotope values. Finally, commercial samples were tested and revealed possible falsifications for several fruit aroma compounds. All the products labelled as "natural vanilla flavour" contained synthetic vanillin. Also, fresh truffle samples from the market are suspected of being flavoured with synthetically derived truffle aroma. As these results indicate that significant doubt exists about the authenticity of flavoured products on the market, and extensive testing is necessary.

Environmental technologies

In cooperation with the Biotechnical Faculty and the Slovenian Forestry Institute, a new technology for sludge treatment is under development. Several experiments were performed where the influence of various treatments on the process of mineralization of sludge on sludge drying reed beds (SDRBs) was studied. First measurements indicate that aeration enhanced the microbial production, so that the SDRBs can be successfully used in sludge treatment. We also participated in an investigation conducted by the Institute of Agriculture and Tourism from Poreč, Croatia, on the potential use of different types of stabilized sewage sludge as a soil amendment. In each sludge sample, physicochemical characteristics, nutritional status, trace metal and radionuclide content were examined. The results of the study revealed that – considering the analysed parameters – eight of the nine studied sludges were safe for agricultural use. Therefore, soil conditioning with sewage sludge remains a viable strategy for nutrient recovery from municipal waste, although long-term impact assessments of repeated applications are necessary.

We have started new research on cement-organics-radionuclide interactions for the safe disposal of low- and intermediate-level radioactive waste within the framework of the work package CORI of the EURAD H2020 European Joint Programme on Radioactive Waste Management, namely, the radiolytic degradation of superplasticizers and sorption/diffusion behaviour of EDTA and NTA in cement.

Environmental management, environmental impact assessment and risk assessment

New approaches in environmental monitoring were tested using novel Earth Observation (EO) systems. To this end, we were involved in activities using the advantages of recent technological developments of sensor technologies, which aim at providing information on an individual's exposure to environmental stressors, such as air and water pollution; using a combination of in-situ and remote sensing, including participatory sensing approaches and modelling, and which also contribute to the Smart Cities concepts and the building of Citizens Observatories. These activities have been carried under the ICARUS (H2020 - Integrated Climate forcing and Air Pollution Reduction in Urban Systems), iGOSP (ERA-NET: Integrated Global Observing Systems for Persistent Pollutants), SMURBS (ERA-NET: SMart URBan Solutions for air quality, disasters and city growth) and the recently started CitieS-Health (H2020: Citizen Science for Urban Environment and Health) projects. In the framework of ICARUS, an integral overview of measures and polices related to air quality improvement and health protection of the citizens in participating cities has also been developed.

In the EU H2020 project SciShops.eu (Enhancing the Responsible and Sustainable Expansion of the Science Shops Ecosystem in Europe) and the associated Centre for Participatory Research at the IJS two projects with NGO Greenpeace Slovenia were performed. Both were about carbon footprints: one was dealing with the single use of plastic bottles, while the other was about the massive use of candles associated with All Saints Day.

A decision analysis for the waste disposal site Boršt at the uranium mine Žirovski vrh has been made within the MODARIA II programme (Modelling and Data for Radiological Impact Assessments), coordinated by the IAEA.

Environmental monitoring

The monitoring of organotin compounds in sea and surface waters was performed in collaboration with the Slovenian Environmental Agency (ARSO), while in collaboration with the Environmental Agency from Croatia monitoring of organotin compounds and polybrominated diphenyl ethers in surface and sea water continued in 2019.

The monitoring of natural radionuclides within the influential area of the former uranium mine and mill at Žirovski vrh was performed. We also participated in off-site monitoring of the Krško Nuclear Power Plant (NPP) with the determination of strontium and tritium in environmental samples, as well as tritium and radiocarbon in gas effluents from the NPP. With analyses of strontium and tritium, we also participated in the monitoring of radioactivity in drinking water in Slovenia, as well as in the monitoring of the living environment in Slovenia. Methods used for the determination of strontium, tritium and radiocarbon for monitoring purposes are accredited by the Slovenian accreditation body (SA LP-090).

We have successfully completed a comprehensive study for the European Commission on transposition and implementation of EURATOM Drinking Water Directive 2013/51/ERATOM in European Union Member States (MSs). The directive lays down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption and represents an important document in ensuring human health and protection from radioactive substances. The study identified good practices and areas for possible improvement, which provided the European Commission with all the necessary elements to decide on the completeness and adequacy of the transposition and implementation of the directive in each MS.

Education

The education of Slovenian and foreign students has become one of the novel educational tools for analytical radiochemistry produced within the MEET-CINCH H2020 project in collaboration with JSI Centre for Knowledge Transfer in Information Technology. Educational videos for teaching the basics of analytical radiochemistry were produced. The main feature of the videos is their modularity, which enables them to be used for different purposes and target audiences. They were tested in the teaching of radiochemistry in a flipped classroom approach where students watch video lessons at home before in-class lectures and time in the presence phase is devoted mainly to practical exercises, discussion and social activities with peers. Three pilot deliveries were executed, one during an Erasmus+ exchange at Al-Farabi Kazakh National University, the second during a hands-on training course on analytical radiochemistry, organised in December 2019 at the JSI and the third in teaching students of Ecotechnology at Jožef Stefan International Postgraduate School. The evaluation of the pilot delivery showed that the flipped classroom concept of teaching and educational videos was highly appreciated by students, which points to the fact that this didactical approach should be used more widely.

Centre for mass spectrometry

The centre is involved in research and analytical measurements within various research programmes and projects in the fields of environmental chemistry, chemistry for sustainable development, organic synthetic and pharmaceutical chemistry, biochemistry, geology, medicine and other natural science fields, whose holders are research groups at the JSI, the National Institute of Chemistry, the National Institute of Biology, University of Ljubljana, Maribor and Nova Gorica, Centers of Excellence, partners from Slovenian industry, etc.

Most studies have been performed with the high-resolution tandem mass spectrometer Q-Tof, coupled to the chromatographic method LC-MS or GC-MS, where various organic compounds, organo-metallic complexes, biopolymers, pollutants and other chemicals have been identified and structurally characterized. Different mass spectrometric techniques were used for the analysis of samples of newly synthesized organic compounds, pharmaceutical compounds, drugs, proteins, lipids and similar organic and biomolecules, ceramic and geological materials, food supplements and food additives, environmental pollutants, food, water and similar matrixes. We developed a new LC-MS analytical method for the speciation of zinc, nickel and chromium in food samples and for a determination of the degradation products in the photo-electro-catalysis of adipic acid. A similar approach was used for the determination of photodecomposition products of sertraline in surface water, where due to the excessive use of drugs such as antidepressants, anti-inflammatory drugs and antibiotics, their degradation products also occur in the aquatic environment of Slovenian rivers.

The GC-MS and LC-MS method was used in the study of photodecomposition of bisphenol A and its derivatives in food-contact materials, where various organic compounds and transformation products are formed that can influence human health through food. In collaboration with the Faculty of Pharmacy at the University of Ljubljana, we investigated with a high-resolution mass spectrometer several substituted N-pyrrolamides as potentially useful GyrB inhibitors with activity against resistant bacteria.

Ecological Laboratory with Mobile Unit

A mobile chemical laboratory of Ecological Laboratory with a Mobile Unit (ELMU), which is organised in the Civil Protection and Rescue System in Slovenia for intervention in ecological accidents with hazardous substances and materials, is also a part of the department. The ELMU chemical mobile laboratory intervened thirteen times in the field in 2019 due to environmental pollution, especially air pollution during fires or in residential areas, spills of hazardous substances into the streams and groundwater and because of irregular waste disposal. Members of the ELME mobile chemistry laboratory unit trained their competence in regular ELMU exercises, tested new equipment and improved the knowledge, procedures and analytical methods of the mobile ecological laboratory for the determination of hazardous substances in the environment.

Some outstanding achievements in the past year

1. Development of a special concept of surface treatment in which we purposefully attach to the surface of the material living micro-organisms, which direct the development of biofilms so that those that cause biologically mediated corrosion did not occur
2. Development of a method for the calibration of oxidized mercury with cold plasma
3. Accreditation certificate LP-090 and official nomination as the national laboratory for the official analysis of stable isotopes in food samples
4. Development of a method for determination of amino acids in food samples
5. Development of a model for verifying the origin of selected vegetable and fruit samples

Some outstanding publications in the past year

1. Rijavec, Tomaž, Zrimec, Jan, Spanning, Rob Van, Lapanje, Aleš. Natural microbial communities can be manipulated by artificially constructed biofilms. *Advanced science,* 6 (2019), https://doi.org/10.1002/advs.201901408.
2. Vrzel, Janja, Ludwig, Ralf, Vižintin, Goran, Ogrinc, Nives. An integrated approach for studying the hydrology of the Ljubljansko polje aquifer in Slovenia and its simulation. Water. 2019, 11, 1753-1-1753-23. DOI: 10.3390/w11091753.
3. Strojnik, Lidija, Potočnik, Doris, Ogrinc, Nives in sod. . Authentication of key aroma compounds in apple using stable isotope approach. Food Chemistry 2019, 277, 766-773. DOI: 10.1016/j.foodchem.2018.10.140.
4. Rovan, Lea, Štrok, Marko. Optimization of the sample preparation and measurement protocol for the analysis of uranium isotopes by MC-ICP-MS without spike addition. J. Anal. Atom. Spectr., 34 (2019) 1882-1891.
5. Stajnko, Anja, Šlejkovec, Zdenka, Mazej, Darja, France Štiglic, Alenka, Sešek-Briški, Alenka, Prpić, Igor, Špirić, Zdravko, Horvat, Milena, Falnoga, Ingrid. Arsenic metabolites; selenium; and AS3MT, MTHFR, AQP4, AQP9, SELENOP, INMT, and MT2A polymorphisms in Croatian-Slovenian population from PHIME-CROME study. Environmental research: 170 (2019) 301-319, doi:10.1016/j.envres.2018.11.045
6. Ogrinc, Nives, Hintelmann, Holger, Kotnik, Jože, Horvat, Milena, Pirrone, Nicola. Sources of mercury in deep-sea sediments of the Mediterranean Sea as revealed by mercury stable isotopes. Scientific reports, 2019, 9, 116261-1-11626-9. DOI: 10.1038/s41598-019-48061-z.
7. Rusjan, Simon, Sapač, Klaudija, Petrič, Metka, Lojen, Sonja, Bezak, Nejc. Identifying the hydrological behavior of a complex karst system using stable isotopes. Journal of Hydrology, 577 (2019), 1-11, doi: 10.1016/j.jhydrol.2019.123956.
8. Borbone, Fabio, Rosolen, Valentina, Mariuz, Marika, Parpinel, Maria, Casetta, Anica, Krsnik, Mladen, Osredkar, Joško, Mazej, Darja, Snoj Tratnik, Janja, Neubauer, David, Kodrič, Jana, Horvat, Milena, et al. Prenatal mercury exposure and child neurodevelopment outcomes at 18 months : results from the Mediterranean PHIME. Int. J of Hyg. Env. Health 222 (2019), 1, 9-21, doi: 10.1016/j.ijheh.2018.07.011.

Awards and Appointments

1. Milena Horvat "ICMGP 2019 Life Achievement award - Kate Mahafy Life Achievement Award", Krakow, Poland, 8-13 September 2019
2. Nives Ogrinc: Zois award for outstanding achievements in the use of stable isotopes in interdisciplinary research, Ljubljana, Slovenia, 20.11.2019
3. Nives Ogrinc was nominated as a Congress Ambassador of Slovenia in 2019, Ljubljana, Slovenia,14.11.2019.
4. Award for best presentation at the conference, Vrzel Janja, Ogrinc Nives, Ludwig Ralf. A modelling framework for simulating groundwater and surface water dynamics and their interactions at the 2nd Atlas Georesources International Congress, Applied Geosciences for Groundwater, Hammamet, Tunisia in March 2019.

5. Best Poster Award, Krajnc, Bor, Nečemer, Marijan, Camin, Federica, Vogel-Mikuš, Katarina, Hamzić Gregorčič, Staša, Strojnik, Lidija, Ogrinc, Nives. Characterization of truffles (Tuber sp.) in Slovenia using stable isotope approach and elemental composition: 1st ISO-FOOD International Symposium on Isotopic and Other Techniques in Food Safety and Quality, Portorož, Slovenia, April 1-3, 2019.
6. Best Poster Award, Chouhan, Raghuraj, Fajon, Vesna, Živković, Igor, Pavlin, Majda, Berisha, Sabina, Jerman, Ivan, Heath, David, Horvat, Milena. Development of an efficient passive sampler adsorbent for the detection of mercury in water via stratified nanostructured knitting. 1st ISO-FOOD International Symposium on Isotopic and Other Techniques in Food Safety and Quality, Portorož, Slovenia, April 1-3, 2019.
7. Best Poster Award, Strojnik, Lidija, Hladnik, Jože, Weber, Nika, Koron, Darinka, Stopar, Matej, Zlatić, Emil, Kokalj, Doris, Naglič Gril, Mateja, Grebenc, Tine, Perini, Matteo, Pianezze, Silvia, Camin, Federica, Ogrinc, Nives. Analytical technique sniffs out aroma: 11th Jožef Stefan International Postgraduate School Students' Conference and 13th Young Researchers' Day, 15-16 May 2019, Planica, Slovenia.

Organization of conferences, congresses and meetings

1. IAEA Workshop "Stable isotopes in environmental and food studies", Reactor centre JSI, Ljubljana, 29–30 January 2019
2. 1st ISO-FOOD Symposium Isotopes and Food Quality and Safety, Grand Hotel Bernardin, Portorož, 1–3 April 2019
3. IAEA Workshop "Regional Training Course on Recent Advances in Receptor Models for Source Identification and Apportionment of Air Particulate Matter", Reactor centre JSI, Ljubljana, 20–24 May 2019
4. 4th MEET-CINCH Meeting, Reactor centre JSI, 5–6 June 2019
5. 4th Meeting: Metrology for Stable Isotope Reference Standards, Reactor centre JSI, Ljubljana, 25–26 September 2019
6. CitieS-Health project meeting, Reactor centre JSI, Ljubljana, 1–2 October 2019
7. BE MERMAID project meeting, Reactor centre JSI, Ljubljana, 4 October 2019
8. MercOx project meeting, Salonit, Anhovo, 17–18 October 2019
9. MEET-CINCH training course "Hands-on training on analysis of alpha, beta and gamma emitters by radiochemical spectroscopic techniques", Reactor centre JSI, Ljubljana, 9–13 December 2019
10. Final meeting of the Hungarian-Slovenian research project N1-0054, Reactor centre JSI, Ljubljana, 9 December 2019
11. Visit of industrial partners of SRIP Food, Reactor centre JSI, Ljubljana, 18 December 2019

INTERNATIONAL PROJECTS

1. CROSSING - Crossing Borders and Scales - An Interdisciplinary Approach
   Asst. Prof. Aleš Lapanje
   Helmholtz-zentrum Dresden-rossendorf E.v.
2. 7FP - HEALS; Health and Environment-wide Associations Based on Large Population Surveys
   Prof. Milena Horvat
   European Commission
3. 7FP - GLOBAQUA; Managing the Effects of Multiple Stressors on Aquatic Ecosystems Under Water Scarcity
   Prof. Radmila Milačič
   European Commission
4. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Prof. Milena Horvat
   European Commission
5. EMPIR; SIRS - Metrology for Stable Isotope Reference Standards
   Prof. Nives Ogrinc
   Euramet E.v.
6. ERDF - UIA; APPLAUSE - Alien Plant Species - From Harmful to Useful with Citizens Let Activities
   Asst. Prof. Aleš Lapanje
   European Regional Development Fund (erdf)
7. EMPIR - EDC-WFD; Metrology for Monitoring Endocrine Disrupting Compounds Under the Water Framework Directive
   Prof. Ester Heath
   Euramet E.v.
8. LIFE18 ENV/SI; LIFE HIDAQUA
   Prof. Radmila Milačič
   European Commission
9. The Use of Stable Isotopes and Elemental Composition for Determination of Authenticity and Geographical Origin of Milk and Dairy Products; Accessible Technologies for the Verification of Origin of Dairy Products as an Example Control System...
   Prof. Nives Ogrinc
   IAEA - International Atomic Energy Agency
10. Enhancing Nuclear Analytical Techniques to Meet the Needs of Forensic Sciences; Forensics with Nuclear Methods: Art and Food Forgery, Drugs in Hair
    Dr. Radojko Jaćimović
    IAEA - International Atomic Energy Agency
11. EMPIR - MercOx; Metrology for Oxidised Mercury
    Prof. Milena Horvat
    Euramet E.v.
12. COST CA 15202; Self-healing As preventive Repair of COncrete Structures
    Asst. Prof. Aleš Lapanje
    Cost Association Aisbl
13. Use of Isotope Techniques for the Evaluation of Water Sources for Domestic Supply in Urban Areas; Multi-isotope characterization of water resources for domestic supply in Ljubljana, Slovenia
    Dr. Polona Vreča
    IAEA - International Atomic Energy Agency
14. Training Fees for Mr Kyrylo Korychenskyi
    Prof. Borut Smodiš
    Ictp - Centro Internazionale Di Fisica Teorica
15. Determination of Organotin Compounds in Certified Reference Materials - Stability Testing of the Materials
    Asst. Prof. Tea Zuliani
    European Commission
16. Authenticity of High-Quality Slovenian Food Products Using Advanced Analytical Techniques; Implementation of Nuclear Techniques for Authentication of Foods with High-Value Labelling Claims (INTACT Food) (D52042)
    Prof. Nives Ogrinc
    IAEA - International Atomic Energy Agency
17. Regional Training Course on Recent Advances in Receptor Models for Source Identification and Apportionment of Air Particulate Matter, Ljubljana, Slovenia, 20 May

2019 - 24 May 2019
Dr. David Kocman
IAEA - International Atomic Energy Agency
18. Stability Study of Br in ERM-EC590 and ERM-EC591
Dr. Radojko Jaćimović
European Commission
19. Isotope Analysis of Water for IAEA
Dr. Polona Vreča
IAEA - International Atomic Energy Agency
20. Stability Testing of ERM-BB185 (Bovine Liver)
Asst. Prof. Tea Zuliani
European Commission
21. Isotope Variability of Rain for Assessing Climate Change Impacts; Trends in Isotopic Composition of Precipitation in Slovenia under Climate Change
Prof. Sonja Lojen
IAEA - International Atomic Energy Agency
22. Training Fee for IAEA"s Fellow Ms Khin Mya Win, (MYA7007), 01.10.2019-30.11.2019
Prof. Ljudmila Benedik
IAEA - International Atomic Energy Agency
23. Characterization Study of ERM-CZ110
Dr. Radojko Jaćimović
European Commission
24. Training Fees for IAEA"s Fellow Mr Ibrahim Kwame Kwarteng, (GHA0018), 04.11.2019-30.04.2020
Asst. Prof. Branko Kontić
IAEA - International Atomic Energy Agency
25. H2020 -IGOSP; Integrated Global Observing Systems for Persistent Pollutants
Prof. Milena Horvat
European Commission
26. H2020 - ICARUS; Integrated Climate Forcing and Air Pollution Reduction in Urban Systems
Prof. Milena Horvat
European Commission
27. H2020 - HBM4EU; European Human Biomonitoring Initiative
Prof. Milena Horvat
European Commission
28. H2020 - SciShops.eu; Enhancing Responsible and Sustainable Expansion of the Science Shops Ecosystem in Europe
Prof. Milena Horvat
European Commission
29. H2020 - MEET-CINCH; A Modular European Education and Training Concept in Nuclear and RadioChemistry
Asst. Prof. Marko Štrok
European Commission
30. H2020 - NEUROSOME; Exploring the Neurological Exposome
Prof. Milena Horvat
European Commission
31. H2020 - CitieS-Health; Citizen Science for Urban Environment and Health
Dr. David Kocman
European Commission
32. H2020 - HERA; Integrating Environment and Health Research: A Vision for the EU
Prof. Milena Horvat
European Commission
33. H2020 - GREENER; InteGRated systems for Effective ENvironmEntal Remediation
Asst. Prof. Aleš Lapanje
European Commission
34. H2020 - EURAD; European Joint Programme on Radioactive Waste Management
Prof. Milena Horvat
European Commission
35. H2020 - FNS-Cloud; Food Nutrition Security Cloud
Prof. Nives Ogrinc
European Commission
36. H2020 - METROFOOD-PP; METROFOOD-RI Preparatory Phase Project
Prof. Nives Ogrinc
European Commission
37. H2020 - MASSTWIN; Spreading Excellence and Widening Participation in Support of Mass Spectrometry and Related Techniques in Health, Environment, and Food Analysis
Prof. Milena Horvat
European Commission
38. Dynamics of Soil Air Components (Radon, Carbon Dioxide, and its Carbon Isotopes) under Semi-Natural Forest Sites
Prof. Nives Ogrinc
Slovenian Research Agency
39. Sewage Sludge Recycling through Agricultural Utilization
Dr. Radojko Jaćimović
Slovenian Research Agency
40. Determination of Geographical Origin of Honey by Using Multi-Element and Isotopic Analysis of Soil, Plants and Honey
Asst. Prof. Tea Zuliani
Slovenian Research Agency
41. Photochemical Fate and Treatment of Pharmaceutical Contaminants in Drinking Water
Asst. Prof. Tina Kosjek
Slovenian Research Agency
42. Mass Balance of Mercury in the Mediterranean Sea
Prof. Milena Horvat
Slovenian Research Agency
43. New Analytical Reference Materials and Techniques for Stable Isotope-Ratio Measurements
Prof. Nives Ogrinc
Slovenian Research Agency
44. Spatial Distribution of d2H, d18O and 87Sr/86Sr in Tap Water and Groundwater from Slovenia
Asst. Prof. Tea Zuliani
Slovenian Research Agency
45. Promotion of the Slovenian Science and Slovenia in the Framework of »Division of Chemistry and Environment« Part of „European Association for Chemical and Molecular Sciences" and IUPAC
Prof. Ester Heath
Slovenian Research Agency

RESEARCH PROGRAMMES

1. Modelling and environmental impact assessment of processes and energy technologies
Prof. Borut Smodiš
2. Cycling of substances in the environment, mass balances, modelling of environmental processes and risk assessment
Prof. Milena Horvat

R&D GRANTS AND CONTRACTS

1. Electrostatic immobilisation of bacterial cells and effects on their physiology
Prof. Milena Horvat
2. Ligands bearing tzNHCs in Organometallic Chemistry and Homoheneous Catalysis: c-C and C-N Bond Formation in Water
Prof. Ester Heath
3. Closing material flows by wastewater treatment with green technologies
Prof. Ester Heath
4. Mortality of lowland oak forests - consequence of lowering underground water or climate change?
Dr. Polona Vreča
5. Redefinition and revival of copper-free Sonogashira cross-coupling reaction
Prof. Ester Heath
6. Non-traditional isotopes as identifiers of authigenic carbonates
Prof. Sonja Lojen
7. Nanomedicines with antibiotics and probiotics for local treatment of periodontal disease
Asst. Prof. Aleš Lapanje
8. Clinico-pharmacological approach to optimize the therapeutic bleomycin concentration in patients undergoing electrochemotherapy
Asst. Prof. Tina Kosjek
9. Ionom of crop plants for safe and quality food production
Prof. Nives Ogrinc
10. Novel innovative solutions for diaper rash treatment using diapers with probiotic bacteria
Asst. Prof. Aleš Lapanje
11. Methodology approaches in genome-based deversity and ecological plasticity study of truffles from their natural distribution
Prof. Nives Ogrinc
12. Lactic acid fermentation for enrichment of microalgae biomass with new nutrients
Prof. Nives Ogrinc
13. Bisphenol A alternatives: transfer from food contact material, fate and human exposure
Prof. Ester Heath
14. Spatial distribution of water isotopes in precipitation in Europe with special fokus on the transect from the Adriatic Coast to the Pannonian Plain
Dr. Polona Vreča
15. Stable isotopes in the study of the impact of increasing CO2 levels on C and Hg cycling in coastal waters
Prof. Nives Ogrinc
16. Neuropsychological dysfunctions caused by low level exposure to selected environmental pollutants in susceptible population – NEURODYS
Prof. Milena Horvat
17. BE MERMAiD - Bioavailable mercury methylation in the Adriatic sea
Prof. Milena Horvat
18. STRAP - Sources, TRansport and fate of persistent Air Pollutants in the environment of Slovenia
Prof. Nives Ogrinc
19. Influence of geotechnical fills from recycled materials on groundwater
Prof. Radmila Milačič

20. EcoFAR: Food security and climate change mitigation by means of ecological farming development - conservation tillage, bioeffectors and sustainable weed management
    Prof. Nives Ogrinc
21. Record of environmental change and human impact in Holocene sediments, Gulf in Trieste
    Prof. Sonja Lojen
22. Photocatalytic water treatment - development of immobilized catalysts and compact reactor systems
    Prof. Ester Heath
23. Improved treatment and monitoring of Water Framework Directive priority pollutants
    Prof. Ester Heath
24. Evaluation of the range of plasma parameters suitable for nanostructuring of polymers on industrial scale
    Dr. Davor Kontić
25. Illict drugs, alcohol and tobacco: wastewater based epidemiology, treatment efficiency and vulnerability assessment of water catchments
    Asst. Prof. Tina Kosjek
26. Innovative configuration of inductively coupled gaseous plasma sources for up-scaling to industrial-size reactors
    Dr. Davor Kontić
27. Exposure of children and adolescents to selected chemicals through their habitat environment
    Prof. Milena Horvat
    Slovenian Research Agency
28. An attempt to interpret the results of biomonitoring in conjuction with data on environmental pollution, with an emphasis on air pollution and an assessment of the potential effects of these pollutants on the health of the population
    Prof. Milena Horvat
    Slovenian Research Agency
29. Identification of Pb sources in the upper Mežiška valley based on Pb isotope composition
    Asst. Prof. Tea Zuliani
    Slovenian Research Agency
30. Food for future - F4F
    Prof. Nives Ogrinc
    Ministry of Education, Science and Sport
31. Innovative ECO plasma seed treatment (for sowing and for human and animal diet/ nutrition
    Prof. Nives Ogrinc
    Ministry of Education, Science and Sport
32. RI-SI EPOS: Development of research Infrastructure for the international competitiveness of Slovenian RRI space-RI-SI
    Prof. Janja Vaupotič
    Ministry of Education, Science and Sport
33. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
    Prof. Nives Ogrinc
    Ministry of Economic Development and Technology
34. Pursuing authenticity and valorization of Mediterranean traditional products
    Prof. Nives Ogrinc
    Ministry of Education, Science and Sport
35. Implementation of the Human Biomonitoring program 2018-2022
    Prof. Milena Horvat
    Ministry of Health
36. Exposure of children and adolescents to selected chemicals through their habitat environment
    Prof. Milena Horvat
    Ministry of Health
37. An attempt to interpret the results of biomonitoring in conjuction with data on environmental pollution, with an emphasis on air pollution and an assessment of the potential effects of these pollutants on the health of the population
    Prof. Milena Horvat
    Ministry of Health
38. Services; Determination of the Isotopic Composition of Carbon in Sugar Samples
    Prof. Nives Ogrinc
39. Different Analyses
    Prof. Sonja Lojen
40. Small Services
    Dr. Tjaša Kanduč
41. Small Services in the Years from 2007 to 2019
    Prof. Milena Horvat
42. Analyses of Metals, TBT and DBT in Sediments, Mussels and Fish
    Prof. Janez Ščančar
43. Mechanisms of Red Tides and Hypoxia as Ecological Marine Disasters and Technologies for its Early Warning and Emergency Security along the Sea of „Belt and Road“ Countries
    Prof. Nives Ogrinc
    Institute Of Hydrobiology
44. HGKYR - Measurements of Elements in Environmental and Biological Samples from Kyrgyzstan
    Prof. Milena Horvat
    Médecins Sans Frontieres, Representation of
45. Identifikacija virov Pb v zgornji Mežiški dolini
    Asst. Prof. Tea Zuliani
    Inovine d. o. o.
46. Identifikacija virov Pb v zgornji Mežiški dolini
    Asst. Prof. Tea Zuliani
    Inovine d. o. o.

NEW CONTRACTS

1. Measurements of gaseous effluents, specific analysis of H-3 and C-14 in year 2019
   Asst. Prof. Marko Štrok
   Nuklearna Elektrarna Krško d. o. o.
2. Annex No. 16 to the contract on performing activities and fulfillment of obligations of holder of national standard in the field of ionising radiation
   Dr. Polona Vreča
   Ministry of Education, Science and Sport
3. Off-site radiological monitoring of the HE Brežice 2019
   Asst. Prof. Marko Štrok
   Nuklearna Elektrarna Krško d. o. o.
4. Environmental radioactivity monitoring of living environment in Republic Slovenia in 2019
   Asst. Prof. Marko Štrok
   Ministry of the Environment and Spatial Planning
5. Determination of elemental composition and stable isotope composition of light elements in selected fruits and vegetables in 2019
   Prof. Nives Ogrinc
   Ministry of Agriculture, Forestry and Food
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52. Nives Ogrinc, Samo Tamše, Saša Zavadlav, Janja Vrzel, Lixin Jin, "Evaluation of geochemical processes and nitrate pollution sources at the Ljubljansko polje aquifer (Slovenia): a stable isotope perspective", *Science of the total environment*, 2019, **646**, 1588-1600.
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54. Hermann Rügner *et al.* (17 authors), "Particle bound pollutants in rivers: results from suspended sediment sampling in Globaqua River Basins", *Science of the total environment*, 2019, **647**, 645-652.
55. Radmila Milačič, Tea Zuliani, Janja Vidmar, Matic Bergant, Eleni Kalogianni, Evangelia Smeti, Nikolaos Skoulikidis, Janez Ščančar, "Potentially toxic elements in water, sediments and fish of the Evrotas River under variable water discharges", *Science of the total environment*, 2019, **648**, 1087-1096.
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66. Marko Černe, Igor Palčić, Igor Pasković, Nikola Major, Marija Romić, Vilim Filipović, Marina Diana Igrc, Aleksander Perčin, Smiljana Goreta Ban, Benjamin Zorko, Branko Vodenik, Denis Glavič-Cindro, Radmila Milačič, David John Heath, Dean Ban, "The effect of stabilization on the utilization of municipal sewage sludge as a soil amendment", *Waste management*, 2019, **94**, 27-38.
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Review Article

1. Lucia Fábelová *et al.* (12 authors), "Environmental ototoxicants, a potential new class of chemical stressors", *Environmental research: multidisciplinary journal of environmental sciences, ecology, and public health*, 2019, **171**, 378-394.
2. Aleš Lapanje, Tomaž Rijavec, "Mikrobiota ustne votline", *Farmacevtski vestnik*, 2019, **70**, 2, 150-161.
3. Luigi Rizzo *et al.* (15 authors), "Consolidated vs new advanced treatment methods for the removal of contaminants of emerging concern from urban wastewater", *Science of the total environment*, 2019, **655**, 986-1008.

Short Article

1. Tine Bizjak, Branko Kontić, "Auditing in addition to compliance monitoring: a way to improve public health", *International Journal of Public Health*, 2019, **64**, 9, 1259-1260.

Published Conference Contribution (invited lecture)

1. Janja Snoj Tratnik, Ingrid Falnoga, Darja Mazej, David Kocman, Vesna Fajon, Marta Jagodic, Anja Stajnko, Ajda Trdin, Zdenka Šlejkovec, Zvonka Jeran, Joško Osredkar, Alenka Sešek-Briški, Mladen Krsnik, Alfred Bogomir Kobal, Lijana Kononenko, Milena Horvat, "Humani biomonitoring v Sloveniji: izbrani elementi pri odraslih moških in doječih ženskah", In: *Varno ravnajmo z nevarnimi snovmi za zdrava delovna mesta in okolje: 10. Posvet Kemijska varnost za vse, Laško, 23. in 24. oktober 2018*, zbornik razširjenih povzetkov, Nacionalni inštitut za javno zdravje, 2019, 38.

Published Conference Contribution

1. Nives Ogrinc, Barbara Koroušić-Seljak, Karl Presser, Marga Ocke, Iulia Iatco, Claudia Zoani, "Promoting metrology in food and nutrition: A position paper on METROFOOD-RI and its e-component", In: *2019 IEEE International Conference on Big Data, Dec. 9 - Dec. 12, 2019, Los Angeles, CA, USA: proceedings*, IEEE, 2019, 5161-5164.
2. David Škufca, Franja Prosenc, Ana Kovačič, Maryline Pflieger, Tina Kosjek, Tjaša Griessler Bulc, Ester Heath, "Removal of bisphenols in laboratory-scale algal bioreactors", In: *2nd IWA Conference on Algal Technologies for Wastewater Treatment and Resource Recovery [and] 2th IWA Specialist Group Conference in Wastewater Pond Technology, IWAlgae2019, July 1 & 2, 2019, Valladolid, Spain*, Book of abstracts, 2019, 532-533.

3. Anja Stajnko, Zdenka Šlejkovec, Darja Mazej, Milena Horvat, Ingrid Falnoga, "AS3MT polymorphisms, arsenic metabolites and pregnancy", In: *Environmental arsenic in a changing world: the 7th International Congress and Exhibition on Arsenic in the Environment (AS 2018), July 1-6, 2018, Beijing, P.R. China*, Arsenic in the environment Proceedings, CRC Press, 2019, 326-327.
4. Maria-Angela Menezes, Radojko Jaćimović, Ilza Dalmázio, Ana Clara Pelaes, "Performance evaluation of the laboratory for neutron activation analysis, CDTN, in the application of the k_0 method to geological samples by the IAEA-WEPAL proficiency testing", In: *Nuclear new horizons: fuels our future: IX. Nuclear Atlantic Conference 2019 (INAC 2019), XXI. Meeting on Nuclear Reactor Physics and Thermal Hydraulics, ENFIR 2019, XIV. Meeting on Nuclear Applications (XIV. ENAN) and the VI. Meeting on Nuclear Industry (VI, ENIN), October 21-25 2019, Santos, Brazil*, Brazilian Nuclear Energy Association, 2019, 292-297.
5. Anže Jazbec, Vladimir Radulović, Sebastjan Rupnik, Andraž Verdir, Marko Rosman, Borut Smodiš, Luka Snoj, "Jožef Stefan Institute TRIGA Research Reactor activities in the period from September 2018 - August 2019", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 506.
6. Polona Vreča, Tjaša Kanduč, Zdenka Šlejkovec, Stojan Žigon, Klara Nagode, Nika Močnik, Branka Bračič-Železnik, Brigita Jamnik, Marjetka Žitnik, "Karakterizacija vodnih virov za javno oskrbo s pitno vodo v Ljubljani s pomočjo različnih geokemičnih analiz", In: *Raziskave s področja geodezije in geofizike 2018: 24. srečanje Slovenskega združenja za geodezijo in geofiziko, Ljubljana, 31. januar 2019*, zbornik del, Fakulteta za gradbeništvo in geodezijo, 2019, 111-119.
7. Dominik Božič, Stefan Marković, Janez Ščančar, Adrijan Košir, Marko Štrok, "Possible application of laser ablation coupled to QQQ-ICP-MS in geochronology", In: *24th Meeting of Slovenian Geologists, Ljubljana, november 2019*, Treatises, reports, (Geološki zbornik, **25)**, 2019, 15-20.
8. Nada Verdel, Albin Pintar, Aleš Lapanje, "White water treatment optimization of wood-free paper industries by means of bioaugmentation-assisted bioremediation", In: *Smart solutions for water resilience: 8th IWA-ASPIRE Conference and Exhibition, 31 October - 2 November 2019, Hong Kong, Hong Kong*, conference e-proceeding, 2019, 474-476.
9. Dániel Erdélyi *et al.* (17 authors), "The potential of precipitation stable isotopes for traceability and authenticity of agricultural products: A reference dataset for Slovenia and Hungary", In: *Synergy & technical development: VI. Synergy International Conference, Engineering, Agriculture and Green Industry Innovations, 4-6 November 2019, Gödölló, Hungary*, abstracts, 2019, 72-73.
10. Marija Sollner Dolenc, Robert Roškar, Ester Heath, Tatjana Tišler, "Bisfenoli v vodnem okolju in njihovi učinki na organizme", In: *Varno ravnajmo z nevarnimi snovmi za zdrava delovna mesta in okolje: 10. Posvet Kemijska varnost za vse, Laško, 23. in 24. oktober 2018*, zbornik razširjenih povzetkov, Nacionalni inštitut za javno zdravje, 2019, 24-26.
11. Johanna A. Robinson, David Kocman, Cirila Jeraj, "A dusty road to Gardaland: turning school's science projects fun", In: *WeBIOPATR2017 Particulate Matter: research and management: the 6th WeBIOPATR Workshop & Conference Belgrade, Serbia 6.-8.9.2017*, Proceedings, Institute of Nuclear Science, 2019, 80-85.

Independent Component Part or a Chapter in a Monograph

1. Branko Kontić, Maruša Matko, "Adapting to climate change in the energy system in Slovenia", In: *Adapting the energy sector to climate change*, IAEA, 2019, 103-116.
2. Maria-Angela Menezes, Radojko Jaćimović, "An overview of the establishment of methodology to analyse up to 5g-sample by k_0-instrumental neutron activation analysis, at CDTN, Brazil", In: *Advances technologies and applications of neutron activation analysis*, IntechOpen, 2019, 89-109.
3. Syed Baker, Sreedharamurthy Satish, M. N. Nagendra Prasad, Raghuraj S. Chouhan, "Nano-agromaterials", In: *Industrial Applications of Nanomaterials*, (Micro & Nano Technologies Series), Elsevier, 2019, 341-363.
4. Simon Wilson *et al.* (39 authors), "Global emissions of mercury to the atmosphere from anthropogenic sources", In: *Technical background report to the global mercury assessment 2018*, Tromsø: AMAP/UNEP, 2019, 3.
5. Nicola Pirrone *et al.* (24 authors), "Levels of mercury in air", In: *Technical background report to the global mercury assessment 2018*, Tromsø: AMAP/UNEP, 2019, 4.
6. David Kocman, Simon Wilson, Katarina Yaramenka, Karin Kindbom, Helen M. Amos, Peter Outridge, Rasmus Parsmo, Kevin Telmer, Milena Horvat, "Releases of mercury to the aquatic environment from anthropogenic sources", In: *Technical background report to the global mercury assessment 2018*, Tromsø: AMAP/UNEP, 2019, 6.
7. Nilandri Basu, Milena Horvat, David C. Evers, Irina Zastenskaya, Pal Weihe, Joanna Tempowski, "Mercury levels and trends in human populations worldwide", In: *Technical background report to the global mercury assessment 2018*, Tromsø: AMAP/UNEP, 2019, 9.

Professional Monograph

1. Milena Horvat, Jože Kotnik, *Technical information report on mercury monitoring in soil*, 2019.

Theses and Mentoring

1. Nada Pavšer, *Environmental crime training needs analysis of Slovene police forces:* doctoral dissertation, Nova Gorica, 2019 (mentor Branko Kontić).
2. Janja Snoj Tratnik, *Exposure to mercury in Slovenia and neurodevelopment of children:* doctoral dissertation, Ljubljana, 2019 (mentor Milena Horvat; co-mentor David Neubauer).
3. Anja Stajnko, *Human genes, gene polymorphisms, and their expression in relation to trace elements:* doctoral dissertation, Ljubljana, 2019 (mentor Ingrid Falnoga; co-mentor Milena Horvat).

DEPARTMENT OF AUTOMATION, BIOCYBERNETICS AND ROBOTICS E-1

Head:
Prof. Aleš Ude

The research strategy within our department supports a variety of multi- and interdisciplinary research projects. Specifically, our research combines the fields of robotics (including intelligent control, humanoids, cognitive robotics, robot learning and robot vision), industrial robotics and automation, factories of the future, biomechanics, biocybernetics, ergonomics and environmental physiology. The common theme of our research endeavours to date has been optimising "the behaviour of man and machine", accounting for interactions with the environment. By combining engineering and life sciences, we have been able to make significant contributions to the development of humanoid robotic systems, a planetary habitat simulation facility, new methods for robot learning based on imitation and deep-learning methodologies, manikins enabling the evaluation of protective garments for industry and recreation, kinematic models of the human body that serve as a basis for the design of anthropomorphic systems, and a medical treatment for frostbite.

The department maintains the programme group "Automation, robotics and biocybernetics" in the field of Production Technologies (leader prof. dr. Igor B. Mekjavic). Members of the department participate in numerous EU projects in the area of robotics and artificial intelligence, factories of the future, health, and space technologies. In 2019 we coordinated two Horizon 2020 projects: ReconCell and SPEXOR. We are also active in transferring our research results to various applications through direct collaboration with industry.

By maintaining a critical mass of researchers in the area of robotics, automation and life sciences within one department, we have managed to foster exciting multidisciplinary projects.

Research in the area of humanoid and cognitive robotics and robot learning is primarily conducted within the Humanoid and Cognitive Robotics Lab (leader dr. Bojan Nemec), which operates within the department. The aim of this laboratory is to create robots that are capable of acquiring new knowledge through learning and to collaborate with people in their natural environments. Another laboratory that operates within the department is the Laboratory for Neuromechanics and Biorobotics, which is led by prof. dr. Jan Babič. The main focus of this lab is to integrate the results of biomechaniscs, neurophysiology and robotics to study human motor control and develop new robot systems that can effectively assist people in their daily activities.

During the past year, our research focused on the development of reconfigurable robotic systems for factories of the future, the automation of production processes in manufacturing, new robot-learning methodologies, primarily based on kinesthetic teaching and deep learning, human-robot collaboration, the development of new control methods for robotic assistive devices such as exoskeletons, studies of human physiology in extreme environments, the evaluation of protective equipment, as well as the development of biomedical methods.

Figure 1: Humanoid robot TALOS writing a digit

Robotics

In 2019 we successfully completed the Horizon 2020 project **ReconCell** (A **Recon**figurable robot work**Cell** for fast set-up of automated assembly processes in SMEs, http://www.reconcell.eu/), which we have been coordinating. The main results of the project are new reconfiguration technologies that enable the fast setup of robotic workcells in industrial production. The realized workcell is based on a number of advanced technologies, including 1. robot programming by kinesthetic teaching, 2. passive hardware components to enable automatic reconfiguration, 3. optimization methods to compute optimal layouts of production cells, 4. integrated pose-estimation and grasp-generation methods, 5. methods for the fast setup of visual quality control, and 6. robot simulation to support reconfiguration. Our software implementation is based on ROS (Robot Operating System), which provides tools for effective communication between all workcell elements.

In the H2020 project ReconCell we developed new, passively reconfigurable hardware and the accompanying methodologies for the automatic, robot-supported reconfiguration of robotic workcells.

Another H2020 project completed in 2019 is **AUTOWARE** (http://www.autoware-eu.org). This project focused on the development of new **digital**

Figure 2: Passive linear rail developed in the ReconCell project to support workcell reconfiguration

technologies including reliable wireless networking, fog computing, reconfigurable and collaborative robotics, modular production lines, augmented virtuality, machine learning, cognitive autonomous systems, etc. The architecture we developed enables the flexible, distributed implementation of tasks and covers all levels, from planning and logistical ones, through manufacturing preparation and execution down to shop-floor equipment control. We implemented these functionalities as computer services of the AUTOWARE platform. In this way, they can be re-utilized by various robot-system developers and system integrators when solving their specific production tasks.

The third project successfully completed in 2019 was **SPEXOR** (http://www.spexor.eu). In this project we developed new control strategies and their implementation for active spinal exoskeletons. The control concept is based on a probabilistic model to determine the state of the system. Based on the probabilistic state classifiers, the high-level controller determines the appropriate assistive torque profile to be provided to the user. The assistive torque profile is the resulting combination of a passive and active torque source. The high-level controller also maximizes the amount of the passive torque source, while minimizing the amount of active torque provided in order to fulfil the required assistive torque profile. The control concept was first evaluated on a SPEXOR active hydraulic spinal exoskeleton and later implemented on the SPEXOR active electromechanical spinal exoskeleton.

We continued working on a Horizon 2020 project in the area of collaborative robotics **CoLLaboratE** (Enabling genuine human-robot collaboration for performing assembly tasks in a co-production cell, https://collaborate-project.eu). CoLLaboratE aims to revolutionize the way industrial robots learn to cooperate with human workers for performing new manufacturing tasks. In 2019, we developed a new approach for kinesthetic learning based on the reuse of existing skills. It provides a simple, natural and gradual trajectory editing capabilities to teach and adapt complex robotic skills. A new system for the collaborative learning of assembly by disassembling an already assembled product was developed. Based on the disassembly, the robot autonomously builds the reverse assembly policy.

In a collaborative project we developed a new method for learning assembly policies based on kinesthetic teaching and autonomous learning of the corresponding disassembly policies.

Figure 3: Robot programming by human demonstration of shoe finishing operation

In the scope of the Horizon 2020 project AnDy (https://andy-project.eu) we evaluated a shoulder exoskeleton for overhead work in the car-production company Revoz, where a redesign of the workplace to accommodate worker's needs is not possible. We tested a passive exoskeleton that was developed by Ottobock within the AnDy project. We tested a group of workers working in the real production line and compared a number of physiological and kinematical parameters before the employment of the exoskeleton, at the first week and after 20 days of its use. We measured heart rate, the kinematics of the arm movements and evaluated the results of two questionnaires. The results of our study demonstrated the benefits of using the exoskeleton by using less energy to perform the required task but emphasized the need of unobtrusive design of the wearable robots so that the users do not feel uncomfortable using them.

In the area of robotics, two new H2020 projects were launched in 2019: TRINITY (Digital Technologies, Advanced Robotics and increased Cyber-security for Agile Production in Future European Manufacturing Ecosystems) and QU4LITY (Digital Reality in Zero Defect Manufacturing).

In the scope of the Director's fund project **Cobotat** (Laboratory for Advancing Collaborative Robot Behaviours in Physical Human-Robot Interaction Scenarios, http://cobotat.ijs.si/), we continued working on setting up new laboratory facilities. The main work was oriented towards the integration of Panda collaborative robots from Franka Emika. Linked to the developments in the CoBoTaT laboratory, we acquired and started working on an ARRS project from an ERC complementary scheme: PhRoCiety - Collaborative Capabilities in Physical Human-Robot Interaction Scenarios. The goal of the PhRoCiety project is to advance cognitive understanding and the current control about cooperative and robust multi-contact physical interaction between multiple agents, where agents are humans or robots. To this end, we performed a laboratory study where 8 pairs (16 participants) were performing a cooperative task. Preliminary findings indicate that the task performance in the collaboration is equal to the task performance of the best from that pair.

The main objective of the **TRINITY** project (https://trinityrobotics.eu/) is to create a network of multidisciplinary and synergistic local digital innovation hubs (DIHs) composed of research centres, companies, and university groups that cover a wide range of topics that can contribute to agile production: advanced robotics as the driving force and digital tools, data privacy and cyber security technologies to support the introduction of advanced robotic

systems in the production processes. In this project we focus on the development of new demonstrators of advanced robotic technologies to support their transfer into industrial applications.

In **QU4LITY** (https://qu4lity-project.eu) we aim to demonstrate, in a realistic, measurable and replicable way, an open, certifiable and highly standardised, SME-friendly and transformative, shared data-driven ZDM product and service model for Factory 4.0 through 14 pilot lines. In this context, we work together with the Slovenian company Kolektor to develop one of the demonstrators.

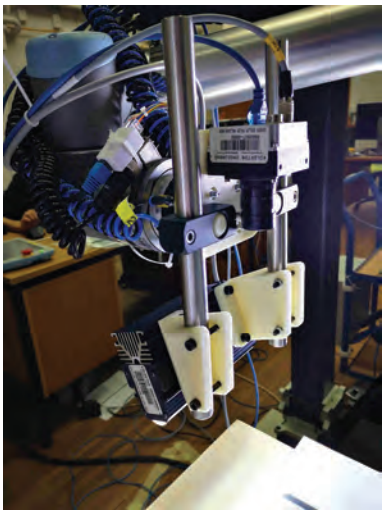

Figure 4: Visual surface inspection for quality control with a line-scan camera

Automation and industrial robotics

A vital mission of our department is the transfer of our research results to industrial applications. In the past years, our department has been working towards the implementation of the **Smart specialization strategy S4**. An important part of this work is the implementation of the GOSTOP Program (Buildings, Tools and Systems for the Factories of the Future), which is **coordinated** by our department (dr. Igor Kovač). The Program GOSTOP is at the moment the largest research/development program in Slovenia in the field of Factories of the Future. Its aim is to accelerate the design and development of the Factories of the future concept in Slovenia and to provide solutions to the current needs of Slovenian industry, where some companies have already started to introduce this concept into their production facilities. We identified four areas in which decisive breakthroughs can be achieved in Slovenia in the near future: control technologies, tooling, robotics, and photonics. In the area of robotics, we collaborate with companies such as Kolektor, Domel, Yaskawa, and Podkrižnik.

Our main topics in the GOSTOP program are: 1. **intelligent sensors and actuators**, 2. **adaptive robotic workcells for visual quality control**, and 3. **platform of the virtual factory**. Research in the area of intelligent sensors and actuators is directed towards the verification of intelligent drive systems with torque-control algorithms and a built-in monitoring system and the possibility for the predictive maintenance of each drive system and conducted experiments. In the second research theme, that is, adaptive robotic workcell, we performed experiments of new flexible grasping and manipulation processes, machine vision, and machine-learning solutions. A specific objective of this activity is to develop an adaptive robotic workcell for the visual quality control of industrial parts. The main goal of the development of the virtual factory platform is to design and produce an intelligent, competitive, and sustainable information system in a smart factory that includes the elements of robotics. This combines research in the field of intelligent control algorithms, discrete event simulation in real time, and Plug & Produce interfaces with the principles of IoT.

We are coordinating a programme in the scope of Slovenia's smart specialization strategy S4 GOSTOP: Building blocks, tools and systems for factories of the future.

As part of the Strategic Research and Innovation Partnership of the Factory of the Future (SRIP FoF), we **chaired** the SRIP FoF Board of Directors, **coordinated** the SRIP FoF Horizontal network (Key Enabling Technology) "Robotics", thus providing support for the introduction of advanced robotic technologies into factories of the future being developed by Slovenian industry. The key achievements of SRIP FoF in 2019 was the emergence of new R&D teams in manufacturing companies active in this field, who fruitfully cooperate with the research departments at the universities and institutes and transfer achievements into industrial practice.

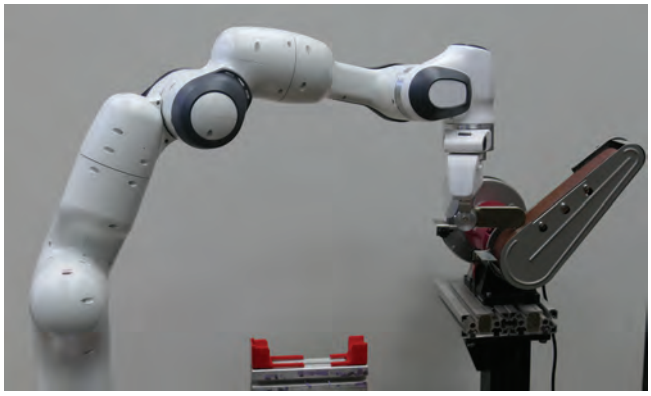

Figure 5: Compliant robotic arm Panda performing grinding operation

Also, in the scope of the Slovenian Smart Specialization Strategy, we have joined the **ROBKONCEL** project, whose main goal is to develop a comprehensive system for quality control in the production processes and inspection of finished products. As part of the project, we will develop demonstration cells for the final inspection of ovens in Gorenje and for forgings in Unior. The cells will be equipped with collaborative robots, cameras and additional sensors depending on the product and the control procedures performed in the cell. Using combinations of different modern artificial intelligence methods, the system will check the functionality of the products, looking for potential defects on the products. The robotic arm will perform the manipulation of the parts in the cell and the mechanical testing of objects necessary for the detection of malfunctioning of the product. The project aims to develop new approaches that will improve the learning of robotic tasks and enable higher flexibility, which is important when products and/or inspection processes in the production cell change.

Environmental physiology and ergonomics

The Environmental Physiology and Ergonomics group conducts research into the influence of extreme environmental factors on humans as well as on the development and evaluation of technologies and strategies to maintain safety and unhindered performance in such environments.

In the PlanHab facility we conduct studies investigating the effect of inactivity and unloading of the weight-bearing limbs on physiological function in the PlanHab facility at the Nordic Centre Planica (Rateče). This facility was established with the support of the European Space Agency and the European Commission (Framework 7 Programme; PlanHab project). The effects of inactivity/unloading, as experienced by astronauts during microgravity exposure in space, is simulated with the bed-rest experimental model. Prolonged exposure to microgravity results in musculoskeletal atrophy and deconditioning of the cardiovascular system, which constitute a threat to the health and well-being of astronauts. Given that various space agencies are aiming to pursue a long-term space mission in the near future, novel issues connected to space habitation are highly important. In particular, for technical reasons, the environment within future Lunar and Mars habitats will be hypobaric and hypoxic. The continued aim of our research programme in space life sciences is to assess the effect of hypoxia on the processes of adaptation to microgravity, which have been observed in a normoxic environment.

Figure 6: Data analysis in the biocybernetics lab

In collaboration with Kimberly-Clark, we investigate novel strategies in the development of optimal personal protective garment including face masks.

We are collaborating in a new research programme initiated by the European Space Agency, investigating the benefit of implementing daily exposures to artificial gravity during deep-space missions (i.e., to Mars), or in Lunar and Planetary (Mars) habitats. Together with the ESA delegation at the Ministry of Economic Development and Technology (Government of Slovenia), and the Nordic Centre Planica, we are conducting a feasibility study regarding the installation of a short-arm human centrifuge (SAHC) in the Olympic sport centre Planica. SAHCs would be used to provide daily exposure of astronauts to artificial gravity. This new facility would allow us, in the future, to investigate the efficacy of different artificial gravity strategies in mitigating the known adaptations of physiological systems to weightlessness. Negotiations are also in progress to have the PlanHab facility approved by the European Space Agency as a ground-based research facility.

We have completed a research programme investigating the concept of physiological cross-tolerance. Specifically, we investigated how prolonged exposure to one environmental stressor will influence the same responses to another stressor. With athletes now combining hypoxic training with heat acclimation, we have also investigated the effect of two concurrent stressors on physical performance. In particular, we compared exercise performance in normal temperature normoxic environments, with performance in hypoxic and hot environments, after combined altitude (4000 m) and heat (35 °C) acclimation.

Figure 7: Manikin for testing protective garments

A major hindrance to future long-term missions on the International Space Station, and to the exploration of the Moon and Mars are the unexplained ophthalmic changes observed in a subset of astronauts, termed Spaceflight Associated Neuro-ocular Syndrome (SANS). A programme of research was initiated to assess the effect of 6° head down tilt (establishing the cephalad displacement noted in astronauts in microgravity) during rest and exercise (simulating exercise performed by astronauts to mitigate the sarcopenia induced by unloading of the weightbearing limbs) in normocapnic and hypercapnic (simulating conditions on the International Space Station) conditions on intracranial pressure and the eye. Preliminary results obtained on astronaut-aged individuals suggests that during hypercapnic static exercise in the 6°head down tilt position increases the IOP significantly above the ocular hypertension threshold.

Climate change is the biggest global health threat of the 21st century with enormous consequences for humanity. Rising temperatures have been observed in Europe, considerably more than in other areas, and have become a growing challenge for our community. Problems are already experienced by millions of Europeans during summer months, particularly in occupational settings. In addition to the well-known effects of heat exposure, a number of studies have confirmed a 2% reduction in productivity for each degree centigrade above 25°C. Given this productivity loss, reducing the impacts of rising workplace temperatures will produce two strategic benefits for the EU: i) it will ensure the well-being of the EU's workforce, and ii) it will improve the EU's competitiveness and secure its future economy. In the framework of the Horizon 2020 project "Heat Shield" (www.heat-shield.eu) we are collaborating with the industrial partner odelo d.o.o. to mitigate the

detrimental effects of heat waves on the workforce in their manufacturing plant. Within the framework of this project, we investigated the effects of different concepts of cooling vests that could be used in industry to ensure the health and well-being of workers during heat waves, and to maintain their productivity. The studies conducted this year assessed the efficacy of cooling vests using the Jožef Stefan Institute Thermal Manikin.

With our industrial partner Kimberly-Clark, we continue to investigate novel strategies in the development of optimal personal protective garments. The focus of our work this year was face masks. The study investigated the physical characteristics of various face-mask concepts, focussing on the perception of thermal comfort, temperature and moisture. Using our breathing simulator and head manikin we also investigated the work of breathing at different minute ventilations, simulating a work shift in industry.

With the Institute of Naval Medicine and industrial partner W. L. Gore and Associates (USA & Germany) we evaluated several glove concepts using our sweating thermal hand manikin. The impetus for this work was several reports of freezing cold injury to the hands of soldiers participating in training exercises in Northern Europe. We continue to work with partner W.L. Gore & Associates in developing a new generation of hand manikins.

Within the framework of the ReMOS (Microclaimate regulation in protective clothing systems) project supported by the Ministry of Defence (Republic of Slovenia) we have established a consortium of companies (Prevent-Deloza d.o.o., Celje; Litia d.o.o., Litija; Tekstina d.o.o., Ajdovščina; Intersocks d.o.o., Kočevje; Versarum d.o.o., Mirna) to develop new smart textile/clothing concepts that could be implemented in existing protective clothing systems, which would provide improved protection of the Slovenian Armed Forces' personnel during exposure to extreme temperature and humidity environments.

Some outstanding publications in the past year

1. U. Ciuha, K. Tobita, A. Mcdonnell, and I. B. Mekjavić (2019) The effect of thermal transience on the perception of thermal comfort. Physiology & behavior, vol. 210, pp. 112623-1-112623-8.
2. T. Petrič, L. Peternel, J. Morimoto, and J. Babič (2019) Assistive arm-exoskeleton control based on human muscular manipulability. Frontiers in neurorobotics, vol. 13, pp. 30-1-30-1.
3. M. Tamošiunaite, M. J. Aein, J. M. Braun, T. Kulvicius, I. Markievicz, J. Kapociute-Dzikiene, R. Valteryte, A. Haidu, D. Chrysostomou, B. Ridge, T. Krilavicius, D. Vitkute-Adzgauskiene, M. Beetz, O. Madsen, A. Ude, N. Krüger, and F. Wörgötter (2019) Cut & recombine: Reuse of robot action components based on simple language instructions, The International Journal of Robotics Research, vol. 38, no. 10-11, pp. 1179-1207.
4. M. Azad, J. Babič, and M. Mistry (2019) Effects of the weighting matrix on dynamic manipulability of robots. Autonomous robots, vol. 43, no. 7, pp. 1867-1879.
5. A. C. McDonnell, O. Eiken, P. Frings-Meuthen, J. Rittweger, and I. B. Mekjavić (2019) The LunHab project: Muscle and bone alterations in male participants following a 10 day lunar habitat simulation, Experimental physiology.

Awards and Appointments

1. Tadej Petrič, Leon Žlajpah: Best Student Paper Award, Kaiserslautern, Germany, RAAD 2019, KUKA LWR Robot Cartesian Stiffness Control Based on Kinematic Redundancy
2. Tadej Petrič and Leon Žlajpah: Second Best Application Paper Award, Kaiserslautern, Germany, RAAD 2019, On-line Adaption of Virtual Guides Through Physical Interaction.
3. Tadej Petrič and Leon Žlajpah: Best Paper Award, Srebrno Jezero, Serbia, IcETRAN 2019, End-effector cartesian stiffness optimization: sequential quadratic programming approach

Organization of conferences, congresses and meetings

1. Intermediate review of GOSTOP programme, Jožef Stefan Institute and Faculty of Mechanical Engineering, Ljubljana, 28. - 29. 3. 2019.
2. Final review meeting of Horizon 2020 project ReconCell, Luxembourg, 24. – 25. 4. 2019.
3. General assembly of GOSTOP programme, Raddison Blu Plaza, Ljubljana, 10. 5. 2019.
4. General assembly of Horizon 2020 project QU4LITY, ožef Stefan Institute, Ljubljana, 13. – 14. 6. 2019.
5. Section "Robotics" at 22nd International Multiconference Information Society, Jožef Stefan Institute, Ljubljana, 11. 10. 2019.
6. Final meeting of H2020 project ReconCell, Luxemburg, 24.-25.4.2019
7. GOSTOP workshop, Ljubljana, 10.5.2019
8. GA meeting of H2020 project Qu4lity, Ljubljana, 13.-14.6.2019

Patent granted

1. Anton Umek, Boris Jerman, Mitja Gliha, Anton Kos, Iztok Špan
   Link member for connection of a gripping assembly to a hydraulic crane arm with integrated dynamic weighing assembly
   SI25473 (A), Urad RS za intelektualno lastnino, 31. 01. 2019.

INTERNATIONAL PROJECTS

1. Manufacture of Finger and Two Hands of the Manikin, and National Instruments Measuring Software
   Prof. Igor Mekjavić
   W. L. Gore & Associates Gmbh
2. Palmer Study
   Prof. Igor Mekjavić
   W. L. Gore & Associates Gmbh
3. Tests of Rt and Re of 5 Insole-Shoe Combinations
   Prof. Igor Mekjavić
   Geox S.p.a.
4. COST CA16116 - 20786; Wearable Robots for Augmentation, Assistance or Substitution of Human Motor Functions
   Prof. Jan Babič
   Cost Office
5. ESA - Individual Variation in Human Response to prolonged Bed Rest in Slovenia Bed Rest Programme
   Prof. Igor Mekjavić
   Esa/estec.
6. COST CA16116 - 20786; Review Panel Meetings
   Prof. Jan Babič
   Cost Association Aisbl
7. H2020 - HEAT-SHIELD; Integrated Inter-Sector Framework to increase the Thermal Resilience of European Workers in the Context of Global Warming
   Prof. Igor Mekjavić
   European Commission
8. H2020 - AUTOWARE; Wireless Autonomous, Reliable and Resilient Production Operation Architecture for Cognitive Manufacturing
   Prof. Aleš Ude
   European Commission
9. H2020 - An.Dy; Advancing Anticipatory Behaviors in Dyadic Human-Robot Collaboration
   Prof. Jan Babič
   European Commission
10. H2020 - CoLLaboratE: Co-production CeLL performing Human-RobotCollaborative AssEmbly
    Asst. Prof. Bojan Nemec
    European Commission
11. H2020 - TRINITY; Digital Technologies, Advanced Robotics and increased Cyber-Security for Agile Production in Future European Manufacturing
    Prof. Aleš Ude
    European Commission
12. H2020 - QU4LITY; Digital Reality in Zero Defect Manufacturing
    Prof. Aleš Ude
    European Commission
13. H2020 - ReconCell; A Reconfigurable Robot Workcell for Fast Set-up of Automated Assembly Processes in SME-s
    Prof. Aleš Ude
    European Commission
14. H2020 - SPEXOR; Spinal Exoskeletal Robot for Low Back Pain Prevention and Vocational Reintegration
    Prof. Jan Babič
    European Commission
15. Obstacle Avoidance as Neuroeconomical Decision Making
    Prof. Jan Babič
    Slovenian Research Agency
16. Stabilization of Centre of Mass to improve The Design of Light-Touch Tactile Feedback Robotic Canes
    Prof. Jan Babič
    Slovenian Research Agency
17. Establishing New Tools to facilitate New Generation Humanoid Robot Capabilities for Collaborative Human-Robot Object Manipulation
    Asst. Prof. Tadej Petrič
    Slovenian Research Agency
18. Learning Cross-Task Generalization for Model-Predictive Control: Application to Dynamic Humanoid Behaviors
    Asst. Prof. Andrej Gams
    Slovenian Research Agency

RESEARCH PROGRAMME

1. Avtomation, robotics and biocybernetics
   Prof. Igor Mekjavić

R&D GRANTS AND CONTRACTS

1. X-ADAPT: Cross-adaptation between heat and hypoxia - novel strategy for performance and work-ability enhancement in various environments
   Asst. Prof. Tadej Debevec
2. The effect of hypercapnic exercise on intracranial pressure and the eye
   Prof. Igor Mekjavić
3. Towards Cooperative Robot Behaviors in Physical Human-Robot Interaction Scenarios
   Asst. Prof. Tadej Petrič
4. Building blocks, tools and systems for the Factories of the Future – GOSTOP
   Asst. Prof. Igor Kovač
   Ministry of Education, Science and Sport
5. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
   Asst. Prof. Igor Kovač
   Ministry of Economic Development and Technology
6. Stimulators and Parts
   Prof. Aleš Ude
7. Customer Service – Abroad
   Prof. Igor Mekjavić
8. TRUExo - Implementation of an Exoskeleton for the Torso in the Rehabilitation Process of Patients with Multiple Myeloma
   Prof. Jan Babič
   Istituto Nazionale Tumori, Centro Di Riferimento
9. Customer Service - Abroad; Street Science
   Dr. Adam Mc Donnell
10. Mitten Testing
    Prof. Igor Mekjavić
    Ministry of Defence

NEW CONTRACTS

1. Development of reconfigurable robotic cell for final product inspection
   Asst. Prof. Leon Žlajpah
   Gorenje Gospodinjski Aparati, d.d.
2. Microclimate regulation in the clothing systems
   Prof. Igor Mekjavić
   Ministry of Defence

VISITORS FROM ABROAD

1. Vladimir Šimović, Zagreb University, Croatia, 11. 1.–13. 1., 18. 1.–20. 1., 25. 1. 2019
2. Marc Priggemeyer, Rheinisch-Westfaelische Technische Hochschule Aachen, Germany, 28.1.2019
3. Djordje Djordjević, Ivamax Belgrade, Serbia, 28.1.2019
4. Mihajlo Despotović, Ivamax Belgrade, Serbia, 28.1.2019
5. Kosta Jovanović, University of Belgrade, Serbia, 28.1.2019
6. Zaviša Gordić, University of Belgrade, Serbia, 28.1.2019
7. Nikola Knezević, University of Belgrade, Serbia, 28.1.2019
8. Edwin van Asseldonk, University of Twente, Netherlands, 24. – 25. 1. 2019
9. Thomas Sugar, Arizona State University, United States of America, 19. – 21. 1. 2019
10. Daniel Matejcek, Otto Bock, Germany, 11.2.2019
11. Dominik Simon Reiter, Otto Bock, Germany, 11.2.2019

12. Benjamin Schirmeister, Otto Bock, Germany, 18.2.2019
13. dr. Riika Virkkunen, VVT Technical Research Centre of Finland, Finland, 8. – 13. 3. 2019
14. Erhan Oztop, Ozyegin University, Turkey, 20. – 25. 3. 2019
15. dr. Ivan Godler, Twist Drive Technologies Inc., Japan, 25.3. – 4.4.2019
16. prof. Claus Thybo, Nilfisk, Denmark, 16.5.2019
17. dr. Oscar Lazaro, Innovalia Association, Spain, 16.5.2019
18. prof. dr. Maria Koskolou, University in Athens, Greece, 30.5.-2.6.2019
19. prof. dr. Pietro di Prampero, University of Udine, Italy, 31.5.2019
20. Irina Ivanovska, University of Skopje, North Macedonia, 2. – 23.6.2019
21. prof. Winfried Amoaku, University in Nottingham, United Kingdom, 15. - 16. 5. 2019
22. Michael Hofbaur, Joanneum Research Institute, Austria, 10.7.2019
23. Mathias Brandstötter, Joanneum Research Institute, Austria, 10.7.2019
24. prof. Ludovic Righetti, New York University, United States of America, 7. - 10. 8. 2019
25. Holger Zuidwijk, W.L. Gore, Germany, 8.8.2019
26. dr. Christoph Siebenmann, EURAC – Institute for Alpine Environment, Italy, 17. - 30. 6. 2019
27. Branko Lukić, University of Belgrade, Serbia, 22.9. - 30. 11. 2019
28. Kosta Jovanović, University of Belgrade, Serbia, 7.10.2019
29. Nikola Knežević, University of Belgrade, Serbia, 7.10.2019
30. Savo Icagić, University of Belgrade, Serbia, 7.10.2019
31. Marko Skakun, University of Belgrade, Serbia, 7.10.2019
32. Michael Hofbaur, Joanneum Research Institute, Austria, 11.10.2019
33. Mathias Brandstötter, Joanneum Research Institute, Austria, 11.10.2019
34. Lucas Wohlhart, Joanneum Research Institute, Austria, 11.10.2019
35. Thomas Haspl, Joanneum Research Institute, Austria, 11.10.2019
36. Mattias Weyrer, Joanneum Research Institute, Austria, 11.10.2019
37. dr. Elizabeth Simpson, University in Nottingham, United Kingdom, 14.-15.11.2019
38. Prof. dr. Ian MacDonald, University in Nottingham, United Kingdom, 14.-15.11.2019
39. dr. Eric Rullman, Karolinska Institutet, Sweden, 14.-15.11.2019
40. doc. dr. Rodrigo Gonzalo, Karolinska Institutet, Sweden, 14.-15.11.2019
41. Wael Bachta, Sorbon University, France, 7.-12.11.2019
42. Angelina Bellicha, Sorbon University, France, 28.11.-3.12.2019
43. prof. dr. Norbert Krüger, University of Southern Denmark, Denmark, 9. -11.12.2019

STAFF

Researchers

1. Prof. Jan Babič
2. Prof. Tadej Debevec*
3. Asst. Prof. Andrej Gams
4. Prof. Polonca Jaki Mekjavić
5. Asst. Prof. Igor Kovač
6. Prof. Igor Mekjavić
7. Asst. Prof. Bojan Nemec
8. Asst. Prof. Tadej Petrič
9. Dr. Anton Ružić
10. Dr. Blaž Stres*
11. *Kunihito Tobita, left 01.04.19*
12. **Prof. Aleš Ude, Head**
13. Asst. Prof. Leon Žlajpah

Postdoctoral associates

14. Dr. Urša Ciuha
15. *Dr. Miha Deniša, on leave 01.08.19*
16. Dr. Adam Mc Donnell
17. Dr. Barry Martin Ridge
18. *Panagiotis Sergouniotis, B. Sc., left 01.02.19*

Postgraduates

19. *Martin Bem, B. Sc., left 01.05.19*
20. *Robert Bevec*, B. Sc., left 01.07.19*
21. Jernej Čamernik, B. Sc.
22. Miha Dežman, B. Sc.
23. Timotej Gašpar, B. Sc.
24. Marko Jamšek, B. Sc.
25. Jaka Jereb, B. Sc.
26. Tjaša Kunavar, B. Sc.
27. Zvezdan Lončarević, B. Sc.
28. Matija Mavsar, B. Sc.
29. Tinkara Mlinar, B. Sc.
30. Rok Pahič, B. Sc.
31. Joshua Toby Royal, B. Sc.
32. Mihael Simonič, B. Sc.

Technical officers

33. *Rosana Černelič, B. Sc., left 15.04.19*
34. Tanja Dragojević, B. Sc.
35. Mitja Gliha, B. Sc.
36. Daša Gorjan, B. Sc.
37. Gregor Klinc, B. Sc.
38. Rebeka Kropivšek Leskovar, B. Sc.
39. Matevž Majcen Hrovat, B. Sc.
40. Primož Radanovič, B. Sc.
41. Simon Reberšek, B. Sc.
42. Andrej Trošt, B. Sc.
43. Tamara Valenčič, B. Sc.
44. Bogomir Vrhovec, B. Sc.
45. *Anja Zrnec, B. Sc., left 01.12.19*

Technical and administrative staff

46. Željka Kukec, B. Sc.
47. Petra Movh, B. Sc.
48. *Dr. Alexandros Sotiridis, left 01.11.19*
49. Danijela Zeljković Anžiček, B. Sc.

Note:
* part-time JSI member

BIBLIOGRAPHY

Original Article

1. Michail E. Keramidas, Roger Kölegård, Igor B. Mekjavić, Ola Eiken, "Interactions of mild hypothermia and hypoxia on finger vasoreactivity to local cold stress", *American journal of physiology. regulatory, integrative and comparative physiology*, 2019, **317**, 3, r418-r431.
2. Morteza Azad, Jan Babič, Michael Mistry, "Effects of the weighting matrix on dynamic manipulability of robots", *Autonomous robots*, 2019, **43**, 7, 1867-1879.
3. Alexandros Sotiridis, Panagiotis Miliotis, Urška Ciuha, Maria D. Koskolou, Igor B. Mekjavić, "No ergogenic effects of a 10-day combined heat and hypoxic acclimation on aerobic performance in normoxic thermoneutral or hot conditions", *European journal of applied physiology*, 2019, **119**, 11/12, 2513-2527.
4. Adam McDonnell, Ola Eiken, Petra Frings-Meuthen, Joern Rittweger, Igor B. Mekjavić, "The LunHab project: muscle and bone alterations in male participants following a 10 day lunar habitat simulation", *Experimental physiology*, 2019, **104**, 8, 1250-1261.
5. Tadej Petrič, Luka Peternel, Jun Morimoto, Jan Babič, "Assistive arm-exoskeleton control based on human muscular manipulability", *Frontiers in neurorobotics*, 2019, **13**, 30.
6. Anton Ušaj, Igor B. Mekjavić, Jernej Kapus, Adam McDonnell, Polona Jaki Mekjavić, Tadej Debevec, "Muscle oxygenation during hypoxic exercise in children and adults", *Frontiers in physiology*, 2019, **10**, 1385.
7. Tadej Debevec, Vincent Pialoux, Grégoire P. Millet, Agnès Martin, Minca Mramor, Damjan Osredkar, "Exercise overrides blunted hypoxic ventilatory response in prematurely born men", *Frontiers in physiology*, 2019, **10**, 437.
8. Miha Dežman, Andrej Gams, "Optimization and analysis of the modified PLVL-variable stiffness actuator", *International journal of mechanics and control*, **20**, 21, 23-33,
9. Minija Tamošiunaitè *et al.* (17 authors), "Cut & recombine: reuse of robot action components based on simple language instructions", *The international journal of robotics research*, 2019, **38**, 10/11, 1179-1207.
10. Daša Gorjan, Jan Babič, Nejc Šarabon, Zrinka Potočanac, "Small, movement dependent perturbations substantially alter postural control strategy in healthy young adults", *Journal of biomechanics*, 2019, **91**, 1-6.
11. Nejc Šarabon, Žiga Kozinc, Jan Babič, Goran Marković, "Effect of rowing ergometer compliance on biomechanical and physiological indicators during simulated 2,000-metre race", *Journal of Sports Science and Medicine: free electronic journal*, 2019, **18**, 2, 264-270.

12. Urška Ciuha, Kunihito Tobita, Adam McDonnell, Igor B. Mekjavić, "The effect of thermal transience on the perception of thermal comfort", *Physiology & behavior*, 2019, **210**, 112623.
13. Luka Peternel, Jan Babič, "Target of initial sub-movement in multi-component arm-reaching strategy", *Scientific reports*, 2019, **9**, 20101.
14. Jan Babič, Tadej Petrič, Katja Mombaur, Idsart Kingma, Jonas Bornmann, José González-Vargas, Saskla Baltrusch, Nejc Šarabon, Han Houdijk, "SPEXOR: design and development of passive spinal exoskeletal robot for low back pain prevention and vocational reintegration", *SN Applied Sciences*, 2019, **1**, 262.
15. Urška Ciuha, Tjaša Pogačar, Lučka Kajfež-Bogataj, Mitja Gliha, Lars Nybo, Andreas D. Flouris, Igor B. Mekjavić, "Interaction between indoor occupational heat stress and environmental temperature elevations during heat waves", *Weather, climate, and society*, 2019, **11**, 4, 755-762.
16. Jurij Gorjanc, Shawnda A. Morrison, Adam McDonnell, Polona Jaki Mekjavić, Rok Blagus, Igor B. Mekjavić, "Ski-Everest (8848 m) expedition: digit skin temperature responses to cold immersion may reflect susceptibility to cold Injury", *Wilderness & environmental medicine*, 2019, **30**, 2, 141-149.

Review Article

1. Olivier White, Jan Babič, Carlos Trenado, Leif Johannsen, Nandu Goswami, "The promise of stochastic resonance in falls prevention", *Frontiers in physiology*, 2019, **9**, 1865.

Short Article

1. Kosta Jovanović, Tadej Petrič, Toshiaki Tsuji, Calogero Maria Oddo, "Editorial: Human-like advances in robotics: motion, actuation, sensing, cognition and control", *Frontiers in neurorobotics*, 2019, **13**, 85.

Published Conference Contribution

1. Pauline Maurice *et al.* (11 avtorjev), "Evaluation of PAEXO, a novel passive exoskeleton for overhead work", In: *44ème Congres Societe de Biomecanique, 28-30 October 2019, Poitiers, France*, (Computer methods in biomechanics and biomedical engineering, **22**, suppl. 1), 2019, s448-s450.
2. Leon Žlajpah, Tadej Petrič, "Bounded self-motion of functional redundant robots", In: *Advances in service and industrial robotics: proceedings of the 28th International Conference on Robotics in Alpe-Adria-Danube Region (RAAD 2019), June 19-21 2019, Kaiserslautern, Germany*, (Advances in intelligent systems and computing, **980)**, Springer, 2019, 285-292.
3. Barry Ridge, Rok Pahič, Aleš Ude, Jun Morimoto, "Convolutional encoder-decoder networks for robust image-to-motion prediction", In: *Advances in service and industrial robotics: proceedings of the 28th International Conference on Robotics in Alpe-Adria-Danube Region (RAAD 2019), June 19-21 2019, Kaiserslautern, Germany*, (Advances in intelligent systems and computing, **980)**, Springer, 2019, 514-523.
4. Timotej Gašpar, Miha Deniša, Aleš Ude, "Knowledge acquisition through human demonstration for industrial robotic assembly", In: *Advances in service and industrial robotics: proceedings of the 28th International Conference on Robotics in Alpe-Adria-Danube Region (RAAD 2019), June 19-21 2019, Kaiserslautern, Germany*, (Advances in intelligent systems and computing, **980)**, Springer, 2019, 346-353.
5. Branko Lukić, Tadej Petrič, Leon Žlajpah, Kosta Jovanović, "KUKA LWR robot Cartesian stiffness control based on kinematic redundancy", In: *Advances in service and industrial robotics: proceedings of the 28th International Conference on Robotics in Alpe-Adria-Danube Region (RAAD 2019), June 19-21 2019, Kaiserslautern, Germany*, (Advances in intelligent systems and computing, **980)**, Springer, 2019, 310-318.
6. Tadej Petrič, Leon Žlajpah, "On-line adaption of virtual guides through physical interaction", In: *Advances in service and industrial robotics: proceedings of the 28th International Conference on Robotics in Alpe-Adria-Danube Region (RAAD 2019), June 19-21 2019, Kaiserslautern, Germany*, (Advances in intelligent systems and computing, **980)**, Springer, 2019, 293-300.
7. Zvezdan Lončarević, Rok Pahič, Mihael Simonič, Aleš Ude, Andrej Gams, "Reduction of trajectory encoding data using a deep auroencoder network: robotic throwing", In: *Advances in service and industrial robotics: proceedings of the 28th International Conference on Robotics in Alpe-Adria-Danube Region (RAAD 2019), June 19-21 2019, Kaiserslautern, Germany*, (Advances in intelligent systems and computing, **980)**, Springer, 2019, 86-94.
8. Jožica Piškur, Sebastjan Šlajpah, Bojan Nemec, Matjaž Mihelj, Marko Munih, "Use of bimanual haptic teleoperation system for optimized task performance with adaptive haptic tunnel", In: *Advances in service and industrial robotics: proceedings of the 28th International Conference on Robotics in Alpe-Adria-Danube Region (RAAD 2019), June 19-21 2019, Kaiserslautern, Germany*, (Advances in intelligent systems and computing, **980)**, Springer, 2019, 329-336.
9. Michael Franke, Gregory Scontras, Mihael Simonič, "Subjectivity-based adjective ordering maximizes communicative success", In: *COGSCI'19, [41st Annual Conference of the Cognitive Science Society], 24-27 July 2019, Montreal, Canada*, Proceedings, Cognitive Science Society, 2019, 344-350.
10. Mihael Simonič, Leon Žlajpah, Aleš Ude, Bojan Nemec, "Autonomous learning of assembly tasks from the corresponding disassembly tasks", In: *HUMANOIDS 2019, IEEE-RAS 19th International Conference on Humanoid Robots, October 15-17, 2019, Toronto, Canada*, IEEE, 2019, 246-252.
11. Miha Dežman, Tamim Asfour, Aleš Ude, Andrej Gams, "Exoskeleton arm pronation/supination assistance mechanism with a guided double rod system", In: *HUMANOIDS 2019, IEEE-RAS 19th International Conference on Humanoid Robots, October 15-17, 2019, Toronto, Canada*, IEEE, 2019, 590-595.
12. Bojan Nemec, Mihael Simonič, Tadej Petrič, Aleš Ude, "Incremental policy refinement by recursive regression and kinesthetic guidance", In: *ICAR 2019, 19th International Conference on Advanced Robotics, Belo Horizonte, Brazil, December 2nd-6th, 2019*, IEEE, 2019, 344-349.
13. Mohamed Elobaid, Yue Hu, Giulio Romualdi, Stefano Dafarra, Jan Babič, Daniele Pucci, "Telexistence and teleoperation for walking humanoid robots", In: *Intelligent systems and applications: proceedings of the 2019 Intelligent Systems Conference (IntelliSys), [September 5-6, 2019, London, UK]*, (Advances in intelligent systems and computing, **1038)**, Springer, 2019, 1106-1121.
14. Barry Ridge, Rok Pahič, Aleš Ude, Jun Morimoto, "Learning to write anywhere with spatial transformer image-to-motion encoder-decoder networks", In: *International Conference on Robotics and Automation (ICRA)-2019, May 20-24, 2019, Montreal, Canada*, IEEE, 2019, 2111-2117.
15. Andrej Gams, Simon Reberšek, Bojan Nemec, Jure Škrabar, Rok Krhlikar, Jure Skvarč, Aleš Ude, "Roboric learning for increased productivity: autonomously improving speed of robotioc visual quality inspection", In: *15th International Conference on Automation Science and Engineering, (CASE), August 22-26, 2019, Vancouver, BC, Canada*, Proceedings, IEEE, 2019, 1275-1281.
16. Zvezdan Lončarević, Rok Pahič, Mihael Simonič, Aleš Ude, Andrej Gams, "Learning of robotic throwing at a target using qualitative learning reward", In: *18th IEEE International Conference on Smart Technologies, EUROCON 2019, 1-4 July, 2019 Novi Sad, Serbia*, Proceedings, Novi Sad University, Faculty of Technical Sciences, 2019.
17. Timotej Gašpar, Miha Deniša, Primož Radanovič, Aleš Ude, "Autonomous adaptation to changes in production demands with a reconfigurable robot workcell", In: *Robotics: proceedings of the 22nd International Multiconference Information Society - IS 2019,11 October, 2019, Ljubljana, Slovenia: volume G*, Institut "Jožef Stefan", 2019, 12-15.
18. Mihael Simonič, Aleš Ude, Bojan Nemec, "Autonomous learning of assembly policy", In: *Robotics: proceedings of the 22nd International Multiconference Information Society - IS 2019,11 October, 2019, Ljubljana, Slovenia: volume G*, Institut "Jožef Stefan", 2019, 7-10.
19. Barry Ridge, Rok Pahič, "Learning robotic handwriting with convolutional image-to-motion encoder-decoder networks", In: *Robotics: proceedings of the 22nd International Multiconference Information Society - IS 2019,11 October, 2019, Ljubljana, Slovenia: volume G*, Institut "Jožef Stefan", 2019, 23-26.
20. Andrej Gams, Simon Reberšek, Aleš Ude, "Visual feedback and learning for optimal velocity of robotic visual quality inspection", In: *Robotics: proceedings of the 22nd International Multiconference Information Society - IS 2019,11 October, 2019, Ljubljana, Slovenia: volume G*, Institut "Jožef Stefan", 2019, 18-21.
21. Marko Jamšek, Jan Babič, "Human trunk stabilization with hip exoskeleton for enhanced postural control", In: *Wearable robotics: challenges and trends: proceedings of the 4th International Symposium on Wearable Robotics, WeRob2018, October 16-20, 2018, Pisa, Italy*, (Biosystems et biorobotics, **22)**, Springer, 2019, 450-454.
22. Mišel Cevzar, Tadej Petrič, Marko Jamšek, Jan Babič, "Real-time control of quasi-active hip exoskeleton based on Gaussian mixture model approach", In: *Wearable robotics: challenges and trends: proceedings of the 4th International Symposium on Wearable Robotics, WeRob2018, October 16-20, 2018, Pisa, Italy*, (Biosystems et biorobotics, **22)**, Springer, 2019, 244-248.

23. Urban Bobek, Elmar Rueckert, Marko Jamšek, Saša Barišić, Jan Babič, "Combining foot placement prediction with obstacle detection to detect tripping", In: *Proceedings of the Twenty-eighth International Electrotechnical and Computer Science Conference ERK 2019, Portorož, Slovenija, 23.-24. september 2019,* Društvo Slovenska sekcija IEEE, 2019, 110-113.
24. Zvezdan Lončarević, Rok Pahič, Gregor Papa, Andrej Gams, "Experimental evaluation of deep-learning applied on pendulum balancing", In: *Proceedings of the Twenty-eighth International Electrotechnical and Computer Science Conference ERK 2019, Portorož, Slovenija, 23.-24. september 2019,* Društvo Slovenska sekcija IEEE, 2019, 219-222.

University, Higher Education or Higher Vocational Education Textbook

1. Matjaž Mihelj, Tadej Bajd, Aleš Ude, Jadran Lenarčič, Aleš Stanovnik, Marko Munih, Jure Rejc, Sebastjan Šlajpah, *Robotics*, 2nd ed., Springer, 2019.

Patent

1. Anton Umek, Boris Jerman, Mitja Gliha, Anton Kos, Iztok Špan, *Link member for connection of a gripping assembly to a hydraulic crane arm with integrated dynamic weighing assembly,* SI25473 (A), Urad RS za intelektualno lastnino, 31. 01. 2019.

Theses and Mentoring

1. Robert Bevec, *Learning of object representations through robotic manipulation:* doctoral dissertation, Ljubljana, 2019 (mentor Aleš Ude).
2. Jurij Gorjanc, *Cold induced vasodilatation as predicting factor for frostbite susceptibility in alpinists:* doctoral dissertation, Ljubljana, 2019 (mentor Matjaž Veselko; co-mentor Igor B. Mekjavić).
3. Alexandros Sotiridis, *Independent and combined effects of heat and hypoxic acclimation on exercise performance in humans:* doctoral dissertation, Ljubljana, 2019 (mentor igor B. Mekjavić; co-mentor Tadej Debevec).

DEPARTMENT OF SYSTEMS AND CONTROL

E-2

The Department of Systems and Control is engaged in the analysis, control and optimization of systems and processes. The activities of the department are focused on the research of new methods and algorithms for automatic control, the development of procedures and tools to support the design of control systems, the development of specific measurement and control modules, and the development and construction of complete systems for the control and supervision of machines, devices and industrial processes.

Head:
Dr. Gregor Dolanc

Basic and applied research in 2019 was devoted to three sub-areas: methodologies for analysis and control systems design; tools and building blocks for implementation; and applied research in the priority problem domains.

The first topic addressed the *modelling and identification of nonlinear and complex dynamical systems*. The research on methods for the dynamical systems' modelling was pursued in the direction of the atmospheric variables modelling with Gaussian-process models. The main focus was on modelling the temperature profile and on investigating relations among the variables of the dynamic model.

We have continued the research and development of model predictive control (MPC) methods based on fast online optimization, with an emphasis on the fast-gradient method. With improved scaling we have achieved better numerical conditioning of the algorithm. This facilitates a more efficient FPGA implementation of the optimization algorithm, which is suitable for the challenging fast multivariable control for the stabilization of the unstable resistive wall modes both for ITER and for dynamically faster medium-sized tokamak experimental devices (Figure 1).

In the field of smart factories our department has started activities for developing a system for automatic stoppage detection within the production process operation. The approach is based on discrete-event modelling, performed directly on representative events from production. For this purpose, a procedure was developed to automatically identify the production workflow from the event log, which arranges production data into a format suitable for the use of standard process data-mining algorithms (Figure 2).

Within the framework of *prognostics and health management*, substantial progress in the field of fuel-cell diagnostics has been made. Evaluating uncertainties in the identified process models is important in a reliable and robust diagnosis. Instead of fully Bayesian approaches, which are computationally demanding, we have elaborated a variational Bayesian approach that is numerically tractable and results in the approximated marginal distributions of the model's parameters. Encouraging initial validations were performed on a problem of solid-oxide fuel cell prognostics of the remaining useful life.

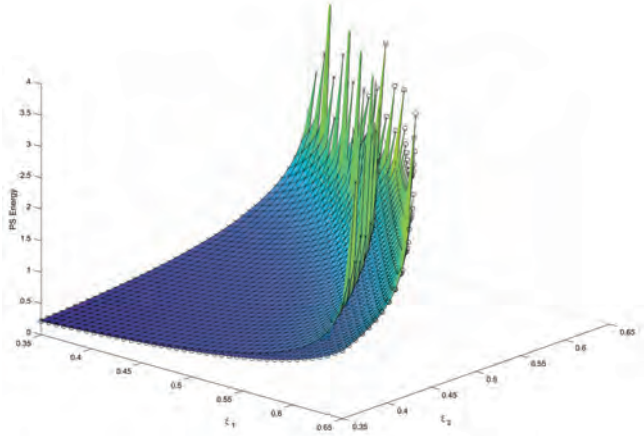

Figure 1: A comparison of the stabilizable regions of the unstable resistive wall modes ξ1 and ξ2. The height for each pair of unstable mode values represents the integral of the power-supply power if the response is stable (x: LQG control; o: MPC control).

In the area **tools and building blocks for** implementation, the majority of activities was carried out within the 3-year programme *Gostop - Building Blocks, tools and systems for factories of the future.* In 2019 work was carried out both within the programme management as well as within the framework of R&D projects, where we participated in a number of R&D areas. In the area of the development of the prototype products for Factories of the Future, we participated in the development and laboratory testing of prototype modules for 100% final product quality control for various types of EC motors. In the same area, we participated in the development of (i) a prototype module for remote process supervision and (ii) a module for data transfer from the industrial devices using 4th-generation mobile networks. In the development of a platform for the synthesis of production data-based models, used for production process supervision, adaptive control and decision support, we developed a concept and a module for stoppage detection on a production line, based on the identification of a data-based discrete event model. In the activities for the development of the platform for adaptive correction of the final product quality in the production of EC motors, we performed a detailed analysis of the production data, aimed at identifying the model of the vibration level in the final quality control, based on the production parameters of the preceding operations, such as rotor balancing, rotor magnetisation, rotor fixing, and axial clearance displacement. In the area of the development of an intelligent tool-management system, we

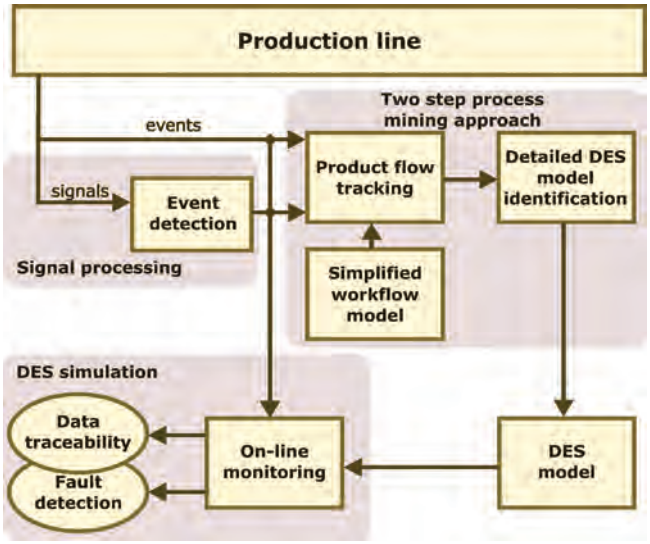

Figure 2: Procedure for discrete-event modelling of a production workflow

developed new algorithms for tool management and defined the data and data structures required for testing the developed tool-management algorithms. In the development of an experimental concept for an intelligent drive, we participated in the development and implementation of a system for measuring vibrations at different points of the motor-gear drive assembly, as well as in the realization of an IoT-based SW module for the drive supervision and control.

Applied research in the priority problem domains was the third sub-area of our interest. For the Slovenian Research Agency project *Method for the forecasting of local radiological pollution of atmosphere using Gaussian process models* most of the activities were comprised of evaluating the different Gaussian-process-based modelling methods for the identification of models useful for forecasting atmospheric variables. Dynamic models for the temperature profile, relative humidity, wind direction and speed were identified. Moreover, research into the dependence relations among the variables and their links to algebraic hyperstructures were pursued.

In 2019 we started implementing a new ARRS application project *Optimization based control of P2G converter connected to hydro power plant*. In the project we are focusing on the optimal control problem of a special case of a P2G Power-to-Gas System linked to the hydro power plant. In periods of excess power in the electric system, dispatchable power sources including hydro power plants can be required to decrease or even stop their production. If the hydro power plant decreases or stops the power generation and if the water accumulation is full, then the incoming water flow has to bypass the turbine generators. This leads to an energy loss (spilled turbinable energy) and a consequent financial loss. An upgrade of the hydro power plant using a P2G system can convert a part of the excess hydro energy into hydrogen and in this way prevents or reduces the energy and financial losses.

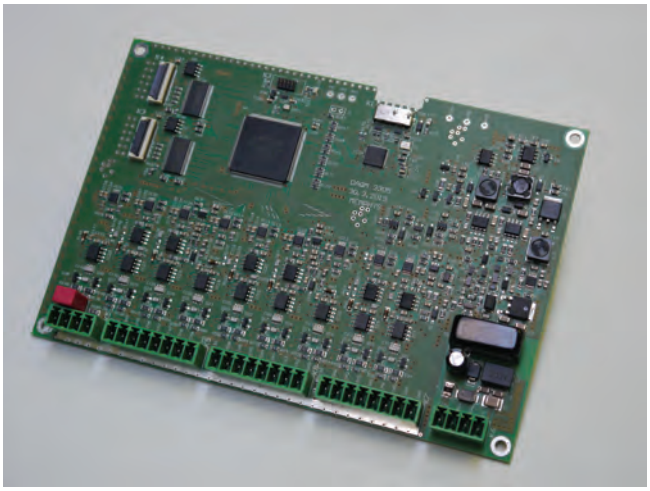

Figure 3: Newly developed electronic module for membrane-based purification of hydrogen system

Following the initiative of the Republic of Slovenia for the establishment and operation of Strategic Innovative Partnerships within the framework of the Slovenian Smart Specialisation Strategy S4, the *Strategic Innovative Partnership Factories of the Future - SRIP ToP* is also operating. Our department has a very active role in *SRIP ToP* in the management of the area *Control Technologies* and in the implementation of its Multi-Annual Action Plan. In 2019 we carried out all the envisaged activities of the Action Plan's second phase and began to prepare an action plan for the next phase.

International R&D projects

The scope of the international project H2020 Memphys - *MEMbrane based Purification of HYdrogen System* is the development of an electro-chemical system for hydrogen compression and cleaning using membranes, similar to the ones used in PEM fuel cells. The task of the Department of Systems and Control is the design of the hardware and the software for the control and diagnostic system. In the past year we developed special electronic modules for diagnostics (excitation of the system by perturbing the electric current and rapid sampling of the responses of the voltage signal of particular cells) see Figure 3.

Another H2020 project INSIGHT has been successfully completed in 2019. Our group contributed a novel approach to the evaluation of a SOFC's impedance based on efficient pseudo-random binary signal probing and using a complex wavelet transform. For the first time an exact evaluation of the uncertainty of the impedance model parameters using the Markov chain Monte Carlo (MCMC) method was performed. The approach has been implemented on a dedicated HW platform developed within the project and tested on a commercial SOFC system.

In collaboration with *Technical University Graz* we have been developing and validating a methodology for on-line monitoring and fault diagnosis in solid-oxide electrolysis cells (SOEC). SOECs are a very promising technology enabler for storing (volatile) electricity. An upgrade of the monitoring system has been made and the first experimental campaigns have been performed.

Within a collaboration with *CEA, Grenoble, France* the focus in 2019 was on the development of a reduced-complexity two-dimensional (2-D) microstructural model of Ni agglomeration that is developed by applying the power-law coarsening theory. This degradation is one of the most critical issues, since it results in reducing the density of the triple-phase boundaries (TPBs) with time and increases the polarization resistance of the SOFC. A preliminary validation based on static and dynamic data has been performed (Figure 4).

IAPUNIT is an international project partly financed by the *Slovenian Ministry of Defence* in association with the *European Defence Agency* (EDA) and started in 2018. The project is from the field of hydrogen technologies and the main goal is to supply military vehicles with electric energy generated by fuel cells powered by military diesel fuel with a high sulphur content. The Department of Systems and Control and the National Institute of Chemistry Slovenia are developing a fuel processor (reformer) that converts military diesel into high-temperature fuel-cell-grade hydrogen. The benefit of this kind of power supply is cleaner exhaust and in particular low noise and a low thermal footprint, which is important for military use.

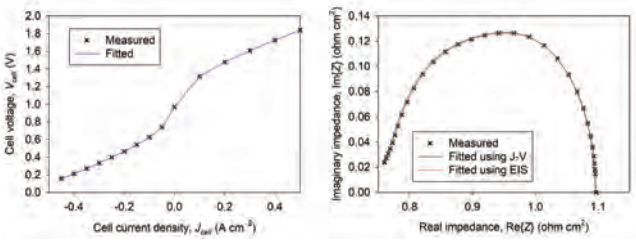

Figure 4: Dynamic model validation on static characteristic (left) and impedance curve (right)

In 2019 we started a project INEVITABLE - *Optimization and performance improving in metal industry by digital technologies*, which has received funding from the European Union's Horizon 2020 research and innovation programme. The 3-year project is estimated at €6 million and is coordinated by our department. The project will develop tools and platforms for optimizing and improving processes in the steel industry using modern digital technologies. Some of the most important companies and R&D institutes from the EU in the field of the steel industry are participating in the project.

Applied work

For Domel Company d.o.o., two diagnostic systems for 100% final control of electric bicycle drives were in the final stages of development (Figure 5). The electric bicycle drive is produced in two stages at different locations. The first phase consists of semi-finished products (half of the drive with integrated electronics, stator winding and rotor unit), then during the second phase the gears and bearings are installed, and the whole is closed with the other half of the housing. When testing semi-finished products, the electrical parameters and vibrations of the rotor are checked, and for the end-product test, the drive is exposed to a series of electrical, functional and safety tests, covering the entire potential operating range. The electrical and mechanical parameters, as well as the vibrations of the gear train and motor assembly, are checked. The results of the diagnostic tests, together with the serial numbers of the key drive components, are recorded in a database and enable further analytics.

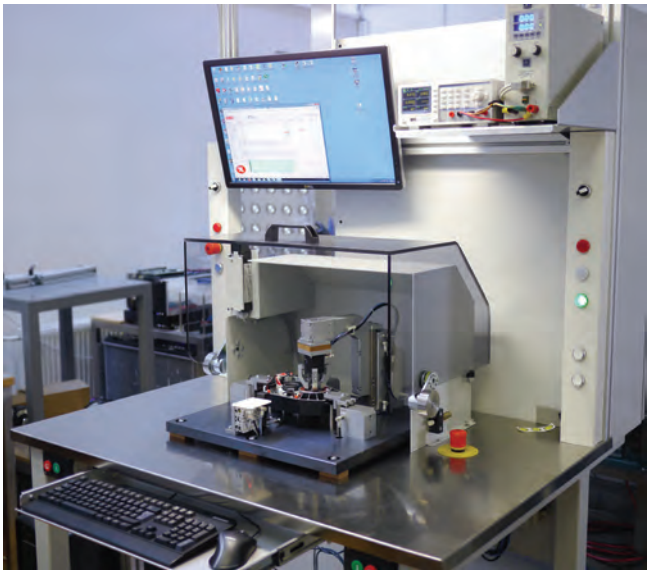

Figure 5: Diagnostic system for end-of-line control of electromotor for bicycle electric drive

Research in the field of biological wastewater treatment was devoted to the design of a hybrid theoretical and data-driven Gaussian process model that improves model prediction accuracy. The models were also used in two application studies. In the study for the Kranj wastewater-treatment plant, the model was first tuned to full-scale data and then used to analyse and propose measures that reduce the sludge bulking. In KET4CP Micro Grant performed for an SME producer of wastewater devices, the model was applied for the design and testing the tank volume when upgrading a small plant to an MBBR process.

In 2019 we collaborated with GOSTOL d.o.o., for which we prepared a feasibility study for implementing advanced predictive maintenance solutions. Together with GOSTOL we reviewed the current technological situation in the company and identified their mid-term vision. Based on the review, we prepared an overview of appropriate methodological solutions for predictive maintenance and recommendations for further development.

Educational and training activities

Some members of the department are giving lectures and practical courses at different faculties and universities: the Faculty of Electrical Engineering, University of Ljubljana, the Faculty of Logistics, University of Maribor, the University of Nova Gorica and the "Jožef Stefan" International Postgraduate School.

Some outstanding publications in the past year

1. Vrečko, Darko, Nerat, Marko, Dolenc, Boštjan, Vrančić, Damir, Meyer, Fabien, Juričić, Đani. Optimizing the operation of a solid oxide fuel cell power system with a supervisory controller based on the extremum-seeking approach. *Energy conversion and management*, ISSN 0196-8904, vol. 187, pp. 53-62, [COBISS.SI-ID 32205863],
2. Stepančič, Martin, Juričić, Đani, Boškoski, Pavle. Fault detection of fuel cell systems based on statistical assessment of impedance data. *Energy conversion and management*, ISSN 0196-8904, vol. 195, pp. 76-85, [COBISS.SI-ID 32343079]
3. Glavan, Miha, Gradišar, Dejan, Moscariello, Salvatore, Juričić, Đani, Vrančić, Damir. Demand-side improvement of short-term load forecasting using a proactive load management: a supermarket use case. *Energy and buildings*, ISSN 0378-7788, vol. 186, pp. 186-194, [COBISS.SI-ID 32090407]
4. Cristea, Irina Elena, Kocijan, Juš, Novak, Michal. Introduction to dependence relations and their links to algebraic hyperstructures. *Mathematics*, ISSN 2227-7390, 2019, vol. 7, 10, pp. 1-14 [COBISS.SI-ID 5453307]
5. Kocijan, Juš, Perne, Matija, Mlakar, Primož, Grašič, Boštjan, Božnar, Marija. Hybrid model of the near-ground temperature profile. *Stochastic environmental research and risk assessment*, ISSN 1436-3240, 2019, vol. 33, no. 11/12, pp. 2019-2032 [COBISS.SI-ID 32875815]

Some outstanding achievements in the past year

1. Our researchers coordinate the new Horizon 2020 project INEVITABLE - *Optimization and performance improving in metal industry by digital technologies*. Some of the most important companies and R&D institutes from the EU in the field of the steel industry are participating in the project.
2. Our department is a partner in the new Horizon 2020 project RUBY - *Robust and reliable general management tool for performance and durability improvement of fuel cell stationary units.*
3. For the company Domel d.o.o., Železniki we developed and put into operation the second diagnostic system for electric bicycle drives.
4. The *Technology Network Advanced Control Technologies* award for the best master thesis in 2019 was granted to our young researcher Žiga Stržinar for his work entitled *Modelling and fault detection in HVAC systems*.

Patent granted

1. Miha Glavan, Damir Vrančić, Dejan Gradišar, Iztok Humar, Mark Umberger, Satja Lumbar
   System and procedure for managing the electrical power of the cooling system by regulating the product temperature and air temperature
   SI25557 (A), Urad RS za intelektualno lastnino, 31. 05. 2019.

INTERNATIONAL PROJECTS

1. KET4CleanProduction Bor-plastika: Implementation of MBBR Technology
   Dr. Nadja Hvala
   Bor-plastika d. o. o.
2. IAPUNIT - Development of an Innovative Auxiliary Power UNIT for military purposes based on high-temperature PEM fuel cell and reforming technology for military logistic fuels
   Dr. Gregor Dolanc
   The European Defence Agency (eda)
3. H2020 - MEMPHYS; Membrane based Purification of Hydrogen System
   Dr. Gregor Dolanc
   European Commission
4. H2020 - INSIGHT; Implementation in Real SOFC Systems of Monitoring and Diagnostic Tools Using Signal Analysis to Increase their Lifetime
   Prof. Đani Juričić
   European Commission
5. H2020 - INEVITABLE; Optimization and Performance Improving in Metal Industry by Digital Technologies
   Dr. Dejan Gradišar
   European Commission
6. Health Monitoring and Lifetime Prediction of Solid Oxide Fuel and Electrolysis Cells
   Prof. Đani Juričić
   Slovenian Research Agency

RESEARCH PROGRAMME

1. Program systems and control
   Prof. Đani Juričić

R&D GRANTS AND CONTRACTS

1. On-line Degradation Monitoring for Extended Durability of High Temperature Steam Electrolysers
   Prof. Đani Juričić
2. Degradation monitoring and performance optimisation of solid oxide electrolysis cells
   Prof. Đani Juričić
3. STRAP - Sources, TRansport and fate of persistent Air Pollutants in the environment of Slovenia
   Prof. Juš Kocijan
4. State-of-health prognostics of electrochemical energy systems
   Dr. Pavle Boškoski
5. E-maintenance of electro-mechanical drives: prognostics and health management solutions under non-stationary operating conditions
   Prof. Đani Juričić
6. Method for the forecasting of local radiological pollution of atmosphere using Gaussian process models
   Prof. Juš Kocijan
7. Optimization based control of P2G converter connected to hydro power plant
   Dr. Gregor Dolanc

8. Building blocks, tools and systems for the Factories of the Future – GOSTOP
   Dr. Vladimir Jovan
   Ministry of Education, Science and Sport

NEW CONTRACT

1. Optimization based control of P2G converter connected to hydro power plant
   Dr. Gregor Dolanc
   Hidroelektrarne na spodnji Savi, d. o. o.

VISITORS FROM ABROAD

1. Cagla Kuru, Dogus University, Istanbul, Turkey, 1 October 2018 to 31 March 2019
2. Muzaffer Oyan, Dogus University, Istanbul, Turkey, 1 October 2018 to 31 March 2019
3. Asst. Prof.Marko Tanasaković, Singidunum University, Belgrade, Serbia, 21 January to 27 January 2019

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4. Dr. Miha Glavan
5. Dr. Giovanni Godena
6. Dr. Dejan Gradišar
7. Dr. Nadja Hvala
8. Dr. Vladimir Jovan
9. Prof. Đani Juričić
10. Prof. Juš Kocijan
11. Dr. Marko Nerat
12. Dr. Matija Perne
13. Dr. Janko Petrovčič
14. Dr. Boštjan Pregelj
15. Asst. Prof. Damir Vrančić
16. Dr. Darko Vrečko

Postdoctoral associate
17. *Dr. Boštjan Dolenc, left 08.07.19*

Postgraduates
18. Tomaž Kos, B. Sc.
19. Tadej Krivec, B. Sc.
20. Gjorgji Nusev, B. Sc.
21. *Martin Stepančič, B. Sc., left 17.06.19*
22. Žiga Stržinar, B. Sc.
23. Luka Žnidarič, B. Sc.

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24. Stanislav Černe, B. Sc.
25. Primož Fajdiga, B. Sc.
26. David Jure Jovan, B. Sc.

Technical and administrative staff
27. Maja Janežič, B. Sc.
28. Miroslav Štrubelj

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3. Miha Glavan, Dejan Gradišar, Salvatore Moscariello, Đani Juričić, Damir Vrančić, "Demand-side improvement of short-term load forecasting using a proactive load management: a supermarket use case", *Energy and buildings*, 2019, **186**, 186-194.
4. Darko Vrečko, Marko Nerat, Boštjan Dolenc, Damir Vrančić, Fabien Meyer, Đani Juričić, "Optimizing the operation of a solid oxide fuel cell power system with a supervisory controller based on the extremum-seeking approach", *Energy conversion and management*, 2019, **187**, 53-62.
5. Martin Stepančič, Đani Juričić, Pavle Boškoski, "Fault detection of fuel cell systems based on statistical assessment of impedance data", *Energy conversion and management*, 2019, **195**, 76-85.
6. Joshua M. Blackstock, Matt Covington, Matija Perne, Joseph M. Myre, "Monitoring atmospheric, soil, and dissolved CO_2 using a low-cost, arduino monitoring platform (CO2-LAMP): theory, fabrication, and operation ", *Frontiers in earth science*, 2019, **7**, 313.
7. Jovan Stefanovski, Đani Juričić, "Input estimation over frequency region in presence of disturbances", *IEEE transactions on automatic control*, 2019, **64**, 12, 5074-5079.
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11. Juš Kocijan, Matija Perne, Primož Mlakar, Boštjan Grašič, Marija Božnar, "Hybrid model of the near-ground temperature profile", *Stochastic environmental research and risk assessment*, 2019, **33**, 11/12, 2019-2032.
12. Tadej Krivec, Dejan Gradišar, Miha Glavan, Gašper Mušič, "Obdelava kompleksnih dogodkov pri spremljanju proizvodnega procesa", *Ventil: revija za fluidno tehniko in avtomatizacijo*, 2019, **25**, 1, 46-53.
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Published Conference Contribution (invited lecture)

1. Boštjan Dolenc, Pavle Boškoski, "Prognostics and health management of solid oxide fuel cell systems: challenges, accomplishments and trends", In: *International Scientific Conference on Information, Communication and Energy Systems and Technologies*, Proceedings of papers: 1, Faculty of Technical Sciences, St. Kliment Ohridski University; Faculty of Electronic Enginering, University of Niš, 2019, 2-9.

Published Conference Contribution

1. Matija Perne, Martin Stepančič, Boštjan Grašič, "Handling big datasets in Gaussian processes for statistical wind vector prediction", In: *5th IFAC Conference on Intelligent Control and Automation Sciences, ICONS 2019, Belfast, United Kingdom, 21-23 August 2019*, (IFAC papersOnline, **52**, 11), 2019, 110-115.
2. Mikuláš Huba, Paulo Moura Oliveira, Damir Vrančić, Pavol Bistak, "ADRC as an exercise for modeling and control design in the state-space", In: *6th International Conference on Control, Decision and Information Technologies, CoDIt 2019, Paris, France April 23-26, 2019*, Proceedings, IEEE, 2019, 464-469.
3. Alenka Trpin, Biljana Mileva Boshkoska, Pavle Boškoski, "Poincaré metric in algorithms for data mining tools", In: *Beyond databases,*

architectures and structures: paving the road to smart data processing and analysis: 15th International Conference, BDAS 2019, Ustroń, Poland, May 28-31, 2019, (Communications in computer and information science, **1018**), Springer, 2019, 195-203.
4. Đani Juričić, Gjorgji Nusev, Boštjan Dolenc, Pavle Boškoski, "Baysian estimation of the solid oxide fuel cell model", In: *International Scientific Conference on Information, Communication and Energy Systems and Technologies*, Proceedings of papers: 1, Faculty of Technical Sciences, St. Kliment Ohridski University; Faculty of Electronic Enginering, University of Niš, 2019, 265-268.
5. Gjorgji Nusev, Gregor Dolanc, Đani Juričić, Pavle Boškoski, "Detection of membrane drying at electrochemical hydrogen compressors", In: *International Scientific Conference on Information, Communication and Energy Systems and Technologies*, Proceedings of papers: 1, Faculty of Technical Sciences, St. Kliment Ohridski University; Faculty of Electronic Enginering, University of Niš, 2019, 99-102.
6. Marija Božnar, Primož Mlakar, Boštjan Grašič, Borut Breznik, Juš Kocijan, "Avtomatizacija procesov za sprotno ocenjevanje vpliva nuklearne elektrarne na okolico", In: *Raziskave s področja geodezije in geofizike 2018, 24. srečanje Slovenskega združenja za geodezijo in geofiziko, Ljubljana, 31. januar 2019*, zbornik del, Fakulteta za gradbeništvo in geodezijo, 2019, 41-50.
7. Boštjan Pregelj, Andrej Debenjak, Gregor Dolanc, Janko Petrovčič, Boris Benedičič, "Diagnostic system for end-of-line quality control of Pedalec electric bike drives", In: *Zbornik enajste konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2019, Maribor, Slovenija*, Društvo avtomatikov Slovenije, 2019, 102-107.
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10. Tadej Krivec, Dejan Gradišar, Miha Glavan, Gašper Mušič, "Fault detection in production plant using complex event processing", In: *Zbornik enajste konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2019, Maribor, Slovenija*, Društvo avtomatikov Slovenije, 2019, 34-39.

Patent

1. Miha Glavan, Damir Vrančić, Dejan Gradišar, Iztok Humar, Mark Umberger, Satja Lumbar, *System and procedure for managing the electrical power of the cooling system by regulating the product temperature and air temperature,* SI25557 (A), Urad RS za intelektualno lastnino, 31. 05. 2019.

ARTIFICIAL INTELLIGENCE LABORATORY

E-3

Head:
Prof. Dunja Mladenić

The Artificial Intelligence Laboratory (http://ailab.ijs.si/) is concerned mainly with the research and development of information technologies, with an emphasis on artificial intelligence. Our main areas of research are: data analysis with an emphasis on text, web and cross-modal data, scalable real-time data analysis, machine learning, analysis and modelling of large networks, visualization of complex data, semantic technologies, language technologies, reasoning methods and knowledge management. The Artificial Intelligence Laboratory has employees and students with an international background and expertise in different areas of artificial intelligence. In addition to publishing their research results in international publications and presenting their work at international events, our researchers have also developed numerous software tools for multimodal data analysis. These tools include: Text-Garden, a suite of text-mining tools; OntoGen (http://ontogen.ijs.si/), a tool for ontology learning; Document-Atlas (http://docatlas.ijs.si/), a tool for complex visualization; Atlas of Slovenian Science (http://scienceatlas.ijs.si/), a web portal for analyzing the scientific community; Enrycher (http://enrycher.ijs.si/), a system for the semantic enrichment of textual data; SearchPoint (http://searchpoint.ijs.si/), a portal for visual and contextualized web browsing; OntoPlus, a methodology for semi-automatic ontology extension; Contextify (http://contextify.net/), a tool for contextualized e-mail and contact management; Qminer (http://qminer.ijs.si/), a data-analytics platform for processing large-scale, real-time streams containing structured and unstructured data; NewsFeed (http://newsfeed.ijs.si/), a clean, continuous, real-time aggregated stream of semantically enriched news articles from RSS-enabled sites across the world; EventRegistry (http://eventregistry.org/), a system for identifying world events in news media; Wikifier (http://wikifier.org), a system for document annotation with links to relevant Wikipedia concepts; StreamStory (http://streamstory.ijs.si), an exploratory data-stream analysis tool offering an alternative type of visualization by representing the multivariate data stream using a Markovian model; Videolectures Explorer (http://explore.videolectures.net/), a tool enabling users to search through the videolectures and find similarities between them; EDSA dashboard (http://jobs.videolectures.net/), a tool aggregating demand data (job postings around Europe) and supply data (training materials) in data science; nextPin (http://traffic.ijs.si/NextPin/?user=demo), a system for the analysis of time-varying data of geographic locations; Connection tool (http://connection.ijs.si), a tool based on Event Registry news data, which allows the user to follow business and personal named entities in time and establish broad relations between named entities (based on shared Wikipedia concepts from news articles) as well as to view the changes in these relations; Graph Based Analytics (http://gba.ijs.si) a service for business relation identification from text that enables identification of business relations, such as mergers and acquisitions, bankruptcy, earnings, dividends, etc. based on sentence level; Streamfusion, universal system for the preprocessing of heterogenous stream data; ELEXIS ER (http://er.elex.is/) a lexicography-adapted version of Event Registry, a public-procurement-anomaly detection tool (http://tbfy.ijs.si/); a service for processing, analysing and searching through environmental legal documents (http://envirolens.ijs.si/) and AIObservatory (https://infominer.ijs.si/). The laboratory's strategy is to combine scientific excellence with strong industrial collaboration, enabling the transfer of research results to real-world business environments.

In the past 17 years, members of the Artificial Intelligence Laboratory have successfully participated in 74 EU projects, of which 5 were concluded in 2019 and 17 were still ongoing. In 2019, we were also involved in 9 national projects and 3 industrial projects.

In 2019, in the area of **statistical data modelling and machine learning** we successfully concluded the EU H2020 project **PrEstoCloud** (*Proactive Cloud Resources Management at the Edge for Efficient Real-Time Big Data Processing*). The main objective of PrEstoCloud was to create substantial research contributions to the modern environments of edge and cloud computing systems to provide a dynamic, distributed architecture for proactive resource management. To this end, the PrEstoCloud solution reaches the extreme edge of the network for efficient data processing during run-time. Our result from this project is a service within the PrEstoCloud platform that is responsible for the Mobile Offloading Processing Microservice. The EU H2020 project **TheyBuyForYou**

(*Enabling procurement data value chains for economic development, demand management, competitive markets and vendor intelligence*) aims at developing methods for analyzing public procurement and the spending of public money in order to ensure greater transparency in the use of public funds and to prevent corruption or other irregularities. In 2019, we developed, tested and implemented several anomaly-detection methods for anomaly detection in financial data and tested these methods on Slovenian spending data. We have also developed several methods for anomaly detection in public procurement data, where we applied several approaches: supervised, unsupervised and statistical analysis. Finally, we also developed a web application for the analysis and visualization of both public-spending data and public-procurement data as well as for displaying groups of entities with detected anomalies and the visualization of detected anomalies in both spending data and in public procurement data. The goal of the EU H2020 project **DataBench** (*Evidence Based Big Data Benchmarking to Improve Business Performance*) is to design a benchmarking process helping European organizations developing BDT to reach for excellence and constantly improve their performance, by measuring their technology development activity against parameters of high business relevance. Within DataBench, we have investigated existing Big Data benchmarking tools and projects, identified the main gaps and provided a robust set of metrics to compare the technical results from those tools. In the EU H2020 project **Perceptive Sentinel** (*BIG DATA knowledge extraction and re-creation platform*) an eo-learn machine-learning framework that enables efficient data processing on top of Big Data acquired from satellites within the Sentinel-1, -2 and -3 missions has been built. In the past year, numerous solutions have been developed for the efficient processing of data, among them: FASTENER algorithm for efficient feature selection process for land-cover classification and rapids-ml library, which includes the very fast implementation of stream-mining algorithms. Both approaches have resulted in the speed-up of land-cover classification by an order of magnitude. The EU H2020 project **Cog-Lo** (*Cognitive Logistics*) started in June 2018. The aim of the project is to design and develop an intelligent logistics platform with cognitive services for postal operators/infrastructure. The project focuses on observing postal infrastructure as an object in time, with dynamic parcel (packets) flow being driven through basic infrastructural tools. The cognitive services platform will utilize infrastructure data to build a digital representation and dynamically route/allocate assets for process performance optimization. In the scope of the project, we have designed a methodology for building a digital representation of a physical infrastructure, methodology for the optimization of resources on graph distribution, and a methodology for large graph processing with clustering. Algorithms for the assessment of logistics events in real time enable an assessment of the optimal response to the ad-hoc requests for interventions in logistics parcels delivery. The analytical pipeline was integrated and tested in a demo solution. The H2020 EU project **enviroLENS** (Copernicus for environmental law enforcement support) started in December 2018. The aim of the project is to assist personnel involved in environmental legal issues (legal firms, non-governmental organizations, etc.) with the discovery of environment-related issues within legislation and other legal documents and to explore potential solutions for finding facts within the remote sensing/earth observation (EO) domain. In the first year of the project, we built a strong foundation for the development of the eLENS portal – a portal that will enable users to monitor environmental changes, receive notifications regarding these changes and obtain relevant environmental laws on a given topic (e.g. deforestation) in the selected area. The Artificial Intelligence Laboratory is in charge of the eLENS Miner System, which enables searches through environmental laws based on the user query. The system is an API service, which enables 1) processing new legal documents, 2) searching through the indexed law and 3) finding similar legal-document examples given another legal document. The first prototype of the system and its documentation is available at http://envirolens.ijs.si/. In the next year of the project, we will improve the system by adding additional functionalities, such as automatic rule discovery within the legal dataset, as well as better matching with the EO data. The EU H2020 project **Naiades** *(A holistic water ecosystem for digitisation of urban water sector)* aims at developing services for potable water preservation. The project aims at solving a whole palette of problems: from water-demand prediction for given areas, optimization of water consumption for public gardening, anomaly detection for water consumption as well as saline intrusion, monitoring water quality for on public areas, etc. The project approaches these problems through the Naiades platform, that will aggregate, process and standardize data from various sources. Based on the pre-processed data, Naiades services will be established, which will, through an appropriate user interface, provide actionable results for end users. In 2019, we established all the necessary working flows as well as defined all the necessary concepts in order to continue with the executable phase of the project. The goal of the **FACTLOG** (*Energy-aware Factory Analytics for Process Industries*) project is to support the process industry through the development of digital twins. Being a digital representation of all the complex processes in a production environment, a digital twin, which is equipped with analytical systems, can support the production process with its cognitive ca-

Ljubljana seat of the UNESCO-sponsored global AI research centre.

Artificial Intelligence Laboratory develops an AI Observatory for the OECD.

pabilities. Its functions include, for example: raising an alarm when encountering an anomaly, planning the optimal order of production and optimally setting the parameters of production machinery. In the project, the Artificial Intelligence Laboratory is leading the work package in charge of the development of analytical tools and supports two business cases: JEMS, a Slovenian company processing waste into fuel and Tupras, a Turkish oil refinery. In the area of data streams analysis, we started the flag-ship project **INFINITECH** *(Tailored IoT & BigData Sandboxes and Testbeds for Smart, Autonomous and Personalized Services in the European Finance and Insurance Services Ecosystem)*, which focuses on the development of advanced analytics technologies, tailored specifically for banking and insurance domains. INFINITECH consists of 14 different pilots, among which we are co-responsible for the implementation of one of these pilots: Pilot Platform for the supervision of money laundering, for the Bank of Slovenia. The EU project **CyberSANE** (*Cyber Security Incident Handling, Warning and Response System for the European Critical Infrastructures*) started in 2019. This project aims to enhance the security and resilience of Critical Information Infrastructures (CIIs) by providing a dynamic collaborative, warning and response system supporting and guiding security officers and operators (e.g., incident-response professionals) to recognize, identify, dynamically analyze, forecast, treat and respond to advanced persistent threats (APTs) and handle their daily cyber incidents utilizing and combining both structured data (e.g., logs and network traffic) and unstructured data (e.g., data coming from social networks and the dark web). Our role is the development of the DarkNET component (Deep and Dark Web Mining and Intelligence), which will provide risks and threats related to information through the analysis of textual and meta-data content available from the dark net.

Figure 1: Elexifier is a cloud-based dictionary-conversion service. It uses advanced XML parsing and machine-learning techniques to help you convert your PDF and XML dictionaries in a standardized machine-readable format. Users can upload their PDF and custom XML dictionaries to Elexifier, define mapping rules for XML transformation or create a learning training set for PDF conversion and download the transformed XML or PDF dictionary in a TEI-compliant file format based on the Elexis Data Model.

In the areas of **text and network analysis and language technologies**, we are part of the EU H2020 project **SILKNOW** (*Silk heritage in the Knowledge Society: from punched cards to big data, deep learning and visual / tangible simulations*). Within the project we have developed methods for multilingual text annotation based on our Wikifier service, extending it with terms from the SILKNOW thesaurus http://wikifier.org/silknow.html. We have also developed a tool for predictions of semantic variables linked to the SILKNOW ontology, that can be used to annotate the collected data from different museums in several languages, and thus populate and enrich the SILKNOW ontology and knowledge graph. We are also coordinating the EU H2020 project **ELEXIS** (*European Lexicographic Infrastructure*) which started in February 2018. The aim of the project is to integrate, extend and harmonize national and regional efforts in the field of lexicography, both modern and historical, with the goal of creating a sustainable infrastructure which will (1) enable efficient access to high-quality lexical data in the digital age, and (2) bridge the gap between more advanced and lesser-resourced scholarly communities working on lexicographic resources. In the past year, in addition to the activities related to project management, we have been maintaining the project website, developed and adapted several tools, such as Elexifinder (a searchable database of academic papers related to lexicography), Elexifier (a tool for converting print dictionaries into modern electronic ones suitable for the web), and Lexonomy (a dictionary-writing system for creating dictionaries and glossaries). Furthermore, in Vienna, we have organized an event for observer institutions (February 2019). By the end of 2019, 40 observer institutions joined the network and are willing to share their data and knowledge for the further development of the lexicographic network. Additionally, we have hosted a travel grant winner – Tanara Zingano Kuhn, a researcher at the University of Coimbra (Portugal). Within the EU H2020 Marie Skłodowska-Curie ITN project **BigDataFinance** (*Training for Big Data in Financial Research and Risk Management*) two doctoral students concluded their work on topics related to text data analysis in connection to financial data: "Deep Knowledge Extraction from Financial, Business, and Social Text" and "Characterising Financial Markets from Event-driven Perspective". In 2019, one of the students chaired the Project Showcase track at the KDD conference in Anchorage, Alaska. The KDD conference is one of the most renowned conferences on Machine Learning and AI. The other doctoral student accepted a full-time job offer in London, UK with the financial services firm Bloomberg LP, which is the leading provider of financial data and news in the world. Finally, a paper written by one of the students received an honourable mention as the runner-up for the 2019 Hillcrest Behavioral Finance Award. Within the H2020 EU Marie Skłodowska-Curie ITN project **CLEOPATRA** (*Cross-lingual Event-centric Open Analytics Research Academy*) we employed two doctoral students who will work on topics "*Information propagation with barriers*" and "*Cross-lingual news reporting bias*". In 2019, CLEOPATRA organized its first event in Dubrovnik, Croatia,

Marko Grobelnik was named as a member of the OECD Expert Group on AI (AIGO).

"*CLEOPATRA Learning Week*". We are also leading the ARRS project **New grammar of contemporary standard Slovene: sources and methods**, which began in 2017. The project aims to explore the linguistic methodological foundations of a complex analysis of written and spoken Slovene, as found in the new corpora developed in recent projects. The resulting methodology and data will provide a sound foundation for future work on an empirically based description of Slovene. Following from the methodology, we intend to compile and publish extensive collections of extracted material from corpora that will be useful for the development of language-technology applications for Slovene. The extracted data will be used for the linguistic analysis of real language, which represents the first step towards the compilation of a new descriptive corpus grammar of Slovene. In line with these goals, in the past year, we participated in the design and development of several tools for lexical data extraction from text corpora (morphology, wordlists, collocations, multi-word expressions, n-grams), and their related analysis. We have published a collection of lists with linguistic data from Slovene reference corpora (Gigafida) and spoken corpora (GOS). The lists contain different levels, from individual symbols in words to n-grams. They were prepared using the program LIST, which was developed in this project and can be used to create similar exports from other corpora databases. Additionally, we organized the event *Quantitative and qualitative methods of corpora analysis with new tools from the project New grammar of contemporary standard Slovene: sources and methods* in November 2019. The program LIST and the analyses of the manually-annotated corpus ssj500k with the tool Q-CAT were presented. Together with the Department of Knowledge Technologies (E8), we continued to lead the Slovene research infrastructure **CLARIN.SI**, which provides easy publication and sustainable access to digital language data for scholars in the humanities and social sciences. In addition to providing support for the CLARIN.SI repository, we also contributed various types of data (lexical resources, corpora, training corpora) and technologies (grammatical annotation, lexical data mining) for Slovene language processing. We are also part of the ARRS project **Collocations as a Basis for Language Description: Semantic and Temporal Perspectives**, whose main objective is to conduct basic research into semantic and temporal aspects of collocation, as well as statistics for measuring it, areas that have been so far largely neglected in Slovenian linguistics, and to some extent also internationally. The second objective is the development and a thorough linguistic evaluation of machine-learning methods for analyses of the Slovene language and extraction of lexical information from corpora. By doing this, we want to introduce into the Slovenian research environment a closer cooperation and synergy between lexicography and linguistics on the one side, and computational linguistics and natural language processing on the other. The third objective is a systematic integration of the results, obtained from various user studies, into the development of project methods and tools, and the preparation of methodological descriptions for transferring project results into practice to ensure their optimal applicability. The overall objective of the Multilingual Resources CEF project **MARCELL** is to provide automatic translations on the body of national legislation (laws, decrees, regulations) in seven countries: Bulgaria, Croatia, Hungary, Poland, Romania, Slovakia and Slovenia. At present, national legislation texts are not automatically available to CEF.AT and current Machine Translation (MT) systems could be improved if they had access to national legislative texts. In the past year, most of the work was focused on obtaining access to legislation corpora in seven languages and this was carried out by other partners.

Figure 2: This visualization, developed by the Artificial Intelligence Laboratory displays all AI publications vs GDP per capita vs All scientific publications (bubble size) by country and region in 2019.

In the area of **semantic technologies**, the team's work has focused on three European projects. The EU H2020 Marie Skłodowska-Curie RISE project **RENOIR** (*Reverse engineering of social information processing*), successfully concluded in 2019. With 2019, we completed 11 secondments to Carnegie Mellon, Rensselaer Polytechnic Institute in the US and ITMO University in Russia. Our work focused on research activities combining machine-learning methods and social network analysis for the reverse engineering of social information processing and the identification of barriers in information flow within social media. The project concluded at the Complex Systems 2019 in Singapore. The EU H2020 project **euBusinessGraph** (*Enabling the European Business Graph for Innovative Data Products and Services*) started in 2017 and was completed in 2019. The aim of the project was to build a European cross-lingual "business graph" that will aggregate, link and provision high-quality company-related data. In the past year, our work on the project consisted of developing tools for cross-lingual semantic annotation for unstructured data, along with event and relation extraction from multi-lingual data. In particular, we have developed a process and a service for business-event-type categorization (based on Event Registry), which allows us to obtain business event types out of text in natural language. In addition, we have created a Connection service for relation tracking from news, that makes it possible to obtain relations between business entities (such as companies and people) and observing the changes in relation in time. The Event Registry service has been integrated into euBusinessGraph business cases and the marketplace. The H2020 **EW-Shopp** project (*Supporting Event and Weather-based Data Analytics and*

Marketing along the Shopper Journey) has been successfully concluded at the end of 2019. The project built a set of tools for the support of data-driven e-commerce and marketing companies. The tools enable the integration of business data with data about weather and events from the news, and the integrated data is used to build analytics models predicting the key operating parameters for companies. The Artificial Intelligence Laboratory was the leader of the development for all the analytics tools in the project and contributed access to the Event Registry platform, which served as the source of event data. The results of the project were deployed in the production processes of a set of business partners from across Europe, among them three Slovenian companies – Ceneje.si, Big Bang and CDE.

In the area of knowledge management, the group's focus includes research and development by using methods and tools from a broader Artificial Intelligence area in real business settings. The EU H2020 project **x5gon** (*Cross Modal, Cross Cultural, Cross Lingual, Cross Domain, and Cross Site Global OER Network*) started in August 2017. The goal of the project is to implement innovative technology elements for connecting scattered Open Educational Resources (OERs) available across Europe and the globe, as well as quick and efficient search through the OER resources. In the past two years, we were successful at developing a strong system which 1) is able to process text, video and audio files, and enrich them with annotations, and 2) enables quick and flexible search through the processed OER resources. On top of this system, we have built several services which are able to analyze the educational patterns of the users, the creation of educational playlists, and help the visually impaired with their educational process. The x5gon platform is available at https://platform.x5gon.org/. From there, the user is able to navigate to the OER discovery tool (https://discovery.x5gon.org/), the educational environment for the visually impaired (https://blind.x5gon.org/), and the educational environment x5learn (https://x5learn.org/). In 2019 we continued with the **Water4Cities** (*Integrated Surface and Groundwater Management for Sustainable Urban Development*) project under the European Horizon 2020 Marie Skłodowska Curie RISE project together with Centre for knowledge transfer in IT. By using AI tools, we analyzed data on groundwater, rivers and stormwater flow in the Ljubljana aquafier and water quality and consumption on the Greek island of Skiathos. We are developing models and a platform that will allow us to monitor optimal water management in real time. In 2019, we attended a special session "Sustainable urban water management" dedicated to the Water4Cities project with a paper on "Water4Cities data collection, analysis and visualization tools supporting smart water management scenarios", which took place as part of the Seventh International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE) and SECOTOX conference. More information is available at http://cemepe7.civil.auth.gr/. In addition to regular webinars, we publish interviews with researchers involved in the project, which are available on the Videolectures.NET subpage - http://videolectures.net/water4cities/. Within the H2020 project **HumaneAI** (*Toward AI Systems That Augment and Empower Humans by Understanding Us, our Society and the World Around Us*) we are involved in developing an EU-funded network of HCI and AI researchers. Our vision is to know how to develop AI systems that augment and empower humans by understanding them, society and the world around them. However, AI is a two-sided coin: it can either empower individuals and society, creating many opportunities to improve human experience, or it can create the tools that can destroy us, enslave individuals, while concentrating the power and wealth in the hands of a few. Humane-AI is intended to understand and critique both; but with a focus on representing a community of researchers and innovators to create the conditions for AI technologies that can empower humans and human society to improve their quality of life. But how can we facilitate AI systems that enhance human capabilities and empower people as individuals, while assuring the evolution of a healthy and nurturing society? A central part of our network involves exploring the symbiosis of humans and AI systems to work together, and how new AI technologies can be designed and implemented that are ethical. HumaneAI has been extended into a new project **HumanE-AI-Net**. This will enable us to create the new science behind the interaction of AI and HCI. The goal of the H2020 project **FIN-TECH** *(A FINancial supervision and TECHnology compliance training programme)* is to develop a program for the exchange of knowledge in the financial environment. In this manner, the goal of the FINTECH project is to create a European training programme aimed at providing shared risk-management solutions that automate the compliance of Fintech companies and, at the same time, increase the efficiency of supervisory activities. The project incorporates 24 partners, covering all 28 EU countries, plus Switzerland. The consortium is composed of universities, and research institutes, while being fully supported by various financial institution. Within this project, our department collaborates with the Bank of Slovenia and in 2019, we prepared four workshops on topics such as the technology of Big Data and Blockchains. The goal of the project **KAUČ - Improving the Quality of Slovene Textbooks** is to develop quality metrics for Slovene primary and secondary school textbooks to be used during their certification and evaluation. The research

We have successfully concluded five EU H2020 projects: BigDataFinance *(Training for Big Data in Financial Research and Risk Management)*, **RENOIR** *(Reverse EngiNeering of sOcial Information pRocessing),* **EW-Shopp** *(Supporting Event and Weather-based Data Analytics and Marketing along the Shopper Journey),* **euBusinessGraph** *(Enabling the European Business Graph for Innovative Data Products and Services)* and **PrestoCloud** *(Proactive Cloud Resources Management at the Edge for Efficient Real-Time Big Data Processing).*

group will develop a prototype of the automatic web-based tool, which will allow an evaluation of textbooks based on their textual and pictorial properties. The tool will support the decision-making process for the selection of the appropriate textbooks. In 2019 we analyzed the compiled corpora of Slovene textbooks and adjusted statistical measures for readability in Slovene (we have also published an article on this topic). We analyzed different criteria on textbook quality, prepared a decision model for textbook quality and adapted it in a such a way that it will be possible to execute this with automatic tools for natural language processing.

Promotion of science is continually present in the efforts of the Artificial Intelligence Laboratory. In 2019, members of the Artificial Intelligence Laboratory were very active in promoting this research topic:

- Luka Stopar was a guest on national TV RTVSlo - *Osvezilna Fronta;*
- Marko Grobelnik gave an interview on national TV RTVSlo – Odmevi;
- John-Shawe Taylor, as UNESCO AI representative, gave an interview for Synced;
- Marko Grobelnik was a panelist at an UN event in New York;
- Mitja Jermol was named the "Name of the Week" on the radio - Val 202

Together with the Centre for Knowledge Transfer in Information Technologies (CT3), we continued to use the Videolectures.NET portal to promote Artificial Intelligence, the Jožef Stefan Institute and Slovenian research in general. Our laboratory is also among the main organizers and supporters of the annual national ACM Computer Science Competition for secondary-school students; in 2019, 177 students from 27 schools participated in the competition. We have also been organizing a touring exhibition about female PhD holders from the area of computer science in Slovenia since 2006, thereby promoting the role of women in science (http://ScienceWithArt.ijs.si/).

In 2019 we were very actively involved in submitting new project proposals, particularly within the EU H2020 Programme. Once again, we were very successful, obtaining funding for one new project: ***HumanE-AI-Net***. We continue with our successful efforts to include the Slovenian industry into the European research area, where over the last 17 years we have produced a list of numerous companies participating in EU projects.

Some outstanding publications in the past year

1. Uurtio, Viivi, Monteiro, João M., Kandola, Jaz, Shawe-Taylor, John, Fernandez-Reyes, Reyes, Rousu, Juho. A tutorial on canonical correlation methods. ACM computing surveys, ISSN 0360-0300. [Print ed.], 2019, vol. 50, no. 6, str. 95-1-95-5.
2. Senožetnik, Matej, Bradeško, Luka, Šubic, Tine, Herga, Zala, Urbančič, Jasna, Škraba, Primož, Mladenić, Dunja. Estimating point-of-interest rating based on visitors geospatial behaviour. Computer science and information systems, ISSN 1820-0214. [Print ed.], 2019, vol. 16, no. 1, str. 131-154.
3. Žitnik, Marinka, Nguyen, Francis, Wang, Bo, Leskovec, Jurij, Goldenberg, Anna, Hoffman, Michael M. Machine learning for integrating data in biology and medicine : principles, practice, and opportunities. Information fusion, ISSN 1566-2535, Oct. 2019, vol. 50, str. 71-91, ilustr. https://www.sciencedirect.com/science/article/pii/S1566253518304482#!
4. Doyle, Casey, Herga, Zala, Dipple, Stephen, Szymański, Bolesław K., Korniss, Gyorgy, Mladenić, Dunja. Predicting complex user behavior from CDR based social networks. Information sciences, ISSN 0020-0255. [Print ed.], 2019, vol. 500, 217-228.
5. Štajner, Tadej, Mladenić, Dunja. Cross-lingual document similarity estimation and dictionary generation with comparable corpora. Knowledge and information systems, ISSN 0219-1377. [Print ed.], 2019, vol. 58, no. 3, str. 729-743.
6. Urbančič, Tanja, Polajnar, Anja, Jermol, Mitja. Open education for a better world : a mentoring programme fostering design and reuse of open educational resources for sustainable development goals. Open praxis, ISSN 1369-9997, 2019, vol. 11, no. 4, str. 1-18.
7. Kenda, Klemen, Kažič, Blaž, Novak, Erik, Mladenić, Dunja. Streaming data fusion for the internet of things. Sensors, ISSN 1424-8220, 2019, vol. 19, no. 8, 1955-1-1955-27.

Awards and Appointments

1. James Hodson recieved an honourable mention as the runner-up for the 2019 Hillcrest Behavioral Finance Award
2. Marko Grobelnik, Representative of Slovenia in Ad hoc Committee on Artificial Intelligence – CAHAI, Strasbourg, France, CAHAI
3. Marko Grobelnik, Head of subcomitte in OECD AI ONE for "AI Classification", Paris, France, OECD

Organization of Conferences, Congresses and Meetings

1. Workshop ''The second Artificial Intelligence workshop'', Zreče, Slovenia, 16–18 September 2019
2. How might it be? – A consultation on the digital future of Slovene, Ljubljana, Slovenia, 27 September 2019
3. SiKDD conference, Ljubljana, Slovenia, 7 October 2019
4. Annual project event: Quantitative and qualitative corpus analyses with newly developed tools from the project New grammar of contemporary standard Slovene: sources and methods (J6-8256), Ljubljana, Slovenia, 19 October 2019

INTERNATIONAL PROJECTS

1. Smart Statistics
   Marko Grobelnik
   Sogeti Luxembourg S.a.
2. INEA/CEF - eTranslation TermBank
   Dr. Simon Krek
   Innovation And Networks Executive Agency (inea)
3. INEA/CEF - MARCELL, Multilingual Resources for CEF.AT in the Legal Domain
   Dr. Simon Krek
   Innovation And Networks Executive Agency (inea)
4. COST CA16105; European Network for Combining Language Learning with Crowdsourcing Techniques
   Dr. Simon Krek
   Cost Office
5. COST CA18209; European Network for Web-Centred Linguistic Data Science
   Dr. Simon Krek
   Cost Association Aisbl
6. COST CA18231; Multi3Generation: Multi-Task, Multilingual, Multi-Modal Language Generation
   Marko Grobelnik
   Cost Association Aisbl
7. H2020 - BigDataFinance; Training for Big Data in Financial Research and Risk Management
   Marko Grobelnik
   European Commission
8. H2020 - RENOIR; Reverse Engineering of Social Information Processing
   Marko Grobelnik
   European Commission
9. H2020 - MOVING; Training Towards a Society of Data-Savvy Information Professionals to enable Open Leadership Innovation
   Marko Grobelnik
   European Commission
10. H2020 - PrEstoCloud; Proactiive Cloud Resources Management at the Edge for Efficient Real-Time
    Marko Grobelnik
    European Commission
11. H2020 - euBusinessGraph; Enabling the European Business Graph for Innovative Data Products and Services
    Prof. Dunja Mladenić
    European Commission
12. H2020 - EW-Shopp; Supporting Event and Weather-based Data Analytics and Marketing along the Shopper Journey
    Marko Grobelnik
    European Commission
13. H2020 - Water4Cities; Holistic Surface Water and Groundwater Management for Sustainable Cities
    Marko Grobelnik
    European Commission
14. H2020 - X5gon; Cross Modal, Cross Cultural, Cross Lingual, Cross Domain, and Cross Site Global OER Network
    Marko Grobelnik
    European Commission
15. H2020 - PerceptiveSentinel; BIG DATA Knowledge Extraction and Re-creation Platform
    Prof. Dunja Mladenić
    European Commission
16. H2020 - DataBench; Evidence Based Big Data Benchmarking to Improve Business Performance
    Marko Grobelnik
    European Commission
17. H2020 - TheyBuyForYou; Enabling Procurement Data Value Chains for Economic Development, Demand Management, Competitive Markets and Vendor Intelligence
    Marko Grobelnik
    European Commission
18. H2020 - SILKNOW; Silk Heritage in the Knowledge Society; From Punched Cards to Big Data, Deep Learning and Visual/Tangible Simulations
    Prof. Dunja Mladenić
    European Commission
19. H2020 - COG-LO; COGnitive Logistics Operations through secure dynamic and ad-hoc collaborative networks
    Marko Grobelnik
    European Commission
20. H2020 - EnviroLENS; Coprenicus for Environmental Law Enforcement Support
    Marko Grobelnik
    European Commission
21. H2020 - Cleopatra; Cross-Lingual Event-Centric Open Analytics Research Academy
    Marko Grobelnik
    European Commission
22. H2020 - Humane AI; Toward AI Systems That Augment and Empower Humas by Understanding Us, our Society and the World Around Us
    Marko Grobelnik
    European Commission
23. H2020 - FIN-TECH; A FINancial supervision and TECHnology compliance training programme
    Marko Grobelnik
    European Commission
24. H2020 - NAIADES; A Holistic Water Ecosystem for Digitisation of Urban Water Sector
    Marko Grobelnik
    European Commission
25. H2020 - CyberSANE; Cyber Security Incident Handling, Warning and Response System for the European Critical Infrastructures
    Marko Grobelnik
    European Commission
26. H2020 - INFINITECH; Tailored IoT&BigData Sandboxes and Testbeds for Smart, Autonomous and Personalized Services in the European Finance and Insurance Services Ecosystem
    Marko Grobelnik
    European Commission
27. H2020 - FACTLOG; Energy-aware Factory Analytics for Precess Industries
    Prof. Dunja Mladenić
    European Commission
28. H2020 - ELEXIS; European Lexicographic Infrastructure
    Dr. Simon Krek
    European Commission
29. Computing Persistent Homology for Geometric Inputs
    Asst. Prof. Primož Škraba
    Slovenian Research Agency

RESEARCH PROGRAMME

1. Knowledge Technologies
   Prof. Dunja Mladenić

R&D GRANTS AND CONTRACTS

1. Integration of mobile devicas into survey research in social sciences: Development of a comprehensive methodological approach
   Marko Grobelnik
2. Collocation as a basis for language description: semantic and temporal perspectives
   Dr. Simon Krek
3. New grammar of modern standard Slovene: resources and methods
   Dr. Simon Krek
4. Causalify - Causality in global social dynamics
   Prof. Dunja Mladenić
5. New Modes and Global Patterns of Online News (Re)production
   Prof. Dunja Mladenić
6. For the Quality of Slovene Textbooks

Dr. Simon Krek
Ministry of Education, Science and Sport

7. Preparation and Analysis of Data for Workshops
Dr. Iztok Kosem
Universidade de Coimbra

VISITORS FROM ABROAD

1. Chiara Perillo, University of Zurich, Zurich, Switzerland, 1–25 February 2019
2. Jose Luis Machado Rei, JSI, Ljubljana, Bologna, Italy, 4–6 February 2019
3. M. Besher Massri, Koc University, Istanbul, Turkey, 9–17 February 2019
4. Marko Jazbec, SavaRe, Ljubljana, Slovenia, 18 February 2019
5. Jošt Dolničar, SavaRe, Ljubljana, Slovenia, 18 February 2019
6. Matjaž Stražišar, SavaRe, Ljubljana, Slovenia, 18 February 2019
7. Matjaž Kristan, Acenta d.o.o., Ljubljana, Slovenia, 18 February 2019
8. Jan Choloniewski, Warsaw University of Technology, Warsaw, Poland, 27 February - 18 April 2019
9. Dr. Slavko Spichal, Fakulteta za družbene vede, Ljubljana, Slovenia, 28 February 2019
10. Mag. Boris Mance, Fakulteta za družbene vede, Ljubljana, Slovenia, 28 February 2019
11. Graeme Ballard, Devolution Media Group, London, United Kingdom, 12 March 2019
12. Božidar Založnik, Devolution Media Group, London, United Kingdom, 12 March 2019
13. Dr. Daniel Schwabe, Pontificia Universidade Católica Rio de Janeiro, Rio de Janeiro, Brazil, 21 March - 20 June 2019
14. Dimitris Kofinas, University of Thessaly, Thessaly, Greece, 3 April 2019
15. Dr Tanara Kuhn, University of Coimbra, Coimbra, Portugal, 25 June - 10 July 2019
16. Milan Cvikl, European Bank for Reconstruction Development, Ljubljana, Slovenia, 5 July 2019
17. Dr Ayse Saliha Sunar, Univerza Bitlis Eren, Turčija, Bitlis, Turkey, 1 July - 31 August 2019
18. Thierry Declerck, Deutsches Forschungszentrum für Künstliche Intelligenz GmbH, Saarbrucken, Germany, 10–12 July 2019
19. Giulio Trichilo, Swiss Federal Institute of Technology Lausanne, Lausanne, Switzerland, 15 July - 15 September 2019
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21. Pat Moore, Bloomberg, New York, New York, USA, 2–5 September 2019
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LABORATORY FOR OPEN SYSTEMS AND NETWORKS E-5

The main activities of the laboratory are R&D in the area of next-generation networks, telecommunications technologies, components and integrated systems, information-society services and applications, especially those that enable better privacy protection of citizens and increased trustworthiness of the information and communication technologies and services.

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Asst. Prof. Tomaž Klobučar

The research in 2019 was performed within the research programme "Future Internet Technologies: concepts, architectures, services and socio-economic issues", funded by the Slovenian Research Agency. In addition, research was carried out in the EU Horizon 2020 projects "CONCORDIA", "Defender" and "Compact", the EU DG Justice "EIO-LAPD" project, the "GIRDA" project from the Erasmus+ programme, the "SI-PASS", "SI-PASS 2.0" and "eID4U" projects from the CEF programme, the "EkoSmart" project from the European Regional Development Fund, and the national "Technological and business aspects of future ecosystem for e-health" project. The focus was the development of technologies and services in advanced next-generation networks, security and privacy in information systems, and technology-enhanced learning.

Members of the laboratory are teaching at the undergraduate and graduate levels at the Jožef Stefan International Postgraduate School, the DOBA Faculty, and the Faculty of Commercial and Business Sciences. The laboratory is also a member of European Cyber Security Organisation (ECSO).

Concepts and architectures of the secure internet

The first area of research and development was focused on security infrastructures and secure services.

The main goal of the **SI-PASS** ("Slovenian eIDAS node and integrated services"), **SI-PASS 2.0** ("Integrating Slovenian e-services with the national eIDAS node") and **eID4U** ("eID for University") projects from the EU CEF (Connecting Europe Facility) programme is to set up an infrastructure for secure cross-border services, based on national electronic identification means, in different application domains. The SI-PASS project, which was coordinated by the Laboratory for Open Systems and Networks, has established the central eIDAS node in Slovenia at the Ministry of Public Administration and has integrated four public and one private cross-border e-services in the fields of e-health (zVEM), pension and disability insurance (eZPIZ), intellectual property protection, company registers (Portal AJPES), and e-commerce (ePero). The eIDAS node is the central point of trust in the country, set up according to the EU eIDAS regulation (The Regulation on electronic identification and trust services for electronic transactions in the internal market) requirements. On the one hand, it connects national infrastructure with foreign service providers and, on the other hand, national identity and service providers with the infrastructures of other EU countries. In 2019 we started the SI-PASS 2.0 project that is also coordinated by the laboratory. The project will integrate, until 2021, additional e-services with the national eIDAS node in the fields of e-government, municipalities, health insurance, and financial services.

We have created building blocks for security infrastructures and secure internet services.

Figure 1: Final SI-PASS workshop for Slovenian public e-service providers

In the eID4U project that ended in 2019, we established an eID4U eIDAS node and integrated it with trusted sources of information about students (central evidence system for e-higher education eVŠ) and a national pre-production identity provider. We analysed the academic attributes needed for Erasmus+ exchanges and developed an XML scheme and the XML definitions of the attributes, upgraded the EU DIGIT reference implementation of an eIDAS node, and developed three secure academic cross-border services. First, we created a plugin for the Moodle open-source learning-management system that enables direct connection to the eIDAS node and learner-identity verification using the eIDAS infrastructure. The learner is given the appropriate role in the system and access to learning material is granted on the basis of national identification means and provided verified academic attributes. Then, we set up an Erasmus+ registration service that also enables cross-border authentication and supports the transfer of academic attributes in electronic form. Finally, we set up an eAccess service that enables access to the wireless network in the laboratory with national electronic identities. The service is based on the Nodogsplash captive portal and its forward authentication service.

The results of all three projects enable citizens of the EU Member States to access Slovenian e-services with their national notified electronic identification means, and will provide, in the near future, when Slovenia notifies its identification scheme, easy access to public e-services in other EU Member States for Slovenian users.

The **Defender** ("Defending the European Energy Infrastructures") project is addressing the issues of European critical energy infrastructures security and dependability. A 3-year project aims at improving the protection of all energy-domain segments, from generation, transmission to distribution. The improvements will result in better infrastructure resilience and dependability. The project is the only large-scale project funded through the Horizon 2020 mechanisms that is addressing the critical energy infrastructure protection. Besides a number of excellent European industrial partners, it has a strong Slovenian consortium, namely the Laboratory for Open Systems and Networks, together with the Department of Communication Systems at Jožef Stefan Institute, the Slovenian transmission operator ELES and the Institute for Corporative Security Studies (ICS). The laboratory has led the work on cyber-physical threats' assessment and analyses, leads piloting and evaluation, and is contributing to the development and implementation of the project threat mitigation and situation awareness solutions. The solutions developed in the project will bring together ELES's physical, business and technical security systems and will be tested in the pilot environment of the RTP Okroglo in 2020.

Our R&D results enable a more secure information society.

In the energy infrastructures and services domain, we have also concluded a 3-year national project **Kritična Konična Tarifa** ("Project Critical Peak Tariff"). The critical peak tariff is a pilot tariff for the distribution system operators that is larger than the regular tariff for the duration of critical energy demand (critical event). Our laboratory supplied a safe digital environment for the collection and transfer of consumption measurements of household customers connected to the distribution network of Elektro Celje, d.d. In addition, we contributed a working model of the daily network demand and peak consumption patterns. We developed a forecasting algorithm to predict the daily demand as well as the time and magnitude of the critical peak in particular. The predictions were tested in a real setting on 42 separate peak events. Our contribution also includes critical peak event analysis and a flexibility evaluation of household consumers for the duration of the critical peak tariff. The work will be continued in 2020 in the newly acquired project **Uporabljaj pametno** ("Use wisely"), again in collaboration with Elektro Celje, d.d.. The critical tariff will be extended with "happy hours" and self-sufficient communities. The laboratory will provide analytical support and implementation for the system operation, secure backend cloud storage, and smart mobile application for the consumers.

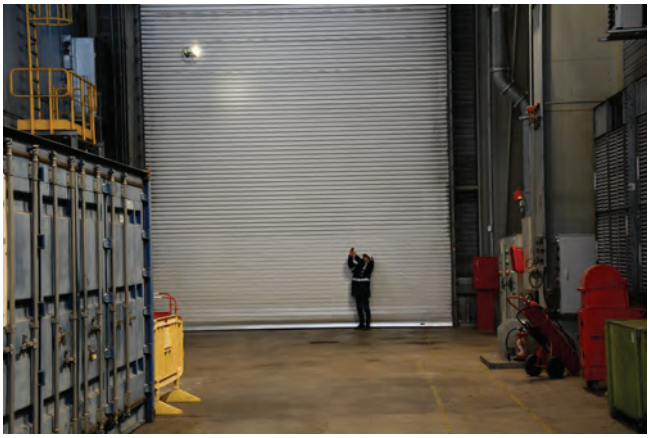

Figure 2: On-site evaluation of the cyber-physical threats to a critical energy infrastructure

In 2019, another three-year national project **EkoSmart** ("Ecosystem of a smart city") was successfully concluded. The project focused on citizens' health, mobility, active lifestyle, and well-being, and included the research and development of new tools and methods based on intensive IKT support for higher-quality living and safety of the citizens and communities. The Laboratory for Open Systems and Networks was involved in the Electronic and Mobile e-Health activity, where the primary goal was the development of information technologies to support medical care at home and in hospitals. New tools and approaches for monitoring the environmental and vital data of individuals were introduced as well as the supporting IKT methods for the collection and analysis of the measured data. Because personal health data is of a sensitive nature, it was important to secure the safe collection and transfer of such data for all customers of the EMZ services. Our laboratory has proposed a database management system to ensure the privacy of the health data and enable both interactive and off-line access and analysis of the health data. Proper precautions were introduced for both scenarios as the proposed framework incorporates different (pseudo)-anonymisation methods, such as the commonly used *k*-anonymity and *l*-diversity as well as the method of differential privacy.

The research project titled "**Technological and business aspects of future ecosystem for e-health**" is focused on implementing the work within the priority area of the European cohesion policy "Smart cities and communities". Its fundamental goal is the creation of a functional model to assure sustainable technological and business development of an ecosystem for e-health. One goal of the project is the analysis of new e-services for discharging patients from the hospital. The first part of 2019 was dedicated to observation and measurement of the discharge process. Based on the collected data from our observations and system logs we modelled the discharge process and analysed the most influential sub-processes in terms of duration of the whole discharge process. This is the basis for measuring an improvement of the process with the integration of e-services.

In 2019 we obtained two new H2020 projects that will start in January 2020 and are related to the security and energy infrastructures and services. The main goal of the **DE4A** ("Digital Europe for All") project is to facilitate

migration towards secure European digital public services co-delivered across borders, across sectors and with different participants, and to implement the latest EU directives and regulation (e.g., eIDAS, Single Digital Gateway). Our main role in the project is coordination of the Studying Abroad pilot, one of the three project pilots. The **BD4OPEM** (Big Data for Open Innovation Energy Marketplace) project will use a data-centric approach to innovate between energy stakeholders' needs and the solutions to be developed. A data flow though the marketplace will allow the development of analytical services to boost business processes. The laboratory is responsible for capturing and analysing the project use cases, security and privacy, and analytical services for predictive maintenance and forecasting.

Under the Infrastructure program in research organizations we keep providing support services that enable better communication among members of the various research programs, as well as students and their mentors from geographically distributed institutions.

Security and privacy in information systems

The provision of security and privacy services is crucial for the modern information society and for the emerging digital market. In 2019 the R&D activities in this field were focused on the research of novel security mechanisms and methods.

A new method and tool for identifying the vulnerabilities of internet systems were developed to improve the security of websites. A key feature is the ability to perform automated, fast and dynamic vulnerability identification on a large scale and with in-built ethical respect. The tool was presented in the IEEE Access journal with an SCI impact factor.

Mathematical models for the construction of symmetric cryptographic algorithms were also the subject of research. We have provided a detailed description of how semi-bent Boolean functions can be implemented in symmetric cryptography, which is interesting from a cryptographic point of view in the defence of a pseudorandom generator used as an important role in the construction of orthogonal variable spreading codes used in code-division multiple-access (CDMA). The results were published as a book chapter in a scientific monograph at IntechOpen. Further results on design methods for semi-bent functions were published in Information Processing Letters journal. An analysis of cryptographic algorithms in IoT was also given. We thoroughly reviewed and compared several existing symmetric and asymmetric lightweight encryption algorithms. The results were published as a book chapter in a scientific monograph at IGI Global.

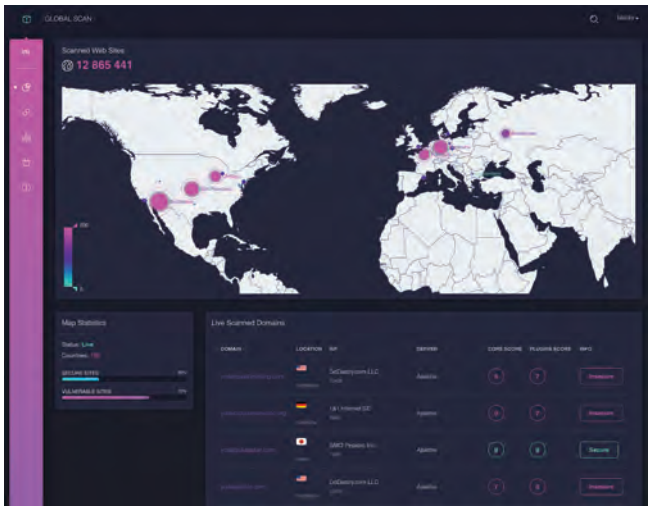

Figure 3: A tool for identifying vulnerable websites on a large scale

The research of the cross-border digital evidence collection and analysis of the Directive 2014/41/EU continued in the new EU DG Justice programme project **EIO-LAPD** ("European Investigation Order – legal analysis and practical dilemmas of international cooperation") where we collaborate with six other institutions from Austria, Croatia, Germany, Italy, Slovenia and Portugal. In 2019 we investigated the current issues and proposed legal remedies for removing the barriers to gathering cross-border electronic evidence in crime investigation. The results were published in two scientific journals: "Information & communications technology law" and "International review of law, computers & technology".

Finally, in 2019 the Laboratory for Open Systems and Networks became a member of CONCORDIA, one of the four European centres of excellence in cyber security from the H2020 programme with leading research, technology, industrial and public competences. The center provides research and development solutions for a safe, resilient and trustworthy European ecosystem. Within CONCORDIA, the laboratory contributes with research on user-centric security, mainly through models for fighting disinformation, facilitating online trust management and establishing electronic identities. In addition, the laboratory is actively involved in the e-Health pilot and is also contributing with data and models for the development of threat intelligence models. In the upcoming year, cyber-education is part of the planned activities as well.

Internet services and applications

The main focus of the research and development activities in the area of technology-enhanced learning was on serious games and new e-learning services and platforms for public employment services. The overall goal of the "Gameplay for Inspiring Digital Adoption (**GIRDA**)" project was to address the problem of the digital divide and barriers to learning and adoption faced by older citizens who often have no digital skills. Seven partners from Slovenia, UK, Austria, and Macedonia investigated with field experiments the efficacy of an alternative approach for facilitating digital literacy and digital adoption based on digital games designed on touch-table technology

devices. Our results were published in the "Education and information technologies" scientific journal. The project closed in August 2019.

The objective of the 3-year H2020 project "From Research to Policy through Raising Awareness of the State of the Art on Social Media and Convergence (**COMPACT**)" (October 2017-2020) is to increase awareness (including scientific, political, cultural, legal, economic and technical areas) of the latest technological discoveries among key stakeholders in the context of social media and convergence. The project is performing extensive research on policies and regulatory frameworks, as well as pre-standardization efforts in social media for preventing fake news, hate speech, and information disorder in general. The Laboratory for Open Systems and Networks leads the work package for policies and regulatory frameworks, where a methodology for examining the regulatory landscape across the EU countries has been analysed. After piloting the developed methodology for that purpose in 11 EU countries in 2018 (Slovenia, Slovakia, Bulgaria, Greece, Croatia, Belgium, UK, Ireland, Latvia, Denmark and Portugal) and in 71 organizations (fact-checking platforms, privacy initiatives, media awareness initiatives, digital rights and gender civil groups, etc.), in 2019 the methodology has been extended and piloted in an additional 13 EU countries (Austria, Hungary, Czech Republic, Romania, Cyprus, Italy, France, Poland, Germany, Spain, Sweden, Estonia and Netherlands) for a total of 141 organizations. The results were analysed in light of the current regulation and directives (GDPR, AVMSD, e-Commerce, etc.) from the aspects of fundamental rights and regulatory implications (transparency and accountability). Concrete policy recommendations were developed for all the relevant stakeholders. Part of the results were already published in an SSCI journal "Javnost" and presented at important events (co) organized by COMPACT, such as the Ljubljana and Brussels COMPACT Symposia, the PCA Congress in Poland, the DRAMA Conference in Athens, Greece. Next, the final results will be presented and disseminated throughout the EU at the upcoming COMPACT Symposia and other relevant events. In June 2019 one of the COMPACT symposia was co-organized by the JSI, together with DATA d.o.o. in Ljubljana. It was attended by around 30 people (lawyers, academics, IT experts, journalists, ministries, media stakeholders and civil organizations) and was considered to be among the most successful events on the topic of social media regulation.

Some outstanding publications in the past three years

1. Kiljander, Jussi, Gabrijelčič, Dušan, Werner-Kytölä, Otilia, Krpič, Andrej, Savanović, Arso, Stepančič, Živa, Palacka, Vladimir, Takalo-Mattila, Janne, Taumberger, Markus. Residential flexibility management: a case study in distribution networks. IEEE access, ISSN 2169-3536, 2019, vol. 7, pp. 80902 – 80915.
2. Cigoj, Primož, Jerman-Blažič, Borka. An intelligent and automated WCMS vulnerability-discovery tool. IEEE access, ISSN 2169-3536, 2019, vol. 7, pp. 175466 – 175473.
3. Trkman, Marina, Mendling, Jan, Trkman, Peter, Krisper, Marjan. Impact of the conceptual model's representation format on identifying and understanding user stories. Information and software technology, ISSN 0950-5849. [Print ed.], Dec. 2019, vol. 116, art. 106169, pp. 1-17.

Organization of conferences, congresses and meetings

1. GIRDA project meeting, Ljubljana, Jožef Stefan Institute, Ljubljana, 5 – 7 February 2019
2. DEFENDER project meeting, Rikli Balance Hotel, Bled, 5–7 March 2019
3. SI-PASS workshop "Compliance of e-services with eIDAS", Secretariat-General of the Government of the Republic of Slovenia, Ljubljana, 24 April 2019
4. COMPACT project symposium "Do we need to regulate social media?", M-hotel Ljubljana, 6 June 2019
5. GIRDA workshop "Intergenerational collaboration and how to teach older people digital skills", Orehov gaj, Ljubljana, 4 July 2019
6. 25th Isabel Anniversary remote sites event: 19 partners from 12 countries from Europe, America and Africa, 2 July 2019
7. eID4U project meeting, Jožef Stefan Institute, Ljubljana, 29–30 October 2019

INTERNATIONAL PROJECTS

1. ERASMUS+; GIRDA - Gameplay for Inspiring Digital Adoption
   Prof. Borka Džonova Jerman Blažič
   European Commission
2. INEA/CEF - eID4U; eID for University
   Asst. Prof. Tomaž Klobučar
   Innovation and Networks Executive Agency (Inea)
3. EIO-LAPD-JUST-AG-2018/JUST-JCOO-AG-2018; European Investigation Order - Legal Analysis and Practical Dilemmas of International Cooperation
   Prof. Borka Džonova Jerman Blažič
   European Commission
4. LIVE_FOR; Criminal Justice Access to Digital Evidences in the Cloud - LIVE_FORensics
   Prof. Borka Džonova Jerman Blažič
   European Commission
5. INEA/CEF - SI-PASS; Slovenian eIDAS Node and Integrated Services
   Asst. Prof. Tomaž Klobučar
   Innovation and Networks Executive Agency (Inea)
6. INEA/CEF - SI-PASS 2.0.; Integrating Slovenian E-Services with the National eIDAS Node
   Asst. Prof. Tomaž Klobučar
   European Commission
7. H2020 - DEFENDER; Defending the European Energy Infrastructures
   Dr. Dušan Gabrijelčič
   European Commission
8. H2020 - COMPACT; From Research to Policy through raising Awareness of the State of the Art on Social Media and Convergence

Dr. Tanja Pavleska
European Commission

9. H2020 - CONCORDIA; Cyber Security Competence Research and Innovation for Research and Innovation
   Dr. Tanja Pavleska
   European Commission

RESEARCH PROGRAMME

1. Future Internet Technologies: concepts, architectures, services and socio-economic issues
   Prof. Borka Džonova Jerman Blažič

R&D GRANTS AND CONTRACTS

1. Smart City Ecosystem – EkoSmart
   Dr. Živa Stepančič
   Ministry of Education, Science and Sport
2. Technological and business aspects of future ecosystem for e-health
   Dr. Marina Trkman
   Ministry of Education, Science and Sport

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2. Primož Cigoj, Borka Jerman-Blažič, "An intelligent and automated WCMS vulnerability-discovery tool", *IEEE access*, 2019, **7**, 175466-175473.
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Published Conference Contribution

1. Helder Aranha, Masi Massimiliano, Giovanni Paolo Sellitto, Tanja Pavleska, "Enabling security-by-design in smart grids", In: *2019 15th European Dependable Computing Conference: EDCC 2019: Naples, Italy, 17-20 September 2019*, Proceedings, IEEE, 2019, 177-179.
2. Marina Trkman, Živa Stepančič, Roko Malkoč, "Evaluation of patients' discharge time on a ward preliminary findings", In: *4th Business & Enterpeneurial Economics Conference 2019, 15/5 - 18/05, 2019, Dubrovnik, Croatia*, Conference proceedings, Student Business Incubator at the University of Zagreb, 2019, 45-49.
3. Borka Jerman-Blažič, Tomaž Klobučar, "Advancement in cybercrime investigation: the new European legal instruments for collecting cross-border E-evidence", In: *Information Technology Systems: proceedings of ICITS 2019, [International Conference on InformationTechnology & Systems, February 68, 2019, Quito, Ecuador]*, (Advances in intelligent systems and computing, **918**), Springer, 2019, 858-867.
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5. Tanja Pavleska, Helder Aranha, Masi Massimiliano, Eric Grandry, Giovanni Paolo Sellitto, "Cybersecurity evaluation of enterprise architectures: the e-SENS case", In: *The practice of enterprise modeling: 2th IFIP Working Conference, PoEM 2019, November 27-29, 2019, Luxembourg, Luxembourg*, (Lecture notes in business information processing, **369)**, Springer, 2019, 226-241.
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9. Tomaž Klobučar, "Improving cross-border educational services with eIDAS", In: *Trends and advances in information systems and technologies. Volume 1: [presented at the 2019 World Conference on Information Systems and Technologies, (WorldCIST'19, Galicia, Spain, April 16-19, 2019]*, (Advances in intelligent systems and computing, **913)**, Springer, 2019, 932-938.
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Independent Component Part or a Chapter in a Monograph

1. Borka Jerman-Blažič, Andrej Jerman Blažič, "Interactive multimedia touch screen tablets and gaming as a vehicle that fosters learning digital skills", In: *Interactive multimedia: multimedia production and digital storytelling*, IntechOpen, 2019, 43-60.
2. Samed Bajrić, "Implementing symmetric cryptography using sequence of semi-bent functions", In: *Modern cryptography: current challenges and solutions*, IntechOpen, 2019, 1-16.
3. Samed Bajrić, "An analysis of cryptographic algorithms in IoT", In: *Smart devices, applications, and protocols for the IoT*, IGI Global, 2019, 83-104.

DEPARTMENT OF COMMUNICATION SYSTEMS E-6

The core activities of the Department of Communication Systems comprise the research, development and design of next-generation telecommunication networks, technologies and services; wireless communication, embedded and sensor systems; and new procedures and algorithms for parallel and distributed computing. Within these activities our research work includes the development of the methods and software tools for the modelling, simulation, analysis and synthesis of communication systems, pilots and experimental testbeds, computer simulations supporting biomedical procedures and specialised equipment and procedures for advanced bio-signal processing and interpretation.

Head:
Prof. Mihael Mohorčič

The research and development activities at the department are carried out in three laboratories, the *Communication Technology Laboratory (CTL),* the *Parallel and Distributed Systems Laboratory (PDSL)* and the *Networked Embedded Systems Laboratory (NESL).* The research work of the three laboratories is complementary, which is reflected in the joint applied projects.

In the **Communication Technology Laboratory**, we were continuing research started in previous years and looking at challenges associated with the access-segment of radio technologies. We focused on the research of radio transmission in terrestrial and satellite communications and the management of radio and network resources. This research is a part of the research program on Communication networks and services (P2-0016).

The research on the modelling and simulation of radio channels was a significant part of the Communication Technology Laboratory activities. We continued to study the ray-tracing algorithms in different environments, looking at algorithms and environment simplification to make radio wave propagation prediction more time efficient and accurate.

Thus, we proposed a variant of the discrete-ray algorithm, which traces a large number of rays from the transmitting source in all directions into the scene. The concept of a reception sphere is needed to detect rays passing by the receivers. Even if variable-sized reception spheres are applied, we fail to detect exactly one ray per wave front due to the geometry of the ray distribution in space. So, we proposed an efficient filtering of rays to avoid double counting and thus improving the channel modelling accuracy, while significantly reducing the algorithm memory requirements. Instead of approximate solutions proposed in the past, we put forward memory space-efficient probabilistic Bloom filters and show their near-optimal wave front differentiation properties. We achieved near-optimal double-counting avoidance at a significantly reduced memory space cost and lower time complexity than any known solution.

For the largest Slovenian mobile network operator Telekom Slovenije, d.d. we developed RaPlaT-GUI.

Furthermore, we optimized the description of the radio environment in terms of making the ray tracing faster and more accurate. We looked at radio propagation in natural caves, where modal analyses have given acceptable results in some cave passages, while multiple bends and highly irregular passages remained problematic. The main goal of this work was to gain basic knowledge of radio-waves propagation principles at different frequencies in this unique environment. In this respect we applied a ray-tracing approach on 3D cave geometry models, which was obtained by the laser scanning of natural caves. This enabled the creation of a cloud of points, which was transformed into the detailed 3D cave models saved in a stereolithography file format. The brute-force approach of running ray tracing on detailed 3D cave models revealed a significant deviation between the measured and simulated results, resulting from a too detailed description of the 3D cave in comparison to the radio waves' wavelength. Thus, the research was focused in the simplification of the cave model, i.e., increasing the size of the facet and transforming the cave details into facet roughness. The proposed approach was evaluated on three different cave passages and at three carrier frequencies interesting for modern communication systems. Despite the difficulties in the inaccurate position of measurements, an acceptable correlation was demonstrated.

In traditional telecommunication channel modelling the wavelength is small compared to the physical dimensions of the observed areas and the object of interest; however, extreme communication speeds, wireless access points closer to the user and smaller pico and femto cells require increased accuracy in predicting radio signals' propagation and testing the accuracy limits of the ray-tracing methods. The increased computing capabilities and the demand for better modelling of radio channels that span smaller geographical areas make numerical full-wave

techniques an attractive alternative even for larger problems. Solving fundamental Maxwell's equations is at the core of computational electrodynamics and best suited for modelling electrical field interactions with physical objects. In this respect, we studied ways of overcoming the excessive time requirements of numerical full-wave techniques while providing acceptable channel-modelling accuracy for the smallest radio cells and possibly wider. We identified several research paths that could lead to improved channel modelling, including numerical algorithm adaptations for large-scale problems, alternative finite-difference approaches, such as meshless methods, and dedicated parallel hardware, possibly as a realization of a dataflow machine.

In deterministic radio channel modelling, the knowledge of the radio-propagation environment is essential for accurate radio-wave propagation prediction. In this respect we proposed a novel idea of estimating the 3D geometry and the building material of indoor environments. The idea is based on the assumption that the received radio signal is distorted due to an interaction with the surrounding objects and thus includes the signature of the radio environment. We proposed a methodology for how to apply radio environment signatures for the characterizing the geometry and building material of indoor environments by applying machine-learning tools, using ray-tracing simulations and ultra-wide-band communication technology.

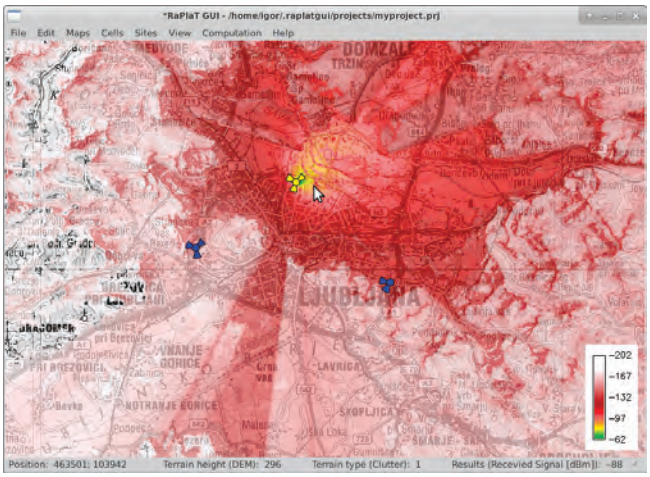

Figure 1: Computed received radio signal power in dBm

The software tool for radio-wave propagation modelling and the network optimization of mobile communication networks was upgraded with a graphical user interface (GUI). The GUI front end for the CLI (command line) package GRASS-RaPlaT (Radio Planning Tool) was developed for the largest Slovenian mobile network operator Telekom. While the original GRASS-RaPlaT is an open-source solution, developed by E6 (IJS), consisting of a number of modules for the open-source GRASS GIS (Geographic Information System), this GUI application has been made for a special branch of GRASS-RaPlaT that is being developed, maintained and used in-house by Telekom. The GUI reads the radio-network configuration data from a file in CSV format. The configuration can be modified, e.g., base stations added, deleted or moved, and their configurations and parameters changed. Base stations are drawn and can be manipulated on an underlying topographic map in the main application window, while their detailed configurations and parameters are shown and can be modified in the base-station editor window. Several propagation models are supported for the prediction of radio-wave propagation, among them also the model 9999, widely applied for cellular network planning. Although GRASS RaPlaT can compute various results, the main result is the received radio signal's strength in dBm at each point of the map, which can be used to estimate the communication link quality. The computed results are shown as a partly transparent color-coded map overlaid over a grayscale topographic map, and can also be stored in a database for further analysis.

Last year we successfully prolonged the SatProSi-Alpha project, carried out for the European Space Agency (ESA), the purpose of which was to investigate the atmosphere impacts on radio-wave propagation in the Ka-band (19.7 GHz) and Q-band (39.4 GHz) beacon signals from the Alphasat satellite. The annex resulted in additional one year of measurements with high 99.6% data availability. The project objective was to collect as much of the propagation data and their mutual analyses as possible, and thus enable an in-depth research of the atmosphere impacts on the satellite radio waves' propagation. In 2019 we conducted statistical analyses and proposed a prediction model of fade duration statistics for satellite communications at the Ka and Q bands. This model is based on a novel method that uses the copula theory and can be applied to single site slant paths as well as to site diversity systems. Experimental data from 21 single site and 10 site diversity experiments were included in the study for model development and evaluation. The performance of the new model for a single site was compared to the ITU-R P. 1623 and the Cheffena Amaya model. The proposed model is notably more accurate and easier to apply than the other two models. The new fade-duration prediction model also performs well for site-diversity systems and it is believed to be the first model in this research field.

The knowledge gained from the FP7 European project "Sustainable and robust networking for smart electricity distribution", SunSeed and knowledge obtained in recent post project research, focusing on the impact of model and measurement uncertainties on a state estimation in three-phase distribution networks, resulted in a book entitled "Observability of Power-Distribution Systems: State-Estimation Techniques and Approaches". The book will be published with Springer at the beginning of 2020. It addresses the challenges of future power-distribution systems, where due to the growth in distributed energy resources, the flow of electricity from utility to consumer has become a two-way street. The main focus of the book is in the design and implementation of a three-phase state estimation that is suitable for power-distribution networks. The research concentrates on the modelling of all the major power-distribution components to enable a three-phase network model's construction. The sensitivity analyses

revealed that the uncertain conductor length has a huge influence on the state-estimation accuracy. The presented sensitivity analysis enables a sensitivity evaluation of the chosen state-estimation algorithms and the measurement configuration. The presented lower and upper interval bounds give a clear indication of the performance of the state-estimation system that can be expected with the given accuracy of the model parameters and measurements.

In 2019 we continued with active participation in the COST Action 15104 IRACON "Inclusive radio communication networks for 5G and beyond", where we are contributing to disciplinary working groups concerned with radio channel, physical layer and network layer, as well as to experimental working groups on the localization and tracking and on the Internet of things.

Research activities in the field of wireless network optimization and management include a novel methodology that enables the prediction of the radio channels' properties beyond what is currently available, by taking the advantage of environmental information, measured channel state information (CSI) and information about the radio nodes. In the field of wireless mesh networks, investigated network coding techniques and network coding aware routing procedures in order to increase network capacity. In particular, we have focused on network and traffic design aspects in network-coding-enabled wireless networks.

We continued our research in the field of the Internet of Things (IoT), where we concentrated on indoor localization and the application of the IoT in the industrial environment. Thus, we upgraded nodes at the LOG a TEC testbed with a Contiki-NG protocol stack, which enables us to carry out experimental research in industrial IoT. In particular, we focused on testing the 6TiSCH standard and its interoperability implemented on different hardware and software platforms. In the scope within a bilateral project with the University of Banja Luka, Faculty of Electrical Engineering, we will look closely at the interoperability between 6TiSCH implementation on Contiki NG and OpenWSN.

The research in indoor localization results in a new self-calibrated device-free localization and activity detection approach based on ultra-wide-band propagation technology. The approach applies an automatic "zero touch" system setup applying a multidimensional scaling (MDS) algorithm for the node self-location and local coordinate system specification. The node-to-node distance estimation is based on two-way ranging. The radio tomography imaging was applied to estimate a person's location. The study revealed that an eight-node system is sufficient to achieve a person's location accuracy below one and half metres using a signal-level measurement.

In the **Parallel and Distributed Systems Laboratory** we continued research on solving computationally intensive problems and problems for which the computation is distributed over heterogeneous computer architectures. To this end, our activities are based on developing algorithms needed in various fields, including numerical simulations, multi-criteria optimizations, analyses of large amounts of data and graph theory. Our group closely cooperates with the Laboratory of Algorithmics at the Faculty of Computer and Information Science (FRI) and the Laboratory for Machine Intelligence at the Faculty of Electrical Engineering (FE) of the University of Ljubljana.

We extended our open-source Medusa library with an original parallel discretization algorithm and used it in applied and research projects.

We continued the development of local meshless methods for numerically solving of systems of partial differential equations (PDEs), where we strive to develop a coordinate free, completely local and general enough approach that can be written in a modular and scalable parallel code. We developed a new version of the algorithm for meshless discretization of an irregular domain, which we applied in a solution of the Navier-Cauchy equation and a h-adaptive solution of contact problems, thereby demonstrating the stability of the proposed methodology. The developed methods have been used in the FWO project "Multi-analysis of fretting fatigue using physical and virtual experiments", where we cooperate with the Universities of Gent and Luxembourg, with the goal to design and implement an alternative adaptive numerical method for solving contact problems, at which we succeeded. We have also employed the proposed algorithms in the solution of the fluid mechanics problem, where we presented an accurate and stable solution of the Navier-Stokes equation on an irregular 3D domain without the use of a mesh. Great attention has been paid to the fusion of the generality of the developed algorithms with generic programming, which is reflected in the Medusa modular open-source library for solving PDE systems.

We started a pilot Ketgate project with SinusPro GmbH. SinusPro is developing a 3D printing simulation. Our group helped to develop the prototype FreeFem++ and Medusa implementations of the thermo-elasticity problem, which is the most computationally complex part of the simulation. We also considered possibilities for coupling the simulation with Matcalc software.

Based on experiences from theoretical studies and technology transfer, we developed a DiTeR software that enables the forecasting of the thermal rating of power lines from operational and weather conditions. The implemented software package has achieved high reliability and industrial level of use (TRL 9), thus representing a product that can be marketed on an international level. In 2019 we successfully completed tests required for its transfer to operational use, and sold to the company ELES, d.o.o. a 3-year license (value €200,000) for its use on 27

transmission lines in the Slovenian power network. Furthermore, it is part of the solution chosen at the tender of the Croatian power transmission system operator for the installation of a pilot system for monitoring the thermal conditions of their network.

In 2019 we started implementing the project "Conceptual solution for estimating the uncertainty of dynamic thermal current as a result of the DTR process" for the client ELES. The aim of the project is to develop a complete operational process for estimating the uncertainty of the calculation of the thermal current, i.e., the highest current at which the transmission line is still operating safely. In 2019 we performed statistical analyses of weather data and temperature measurements of conductors on the Slovenian transmission line network. We estimated the uncertainty of the DTR process itself and prepared a prototype environment for performing Monte Carlo simulations for calculating the probability distributions of the dynamic thermal current as a function of weather and operational conditions.

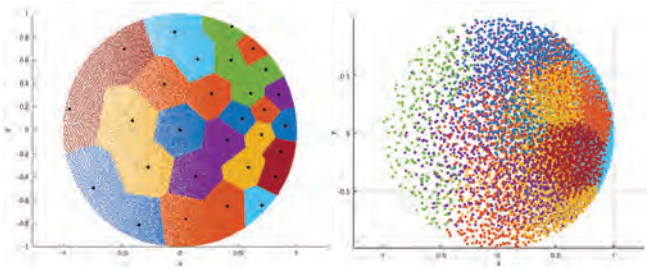

Figure 2: Discretization of an irregular domain with a parallel algorithm in 2D and 3D.

In 2019 we completed a bilateral project with Hungary "Graph Optimization and Big Data". Nowadays, data plays a big role in solving many actual problems related to the modern world. Despite the great computational power that is relatively easily accessible today, their effective analysis requires proper presentation and thoughtful and optimized approaches. The nature of the data frequently implies modelling the problem with graph data structures and replacing analytical and exact approaches with empirical and approximate ones. Graph data structures are usually in the focus of interest of discrete mathematicians, while computational approaches are in the focus of experts in the field of computer science. Therefore, the main goal of the project was to establish a close cooperation between a group of experts in discrete mathematics from the Alfréd Rényi Institute of Mathematics in Budapest, the University of Pécz and the University of Szeged and a group of experts in computer science from the Faculty of Computer and Information Science, University of Ljubljana, and the Jožef Stefan Institute.

As a continuation of our efforts in building a framework for the ambulatory collection of ECG signals, we have made upgrades to the ECG sensor and the related software items. For a project financed by the Ruđer Bošković Institute in Zagreb, we have upgraded the sensor hardware with an accelerometer for assessing a person's physical activity during the ECG measurement. In a continuous effort to increase the acceptance of the developed ECG sensor in primary medicine, we have been evolving its design to comply with the IEC 60601-2-47 standard for medical-grade ECG measurement apparatus. When the evolved sensor will be certified, the number of measurements with it should increase dramatically, aiding our goal of creating a database of long-term ambulatory ECG measurements for scientific research.

In the area of ECG signal analysis, we applied deep learning for the task of heartbeat classification and investigated how different segmentation techniques and evaluation schemes influence the overall classification results. Furthermore, we investigated methods for feature extraction in single-lead ECG for the purpose of heartbeat classification. The used feature-extraction methods originate from the field of time-series analysis. Results show that features emerging from different scientific areas can provide information for the separation of different class distributions that appear in the heartbeat classification problem. For this work, we received the Exceptional Outstanding Paper Award at the MIPRO 2019 conference.

In the field of formal methods for distributed systems, we discovered new sufficient conditions for the realizability and causal-consistent reversibility of global choreographies for systems with asynchronous inter-process communication.

In the **Networked Embedded Systems Laboratory** we continued the research, design, development and implementation of advanced hardware and software solutions for connecting various things and devices with the aim to improve their accessibility, utility and efficiency. To this end we are making use of contemporary concepts such as service-oriented architecture, dynamic service composition, cognitive communications, Internet of Things and others. The emphasis is placed on the vertical integration of different wireless-sensor and communication-network technologies in support of new applications, making use of the modular platform VESNA as the core building block in the development process and the LOG-a-TEC wireless testbed for testing, experimentation and validation.

We participated in a number of projects concerned with the development, testing and pilot validation of 5G services in various vertical application areas.

The LOG-a-TEC wireless testbed is part of the Next-Generation Internet Experimentation (NGI-EXP) initiative (previously FIRE/FIRE+ initiative) through the H2020 Fed4FIRE+ (Federation for FIRE plus) project and available through a common Fed4FIRE portal also to the community of external experimenters. In 2019 the LOG-a-TEC testbed was upgraded with the framework

to support also continuous integration (CI) and continuous delivery (CD) investigation and experimentation on devices with restricted capabilities in complex wireless operating environments.

In 2019 we continued with the research work in the H2020 projects NRG-5, DEFENDER and SAAM and the basic research project funded by the Slovenian Research Agency J2-9232 "Resource management for low latency reliable communications in smart grids - LoLaG". We also started a new H2020 project RESILOC and an industrial project eBOTTLE with Steklarna Hrastnik, and acquired an H2020 project BD4OPEM.

In NRG-5, which was also successfully concluded in 2019, we continued the investigation on link-quality estimation and radio-spectrum occupancy, focusing on the provision of massive ultra-reliable low-latency communications for control and fault localization in energy grids. We participated in the development of network and processing infrastructure monitoring and of a short-term predictor for energy production using photovoltaic panels, and supported pilot verification in a real operating environment. The above research activities were complemented with basic research in the LoLag project (ARRS J2-9232), where we investigated the provision of ultra-reliable massive low-latency communications and edge computing to support real-time monitoring, autonomous protection and distributed control. In 2019 we investigated new data-driven methods for advanced radio resource management, in particular the automated detection of wireless transmissions to support radio-spectrum sharing and link-quality estimation (LQE); developed a distributed platform for edge computing on devices with restricted capabilities; and extensively tested a phasor measurement unit (PMU) in dynamic simulations of an electric energy system using a real-time digital simulation (RTDS) framework focusing on standardized performance parameters.

Figure 3: SAAM system components: PMC in additional external housing and eGW with integrated UWB transceiver

In DEFENDER we continued with the design and implementation of advanced data-processing algorithms for the detection, identification and localization of cyber-physical threats based on data from PMU devices deployed in the energy grid. We concluded a thorough experimental verification of those algorithms in a laboratory environment using RTDS with hardware in the loop. The verified PMU devices will be deployed in a real operating pilot environment at the Italian Distribution System Operator ASM Terni for the demonstration of the identification and localization of cyber-physical threats.

In SAAM we participated in the design of a system for unobtrusive sensing support for monitoring and identifying the activity of the elderly population in their home environment. Our main focus in 2019 was on (i) finalizing the algorithms for multimodal activity and context monitoring via the energy consumption of home appliances and interference in the UWB radio channel; (ii) testing, validation and integration of individual components in a functional prototype user-side system; and (iii) support to initial pilot deployments in real home environments in Bulgaria.

In June 2019 we started a new H2020 project RESILOC in the security area concerned with the resilience of local communities to different disasters and events. Our role of a technical partner is focusing on the investigation and provision of technical means and solutions for the radio localization of victims or first responders, monitoring environmental parameters and basic infrastructure-less communication, thus improving the resilience indicators of a community.

We also started a collaboration with Steklarna Hrastnik on the eBOTTLE project concerned with the life-cycle management of glassware, where we are focusing on the development of smart tags, backend system for data and tags management and reference mobile and web applications aimed at different stakeholders in the value chain. In 2019 we investigated the most suitable candidate technologies for smart tags and started with the development of functional prototypes of reference active and passive tags to be integrated into bottles.

Some outstanding publications in the past year

1. Kuhar, Urban, Pantoš, Miloš, Kosec, Gregor, Švigelj, Aleš. The impact of model and measurement uncertainties on a state estimation in three-phase distribution networks. IEEE transactions on smart grid, ISSN 1949-3053. [Print ed.], 2019, vol. 10, no. 3, str. 3301-3310, ilustr. https://ieeexplore.ieee.org/document/8331939/, doi: 10.1109/TSG.2018.2823398
2. Novak, Roman. Bloom filter for double counting avoidance in radio frequency ray tracing. IEEE transactions on antennas and propagation, ISSN 0018-926X. [Print ed.], 2019, vol. 67, no. 4, str. 2176-2190, doi: 10.1109/TAP.2019.2905780.
3. Kelmendi, Arsim, Hrovat, Andrej, Mohorčič, Mihael, Vilhar, Andrej. Prediction model of fade duration statistics for satellite communications at ka and Q bands. IEEE transactions on antennas and propagation, ISSN 0018-926X. [Print ed.], 2019, vol. 67, no. 8, str. 5519-5531, doi: 10.1109/TAP.2019.2916657.

4. Slak, Jure, Kosec, Gregor. On generation of node distributions for meshless PDE discretizations. SIAM journal on scientific computing, ISSN 1064-8275, 2019, vol. 41, no. 5, str. A3202-A3229, doi: 10.1137/18M1231456.
5. Kosec, Gregor, Slak, Jure, Depolli, Matjaž, Trobec, Roman, Pereira, Kyvia, Tomar, Satyendra, Jacquemin, Thibault, Bordas, Stéphane Pierre Alain, Wahab, Magd Abdel. Weak and strong from meshless methods for linear elastic problem under frettingcontact conditions. Tribology international, ISSN 0301-679X, 2019, vol. 138, str. 392-402, doi: 10.1016/j.triboint.2019.05.041.
6. Maksić, Miloš, Djurica, Vladimir, Souvent, Andrej, Slak, Jure, Depolli, Matjaž, Kosec, Gregor. Cooling of overhead power lines due to the natural convection. International journal of electrical power & energy systems, ISSN 0142-0615. [Print ed.], 2019, vol. 113, str. 333-343, doi: 10.1016/j.ijepes.2019.05.005.
7. Kuru, Kaya, Ansell, Darren, Khan, Wasiq, Yetgin, Halil. Analysis and optimization of unmanned aerial vehicle swarms in logistics. IEEE access, ISSN 2169-3536, 2019, vol. 7, str. 15804-15831, doi: 10.1109/ACCESS.2019.2892716.
8. Kuru, Kaya, Yetgin, Halil. Transformation to advanced mechatronics systems within new industrial revolution : a novel framework in automation of everything (AoE). IEEE access, ISSN 2169-3536, 2019, vol. 7, str. 41395-41415, doi: 10.1109/ACCESS.2019.2907809.
9. Šolc, Tomaž, Yetgin, Halil, Gale, Timotej, Mohorčič, Mihael, Fortuna, Carolina. Whitelisting in RFDMA networks. IEEE access, ISSN 2169-3536, 2019, vol. 7, str. 159284-159299, doi: 10.1109/ACCESS.2019.2950754.

Awards and Appointments

1. Prof. Gorazd Kandus, Emeritus Scientist of the Jozef Stefan Institute, Ljubljana, Jozef Stefan Institute

Organization of Conferences, Congresses and Meetings

1. Meeting and worshop of the project H2020 – DEFENDER, Ljubljana, 5–7 March 2019
2. Meeting and worshop of the project H2020 – SAAM, Ljubljana, 10–12 April 2019

INTERNATIONAL PROJECTS

1. Antenna Tracking System Simulator Verification
   Dr. Andrej Vilhar
   Hitec Luxembourg S.a.
2. CROSSING - Crossing Borders and Scales - An Interdisciplinary Approach
   Dr. Matjaž Depolli
   Helmholtz-zentrum Dresden-rossendorf E.v.
3. COST IC1405; Reversible Computation - Extending Horizons of Computing
   Prof. Monika Kapus Kolar
   Cost Office
4. COST CA15104; Inclusive Radio Communication Networks for 5G and Beyond (IRACON)
   Prof. Tomaž Javornik
   Cost Office
5. ESA - SatProSi-Alpha; Ka/Q-band Propagation Measurements and Modelling - Slovenian Contribution to the Alphasat TDP#5 Scientific Mission
   Prof. Aleš Švigelj
   Esa/estec.
6. COST CA18203; ODIN - Optimising Design for Inspection
   Prof. Roman Trobec
   Cost Association Aisbl
7. H2020 - Fed4FIREplus; Federation for FIRE Plus
   Prof. Mihael Mohorčič
   European Commission
8. H2020 - DEFENDER; Defending the European Energy Infrastructures
   Prof. Mihael Mohorčič
   European Commission
9. H2020 - EuConNeCts3; European Conferences on Networks and Communications (EuCNC)
   Prof. Mihael Mohorčič
   European Commission
10. H2020 - NRG-5; Enabling Smart Energy as a Service via 5G Mobile Network Advances
    Dr. Carolina Fortuna
    European Commission
11. H2020 - SAAM; Supporting Active Ageing through Multimodal Coaching
    Prof. Mihael Mohorčič
    European Commission
12. H2020 - RESILOC; Resilient Europe and Societies by Innovating Local Communities
    Prof. Mihael Mohorčič
    European Commission
13. Joint Scheduling and Routing Algorithm for Delay Sensitive Industrial Applications in Wireless Networks
    Asst. Prof. Andrej Hrovat
    Slovenian Research Agency

RESEARCH PROGRAMMES

1. Communication networks and services
   Prof. Mihael Mohorčič
2. Parallel and Distributed Systems
   Prof. Roman Trobec

R&D GRANTS AND CONTRACTS

1. Graph Optimisation and Big Data
   Dr. Matjaž Depolli
2. Multi-analysis of fretting fatigue using physical and virtual experiments
   Prof. Roman Trobec
3. Resource management for low latency reliable communications in smart grids – LoLaG
   Prof. Mihael Mohorčič
4. Advanced Ray-Tracing Techniques in Radio Environment Characterization and Radio Localization
   Prof. Mihael Mohorčič
5. Smart City Ecosystem – EkoSmart
   Prof. Roman Trobec
   Ministry of Education, Science and Sport
6. Central European SME Gateway zo Key-enabling Technology Infrastructures - Sparking new Transnational KET Innovation Ecosystem
   Dr. Gregor Kosec
   Bay Zoltan Alkalmazott Kutatasi Kozhasznu
7. Fusion of ECG and Motion Sensor Data
   Prof. Roman Trobec
   Ruđer Bošković Institute

NEW CONTRACTS

1. Implementation of GUI interface for RaPlaT
   Prof. Tomaž Javornik
   Telekom Slovenije, d. d.
2. Advanced ICT services for the analysis of the life cycle of glass packaging
   Prof. Mihael Mohorčič
   Razvojni Center Enem Novi Materiali d. o. o.
3. Conceptual solution of dynamic thermal current uncertainty estimation as a result of DTR process
   Dr. Gregor Kosec
   Eles, d. o. o.

VISITORS FROM ABROAD

1. Claus Pribbernow, Interactive Wear AG, Starnberg, Germany, 7–9 January 2019
2. dr. Satyendra Tomar, Université du Luxembourg, Luxembourg, Luxembourg, 14 January to 1st April 2019
3. Teodora Kocevska, Faculty of Electrical Engineering and Information Technologies, The Saints Cyril and Methodius University, Skopje, Republic of North Macedonia, 15 April to 15 June 2019 and 23 September to 30 November 2019
4. Elena Merdjanovska, Faculty of Electrical Engineering and Information Technologies, The Saints Cyril and Methodius University, Skopje, Republic of North Macedonia, 1–21 June 2019 and 23 September to 30 November 2019
5. Rares Mosoi, Technical University of Cluj-Napoca, Cluj-Napoca, Romania, 1st July to 31st August 2019
6. dr. Dragan Vasiljević, Telecommunications of Republika Srpska, Banja Luka, Bosnia and Herzegovina, 5–21 September 2019

STAFF

Researchers
1. Dr. Viktor Avbelj
2. Dr. Matjaž Depolli
3. Dr. Carolina Fortuna
4. Asst. Prof. Andrej Hrovat
5. Prof. Tomaž Javornik
6. Prof. Monika Kapus Kolar
7. Dr. Gregor Kosec
8. Prof. Andrej Lipej*
9. **Prof. Mihael Mohorčič, Head**
10. Asst. Prof. Roman Novak
11. Dr. Igor Ozimek
12. Dr. Aleksandra Rashkovska Koceva
13. Prof. Aleš Švigelj
14. Prof. Roman Trobec
15. Halil Yetgin, B. Sc.

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17. Dr. Arsim Kelmendi*
18. Dr. Rituraj Singh

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19. Gregor Cerar, B. Sc.
20. Marko Hudomalj, B. Sc.
21. Jure Slak, B. Sc.
22. Denis Sodin, B. Sc.

Technical officers
23. Polona Anžur, B. Sc.
24. Mitja Jančič, B. Sc.
25. Miha Mohorčič, B. Sc.
26. Miha Smolnikar, B. Sc.

Technical and administrative staff
27. Tomaž Krištofelc
28. Tamara Matevc, B. Sc.
29. Marko Mihelin*, B. Sc.
30. Matevž Vučnik, B. Sc.

Note:
* part-time JSI member

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Original Article

1. Michelangelo Ceci, Roberto Corizzo, Donato Malerba, Aleksandra Rashkovska, "Spatial autocorrelation and entropy for renewable energy forecasting", *Data mining and knowledge discovery*, 2019, **33**, 3, 698-729.
2. Naim Suleyman Ting, Yakup Sahin, Halil Yetgin, "Design and implementation of an IBC reduced voltage across output capacitor", *Electrical engineering*, 2019, **101**, 2, 517-525.
3. Jure Slak, Gregor Kosec, "Refined meshless local strong form solution of Cauchy-Navier equation on an irregular domain", *Engineering analysis with boundary elements*, 2019, **100**, 3-13.
4. Rituraj Singh, Krishna Mohan Singh, "Interpolating meshless local Petrov-Galerkin method for steady state heat conduction problem", *Engineering analysis with boundary elements*, 2019, **101**, 56-66.
5. Rituraj Singh, Krishna Mohan Singh, "Stabilised MLS in MLPG method for heat conduction problem", *Engineering computations*, 2019, **36**, 4, 1323-1345.
6. Klemen Bregar, Roman Novak, Mihael Mohorčič, "Evaluation of range-based indoor tracking algorithms by merging simulation and measurements", *EURASIP Journal on wireless communications and networking*, 2019, **2019**, 173.
7. Kaya Kuru, Darren Ansell, Wasiq Khan, Halil Yetgin, "Analysis and optimization of unmanned aerial vehicle swarms in logistics", *IEEE access*, 2019, **7**, 15804-15831.
8. Kaya Kuru, Halil Yetgin, "Transformation to advanced mechatronics systems within new industrial revolution: a novel framework in automation of everything (AoE)", *IEEE access*, 2019, **7**, 41395-41415.
9. Tomaž Šolc, Halil Yetgin, Timotej Gale, Mihael Mohorčič, Carolina Fortuna, "Whitelisting in RFDMA networks", *IEEE access*, 2019, **7**, 159284-159299.
10. Arsim Kelmendi, Andrej Hrovat, Mihael Mohorčič, Andrej Vilhar, "Prediction model of fade duration statistics for satellite communications at ka and Q bands", *IEEE transactions on antennas and propagation*, 2019, **67**, 8, 5519-5531.
11. Roman Novak, "Bloom filter for double counting avoidance in radio frequency ray tracing", *IEEE transactions on antennas and propagation*, 2019, **67**, 4, 2176-2190.
12. Urban Kuhar, Miloš Pantoš, Gregor Kosec, Aleš Švigelj, "The impact of model and measurement uncertainties on a state estimation in three-phase distribution networks", *IEEE transactions on smart grid*, 2019, **10**, 3, 3301-3310.
13. Jure Slak, Gregor Kosec, "Adaptive radial basis function-generated finite differences method for contact problems", *International journal for numerical methods in engineering*, 2019, **119**, 7, 661-686.
14. Jurij-Matija Kališnik, Viktor Avbelj, Jon Vratanar, Giuseppe Santarpino, Borut Geršak, Theodor Fischlein, Roman Trobec, Janez Žibert, "Cardiac autonomic regulation and PR interval determination forenhanced atrial fibrillation risk prediction after cardiac surgery", *International journal of cardiology*, 2019, **289**, 24-29.
15. Kemal Alič, Mihael Mohorčič, Aleš Švigelj, "Network and traffic design aspects in network-coding-enabled wireless networks", *International Journal of Computers, Communications & Control*, 2019, **14**, 3, 293-310.
16. Miloš Maksić, Vladimir Djurica, Andrej Souvent, Jure Slak, Matjaž Depolli, Gregor Kosec, "Cooling of overhead power lines due to the natural convection", *International journal of electrical power & energy systems*, 2019, **113**, 333-343.
17. Spiros Ventouras *et al.* (25 authors), "Assessment of spatial and temporal properties of Ka/Q band earth-space radio channel across Europe using Alphasat Aldo Paraboni payload", *International journal of satellite communications and networking*, 2019, **37**, 5, 477-501.
18. Boris Širaiy, Roman Trobec, Vladimir Ilić, "Quality of one-channel telemetric ECG sensor Signal in maximum exercise stress tests", *Measurement science review*, 2019, **19**, 3, 79-85.
19. Jure Slak, Gregor Kosec, "On generation of node distributions for meshless PDE discretizations", *SIAM journal on scientific computing*, 2019, **41**, 5, a3202-a3229.
20. Gregor Kosec, Jure Slak, Matjaž Depolli, Roman Trobec, Kyvia Pereira, Satyendra Tomar, Thibault Jacquemin, Stéphane Pierre Alain Bordas, Magd Abdel Wahab, "Weak and strong from meshless methods for linear elastic problem under fretting contact conditions", *Tribology international*, 2019, **138**, 392-402.

Published Conference Contribution

1. Ke Guan, Danping He, Bo Ai, Bile Peng, Andrej Hrovat, Junhyeong Kim, Zhangdui Zhong, Thomas Kürner, "Millimeter-wave communications for smart Rail Mobility: from channel modeling to prototyping", In: *2019 IEEE International Conference on Communications Workshops, (ICC Workshops): Shanghai, China, 22-24 May 2019*, Proceedings, IEEE, 2019.
2. Boro P. Popovski, Andrej Lipej, Zoran Markov, Predrag Popovski, "Optimisation of Pelton turbine jet deflector using CFD analysis", In: *29th IAHR Symposium on Hydraulic Machinery and Systems, September 17-21, 2018, Kyoto (Japan)*, (IOP conference series. Earth and environmental science, **240**, 2), 2019, 022031.
3. Andrej Lipej, Simon Muhič, Duško Mitruševski, "Wall roughness influence on the NPSH characteristics of centrifugal pumps", In: *29th IAHR Symposium on Hydraulic Machinery and Systems, September 17-21, 2018, Kyoto (Japan)*, (IOP conference series. Earth and environmental science, **240**, 3), 2019, 032019.
4. Ivan Boškov, Matevž Vučnik, Carolina Fortuna, Mihael Mohorčič, "Automated initial configuration of wireless embedded devices in the internet of things", In: *BalkanCOM 2019, 5G and beyond*, 2019, 5.
5. Jure Slak, Gregor Kosec, "Fast generation of variable density node distributions for mesh-free methods", In: *Boundary Elements and other Mesh Reduction Methods XXXXI*, (WIT transactions on Engineering sciences, **122)**, WIT Press, 2019, 163-173.
6. Andrej Hrovat, Ke Guan, Teodora Kocevska, Tomaž Javornik, "3D indoor environment characterization based on radio scanning", In: *ICECOM 2019, 23rd International Conference on Applied Electromagnetics and Communications, September 30, 2019 - October 2, 2019, Dubrovnik, Croatia*, Conference proceedings, KoREMA, 2019.
7. Klemen Bregar, Tomaž Javornik, Andrej Hrovat, Mihael Mohorčič, Gorazd Kandus, "Passive ultra-wideband coarse localization and activity detection system for assisted living", In: *ICECOM 2019, 23rd International Conference on Applied Electromagnetics and Communications, September 30, 2019 - October 2, 2019, Dubrovnik, Croatia*, Conference proceedings, KoREMA, 2019.
8. Klemen Bregar, Andrej Hrovat, Roman Novak, Tomaž Javornik, "Channel impulse response based vehicle analysis in tunnels", In: *EuCAP 2019*, Proceedings, EurAAP, 2019.
9. Arsim Kelmendi, Andrej Vilhar, Andrej Hrovat, Mihael Mohorčič, "Modelling of fade duration statistics in earth-satellite slant paths using copulas", In: *EuCAP 2019*, Proceedings, EurAAP, 2019.
10. Naim Suleyman Ting, Yakup Sahin, Halil Yetgin, "An active snubber cel for soft switched PFC boost converters", In: *VII. UMTEB International Congress on Vocational & Technical Sciences, August, 5-7, 2019, Batumi, Georgia*, Full text book, Institute of Economic Development and Social Researches Publications, 2019, 25-31.
11. Vladimir Djurica, Klemen Jevnikar, Miloš Maksić, Gregor Kosec, "Laboratory measurements of thermal behavior of overhead power lines due to natural convection", In: *Innovation in the Power System Industry: special of the 21st International Symposium of High Voltage Engineering (ISH) 2019, August 2019, Budapest, Hungary*, (Cigre science engineering, **16)**, 2019, 29-34.
12. Tomaž Javornik, Aleš Švigelj, Andrej Hrovat, Igor Ozimek, "Users' QoS driven radio resources optimization based on radio environment map", In: *International Conference on Mathematical Models & Computational Techniques in Science & Engineering 23-25, February 2019, London, UK*, (Journal of physics, Conference series, **1334)**, 2019, 012016.
13. Ivan Tomašić, N. Petrović, Mikael Linden, Aleksandra Rashkovska, "Comparison of publicly available beat detection algorithms performances on the ECGs obtained by a patch ECG device", In: *MIPRO 2019: 42nd International Convention, May 20 -24, 2019, Opatija, Croatia*, Proceedings, MIPRO, 2019, 294-297.
14. Matjaž Depolli, Roman Trobec, "Computational efficiency of linear system construction for MLPG method on a multicore computer", In: *MIPRO 2019: 42nd International Convention, May 20 -24, 2019, Opatija, Croatia*, Proceedings, MIPRO, 2019, 211-216.
15. Roman Trobec, Matevž Jan, Mikael Linden, Ivan Tomašić, "Detection and treatment of atrial irregular rhythm with body gadgets and 35-channel ECG", In: *MIPRO 2019: 42nd International Convention, May 20 - 24, 2019, Opatija, Croatia*, Proceedings, MIPRO, 2019, 320-327.
16. I. Grubišić, Danijel Davidović, Karolj Skala, Matjaž Depolli, Miha Mohorčič, Roman Trobec, "Enriching heart monitoring with accelerometer data", In: *MIPRO 2019: 42nd International Convention, May 20 -24, 2019, Opatija, Croatia*, Proceedings, MIPRO, 2019, 328-332.
17. Jasmin Bogatinovski, Dragi Kocev, Aleksandra Rashkovska, "Feature Extraction for Heartbeat Classification in Single-Lead ECG", In: *MIPRO 2019: 42nd International Convention, May 20 -24, 2019, Opatija, Croatia*, Proceedings, MIPRO, 2019, 339-343.
18. Jure Močnik Berljavac, Jure Slak, Gregor Kosec, "Parallel simulation of time-domain acoustic wave propagation", In: *MIPRO 2019: 42nd International Convention, May 20 -24, 2019, Opatija, Croatia*, Proceedings, MIPRO, 2019, 223-228.
19. Blaž Stojanovič, Jure Slak, Gregor Kosec, "RBF-FD Solution of Electromagnetic Scattering Problem", In: *MIPRO 2019: 42nd International Convention, May 20 -24, 2019, Opatija, Croatia*, Proceedings, MIPRO, 2019, 217-222.
20. Maja Brložnik, Aleksandra Domanjko-Petrič, Vesna Kadunc Kos, Aleksandra Rashkovska, Viktor Avbelj, "Wireless body sensor for electrocardiographic monitoring in equine medicine", In: *MIPRO 2019: 42nd International Convention, May 20 -24, 2019, Opatija, Croatia*, Proceedings, MIPRO, 2019, 279-283.
21. Halil Yetgin, "A survey of joint routing and energy optimization techniques for underwater acoustic sensor networks", In: *ICATCES 2019, International Conference on Advanced Technologies, Computer Engineering and Science, 26-28 Apr. 2019, Alanya, Turkey*, Proceedings book, 71-76.
22. Ali Tilfargil, İdil Koç, Halil Yetgin, "Eektrikiç tesislerinde 8 kanalli röle kontrol karti iile akilli sistem tasarimi", In: *Proceedings book*, Cizgi Kitabevi, 2019, 408-414.
23. Naim Suleyman Ting, Yakup Sahin, Halil Yetgin, "A new interleaved boost converter reduced voltage on output filter capacitor", In: *Proceedings book*, Cizgi Kitabevi, 2019, 1243-1248.
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25. Denis Sodin, Marko Mihelin, Miha Smolnikar, Urban Rudež, "IEEE standards compliance testing of PMU with RTDS", In: *Štirinajsta konferenca slovenskih elektroenergetikov, Laško, 21.-23. maj 2019*, Referati in predstavitve, Slovensko združenje elektroenergetikov CIGRE - CIRED, 2019.
26. Matevž Vučnik, Aleš Švigelj, Gorazd Kandus, Mihael Mohorčič, "Secure hybrid publish-subscribe messaging architecture", In: *SoftCOM 2019, International Conference on Software, Telecommunications & Computer Networks, 19-21 September, 2019, Split, Croatia*, Proceedings, FESB, 2019.
27. Diego Rivera, Edgardo Montes de Oca, Wissam Mallouli, Ana R. Cavalli, Brecht Vermeulen, Matevž Vučnik, "Industrial IoT security monitoring and test on Fed4Fire+ platforms", In: *Testing software and systems: 31st IFIP WG 6.1 International Conference, ICTSS 2019, Paris, France, October 15-17, 2019* Proceedings, (Lecture notes in computer science, **11812)**, Springer, 2019, 270-278.
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30. Andrej Hrovat, Gregor Cerar, Gordana Gardašević, Dragan Vasiljević, Tomaž Javornik, "Testing the interoperability of the joint scheduling and routing algorithm for IIoT applications", In: *Proceedings of the Twenty-eighth International Electrotechnical and Computer Science Conference ERK 2019*, *Portorož, Slovenija, 23.-24. september 2019,* Društvo Slovenska sekcija IEEE, 2019, 40-43.

Independent Component Part or a Chapter in a Monograph

1. Nenad Korolija, Roman Trobec, "An overview of selected DataFlow applications in physics simulations", In: *Exploring the DataFlow supercomputing paradigm: example algorithms for selected applications*, (Computer communications and networks), Springer, 2019, 229-240.

Theses and Mentoring

1. Klemen Bregar, *Modelling the effects of indoor environments on localization with ultra-wideband radio signals:* doctoral dissertation, Ljubljana, 2019 (mentor Mihael Mohorčič).

COMPUTER SYSTEMS DEPARTMENT E-7

The Computer Systems Department is concerned primarily with the development of efficient algorithms for massive-data processing, advanced computing structures for the faster and more reliable execution of algorithms and effective interfaces for human-computer interactions. Within this broad area, we are concentrating on self-reparable and self-adapting systems, the modelling and optimizing of complex, dynamic and non-deterministic systems. Our research results are implemented within applications for production, transport, energy, bioinformatics, health, and medicine. As an integral part of our research activities, members of the department have close contacts and collaborations with scientists world-wide, through academic links and industrial contacts, thus enabling us to keep at the forefront of rapidly developing fields.

Head:
Prof. Gregor Papa

In 2019 we started with the next 6-year period of our updated **research programme**, funded by the Slovenian Research Agency. The programme is aligned with European and national roadmaps and strategic papers: the Slovenian Research and Innovation Strategy, the HiPEAC Vision, the ARTEMIS strategic research agenda, and Slovenia's Smart Specialisation Strategy, as well as being closely correlated with the research objectives of the EU Framework Programme for Research and Innovation Horizon 2020. The programme is focused on relevant research and development in areas related to reconfigurable systems: reliability, architectures for data-intensive systems, hardware/software co-design, resource planning and scheduling, adaptive and learning control methodologies, dynamic adaptation to changing contexts, decision in uncertain and changing contexts. The interdisciplinary state-of-the-art research challenges combine fields from computer science, engineering and mathematics. These challenges include reconfigurable optimisation algorithms (to efficiently deal with massive data in dynamic and uncertain environments), context-awareness with the support of applied statistical analyses and network topology (to determine when and how to reconfigure), reconfigurable hardware platforms (based on intrinsically parallelized FPGAs) with self-correction (for higher reliability) and approximate computing (for energy efficiency).

Our research work in 2019 was complemented by the design, development and implementation of various solutions within 12 European projects in *Horizon 2020, FP7, COST* and *EFSA* programs, as well as in 13 national projects. Our work is also actively connected to activities of the Slovenian *Strategic research and innovation partnerships* in the domains of *Smart cities and communities* and *Factories of the future*.

Algorithms for Data Processing

The research in the field of efficient algorithms for data processing was focused on the development of multi-objective optimisation approaches, approaches for statistical comparison and knowledge extraction, neural networks and pattern recognition. Several solutions were used at the application level within computer support for our *Open platform for clinical nutrition*, as well as for intelligent support of smart factories and smart cities.

Optimisation algorithms

Many real-world application areas, such as advanced manufacturing, involve the optimisation of several, often time-consuming and conflicting objectives. They may require the maximisation of the product quality while minimising the production cost, relying on demanding numerical simulations. These **multi-objective optimisation** problems can be solved more effectively if **parallelisation** is used to execute the simulations simultaneously and if the simulations are partly replaced by **surrogate models**. We worked on a Horizon 2020 Twinning project *SYNERGY - Synergy for smart multi-objective optimisation* (http://synergy-twinning.eu/), where the overall goal was to enhance the research in multi-objective optimisation at the Jožef Stefan Institute (JSI). We were a coordinating partner, and collaborated with two high-profile research institutions with complementary expertise, Université des sciences et technologies de Lille, France, and TH Köln - University of Applied Sciences, Germany. The project has significantly strengthened the JSI's expertise in surrogate-assisted multi-objective optimisation and large-scale parallel architectures for multi-objective optimisation, and provided the supporting actions needed to merge these two efficient concepts into smart multi-objective optimisation. Together, the partners dealt with the optimisation of complex real-world problems more efficiently and the acquired knowledge was disseminated to Slovenian industry and other research institutions. The results of this collaboration improved the excellence of researchers at the JSI, raised our research profile and provided the means for spreading innovation to industry.

Improved excellence and recognisability can be also seen in the organisation of workshops, special sessions and tutorials at renowned conferences.

We continued with Horizon 2020 Marie Skłodowska-Curie Actions project *UTOPIAE - Uncertainty Treatment and OPtimisation In Aerospace Engineering* (http://utopiae.eu/). The main aim is in bridging **optimisation and uncertainty quantification** in aerospace systems applications. Developing fundamental mathematical methods and algorithms to bridge the gap between uncertainty quantification and optimisation and between probability theory and imprecise probability theory for uncertainty quantification will lead to efficient solutions of high-dimensional, expensive and complex engineering problems. We organized and hosted, in collaboration with ESTECO, Italy, the Second Global Virtual Workshop (GVW-II). It was focused on the topics of programming and optimisation. The lectures on topics were given by the lecturers from three different Slovenian universities (Ljubljana, Maribor and Primorska) and from ESTECO. The integrated part of the GVW-II event was also the co-located *Fifth Optimisation in Space Engineering workshop (OSE5)*. It was co-organized with the European Space Agency, the University of Strathclyde and ESTECO. Its goal was to discuss recent advances in space technology and further research in the area of optimisation in space engineering.

The main objective of the ARRS research project *Biomedical data fusion by nonnegative matrix tri-factorisation*, in collaboration with the University of Ljubljana, is the development of new, efficient and accurate **methods for non-negative matrix factorisation** (NMTF) and their use to search for previously unknown associations in biomedical data. Such associations can lead to further patient stratification, the discovery of new disease biomarkers, drug repurposing and similar. Our research group extensively explored the effectiveness of evolutionary and memetic approaches for solving NMTF problems. During this study single-solution gradient-based optimisation algorithms were found to be especially effective in solving NMTF problems. Based on this observation our group developed a library *nmfgd* that can be used to perform gradient-based optimisation on generalized NM(T)F problems. The library implements both multi-core and multi-node parallelism, the ability to use sparse matrices and various types of regularisations and constraints. This library will be tested on an inflammatory bowel disease (IBD) data to search for new associations among genetic, metagenetic, metabolomic and dietary data of patients with IBD. An extensive comparison of different gradient-based optimisation algorithms for this problem is currently in progress. In scope of this research topic, Rok Hribar spent a one-month secondment at the Life Sciences department at the Barcelona Supercomputing Center, Spain.

The ARRS young researcher project of Rok Hribar is dealing with the application of **gradient-based methods in machine learning and large-scale optimisation**. The exploration of the effectiveness of gradient-based methods was performed in all three branches of machine learning: supervised, unsupervised and reinforcement learning. In the supervised learning domain, work was reported in the *Energy* journal. In the unsupervised domain a library for solving the kernel *k*-means clustering problem using gradient-based methods was developed and is being used to cluster IBD data to search for new associations among data. In the reinforcement learning domain, gradient-based optimisation was used to find strategies for initial point generation and parameter control of general optimisation algorithms with simulated annealing and differential evolution being the use cases. In the large-scale optimisation domain, two use cases are being explored: general action minimisation found in physics and shape optimisation of moving objects under the finite-boundary method.

The ARRS young researcher project of Urban Škvorc was focused on **landscape analysis** within the areas of optimisation algorithms, benchmarking and machine learning. He attended the training school at the University of Coimbra, Portugal, organized in the scope of COST Action *ImAppNIO – Improving Applicability of Nature-Inspired Optimisation by Joining Theory and Practice* (http://imappnio.dcs.aber.ac.uk/). During the course of his studies, two research papers were published and presented at the *GECCO 2019* and *CEC 2019* conferences, and in *Applied Soft Computing* journal.

Tome Eftimov received ARRS post-doc funding for the project *Mr-BEC: Modern approaches for Benchmarking in Evolutionary Computation* (http://cs.ijs.si/project/mrbec/). The main objective of the project is to invent, develop, implement, and evaluate a framework for **benchmarking in evolutionary computation**, which will consist of methodologies that will bring an in-depth understanding of the algorithms' behaviour, especially focusing on identifying practical significance, obtaining knowledge on performance using the information from space distribution (high-dimensional data), and making a more general benchmarking conclusion using a set of performance metrics. The methodologies will be based on a synergism between statistics, information theory, and random matrix theory. The results of the research include two papers in *Applied Soft Computing* journal, one in *Information Fusion* journal, conference paper at the *BPOD/IEEE BigData 2019*, and one tutorial at the *IEEE SSCI 2019*. Tome Eftimov received the Best Young Research award for 2018 in North Macedonia, given by the president of the country. He also received the 2019 award for extraordinary achievements in science in his home city, Strumica, North Macedonia. He performed a one-year postdoctoral research at Stanford University, USA.

At the *IEEE Congress on Evolutionary Computation – IEEE CEC 2019*, we organized together with Artificial Intelligence Research Institute, Spanish National Research Council, the 1st International Workshop on Understanding of Evolutionary Algorithms Behavior – *UEOB 2019*.

In cooperation with the Department of Intelligent Systems at the JSI and the Faculty of Electrical Engineering and Computer Science, University of Maribor, we organized, for the sixteen consecutive year, the **Nature-inspired algorithms workshop** dealing with stochastic optimisation techniques.

Statistical approaches

A novel statistical approach, **extended Deep Statistical Comparison** (eDSC), for comparing meta-heuristic stochastic optimisation algorithms according to the distribution of the solutions in the search space was introduced. Its main contribution is that the algorithms are compared not only according to obtained solutions values, but also according to the distribution of the obtained solutions in the search space. The information it provides can additionally help to identify exploitation and exploration powers of the compared algorithms. This is important when dealing with a multimodal search space, where there are a lot of local optima with similar values. The benchmark results show that our approach can be used for a statistical comparison of meta-heuristic stochastic optimisation algorithms according to solutions values and their distribution in the search space. The work was published in the *Information Sciences* journal. An extension of the DSC approach, i.e., practical Deep Statistical Comparison (pDSC), which takes into account practical significance when making a statistical comparison of meta-heuristic stochastic optimisation algorithms for single-objective optimisation was published in the *Applied Soft Computing* journal.

DSCTool is a statistical tool for comparing the performance of stochastic optimisation algorithms on a single benchmark function (i.e., single-problem analysis) or a set of benchmark functions (i.e., multiple-problem analysis). DSCTool implements a recently proposed approach, DSC and its variants. The main advantage of DSCTool are its REST web services, as all its functionalities can be accessed from any programming language. Its details are presented in the *Applied Soft Computing* journal.

Information extraction and knowledge discovery

Within the Horizon 2020 project *SAAM – Supporting Active Ageing through Multimodal coaching* (http://bilsp.org/saam-active-ageing/) we created a **FoodOntoMap** resource that consists of food concepts extracted from recipes. For each food concept, semantic tags from four food ontologies are assigned. With this we have created a resource that provides a link between different food ontologies that can be further reused to develop applications for understanding the relation between food systems, human health, and the environment. Assessing the nutritional components of food is very challenging and we developed the idea of finding similar recipes with regard to their macro-nutrient values based on learned recipe vector representation. The work was presented at the *KEOD/IC3K 2019* conference. On a scientifically proven dataset of recipe data containing description and macro-nutrient values we introduce word and paragraph embeddings, learn concept representations for the textual descriptions, proceed with calculating similarity between the embeddings, and then compare with the similarity between nutrient values. The work was presented at the *BFNDMA/IEEE BigData 2019* conference.

FoodIE is a rule-based **named-entity recognition** method for food-information extraction. It is comprised of a small number of rules based on computational linguistics and semantic information that describe the food entities. Experimental results from the evaluation show very promising results. The work was presented at the *ICPRAM 2019* conference.

We developed an approach for analysing micro-array gene expression data from a homogeneous group of children diagnosed with classic autism. The proposed approach is a synergy of signal processing and machine-learning techniques. The work was done in collaboration with the Ss. Cyril and Methodius University, North Macedonia and presented at the *BIOINFORMATICS 2019* conference.

In collaboration with Stanford University we created the **Opioid Drug Knowledge Graph** (ODKG), a network of opioid-related drugs, active ingredients, formulations, combinations, and brand names. We use the ODKG to normalize drug strings in a clinical data warehouse consisting of patient data from over 400 healthcare facilities in 42 different states, in the US. We showcase the use of ODKG to generate summary statistics of opioid prescription trends across the US regions. These methods and resources can aid the development of advanced and scalable models to monitor the opioid epidemic and to detect illicit opioid misuse behaviour. Our work is relevant to policymakers and pain researchers who wish to systematically assess factors that contribute to opioid over-prescribing and iatrogenic opioid addiction in the US. The work was presented at the *ICLR 2019* conference.

In collaboration with Stanford University and the Pacific Northwest National Laboratory we explored the use of graph-based embedding methods to **learn embeddings for medical concepts** from electronic health records or medical claims datasets. We propose learning embeddings for medical concepts on SNOMED-CT, a widely popular knowledge graph in the healthcare domain with numerous operational and research applications. Current work

presents an empirical analysis of various embedding methods, including the evaluation of their performance on multiple tasks of biomedical relevance (node classification, link prediction, and patient state prediction). The results show significant improvement in patient diagnosis. The work was presented at the *DSHealth/KDD 2019* conference.

Neural networks

Within our research on **machine-vision quality control** we worked on the industrial micro-grant project, related to the MPT d.o.o. company, within the Ket4CleanProduction initiative. The aim of the project was to specify a machine-vision-based quality-control system for the specific plastic part manufactured in large quantities by the injection moulding technological company and to verify this system with the production data. Our role was to specify all the necessary components of the machine-vision inspection system, to define, select and test the image processing, feature selection and classification algorithms, and to specify the software solution that will control all the phases of the visual inspection. We tested several machine-vision system components (lighting, cameras, optics) with the collected false parts received from the company. We also tested the image processing algorithms for extraction of the features that will be used to detect false parts. We specified the necessary positions of the plastic part within the machine-vision system that need to be ensured by the manipulation system.

The Mr-BEC methodologies will be based on a synergism between statistics, information theory, and random matrix theory.

In the area of **pattern recognition**, we developed approaches to evaluate different settings of parameters needed for the pre-processing of ECG signals used for blood-pressure (BP) classification. We propose a multi-level information-fusion approach for learning a predictive model for BP using ECG sensor data. The approach fuses the information on five different levels: (i) data collection, where data from multiple ECG sensors is collected; (ii) feature extraction, where features are extracted from the collected data by different pre-processing methods; (iii) information fusion, fusing the evaluation information from different classifiers; (iv) information fusion using the information from multi-target regression models for each BP class; and (v) information fusion using the information from multi-target regression models from all configurations as a single model. This is used for predicting the BP values (systolic BP, diastolic BP, and mean arterial pressure). The work was done in collaboration with the Faculty of Computer Science and Engineering, Ss. Cyril and Methodius University, North Macedonia and was presented at *BIOSIGNALS 2019* conference and published in *Information Fusion* journal.

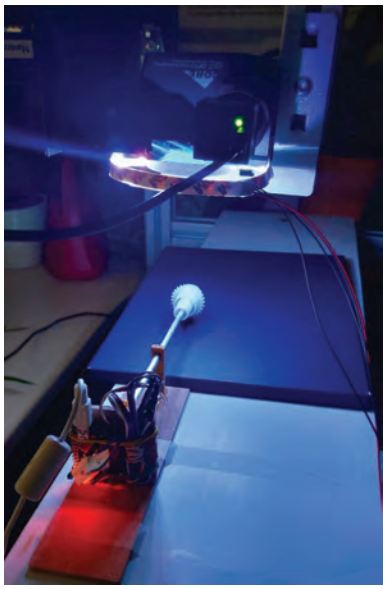

Figure 1: Development of machine-vision inspection system

We participated in research with the University of Buenos Aires, Argentina, on the proarrhythmic drugs' influence on different parts of the rabbit-heart ECG signal measured in-vitro in a multi-electrode chamber. Our role was to investigate which of the several newly defined velocity cardiomarkers for ventricular dispersion significantly represents the proarrhythmic risk. Using the machine-learning classification and statistical computation we found the two novel dynamic features that are more efficient than current standards. Using these two features we were able to correctly separate drug-induced from non-drug induced ECG signals in 21 out of 22 experiments.

The Ket4CleanProduction project *Optimal planning of tool shop operations* deals with improved planning of manufacturing processes for individualized tools at PLAMTEX INT., d.o.o. The main objective is to improve the estimation of operation durations of highly individualized actions in their tool production process using an artificial-intelligence-based analysis. The key challenge to be addressed is the correct estimation of the duration of the production process steps for a tool design where an individual tool has never before been produced. The work is being carried out in collaboration with the Department of Intelligent Systems at the JSI and the company Hahn-Schickard, Germany.

Within the *SAAM* project we continued our work on the research findings of the finished FP7 project *Era-Chair ISO-FOOD – ERA Chair for isotope techniques in food quality, safety and traceability* (http://isofood.eu). We developed advanced methodologies for the automatic recognition of food and drinks from images using **deep learning**. The findings are a step towards automating dietary assessment and food-choice research. The methodology outperforms other approaches in pixel accuracy, and since it is the first automatic solution for recognizing the images of fake foods, the results could be used as a baseline for possible future studies. This work was presented at the *FENS 2019* conference as one of the top three innovative solutions.

We presented an invited talk *Synergy of deep learning, natural language processing, and statistics for nutrition science* at the *AMLD 2019* of the *AI & Nutrition track*, at EPFL, Switzerland. We also presented an invited talk *An application on advanced computer methods in Nutrition science* at the Nestle Research Center, Switzerland.

In the bilateral project with HZDR, Germany *CROSSING - Crossing borders and scales: CFD and High-performance computing* (https://www.hzdr.de/db/Cms?pOid=60402&pNid=0) we collaborate on the topic of the numerical simulation of condensation-induced water hammers, which cause serious damage in industrial facilities. Our main task is to investigate the possibilities to implement a class method on graphical processor units and the

application of suitable machine-learning methods to significantly reduce the computing time. This would lead to more challenging and larger multiphase flow simulations.

Databases

To create digital textual corpora of preserved historical sources in the field of digital humanities, tools that will support digitalisation and semantic annotation are required. To support this process, we developed a rule-based named-entity recognition method for the extraction of place names (toponyms) from Latin text. The method based on Computational Linguistics Rules and using the language properties of the Latin language. Experimental results showed very promising results. This also allows us to create a weakly-annotated corpus that can be further explored using supervised machine-learning methods and developing a more robust model that can be used for location extraction. The tool was developed within the ARRS project *Toponomastical Heritage of Primorska Region*, which is part of a wider research aimed at the realisation of a thorough and reliable digital (interactive) version of the Slovenian Historical Topography, in collaboration with the Slovenian Academy of Sciences and Arts. The work was presented at the *HistoInformatics 2019* conference.

We continued with the upgrade of the database and further development of our *Open platform for clinical nutrition - OPEN* (http://www.opkp.si). The upgrades include the refreshment of existing data, inclusion of new FNS databases, new and improved classification and mapping of data in FoodEx2. Also, we pre-processed and cured data for research work on the intake of sugar, vitamin D and fatty acids in the Slovenian population.

In collaboration with EFSA *EU Menu Slovenija*, we contributed to a national survey on dietary habits by developing a web tool for 24-hour recall that is primarily aimed at collecting food-consumption data and submitting it to the European Food Safety Agency. We analysed a subset of data (about 200 participants) in the SI.Menu survey carried out in 2016/17 in Slovenia by using unsupervised machine-learning techniques. The work was presented at the *BFNDMA/IEEE BigData 2019* conference, and is published in the Slovenian national food-consumption surveys and in the *Journal of food composition and analysis*.

We concluded the ARRS applied project *Trans fatty acids*, where we developed statistical methods for data mapping. Our department contributed to an estimation of the intake of trans fatty acids of the Slovenian citizens by the use of the *Open platform for clinical nutrition*. The work was presented at the *Health of the Working-Age Population 2019* conference.

We started the Horizon 2020 project *FNS-Cloud - Food Nutrition Security Cloud* (http://www.fns-cloud.eu/). We will **consolidate the existing FNS resources** (data, knowledge and tools) for health and agri-food sciences, which are fragmented, lack critical mass, and their access by user communities is 'unevenly' distributed. Particularly, we will develop an advanced methodology for work with heterogeneous data on food, nutrition and health. We developed a new annotated corpus of food entities, i.e., FoodBase, that can be used for detecting semantic differences/similarities between food concepts, and it will open a new path for learning food embedding space that can be used in predictive studies. The initial work was presented at the *BFNDMA/IEEE BigData 2019* conference and is published in the *Database* journal.

The missing data in food-composition databases can be either for selected foods or for specific components only. Most often, the problem is solved by human experts subjectively borrowing data from other FCDBs, for data estimation or imputation. Such an approach is not only time-consuming but may also lead to wrong decisions as the value of certain components in certain foods can vary within different databases due to differences in the analytical methods. To ease missing-data borrowing and increase the quality of missing-data selection, we proposed a new computer-based methodology, i.e., **MIGHT** - Missing nutrient value imputation using null hypothesis testing, that enables the optimal selection of missing data from different FCDBs. The evaluation on a subset of European FCDBs, available through EuroFIR and complied with the Food data structure, gives more accurate results than techniques currently applied for missing value imputation in FCDBs. The work was published in the *Applied Sciences* journal.

At the *IEEE International Conference on Big Data – IEEE BigData 2019*, we organized in collaboration with Stanford University the *1st International Workshop on Big Food and Nutrition Data Management and Analysis – BFNDMA 2019*. The workshop had two established invited speakers and consisted of 15 accepted papers.

At the *ELIXIR Food and Nutrition Community Workshop* we presented an invited talk *Application of artificial intelligence methods for Nutrition Science*. We described our five methodologies that incorporate **Artificial Intelligence in Nutrition Science**: NutriNet – Food Image Recognition using deep learning; DrNER – Information extraction from evidence-based dietary recommendations; StandFood – Food and nutrition data standardisation using text normalisation methods; Mapping Food Composition Data to a Domain Specific Ontology – data harmonisation; MIGHT – Missing value imputation using statistical approaches.

Computing Structures

To support and accelerate our algorithms, several approaches were studied and developed on the level of hardware and computing structures, which includes the use and **online reconfiguration of FPGAs**, customized embedded systems and sensors. We started building the FPGA acceleration infrastructure based on Xilinx ALVEO acceleration cards. These will be used within our hybrid adaptive computing system, designed for the fast processing of complex data in near-real time. It will be connected with other efficient CPU and GPU components to allow fast processing on a large number of different processing units.

Redesigned Libra leading to substantial savings in production cost and energy consumption.

In the field of **embedded systems** and within the *Ballerina* project (http://ballerina.ijs.si), in collaboration with Nutritics LTD, Ireland company, we developed new energy-efficient, pocket-size kitchen scale with a Bluetooth 5 interface. Libra was redesigned from scratch, leading to substantial savings in production costs as well as energy consumption. The result is the integration of Libra with the existing Nutritics services (mobile app Libro, Nutritics for Healthcare, Nutritics for Research, Nutritics for Sport). The API interface of the scale is backward compatible with previous versions. The core of the pocket kitchen scale is based on Nordic nRF52 Bluetooth microcontroller with a separate, precise ADC converter for accurate weight measurements. The scale also includes a power-supply management unit and a UART interface for debugging purposes. The power consumption is reduced by switching off unused modules and by switching the microcontroller to low-power sleep mode when idle. The integrated solution is already under test and is ready to be placed on the specialized market. To maximize its social impact, the hardware of the scale, the API interface, and testing mobile app are licensed as open source (CERN OHL v1.2 and GNU GPL v3).

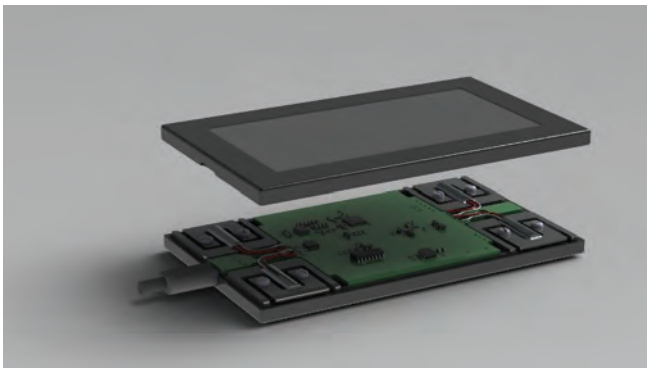

Figure 2: Redesigned pocket-size wireless Libra

Within the *SAAM* project we developed a data-acquisition system and integrated other modules of the **ambiental sensor device** and we are integrating our wireless, pocket-size kitchen scale with the couching database system. The sensor device consists of an ambient data-acquisition system, voice-command module, rendering module, and management system. The ambient data-acquisition system collects environment data like temperature, humidity, pressure, acceleration from the sensor board and transmits them to the couching database system. The voice-command module detects and recognizes voice commands and transmits them to the database system. The rendering module delivers messages to the primary user using light effects and by playing messages over the speaker. The messages are sent from the central coaching system.

An important aspect when choosing a Bluetooth Low Energy (BLE) solution is to analyse its energy consumption for various connection parameters and desired throughput to build an optimal low-power Internet-of-Things (IoT) application and to extend the battery life. In this paper, **energy consumption and data throughput** for various BLE versions are studied. We have tested the effect of the connection interval on the throughput and compared power efficiency relating to throughput for various BLE versions and different transactions The presented results reveal that shorter connection intervals increase throughput for read/write transactions, but that is not the case for the notify and read/write without response transactions. Furthermore, for each BLE version, the energy consumption is mainly dependable on the data volume. The obtained results provide a design guideline for implementing an optimal BLE IoT application. The work was published in the *Sensors* journal.

In the frame of Horizon 2020 *TETRAMAX - Technology Transfer via Multinational Application Experiments* (https://www.tetramax.eu/) project supporting the European *Smart Anything Everywhere* initiative in the domain of **customized low-energy computing** (CLEC) for cyber-physical systems and internet of things, we act as a Slovenian competence center (CC) in charge of expanding the European-wide network (CCN) and organize various workshops in the region. The purpose of the workshops is to bring together the local community to exchange best practices and identify its "smart specialisation" and to capture the local supply and demand on the CLEC technologies. We organized two open workshops for the Slovenian community (i.e., the local ecosystem partners – LEPs and DIHs), where we explained the *TETRAMAX* mission and presented open calls. The workshops were organised in cooperation with the SRIP PMiS and the Knowledge and Technology Transfer Office at the University of Maribor. In cooperation with SRIP PMiS and SRIP ToP we also organized three technical courses (with the topics on usability testing, FPGAs and Android programming), to explain some key CLEC technologies to SMEs and mid-caps.

Human-Computer Interaction

In the area of efficient interaction systems, we focused on the web tools for nutrition and food informatics. In addition, we deeply investigated and designed graphical and typographical representations for various projects and applications, like logos, posters and web pages.

Within the project *SAAM* we are developing a mobile app, which connects to our wireless kitchen scale Libra and a food-composition database, in order to collect information about weighed meals to be sent to the SAAM couching database system. We prepared a technical report on the development of a nutrition module, which includes a description of advanced methodology and computer tools to support dietary assessments of the elderly. It also includes recommendations for healthy eating for the elderly, adapted to the requirements of the pilot countries, Slovenia, Austria and Bulgaria, taking into account the findings of the study presented in the *European journal of clinical nutrition*.

Within the project *Innovative solutions for informed decisions* in collaboration with NUTRIS - Inštitut za nutricionistiko and Zveza potrošnikov Slovenije we prepared a national database of branded foods and a **mobile application Veš, kaj ješ?** (in English: Know what you eat?). The mobile application helps people make informed food choices, as it allows them to scan the barcode of a packed food item and then display the nutritional information within the context of the food traffic light. For the project, we developed Android and iOS mobile applications, backend and *Bazil.si* web application for editing crowd-sourced data. The mobile app was downloaded by 90,000 users in Slovenia and they contributed nearly 10,000 items to the database. The application received the *Information Strawberry* (highest) award at the *IS 2019* conference.

Veš, kaj ješ? mobile app was downloaded by 90,000 users in Slovenia and they contributed nearly 10,000 items to the database. The application received the Information Strawberry award.

We concluded the Horizon 2020 project *REFRESH – Resource Efficient Food and dRink for the Entire Supply cHain* (http://eu-refresh.org/), where we developed **web tool FoodWasteEXplorer for gathering and handling of data of food waste** and developed web services to connect the web tool with other information systems. The application is aimed mainly for researchers and industrial partners performing the valorisation of food wastage and is available at https://www.foodwasteexplorer.eu. Within the project we collected over 27,000 data points, representing 587 nutrients, 698 bio-actives and 49 toxicants, collected from a variety of sources, including scientific (peer-reviewed) papers, manufacturers' data (grey literature) and other data sources. Data is stored in a relational database. To enrich and make best use of it, we automatically transform the collected information into a new food-waste ontology. The created Food Waste Ontology provides a formal description of knowledge from the food-waste domain. Examples of its application are: (i) database querying based on natural language questions, and (ii) finding new or missing data from other datasets. The collaborative work with Ss. Cyril and Methodius University, North Macedonia and the Quadram Institute, UK, was presented at the *BFNDMA/IEEE BigData 2019* conference.

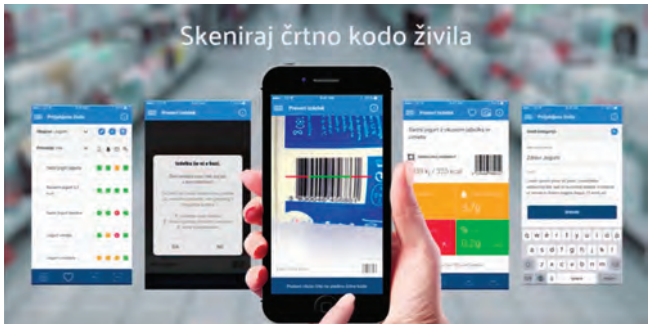

Figure 3: Android and iOS mobile application "Veš, kaj ješ?"

At the beginning of 2019 we collaborated in establishing the **ACM local chapter Bled**, which connects research organisations in the area dealing with human-computer interaction. We co-organized the **Human-computer interaction in information society 2019** conference, which is the main event and meeting point for the chapter. The conference is steadily growing and is gaining popularity in the region and beyond.

In the field of **serious gaming**, we brought forward our concept of smart balance board, which was presented at the *Health of children and adolescents* conference which lead to currently ongoing testing in two elementary schools. Staying in the sports domain, we attended the *BASES 2019* conference, where we presented our work in the field of bike-fitting.

Usability Testing

The goal of UsabEU is to provide a starting point for **usability evaluations** with questionnaires in native or mother tongue. The platform supports online collaborative translation of usability questionnaires and their validation. Additionally, it serves as a repository for all the validated questionnaires and a tool to perform statistically sound usability evaluations. The current proof-of-concept platform supports the translation and validation of the System Usability Scale questionnaire and statistical assistance for sample size estimation and data summarisation. The work was presented at the *HCII 2019* conference. The usability evaluation of the interface of mobile application for nutrition tracking for people with Parkinson's disease was presented at the *HCII 2019* conference. Similarly, we presented the method for an optimal nutrition-related questionnaire related to mobile nutrition monitoring for well-being at the *UbiComp/ISWC '19* conference.

User interfaces

In collaboration with partners and end-users, we analysed user needs and defined appropriate user experiences and designed corresponding interfaces for several tools related to nutrition.

Within the national project *School pot* (http://solskilonec.si) we designed, implemented, tested and improved the web-tool for the planning of healthy meals in kindergartens, primary and high schools in a user-friendly way. We designed dynamic visualisations of tracked nutrients, indicators of appropriate and alerts of inappropriate values. Compared with textual instructions it allows users to construct healthy meals much faster. We redesigned the interaction in such a way that it minimizes the required clicks when inputting food items and their quantities. We removed the need for scrolling by designing all the steps in the meal planning by designing each step to fit on a single screen. We designed the menu structure in such a way that it resembles the most convenient way for planning the meals for the educational institutions. We performed tests with future-to-be users, evaluated the interface and further improved it. While the first part of the tool – the one that enables meal planning – is finished, we are now working on the next parts that involve planning food preparation and managing the logistics of classes of children in different educational institutions. The work was presented at *Health of the working-age population 2019* conference.

Within the development of *Bazil* (http://bazil.si) we further designed parts of the established platform for managing a food-composition database (established at IJS in cooperation with the Institute for nutrition and the Ministry of health), enabling administrators to review and edit nutrition data quickly and efficiently. We achieved this by improving the database browsing screen with easy accessible filters and sorting options as well as visual indicators of characteristics of each food item. This enabled the editors to quickly scan a large number of food items and find the desired ones. We designed the food item screen to contain all the information on a single page and established a clear visual hierarchy to enable scanning the data and jumping to the important parts easily. We tested the tool with the database editors and further improved it based on their feedback.

Some outstanding publications in the past year

1. Tome Eftimov, Peter Korošec, "A novel statistical approach for comparing meta-heuristic stochastic optimization algorithms according to the distribution of solutions in the search space", *Information sciences*, ISSN 0020-0255. 2019, vol. 489, pp. 255-273, doi: 10.1016/j.ins.2019.03.049.
2. Tome Eftimov, Peter Korošec, "Identifying practical significance through statistical comparison of meta-heuristic stochastic optimization algorithms", *Applied soft computing*, ISSN 1568-4946. 2019, vol. 85, pp. 105862-1-105862-18, doi: 10.1016/j.asoc.2019.105862.
3. Rok Hribar, Primož Potočnik, Jurij Šilc, Gregor Papa, "A comparison of models for forecasting the residential natural gas demand of an urban area" *Energy*, ISSN 0360-5442, 2019, vol. 167, pp. 511-522, doi: 10.1016/j.energy.2018.10.175.
4. Gorjan Popovski, Barbara Koroušić-Seljak, Tome Eftimov, "FoodBase corpus: a new resource of annotated food entities", *Database*, ISSN 1758-0463, 2019, vol. 2019, pp. 1-13, doi: 10.1093/database/baz121.
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7. Patricio Bulić, Gašper Kojek, Anton Biasizzo, "Data transmission efficiency in bluetooth low energy versions", *Sensors*, ISSN 1424-8220, 2019, vol. 19, no. 17, pp. 1-17, doi: 10.3390/s19173746.

Awards and Appointments

1. Dr. Bojan Blažica, prof. Dr Barbara Koroušić Seljak, Peter Novak, mag. graf. inž, Urban Škorc, mag. inž. rač. in inf, Eva Valenčič, mag. inž. preh.: Information Strawberry, Ljubljana, 22nd International Multimedia Conference "Information Society". Award for the mobile app Know What You Eat - as the best achievement of the information society in 2018/19, 11. 10. 2019
2. Dr. Tome Eftimov: Best young scientist in North Macedonia for 2018, an award received from the president of North Macedonia Skopje, North Macedonia, 4. 4. 2019
3. Dr. Tome Eftimov: Extraordinary achievements in science, an award received from the mayor of Strumica, Strumica, North Macedonia, 11. 12. 2019
4. Prof. Barbara Koroušić Seljak, Supervisor of the Year 2018, Ljubljana, Young Academy of Slovenia, 19. 3. 2019
5. Eva Valenčič, Prešeren Award of the Biotechnical Faculty, Ljubljana, Award for the work "Optimization of the Slovene Food Basket Using the Linear Programming Method", 25. 11. 2019

Organization of conferences, congresses and meetings

1. SYNERGY project meeting, Ljubljana, 17.–18. 1. 2019

2. TETRAMAX training course: "Usability Testing", Ljubljana, 23. 1. 2019
3. GEMINI BLADES working meeting, Ljubljana, 8.–9. 4. 2019
4. CROSSING kick-off meeting, Ljubljana, 11.–12. 4. 2019
5. Understanding Evolutionary Optimization Behaviour (UEOB 2019) at the 2019 IEEE Congress on Evolutionary Computation (CEC 2019), Wellington, New Zealand, 10. 6. 2019
6. 34th Slovenian workshop "Algorithms by Nature Models", Boč, 13. 9. 2019
7. The 3rd annual scientific and professional international conference "Health of Children and Adolescents", Piran, 20. 9. 2019
8. Presentation at the workshop TETRAMAX "How to get a grant for your Open Call Project", Ljubljana, 2. 10. 2019
9. HCI-IS 2019 Conference (Human-Computer Interaction in Information Society), Ljubljana, 9. 10. 2019
10. TETRAMAX training course: "Basic of FPGA Programmable Circuits", Ljubljana, 16. 10. 2019
11. Presentation at the workshop TETRAMAX "How to get a grant for your Open Call Project", Maribor, 24. 10. 2019
12. TETRAMAX workshop: Introduction to Android Programming, Ljubljana, 20. 11. 2019
13. UTOPIAE GVW-II Workshop, Ljubljana, 18.–20.11.2019
14. OSE5 Workshop, Ljubljana, 21.–22. 11. 2019
15. UTOPIAE Week of Code, Trieste, Italy, 25.–29. 11. 2019
16. 35th Slovenian workshop "Algorithms by Nature Models", Ljubljana, 29. 11. 2019
17. Big Food and Nutrition Data Management and Analysis, IEEE BigData, Los Angeles, USA, 9. 12. 2019

INTERNATIONAL PROJECTS

1. CROSSING - Crossing Borders and Scales - An Interdisciplinary Approach
   Prof. Gregor Papa
   Helmholtz-zentrum Dresden-rossendorf E.v.
2. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Prof. Barbara Koroušić Seljak
   European Commission
3. EU MENU Slovenija; LOT 1; Support to National Dietary Survey in Compliance with the EU MENU Methodology - Fourth Support
   Prof. Barbara Koroušić Seljak
   European Food Safety Authority - Efsa
4. EU MENU Slovenija; LOT 2; Support to National Dietary Survey in Compliance with the EU MENU Methodology - Fourth Support
   Prof. Barbara Koroušić Seljak
   European Food Safety Authority - Efsa
5. COST CA15140 - ImAppNIO; Improving Applicability of Nature-Inspired Optimisation by Joing Theory and Practise
   Dr. Vida Vukašinović
   Cost Office
6. H2020 - REFRESH; Resource Efficient Food and Drink for the Entire Supply Chain
   Prof. Barbara Koroušić Seljak
   European Commission
7. H2020 - UTOPIAE; Uncertainty Treatment and OPtimization in Aerospace Engineering
   Prof. Gregor Papa
   European Commission
8. H2020 - TETRAMAX; TEchnology TRAnsfer via Multinational Application eXperiments
   Dr. Marina Santo Zarnik
   European Commission
9. H2020 - SAAM; Supporting Active Ageing through Multimodal Coaching
   Prof. Barbara Koroušić Seljak
   European Commission
10. H2020 - FNS-Cloud; Food Nutrition Security Cloud
    Prof. Barbara Koroušić Seljak
    European Commission
11. H2020 - METROFOOD-PP; METROFOOD-RI Preparatory Phase Project
    Prof. Barbara Koroušić Seljak
    European Commission
12. H2020 - SYNERGY; Synergy for Smart Multi-Objective Optimisation
    Prof. Peter Korošec
    European Commission

RESEARCH PROGRAMME

1. Computer Structures and Systems
   Prof. Gregor Papa

R&D GRANTS AND CONTRACTS

1. Biomedical data fusion by nonnegative matrix tri-factorization
   Prof. Gregor Papa
2. The content of trans fats in foods and population intakes - public health implications
   Prof. Barbara Koroušić Seljak
3. Toponomastical heritage of Primorska Region
   Asst. Prof. Jurij Šilc
4. Synergic Networking for Innovativeness Enhancement of central european actoRs focused on hiGh-tech industry
   Prof. Gregor Papa
   Interreg Central Europe Programme
5. School pot: Upgrade of the web portal for school nutrition "Šolski lonec" with respect to the national dietary guidelines
   Prof. Barbara Koroušić Seljak
   Ministry of Health
6. Innovative solutions for informed choices: Supporting consumers in monitoring and evaluating food composition data as a tool to promote healthy choices
   Prof. Barbara Koroušić Seljak
   Ministry of Health
7. Data and information repository about dietary supplements 2
   Prof. Barbara Koroušić Seljak
   Javni Štipendijski, Razvojni, Invalidski In
8. School pot: Continuous upgrade of the web portal „Šolski lonec" to support the implementation of the national dietary guidelines in educational institutions and the transfer of skills in using e-tools for planning quality school menus into practice
   Prof. Barbara Koroušić Seljak
   Ministry of Health
9. Innovative solutions for informed choices: A tool to encourage healthier choices by supporting consumers to monitor and evaluate food composition data
   Dr. Bojan Blažica
   Ministry of Health
10. You know what you drink: employing mobile application for reducing alcohol related harm
    Dr. Bojan Blažica
    Ministry of Health
11. Strategic Research & Innovation Partnership Factories of the Future (SRIP PMIS)
    Prof. Gregor Papa
    Ministry of Economic Development and Technology
12. OPKP: Upgrade of the Open platform for clinical Nutrition (OPKP) with respect to the national dietary guidelines and state-of-the-art ICT
    Prof. Barbara Koroušić Seljak
    Ministry of Health
13. Reimbursement of the costs of scientific publications in the golden open access for 2019
    Prof. Gregor Papa
    Slovenian Research Agency
14. Services Provided: Engineering Services Provided on Content and Strategy of Research for Proposal GEMINI BLADES; Expertise: Systems Engineering, Test Methods, Computer Science and ICT, AI and ML and EU Proposals
    Prof. Gregor Papa
15. The 5th Workshop on Optimisation in Space Engineering (OSE5), JSI, Ljubljana, Slovenia, 21.-22.11.2019
    Prof. Gregor Papa
    University of Strathclyde

NEW CONTRACTS

1. Machine vision quality control of molded plastic parts
   Dr. Drago Torkar
   Mpt, d. o. o.
2. Improved planning of manufacturing processes for individualized tools
   Prof. Peter Korošec
   Plamtex Int., Trgovina in Proizvodnja, d. o. o.

VISITORS FROM ABROAD

1. Gorjan Popovski, Ss Cyril and Methodius University of Skopje, Faculty of Computer Science and Engineering, Skopje, North Macedonia, 18.–22. 3. 2019
2. Prof. Petr Gregor, Charles University in Prague, Faculty of Mathematics and Physics, Prague, Czech Republic, 13.– 17. 5. 2019.
3. Prof. Tamara Bucher, Newcastle University, Australia, 10.–14. 6. 2019.
4. Nina Hadji Kotarova, Ss Cyril and Methodius University of Skopje, Faculty of Computer Science and Engineering, Skopje, North Macedonia, 2. 7.–29. 8. 2019
5. Ss Cyril and Methodius University, Faculty of Computer Science and Engineering of Skopje, Skopje, North Macedonia, 10.–30. 9. 2019
6. Prof. Petr Gregor, Charles University in Prague, Faculty of Mathematics and Physics, Prague, Czech Republic, 11.–17. 9. 2019.
7. Prof. Paul Glen Flikkema, North Arizona University, Department of Electrical Engineering and Computer Science, North Arizona, USA, 1.10. 2019 – 31.1.2020

STAFF

Researchers
1. Asst. Prof. Anton Biasizzo
2. Prof. Peter Korošec
3. Prof. Barbara Koroušić Seljak
4. *Prof. Franc Novak, left 01.03.19*
5. **Prof. Gregor Papa, Head**
6. Asst. Prof. Veljko Pejović*
7. Dr. Marina Santo Zarnik
8. Asst. Prof. Jurij Šilc
9. Dr. Drago Torkar

Postdoctoral associates
10. Dr. Bojan Blažica
11. Dr. Tome Eftimov
12. Dr. Marko Pavlin*
13. Dr. Vida Vukašinović

Postgraduates
14. Margarita Antoniou, B. Sc.
15. Rok Hribar, B. Sc.
16. Gordana Ispirova, B. Sc.
17. Urban Škvorc, B. Sc.
18. Eva Valenčič, B. Sc.

Technical officers
19. Peter Novak, B. Sc.
20. Matevž Ogrinc, B. Sc.

Technical and administrative staff
21. Jolanda Jakofčič
22. Andreja Vlašič, B. Sc.

Note:
* part-time JSI member

BIBLIOGRAPHY

Original Article

1. Qiang Sun, Barbara Ikica, Riste Škrekovski, Vida Vukašinović, "Graphs with a given diameter that maximise the Wiener index", *Applied mathematics and computation*, 2019, **356**, 438-448.
2. Gordana Ispirova, Tome Eftimov, Peter Korošec, Barbara Koroušić-Seljak, "MIGHT: statistical methodology for missing-data imputation in food composition databases", *Applied sciences*, 2019, **9**, 19, 4111.
3. Tome Eftimov, Peter Korošec, "Identifying practical significance through statistical comparison of meta-heuristic stochastic optimization algorithms", *Applied soft computing*, 2019, **85**, 105862.
4. Gorjan Popovski, Barbara Koroušić-Seljak, Tome Eftimov, "FoodBase corpus: a new resource of annotated food entities", *Database*, 2019, **2019**, baz121.
5. Rok Hribar, Primož Potočnik, Jurij Šilc, Gregor Papa, "A comparison of models for forecasting the residential natural gas demand of an urban area", *Energy*, 2019, **167**, 511-522.
6. Tome Eftimov, Gordana Ispirova, Doris Potočnik, Nives Ogrinc, Barbara Koroušić-Seljak, "ISO-FOOD ontology: a formal representation of the knowledge within the domain of isotopes for food science", *Food chemistry*, 2019, **277**, 382-390.
7. Jhihoon Joo, Myung Chul Park, Dong Seog Han, Veljko Pejović, "Deep learning-based channel prediction in realistic vehicular communications", *IEEE access*, 2019, **7**, 27846-27858.
8. Tome Eftimov, Peter Korošec, "A novel statistical approach for comparing meta-heuristic stochastic optimization algorithms according to the distribution of solutions in the search space", *Information sciences*, 2019, **489**, 255-273.
9. Susanne Westenbrink, Agi Kadvan, Mark Roe, Barbara Koroušić-Seljak, Angelika Mantur-Vierendeel, Paul M. Finglas, "12th IFDC 2017 Special: evaluation of harmonized EuroFIR documentation for macronutrient values in 26 European food composition databases", *Journal of food composition and analysis*, 2019, **80**, 40-50.
10. Marina Santo-Zarnik, Franc Novak, Gregor Papa, "Thermal phenomena in LTCC sensor structures", *Sensors and actuators. A, Physical*, 2019, **290**, 198-206.
11. Patricio Bulić, Gašper Kojek, Anton Biasizzo, "Data transmission efficiency in bluetooth low energy versions", *Sensors*, 2019, **19**, 17, 3746.

Published Conference Contribution

1. Urban Škvorc, Tome Eftimov, Peter Korošec, "CEC real-parameter optimization competitions: progress from 2013 to 2018", In: *2019 IEEE Congress on Evolutionary Computation, (CEC), Wellington, New Zealand*, Proceedings, IEEE, 2019, 3127-3134.
2. Gordana Ispirova, Tome Eftimov, Barbara Koroušić-Seljak, "Comparing semantic and nutrient value similarities of recipes", In: *2019 IEEE International Conference on Big Data, Dec. 9 - Dec. 12, 2019, Los Angeles, CA, USA*, Proceedings, IEEE, 2019, 5131-5139.
3. Gorjan Popovski, Bibek Paudel, Tome Eftimov, Barbara Koroušić-Seljak, "Exploring a standardized language for describing foods using embedding techniques", In: *2019 IEEE International Conference on Big Data, Dec. 9 - Dec. 12, 2019, Los Angeles, CA, USA*, Proceedings, IEEE, 2019, 5172-5176.
4. Martin Gjoreski, Stefan Kochev, Nina Reščič, Matej Gregorič, Tome Eftimov, Barbara Koroušić-Seljak, "Exploring dietary intake data collected by FPQ using unsupervised learning", In: *2019 IEEE International Conference on Big Data, Dec. 9 - Dec. 12, 2019, Los Angeles, CA, USA*, Proceedings, IEEE, 2019, 5126-5130.

5. Riste Stojanov, Tome Eftimov, Hannah Pinchen, Maria Traka, Paul M. Finglas, Drago Torkar, Barbara Koroušić-Seljak, "Food waste ontology: a formal description of knowledge from the domain of food waste", In: *2019 IEEE International Conference on Big Data, Dec. 9 - Dec. 12, 2019, Los Angeles, CA, USA*, Proceedings, IEEE, 2019, 5190-5194.
6. Barbara Koroušić-Seljak, Krijn J. Poppe, Paul M. Finglas, Lada Timotijević, Pieter Van't Veer, Karin Zimmermann, "Infrastructure for innovative research food choice, preparation and comsuption: a position paper on the RICHFIELDS project", In: *2019 IEEE International Conference on Big Data, Dec. 9 - Dec. 12, 2019, Los Angeles, CA, USA*, Proceedings, IEEE, 2019, 5183-5185.
7. Bibek Paudel, Dragi Kocev, Tome Eftimov, "Mix and rank: a framework for benchmarking recommender Systems", In: *2019 IEEE International Conference on Big Data, Dec. 9 - Dec. 12, 2019, Los Angeles, CA, USA*, Proceedings, IEEE, 2019, 3717-3726.
8. Nives Ogrinc, Barbara Koroušić-Seljak, Karl Presser, Marga Ocke, Iulia Iatco, Claudia Zoani, "Promoting metrology in food and nutrition: A position paper on METROFOOD-RI and its e-component", In: *2019 IEEE International Conference on Big Data, Dec. 9 - Dec. 12, 2019, Los Angeles, CA, USA*, Proceedings, IEEE, 2019, 5161-5164.
9. Simon Mezgec, Barbara Koroušić-Seljak, "Using deep learning for food and beverage image recognition", In: *2019 IEEE International Conference on Big Data, Dec. 9 - Dec. 12, 2019, Los Angeles, CA, USA*, Proceedings, IEEE, 2019, 5149-5151.
10. Ivona Milanova, Jurij Šilc, Miha Seručnik, Tome Eftimov, Hristijan Gjoreski, "LOCALE: a rule-based location named-entity recognition method for Latin text", In: *The 5th International Workshop on Computational History (HistoInformatics 2019) co-located with the 23rd International Conference on Theory and Practice of Digital Libraries (TPDL 2019) Oslo, Norway, September 12th, 2019*, (CEUR workshop proceedings, **2461)**, CEUR-WS, 2019, 13-20.
11. Maulik R. Kamdar, Tymor Hamamsy, Shea Shelton, Ayin Vala, Tome Eftimov, James Zou, Suzanne Tamang, "A knowledge graph-based approach for exploring the U.S. opioid epidemic", In: *AI for social good workshop: ICLR 2019, Seventh International Conference on Learning Representations, May 6th, 2019, New Orleans, USA*, 2019.
12. Monika Simjanoska, Gregor Papa, Barbara Koroušić-Seljak, Tome Eftimov, "Comparing different settings of parameters needed for pre-processing of ECG sgnals used for blood pressure classification", In: *BIOSTEC 2019, 12th International Joint Conference on Biomedical Engineering Systems and Technologies, February 22-24, 2019, Prague, Czech Republic*, Proceedings, 4: Biosignals, SCITEPRESS, 2019, 62-70.
13. Gordana Ispirova, Tome Eftimov, Barbara Koroušić-Seljak, "Analysis of medical and health-related data about adult obesity using supervised and unsupervised learning", In: *CIIT 2018: the 15th International Conference on Informatics and Information Technologies, April 20-22, 2018, Mavrovo, Macedonia*, Proceedings, Cyril and Methodius University, Faculty of Computer Science and Engineering, 2019, 27-33.
14. Gordana Ispirova, Tome Eftimov, Barbara Koroušić-Seljak, "Overview of creativity assessment framework for a computer program", In: *CIIT 2018: the 15th International Conference on Informatics and Information Technologies, April 20-22, 2018, Mavrovo, Macedonia*, Proceedings, Cyril and Methodius University, Faculty of Computer Science and Engineering, 2019, 49-52.
15. Bojan Blažica, Tome Eftimov, "UsabEU: online platform for translation, validation and native use of usability questionnaires with multilingual user groups", In: *Cross-cultural design: methods, tools and user experience: 11th International Conference, CCD 2019 held as part of the 21st HCI International Conference, HCII 2019, Orlando, FL, USA, July 26-31, 2019*, Proceedings, Part 1, (Lecture note in computer science, **11576)**, Springer, 2019, 229-238.
16. Bojan Blažica, Peter Novak, Franc Novak, Barbara Koroušić-Seljak, "Design and usability evaluation of interface of mobile application for nutrition tracking for people with Parkinson's disease", In: *Digital human modeling and applications in health, safety, ergonomics and risk management: healthcare applications: 10th International Conference, DHM 2019, held as part of the 21st HCI International Conference, HCII 2019, Orlando, FL, USA, July 26-31, 2019*, Proceedings, Part II, (Lecture notes in computer science, **11582)**, Springer, 2019, 200-208.
17. Urban Škvorc, Tome Eftimov, Peter Korošec, "GECCO black-box optimization competitions: progress from 2009 to 2018", In: *GECCO' 19: the Genetic and Evolutionary Computation Conference Companion, Prague, Czech Republic - July 13 - 17, 2019*, Proceedings, ACM, 2019, 275-276.
18. Tome Eftimov, Peter Korošec, "Understanding exploration and exploitation powers of meta-heuristic stochastic optimization algorithms through statistical analysis", In: *GECCO' 19: the Genetic and Evolutionary Computation Conference Companion, Prague, Czech Republic - July 13 - 17, 2019*, Proceedings, ACM, 2019, 21-22.
19. Timotej Knez, Martin Gjoreski, Veljko Pejović, "Analiza vpliva težavnosti računalniške igre na izmerjene vrednosti fizioloških signalov", In: *Human-Computer Interaction in Information Society: proceedings of the 22nd International Multiconference Information Society - IS 2019, 9 October, 2019, Ljubljana, Slovenia: volume H*, Institut "Jožef Stefan", 2019, 5-8.
20. Gorjan Popovski, Barbara Koroušić-Seljak, Tome Eftimov, "FoodOntoMap: linking food concepts across different food ontologies", In: *The 11th International joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management, IC3K 2019, September 17-19, 2019, Vienna, Austria*, Proceedings, 2: KEOD, SCITEPRESS, 2019, 195-202.
21. Tome Eftimov, Dragi Kocev, "Performance measures fusion for experimental comparison of methods for multi-label classification", In: *The AAAI 2019 Spring Symposium on Combining Machine Learning with Knowledge Engineering (AAAI-MAKE 2019): Stanford University, Palo Alto, California, USA, March 25-27, 2019*, Proceedings, AAI Press, 2019.
22. Antonio Antovski, Stefani Kostadinovska, Monika Simjanoska, Tome Eftimov, Nevena Ackovska, Ana Madeva Bogdanova, "Data-driven autism biomarkers selection by using signal processing and machine learning techniques", In: *12th International Joint Conference on Biomedical Engineering Systems and Technologies, February 22-24, 2019, Prague, Czech Republic*, Proceedings, 3: Bioinformatics, SCITEPRESS, 2019, 201-208.
23. Gorjan Popovski, Stefan Kochev, Barbara Koroušić-Seljak, Tome Eftimov, "FoodIE: a rule-based named-entity recognition method for food information extraction", In: *8th International Conference on Pattern Recognition Applications and Methods, February 19-21, 2019, Prague, Czech Republic*, Proceedings, SCITEPRESS, 2019, 915-922.
24. Nina Reščič, Eva Valenčič, Enej Mlinarič, Barbara Koroušić-Seljak, Mitja Luštrek, "Mobile nutrition monitoring for well-being", In: *UbiComp/ISWC'19 adjunct proceedings of the 2019 ACM International joint Conference on Pervasive and Ubiquitous Computing and proceedings of the 2019 ACM International Symposium on Wearable Computers, September, 9-13, 2019, London, UK*, ACM, 2019, 1194-1197.
25. Zvezdan Lončarević, Rok Pahič, Gregor Papa, Andrej Gams, "Experimental evaluation of deep-learning applied on pendulum balancing", In: *Proceedings of the Twenty-eighth International Electrotechnical and Computer Science Conference ERK 2019*, *Portorož, Slovenija, 23.-24. september 2019,* Društvo Slovenska sekcija IEEE, 2019, 219-222.

Independent Component Part or a Chapter in a Monograph

1. Gregor Papa, Peter Korošec, "Comparison of multi-objective approaches to the real-world production scheduling", In: *Advances in evolutionary and deterministic methods for design, optimization and control in engineering and sciences*, (Computational methods in applied sciences), Springer, 2019, 457-488.
2. Goreti Marreiros *et al.* (20 authors), "From KPI dashboards to advanced Visualization", In: *The MANTIS book: cyber physical system based proactive collaborative maintenance*, (River publishers series in automation, control and robotics), River Publishers, 2019, 245-315.
3. Rafael Socorro *et al.* (80 authors), "Success stories on real pilots", In: *The MANTIS book: cyber physical system based proactive collaborative maintenance*, (River publishers series in automation, control and robotics), River Publishers, 2019, 311-496.
4. Miran Kondrič, Drago Torkar, Matej Supej, Jan Ogrin, Nicolae Ochianã, Tina Matjašič, "Measuring ball speed and height above net in table tennis", In: *Science and racket sports VI*, Mahidol University, 2019, 167-172.

DEPARTMENT OF KNOWLEDGE TECHNOLOGIES E-8

The Department of Knowledge Technologies is involved in the development of artificial-intelligence methods and advanced information technologies aimed at acquiring, storing and managing knowledge to be used in the development of the information- and knowledge-based society. Established areas of our work include intelligent data analysis (machine learning, data mining, and knowledge discovery in databases), language technologies, computational creativity, decision support and knowledge management. In addition to research in knowledge technologies, we develop applications in environmental sciences and management, agronomy, medicine, biomedicine and bioinformatics, ambient intelligence, space technologies, economics, finance and marketing. The department is also a recognised centre of linguistic research and digital humanities.

Head:
Prof. Nada Lavrač

In 2019 we were involved in fourteen national projects, ten Horizon 2020 projects (we acted as coordinator of one: EMBEDDIA), two COST actions, one INTERREG V-A Slovenia-Italy project, one infrastructure project, one smart-specialization project, and two industry projects. The department hosted five junior researchers working towards their PhDs.

In the area of **intelligent data analysis, data mining and heterogeneous information network analysis** we developed several new methods and used them in a number of application domains. We developed the NetSDM methodology for semantic data mining (SDM), published in JMLR journal, which empowers rule learning with the use of semantic background knowledge, available in domain ontologies. NetSDM transforms the data, ontology relations and concepts into a network, and using network-analysis methods estimates which background-knowledge concepts are important for rule learning. NetSDM represents a new milestone in SDM given its up to 100-fold speedup compared to existing SDM methods, allowing it to be used in big-data analysis scenarios.

We developed the Community-Based Semantic Subgroup Discovery (CBSSD) algorithm, which enables subgroup discovery through community detection based on the structural properties of domain ontology relations and concepts, related to the studied phenomenon. The CN+BSSD approach was tested on ten datasets composed of genes related to complex diseases and metabolic processes and demonstrated that CBSSD can be applied to complex network analysis. A novel BioMine Explorer tool was developed, enabling the interactive exploration and visualization of heterogeneous biological networks, with the paper being published in the Bioinformatics journal. We also developed a new Python library called Py3plex for the analysis and visualization of multi-layer networks and a new approach to symbolic graph embedding using frequent pattern mining.

Nada Lavrač gave an invited lecture "Semantic relational learning" at the 23rd European Conference Advances in Databases and Information Systems (ADBIS 2019), (Bled, Slovenia, 8-11 September 2019).

Within the H2020 project PD_manager, which we coordinated, we developed a method for discovering and visualizing the connections between Parkinson's disease subtypes and patients' symptoms progression. Within the SAAM H2020 project "Supporting Active Ageing through Multimodal Coaching", aimed at developing a virtual assistant-coach that supports the aging population living at home, we developed modelling and reasoning components of the coaching system, an approach for emotion recognition from audio-visual features, and implemented software and communication components of the system's ambiance sensor. We participated at the Week of Health and Innovation in Odense in Denmark, where we presented and demonstrated the technical solutions of the project. For the F4F project (Food 4 Future), we have designed a methodology for distinguishing between natural and synthetic aromas and implemented it as a web application. In 2019 we also started work on the new Horizon 2020 EU project RESILOC (Resilient Europe and Societies by Innovating Local Communities), which aims at improving the resilience of local communities; our department is involved in the project's sentiment analysis and data-mining tasks.

In the area of the automated modelling of dynamic systems, we designed a novel method for network reconstruction based on feature ranking. The features for a given node are the values of the trajectories (time series) of other nodes, and from them we can extract information on what other nodes are most likely to be connected with the considered node. The key property of the method is that it requires no assumption about the knowledge of interaction functions or the dynamical model of the network, and that it makes no hypotheses on the nature of the available trajectories (data). We tested the performance of our method using networks of coupled logistic

maps and obtain good results for a range of coupling strengths and network sizes. In addition, our method is able to perform well even for relatively short trajectories and it is fairly robust to noise.

In the context of the process-based modelling of dynamic systems, we have developed methods for heuristic search through the space of model structures, which perform almost as well as exhaustive search, while being more efficient and allowing the exploration of the larger spaces of structures. We have also developed an environment for the annotation, storage and querying of process-based models, specifically in the domain of aquatic ecosystems, which facilitates model reusability. We have also explored the learning and use of surrogate models in several settings. On one hand, this includes more efficient parameter estimation in the process-based modelling of dynamic systems, while, on the other hand, it includes the use of models of the response of human skin to light for diagnostic purposes, where we learn surrogate models that can be used for a very fast estimation of different skin parameters and properties.

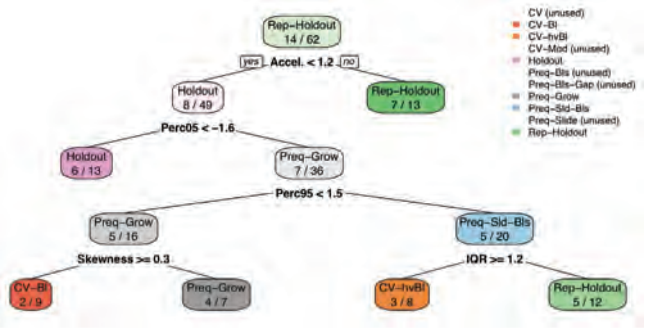

Figure 1: Decision tree that maps the features of the time series to the most appropriate estimation method. In the above tree, the following features are used in the nodes: Accel (acceleration) is the average ratio between a simple moving average and the exponential moving average; Perc05 and Perc95 are the 5th and 95th percentiles, respectively, of the standardized time series; Skewness measures the symmetry of the distribution of the time series; and IQR (inter-quartile range) measures the spread of the standardized time series.

In the area of mining big and complex data, we developed various methods addressing different machine-learning tasks. First, we designed novel methods for feature ranking in the context of structured output prediction. We proposed and evaluated methods in the setting of supervised multi-target regression, comparing an extension of the Relief method to an extension of tree-ensemble-based feature ranking, as well as in the context of semi-supervised classification. Next, we investigated different approaches for structuring, i.e., creating hierarchies on the output space in multi-target regression. Furthermore, we developed methods to utilize hierarchies on the output space in multi-target regression on data streams. Finally, we have explored the problem of fusing different performance measures in multi-label classification.

We applied previously developed methods to data-analysis tasks in a variety of areas, including medicine and the life sciences, ecology and environmental sciences, multimedia and space operations. Considering applications in medicine and the life sciences, we have applied machine-learning methods to the tasks of unveiling relevant factors in chronic disease treatments, the extraction of features for heartbeat classification in single-lead ECG, the multi-level fusion of ECG sensor data for blood-pressure prediction, and we have contributed to a large-scale comparative study in protein-function annotation. In ecology and environmental sciences, in general, we applied multi-target regression to learn how to estimate herbage production and nutrient uptake on Irish dairy farms. In multimedia, we have applied multi-label classification methods to the task of web-genre classification. Finally, we have applied a variety of methods for multi-target regression, both in a batch-learning and in an online learning setting, to the task of predicting thermal power consumption for the Mars Express satellite.

In the context of the FET Flagship Human Brain Project, we are developing new data-mining methods and applying them to discover biological signatures of neurodegenerative diseases. A novel method was developed for learning rule ensembles for multi-target regression, where each model in the ensemble works on a random output subspace, i.e., a subset of the target variables. We have also developed an ontology for describing the data about patients with neurodegenerative diseases.

Martin Žnidaršič gave an invited lecture "Decision support system for ambient-intelligent coaching of the elderly" at WHINN 2019 - Week of Health and Innovation (Odense, Denmark, 20-21 November 2019).

In the area of **knowledge discovery from ecological and agriculture data**, we are involved in several projects where we apply data-mining and decision-support methodologies for the development of predictive and decision-support models in the area of agronomy and systems ecology. In the H2020 project LANDMARK (Land Management, Assessment, Research, Knowledge base), which ended in 2019, we finalized the decision-support system that we had been developing throughout the project; the system, called Soil Navigator, simultaneously assesses five soil functions. We have developed a graphical user interface for the system in six languages for easier communication with end-users. The system was extensively tested at many workshops by different end-users, which allowed us to adapt it to the users' requirements and to test and validate it thoroughly. The methodology used in the development of the system and decision models for each soil function was published in several journal and conference papers. We have, in collaboration with VideoLectures, also made video tutorials about the system in four different languages. The Soil Navigator was officially launched at the Soil Horizons workshop, which was organized in Wageningen, the Netherlands, and was attended by 110 participants. The Soil Navigator DSS is the most important result of this LANDMARK project.

Within the H2020 project TRUE (TRansition paths to sUstainable legume based systems in Europe), we are developing a decision-support system for the assessment of the sustainability of agri-food chains. In order to do that,

we have taken into account three different sustainability aspects – environmental, social and economic. For that purpose, we organized several workshops where, together with project partners, we developed 15 decision models based on the DEX methodology that represent the basis for the overall sustainability DSS. We organized a Legume Innovation Network in Ljubljana, which was attended by stakeholders and representatives of the agri-food chain from Slovenia and abroad (producers, representatives from the food industry, transport, markets and customers) who include or plan to include legumes in their activities. At the workshop, we carried out SWOT analyses of each link in the chain and used the results of the analyses to improve the decision models for the sustainability assessment of each link in the agri-food chain.

In the H2020 project TomRes (A novel and integrated approach to increase multiple and combined stress tolerance in plants using tomato as a model), we organised several workshops where, together with project partners, we worked on the development of a decision-support system for the assessment of combined water and nutrient stress for different tomato genotypes, using different criteria for managing the eco-physiological stress in tomatoes. In addition, we applied machine learning to model tomato resilience under different combined stresses. The developed decision models are currently in the phase of validation and testing, after which they will be integrated into an overall DSS.

In the area of **text, web and network analyses** our research approach is to combine methods of text mining, network analysis and sentiment analysis to reveal and highlight underlying characteristics in different domains. The main sources of data that we analyse are social media (Twitter, Facebook), online news, annual financial reports, and other more structured data.

In machine learning, performance-estimation methods are used for assessing the generalization ability of predictive models. It is not always obvious which estimation method to employ to obtain the most realistic estimate of the errors that a predictive model will incur on unseen data. In our work we empirically evaluated the application of several methods to time-series forecasting tasks. We used 62 real-world time series and three synthetic time series. It turns out that the choice of the most appropriate estimation method depends on the stationarity or different sources of non-stationarity of the time series (see Figure 1).

In the analysis of online news, we described how to construct time-varying, multi-layer networks linking entities recognized in the news. We demonstrated the approach on a collection of over 36 million news articles that were published around the world. Our multi-fold approach identified interesting events from thousands of daily news and models temporal interactions between the entities in the news. We compared the news network to empirical, real-world networks and showed that geographical proximity highly influences the co-occurrence of countries in the news as well as that countries with significant trade exchange tend to be mentioned jointly in a positive context. Finally, we proposed an approach for identifying the most relevant events linking different entities, and showed that top news are not as positive as general news.

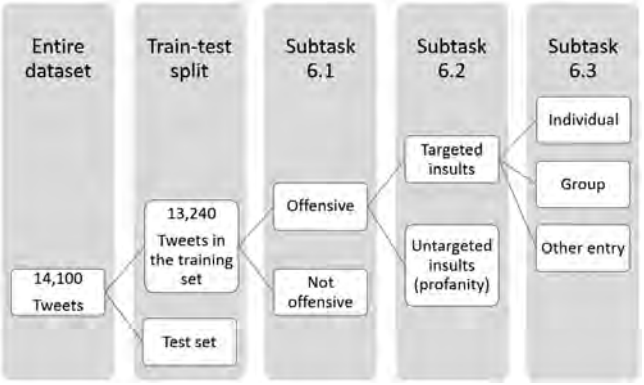

Figure 2: The International Workshop on Semantic Evaluation 2019 Shared Task 6: Identifying and Categorizing Offensive Language in Social Media was divided into three sub-tasks, namely, offensive-language identification (Sub-task A), automatic categorization of offense types (Sub-task B) and offense target identification (Sub-task C). The organizers provided a new dataset called OLID, which included tweets labelled according to the three-level hierarchical model. On the very first level, each tweet is labelled as offensive (OFF) or not offensive (NOT). All the offensive tweets are then labelled as targeted insults (TIN) or as untargeted insults (UNT), which simply contain profanity. On the last level, all targeted insults are categorized as targeting an individual (IND), a group (GRP) or other entity (OTH). The dataset contains 14,100 tweets split into training and test sets.

We collaborated on a position paper outlining a scientific perspective on (mis)information operations. The diffusion of social media fosters new content-consumption patterns where users predominantly interact with information adhering to their preferred narrative and ignore dissenting information. Confirmation bias has an important role for users' decisions about consuming and spreading content; and, at the same time, the aggregation of favoured information within those communities reinforces group polarization. In the paper, the (mis)information-operations problem is addressed in a holistic manner and a research roadmap is proposed to tackle this complex problem.

We published several papers resulting from the FORMICA project (Influence of formal and informal corporate communications on capital markets). We studied the importance of textual features for predictive models of financial indicators, considered text-based classification using deep learning and developed a workflow for the rapid classification and analysis of financial reports. We have also tested different readability measures to predict text complexity.

In the area of **language technologies and digital humanities**, we work on producing various types of language resources and on methods to annotate and analyse text, with a focus on Slovenian and related languages.

In 2019 we published various research findings stemming from the recently concluded national research project JANES (Resources, Tools and Methods for Research of Non-standard Internet Slovenian). On the more computational side, we investigated various approaches to morphosyntactic tagging of non-standard and historical language and produced a new version of the manually annotated linguistic datasets for internet Slovenian, Croatian and Serbian,

which now also include morphosyntactic information in the Universal Dependencies formalism. The more linguistic investigations, based on the corpora compiled in the scope of the JANES project, comprised a study of attitudes towards language in Slovenian Twitterese, an analysis of the collocations in Slovenian user-generated content, of corporate communication on Twitter in Slovenia, of linguistic boundaries between the Bosnian, Croatian, Montenegrin and Serbian languages, of language accommodation on Serbian Twitter and an analysis of collocations in Slovenian user-generated content.

Petra Kralj Novak and Sašo Džeroski participated in the organization of the international conference "Discovery Science 2019" (Split, Croatia, 28-30 October 2019) as program and general chairs, respectively.

We concluded our work in the scope of the national research project KAS (Slovenian scientific texts: resources and description), where we investigated extracting Slovenian terms from doctoral theses via supervised machine learning and compiled a collocation lexicon of Slovenian academic discourse, which is available on the Web portal Termania and has also been archived in the CLARIN.SI repository. The main deliverable, however, was the public release of the KAS corpus on the CLARIN.SI repository, and its three sub-corpora, which contain almost 65,000 BA/BSc, 16,000 MA/MSc and 1,600 PhD theses, in total 5 million pages or 1.7 billion tokens.

We continued work on the national research project FRENK (Resources, methods, and tools for the understanding, identification, and classification of various forms of socially unacceptable discourse in the information society) as well as starting work on the Slovenian-Flemish bilateral basic research project LiLah (Linguistic landscape of hate speech on social media). We investigated the impact of neural modelling on morphosyntactic annotation and lemmatization of Slovenian, Croatian and Serbian, compiled the FRENK datasets of socially unacceptable discourse in Slovenian and English, studied the lexical inventory of socially unacceptable discourse in Slovenian on Facebook and analysed nonstandard language in online hate speech.

In 2019 we started to coordinate a new H2020 project EMBEDDIA (Cross-Lingual Embeddings for Less-Represented Languages in European News Media). The project aims to solve many problems for the news-media industry as well as to analyse news articles and comments through innovative methods using cross-lingual embeddings and deep neural networks. We developed an efficient semantics-aware recurrent deep neural architecture, allowing the system to learn simultaneously from semantic vectors and from raw-text documents, and tested it in a text-classification setting. We proposed a novel approach combining n-grams and deep convolutional features for language-variety classification. We have also studied how word embeddings reflect gender bias in language corpora. Last but not least, we present an approach to construct graphs from large text corpora that we use for a language comparison using network topology metrics, and for unsupervised keyword extraction, in our approach called RaKUn: Rank-based Keyword extraction via Unsupervised learning and Meta vertex aggregation. We have addressed the task of hate and offensive speech prediction by not only building a classifier but also by proposing an adaptation of deep neural networks that can efficiently estimate the prediction uncertainty, while on a shared-task competition OffensEval 2019: Identifying and Categorizing Offensive Language in Social Media, a system developed in the scope of EMBEDDIA was ranked 4th out of 115 participating teams. The project EMBEDDIA was also presented at several events in Slovenia.

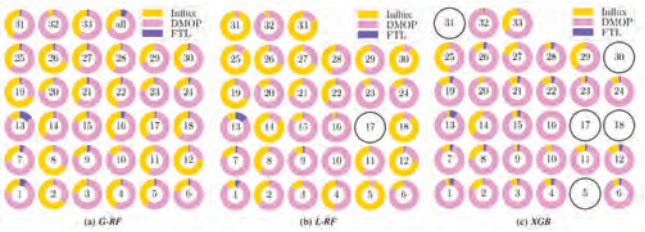

Figure 3: Distribution of different feature groups in the feature rankings produced by (a) Global-RF, (b) Local-RF and (c) XGB ensembles, for the 33 power lines of the Mars Express Spacecraft. In each of the individual diagrams, the presence of a given feature group type (describing different aspects of the spacecraft) is proportional to the sum of the Genie3 relevance over the features from the group. The empty diagrams denote ensembles constructed from constant models. The Global-RF method allows for the additional global feature importance denoted as "all".

We have continued our work on author profiling, including participation in the author-profiling shared task PAN at CLEF 2019, addressing the task of profiling (gender, age, occupation and fame) of celebrities given their tweets, and the tasks of distinguishing between bots, males and females. In the CLIN29 shared task on cross-genre gender detection in Dutch, we achieved second place.

In the scope of the ARRS project "TermFrame: Terminology and Knowledge Frames across Languages", we focused on terminology extraction and alignment. We developed TermEnsembler, a novel ensemble learning approach to bilingual term alignment, and in a reproducibility study, reimplemented and adapted one bilingual term alignment state-of-the-art approach, and proposed a set of best practices for the reproducibility and replicability of NLP. For the needs of the TermFrame project, we have extracted terms and definitions from the karst domain corpus and used graph-based techniques to detect communities of related terms in a karst terminology co-occurrence network.

We organized the 7th international conference "Statistical language and speech processing" (SLSP 2019), which brought together 46 researchers from 16 countries, and published the conference proceedings in the LNAI Springer series.

As part of a cooperation established in previous projects, such as COST ENeL, the European Network for Lexicography, we surveyed the state of the art in Croatian lexicography and edited a monograph on the use of com-

parable corpora for under-resourced areas of machine translation, where we also wrote the chapter on extracting data from comparable corpora. We edited the Proceedings of the Sixth Workshop on NLP for Similar Languages, Varieties and Dialects (VarDial).

In our work in digital humanities, we studied how to encode textual variants of early modern Slovenian poetic texts in TEI and performed a corpus-based study of 16th century Slovenian clitics and clitic-like elements. In the scope of the COST action "Distant Reading for European Literary History", we compiled the first release of the ELTeC-slv corpus with 94 Slovenian novels published between 1840 and 1920 in COST/ELTeC in level 1 TEI encoding.

We lead CLARIN.SI, the Slovenian national node of the CLARIN ERIC research infrastructure, which provides easy publication and sustainable access to digital language data for scholars in the humanities and social sciences as well as other disciplines that use or produce language resources.

In 2019, 55 new or upgraded resources were deposited into the CLARIN.SI repository, amounting to a total of 159 resources at the end of the year. Apart from the already-mentioned datasets, we contributed to the compilation of the fourth version of the spoken corpus Gos VideoLectures, which contains multiply-normalised transcriptions of 55 public lectures with 22 hours of aligned speech, the second major release of the large reference morphological lexicon Sloleks, now also containing phonological information, as well as new versions of the reference morphological lexicons for Croatian and Serbian. We produced a fork of the StanfordNLP neural pipeline for natural language processing, significantly improving the processing of Slavic languages, and published models for the morphosyntactic annotation of standard Slovenian, Croatian and Serbian as well as for the dependency parsing of standard Slovenian, Croatian and Serbian. We co-authored the DSI corpus, which contains 1,776 articles from Slovenian conferences and journals from the field of informatics, useful as a terminological resource in this field, the ŠUSS archive of questions and answers about the Slovenian language (1998–2010), and the Corpus of "Attacks on the Yugoslav National Army", a corpus from 1989 and, in fact, the oldest corpus compiled at the Jožef Stefan Institute, but now released for the first time.

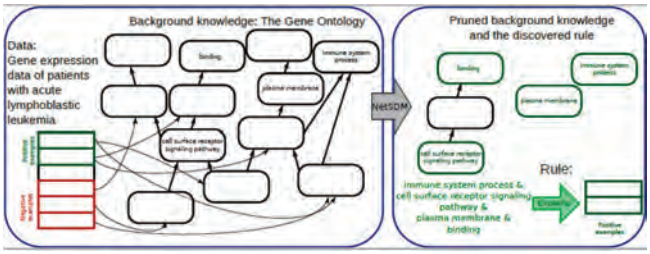

Figure 4: NetSDM methodology for semantic data mining first transforms the data into a network format and uses network-analysis methods to estimate which ontology concepts are important for rule construction. The utility of NetSDM was demonstrated in gene expression analysis from cancer data (shown in this figure) and analysis of plant response to virus infection. NetSDM performs up to 100 times quicker that the existing methods: semantic data analysis can now be done in minutes rather than in hours of processing time, which enables big-data analysis.

We also published an overview of manually morphosyntactically annotated corpora in the CLARIN infrastructure and investigated how to improve morphosyntactic annotation in the Universal Dependencies framework with the help of satellite resources for morphology.

We successfully applied for CLARIN.SI to become a CLARIN ERIC Knowledge Center for South Slavic languages and invited the Croatian CLARIN-HR and Bulgarian CLADA-BG to join the initiative. The first activity of the knowledge center was the publishing of frequently asked questions on available language resources and technologies for Slovenian, Croatian, Serbian, and Bulgarian. We improved and documented the ReLDIanno API for processing texts in Slovenian, Croatian and Serbian. We also applied for a related CLARIN ERIC user-involvement workshop together with CLADA-BG to be held in Ljubljana in May 2020.

Through a collaboration with the NGO "Danes je nov dan", the authors of the ParlaMeter analytical tool for parliamentary data, we published the Slovenian parliamentary corpus ParlaMeter-sl (2016 to 2018) and the Croatian parliamentary corpus ParlaMeter-hr (2014 to 2018). As part of our collaboration with the DARIAH-SI infrastructure for the humanities, we then also compiled the siParl corpus, which contains carefully structured proceedings of the Slovenian parliament (1990 to 2018) with over 200 million words. This led to a CLARIN workshop where we introduced our proposal for a standard CLARIN TEI-based format for parliamentary proceedings and afterwards developed a draft of this proposal, which was also presented at the Workshop for Central and Eastern European countries, organized by the EU project PARTHENOS in Sofia.

In 2018 CLARIN.SI co-organized the traditional biennial conference on Language Technologies and Digital Humanities. In 2019 we edited a special issue of the Journal of Recent History, which contains selected and extended papers of the conference. In 2019 CLARIN.SI was also featured in the "Tour de CLARIN" initiative.

We contributed to the work of the Slovenian Institute for Standardization as the Slovenian representatives in ISO/TC37/SC4 (Terminology and Other Language and Content Resources / Language Resources Management) by reviewing, translating and approving Slovenian standards from this field. We also continued to serve as technical editors for the online Slovenian Biographical Lexicon.

In the area of **decision support**, our long-term goal is to develop methods and techniques of decision modelling, support them with software and integrate them with data-mining systems. In 2019 we were developing four major decision-support systems. We completed the development of the system HeartMan for supporting patients in the management of congestive heart disease (two publications are in preparation). In the framework of the Horizon 2020 project NARSIS, we designed and began implementing the Severa system for decision support in the case of

severe accidents in nuclear power plants. We developed corresponding multi-criteria models for the assessment of the state of vital power-plan components after the accident and implemented about one-third of the software, whose completion is expected in 2020. The third system is aimed at the implementation of an extended and renewed method DEX for the development of qualitative hierarchical multi-criteria decision models. In accordance with the proposed methodology, which was published in 2018, we developed a corresponding software library and designed a web-based architecture of the new system. The fourth system, which is aimed at finding optimal tunnel routes, is being developed in the industry project TOPP. In this context, we developed a program module that implements weight-based hierarchical models, specifically adapted for optimization. We also developed a novel method for the ranking of decision alternatives in qualitative decision models, using optimization approaches.

In the area of **computational creativity**, we contributed an overview of conceptual representations for computational concept creation, proposed a conceptual blending use case as part of a computational creativity infrastructure for online software composition and presented the approaches to bisociative knowledge discovery to cross-domain literature mining.

There is also huge potential for using knowledge technologies in **education**. Our investigations in this field were carried out in collaboration with the University of Nova Gorica and the JSI Center for Knowledge Transfer in IT, and fit into the framework of the UNESCO Chair in Open Technologies for Open Educational Resources and Open Learning at JSI. In our research we focused on the transformation of educational activities towards more flexible and open forms, where we developed a new model of a mentoring program for open education. The model was thoroughly tested and proven in an international context. It is called Open Education for a Better World (oe4bw.org) since projects included into the program aim at contributing to the implementation of the UNESCO Sustainable Development Goals. Due to a large increase in interest (from 14 projects in 2018 to 35 in 2019), we focused on solutions supporting increased complexity, such as introducing a hierarchical structure, the use of e-platform and topical clustering. This turned out to be crucial, resulting in even more successful continuation – we received 85 proposals from across the world. On the basis of the introduced improvements, we were able to accept 82 of them to be implemented within the program in 2020.

Some outstanding publications in the past year

1. Simjanoska, Monika, Kochev, Stefan, Tanevski, Jovan, Bogdanova, Ana Madevska, Papa, Gregor, Eftimov, Tome. Multi-level information fusion for learning a blood pressure predictive model using sensor data. Information fusion, ISSN 1566-2535,] 2019.
2. Madjarov, Gjorgji, Vidulin, Vedrana, Dimitrovski, Ivica, Kocev, Dragi. Web genre classification with methods for structured output prediction. Information sciences, ISSN 0020-0255. 2019, vol. 503, pp. 551-573.
3. Zupan, Katja, Ljubešić, Nikola, Erjavec, Tomaž. How to tag non-standard language : normalisation versus domain adaptation for Slovene historical and user-generated texts. Natural language engineering, ISSN 1351-3249, 2019, vol. 25, spec. iss. 5, pp. 651-674.
4. Grau Leguia, Marc, Levnajić, Zoran, Todorovski, Ljupčo, Ženko, Bernard. Reconstructing dynamical networks via feature ranking. Chaos, ISSN 1054-1500, 2019, vol. 29, no. 9.
5. Petković, Matej, Boumghar, Redouane, Breskvar, Martin, Džeroski, Sašo, Kocev, Dragi, Boumghar, Redouane, Levatić, Jurica, Lucas, Luke, Osojnik, Aljaž, Ženko, Bernard, Simidjievski, Nikola. Machine learning for predicting thermal power consumption of the Mars Express spacecraft. IEEE aerospace and electronic systems magazine, ISSN 0885-8985, 2019, vol. 34, no. 7, pp. 46-60.
6. Kralj, Jan, Robnik Šikonja, Marko, Lavrač, Nada. NetSDM : semantic data mining with network analysis. Journal of machine learning research, ISSN 1532-4435. 2019, vol. 20, pp. 1-50.
7. Trajanov, Aneta, Spiegel, Heide, Debeljak, Marko, Sandén, Taru. Using data mining techniques to model primary productivity from international long-term ecological research (ILTER) agricultural experiments in Austria. Regional environmental change, ISSN 1436-3798, 2019, vol. 19, no. 3, pp. 325-337.
8. Repar, Andraž, Podpečan, Vid, Vavpetič, Anže, Lavrač, Nada, Pollak, Senja. An ensemble learning approach to bilingual term extraction and alignment. Terminology, ISSN 1569-9994. Electronic ed., 2019, vol. 25, no. 1, pp. 93-120.

Awards and appointments

1. The paper "Multi-criteria Modelling Approach for Ambient Assisted Coaching of Senior Adults", which is co-authored by Department members Martin Žnidaršič, Bernard Ženko, Aljaž Osojnik, Marko Bohanec and Panče Panov, received the best paper award at the 11th International Conference on Knowledge Engineering and Ontology Development (Vienna, Austria, 17-19 September 2019).

2. The paper "Feature extraction for heartbeat classification in single-lead ECG" co-authored by Department members Jasmin Bogatinovski and Dragi Kocev received an exceptional and outstanding paper award at the 42nd International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO) (Opatija, Croatia, 25-29 May 2019).
3. Panče Panov received an award from the Faculty of Information Studies in Novo mesto for his contribution to raising the quality and outstanding achievements in the field of education for the year 2018.

Organization of conferences, congresses and meetings

1. 7th International Conference on Statistical Language and Speech Processing, SLSP 2019, Ljubljana, 14-16 October 2019
2. TOMRES "A novel and integrated approach to increase multiple and combined stress tolerance in plants using tomato as a model" project meeting, JSI, Ljubljana, 18-19 November 2019
3. EMBEDDIA "Cross-Lingual Embeddings for Less-Represented Languages in European News Media" project meeting, City hotel, Ljubljana, 23.-25 January 2019
4. "FRENK" project meeting, JSI, Ljubljana, 25 November 2019
5. 12. International Ljubljana-Zagreb workshop on Knowledge Technologies and data Science, University of Zagreb, Faculty of Electrical Engineering and Computing, Zagreb, 24-25 October 2019
6. NetSlo19, IJS, Ljubljana, 24 January 2019
7. LANDMARK "LAND Management: Assessment, Research, knowledge base" project meeting, JSI, Ljubljana, 24-28 June 2019
8. ICGEB-TRAIN workshop, Bled, 13-17 May 2019

INTERNATIONAL PROJECTS

1. Method for Robust Model Integration in Ensemble Learning
   Prof. Sašo Džeroski
   Nec Laboratories Europe Gmbh
2. COST CA16204; Distant Reading for European Literary History
   Prof. Tomaž Erjavec
   Cost Association Aisbl
3. COST CA18237; European Soil-Biology Data Warehouse for Soil Protection
   Prof. Marko Debeljak
   Cost Association Aisbl
4. CLARIN Project ParlaFormat - Developing a Standard Format for Parliamentary Data
   Prof. Tomaž Erjavec
   Clarin Eric
5. H2020 - TRUE; Transition Paths to Sustainable Legume based Systems in Europe
   Prof. Marko Debeljak
   European Commission
6. H2020 - TomRes; A Novel and Integrated Approach to increase Multiple and Combined Stress Tolerance in Plants Using Tomato as a Model
   Prof. Marko Debeljak
   European Commission
7. H2020 - LANDMARK; LAND Management: Assessment, Research, Knowledge Base
   Prof. Marko Debeljak
   European Commission
8. H2020 - NARSIS; New Approach to Reactor Safety Improvements
   Prof. Marko Bohanec
   European Commission
9. H2020 - SAAM; Supporting Active Ageing through Multimodal Coaching
   Asst. Prof. Bernard Ženko
   European Commission
10. H2020 - HBP SGA2; Human Brain Project Specific Grant Agreement 2
    Prof. Sašo Džeroski
    European Commission
11. H2020 - AI4EU; A European AI On Demand Platform and Ecosystem
    Prof. Sašo Džeroski
    European Commission
12. H2020 - RESILOC; Resilient Europe and Societies by Innovating Local Communities
    Dr. Aljaž Osojnik
    European Commission
13. H2020 - FNS-Cloud; Food Nutrition Security Cloud
    Prof. Nada Lavrač
    European Commission
14. H2020 - HeartMan; Personal Decison Support System for Heart Failure Management
    Prof. Marko Bohanec
    European Commission
15. H2020 - ELEXIS; European Lexicographic Infrastructure
    Prof. Tomaž Erjavec
    European Commission
16. H2020 - EMBEDDIA: Cross-Lingual Embeddings for Less-Represented Languages in European News Media
    Asst. Prof. Senja Pollak
    European Commission

RESEARCH PROGRAMME

1. Knowledge Technologies
   Prof. Nada Lavrač

R&D GRANTS AND CONTRACTS

1. TermFrame: Terminology and Knowledge Frames across Languages
   Asst. Prof. Senja Pollak
2. The linguistic landscape of hate speech on social media
   Prof. Tomaž Erjavec
3. Machine Learning for Systems Sciences
   Prof. Sašo Džeroski
4. Resources, methods and tools for the understanding, identification and classification of various forms of socially unacceptable discourse in the information society
   Prof. Tomaž Erjavec
5. Semantic Data Mining for Linked Open Data Science
   Prof. Nada Lavrač
6. Improving Reproducibility of Experiments and Reusability of Research Outputs in Complex Data Analysis
   Asst. Prof. Panče Panov
7. Neuropsychological dysfunctions caused by low level exposure to selected environmental pollutants in susceptible population – NEURODYS
   Prof. Sašo Džeroski
8. Restoration of moldy canvas paintings: improvement or deterioration?
   Prof. Sašo Džeroski
9. Automating the Synthesis and Analysis of Scientific Models
   Prof. Sašo Džeroski
10. Human Rights and Regulation of Trustworthy Artificial Inteligence
    Prof. Ljupčo Todorovski
11. Food for future - F4F
    Asst. Prof. Bernard Ženko
    Ministry of Education, Science and Sport
12. TRAIN: Big Data and Disease Models: A Cross-border Platform for Validated Biotech Industry Kits
    Prof. Sašo Džeroski
    Regione Autonoma Friuli Venezia Giulia, Direzione
13. Development of research Infrastructure for the international competitiveness of Slovenian RRI space -RI-SI ELIXIR
    Prof. Sašo Džeroski
    Ministry of Education, Science and Sport
14. Data Mining and Decision support in Sustainable Food Production

Dr. Vladimir Kuzmanovski
Ministry of Education, Science and Sport
15. Learning models of diseases and treatments for systems and personalized medicine
Dr. Jovan Tanevski
Ministry of Education, Science and Sport
16. Development of research Infrastructure for the international competitiveness of Slovenian RRI space - RI-SI CLARIN
Prof. Tomaž Erjavec
Universit of Maribor
17. Human Rights and Regulation of Trustworthy Artificial Inteligence
Prof. Ljupčo Todorovski
Slovenian Research Agency
18. Financing project visits at Slovenian higher education institutions
Prof. Nada Lavrač
Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia
19. ICGEB - TRAIN Workshop on High Content Imaging and Data Science for Virtual Screening and Drug Discovery, 13-17 May 2019, Bled, Slovenia
Prof. Sašo Džeroski
Icgeb - International Centre For Genetic
20. 7th International Conference on Statistical Language and Speech Processing - SLSP 2019, JSI, Ljubljana, Slovenia, 14.-16.10.2019
Asst. Prof. Senja Pollak
Irdta - Institute For Research Development,

NEW CONTRACTS

1. Multicriteria decision modeling for transparent tunnel
Asst. Prof. Bernard Ženko
Elea Ic d. o. o.
2. Machine vision quality control of molded plastic parts
Asst. Prof. Bernard Ženko
Mpt, d. o. o.

VISITORS FROM ABROAD

1. Prof. Dr Mateja Jamnik, Department of Computer Science and Technology (Computer Laboratory) at the University of Cambridge, Great Britain, 22. 8. 2018–5. 8. 2019
2. Claus Pribbernow, Interactive Wear AG, Starnberg, Germany, 7.–9. 1. 2019
3. Nenad Anchev, Faculty of Computer Science and Engineering, Skopje, North Macedonia, 21.–26. 1. 2019
4. Shane Sheehan, The University of Edinburgh, Usher Institute, Edinburg, Great Britain, 22.–26. 1. 2019
5. Dr Tomislav Stankovski, Faculty of medicine, Skopje, North Macedonia, 22.–29. 1. 2019
6. Dr Saturnino Luz, The University of Edinburgh, Edinburgh, Great Britain, 23.–25. 1. 2019
7. Dr Fabiana Zollo, University Of Venice, Venice, Italy, 23. –25. 1. 2019
8. Irina Ivanovska, Ss. Cyril and Methodius University Skopje, North Macedonia, 10.–18. 2. 2019
9. Viktor Srbinoski, Ss. Cyril and Methodius University Skopje, North Macedonia, 10.–16. 2. 2019
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11. Dr Iarla Kilbane-Dawe, European Space Agency ESRIN Paris, France, 14. 2. 2019
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13. Dr Tiziana Centofanti, ESSRG, Budapest, Hungary, 21.–22. 2. 2019
14. Dr Ivica Dimitrovski, Faculty of Computer Science and Engineering, University of Skopje, North Macedonia, 17.–21. 3. 2019, 15.–17. 7. 2019, 2.–6. 12. 2019
15. Prof. Dr Bart De Moor, Katholieke Universiteit Leuven, Leuven, Belgium, 24.–26. 3. 2019
16. Prof. Dr Geoff Webb, Monash University, Melbourne, Australia, 27.-31. 3. 2019
17. Prof. Dr Bernhard Nebel, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany, 2.–5. 4. 2019
18. Dr Richard Wheeler, The University of Edinburgh, Edinburgh, Great Britain, 8.–14. 4. 2019
19. Fasih Haider, The University of Edinburgh, Edinburgh, Great Britain, 8.–14. 4. 2019
20. Dr Tanja Wissik, Österreichische Akademie der Wissenschaften, Vienna, Austria, 15. 4.–18. 4. 2019
21. Dr Günter Klambauer, Johannes Kepler University Linz, Austria, 13.–15. 5. 2019
22. Pauline Mangin, Arvalis, Institue du Vegetal, Paris, France, 26. 5. 2019–20. 7. 2019
23. Luke John Schafer, University of Copenhagen, Denmark, 24.–28. 6. 2019
24. Lisa Molgaard Lehmann, University of Copenhagen, Denmark, 24.–28. 6. 2019
25. Talke Heidkroβ, Chamber of Agriculture Lower Saxony, Oldenburg, Germany, 24.–28. 6. 2019
26. Dr Francesca Bampa, Wageningen University and Research, The Netherlands, 24.–28. 6. 2019
27. Prof. Dr Mateja Jamnik, Department of Computer Science and Technology, Computer Laboratory, University of Cambridge, Cambridge, Great Britain, 22. 8. 2018-5 .8. 2019
28. Dr Pete Iannetta, The James Hutton Institute, Scotland, Great Britain, 16.–17. 9. 2019
29. Dr Shailesh Shrestha, Scotland's Rural College, Scotland, Great Britain, 16.–17. 9. 2019
30. Dr Tiziana Centofanti, Central European University, Vienna, Austria, 16.–17. 9. 2019
31. Henrik Maaß, University of Hohenheim, Stuttgart, Germany, 16.–17. 9. 2019
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48. Nika Eržen, B. Sc.

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49. Tina Anžič, B. Sc.

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ORIGINAL ARTICLE

1. Ping Xiao *et al.* (28 authors), "Conceptual representations for computational concept creation", *ACM computing surveys*, 2019, **52**, 1, 9.
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1. Isao T. Tokuda, Zoran Levnajić, Kazuyoshi Ishimura, "A practical method for estimating coupling functions in complex dynamical systems", *Philosophical transactions. Mathematical, physical and engineering sciences*, 2019, **377**, 2160, 20190015.
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1. Tadej Škvorc, Marko Robnik Šikonja, "Prepoznavanje idiomatskih besednih zvez z uporabo besednih vložitev", *Uporabna informatika*, 2019, **27**, 3, 110-114.

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3. Dominik Kozjek, Rok Vrabič, David Kralj, Peter Butala, Nada Lavrač, "Data mining for fault diagnostics: a case for plastic injection molding", In: *52nd CIRP Conference on Manufacturing Systems (CMS), Ljubljana, Slovenia, June 12-14, 2019*, (Procedia CIRP, **81)**, Elsevier, 2019, 809-814.
4. Panče Panov, Ana Kostovska, Ilin Tolovski, Sašo Džeroski, "Semantic annotation of data on neurodegenerative diseases in patients using ontologies", In: *2nd HBP Student Conference - Transdisciplinary Research Linking Neuroscience, Brain Medicine and Computer Science, 14-16 February 2018, Ljubljana, Slovenia*, Abstract book, Frontiers Media SA, 2019, 48-50.
5. Anita Valmarska, Dragana Miljković, Marko Robnik Šikonja, Nada Lavrač, "Connection between the Parkinson's disease subtypes and patients' symptoms progression", In: *Artificial intelligence in medicine*, Proceedings, (Lecture notes in computer science, **11526)**, Springer, 2019, 263-268.
6. Alenka Trpin, Biljana Mileva Boshkoska, Pavle Boškoski, "Poincaré metric in algorithms for data mining tools", In: *Beyond databases, architectures and structures: paving the road to smart data processing and analysis: 15th International Conference, BDAS 2019, Ustroń, Poland, May 28-31, 2019*, Proceedings, (Communications in computer and information science, **1018)**, Springer, 2019, 195-203.
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14. Vladimir Kuzmanovski, Mika Sulkava, Taru Palosuo, Jaakko Hollmén, "Temporal analysis of adverse weather conditions affecting wheat production in Finland", In: *Discovery Science: 22nd International Conference, DS 2019, Split, Croatia, October 28-30, 2019*, Proceedings, (Lecture notes in computer science, **11828)**, Springer, 2019, 176-185.
15. Aljaž Osojnik, Panče Panov, Sašo Džeroski, "Utilizing hierarchies in tree-based online structured output prediction", In: *Discovery Science: 22nd International Conference, DS 2019, Split, Croatia, October 28-30, 2019*, Proceedings, (Lecture notes in computer science, **11828)**, Springer, 2019, 87-95.
16. Dragana Miljković, Jan Kralj, Uroš Stepišnik, Senja Pollak, "Communities of related terms in a karst terminology co-occurrence network", In: *Electronic lexicography in the 21st century: eLex 2019 Conference, 1-3 October 2019, Sintra, Portugal*, Proceedings, Lexical Computing, 2019, 357-373.
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18. Pietro Iannetta *et al.* (21 authors), "The industrialisation of agri-food systems and the demise of home-grown legumes in Europe", In: *European Conference on Crop Diversification, September 18-21, 2019, Budapest, Hungary*, book of abstracts, 2019.

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20. Fasih Haider, Senja Pollak, Pierre Albert, Saturnino Luz, "Extracting audio-visual features for emotion recognition through active feature selection", In: *GlobalSIP 2019, 7th IEEE Global Conference on Signal and Innovation Proceesing, Nov. 4, 2019, Ottawa, Canada*, Conference proceedings, IEEE, 2019, 49-55.
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33. Nikola Ljubešić, Kaja Dobrovoljc, "What does neural bring? Analysing improvements in morphosyntactic annotation and lemmatisation of Slovenian, Croatian and Serbian", In: *The 7th Workshop on Balto-Slavic Natural Language Processing, BSNLP'2019, August 2, 2019, Florence, Italy*, Proceedings of the workshop, Association for Computational Linguistics, 2019, 29-34.
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49. Ana Zwitter Vitez, Senja Pollak, "Profiliranje avtorjev besedil: viri, metode in uporaba na področju humanistike in družboslovja", In: *Znanost in družbe prihodnosti, Slovensko sociološko srečanje, Bled, 18.-19. oktober 2019*, Slovensko sociološko društvo, 2019, 168-171.

Independent Component Part or a Chapter in a Monograph

1. Damjan Popič, Darja Fišer, Teja Kavčič, "Attitudes towards language in Slovenian Twitterese", In: *Building computer-mediated communication corpora for sociolinguistic analysis*, (Collection Cahiers du Laboratoire de Recherche sur le Langage, **8**), Presses Universitaires Blaise-Pascal, 2019, 177-197.
2. Nada Lavrač, Matjaž Juršič, Borut Sluban, Matic Perovšek, Senja Pollak, Tanja Urbančič, Bojan Cestnik, "Bisociative knowledge discovery for cross-domain literature mining", In: *Computational creativity: the philosophy and engineering of autonomously creative systems*, (Computational synthesis and creative systems), Springer, 2019, 121-139.
3. Borut Sluban, Jasmina Smailović, Miha Grčar, Igor Mozetič, "Multilevel news networks", In: *Multiplex and multilevel networks*, Oxford University Press, 2019, 116-137.
4. Petra Kralj Novak, Jasmina Smailović, Borut Sluban, Igor Mozetič, "Emoji sentiment ranking 1.0", In: *Tour de CLARIN: volume two*, CLARIN, 2019, 81-83.
5. Marcis Pinnis, Nikola Ljubešić, Dan Ştefănescu, Inguna Skadina, Marko Tadić, Tatjana Gornostaja, Špela Vintar, Darja Fišer, "Extracting data from comparable corpora", In: *Using comparable corpora for under-resourced areas of machine translation*, (Theory and applications of natural language processing), Springer, 2019, 89-139.

University, Higher Education or Higher Vocational Education Textbook

1. Bojan Cestnik, Hubert Fröhlich, *Informatika za podjetnike*, Ljubljana: GEA College - Fakulteta za podjetništvo, 2019.

Patent Application

1. Jihed Khiari, Luis Moreira-Matias, Sašo Džeroski, Bernard Ženko, *Method and system for model integration in ensemble learning,* US2019303795 (A1), US Patent Office, 03. 10. 2019.

Theses and Mentoring

1. Martin Breskvar, *Tree and rule ensembles for multi-target prediction with random output subspaces:* doctoral dissertation, Ljubljana, 2019 (mentor Sašo Džeroski; co-mentor Dragi Kocev).
2. Marco Faggian, *Outstanding problems in nonequilibrium statistical physics:* doctoral dissertation, Novo Mesto, 2019 (mentor Francesco Ginelli; co-mentor Zoran Levnajić).
3. Marc Grau Leguia, *Automatic reconstruction of complex dynamical networks:* doctoral dissertation, Novo Mesto, 2019 (mentors Zoran Levnajić, Ralph Gregor Andrzejak; co-mentor Bernard Ženko).
4. Jernej Jevšenak, *Nonlinear modeling of the relationship between xylem tree-rings and environment:* doctoral dissertation, Ljubljana, 2019 (mentor Tomislav Levanič; co-mentor Sašo Džeroski).

DEPARTMENT OF INTELLIGENT SYSTEMS E-9

The Department of Intelligent Systems develops new methods and techniques for intelligent computer systems, with applications in the areas of the information society, computer science and informatics, and network communication systems. The main research areas are ambient intelligence, computational intelligence, agent and multi-agent systems, language and speech technologies, electronic and mobile health, and smart cities. The department collaborates closely with the Faculty of Computer and Information Science of the University of Ljubljana in the joint research program "Artificial Intelligence and Intelligent Systems. The department also continuously collaborates with industry and contributes significantly to the inclusion of intelligent systems in products and services.

Head:
Prof. Matjaž Gams

Intelligent systems simulate intelligence so that a typical user perceives them as truly intelligent. In reality, these systems use complex mechanisms and implement them on digital platforms to imitate human behaviour by exploiting raw, exponentially growing computer power. This field is somewhat broader than artificial intelligence, both are rapidly growing worldwide and are enabling the development of the information society.

Ambient intelligence is a research area aiming to introduce technology into our everyday environment in a friendly way that is undemanding for the user. The main area where the department applies methods of ambient intelligence is health. We finished the H2020 project **HeartMan**, which developed an application to help congestive-heart-failure patients manage their condition. A clinical trial showed that the application helps patients both physically and psychologically. The objective of the H2020 project **CrowdHealth** is to mine health data to help craft better public-health policies. In collaboration with the Faculty of Sports of the University of Ljubljana, we built methods to accurately forecast physical fitness and the characteristics of students, as well as predict their health risk. The H2020 project **WellCo** is creating a virtual coach to advise older users on wellbeing and health. We developed methods to monitor nutrition with sensors in a smart watch and with questionnaires. We also developed methods to recognize the users' emotions from their voice, to enable an affective user interface. The H2020 project **Insension** will help people with severe intellectual disability use digital services. We are developing methods for camera-based monitoring of heart rate, as well as methods to reason about the users' intent from observations of them and their context. In the Flemish-Slovenian project **STRAW**, whose objective it is to develop stress recognition from physiological signals and to learn more about stressors in the workplace, we finished the preparation for data collection. We also started the AAL project **CoachMyLife**, whose objective is to help seniors with memory impairment perform everyday tasks. As a **doctoral research project**, we developed a method that can intelligently adjust the operation of sensors in such a way that the energy consumption is as small as possibly without sacrificing a lot of quality of the results obtained with these sensors. Another doctoral student is working on advanced machine learning in the area of affective computing. Finally, we were successful at **competitions** in activity recognition with sensors: we won the Sussex-Huawei Locomotion Recognition Challenge for the second time, and together with colleagues from North Macedonia we won Challenge UP and Emteq Activity Recognition Challenge. Because of this, we received the Information Society conference award for current work, while related achievements of the past year received the Excellent in Science award from the Slovenian Research Agency.

We scored three victories at international competitions in activity recognition with sensors. Because of this, we received the Information Society conference award for current work, while related achievements in the past year received the Excellent in Science award from the Slovenian Research Agency.

Computational intelligence is the study of stochastic search, optimization and learning methods, inspired by biological and physical systems. Research in this area at the Department of Intelligent Systems focuses on evolutionary computation and optimization. We study evolutionary algorithms for multiobjective optimization, their acceleration through parallel computing and surrogate models, visualization of their results, methodology of algorithm benchmarking, and their applicability in science and engineering. In 2019 we completed the H2020 Twinning project **SYNERGY**, aimed at strengthening our research and innovation potential in parallelization, surrogate modelling and combining the two techniques in multi-objective optimization. The project was carried out by three partners with complementary

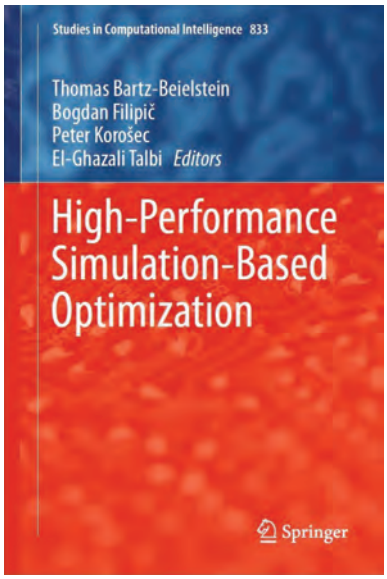
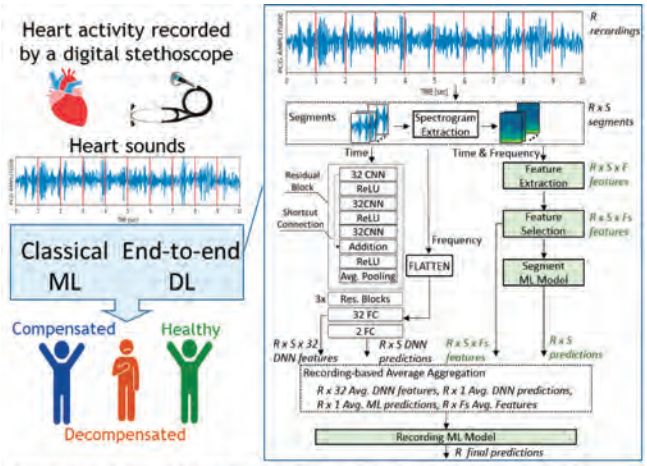


Figure 1: Springer published a scientific monograph High-Performance Simulation-Based Optimization that resulted from the H2020 project SYNERGY.

Figure 2: We are carrying out a Key Enabling Technologies for Clean Production (KET4CP) project devoted to the improved planning of tool manufacturing for injection molding.

We are designing a computer system to schedule flexible offers for electricity production and consumption aimed at reducing the mismatch between the available and the needed electrical energy.



Combination of classical feature-based machine learning and end-to-end deep learning for detection of CHF from heart sounds. The method's accuracy is 93% (on 947 subjects from seven datasets), the 7% misclassification is relatively close to the percentage of recordings labeled as "Unknown" by experts (10%).

Figure 3: Showing a scheme that combines classical feature-based machine learning and end-to-end deep learning, used for the detection of chronic heart failure from heart sounds. The method's accuracy is 93% (on 947 subjects from seven datasets). Published as: Machine learning and end-to-end deep learning for the detection of chronic heart failure from heart sounds.

Our paper entitled "Artificial intelligence and ambient intelligence" published in the "Journal of Ambient Intelligence and Smart Environments" is in the top three most-read and cited articles of that journal in 2019.

expertise: the Jožef Stefan Institute, the University of Lille, and Cologne University of Applied Sciences. One of the key scientific achievements of the project is the publication of our monograph High-Performance Simulation-Based Optimization by Springer, while the knowledge and solutions gained in the project were passed on to both academic and industrial organizations, particularly those participating in the Slovenian Smart Specialization Strategy. We have also completed the postdoctoral basic research project **Incorporating real-world problems into the benchmarking of multiobjective optimizers**, where we have designed six suites of benchmark problems consisting of mixed-integer problems and real-world problems based on games. We have integrated them into the state-of-the-art open-source COCO (Comparing Continuous Optimizers) platform for optimization algorithm benchmarking. The transfer of our knowledge and methods to industrial end users is carried out in several applied projects. We are designing **a computer system to schedule flexible offers for electricity production and consumption** aimed at reducing the mismatch between the available and the needed electrical energy, where mixed-integer linear programming is used as an optimization methodology. We work on **Multiobjective optimization for transparent tunnel design** where clothoids and multiobjective evolutionary algorithms are used to find tunnel routes that satisfy diverse objectives, such as minimal costs, best technical characteristics and minimal environmental impacts. Finally, we participate in two **Key Enabling Technologies for Clean Production (KET4CP)** projects for small manufacturing enterprises of which one deals with the improved planning of tool manufacturing for injection molding and the other with machine-vision quality control of molded plastic parts.

In the field of **agent and multi-agent systems**, the key research areas are focused on the development of smart autonomous systems for the control of smart cities, smart homes and intelligent systems for health and tourism. In the Slovenian Smart Specialization program **EkoSMART** we finished with the research activities in the field of smart cities and communities. In the project we developed a smart-city ecosystem with all the support mechanisms that are necessary for the efficient, optimized and gradual integration of different smart-city areas into a unified and well-connected system. Within the programme we were involved in activities linked to the research and development projects *"Zasnova ekosistema pametnega mesta"* and *"Electronic and mobile health"* (**EMH**), where we are the leading partner. We developed new and innovative devices and solutions to support the elderly and chronic patients at home. One of the prototypes is a smart watch with 16 functions for the elderly. We also successfully finished the Smart Specialization program **IQDOM** in the field of smart buildings and homes, coordinated by Gorenje. Our focus was on the development of smart home-automation services. We applied advanced machine learning and optimization methods to build user models and consumption profiles for housing units in order to generate control strategies that increase user comfort and, at the same time, decrease operational costs of the smart home. A similar approach was also applied to the heat pumps where the controller learns the usage behavior and formulates a strategy for water heating during periods of cheaper electricity and, at the same time, lowers the temperature of the stored water during days of lower consumption. In the Interreg **AS-IT-IC** project, we developed an integrated tourist platform for cross-border tourist exchange, tour planning and effective communication between tourists and tourist offices. The platform supports natural-language communication between the users and the system and the automatic creation of personalized itineraries based on the search concepts and preferences of users.

In the InnoStars European project **HomeCare2020** we upgraded the existing smart bracelet for the elderly. The JSI upgraded the fall-detection algorithms and extended the functionality with additional features (idle detection, warnings, wear detection, irregular activity detection), that were possible due to new sensors. We also started with ERA PerMed European project called **BATMAN**, where we will research Acne Inversa condition and system for offering support to patients. The JSI will take care of support systems for collecting and presenting the obtained data. In the final phase, we will use machine learning to analyze the data and present the models. For the project **ROBKONCEL**, we started, in cooperation with Gorenje and Unior, the development of the intelligent system for comprehensive quality control in production with a reconfigurable robotic control cell and intelligent process control system. Additionally, we also started with two commercial projects. In the first one we were chosen by the Comland Company for help in the development of a hands-free system to control application in natural language. The second one will be done in cooperation with the NiceLabel Company, where we will develop the Smart Issue Retrieval Application for grouping different incoming emails and in the next phase also suggesting what to answer to those emails.

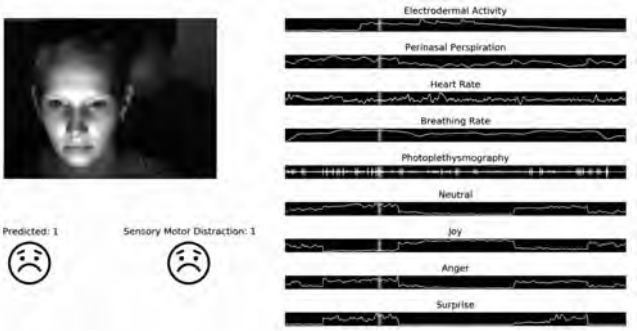


Figure 4: A collaboration between the JSI and the Fraunhofer Institute for Integrated Circuits, where machine learning was used to monitor driver distractions using psychological and visual signals.

In the field of **speech and language technologies** we work on speech synthesis, semantic analysis of text and question answering. Together with companies Alpineon and Amebis we developed a new, high-quality speech synthesizer eBralec (http://ebralec.si/). The synthesizer is improved for both comprehensibility and the natural perception of the speech. The software package has more than a thousand subscribers and is an indispensable tool for blind and visually-impaired users (it is the "official" speech synthesizer of the Slovenian Association for the Blind and Visually Impaired) and people with reading impairments (the Bravo association). For these users, eBralec is free of charge and can be ordered at the Library for the Blind and Visually Impaired (http://www.kss-ess.si/ebralec-sintetizator-govora-slovenskega-jezika/). eBralec is also an integral part of the DarsTraffic+ application, which provides traffic information, while its server version has been used by the National and University Library since 2017. We have also developed a service of speech synthesis for mobile devices (http://dis.ijs.si/dyslex/), which is free for anyone to use.

Figure 5: The paper by Matjaz Gams, Irene Yu-Hua Gu, Aki Härmä, Andrés Muñoz and Vincent Tam titled "Artificial intelligence and ambient intelligence" and published in the Journal of Ambient Intelligence and Smart Environments (JAISE). It was among the three most read and cited papers in that journal in 2019.

We are involved in the CityVOICE project: "Speech Technologies with Advanced Language Resources", and the AudiBook project: "Education accessibility through a digital audio library for the blind and visually impaired".

The **22nd International Multiconference Information Society – IS 2019** (is.ijs.si) took place at the Jožef Stefan Institute from October 7 to 11, 2019. It consisted of 12 independent conferences with 200 presentations. Four conference awards were presented: for lifetime achievements ("Donald Michie and Alan Turing" award) to prof. dr. Marjan Mernik, for current achievements in the field of information society to the department of intelligent system E9 JSI, and the information strawberry (Veš kaj ješ?!) and lemon (E-Zdravje) for the best and worst public information-society services.

Some outstanding publications in the past year

1. Dovgan, E., Gams, M., Filipič, B. A real-time multiobjective optimization algorithm for discovering driving strategies. Transportation Science, 53 (3) (2019), 695–707
2. Gams, M., Gu, I. Y. H., Härmä, A., Muñoz, A., & Tam, V. (2019). Artificial intelligence and ambient intelligence. Journal of Ambient Intelligence and Smart Environments, 11(1), 71-86.
3. Gradišek, A., van Midden, M. Koterle, M., Prezelj, V., Strle, D., **Štefane**, B., Brodnik, H., Trifkovič, M., Kvasić, I., Zupanič, E., Muševič, I. Improving the Chemical Selectivity of an Electronic Nose to TNT, DNT and RDX Using Machine Learning. Sensors 2019, 19, 5207.
4. Janko, V., Gjoreski, M., Slapničar, G., Mlakar, M., Reščič, N., Bizjak, J., ... & Luštrek, M. (2019). Winning the Sussex-Huawei locomotion-transportation recognition challenge. In Human Activity Sensing (pp. 233-250). Springer, Cham.
5. Slapničar, G., Mlakar, N., Luštrek, M. Blood pressure estimation from photoplethysmogram using a spectrotemporal deep neural network. Sensors, 19 (15) (2019), 3420-1–3420-17

Organization of conferences, congresses and meetings

1. BBOB (Blackbox Optimization Benchmarking) workshop at the Genetic and Evolutionary Computation Conference, GECCO 2019, Prague, Czech Republic, 13. 7. 2019
2. GBEA (Game-Benchmark for Evolutionary Algorithms) workshop at the Genetic and Evolutionary Computation Conference, GECCO 2019, Prague, Czech Republic, 14. 7. 2019
3. GECCO Job Market at the Genetic and Evolutionary Computation Conference, GECCO 2019, Prague, Czech Republic, 15. 7. 2019
4. Session Evolutionary Computation in Practice (ECiP) at the Genetic and Evolutionary Computation Conference, GECCO 2019, Prague, Czech Republic, 15. 7. 2019
5. 34th Slovenian Workshop on Nature-Inspired Algorithms, AVN, Boč, Slovenia, 13. 9. 2019
6. 22nd International Multiconference Information Society, IS 2019, Ljubljana, Slovenia, 7.–11. 10. 2019; independent conferences:
   - 6. Student computer science research conference
   - Professional ethics
   - Human-computer interaction in information society
   - Data mining and data warehouses
   - Cognitive science
   - International conference on cognitonics
   - People and environment
   - International conference of transfer of technologies
   - Robotics
   - Slovenian conference on artificial intelligence
   - Middle-European conference on applied theoretical computer science
   - Education in information society
7. 35th Slovenian Workshop on Nature-Inspired Algorithms, AVN, Ljubljana, Slovenia, 29. 11. 2019
8. Workshop Machine Learning for the Diagnosis and Treatment of Affective Disorders (ML4AD), ACII 2019 3. 9. 2019, Cambridge, England

Awards and appointments

1. Vito Janko, Martin Gjoreski, Nina Reščič, Carlo Maria de Masi, Matjaž Gams, Mitja Luštrek: SHL Challange – Sussex-Huawei Locomotion and Transportation Recognition Challenge, 1st Place Award; Ubicomp 2019, London.
2. Hristijan Gjoreski, Simon Stankoski, Ivana Kiprijanovska, Anastasija Nikolovska, Natasha Mladenovska, Marija Trajanoska, Bojana Velichkovska, Martin Gjoreski, Mitja Luštrek, Matjaž Gams: Challenge Up: Multimodal Fall Detection, 1st Place Award; International Joint Conference on Neural Networks (IJCNN) 2019.
3. Hristijan Gjoreski, Simon Stankoski, Ivana Kiprijanovska, Stefan Kalabakov, Martin Gjoreski: Emteq Activity recognition challenge. 1st Place Award; Ubicomp 2019, London
4. Božidara Cvetković, Robert Szeklicki, Vito Janko, Przemyslaw Lutomski, Mitja Luštrek: Excellent in science; Ljubljana; Slovenian Research Agency; human activity recognition with sensors
5. Marko Katrašnik, Junoš Lukan, Mitja Luštrek, Vitomir Štruc: Best paper award, Ljubljana, Program and organizing committee of Slovenian conference on artificial intelligence 2019 (International multiconference Information society), "Diarization procedure development using machine learning algorithms"E9 members: Award for current work in the area of information society; Ljubljana; Information Society 2019 multiconference programme and organisation committee; recent success at scientific competitions

Patent granted

1. Tomaž Kompara, Igor Gornik, Peter Virtič, Rene Markovič, Miha Mlakar, Matjaž Gams, Danijel Jankovec, Jože Dermol
   A smart home control system using artificial intelligence
   SI 25667 (A), Urad RS za intelektualno lastnino, 31. 12. 2019.

INTERNATIONAL PROJECTS

1. ERASMUS+; Audio Library for Visually Impaired; Education Accessibility through a Digital Audio Library for the Blind and Visually-Impaired
   Dr. Tomaž Šef
   European Commission
2. CardioRNA - Catalysing Transcriptomics Research in Cardiovascular Disease
   Dr. Mitja Luštrek
   Cost Association Aisbl
3. H2020 - CrowdHEALTH; Collective Wisdom Driving Public Health Policies
   Dr. Mitja Luštrek
   European Commission
4. H2020 - INSENSION; Personalized Intelligent Platform Enabling Interaction with Digital Services to Individuals with Profound and Multiple Learning Disabilities
   Dr. Mitja Luštrek
   European Commission
5. H2020 - WellCo; Wellbeing and Health Virtual Coach
   Dr. Mitja Luštrek
   European Commission
6. H2020 - HeartMan; Personal Decison Support System for Heart Failure Management
   Dr. Mitja Luštrek
   European Commission
7. H2020 - SYNERGY; Synergy for Smart Multi-Objective Optimisation
   Prof. Bogdan Filipič
   European Commission
8. Development of AI Methods for Monitoring Affective States Using Unobtrusive Sensors
   Prof. Matjaž Gams
   Slovenian Research Agency

RESEARCH PROGRAMME

1. Artificial Intelligence and Intelligent Systems
   Prof. Matjaž Gams

R&D GRANTS AND CONTRACTS

1. Disentangling the sources and context of daily work stress: a comprehensive real-time modelling study using wearables and technological detections
   Dr. Mitja Luštrek
2. Intelligent home of the new generation designed on smart appliances and wood
   Prof. Matjaž Gams
   Ministry of Education, Science and Sport
3. Smart City Ecosystem – EkoSmart
   Prof. Matjaž Gams
   Ministry of Education, Science and Sport
4. Food for future - F4F
   Dr. Mitja Luštrek
   Ministry of Education, Science and Sport
5. Austrian-Slovenian Intelligent Tourist Information Center (AS-IT-IC)
   Prof. Matjaž Gams
   Government Office for Development and European Cohesion Policy
6. CoachMyLife
   Dr. Mitja Luštrek
   Ministry of Public Administration
7. 22nd International Multiconference Information Society 2019, IS 2019, Ljubljana, Slovenia, 7 October 2019 - 11 October 2019
   Prof. Matjaž Gams
8. BATMAN: Biomolekularne analize za personalizirano
   Prof. Matjaž Gams
   National Nuclear Research Center

NEW CONTRACTS

1. Multiobjective optimization for transparent tunnel design
   Dr. Tea Tušar
   Xlab, d. o. o.
2. Development of reconfigurable robotic cell for final product inspection
   Prof. Matjaž Gams
   Gorenje Gospodinjski Aparati, d.d.
3. Machine vision quality control of molded plastic parts
   Prof. Bogdan Filipič
   MPT, d. o. o.
4. Improved planning of manufacturing processes for individualized tools
   Prof. Bogdan Filipič
   Plamtex Int., Trgovina in Proizvodnja, d. o. o.
5. MightyFields with voice control
   Dr. Aleš Tavčar
   Comland, d. o. o.
6. NiceLabel virtual assistent
   Dr. Miha Mlakar
   Euro Plus, d. o. o.

VISITORS FROM ABROAD

1. Prof. Boris Naujoks, Beate Breiderhoff, Cologne University of Applied Sciences (TH Köln), Gummersbach, Germany, 17.–18. 1. 2019
2. Prof. El-Ghazali Talbi, prof. Nouredine Melab, University of Lille, Lille, France, 17.–18. 1. 2019
3. Prof. Yoshiaki Ichikawa, dr. Norihiko Moriwaki, Masaaki Ito, Hitachi, Tokyo, Japan, 7. 2. 2019
4. Pia Ana Čuk, University of Tübingen, Tübingen, Germany, 1. 3.–30. 6. 2019
5. Jörg Aschenbrenner, AVL Software and Functions, Regensburg, Germany, 2.–3. 4. 2019
6. Dr. Heiko Borchert, CSET, Vienna, Austria, 2.–3. 4. 2019
7. Paul Elberg, Milrem, Tallinn, Estonia, 2.–3. 4. 2019
8. Dr. Andreas Fognini, Single Quantum, Delft, The Netherlands, 2.–3. 4. 2019
9. Christian Müller, Hirtenberger Defence Systems, Hirtenberg, Austria, 2.–3. 4. 2019
10. Dr. Bernhard Peischl, AVL List Gmbh, Graz, Austria, 2.–3. 4. 2019
11. Roland Pittracher, Hirtenberger Defence Systems, Hirtenberg, Austria, 2.–3. 4. 2019
12. Johannes Sequard-Base, Ballistix Academy, Rittschen, Austria 2.–3. 4. 2019
13. Dr. Aslak Silijander, VTT Research, Espoo, Finland, 2.–3. 4. 2019
14. Martin Simon, DefSecIntel, Talin, Estonia, 2.–3. 4. 2019
15. Prof. Gerhard Skoff, AVL List Gmbh, Graz, Austria, 2.–3. 4. 2019
16. Ahto Truu, Guardtime, Tallin, Estonia, 2.–3. 4. 2019
17. Menso van Sijll, NRL, Schiphol, Netherland, 2.–3. 4. 2019
18. Tomi Viitanen, VTT Research, Espoo, Finland, 2.–3. 4. 2019
19. Sébastien Leonce, University of Paris Sud, Paris, France, 29. 4.–5. 7. 2019
20. Diclan Laurent, University of Paris Sud, Paris, France, 29. 4.–5. 7. 2019
21. Florentin Michel, University of Paris Sud, Paris, France, 29. 4.–5. 7. 2019
22. Dr. Anne Auger, Dr. Dimo Brockhoff, INRIA Palaiseau, France, 23. 4.–3. 5. 2019
23. Aidan Michael White, Bowling Green State University, Ohio, USA, 21. 5.–30. 8. 2019
24. Prof. Sergio Crovella, IRCCS, Trieste, Italy, 30. 5. and 13. 9. 2019
25. Dr. Paola Maura Tricarico, IRCCS, Trieste, Italy, 30. 5. and 13. 9. 2019
26. Dr. Octavian Machidon, Department of Electronics and Computers, Transilvania University of Brasov, Brašov, Romania, 1.–20. 7. and 15.–23. 10. 2019
27. Rossella Gratton, IRCCS, Trieste, Italy, 13. 9. 2019
28. Luisa Zupin, IRCCS, Trieste, Italy, 13. 9. 2019
29. Prof. Michele Boniotto, Université Paris Est-Créteil, Paris, France, 13. 9. 2019
30. Cecile Nait-Meddour, Université Paris Est-Créteil, Paris, France, 13. 9. 2019
31. Prof. Esther von Stebut-Borschitz, Institute Klinik für Dermatologie und Venerologie, Köln, Germany, 13. 9. 2019
32. Prof. Matthias Schmuth, Medical University Innsbruck, Innsbruck, Austria, 13. 9. 2019
33. Prof. Vincent Flacher, CNRS, Strasbourg, France, 13. 9. 2019
34. Chiara Moltrasio, Fondazione IRCCS Ca' Granda-Ospedale Maggiore Policlinico, Milano, Italy, 13. 9. 2019
35. Alexander Tietz, University of Rostock, Institute for Biostatistics and Informatics in Medicine and Ageing Research, Rostock, Germany, 15. 9.–1. 10. and 12.–26. 10. 2019
36. Peter Wappler, Hahn-Schickard, Stuttgart, Germany, 15. 10. 2019
37. Prof. Akira Oyama, Japan Aerospace Exploration Agency (JAXA), Sagamihara, Japan, 20.–22. 11. 2019
38. Dr. Carlos Kavka, dr. Mariapia Marchi, ESTECO, Trieste, Italy, 21.–22. 10. 2019
39. Prof. Boris Naujoks, Cologne University of Applied Sciences (TH Köln), Gummersbach, Germany, 2.–22. 11. 2019

STAFF

Researchers

1. Dr. Erik Dovgan
2. Prof. Bogdan Filipič
3. **Prof. Matjaž Gams, Head**
4. Asst. Prof. Anton Gradišek
5. Dr. Mitja Luštrek

6. Dr. Miha Mlakar
7. Dr. Tomaž Šef
8. Dr. Tea Tušar

Postdoctoral associates

9. Dr. Carlo Maria De Masi
10. *Dr. Matej Guid, left 01.02.19*
11. Dr. Rok Piltaver*
12. *Dr. Aleksander Pivk*, left 29.10.19*
13. Dr. Aleš Tavčar*

Postgraduates

14. Martin Gjoreski, B. Sc.
15. Vito Janko, B. Sc.
16. Tine Kolenik, B. Sc.
17. Tomaž Kompara*, B. Sc.
18. Dr. Jana Krivec*
19. Gašper Slapničar, B. Sc.
20. Aljoša Vodopija, B. Sc.
21. Jernej Zupančič, B. Sc.

Technical officers

22. Andrejaana Andova, B. Sc.
23. *Mateja Drnovšek, B. Sc., left 18.03.19*
24. David Golob, B. Sc.
25. Gregor Grasselli, B. Sc.
26. Primož Kocuvan, B. Sc.
27. Maj Smerkol, B. Sc.
28. Jakob Valič, B. Sc.

Technical and administrative staff

29. Jani Bizjak, B. Sc.
30. Matej Cigale, B. Sc.
31. Vesna Koricki, B. Sc.
32. Mitja Lasič
33. Liljana Lasič
34. Junoš Lukan, B. Sc.
35. Blaž Mahnič, B. Sc.
36. Nina Reščič, B. Sc.
37. Marjetka Šprah, B. Sc.
38. Lana Zemljak

Note:
* part-time JSI member

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Original Article

1. Anton Gradišek, Mario Cifelli, Micham Wojcik, Tomaž Apih, Sergey V. Dvinskikh, Ewa Górecka, Valentina Domenici, "Study of liquid crystals showing two isotropic phases by ^{1}H NMR diffusometry and ^{1}H NMR relaxometry", *Crystals*, 2019, **9**, 3, 178.
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7. Matjaž Gams, Irene Yu-Hua Gu, Aki Härmä, Andrés Muñoz, Vincent Tam, "Artificial intelligence and ambient intelligence", *Journal of ambient intelligence and smart environments*, 2019, **11**, 1, 71-86.
8. Matjaž Gams, "IKT trendi v oskrbi", Kakovostna starost: časopis za socialno gerontologijo in gerontagogiko, 2019, **22**, 4, 14-26.
9. Clarissa P. C. Gomes *et al.* (55 authors), on Behalf of the EU-CardioRNA COST Action (CA17129), "Catalyzing transcriptomics research in cardiovascular disease: the CardioRNA COST action CA17129", *Non-coding RNA*, 2019, **5**, 2, 31.
10. Gašper Slapničar, Nejc Mlakar, Mitja Luštrek, "Blood pressure estimation from photoplethysmogram using a spectrotemporal deep neural network", *Sensors*, 2019, **19**, 15, 3420.
11. Anton Gradišek, Marion Van Midden, Matija Koterle, Vid Prezelj, Drago Strle, Bogdan Štefane, Helena Brodnik Žugelj, Mario Trifković, Ivan Kvasić, Erik Zupanič, Igor Muševič, "Improving the chemical selectivity of an electronic Nose to TNT, DNT and RDX using machine learning", *Sensors*, 2019, **19**, 23, 5207.
12. Erik Dovgan, Matjaž Gams, Bogdan Filipič, "A real-time multiobjective optimization algorithm for discovering driving strategies", *Transportation science*, 2019, **53**, 3, 695-707.

Published Conference Contribution (invited lecture)

1. Matjaž Gams, "Artificial inteligence and information society laws", In: *Zbornik enajste konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2019, Maribor, Slovenija*, Društvo avtomatikov Slovenije, 2019, 1-6.

Published Conference Contribution

1. Vito Janko, Mitja Luštrek, "Cost-sensitive trees for energy-efficient context recognition", In: *15th International Conference on Intelligent Environments, IE'19, June 24-27, 2019, Rabat Morocco*.
2. Martin Gjoreski, Stefan Kochev, Nina Reščič, Matej Gregorič, Tome Eftimov, Barbara Koroušić-Seljak, "Exploring dietary intake data collected by FPQ using unsupervised learning", In: *2019 IEEE International Conference on Big Data, Dec. 9 - Dec. 12, 2019, Los Angeles, CA, USA: proceedings*, IEEE, 2019, 5126-5130.
3. Miha Štravs, Jernej Zupančič, "Named entity recognition using Gazetteer of hierarchical entities", In: *Advances and trends in artificial intelligence: from theory to practice: 32nd International Conference on Industrial, Engineering and other Applications of Applied Intelligent Systems, IEA/AIE 2019, Graz, Austria, July 9-11, 2019*, Proceedings, (Lecture notes in computer science, **11606)**, Springer, 2019, 768-776.
4. Janez Malavašič, Matjaž Gams, "Ugotovitve in predlogi", In: *Bela knjiga slovenske demografije: "evropska demografska zima"*, Institut "Jožef Stefan", 2019, 7-10.
5. Matjaž Gams, "Zaključki posveta "Kako preprečiti izumiranje slovenskega naroda"", In: *Bela knjiga slovenske demografije: "evropska demografska zima"*, Institut "Jožef Stefan", 2019, 26-31.
6. Matjaž Gams, "Demografski trendi v svetu in Sloveniji", In: *Bela knjiga slovenske demografije: "evropska demografska zima"*, Institut "Jožef Stefan", 2019, 35-39.
7. Matej Guid, Matevž Pavlič, Martin Možina, "Automated feedback generation for argument-based intelligent tutoring systems", In: *CSEDU 2019. Vol. 1*, SCITEPRESS, 2019, 70-77.
8. Erik Dovgan, Bojan Leskošek, Gregor Jurak, Gregor Starc, Maroje Sorić, Mitja Luštrek, "Enhancing BMI-based student clusteringby considering fitness as key attribute", In: *Discovery Science: 22nd International Conference, DS 2019, Split, Croatia, October 28-30, 2019*, Proceedings, (Lecture notes in computer science, **11828)**, Springer, 2019, 155-165.
9. Matjaž Gams, "Computer science ethics", In: *Professional Ethics: proceedings of the 22nd International Multiconference Information*

Society - IS 2019, 9 October, 2019, Ljubljana, Slovenia: volume D, Institut "Jožef Stefan", 2019, 19-22.
10. Andrea De Lorenzo, Eric Medvet, Tea Tušar, Alberto Bartoli, "An analysis of dimensionality reduction techniques for visualizing evolution", In: *GECCO' 19: Genetic and Evolutionary Computation Conference Companion, Prague, Czech Republic - July 13 - 17, 2019*, Proceedings, ACM, 2019, 1864-1872.
11. Dimo Brockhoff, Tea Tušar, "Benchmarking algorithms from the platypus framework on the biobjective bbob-biobj testbed", In: *GECCO' 19: Genetic and Evolutionary Computation Conference Companion, Prague, Czech Republic - July 13 - 17, 2019*, Proceedings, ACM, 2019, 1905-1911.
12. Aljoša Vodopija, Akira Oyama, Bogdan Filipič, "Ensemble-based constraint handling in multiobjective optimization", In: *GECCO' 19: Genetic and Evolutionary Computation Conference Companion, Prague, Czech Republic - July 13 - 17, 2019*, Proceedings, ACM, 2019, 2072-2075.
13. Tea Tušar, Dimo Brockhoff, Nikolaus Hansen, "Mixed-integer benchmark problems for single- and bi-objective optimization", In: *GECCO' 19: Genetic and Evolutionary Computation Conference Companion, Prague, Czech Republic - July 13 - 17, 2019*, Proceedings, ACM, 2019, 718-726
14. Vanessa Volz, Boris Naujoks, Pascal Kerschke, Tea Tušar, "Single- and multi-objective game-benchmark for evolutionary algorithms", In: *GECCO' 19: Genetic and Evolutionary Computation Conference Companion, Prague, Czech Republic - July 13 - 17, 2019*, Proceedings, ACM, 2019, 647-655.
15. Parisis Gallos *et al.* (23 authors), "CrowdHEALTH: big data analytics and holistic health records", In: *ICT for Health Science Research: STC 2019, the EFMI 2019 special topic conference, 7-10 April 2019, Hanover, Germany*, Proceedings, (Studies in health technology and informatics, **258)**, 2019, 255-256.
16. Martin Gjoreski, Anton Gradišek, Borut Budna, Matjaž Gams, Gregor Poglajen, "Toward early detection and monitoring of chronic heart failure using heart sounds", In: *Intelligent environments 2019: workshop proceedings of the 15th International Conference on Intelligent Environments in conjunction with the 15th International Conference on Intelligent Environments (IE19), Rabat, Morocco, 24-27 June 2019*, (Ambient intelligence and smart environments, **26)**, IOS Press, 2019, 336-343.
17. Michał Kosiedowski *et al.* (12 authors), "On applying ambient intelligence to assist people with profound intellectual and multiple disabilities", In: *Intelligent systems and applications: the 2019 Intelligent Systems Conference (IntelliSys), [September 5-6, 2019, London, UK]*, Proceedings, 2, (Advances in intelligent systems and computing, **1037)**, Springer, 2019, 895-914.
18. Matej Guid, Martin Možina, Matevž Pavlič, Klemen Turšič, "Learning by arguing in argument-based machine learning framework", In: *Intelligent tutoring systems*, Proceedings, (Lecture notes in computer science, **11528)**, Springer, 2019, 112-122.
19. Timotej Knez, Martin Gjoreski, Veljko Pejović, "Analiza vpliva težavnosti računalniške igre na izmerjene vrednosti fizioloških signalov", In: *Human-Computer Interaction in Information Society: proceedings of the 22nd International Multiconference Information Society - IS 2019, 9 October, 2019, Ljubljana, Slovenia: volume H*, Institut "Jožef Stefan", 2019, 5-8.
20. Beno Šircelj, Laura Blatnik Guzelj, Ajda Zavrtanik Drglin, Matjaž Gams, "Expected human longevity", In: *Cognitive Science: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume B*, Institut "Jožef Stefan", 2019, 61-65.
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22. Tine Kolenik, Matjaž Gams, "The state of the integrated information theory, its boundary cases and the question of "Phi-conscious" AI", In: *Cognitive Science: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume B*, Institut "Jožef Stefan", 2019, 25-29.
23. Matjaž Gams, "Proposals for scientific approach to environmental problems", In: *People and Environment: proceedings of the 22nd International Multiconference Information Society - IS 2019, 7 October, 2019, Ljubljana, Slovenia: volume F*, Institut "Jožef Stefan", 2019, 5-8.
24. Matjaž Gams, "Environmental movement through scientific approach", In: *People and Environment: proceedings of the 22nd International Multiconference Information Society - IS 2019, 7 October, 2019, Ljubljana, Slovenia: volume F*, Institut "Jožef Stefan", 2019, 9-13.
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27. Martin Gjoreski, Anton Gradišek, Borut Budna, Gregor Poglajen, "Feature analysis for detecting different chronic heart failure stages", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 9-12.
28. Jernej Zupančič, Gregor Grasselli, Matjaž Gams, "Austrian-Slovenian intelligent tourist-information Center Platform", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 53-56.
29. Matej Cigale, Gašper Slapničar, Mitja Luštrek, "Categorising behavioural states of people with profound intellectual and multiple disabilities", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 29-32.
30. Aljoša Vodopija, Bogdan Filipič, "CmoPy: Constrained Multiobjective optimization in Python", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 65-68.
31. Mitja Luštrek, Benjamin Fele, Nina Reščič, Vito Janko, "Counting bites with a smart watch", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 49-52.
32. Tine Kolenik, Martin Gjoreski, Matjaž Gams, "Designing an intelligent cognitive assistant for behavior change in mental health", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 69-72.
33. David Golob, Matjaž Gams, Aleš Tavčar, "EkoSmart asistent za iskanje po integracijski platformi", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 17-20.
34. Erik Dovgan, Mitja Luštrek, "Fitness-based student clustering combining clustering algorithms and dimensionality reduction", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 45-48.
35. Tea Tušar, Vanessa Volz, Dimo Brockhoff, Nikolaus Hansen, "Handling real-world problems within the COCO platform", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 37-40.
36. Tomaž Šef, Miro Romih, Jerneja Žganec Gros, "Development of a speech corpus for Slovenian text-to-speech synthesis", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 33-36.
37. Carlo De Masi, Mitja Luštrek, "Object detection overview", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 13-16.
38. Jakob Valič, Miha Mlakar, Borut Budna, Mitja Luštrek, "Predictive modelling of feeling of health for congestive heart failure patients", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 25-28.
39. Marko Katrašnik, Junoš Lukan, Mitja Luštrek, Vitomir Štruc, "Razvoj postopka diarizacije govorcev z algoritmi strojnega učenja", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 57-60.

40. Primož Kocuvan, Aleš Tavčar, Gregor Grasselli, Matjaž Gams, "Virtual assistant aggregator for the project electronic and mobile health", In: *Slovenian Conference on Artificial Intelligence: proceedings of the 22nd International Multiconference Information Society - IS 2019, 10 October, 2019, Ljubljana, Slovenia: volume A*, Institut "Jožef Stefan", 2019, 21-24.
41. Miha Hafner, David Rajšter, Marko Žibert, Tea Tušar, Bernard Ženko, Martin Žnidaršič, Flavio Fuart, Daniel Vladušič, "Artificial intelligence support for tunnel design in urban areas", In: *Tunnels and underground cities. Engineering and innovation meet archaeology, architecture and art: the WTC 2019 ITA-AITES World Tunnel Congress (WTC 2019), May 3-9, 2019, Naples, Italy*, Proceedings, CRCPress, 2019.
42. Vito Janko, Martin Gjoreski, Carlo De Masi, Nina Reščič, Mitja Luštrek, Matjaž Gams, "Cross-location transfer learning for the sussex-huawei locomotion recognition challenge", In: *UbiComp/ISWC'19 adjunct proceedings of the 2019 ACM International joint Conference on Pervasive and Ubiquitous Computing and proceedings of the 2019 ACM International Symposium on Wearable Computers, September, 9-13, 2019, London, UK*, ACM, 2019, 730-735.
43. Nina Reščič, Eva Valenčič, Enej Mlinarič, Barbara Koroušić-Seljak, Mitja Luštrek, "Mobile nutrition monitoring for well-being", In: *UbiComp/ISWC'19 adjunct proceedings of the 2019 ACM International joint Conference on Pervasive and Ubiquitous Computing and proceedings of the 2019 ACM International Symposium on Wearable Computers, September, 9-13, 2019, London, UK*, ACM, 2019, 1194-1197.
44. Martin Gjoreski, Stefan Kalabakov, Mitja Luštrek, Matjaž Gams, Hristijan Gjoreski, "Cross-dataset deep transfer learning for activity recognition", In: *UbiComp/ISWC'19 adjunct proceedings of the 2019 ACM International joint Conference on Pervasive and Ubiquitous Computing and proceedings of the 2019 ACM International Symposium on Wearable Computers, September, 9-13, 2019, London, UK*, ACM, 2019, 714-718.
45. Vesna Novak, Matej Guid, "Gradnja napovednih modelov za klike na oglase v družabnih omrežjih", In: *Proceedings of the Twenty-eighth International Electrotechnical and Computer Science Conference ERK 2019*, *Portorož, Slovenija, 23.-24. september 2019,* Društvo Slovenska sekcija IEEE, 2019, 223-226.
46. Miha Hafner, David Rajšter, Marko Žibert, Ulrich Zorin, Bernard Ženko, Tea Tušar, "New optimization and decision support technologies in tunnel design, operation and traffic management", In: *12th International Tunnelling and Underground Structures Conference, 21-22 November 2019, Ljubljana*, Proceedings, Slovenian Society for Underground Structures, 2019, 37-49.

Independent Component Part or a Chapter in a Monograph

1. Vito Janko, Martin Gjoreski, Gašper Slapničar, Miha Mlakar, Nina Reščič, Jani Bizjak, Vid Drobnič, Matej Marinko, Nejc Mlakar, Matjaž Gams, Mitja Luštrek, "Winning the Sussex-Huawei locomotion-transportation recognition challenge", In: *Human activity sensing: corpus and applications*, (Springer series in adaptive environments), Springer, 2019, 233-250.

Patent

1. Tomaž Kompara, Igor Gornik, Peter Virtič, Rene Markovič, Miha Mlakar, Matjaž Gams, Danijel Jankovec, Jože Dermol, *A smart home control system using artificial intelligence,* SI 25667 (A), Urad RS za intelektualno lastnino, 31. 12. 2019.

DEPARTMENT OF REACTOR ENGINEERING

R-4

The Department of Reactor Engineering is involved in basic and applied research in the fields of nuclear engineering and safety. Topics include theoretical and experimental research of basic thermal-hydrodynamic phenomena, thermal-hydraulic safety analyses of design-basis and severe accidents, structural safety analyses and probabilistic safety assessment. Most research activities are part of international cooperation programs. Research results are incorporated in projects for the industry and for the regulatory authority, as well as in under-graduate and doctoral studies programmes.

Head:
Prof. Leon Cizelj

Modelling of basic thermal-hydrodynamic phenomena

Turbulent heat transfer in single-phase flow was investigated by performing direct numerical simulations, using the spectral element method and the computer code nek5000, within the European project SESAME that was dedicated to the thermal hydraulics of liquid metals. Simulations were performed in the geometry of a backward-facing step, with heat transfer from the floor after the step. The results obtained at low Reynolds numbers are available to the international research community for the validation of turbulent heat-transfer models.

In the frame of two-phase flow research, a Taylor bubble (that extends almost over the entire tube cross-section) in the turbulent co-current flow regime was simulated using the OpenFoam open-source computational fluid dynamics (CFD) code. The volume of fluid (VOF) method was used together with the large eddy simulation approach, which allows a high-fidelity reproduction of the turbulent flow. In order to obtain an accurate as possible accumulation of the flow statistics, a moving frame of reference was implemented, which followed the motion of the Taylor bubble in the flow. The results were validated using experimental measurement results from the literature.

A direct numerical simulation of turbulent flow over a backward-facing step, with heat transfer from the floor after the step, was performed.

The basic phenomena of vapour explosion, which might occur during a hypothetical severe accident in a nuclear power plant (NPP) if a hot reactor-core melt comes into contact with coolant, were investigated. The study of vapour explosions in stratified melt-water configurations was continued. The performed sensitivity study related to the PULiMS and SES experiments (Royal Institute of Technology, Sweden) using the MC3D code (Institut de Radioprotection et de Sûreté Nucléaire - IRSN, France) demonstrated the importance of the fine-fragmentation modelling. The developed mechanistic model of the premixing layer formation, based on theoretical research and recent experiments, was implemented into the MC3D code, and initial tests were performed.

The potential of vapour explosions during core melt-sodium interaction was also further investigated. A two-phase numerical investigation of heat transfer around melt fragments in sodium using the ANSYS CFX code was initiated. The first results show a reasonable agreement between the simulation and the theoretically based correlation. Furthermore, the first simulations of sodium vapour explosion were performed using the MC3D code in potential experimental conditions. The results in selected geometries indicate that pressure loads of vapour explosions in sodium are lower than in water.

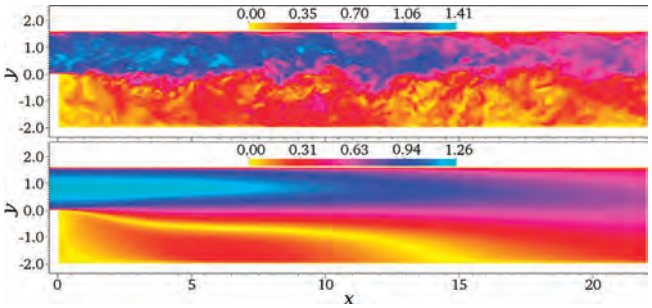

Figure 1: Instantaneous (top) and average (bottom) velocity fields of turbulent flow over backward facing step. Inflow: left; outflow: right.

In the field of hydrogen distribution in the NPP containment, research on the scaling of results, obtained in experimental facilities, to real plants, was continued. Within the SAMHYCO-NET project, we also participated in the second phase of the benchmark on hydrogen and carbon monoxide distribution in a generic containment. Simulations were carried out with the ASTEC (IRSN) system code.

In the field of hydrogen combustion, simulations of experiments in the THAI+ facility (Becker Technologies, Germany) were continued with the ASTEC code within the ASCOM project. Two experiments were simulated, in which the flammable gas mixture was ignited under the same conditions at different locations: at the bottom of the main vessel and at the bottom of the attached parallel cylinder. In both cases, the simulated flame propagation direction agreed with the experiment up to two-thirds of the height of both cylindrical vessels.

In pool scrubbing, used for gas decontamination during a severe accident, gas in the form of bubbles flows through a liquid pool, so that fission products in the form of solid particles (aerosols and larger) move from the

bubbles into the liquid. Using a four-fluid model (air in bubbles, surrounding liquid water, particles in bubbles, and particles in water) within the OpenFoam code, simulations of pool scrubbing were continued at the SCRUPOS (Ricerca sul Sistema Energetico, Italy) experimental conditions. The research is also part of the IPRESCA project.

Experimental investigations in the THELMA laboratory

Following the commissioning of the Thermal-Hydraulics Experimental Laboratory for Multiphase Applications (THELMA), the first measurements were performed in a test section that represents part of a single rod in a nuclear-reactor fuel assembly. In order to close the thermal balances, measurements were performed in the single-phase flow regime. In the two-phase flow regime, nucleate boiling was successfully observed with a fast camera for the first time. A further approach closer to the critical heat flux will require some improvements of the test section inlet and outlet headers. An analysis of the heat transfer in the test section was performed as a design support study using a series of CFD calculations, which detected some weaknesses of the present design. Suggested modifications will be implemented in the current year.

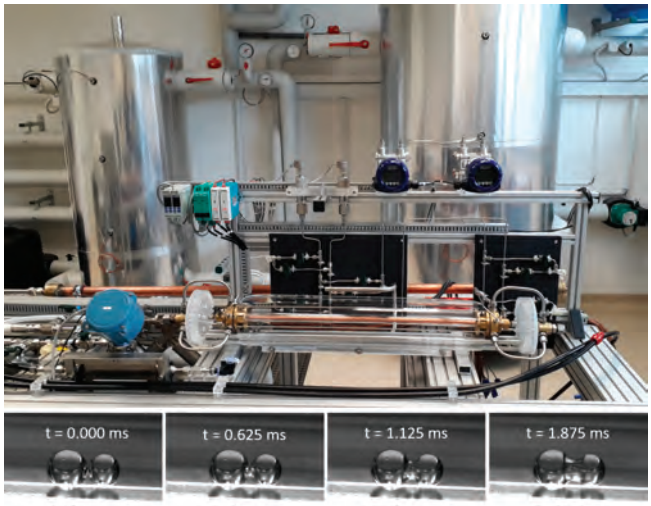

Figure 2: Experimental facility of THELMA laboratory for heat-transfer measurements in multiphase flow (top) and bubble coalescence recorded with a high-speed camera (below).

A new experimental setup was designed and constructed in the laboratory to study the behaviour of a Taylor bubble in different flow conditions. The disintegration of the bubble was observed in counter-current laminar and turbulent flow regimes. Such measurements will be used for validation of the two-phase flow simulations.

Modelling of turbulent heat transfer behind a backward-facing step with DNS produced an accurate description of the flow field. A new test section made of plexiglass was produced in the laboratory and the first detailed measurements of the velocity field, without heat transfer, were performed in water using the Particle Image Velocimetry technique and compared with simulations.

Thermal-hydraulic safety analyses

Following the nuclear power plant (NPP) Fukushima Daiichi accident in Japan in 2011, design extension conditions were introduced in Europe as a preferred method for considering complex sequences and severe accidents, without including them in design-basis conditions. An analysis was performed to see whether the plant design can prevent a spectrum of loss-of-coolant accidents together with the complete loss of one emergency core-cooling function (e.g., high-pressure or low-pressure injection). The analysed break spectrum ranged from 1/2" (1.27 cm) to 12" (30.48 cm). For simulations, the latest RELAP5/MOD3.3 thermal-hydraulic computer code and the RELAP5 input model of the Krško NPP were used.

The thermal loading of the planned fusion reactor DEMO in-vessel components, without active cooling during remote maintenance operation and during in-vessel loss of coolant accident, was analysed.

The European project PIACE considers the concept of a passive isolation condenser, which is suitable for the automatic limitation of the reactor-core cooling rate during an accident. For water-cooled reactors, the concept is suitable for preventing thermal shocks in the vessel and piping walls. We designed a model of a passive isolation condenser and demonstrated its applicability for a pressurized-water reactor using simulations performed with the RELAP5 code.

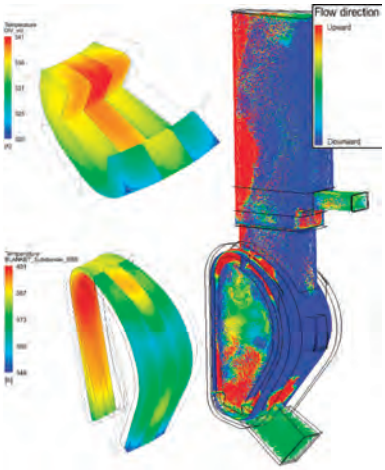

Figure 3: Temperature distribution in divertor and breeding blanket (left) during postulated loss-of-coolant accident; helium flow patterns inside vacuum vessel cask due to natural circulation (right).

A postulated helium-ingress event in the planned DEMO fusion reactor foresees loss of cooling in the magnets and thermal shields, leading to helium leakage into the cryostat. During and after this ingress, the natural convection of helium between the warm cryostat walls and the cold magnet and thermal shield structures is established. New simulations of helium natural convection in the cryostat considered the labyrinth sealing of thermal shields and the modified cooling of vacuum vessel walls. These analyses were related to the European nuclear fusion project WPPMI.

Thermal loading of the DEMO reactor in-vessel components without active cooling during remote maintenance operation and during an in-vessel loss-of-coolant accident (LOCA) was analysed. Steady-state CFD simulations were performed to evaluate the temperature distribution of passive in-vessel components due to in-vessel natural air convection. Very high temperatures of the passive blanket and divertor components occur especially during the LOCA scenario, where a relatively high decay heat 1h after shutdown is considered. Based on the temperature distribution, the thermal expansion of blanket and divertor segments was estimated. The research was performed within the EUROfusion project.

The thermal response of a multi-purpose probe for plasma diagnostics in small fusion tokamaks was studied in the frame of the European fusion project WP-MST2. The thermal response of the probe

head during immersion in the hot plasma of the TCV (Tokamak à Configuration Variable) tokamak in Switzerland was simulated. The results showed that critical temperatures in the vital parts of the probe head are not exceeded.

A conceptual design of the calorimeter for the Neutral Beam Injector (NBI) that will be installed in the Divertor Test Tokamak (DTT) in Italy, was developed. The calorimeter, which is designed as a movable panel with cooling U-tubes equipped with swirl tape inserts, is used as a beam-stopping element before entering the tokamak. Dedicated thermal-hydraulic analyses were performed to optimise the design while respecting the boundary conditions on the cooling flow, pressure drop, material limitations and overall dimensions. The work was performed in collaboration with Consorzio RFX (Italy).

Structural safety analyses

In structural safety analyses, the influence of mechanical loads on the behaviour of solid materials is being investigated.

In cooperation with the Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA, France), the effect of different grain-boundary types on intergranular normal stresses was studied in a polycrystalline material. It was found that grain-boundary tilt, as seen from the two neighbouring grains, has the strongest influence on intergranular stresses. In another study with CEA, an in-house tool was developed to automatically build realistic finite-element meshes from the measured electron-backscatter diffraction maps of proton-irradiated stainless-steel specimens.

The crystal plasticity finite-element and the crystal plasticity fast-Fourier-transform-based methods were compared when used for neutron-irradiated austenitic stainless steel that are currently used in nuclear-reactor-vessel internals.

The use of probabilistic fracture mechanics in structural integrity analyses of nuclear components was investigated in cooperation with the Paul Scherrer Institute (Switzerland). Two analyses were performed: a study of an embrittled reactor pressure vessel under loss-of-coolant accidents leading to pressurized thermal shock loads, and leak-before-break evaluations of the nuclear piping. In combination with deterministic analyses, the applied approach was shown to be able to provide the likelihood of loss of structural integrity in terms of probabilities of leakage and component failure.

Within the European project SOTERIA and in collaboration with IRSN and the Centre National de la Recherche Scientifique (CNRS, France), a comparison between finite-element method simulations and fast Fourier-transform-based simulations was performed on monocrystalline and polycrystalline simulations of irradiated austenitic stainless steel. Grain-boundary stresses in bi-crystal and polycrystal models, all with periodic boundary conditions, were calculated and compared between the two methods.

Within the European project ATLAS+, thermo-mechanical analyses and fatigue crack-growth calculations were performed for a T-junction pipe with turbulently mixing fluids of different temperatures. Synthetic signals were generated by an in-house code. Following a simplified description of the pipes, the uncertainties in the fatigue predictions were evaluated using real and synthetic fluid data in the fatigue analyses.

We also participated in the European fusion project WPDC (diagnostics and control) where a finite-element analysis on electric current distribution was carried out for the divertor thermo-current measurement in the DEMO fusion reactor. A maximum allowed shunt resistance was estimated to protect the piping against large currents induced during plasma disruption events.

Probabilistic safety assessment

The purpose of probabilistic safety assessment (PSA) is the quantification of risk in complex industrial systems.

A PSA method for the security of supply in gas networks supported by physical models was further developed. The method is based on a procedure for the automatic generation of fault trees, which estimates the probability of disruption of gas delivery from terminals/storages to each consumer node in the network. The method, which allows probabilistic analyses of the availability of the demand nodes and of the overall availability of the gas network, was tested on the reduced United Kingdom network.

An analysis of the impact of an electric power frequency change resulting from sub-synchronous resonance on nuclear safety was performed.

An analysis of the impact of electric power frequency change resulting from sub-synchronous resonance on nuclear safety was performed. The model of the nuclear power plant (NPP) generator with power grid interconnections was used for the analysis of the frequency change. A detailed deterministic safety-analysis model was used for the analysis of the impact on NPP safety.

The European NARSIS project aims to extend present PSA methodologies to extreme events with very low frequencies. A study of how to constrain the uncertainties in PSA was performed. A station-blackout event tree was also proposed.

Technical cooperation, consulting services and education

In 2019, the Reactor Engineering Division cooperated in projects for the industry and the state administration as well. As an authorized institution for radiation and nuclear safety, we prepared an independent evaluation of the implementation of the emergency control room in the Krško NPP. The installation of new instruments due to the addition of this room leads to changes in the NPP Updated Safety Analysis Report. We also monitored outage and refuelling activities in the plant.

For the Slovenian nuclear safety administration, we analysed the influence of the radionuclides distribution in the Krško NPP containment on severe-accident-management guidelines.

Researchers of the department represent the core staff of the Chair for Nuclear Engineering at the Faculty of Mathematics and Physics at the University of Ljubljana, and are involved in nuclear engineering undergraduate, master and doctoral studies. The programmes are associated with the European Nuclear Education Network (ENEN).

Some outstanding publications in the past year

1. J. Oder, A. Shams, L. Cizelj, I. Tiselj, Direct numerical simulation of low-Prandtl fluid flow over a confined backward facing step, International journal of heat and mass transfer 142 (2019), 118436-1-118436-20
2. M. Draksler, B. Končar, L. Cizelj, On the accuracy of Large Eddy Simulation of multiple impinging jets, International journal of heat and mass transfer 133 (2019), 596-605
3. T. Holler, E.M.J. Komen, I. Kljenak, The role of CFD combustion modeling in hydrogen safety management. VII. Validation for hydrogen deflagration in large-scale hydrogen-air-steam experiment, Nuclear Engineering and Design 342 (2019), 133-146
4. M. Leskovar, V. Centrih, M. Uršič, J. Kokalj, Investigation of steam explosion duration in stratified configuration, Nuclear Engineering and Design 353 (2019), 110233-1-10233-14
5. A. Volkanovski, A. Prošek, Electric power frequency and nuclear safety: subsynchronous resonance case study, Nuclear Engineering and Technology 51 (2019), 1017-1023

Awards and appointments

1. Iztok Tiselj: Gold plaque for outstanding merit in developing scientific, pedagogical or artistic creativity and for strengthening the university's reputation, University of Ljubljana, 3 December 2019
2. Mitja Uršič, Žan Kogovšek, Matjaž Leskovar, Matej Tekavčič: Best poster award (NENE2019 conference, Portorož, Slovenia, 9-12 September 2019), Nuclear Society of Slovenia, for the paper "Simulations of heat and mass transfer around circular core fragment in sodium coolant".

Organization of conferences, congresses and meetings

1. Special interest Group 15 - Turbulence modelling, Jožef Stefan Institute Reactor Center, 15.-16. 10. 2019
2. 27. EUROfusion General Assembly, City hotel, Ljubljana, 17.-18. 10. 2019

INTERNATIONAL PROJECTS

1. CROSSING - Crossing Borders and Scales - An Interdisciplinary Approach
   Dr. Boštjan Končar
   Helmholtz-zentrum Dresden-rossendorf E.v.
2. Analysis to Support Implementation in Practise of Articles 8a-8c of Directive 2014/87/Euratom
   Prof. Leon Cizelj
   European Commission, Directorate-general for Energy
3. Training and Tutoring for Experts of the National Regulatory Authorities and their Technical Support Organisations for Developing or Strengthening their Regulatory and Technical Capabilities - MC3.01/13
   Prof. Leon Cizelj
   Iter-consult Srl - Independent
4. H2020 - SESAME; thermal hydraulics Simulations and Experiments for the Safety Assessment of MEtal cooled reactors
   Prof. Iztok Tiselj
   European Commission
5. H2020 - SOTERIA; Safe Long Term Operation of Light Water Reactors based on Improved Understanding of Radiation Effects in Nuclear Structural Materials
   Prof. Leon Cizelj
   European Commission
6. H2020 - ANNETTE; Advanced Networking for Nuclear Education and Training and Transfer of Expertise
   Prof. Leon Cizelj
   European Commission
7. H2020 - ATLASplus; Advanced Structural Integrity Assessment Tools for Safe Long Term Operation
   Prof. Leon Cizelj
   European Commission
8. H2020 - NARSIS; New Approach to Reactor Safety Improvements
   Dr. Andrej Prošek
   European Commission
9. H2020 - ENENplus; Attract, Retain and Develop New Nuclear Talents Beyond Academic Curricula
   Asst. Prof. Ivo Kljenak
   European Commission
10. H2020 - PIACE; Passive Isolation Condenser
    Asst. Prof. Ivo Kljenak
    European Commission
11. H2020 - sCO2-4-NPP; Innovative sCO2-Based Heat Removal Technology for an Increased Level of Safety of Nuclear Power Plants
    Dr. Andrej Prošek
    Electricite De France S.a.
12. H2020 - EURAD; European Joint Programme on Radioactive Waste Management
    Prof. Leon Cizelj
    European Commission
13. H2020 EUROfusion - Research Unit - Administration and Services RU – FU
    Dr. Boštjan Končar
    European Commission
14. H2020 EUROfusion - Education-ED-FU

Dr. Boštjan Končar
European Commission
15. H2020 EUROfusion - Plant Level System Engineering-PMI-PPPT-FU
Dr. Boštjan Končar
European Commission
16. H2020 EUROfusion - JET Enhancements-JET4-FU, EUROFUSION
Dr. Boštjan Končar
European Commission
17. H2020 EUROfusion - Diagnostic and Control-WPDC-PPPT-FU
Dr. Samir El Shawish
European Commission
18. H2020 - EUROFUSION - WPSAE-PPPT-FU, WP27
Dr. Boštjan Končar
European Commission
19. Confirmation of ETSON General Assembly - Member of the Governing Board
Prof. Leon Cizelj
Slovenian Research Agency
20. General Assembly of the ENEN Association - President of the Governing Board
Prof. Leon Cizelj
Slovenian Research Agency

RESEARCH PROGRAMMES

1. Reactor engineering
Prof. Leon Cizelj
2. Fusion technologies
Dr. Boštjan Končar

R&D GRANTS AND CONTRACTS

1. Pressurization process during vapour explosion in sodium cooled fast reactors
Dr. Mitja Uršič
2. Efficient cooling concepts for high heat flux components in fusion reactor
Dr. Boštjan Končar
3. Investigation of turbulent heat transfer in an annulus through advanced experimental and computational methods
Prof. Iztok Tiselj
4. Simulation of selected design extension conditions without core melt
Dr. Boštjan Končar
5. Understanding stratified steam explosions in reactor conditions
Dr. Matjaž Leskovar
6. Financing pf project visits at the Slovenian higher eduaction institutions - dr. Mikuž
Dr. Blaž Mikuž
Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia
7. Code Applications and Maintenance Program (CAMP); Thermal-Hydraulic Code Applications and Maintenance
Dr. Andrej Prošek
United States Nuclear Regulatory Commission, USNRC
8. 16th ERCOFTAC SIG15 Workshop: Modelling of Wall Bounded Turbulent Natural Convection, JSI, Ljubljana, Slovenia, 15 October 2019 - 16 October 2019
Prof. Leon Cizelj

NEW CONTRACTS

1. Analysis of influence of radionuclides distribution in Krško NPP containment on severe accident management guidelines
Dr. Matjaž Leskovar
Ministry of the Environment and Spatial Planning
2. Simulation of selected design extension conditions without core Melt
Dr. Boštjan Končar
Nuklearna Elektrarna Krško d. o. o.
3. Understanding stratified steam explosions in reactor conditions
Dr. Matjaž Leskovar
Nuklearna Elektrarna Krško d. o. o.
4. Independent Expert Opinion by the Authorized Radiation and Nuclear Safety Expert - Phase 4 of modification 1007-XI-L, „Construction of NEK emergency control room - NPP Krško ECR“
Dr. Mitja Uršič
Nuklearna Elektrarna Krško d. o. o.
5. Independent expert opinion by the authorized radiation and nuclear safety expert on overhaul, interventions and performed tests during the NEK outage 2019
Dr. Mitja Uršič
Elektroinštitut Milan Vidmar

VISITORS FROM ABROAD

1. Dr Meta Dobnikar, Ministry of Education, Science and Sport of the Republic of Slovenia, Ljubljana, 7. 3. 2019
2. Tatjana Jurkovič, Ministry of Education, Science and Sport of the Republic of Slovenia, Ljubljana, 7. 3. 2019
3. Mojca Boc, Slovenian Research Agency, Ljubljana, 7. 3. 2019
4. Bertrant Bouchet, CEA, French Alternative Energies and Atomic Energy Commission, Paris, France, 7. 3. 2019
5. Denis Robert-Mougin, CEA, French Alternative Energies and Atomic Energy Commission, Paris, France, 7. 3. 2019
6. Prof. Anton Čauševski, Faculty of Electrical Engineering and Information Technologies, Ciril and Methodius University, Skopje, North Macedonia, 8.-12. 4. 2019
7. Prof. Laurent Pilon, University of California, Los Angeles, USA, 16. 4. 2019
8. Prof. Piergiorgio Sonato, Consorzio RFX, Ricerca Formazione Innovazione, Padua, Italy, 29. 5. 2019
9. Dr Vanni Toigo, Consorzio RFX, Ricerca Formazione Innovazione, Padua, Italy, 29. 5. 2019
10. Dr Pierluigi Zaccaria, Consorzio RFX, Ricerca Formazione Innovazione, Padua, Italy, 29. 5. 2019
11. Igor Sirc, Slovenian Nuclear Safety Administration, Ljubljana, 12. 7. 2019
12. Djordje Vojnovič, Slovenian Nuclear Safety Administration, Ljubljana, 12. 7. 2019
13. Matjaž Podjavoršek, Slovenian Nuclear Safety Administration, Ljubljana, 12. 7. 2019
14. Dr Andreja Peršič, Slovenian Nuclear Safety Administration, Ljubljana, 12. 7. 2019
15. Dr Piero Agostinetti, Consorzio RFX, Ricerca Formazione Innovazione, Padua, Italy, 12. 7. 2019
16. Richard Meller, Helmholtz-Zentrum Dresden Rossendorf, Dresden, Germany, 29. 7. - 2. 8. 2019
17. Prof. Yassin A. Hassan, Texas A&M University, Texas, USA, 13. 9. 2019
18. Dr Mohit Pramod Sharma, Institute for Plasma Research, Gujarat, India, 8.-21. 10. 2019
19. Dr Henri Safa, I2EN, Paris, France, 4. 12. 2019

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10. Dr. Andrej Prošek
11. Prof. Iztok Tiselj
12. Dr. Mitja Uršič
13. *Dr. Andrija Volkanovski, left 16.08.19*

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17. Rok Krpan, B. Sc.
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27. Zoran Petrič, B. Sc.
28. Nina Rehar, B. Sc.

BIBLIOGRAPHY

Original Article

1. Blaž Mikuž, Afaque Shams, "Assessment of RANS models for flow in a loosely spaced bare rod bundle with heat transfer in low Prandtl number fluid", *Annals of Nuclear Energy*, 2019, **124**, 441-459.
2. Tomaž Skobe, Matjaž Leskovar, "Influence of corium composition on ex-vessel steam explosion", *Annals of Nuclear Energy*, 2019, **133**, 359-377.
3. Andrej Prošek, Mitja Uršič, "Review of design extension conditions experiments and analyses for non-degraded core", *Energija*, 2019, **68**, 2/3, 112-125.
4. Cedric Flageul, Iztok Tiselj, Sofiane Benhamadouche, Martin Ferrand, "A correlation for the discontinuity of the temperature variance dissipation rate at the fluid-solid interface in turbulent channel flows", *Flow, turbulence and combustion*, 2019, **103**, 1, 175-201.
5. Jure Oder, Afaque Shams, Leon Cizelj, Iztok Tiselj, "Direct numerical simulation of low-Prandtl fluid flow over a confined backward facing step", *International journal of heat and mass transfer*, 2019, **142**, 118436.
6. Martin Draksler, Boštjan Končar, Leon Cizelj, "On the accuracy of Large Eddy Simulation of multiple impinging jets", *International journal of heat and mass transfer*, 2019, **133**, 596-605.
7. Ferry Roelofs, D. Dovizio, H. Uitslag-Doolaard, D. De Santis, A. Mathur, Blaž Mikuž, Afaque Shams, "Core thermal hydraulic CFD support for liquid metal reactors", *Nuclear Engineering and Design*, 2019, **355**, 110322.
8. Matjaž Leskovar, Vasilij Centrih, Mitja Uršič, Janez Kokalj, "Investigation of steam explosion duration in stratified configuration", *Nuclear Engineering and Design*, 2019, **353**, 110233.
9. Afaque Shams *et al.* (11 authors), "Reference numerical database for turbulent flow and heat transfer in liquid metals", *Nuclear Engineering and Design*, 2019, **353**, 110274.
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11. Ferry Roelofs *et al.* (13 authors), "Towards validated prediction with RANS CFD of flow and heat transport in a wire-wrap fuel assembly", *Nuclear Engineering and Design*, 2019, **353**, 110273.
12. Andrija Volkanovski, Andrej Prošek, "Electric power frequency and nuclear safety: subsynchronous resonance case study", *Nuclear Engineering and Technology*, 2019, **51**, 4, 1017-1023.
13. Bernd Sebastian Schneider *et al.* (16 authors), "New diagnostic tools for transport measurements in the Scrape-Off Layer (SOL) of medium-size tokamaks", *Plasma physics and controlled fusion*, 2019, **61**, 5, 054004.

Published Conference Contribution

1. Andrija Volkanovski, "Accident sequence probability in PSA", In: *16th ANS International Topical Meeting on Probabilistic Safety Analysis and Analysis, PSA 2019, April 28-May 2019, Charleston, South Carolina USA*, Proceedings, American Nuclear Society, 2019, 300-303.
2. Andrija Volkanovski, "Application of qualitative importance measures", In: *16th ANS International Topical Meeting on Probabilistic Safety Analysis and Analysis, PSA 2019, April 28-May 2019, Charleston, South Carolina USA*, Proceedings, American Nuclear Society, 2019, 691-697.
3. Diego F. Mora, Roman Mukin, Oriol Costa Garrido, Markus Niffenegger, "Fracture mechanics analysis of a PWR under PTS using XFEM and input from trace", In: *ASME 2019, Pressure Vessels and Piping Conference: July 15- 17, San Antonio, Texas, USA*, Proceedings, ASME, 2019, 94019.
4. Markus Niffenegger, Oriol Costa Garrido, D. F. Mora, Roman Mukin, M. Sharabi, N. Lafferty, Bojan Ničeno, G. Qian, "Uncertainties in pressurized thermal shock analyses", In: *ASME 2019, Pressure Vessels and Piping Conference: July 15- 17, San Antonio, Texas, USA*, Proceedings, ASME, 2019, 94076.
5. E. M. A. Frederix, Blaž Mikuž, Ed. M. J. Komen, "LES of a Taylor bubble in co-current turbulent pipe flow", In: *DLES 12, Workshop Direct and Large Eddy Simulation,: June 5th-7th 2019, Madrid, Spain*, Proceedings, Universidad Carlos III, 2019.
6. Matjaž Leskovar, Vasilij Centrih, Mitja Uršič, Janez Kokalj, "Analysis of steam Explosion duration in stratified configuration", In: *ERMSAR 2019, 9th European Review Meeting on Severe Accident Research, May 18-20, 2019, Prague, Czech Republic*, Proceedings, NUGENIA, 2019, 91.
7. D. Manara *et al.* (16 authors), "Severe accident research priority ranking: a new assessment eight years after the Fukushima Daiichi accident", In: *ERMSAR 2019, 9th European Review Meeting on Severe Accident Research, May 18-20, 2019, Prague, Czech Republic*, Proceedings, NUGENIA, 2019, 835.
8. Rok Krpan, Ivo Kljenak, Houjun Gong, Ying Wang, Yuanfeng Zan, Pengzhou Li, Etienne Studer, Ahmed Bentaib, Namane Mechitoua, "Simulation of experiment on light gas layer erosion in small-scale mcthbf containment experimental facility", In: *ERMSAR 2019, 9th European Review Meeting on Severe Accident Research, May 18-20, 2019, Prague, Czech Republic*, Proceedings, NUGENIA, 2019, 673.
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1. Andrej Prošek, *Semiscale S-NC-02 and S-NC-03 natural circulation tests performed by RELAP5/MOD3.3 Patch05*, Washington: U.S. Nuclear Regulatory Commission, 2019.

Theses and Mentoring

1. Tadej Holler, *Turbulent hydrogen combustion modelling in experimental containment facility:* doctoral dissertation, Ljubljana, 2019 (mentor Ivo Kljenak).
2. Jure Oder, *Direct numerical simulation of flow separation with heat conduction:* doctoral dissertation, Ljubljana, 2019 (mentor Iztok Tiselj).

REACTOR INFRASTRUCTURE CENTRE RIC

The Reactor Infrastructure Centre (RIC) incorporates a TRIGA Mark II research reactor and a Hot Cells Facility. The reactor, operating since 1966, is used for neutron research, education and training, and radioactive isotope production. A detailed technical description of the reactor is available at http://www.rcp.ijs.si/~ric/. The Hot Cells Facility is used for the treatment and handling of radioactive materials and radioactive waste, for both research and applicative projects. In addition, it is used for performing regular radiological measurements of radioactive waste and irradiated samples.

Members of the reactor staff operate and maintain the reactor. They also participate in other activities, requiring specialists skilled in working with sources of radiation and in reactor technology, such as servicing of industrial radioactive sources and surveillance of fuel management in NPP Krško.

Head:
Prof. Borut Smodiš

The reactor operated in accordance with the programme that is approved on a weekly basis by the Heads of RIC and the Radiation Protection Unit – RPU (SVPIS in Slovene). In 2019, the reactor operated for 137 days and produced 112.6 MWh of heat. Altogether, ninety pulses were carried out and 835 samples were irradiated in the rotary specimen rack, irradiation channels and in the pneumatic transfer system.

The reactor operators supported researchers by performing operations and services for which the researchers are not qualified and authorized, such as operating the reactor, performing irradiations and manipulating irradiated radioactive samples.

In 2019 the reactor was mainly used as a neutron source for neutron-activation analysis, irradiation of electronic components, education and training. For educational purposes, it was mostly used by the J. Stefan Institute's Nuclear Training Centre. For the irradiation of samples, it was mostly used by the Department of Environmental Sciences (O2) and the Department of Experimental Particle Physics (F9). The Reactor Physics Department (F8) used the reactor for experiments in reactor physics.

The shutdown reactor, being a powerful source of gamma radiation, was used for testing the resistance of electronic components to radiation, irradiation of ceramic samples for the Department of Electronic Ceramics (K5) and sterilization of samples for the Department for Nanostructured Materials (K7).

In the Hot Cells Facility, the activities were mostly performed by the Department of Environmental Sciences (O2), the Radiation Protection Unit and the Slovenian Agency for Radioactive Waste Management (ARAO) – processing and preparation of radioactive waste for storage.

The reactor was used for the following research activities:

- Reactor physics and neutronics;
- Activation analysis;
- Research on radiation damage of semiconductors;
- Neutron dosimetry and spectrometry;
- Activation of materials, nuclear waste and decommissioning;
- Radiation hardness studies;
- Irradiation of materials for fusion reactors;
- Irradiation of electronic and medical components;
- Development and testing of new detectors;
- Development of new methods for measuring power profiles, neutron spectra, etc.;
- Verification and validation of methods for calculating the transport of neutrons, photons and electrons;
- Development of educational tools in reactor physics.

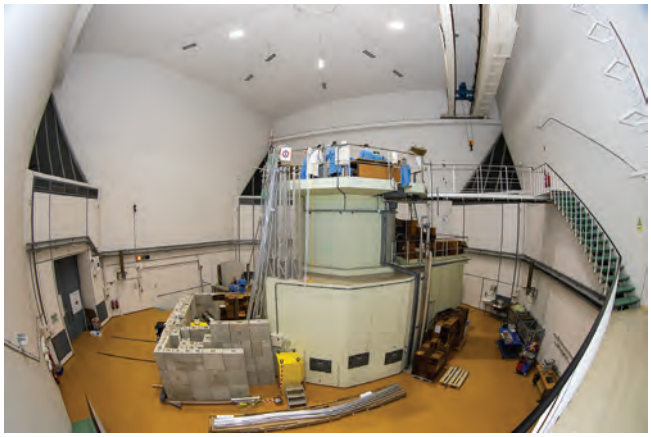

Figure 1: Last year in September, TRIGA participated in event called "Noč raziskovalcev". Everybody was able to observe the reactor during operation.

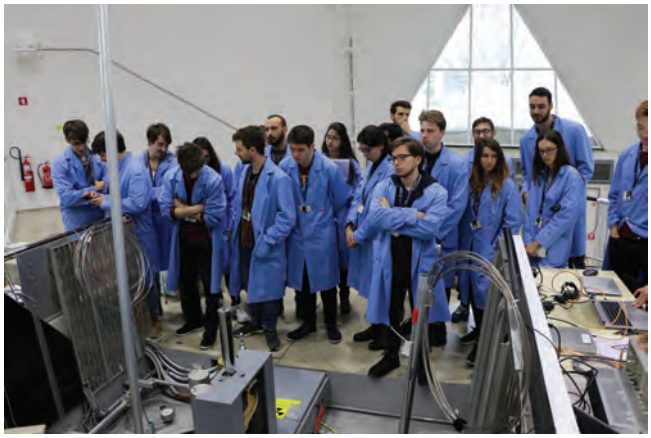

Figure 2: Students from the University of Milan during a short training course on prompt critical nuclear systems.

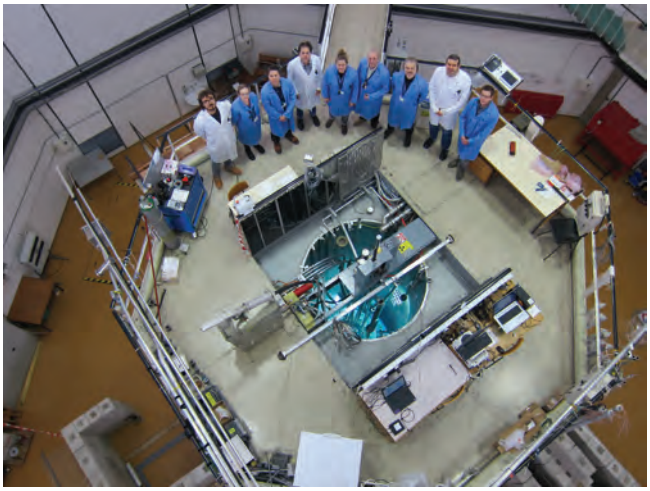

Figure 3: Precision Acoustics, TWI and Ionix developers of ultrasonic sensors during a test campaign at JSI TRIGA reactor.

Figure 4: Students from Uppsala university during a 3-day training course at JSI TRIGA reactor.

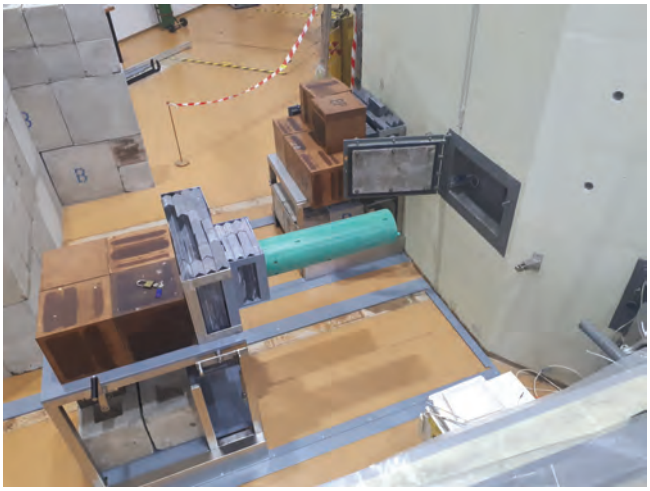

Figure 5: Last year, beam port No. 5 was modified for the purpose of irradiating large fission chambers. The facility is used by Rolls Royce Civil Nuclear S.A.S.

In the framework of collaboration between the Reactor Physics Department (F8) and the French Alternative Energies and Atomic Energy Commission (CEA), Cadarache, irradiations of samples were carried out. Subsequently, they were analysed at CEA by FT-TIMS (Fission Track – Thermal Ionization Mass Spectrometry).

Due to good formal and informal cooperation with CEA, the abovementioned activities will also be continued in 2020.

The JSI TRIGA Mark II Reactor is a reference centre for neutron irradiation in the development of ATLAS detectors (http://aida2020.web.cern.ch/content/jsi) in CERN. Since 2011, the TRIGA Reactor has participated in the FP7 AIDA (*Advanced Infrastructures for Detectors and Accelerators*) and in the project "*Horizon 2020 - the AIDA-2020 GA No. 654168, Task 15.5 - Irradiation Facilities*" (http://aida.web.cern.ch/aida/index.html), which brings together advanced European infrastructures for future particle physics experiments. This cooperation continues as part of the AIDA II project.

In January, ultrasound detectors were exposed to high neutron and gamma radiation. For that purpose, the reactor was operated at full power for almost 40 hours. An online test of the detectors' survivability was performed by the companies Precision Acoustics, IONIX and TWI.

In the scope of the NATO SPS project E-SiCure (http://e-sicure.web.ua.pt/), in which the Reactor Physics Department (F8) is also involved, the reactor was used to perform test irradiations of silicon carbide samples to study the neutron-induced defects in the material. The project is aimed at engineering silicon carbide material for the detectors of special nuclear material for border and port security. Irradiations took place in June and November.

In July and December, a team from Rolls Royce Civil Nuclear SAS performed tests on their nuclear-acquisition system. As a detector, a fission chamber was placed inside the beam tube no. 5. The company has established a contract with the JSI for the following two years, with the possibility of extending the time frame to 5 years.

The reactor was often used by researchers from the Reactor Physics department to test their equipment, which is used to perform physical tests at the Krško NPP. For the first time, RIC personnel also participated at the physical tests.

In November, the reactor hosted researchers from the Department of Experimental Particle Physics, who were collaborating with Turkish Nuclear Radiation Detectors Application and Research Centre in testing semiconductor radiation detectors.

In November, irradiations of boron nitride nano powder were performed in collaboration with the Institute of Radiation Problems of Azerbaijan National Academy of Sciences.

In December, samples of special rubber were tested on radiation hardness. Irradiations were made with gamma rays only. The company MK-TEAM is developing rubber to be used as a seal on barrels for radioactive waste storage.

In December, the TRIGA staff replaced radiation sources Kr-85 on a device used by Papirnica Vevče. Sources are a crucial component for the online measurement of paper thickness and density.

Throughout the whole year, over 500 samples were irradiated for the Department of Environmental Sciences, performing neutron-activation analysis. Several samples of semiconductors were also irradiated for CERN.

In the autumn, students from the Faculty of Mathematics and Physics were hosted. They performed practical exercises for the course on reactor physics. Several times, the undergraduate students were also hosted, performing basic versions of the practical exercises.

In October, the Reactor Centre hosted the EERRI "Group fellowship training course program" in collaboration with the International Atomic Energy Agency. The course was attended by nine participants from all over the world.

In September, six students from the Uppsala University took a short course on practical reactor physics.

In November, students from the University of Milan participated at a one-day practical course at the TRIGA reactor.

Cooperation with Slovenian companies DITO d.o.o. and Nanocut d.o.o. in the development of radiation-resistant LED lights has continued.

In 2019, RIC was supporting research programmes and projects between the JSI and the Faculty of Mathematics and Physics (University of Ljubljana), the Faculty of Electrical Engineering (University of Ljubljana) and the Faculty of Energy Technology (University of Maribor).

In 2019, there were more than 60 group visits to the reactor. The visitors were mainly foreign scientists, students and 47 groups of schoolchildren. Their total number was more than 1500. In March, the *Jožef Stefan Institute´s Open Days* were organized, when the reactor was visited by around 250 visitors. In September, an event called *Noč raziskovalcev* was organized, during which about 150 people visited the reactor.

Organization of conferences, congresses and meetings

1. 28th International Conference Nuclear Energy for New Europe, NENE2019, Portorož, Slovenia, 9–12 September 2019

INTERNATIONAL PROJECTS

1. Experimental Testing of Self-Powered Neutron Detectors for the Thermocoax Company
   Prof. Borut Smodiš
   Thermocoax Sas
2. Irradiation Services for the Rolls-Royce Civil Nuclear SAS Company
   Prof. Borut Smodiš
   Rolls-royce Civil Nuclear Sas
3. Training Costs for IAEA"s Fellow Mr. Ismail Marrhich (FS-MOR1011-1802851), 2.9.-28.9.2018
   Prof. Borut Smodiš
   IAEA - International Atomic Energy Agency
4. Training Costs for IAEA"s Fellow Mr. Said Otmani (FS-MOR1011-1802851), 2.9.-28.9.2018
   Prof. Borut Smodiš
   IAEA - International Atomic Energy Agency
5. H2020 - ENEEP; European Nuclear Experimental Educational Platform
   Prof. Borut Smodiš
   European Commission
6. H2020 - AIDA-2020; Task 11 Irradiation test facilities (TA2)
   Prof. Borut Smodiš
   European Commission

R&D GRANTS AND CONTRACTS

1. Irradiation for FT-TIMS Method at the JSI TRIGA Mark II Reactor
   Prof. Luka Snoj
2. Irradiations in TRIGA Nuclear Reactor
   Prof. Borut Smodiš
3. Irradiation of Glycol
   Anže Jazbec, B. Sc.
   Lancaster University
4. Irradiations on the TRIGA Reactor
   Prof. Borut Smodiš
5. Experimental Testing of Self-Powered Neutron Detector Assemblies for CEA - INFINI Project
   Prof. Borut Smodiš
   Cea List Institute, Dept. of Metrology,
6. Irradiation of FT-TIMS Samples
   Anže Jazbec, B. Sc.
   Cea - Commissariat a L' Energie Atomique
7. Irradiation and Analysis of Nano SiC Samples in the Year 2019
   Anže Jazbec, B. Sc.
   Institute of Radiation Problems of
8. Irradiation and Analysis of Samples in the Year 2019 - Part II
   Anže Jazbec, B. Sc.
   National Nuclear Research Center

VISITORS FROM ABROAD

1. Prof. Michael Österlund and Prof. Ali Al-Adili, University of Uppsala, Uppsala, Sweden, 3–4 January 2019
2. Dr Peter Cowin, Ionix Advanced Technologies, Huddersfield, United Kingdom; James Kern, TWI Ltd, Cambridge, United Kingdom; Thomas Kelley, Kyle James Hutchings, Megan Jenkinson, Katherine Challoner Bates, Precision Acoustics, Dorchester, United Kingdom, 21–25 January 2019
3. Elchin M. Huseynov and Sahil Valiyev, Institute of Radiation Problems of Azerbaijan National Academy of Sciences, Baku, Azerbaijan, 3–15 February 2019
4. Walton Gusztav, Vysotsky V. Dmitry, Kuatbekov P. Ruslan in Mitinskaya V. Victoria, Rosatom Central Europe s.r.o., 21 May 2019
5. Ivana Capan, Takeshi Ohshima, Yuichi Yamazaki, Takahiro Makino, Jose Coutinho, Željko Pastuović, Adam Sarbutt, Robert Bernat, Victor Torres and Zoran Ereš, project E-SiCure, NATO SPS, 10–14 June 2019
6. Stephane Serge Fargues, Pierre Vignollet Clement, Barnier Gael De Cargouet, Rolls Royce Civil Nuclear S.A.S, Meylan, France, 15–19 July 2019
7. Manuel Cargnelutti, Danilo Bisiach, Instrumentation Technologies, d.d., Slovenia, 21 August 2019
8. Gregoire De Izarra, Loic Barbot, Mathieu Trocme, Yoann Moline, CEA, France ter Manuel Cargnelutti, Danilo Bisiach, Aleš Bardorfer, Instrumentation Technologies, d.d., Solkan, Slovenia, 23–27 September 2019
9. Students: Bergström Holm Johan, Bernroth Carl, Hendricks Mattias, Makronikos Asp Andreas and Rezai Abdullah, and their professors: Prof. Ali Al-Adili, Prof. Michael Österlund, Prof. Ane Håkansson and Prof. Andreas Solders, University of Uppsala, Uppsala, Sweden, 30 September 2019 – 2 October 2019
10. Miroslav Konecny, ADDSEN, Malacky, Slovakia, 23 October 2019
11. Students: Antonio Cammi, Stefano Lorenzi, Pasquale Barbato, Nurberk Sungur, Arianna Jasmin Astaneh, Davide Castelli, Lorenzo Cattoni, Martina Di Cennaro, Riccardo Giorgi, Francesco Gatti, Marco Bonacina, Enrico Emanuelli, Arnaldo Samuele Mattioli, Marco Herbas Lopez, Stefano Colombo, Giulia Merla, Frederico Caruggi, Diego Taramillo Sierra, Simone Sparacio, Symeon Grivas, Pierfrancesco Ombrini, Daniele Calzolari, Letizia Di Matteo, Nikita Nemykim, Martina Di Gennaro, Arnaldo Samvele Mazziol, Stefano Cocombo, and Asst. Prof. Raffaele Giordano, Politecnico di Milano, Italy, 11 November 2019
12. Elchin M. Huseynov, Institute of Radiation Problems of Azerbaijan National Academy of Sciences, Baku, Azerbaijan, 14–23 November 2019
13. Raffaelle Giorgano, Gaël De Cargouët in Piere Vignollet, Rolls Royce Civil Nuclear S.A.S, Meylan, France, 10–12 December 2019

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5. Marko Rosman
6. Sebastjan Rupnik, B. Sc.
7. Nina Udir, B. Sc.
8. Andraž Verdir, B. Sc.

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Original Article

1. Elchin Huseynov, Anže Jazbec, Luka Snoj, "Temperature vs. impedance dependencies of neutron-irradiated nanocrystalline silicon carbide (3C-SiC)", *Applied physics. A, Materials science & processing*, 2019, **125**, 1, 9.

Published Conference Contribution

1. Vladimir Radulović, Klemen Ambrožič, Tanja Goričanec, Bor Kos, Sebastjan Rupnik, Anže Jazbec, Luka Snoj, "Neutron activation measurements and calculations in support of detecor testing experiments at the JSI TRIGA reactor", In: *European Research Reactor Conference, RRFM 2019, 24-28 March 2019, Jordan, Amman*, Conference proceedings, ENS, 2019.
2. Anže Jazbec, Bor Kos, Luka Snoj, "Gamma dose rate analysis in case of loss of water event at the Jožef Stefan Institute TRIGA Mark II Research reactor", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 609.
3. Anže Jazbec, Vladimir Radulović, Sebastjan Rupnik, Andraž Verdir, Marko Rosman, Borut Smodiš, Luka Snoj, "Jožef Stefan Institute TRIGA Research Reactor activities in the period from September 2018 - August 2019", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 506.
4. Jan Malec, Anže Pungerčič, Bor Kos, Klemen Ambrožič, Andrej Žohar, Vladimir Radulović, Anže Jazbec, Sebastjan Rupnik, Vid Merljak, Aljaž Čufar, Žiga Štancar, Luka Snoj, "Towards a new research reactor in Slovenia", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 1114.

NETWORKING INFRASTRUCTURE CENTRE NIC

The Networking Infrastructure Centre (NIC) is responsible for the administration, development, management and expansion of the core network, ICT services and infrastructure of the Jožef Stefan Institute. It also supports the development of computational, communication, data and security infrastructure for our research departments, centres and services.

Head:
Dr. Jan Jona Javoršek

The NIC's main mission is to maintain the computing networks, services and hardware necessary to support the work of users at the Jožef Stefan Institute, their collaborators, projects and research groups. We provide a high level of connectivity and integration with local and international communication networks and infrastructures, but we also deliver ICT support for research activities at the Jožef Stefan Institute, including the development, management and administration of ICT infrastructure, computing facilities and services. NIC is responsible for four main domains: networking infrastructure, network security, network services and distributed network supercomputing.

Networking Infrastructure. The Networking Infrastructure Centre is responsible for the development, management, administration and support of the Institute's physical networking infrastructure. It delivers support for local networks, ensuring local and internet connectivity for users and services at the Institute. This task includes the management of wireless networks at all Institute locations and providing a number of dedicated networks for specific services, projects and activities (i.e., dedicated links to other institutions, secure links to the Reactor Infrastructure Centre Podgorica, connections to scientific VPN networks through GÉANT, etc.).

Physical Network: In 2019 we continued extending and optimising parts of the physical network and cabling installations as well as updating and upgrading our active equipment, including wireless access point installations and core backbone network routers, to support extensions and optimisations of the Institute backbone network as well as the use of virtual network links for dispersed internal networks, (super)computing clusters and virtual machine farms, including remote VPN access and device support access for outside contractors. External connections have been monitored and optimised to support high network throughput work and experiments needed for collaboration within WLCG (Worldwide Large Hadron Collider Computing Grid) for ATLAS, but also Belle2 and other EGI and PRACE using projects over general GÉANT networks and also dedicated scientific VPNs such as LHCONE and PRACE.

A modern, up-to-date, multiple 10 Gbit/s network backbone supporting modern protocol stacks and dedicated external links is the basis of a flexible modern network environment at the Jožef Stefan Institute, where high availability and advanced services supporting many fixed and wireless clients is a requirement for day-to-day work.

Monitoring: Development and integration of our traffic, event and status-monitoring infrastructure, implemented on the basis of software packages Nagios for monitoring and alerting, Ganglia, Cacati and Observium for network monitoring, a customised dynamic analytical visualisation package built with Kibana and ElasticSearch, and Grafana-based aggregated monitoring to display an integrated report and react to usage fluctuations and unexpected events in the domain of web services, security policies, firewalls, authentication and authorization, network time systems, e-mail delivery, analysis, processing and security systems, physical machine sensory status, environmental data, power line data etc.

Wireless network: Thanks to cheap, highly efficient components and better central control we were able to continue to improve the wireless coverage and density of our wireless networks where needed.

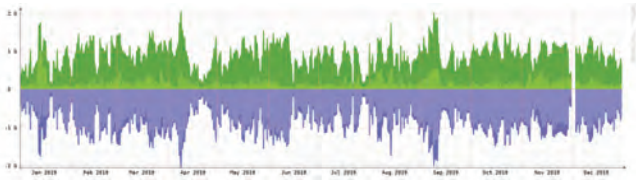

Figure 1: General outside network shows some fluctuations, but it has been well within the optimum capacity limits, since the portion of the traffic routed over dedicated traffic science VPNs is growing, but is limited by the available national connectivity.

Network Security. The NIC is responsible for implementing security measures and policies at the external network borderline, in the internal network NS regarding the services and software deployments for the users. External network security is implemented with dynamic management and configuration of active deep packet inspection firewall systems and routing configurations, while dedicated links are managed with passive measures (configuration, filtering and supervision) to facilitate high throughput. Constant dynamic supervision, traffic monitoring and event analysis is needed to ensure suitable security in the complex constraints and requirements of an open academic network that collide with current security considerations and demands for high throughput.

Ensuring a secure and open environment requires disproportionate increases in equipment capabilities and efforts in the dynamic security policy configuration, event monitoring and analytics. We have started testing ethernet port security in some networks, which also enables advanced features, such as the autonomous registration of new devices, i.e., in computer lecture rooms and laboratories.

Internal development of e-mail security and dynamic network firewalling, encrypted connections, virtual networks, advanced analysis and monitoring ensure the security of an open academic network in the age of a hostile Internet.

Since the NIC is responsible for the security of the ICT infrastructure of the Institute, we are active members of relevant institutions and groups, notably the national security response centre SI-CERT, FIRST (Forum of Incident Response and Security Teams) and EGI CSIRT (European Grid Initiative distributed computing security incident response team). We also take part in the response team of the national distributed computing network consortium SLING. The national science certificate agency SiGNET CA (Slovenian Grid Network Certification Authority), managed by the NIC, is a full member of EU Grid PMA (EU Grid Policy Management Authority) and IGTF (Interoperable Global Trust Federation). We participate in the work of the Slovenian network technology and security association SINOG (Slovenian Network Operators Group) and supported the organization by hosting a technical workshop at the Institute this year.

E-Mail: In the area of e-mail security and protection against undesired or malignant messages, we have continued with in-house software development of Amavisd, the open-source e-mail content filter, and its SpamAssassin package integration, but also with continuous improvements in the support for new and advanced features in e-mail message and protocol stack handling and filtering.

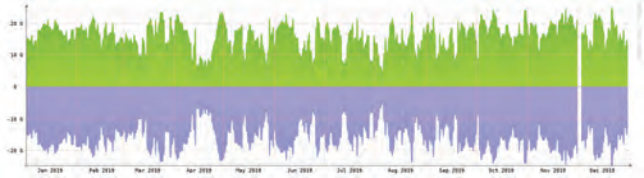

Figure 2: Traffic on the 20 Gbit/s dedicated science VPN LHCOne link between the Institute and Arnes has been limited by local and national connectivity. It fluctuates due to differences in the loads from CPU-limited and data-limited computing tasks.

Cryptography and certification: We have continued with gradual integration of DNSSEC-signed internet domain names using automated mechanisms for the verification of the signatures and with the gradual introduction of the DANE system (integration of TLS certificates with the DNS system) in e-mail transfers and publishing SSHFP records via DNS servers. The number of digital certificates used on the Institute's servers has continued to rise, mostly using free DigiCert server certificates, courtesy of Arnes and GÉANT. We have also continued expanding the use of TLS encryption by widely introducing "Let's Encrypt" certificates to many services. The number or users of our VPN infrastructure has been steadily increasing.

ICT services. The NIC provisions, develops and maintains a number of core and some secondary ICT services. The most important among these are e-mail (e-mail routing and delivery, in-box management, directory management, webmail services etc.) and world wide web support (main Institute web server, web hosting for users, departments and projects, a web directory). Secondary ICT services are provided in support of certain core or specific activities at the Institute, such as web presentations, a conference system, supervision and monitoring, etc. In some of these services the NIC is directly invested in the software or infrastructure development, such as the network time services and e-mail filtering and security, while others are simply administered and maintained. The third NIC service category is comprised of services supporting our users (calendaring, event management, directories) and software/system developers (code repositories, integration and verification, licence management, mobile platform software development, integration and shipping for Apple Appstore and Google Play). Software development repository has stood out by attracting a large number or new users in previous years, and in the past two years there has been a sharp increase in the use of our testing deployment of a NextCloud file repository and collaboration centre. We also provide physical server hosting and management, aimed primarily at larger projects and systems, the administration of directories for personal computing and user management (such as departmental single sign-on or directory services) and the administration of mission-critical workstations and components.

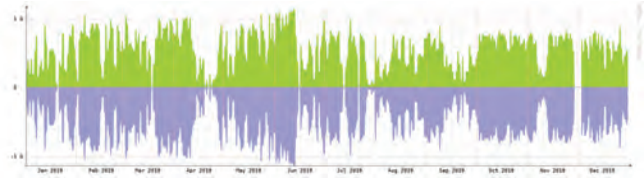

Figure 3: Network usage at the common cluster reflects large differences in data sets and network requirements that we see due to substantially different user requirements.

In 2019, we approached the limit of expanding for the computationally-intensive infrastructure in the new computing centre at Teslova that was established in 2015, with the available electrical power while at the NIC computing centre, where we can provide highly reliable cooling, network connectivity and uninterrupted power supply for critical services, we have continued to host ever more computationally less intensive servers from several departments. We have also expanded our web hosting activity (over 110 distinct sites).

We have continued the updating of our user-facing documentation and our user interfaces. A Single-Sign-On (SSO) service, integrated with the national AAI federation at Arnes and European eduGAIN federation is now used extensively since it gives our users easier access to numerous national and international services using their institute

credentials. We hope that this facility will simplify user and authentication management at the institute and for software developers who work on internal projects and services in the future.

Network super-computing. In the field of network computing technology and infrastructure, high-throughput computing, high-performance computing, network and grid middleware, vectorisation, software containers, virtualisation and ICT as a service (cloud) continued to converge, which confirmed our strategy of integrating all of the above approaches. NIC has continued to maintain central computing facilities for the IJS and has been collaborating with our other computing clusters, while taking part directly in the Slovenian National Supercomputing Network SLING as a funding member and core partner, participating in the development and integration efforts of the consortium. The NIC maintains the Slovenian certification agency SLING CA for science, research and grid computing, takes part in the maintenance and support of the core national supercomputing grid network services and coordinates work with international infrastructure projects and collaborations.

The constant growth of network services and network computing with ever-better support for collaboration and teamwork, software development, data protection and access to large computing and data resources for scientific research at home and abroad are a crucial cornerstone for modern scientific work.

In 2019, the New System Cluster (NSC), the common computing cluster in the facilities of the Jožef Stefan Institute's Computing Centre Teslova, has continued to see a steady increase in user demand. The cluster with 1984 64-bit computing cores, 16 GPGPU accelerators (NVidia Kepler 40), almost 9 TB RAM and 90 TB disk storage is now too small and old to meet all the demands, but it is important for the promotion and availability of supercomputing at the Jožef Stefan Institute since it is the only cluster that is available to all researchers at the Institute and can therefore provide an important modern computing platform to all of our departments. As a common infrastructure, it is instrumental in forwarding collaboration among departments with their own computing facilities and among researchers and groups with similar software requirements or computational problems that can be solved in an environment that can support supercomputing and high-throughput computing. In the context of this work, besides supporting users of JSI clusters, we also work on the integration of clusters with the national supercomputing network SLING using the NorduGrid ARC Grid Middleware to enable users to use all the resources in the network with the same interfaces and to use software containers to facilitate portability of user software.

Figure 4: Power consumption of the JSI computer centre Teslova reflects how intensively the facility hosting our HPC systems is used. The graph shows higher efficiency of the cooling system in winter months, when we can use free cooling, and increased consumption in the second half of the year, when the power requirements forced us to start using both cooling systems in parallel.

In the domain of network supercomputing we have been most involved with Slovenian National Supercomputing Network (SLING), but we also worked within the European Grid Initiative EGI, PRACE (Partnership for Advanced Computing in Europe), the NorduGrid ARC collaboration and a number of international projects (ATLAS – dedicated link, Belle2 – computing support , CLARIN – support for different services of Slovenian national node, ELIXIR – collaboration with the national node and the European collaboration). SLING has supported a number of research projects and applications, among others in high-energy physics, medical sensor and image analysis, theoretical physics, astrophysics, biochemistry, protein-folding simulations, crystal analysis, knowledge technologies, artificial intelligence, statistical analysis and fluid dynamics, computational linguistics, etc. In a number of cases we have been involved as part of the SLING support group in the parallelization and preparation of computing tasks and administration of the required run-time environments. Members of NIC have also contributed as advisors in EuroHPC and European Open Science Cloud, HPC RIVR consortium expert commitee, training and set-up of the new national supercomputer HPC RIVR Maister at the University of Maribor and the sucessful slovenian candidacy for a EuroHPC petascale site at IZUM with the HPC RIVER Vega machine.

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3. Barbara Krašovec, M. Sc.
4. Mark Martinec, B. Sc.

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6. Janez Jezeršek
7. Matjaž Levstek
8. Janez Srakar
9. Matej Wedam

SCIENCE INFORMATION CENTRE SIC

The Jožef Stefan Institute Science Information Centre is the central Slovenian physics research library and the largest research library in Slovenia. Our main tasks are the acquisition, archiving, and loan of books and periodicals, and the input, update and control of bibliographic data of the Institute's staff, as requested by the funding ministry.

Head:
Dr. Luka Šušteršič

Our collection of over 100,000 publications covers the fields of physics, chemistry, biochemistry, electronics, information science, artificial intelligence, nuclear technology, energy management and environmental science. We provide access to over 4000 electronic journals. We are a founding member of the ScienceDirect, SpringerLink, Wiley online library, IEEExplore and ACS consortia. We subscribe to the SCOPUS, INSPEC and Web of Science databases, and to the SciVal research evaluation and management tool.

We manage bibliographic data for approximately 700 researchers. Our bibliographic database, which is a part of the COBISS system, contains about 80,000 records, going back to the Institute's inception in 1949. Last year's data is included as part of this report.

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7. Jože Škulj
8. Branka Štrancar
9. Ana Tratnik
10. Saša Žnidar, B. Sc.

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Professional Monograph

1. Alenka Kavčič-Čolić, Angela Čuk, Katja Kranjc, Tjaša Obal, Helena Pečko-Mlekuš, Luka Šušteršič, Maja Vavtar, Igor Zemljič, *Strokovni standardi za specialne knjižnice: (26. 11. 2018 - 25. 11. 2028)*, Zveza bibliotekarskih društev Slovenije, 2019.

ENERGY EFFICIENCY CENTRE

EEC

The basic activities of the Energy Efficiency Centre are in efficient energy use, long-term planning in energy and the reduction of greenhouse-gases (GHG) emissions. The centre is a focal point for the collection and transfer of energy-efficiency technologies to energy users, the state, energy service and equipment providers, and other interested agencies. At the same time it covers the environmental effects of energy use and conversion. The most significant part of the EEC's activities is thus cooperation with state institutions in the preparation of strategic documents and legislation in the field of efficient energy use, energy planning, distributed electricity production and emission trading. Nevertheless, it still remains strongly connected, by its consulting and training role in energy, with industrial companies and other institutions as well as also being increasingly involved in European research projects.

Head:
Stane Merše, M. Sc.

Energy and the environment

In 2019 the EEC with its professional work ensured high-quality support to ministries in the preparation of the strategic development documents and transfer of EU legislation. Energy efficiency is a priority field to achieve global climate and energy goals and in accordance with the Directive on Energy Efficiency (2012/27/EU) EEC report on the implementation of the Action Plan for Energy Efficiency for the period 2014–2020 was prepared. The EEC was leading the consortium for the preparation of the analytical basis and draft of the National Energy and Climate Plan (NECP) of Slovenia. and started preparation of the long-term renovation strategy to support the renovation of national building stock into a highly energy-efficient and decarbonised building stock by 2050.

Within the expert support of the Ministry of the Environment and Spatial Planning EEC activities focused on the preparation of the analytical basis and long-term GHG emission projection within the LIFE ClimatPath2050 project with the goal to contribute to better climate governance by enhanced monitoring and planning of GHG mitigation measures in buildings, transport, industry, agriculture, forestry and waste. The second Climate Action Mirror was prepared, which also presents a report on the implementation of the Operative programme of measures for GHG emission reduction until 2020 and the Local Climate Activity Scoreboard of Municipalities LIFE IP CARE4CLIMATE - Boosting greenhouse gas emissions reduction by 2020 with a view to 2030 started on 1st January 2020 where the EEC leads several actions on training, local energy planning and development of advanced instruments for sustainable buildings retrofit. The EEC was also involved in the preparation of the analytical basis for international reporting in the framework of the MMR. and continued preparation of the professional support for the design of National Air Pollution Control Programmes (NAPCP) prescribed by the NEC directive.

Research and development work of the Energy Efficiency Centre is an important contribution to the preparation of key documents in Slovenia in the field of energy development, energy efficiency, renewables exploitation and the transition of Slovenia to a carbon-neutral society, with training activities and support to industry it significantly contributes to an increase in competitiveness and development restructuring.

The EEC cooperates with the Statistical Office of the Republic of Slovenia, where, every year, it prepares a model calculation for fuels and energy use in households for the national energy statistics. Also in 2019, EEC continued with activities of the state referential centre for energy with the preparation of an expanded set of indicators for energy and the environment. For the Energy Agency EEC prepared "Report on the achievement of national goals in the field of RES and CHP for the period 2017–2018" and set new reference electricity generation costs for the support scheme for RES and cogeneration electricity production units.

Figure 1: Local Climate Activity Scoreboard of Municipalities – The value of stimulated investments in energy efficiency and renewable energy in households per capita in 2018.

Promotion of efficient energy use and energy consulting

In 2019 the EEC continued with its training activities where already the twelfth cycle of energy managers' training was successfully concluded within the European programme EUREM. Due to a very positive reaction of participants and their interest (in Slovenia there are already more than 240 energy managers with the EUREM

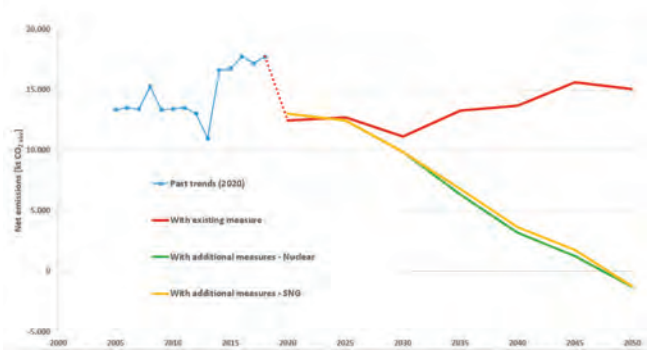

Figure 2: Net GHG emission scenarios for the transition to a climate-neutral society within the analytical basis for the Long-Term Strategy (Life Climate Path 2050)

Figure 3: Awarding of prizes to the 12th generation of EUREM energy managers.

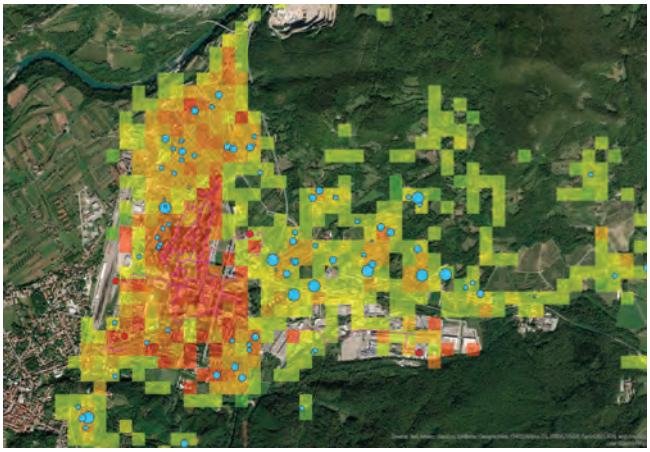

Figure 4: Heat-map application for City Municipality of Nova Gorica for 2020

licence), it is clear that there is a great need for such training. High-quality knowledge in this field is namely of key importance for the execution of efficient solutions in practice.

In 2019 the EEC continued its intensive development work in the field of district heating (DH) and began preparing a Benchmark Study of District Heating Companies, where a detailed analysis of the operation and development of 13 DH systems in Slovenia was made. In cooperation with a Geological Survey of Slovenia analysis, the "Exploitation of shallow geothermal energy in the district heating system of the city of Maribor" was prepared for the company Energetika Maribor. An intensive development of the GIS tool for the spatial analysis of heat consumption in buildings ("heatmap") – Heat maps of Slovenia (Figure 4).

Together with the company ELEK, a study "Possibilities and cost scenarios and the own price of synthetic natural gas production in Slovenia (Power to Gas)" was prepared for the company Plinovodi. The EEC started preparation of the "Strategy for energy and material efficiency and sustainable development of DARS d. d. by 2030", where energy and environmental impact assessments of the removal of motorway toll stations was prepared (Figure)

The professional cooperation with steel company Metal Ravne in field of waste-heat utilisation continued with preparatory activities for the installation of a pilot plant in 2020.

The EEC prepared the programme for the 21st conference "Energy Managers Days", the annual meeting of energy managers with more than 200 participants confirms the quality and public profile of the EEC professional work.

International cooperation

In 2019 the EEC carried out as many as 9 international projects, financed from the European Union resources in the framework of LIFE and HORIZON 2020. Projects cover activities in the fields of:

- Slovenian mid-century climate path (LIFE ClimatePath2050)
- Boosting greenhouse-gas emissions reduction by 2020 with a view to 2030, (LIFE IP CARE4CLIMATE)
- Heat-pipe technology for the waste-heat recovery in industry (ETEKINA),
- Driving investment in energy -services through quality assurance (QualitEE),
- Monitoring of indicators of for energy use and energy efficiency in the EU – (ODYSSEE MURE),
- Improving the Performance of District Heating Systems in Central and East Europe (KeepWarm)
- Making heating and cooling for European consumers efficient, economically resilient, clean and climate-friendly (REPLACE)
- carrying out the EU directive on energy efficiency (CA – EED),
- carrying out the EU directive on renewable energy sources (CA – RES).

Projects include cooperations with research and development organisations from Europe, with a strong emphasis on concrete applications and the promotion of energy efficiency. In the framework of each project the EEC staff took part in numerous foreign professional meetings and visits.

Some outstanding achievements in the past three years

1. **Preparation of several key support documents for the government of the Republic of Slovenia** in the field of energy policy (National Energy and Climate Plan - NECP)), energy efficiency (First and Second National Action Plan for Energy Efficiency), renewable energy sources (Action Plan for Renewable energy sources for the period 2010–2020) and climate policy (Operative programme of GHG emissions reduction up to 2020).
2. **Establishment of energy managers' training** in the framework of the European project EUREM and **professional support to industry and other institutions** by carrying out energy audits, feasibility studies and

other consulting (Goodyear, TE-TOL, Luka Koper, Salonit Anhovo, Telekom Slovenije, Letrika–Mahle, BTC, KOTO, etc.).

3. In the framework of the European project **Transparense** the EEC led, very successfully, the preparation of the **European code of Conduct for energy contracting**. The Code identifies the basic values and principles, which are of key importance for the successful preparation and carrying out of projects with third-party financing. The Code was very successfully accepted at the European level and currently already has 171 signatories, among them the European association of companies for energy services (eu.ESCO) and the European federation for intelligent services of energy efficiency (EFIEES), supported also by the European Commission. In Slovenia the code was already tested in practice in a project of integrated energy renovation of the municipal building of the municipality Brda.

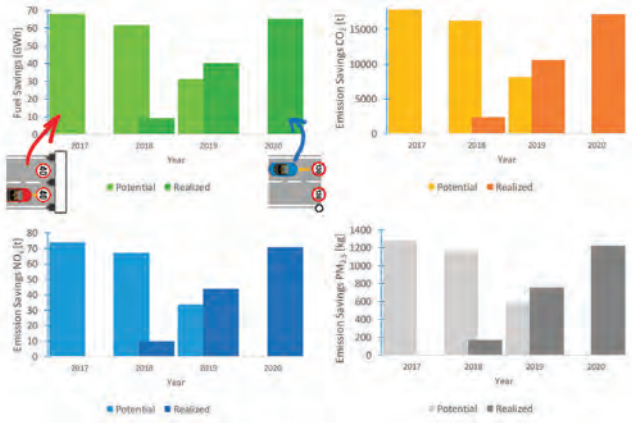

Figure 5: Analysis of fuel (energy) savings and emission reduction as a consequence of the removal of DARS toll stations

Awards and Appointments

1. Gašper Stegnar: PhD Student award for outstanding and original contributions to research in the field of district heating and cooling at the 19th Eurheat & Power Congress, Nantes, France, the award was given by the DHC + Technology Platform

Organization of conferences, congresses and meetings

1. Strategic environmental impact assessment process and evaluation of scenarios - workshop on Life Climate Path 2050 project, ARSO, Ljubljana, Slovenia, 14 February, 2019
2. Potential of biomass for energy use and potentials up to 2050 – technical workshop on Life Climate Path 2050, JSI, Brinje, Slovenia, 5 March, 2019
3. An overview of Strategic environmental impact assessment for hydropower plants and wind turbines - workshop on Life Climate Path 2050 project, ARSO, Ljubljana, Slovenia, 7 March, 2019
4. Consortium meeting NEPN, JSI, Brinje, Slovenia, 15 March 2019
5. Consortium meeting NEPN, JSI, Brinje, Slovenia, 24 March 2019
6. LULUCF model and its assumptions – workshop on Life Climate Path 2050 project, GIS, Ljubljana, Slovenia, 26 March, 2019
7. 21st Energy Days, Meeting of energy managers of Slovenia, Portorož, Slovenia, 19-17 April 2019
8. Possibilities for energy renovation of cultural heritage buildings until 2030 and 2050 – workshop on Life Climate Path 2050 project, MK, Ljubljana, Slovenia, 19 April, 2019
9. Preparation workshop for Climate Action Mirror 2019 on Climate Path 2050 project, ARSO, Ljubljana, Slovenia, 25 April, 2019
10. Incentives/subsidies to reduce GHG emissions in the economy – workshop on Climate Path 2050 project, JSI, Brinje, Slovenia, 10 May, 2019
11. Sustainable mobility and user behaviour- measures to promote public passenger transport - workshop on Life Climate Path 2050 project, MK, Ljubljana, Slovenia, 14 May, 2019
12. GHG emissions in Agriculture – workshop on Life Climate Path 2050 project, KIS, Ljubljana, Slovenia, 6 Jun, 2019
13. Future of natural gas and development of low carbon fuels - meeting of experts on Life Climate Path 2050 project, JSI, Brinje, Slovenia, 11 Jun, 2019
14. Climate Action Mirror 2019 and Local Action Scoreboard 2019 on Climate Path 2050 project, MAO, Fužine castle, Ljubljana, Slovenia, 12 Jun, 2019
15. Climate neutrality - from weather to how; consultation about long term climate strategy for Slovenia – meeting on Climate Path 2050 project, National Council of the Republic of Slovenia, Ljubljana, Slovenia, 20 Jun, 2019
16. Regional conference on the preparation of NEPN, Energy Industry Chamber of Slovenia (EICS), Ljubljana, Slovenia, 4 July, 2019
17. Alumni EUREM Slovenia 2019, Ljubljana, Slovenia, 19 September, 2019
18. 4th Steering Committee Meeting on EU Keep Warm project, RCP, Brinje, Slovenia, 24-27 September, 2019
19. Quality assurance of energy efficiency projects (Expert seminar within the EU project H2020 QualitEE, Brinje, Slovenia, 5 December, 2019
20. Financing the transition to low carbon society, part 1 – workshop on Life Climate Path 2050 project, JSI, Brinje, Slovenia, 11 December, 2019

INTERNATIONAL PROJECTS

1. Life IP Care4Climate - Boosting greenhouse gas emissions reduction by 2020 with a view to 2030
   Stane Merše, M. Sc.
   European Commission
2. „LIFE ClimatePath 2050“ Slovenian Path towards the Mid-Century Climate Target
   Andreja Urbančič, M. Sc.
   European Commission
3. H2020 - ENERFUND; An ENErgy Retroit FUNding rating tool
   Jure Čižman, M. Sc.
   European Commission
4. H2020 - guarantEE; Energy Efficiency with Performance Guarantees in Private and Public Sector
   Damir Staničić, M. Sc.
   European Commission
5. H2020 - QualitEE; Quality Certification Frameworks for Energy Efficiency Services to scale up Responsible Investment in the Building Sector
   Damir Staničić, M. Sc.
   European Commission
6. H2020 - KeepWarm; Improving the performance of district heating systems in Central and East Europe
   Stane Merše, M. Sc.
   European Commission
7. H2020 - ODYSEE-MURE; Monitoring EU Energy Efficiency First Principle and Policy Implementation
   Dr. Fouad Al-Mansour
   European Commission
8. H2020 - REPLACE; Making Heating and Cooling for European Consumers Efficient, Economically Resilient, Clean and Climate-Friendly
   Gašper Stegnar, B. Sc.
   European Commission

RESEARCH PROGRAMME

1. Modelling and environmental impact assessment of processes and energy technologies
   Dr. Fouad Al-Mansour

R&D GRANTS AND CONTRACTS

1. Social acceptability of territorial effects in RES scenarios
   Andreja Urbančič, M. Sc.
2. Evaluation of greenhouse gasses mitigation measures in industry
   Dr. Matevž Pušnik
3. Development and design of energy consuption monitoring by connecting various databases
   Dr. Fouad Al-Mansour
4. Evaluation of greenhouse gasses mitigation measures in industry
   Dr. Matevž Pušnik
   Ministry of the Environment and Spatial Planning
5. Development and design of energy consuption monitoring by connecting various databases
   Dr. Fouad Al-Mansour
   Ministry of Infrastructure
6. European Energy Manager - EUREM XII
   Dr. Boris Sučić

NEW CONTRACTS

1. National Air Pollution Control Programme (OP-NEC)
   Matjaž Česen, B. Sc.
   Ministry of the Environment and Spatial Planning
2. Benchmarking of district heating systems
   Damir Staničić, M. Sc.
   Energetska Zbornica Slovenije
3. LIFE17 IPC7SI/000007 - LIFE IP CARE4CLIMATE
   Stane Merše, M. Sc.
   Ministry of the Environment and Spatial Planning
4. Opportunities and scenarios for the production of synthetic natural gas from RES - price ratios, sectors coupling and synthetic gas in transmission gas network
   Stane Merše, M. Sc.
   Plinovodi d. o. o.
5. Long-term renovation strategy to support the energy renovation to 2050
   Gašper Stegnar, B. Sc.
   Ministry of Infrastructure
6. Strategy for future utilization of renewable energy sources and improvement of energy and resource efficiency in the overall sustainable transformation of DARS d.d. by 2030
   Dr. Boris Sučić
   Dars, d.d.

VISITORS FROM ABROAD

1. Iñigo Bonilla, University of Basque Country, Leioa, Spain, 30 November, 2018 to 1 March, 2019
2. Daniel Brouht, Navid Khordehgan, Brunel University, London, Great Britain, 9-11 December, 2019

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5. Andreja Urbančič, M. Sc.

Postdoctoral associate

6. Dr. Matevž Pušnik

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1. Gašper Stegnar, Tomo Cerovšek, "Information needs for progressive BIM methodology supporting the holistic energy renovation of office buildings", *Energy*, 2019, **173**, 317-331.
2. Marko Kovač, Gašper Stegnar, Fouad Al-Mansour, Stane Merše, Andrej Pečjak, "Assessing solar potential and battery instalment for self-sufficient buildings with simplified model", *Energy*, 2019, **173**, 1182-1195.
3. Gašper Stegnar, Damir Staničić, Matjaž Česen, Jure Čižman, Simona Pestotnik, Joerg Prestor, Andreja Urbančič, Stane Merše, "A framework for assessing the technical and economic potential of shallow geothermal energy in individual and district heating systems: A case study of Slovenia", *Energy*, 2019, **180**, 405-420.
4. Blaž Luin, Stojan Petelin, Fouad Al-Mansour, "Microsimulation of electric vehicle energy consumption", *Energy*, **174**, 24-32.
5. Janez Merlak, Aleš Groznik, Fouad Al-Mansour, "Determination of environmental footprint of inland container terminals", *Istraživanja i projektovanja za privredu*, 2019, **17**, 2, 144-156.

Published Conference Contribution

1. Blaž Luin, Fouad Al-Mansour, Darja Šemrov, "Estimate of traffic energy consumption from vehicle fleet distribution forecast", In: *International Conference on Advances in Energy Systems and Environmental Engineering (ASEE19)*, (E3S web of conferences, **116)**, 2019, 00046.
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3. Marko Kovač, Damir Staničić, Stane Merše, Andreja Urbančič, "Is heat storage with a possibility of district heating beneficial to Solar Plus micro grids", In: *Papers and abstracts, eceee 2019 Summer Study on energy efficiency, 3-8 June, Presqu'île de Giens*, (eceee Summer Study proceedings), 2019, 817-823.
4. Boštjan Zajec, Marko Matkovič, Leon Cizelj, "Analysis of statistical uncertainties in a direct numerical simulation of flow in a backward facing stepheat transfer measurements in a single-phase flow of refrigerant R245fa in annular geometry", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 207.
5. Anil Kumar Basavaraj, Blaž Mikuž, Marko Matkovič, "Flow and heat transfer CFD analysis in the section of THELMA for wall surface temperature determination", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 209.
6. Nejc Kosanič, Boštjan Zajec, Marko Matkovič, Jure Oder, Iztok Tiselj, "PIV measurements of turbulent flow over backward-facing step", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 210.
7. Boris Sučić, Stane Merše, Željko Tomšić, "Modeliranje i optimiranje potrošnje energije u zgradarstvu - analiza slučaja unutar kompleksa zgrada koje pripadaju zanstvenoistraživačkoj instituciji", In: *Referati = Papers, 14. savjetovanje HRO CIGRÉ, 10.-13. studenoga 2019, Šibenik, 14th HRO CIGRÉ Session, November 10-13, 2019, Šibenik*, Hrvatski ogranak CIGRÉ, 2019, 9
8. Boris Sučić, Stane Merše, Damir Crnčec, Matevž Pušnik, Matjaž Česen, Gašper Stegnar, "Challenges of national energy and climate planning - case study Slovenia", In: *Renewable and sustainable energy developments beyond 2030: 12th International Conference on Sustainable Energy & Environmental Protection, SEEP Conference 2019, 18-21 November 2019, Sharjah, United Arab Emirates*, Proceedings, Sharjah University, 2019, 104-108.
9. Marko Kovač, Boris Sučić, Stane Merše, "The essential parameters of optimal solar tariff for mitigation of a duck curve", In: *Renewable and sustainable energy developments beyond 2030: 12th International Conference on Sustainable Energy & Environmental Protection, SEEP Conference 2019, 18-21 November 2019, Sharjah, United Arab Emirates*, Proceedings, Sharjah University, 2019, 410.

CENTRE FOR ELECTRON MICROSCOPY AND MICROANALYSIS CEMM

The Centre for Electron Microscopy and Microanalysis (CEMM) is an instrumental centre at the JSI that combines analytical equipment in the field of electron microscopy and microanalysis. Access to the research equipment of CEMM is provided to other JSI departments as well as other research institutions, universities and industrial partners. The equipment at the CEMM is used by researchers who are interested in the morphology and structural and chemical characterization of materials between the micrometre and the atomic levels. At the CEMM there are currently two scanning electron microscopes (SEM) JSM-5800 and JSM-7600F, two transmission electron microscopes (TEM) JEM-2100 (CO NiN) and JEM-2010F, and the equipment for TEM and SEM sample preparation. The Centre of Excellence NAMASTE contributed to the equipment for electron microscopy a CCD camera and an ADF (annular dark field) detector for the JEM-2010F microscope and an EBSD system for the JSM-7600F. Additionally, the IJS is a co-owner (20%) of a JEM ARM 200CF (transmission electron microscope with atomic resolution) at the National Chemistry Institute. Furthermore, the CEMM helps with the maintenance of the FIB (focused ion beam) microscope Helios Nanolab 650 at the Nanocenter Centre of excellence.

Head:
Prof. Miran Čeh

At the end of 2019, the equipment of the CEMM was upgraded with a new high-level, high-resolution scanning electron microscope Verios G4 HP (Thermo Fisher Scientific). This type of microscope, with extreme high resolution at low accelerating voltages, is unique in this part of the Europe. Besides an EDSX detector, the microscope is equipped with the latest-developed detector for transmission microscopy (STEM). The microscope will be installed and ready to use in the middle of the 2020.

The research involving the staff and equipment at the CEMM is diverse regarding the investigated materials and the methods used.

- Scanning electron microscopy is employed to observe the morphology and structure of the surfaces and for the microstructural investigation and determination of the chemical composition. Samples that are mostly investigated are ceramics (polycrystalline oxide and non-oxide compositions), nanostructured materials, metallic magnetic materials, metals, alloys glass, etc. All of the scanning electron microscopes in the CEMM are equipped with an energy-dispersive (EDXS) and/or wavelength dispersive (WDXS) spectrometer for X-rays, allowing a non-destructive determination of the chemical composition of the investigated materials. The scanning electron microscope JSM-7600F is additionally equipped with an electron back-scatter diffraction (EBSD) detector and an electron lithography system.
- Transmission electron microscopy (TEM) provides an insight into the structure of the material on the nanoscale (atomic level). Transmission electron microscopy enables structural and chemical analyses of the grain boundaries and study of precipitates, planar defects and dislocation determinations. In addition to ceramic samples, other materials and structures are investigated, such as thin films on different substrates, alloys, delicate metallic magnetic materials, polymers, etc. The transmission electron microscope JEM-2100 is equipped with an EDXS spectrometer and a CCD camera, and the JEM-2010F is additionally equipped with a scanning transmission electron (STEM) unit, EDXS and EELS (electron energy loss) spectrometers, and a CCD camera.
- The CEMM also manages the necessary equipment for the SEM and TEM sample preparation.

Figure 1: Training of new operators.

Figure 2: Organisation of experiments for the JSI visitors.

The operation of the Centre is managed by properly trained employees. Besides maintenance of the equipment, other CEMM activities include,

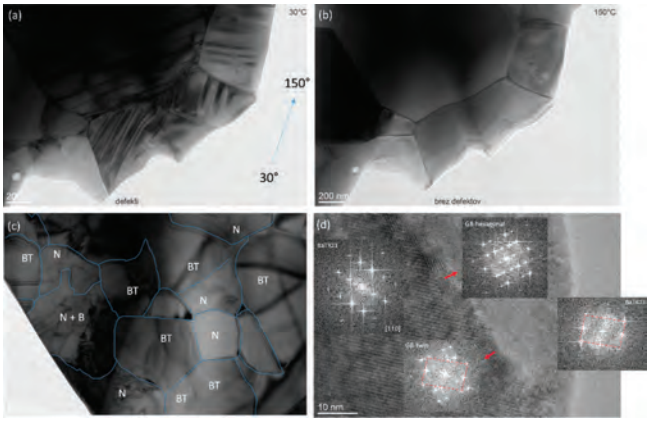

Figure 3: TEM analysis of grain boundaries between $BaTiO_3$ and metal Ni. (a,b) Heating experiment showing transformation from tetragonal to cubic structure. (c) Grain boundaries between $BaTiO_3$ and Ni and (d) SAED of bulk and boundary region (Zajc I., K8, Drev S., CEMM, JEM 2100).

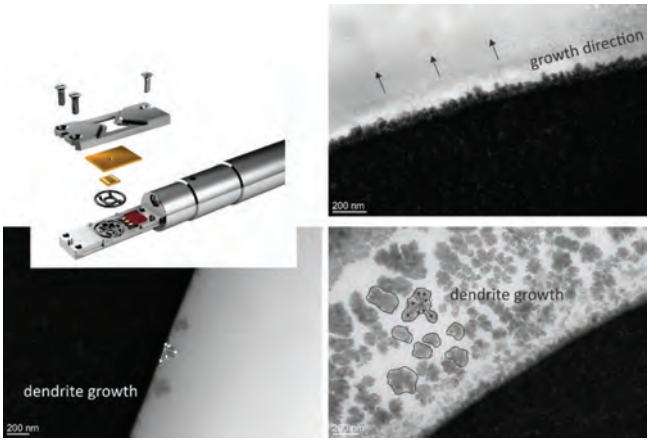

Figure 4: (a) Liquid cell in TEM. (b,c,d) Dendritic growth of Ni from solution observed on the Pt work electrode (Koblar M., Drev S., CEMM, JEM 2100).

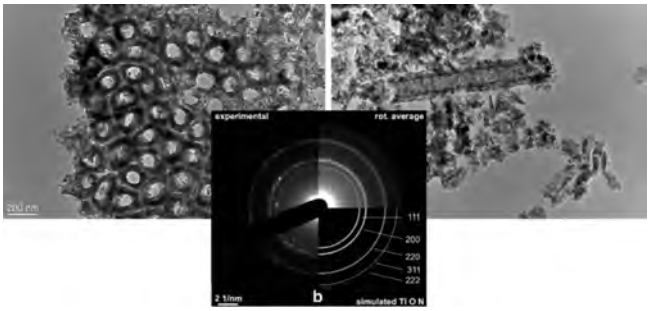

Figure 5: BF TEM image of Ti-O-N sample with the corresponding SAED pattern, demonstrating phase transformation of TiO_2 anatase to Ti-O-N phase (Drev S., CEMM, JEM 2010F).

training of new operators (Figure 1), organization of workshops and conferences on the topic of electron microscopy, providing services for industrial partners and the implementation of new analytical techniques. CEMM personnel are also responsible for the dissemination of electron-microscopy techniques to the general public in the scope of organized visits to the IJS, as well through publications in traditional and digital media (Figure 2).

In 2019 the CEMM organized the 8th and 9th workshops (SEM sample preparation and scanning electron microscopy with microanalysis, EDXS) for users of the CEMM equipment. The aim of the workshops was to explain the operation and handling of the equipment.

Examples of microstructural and nanostructural investigations using the CEMM equipment

The examples of analyses of structural and chemical characterisations of different materials using electron microscopy techniques were performed by the CEMM employees as well as operators from different JSI departments.

1. Heating experiment in TEM

Heating experiment of $BaTiO_3$ doped with metal Ni was performed in the JEM-2100 transmission electron microscope. Experiments were conducted within the temperature range of the phase transformation at ~120°C. The study of the heating experiment was aimed: (a) to show the phase transformation from tetragonal to cubic $BaTiO_3$, (b) to identify structural defects (domains or twins of tetragonal $BaTiO_3$) and (c) to investigate the nature of grain boundaries between $BaTiO_3$ and Ni (Figure 3) (Zajc I., K8; Drev S., CEMM).

2.Electrochemical *in-situ* experiment in TEM

In the field of electrochemistry, we performed ***in-situ*** experiments of electrochemical deposition of metal Ni on a Pt working electrode during potential cycling between the working electrode and the cathode (Figure 4) (Koblar M., Drev S., CEMM).

3. Titanium oxynitride structure

TEM analysis of anatase nanotube sintered in NH_3 atmosphere. SAED study of anatase nanotubes confirmed the phase transformation from anatase to titanium oxynitride (Figure 5).

In: Suhadolnik. L.; Jurković. L. D.; Likozar. B; Bele. M.; Drev. S.; Čeh. M. Structured titanium oxynitride (TiOxNy) nanotube arrays for a continuous electrocatalytic phenol-degradation process: Synthesis, characterisation, mechanisms and the chemical reaction micro-kinetics. Applied Catalysis B: Environmental, 2019, 257, 117894-117904

4. Ferro-elastic domains in sintered perovskite ceramics

TEM analysis of ferro-elastic domains in spark-plasma sintered $Na(Nb_{0.2}Ta_{0.8})O_3$ perovskite ceramics, crystallized with ***Pcmn*** orthorhombic symmetry. Superstructure reflections from doubling of the unit cell revealing rotation of oxygen octahedral in structure (Figure 6).

In: Bian. J.J.; Otoničar. M.; Spreitzer. M.; Vengust. D.; Suvorov. D. Structural evolution, dielectric and energy storage properties of Na ($Nb_{1-x}Ta_x$)O_3 ceramics prepared by spark plasma sintering. Journal of the European Ceramic Society, 2007, 39, 2339-2347

5. $(Nd,Na)(SO_4)_2$ x H_2O crystals

Analysis and study of grain growth and morphological characterisation of $(Nd,Na)(SO_4)_2$ x H_2O was performed in a scanning electron microscope (Figure 7).

6. Al_2O_3/Ru magnetic sample

Magnetic samples based on Al_2O_3/Ru were analysed by transmission electron microscopy. Samples are composed of aluminium oxide grains that are surrounded with Ru nanoparticles (Figure 8).

7. SnO_2 ceramics

Analysis of thermal etching SnO ceramics doped with CoO and NB_2O_5 showed the appearance of many twins in SnO_2 grains in (101) planes (Figure 9).

In: Tominc. S.; Rečnik. A.; Samardžija. Z.; Dražić. G.; Podlogar. M.; Bernik. S.; Daneu. N. Twinning and charge compensation in Nb_2O_5-doped SnO_2-CoO ceramics exhibiting promising varistor characteristics. Ceramics international, 2018, 44, 1603-1613

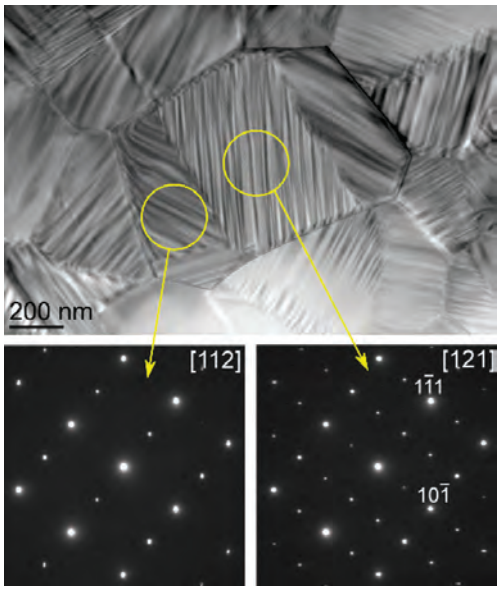

Figure 6: Analysis of ferro elastic domains in $Na(Nb_{0.2}Ta_{0.8})O_3$ perovskite ceramics (Otoničar M., K5, JEM 2100).

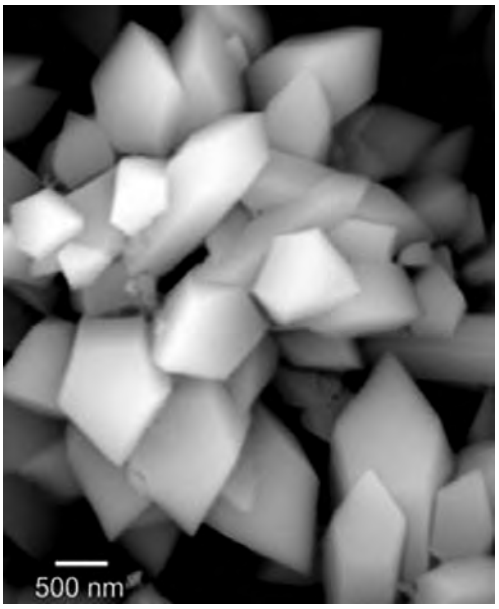

Figure 7: $(Nd,Na)(SO_4)_2 x H_2O$ crystals (Xu. X., Samardžija Z., K7, JSM 7600F).

8. Mn-oxide nanoparticles

High-resolution image of Mn-oxide nanoparticles revealed orientation along [131] zone (Figure 10).

In: Ristić. A.;Mazaj. M.; Arčon. I.; Daneu. N.; Zabukovec. L. N.; Gläser. R.; Novak. T. N. New insights into manganese local environment in MnS-1 nanocrystals. Crystal Growth and Design, 2019, 19, 3130-3138

Figure 8: TEM image of the Ru nanoparticles-decorated magnetic alumina catalyst (Gyergyek S., K8, JEM 2100).

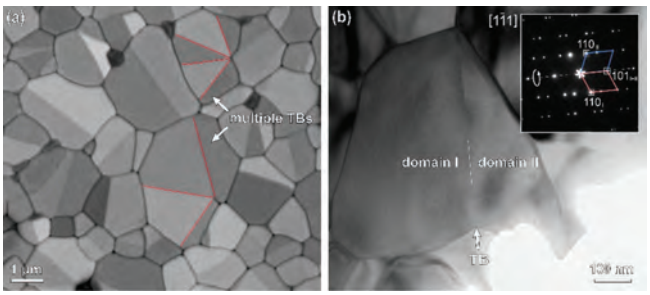

Figure 9: (a) SEM/BSE image of thermally etched cross-section of SnO_2-based ceramics doped with CoO and Nb_2O_5 shows abundant formation of twins in SnO_2 grains. Different shades of BSE contrast are due to different orientations of SnO_2 grains. (b) TEM analysis revealed that twins lie in (101) planes of the SnO_2 structure (Tominc S., K7, Rečnik A., K7, Daneu N., K9, JSM 7600F, JEM 2100).

9. $Bi_4Ti_3O_{12}$ transformation

Within the research project of the study mechanism of transformation of $Bi_4Ti_3O_{12}$ nanoparticles in $SrTiO_3$ nanoplatelets (M.ERA-NET 3184 HarvEnPiez; leader dr. Marjeta Maček Kržmanc) an analysis of the mechanism of topochemical transformation $Bi_4Ti_3O_{12}$ (BIT) to $SrTiO_3$ (STO) under hydrothermal conditions was made. Analyses showed BIT platelets terminated with $Bi_2O_2^{2+}$ layer, starts at the edges and proceeds towards the interior of the plate (Figure 11).

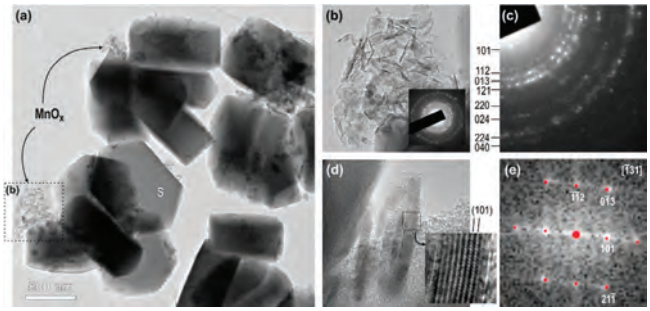

Figure 10: (a) Mn-oxide nanoparticles on zeolite silicalite-1 (S-1) with MFI structure. (b,c) The nanoparticles are hausmannite (Mn_3O_4) as revealed by SAED. (d) HRTEM image and (e) indexed FF pattern of the rod-shaped crystallite oriented along [-131] zone axis (Daneu N., K9, JEM 2100).

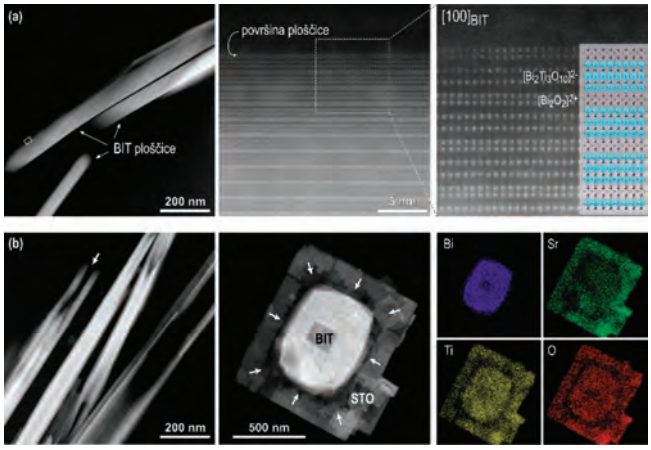

Figure 11: TEM study of the mechanism of topochemical transformation of $Bi_4Ti_3O_{12}$ (BIT) to $SrTiO_3$ (STO) (a) Initial BIT nanoplatelets have atomically flat surface and are $Bi_2O_2^{2+}$ terminated. (b) Analysis of partially transformed BIT platelets to STO shows that the transformation starts at the edges and proceeds towards the interior of the plate (Daneu N., K9, ARM 200F).

INTERNATIONAL PROJECTS

1. H2020 EUROfusion - Education-ED-FU
   Prof. Miran Čeh
   European Commission
2. Micro-to Nanoscale Textures of Ore Minerals: Methods of Study and Significance
   Dr. Janez Zavašnik
   Slovenian Research Agency
3. Investigation of Helium Retention in Plasma Facing Materials Using Advanced Analytical Methods
   Andreja Šestan Zavašnik, B. Sc.
   Slovenian Research Agency

R&D GRANTS AND CONTRACTS

1. Nanoscale investigations of diffusion controlled topotaxial phase transformations in rutile-corundum host systems
   Dr. Sandra Drev

NEW CONTRACTS

1. Compatibility assessment between chosen primary wrapper and biological drug
   Prof. Miran Čeh
   Lek, d.d.
2. Electron microscopy and microanalysis - preparation of samples for microscopy
   Prof. Miran Čeh

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Postgraduate
4. Andreja Šestan Zavašnik, B. Sc.

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2. Siegfried Hofmann, G. Zhou, Janez Kovač, Sandra Drev, S. Y. Lian, B. Lin, Y. Liu, Jiang Yong Wang, "Preferential sputtering effects in depth profiling of multilayers with SIMS, XPS and AES", *Applied Surface Science*, 2019, **483**, 140-155.
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Published Conference Contribution

1. Aleksandar Pačevski, Janez Zavašnik, Andreja Šestan, Aleksandar Luković, Ivana Jelić, Aleksandar Kremenović, Alena Zdravković, Suzana Erić, Danica Bajuk-Bogdanović, "Micro-to nanoscale textures of ore minerals: methods of study and significance", In: *XIII International Mineral Processing and Recycling Conference, MPRC, 8-10 May 2019, Belgrade, Serbia*, Proceedings, University of Belgrade, Technical Faculty, 2019, 98-100.

CENTRE FOR KNOWLEDGE TRANSFER IN INFORMATION TECHNOLOGIES CT-3

The Centre for Knowledge Transfer in Information Technologies performs educational, promotional and infrastructural activities and provides for the direct exchange of information and experience between researchers and the users of their research results. The centre has thirteen researchers and technical staff working in the areas of research results' dissemination and eLearning. In particular, the centre is well known by portals: VideoLectures.NET with multimedia materials of numerous scientific events, on-line training materials, and collection of tutorials on different scientific fields; ScienceAtlas.ijs.si and IST-World.Org for analysis and visualization of large bibliographic and project databases. The Centre is covering management, training and dissemination activities of several EU projects.

Head:
Mitja Jermol, M. Sc.

In 2019 we were active in the following projects from the H2020 programme: +MOVING (TrainInG towards a society of data-saVvy inforMation prOfessionals to enable open leadership Innovation), EW-SHOPP (Supporting Event and Weather-based Data Analytics and Marketing along the Shopper Journey), EUBUSINESSGRAPH (Enabling the European Business Graph for Innovative Data Products and Services), PRESTOCLOUD (Proactive Cloud Resources Management at the Edge for Efficient Real-Time Big Data Processing), WATER4CITIES (Holistic Surface Water and Groundwater Management for Sustainable Cities), MEET CINCH (A Modular European Education and Training Concept In Nuclear and RadioCHemistry), X5GONE (Cross Modal, Cross Cultural, Cross Lingual, Cross Domain, and Cross Site Global OER Network), THEYBUYFORYOU (Enabling procurement data value chains for economic development, demand management, competitive markets and vendor intelligence) DATABENCH (Evidence Based Big Data Benchmarking to Improve Business Performance), PerceptiveSentinel (BIG DATA Knowledge Extraction and re-creation Platform), ELEXIS (European Lexicographic Infrastructure), SILKNOW (Silk heritage in the Knowledge Society: from punched cards to big data, deep learning and visual/zangible simulations), COG-LO; (COGnitive Logistics Operations trough secure, dynamic and ad-hoc collaborative networks), EnviroLENS; Copernicus for envir law enforcement support) Humane AI (Toward AI Systems That Augment and Empower Humas by Understanding Us, our Society and the World Around), FIN-TECH (A FINancial supervision and TECHnology compliance training programme), NAIADES (A Holistic Water Ecosystem for Digitisation of Urban Water Sector), CyberSANE (Cyber Security Incident Handling, Warning and Response System for the European Critical Infrastructures), INFINITECH (Tailored IoT&BigData Sandboxes and Testbeds for Smart, Autonomous and Personalized Services in the Europe), FACTLOG (Energy-aware Factory Analytics for Process Industries) and in ERASMUS+: Micro HE (Support Future Learning Excellence through Micro-Credentialing in Higher Education) in MentorTrain (Training and Equipping Mentors in SMEs to provide Quality Apprenticeships),

In 2019 the Centre for knowledge transfer in IT was actively involved in 22 European projects

The centre prepares and organizes educational events, such as: conferences, seminars, workshops, and summer schools. They are targeted at experts who would like to apply the latest knowledge and achievements from intelligent data analysis, knowledge technologies, data mining, text mining and decision support to the areas of network organizations, business decisions, finance, and marketing. A special consideration is put on the managers and decision makers who are aware of the strengths and benefits to the success of their business. All the educational events are designed to transfer basic, additional and the latest expert knowledge to the companies, research and educational organizations.

In order to make the knowledge transfer efficient, we are combining traditional and ICT-supported training methods. For this purpose we are operating a number of training web portals. The most popular one is http://videolectures.net/. The main purpose of the portal is to provide free and open access to high-quality video lectures presented by distinguished scholars and scientists at the most important and prominent events. In today's world VideoLectures.NET represents a free knowledge hub, a way of opening up education to everyone for everyone and as there is a great need to share educational content at all levels in order to benefit society and foster the economy. It also gives a learning opportunity to audiences of all social levels.

VideoLectures.Net has strong connections in the Open Cast Foundation, Open Course Ware Consortium and Knowledge 4 All Foundation Ltd. We recorded and published 1170 new individual lectures. The majority of this content was produced by us, while 20 smaller-scale events were produced externally and submitted to us for publishing.

The biggest events we recorded and published in 2019 were: 25TH ACM SIGKDD Conference on Knowledge Discovery and Data Mining - KDD 2019, The International Semantic Web Conference - ISWC 2019 in The European Semantic Web Conference - ESWC 2019.

In addition, a substantial amount of content was published in a cooperation based on long-term cooperation established with institutions such as NiB, Chemistry Institute of Slovenia, the CLARIN ERIC organization, University of Nova Gorica, Faculty of Architecture at the University of Ljubljana, EnetConnect Cost action and smaller events we continuously record at JSI and in cooperation with other organizations in Slovenia and abroad. In addition to publishing new content at the repository, we completed or enabled the execution of all tasks related to Videolectures. Net in projects: MeetCINCH, Moving, X5GON, Elexis and Mentortrain. Videoelctures.Net successfully implemented the results of the X5gon project, which enables the aggregation of Open Educational Resources, found online globally. We have made publicly available a recommender system, which recommends content supported by AI. The content of the Videoelctures.Net repository is therefore available to the visitors of other repositories, while our viewers are offered content outside of our repository, based on relevant content. We have provided dissemination channels to the Water4Cities project among others also with secondments at the coordinator's institution.

X5GON has been shortlisted as one of the top 10 projects out of 113 applications from around the world for the 2019 UNESCO King Hamad Bin Isa Al-Khalifa Prize for the use of ICT in education

In 2019, Videolectures.Net recorded and published 35 courses in the scope of the project "A Modular European Education and Training Concept In Nuclear and RadioCHemistry Courses" (Meet-Cinch). Our Center is collaborating with the Department of Environmental Sciences at the JSI in the development and design of extensive courses in the field of radiochemistry.

In March 2019 we organized the 14th Student Competition in Computer Science, attended by 341 students from Slovenian secondary schools.

The UNESCO Chair on Open Technologies for OER and Open Learning (Chair) and University of Nova Gorica started managing a free international online "Open Education for Better World" mentoring programme. In 2019 we organized the second cycle of an international online mentoring program, "Open Education for a Better World" (OE4BW), which is linked to the United Nations Sustainable Development Goals. The program is developed and managed by prof. dr. Tanja Urbančič, Dean of the Faculty of Business and Technology, University of Nova Gorica, and Fellow of the Department of Knowledge Technologies at the Jožef Stefan Institute, and M.Sc. Mitja Jermol, Chair of the UNESCO Chair in Open Technologies for Open Educational Resources and Open Learning. The response to the second call was excellent, with 50 mentors willing to participate as volunteers. In the second year, the programme was completed by 35 developers who, with the help of their mentors, developed open educational resources in various fields. Descriptions are available at http://oe4bw.ijs.si/projects/ The program, which addresses specific challenges of the modern world related to the Sustainable Development Goals, has been delivered in various languages. In response to the excellent feedback, we started the third cycle of the mentoring program in October 2019. A total of 85 developers and 100 mentors from all over the world applied to the programme. Due to the increased number of participants and time differences, we organized five regional and one thematic hub. The hubs cover North America, South America, Europe, Africa and Asia. In the third round a new, topic-oriented SDG7 Hub, which addresses "access to affordable, reliable, sustainable and modern energy for all" was added.

In early July, a four-day workshop "Open education design – Course for practitioners" was held at the premises of the University of Nova Gorica in the Lanthieri mansion in Vipava. The course was organized by the University of Nova Gorica and the UNESCO Chair of Open Technologies for Open Educational Resources and Open Learning, which operates within the Jožef Stefan Institute. The aim of the course was to provide participants with basic knowledge, practical tips and experiences that will help them to use open educational resources (OERs) and to prepare their own educational materials. Participants were introduced to open education practices, methods and tools. They heard how to align open education with developmental and strategic goals. They acquired basic knowledge of open education concepts, pedagogical aspects and issues related to the content of open education from recognized experts and practitioners. The course also included practical work. The course was attended by 60 participants from 17 countries (Slovenia, Brazil, Fiji, France, India, Indonesia, Italy, South Africa, Canada, Lebanon, Germany, North Macedonia, Slovakia, Sudan, Switzerland, United Kingdom and USA).

This year we also started implementing a new mentoring program, the Library of Open Education of Slovenia (KOIS). With the program, we strive for the development and implementation of freely accessible educational resources that contribute to improving the quality and efficiency of education in Slovenia. The purpose of KOIS is to spread knowledge about the concepts of open education, to develop various pedagogical processes and to introduce new didactic approaches, and to support campaigns for the inclusion and dissemination of freely accessible educational resources. In the pilot year, the KOIS program consisted of teams from 6 schools, namely 4 primary

and 2 secondary schools. The selected schools applied for 8 projects, which were also presented on the Ministry of Education, Science and Sport at the end of June in the same year.

In 2019 we completed our fifth cycle of activities within the MyMachine project.

We completed work on two products and have started new activities of developing prototypes with the participation of the following: Electrotechnical and Computer Technical School and Gymnasium Ljubljana, Velenje High School Center, Primary school Savsko naselje and Primary school Elvire Vatovec Prade and started collaborations with the British International School and primary school of Vipava.

The international collaborations concluded in the publication of a book, which is a collection of essays from world-renowned scholars and practitioners of project-based learning, creativity in education and open education to which MyMachine Slovenia contributed a chapter on open education.

We also developed, tested and implemented several anomaly-detection methods for anomaly detection in financial data for the project TheyBuyForYou. We tested these methods on Slovenian spending data. We have also developed several methods for anomaly detection in public procurement data. We have applied several approaches: supervised, unsupervised and statistical analysis. For-the project we developed a web application, which is used for the analysis and visualization of public spending data and public procurement data and also for displaying groups of entities with detected anomalies and the visualization of detected anomalies in spending data and in public procurement data. We have also implemented a basic search service among the data and some basic visualizations of data.

We continued to work on the promotion of programming among youngsters. In February we participated in a workshop for school children (in cooperation with Codeweek), where we showed children the use of computers and sensors in chemical experiments and how computers can be used in traffic (we developed a simple traffic counter and speed-measurement radar). We also presented the use of sensors in chemistry to children who participated in the School of Experimental Chemistry, which has been organized in cooperation with the Slovenian Society of Chemistry Fans and co-workers from section K1 (Department of Inorganic Chemistry and Technology). Together with children we developed a simple pH meter, temperature sensor, particulate matter detector and a detector of various gases (including a simple alcotest), using a micro-controller Arduino and various sensors. Children then carried out a series of chemical experiments with those sensors. At the end of September we participated in the event "Night of researchers", where we presented use of sensors in chemistry to the students from Maribor.

We started the third cycle of the mentoring programme "Open Education for a Better World" (OE4BW) in October 2019. A total of 85 developers and 100 mentors from all over the world applied to the programme. Due to the increased number of participants and time differences, we organized five regional and one thematic hub. The hubs cover North America, South America, Europe, Africa and Asia. In the third round a new, topic-oriented SDG7 Hub, which addresses "access to affordable, reliable, sustainable and modern energy for all" was added.

In 2019 we finished with two mentorings within the project SKOZ (Center for Career Orientation - West). This project is intended for gifted students from the western Slovenian region who, under the mentoring of researchers, are conducting their own research. Our department is involved in the mentoring of two groups of students. The first group of students (where co-mentoring is conducted with a colleague from section K1), finished the development and testing of the detector of harmful gases in agriculture. Another group of students developed a prototype of a device for measuring temperature, humidity and UV index. We developed both devices in cooperation with the Association of Electronics of Slovenia. We also introduced the process of designing a prototype electronic device and making a printed-circuit board to students working on a project.

The first group of students (where co-mentorship is conducted with a colleague from section K1), started the development of the detector of harmful gases in agriculture. Within the project, we developed a device that contains various gas sensors to detect the presence of harmful gases that occur in agriculture (e.g., carbon monoxide, carbon dioxide, methane, ammonia, various volatile organic compounds (VOCs), etc.). The device, for which we also developed enclosure that was printed with a 3D printer, records the measurements to a database, and also sends it to the end users via the web application.

Another group of students is developing a device for measuring temperature, humidity and UV index, which will inform users and issue a warning about the level of UV radiation in the environment via the built-in screen or Bluetooth. We developed both devices in cooperation with the Association of Electronics of Slovenia. We also introduced the process of designing a prototype electronic device and making a printed circuit board to students working on a project.

We continued with the *Water4Cities - Integrated Surface and Groundwater Management for Sustainable Urban Development* project under the European Horizon 2020 Marie Sklodowska Curie RISE project. In 2019 we analysed data on groundwater and stormwater flow in the Ljubljana aquafier and water consumption in the Greek island of Skiathos. We are developing models and a platform that will allow us to monitor optimal water management in real time. In 2019, we attended and recorded a special session dedicated to the Water4Cities project, which took place as part of the CEMPE conference on Mykonos Island, Greece. In addition to regular webinars, we

publish interviews with researchers involved in the project, which are available on the Videolectures.NET subpage - http://videolectures.net/water4cities/

The the H2020 project MOVING (TrainInG towards a society of data-saVvy inforMation prOfessionals to enable open leadership INnovation) is in its final year. CT3, with the involvement of E3, was mostly active in producing video demonstrations about the developed technologies, services and the MOVING platform, for the purpose of dissemination and exploitation activities. The videos also serve for the didactic and curricula development in the MOVING platform, that enables its users to improve their information literacy by training how to exploit data-mining methods in their daily research tasks. Its novel integrated working and training environment supports the education of data-savvy information professionals and allows them to address the big data and open-innovation challenges. Moreover, the MOVING consortium has been working on developing new and more effective methods for lecture video fragmentation and fragment-level annotation, to allow for fine-grained access to lecture video collections. In the latest MOVING method, developed by the partner CERTH, automatically generated speech transcripts of the lecture video are analysed with the help of word embeddings that are generated from pre-trained state-of-the-art neural networks. This lecture video fragmentation method is part of the MOVING platform, and its results are also being included in the VideoLectures.NET portal, making it possible for the users of both platforms to access and view specific fragments of lecture videos that cater to their information needs.

In 2019 we participated in the activities of the Erasmus+ project "Training and Equipping Mentors in SMEs to provide Quality Apprenticeships" (Mentortrain), in which we will participate with the online repository Videolectures.net. In 2019 we collaborated with the partners of the project in creating video content, which will be an integral part of an educational training module for the mentors of pupils of vocational pupils across Europe.

Work on project "Support Future Learning Excellence through Micro-Credentialling in Higher Education" (MicroHE) focused in 2019 mostly on tasks of the technical work package, which we are leading. In 2019 we achieved all the objectives of the work package we are leading and have developed the micro-credentials metadata standard and designed a micro-credentials clearinghouse, which is already in use and is being tested by some higher-education institutes.

At the end of the year we started with work on a CyberSANE project. It is a cybersecurity project for cybersecurity incident handling, warning and response system for the European critical infrastructures. CyberSANE aims to enhance the security and resilience of Critical Information Infrastructures (CIIs) by providing a dynamic collaborative, warning and response system The role of JSI is to develop the tool for dark web analysis.

The UNESCO Chair has attended the CI Sector Commission of the 40th General Conference of UNESCO, which recommended the adoption of the UNESCO OER Recommendation draft by the Plenary Session of the 40th General Conference in November 2019. The Plenary of the General Conference examined the Recommendation on OER with a view to its adoption by the 40th General Conference of UNESCO. The UNESCO Chair has also been deeply involved in working with the Slovenian Government towards creating a Dynamic Coalition that will work on implementing the OER Recommendation in 195 Member States and which reflects the Ministerial Statement for the 2nd World OER Congress, and point (v) of the UNESCO OER Recommendation, 'Promoting and reinforcing international cooperation'. It would aim to expand and consolidate commitments to actions and strategies in the area of OER, as well as to promote and reinforce international cooperation among all relevant stakeholders.

X5GON has been shortlisted as one of the top 10 projects out of 113 applications from around the world for the 2019 UNESCO King Hamad Bin Isa Al-Khalifa Prize for the use of ICT in education. It has reached its research maturity and has been working on ways to present its data to creative communities across Europe. The path chosen was to create a set of X5GON hackathons on Open Education and Artificial Intelligence, titled "AI for the Common Good: F'AI'R Education Hackathon". These hackathons were supported by the UK Science & Innovation Network at the British Embassy in Paris, the United Nations ANCSSC, X5GON and UCL Computer Science intends to allow students at several partner sites at international universities to take part in an early requirements capture process, leading to design and build stage to develop a working prototype that supports Open Education with AI.

The hackathons started on September 25th 2019 and finished on February 26th 2020 in Paris, France. There were more than 500 students involved across four locations, London (UK), Paris (FR), Osnabruck (GE), and Maribor (SI). For the final fourth event, any partner country could submit up to three teams to the final event at the British Embassy in Paris in February 2020. The final teams took part in a final Hackathon in Paris where all of the European teams were competing in a new one-day Open Education and AI challenge that presented back to the judging panel on Day 2. The judging panel announced the overall winning team in Paris.

Organization of conferences, congresses and meetings

1. Project meeting of the EU project Silknow, Bled, 26. 2. – 27. 2. 2019
2. Organization and kick off meeting of new project "Knjižnica odprtega izobraževanja Slovenije", Ljubljana, 5. 3. 2019

3. 14th Student competition in computer science, Ljubljana, 23. 3. 2019
4. Organization of event "Predstavitev projektov iniciative Knjižnica odprtega izobraževanja Slovenije", Ljubljana, 26. 6. 2019
5. Co-organization of the workshop "Open Education Design Workshop 2019", Vipava, Slovenia, 1. 7. - 5. 7. 2019
6. Project meeting of the EU project Factlog, Ljubljana, 11. 12. – 12. 12. 2019

INTERNATIONAL PROJECTS

1. ERASMUS+: Micro HE - Support Future Learning Excellence through Micro-Credentialing in Higher Education
   Mihajela Črnko
   European Commission
2. INEA/CEF - MARCELL, Multilingual Resources for CEF.AT in the Legal Domain
   Mitja Jermol, M. Sc.
   Innovation And Networks Executive Agency (inea)
3. ERASMUS+; MentorTrain - Training and Equipping Mentors in SMEs to provide Quality Apprenticeships
   Mihajela Črnko
   European Commission
4. H2020 - MOVING; Training Towards a Society of Data-Savvy Information Professionals to enable Open Leadership Innovation
   Dr. Tanja Zdolšek Draksler
   European Commission
5. H2020 - PrEstoCloud; Proactiive Cloud Resources Management at the Edge for Efficient Real-Time
   Mitja Jermol, M. Sc.
   European Commission
6. H2020 - euBusinessGraph; Enabling the European Business Graph for Innovative Data Products and Services
   Mitja Jermol, M. Sc.
   European Commission
7. H2020 - EW-Shopp; Supporting Event and Weather-based Data Analytics and Marketing along the Shopper Journey
   Mitja Jermol, M. Sc.
   European Commission
8. H2020 - Water4Cities; Holistic Surface Water and Groundwater Management for Sustainable Cities
   Mitja Jermol, M. Sc.
   European Commission
9. H2020 - MEET-CINCH; A Modular European Education and Training Concept in Nuclear and RadioChemistry
   Mihajela Črnko
   European Commission
10. H2020 - X5gon; Cross Modal, Cross Cultural, Cross Lingual, Cross Domain, and Cross Site Global OER Network
    Mitja Jermol, M. Sc.
    European Commission
11. H2020 - PerceptiveSentinel; BIG DATA Knowledge Extraction and Re-creation Platform
    Mitja Jermol, M. Sc.
    European Commission
12. H2020 - DataBench; Evidence Based Big Data Benchmarking to Improve Business Performance
    Mitja Jermol, M. Sc.
    European Commission
13. H2020 - TheyBuyForYou; Enabling Procurement Data Value Chains for Economic Development, Demand Management, Competitive Markets and Vendor Intelligence
    Dr. Matej Kovačič
    European Commission
14. H2020 - SILKNOW; Silk Heritage in the Knowledge Society; From Punched Cards to Big Data, Deep Learning and Visual/Tangible Simulations
    Mitja Jermol, M. Sc.
    European Commission
15. H2020 - COG-LO; COGnitive Logistics Operations through secure dynamic and ad-hoc collaborative networks
    Mitja Jermol, M. Sc.
    European Commission
16. H2020 - EnviroLENS; Coprenicus for Environmental Law Enforcement Support
    Mitja Jermol, M. Sc.
    European Commission
17. H2020 - Humane AI; Toward AI Systems That Augment and Empower Humas by Understanding Us, our Society and the World Around Us
    Mitja Jermol, M. Sc.
    European Commission
18. H2020 - FIN-TECH; A FINancial supervision and TECHnology compliance training programme
    Mitja Jermol, M. Sc.
    European Commission
19. H2020 - NAIADES; A Holistic Water Ecosystem for Digitisation of Urban Water Sector
    Mitja Jermol, M. Sc.
    European Commission
20. H2020 - CyberSANE; Cyber Security Incident Handling, Warning and Response System for the European Critical Infrastructures
    Mitja Jermol, M. Sc.
    European Commission,the Directorate-general
21. H2020 - INFINITECH; Tailored IoT&BigData Sandboxes and Testbeds for Smart, Autonomous and Personalized Services in the European Finance and Insurance Services Ecosystem
    Mitja Jermol, M. Sc.
    European Commission
22. H2020 - FACTLOG; Energy-aware Factory Analytics for Precess Industries
    Mitja Jermol, M. Sc.
    European Commission
23. H2020 - ELEXIS; European Lexicographic Infrastructure
    Mitja Jermol, M. Sc.
    European Commission

R&D GRANTS AND CONTRACTS

1. Videorecording and Post-Processing
   Mitja Jermol, M. Sc.
2. CLARIN - European Research Infrastructure for Language Resources and Technology
   Mitja Jermol, M. Sc.
   Clarin Eric
3. Recording, Publishing and Disseminating of the Scientific Content of the EnetCollect Project on Videolectures.net
   Mihajela Črnko
   Eurac Research
4. US-Slovenia S&T Cooperation Overview
   Dr. Matej Kovačič
   Embassy Of The United States Of America
5. Unesco Open Learning Tools and Models
   Mitja Jermol, M. Sc.
   The United Nations Educational, Scientific And
6. 14th Student Competition in Computer Science
   Mitja Jermol, M. Sc.

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1. Anja Polajnar, B. Sc.

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2. **Mitja Jermol, M. Sc., Head**
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4. Dr. Ervin Pfeifer*
5. Matjaž Rihtar, B. Sc.
6. Dr. Tanja Zdolšek Draksler

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11. Monika Kropej, B. Sc.
12. Simon Marolt, B. Sc.
13. Davor Orlić, B. Sc.
14. Matija Ovsenek
15. Špela Sitar, B. Sc.

Note:

* part-time JSI member

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1. Tanja Urbančič, Anja Polajnar, Mitja Jermol, "Open education for a better world: a mentoring programme fostering design and reuse of open educational resources for sustainable development goals", *Open praxis*, 2019, **11**, 4, 409-426.

Theses and Mentoring

1. Tanja Zdolšek Draksler, *How entrepreneurship education affects students entrepreneurial intentions - a comparison of students with entrepreneurship education with other students in tertiary education in Slovenia:* doctoral dissertation, Maribor, 2019 (mentor Karin Širec).

MILAN ČOPIČ NUCLEAR TRAINING CENTRE ICJT

The mission of the ICJT training centre is training in the field of nuclear technologies and radiation protection. In addition, the ICJT is actively informing the public about these technologies.

Head:
Dr. Igor Jenčič

Training in the area of nuclear technologies is our primary mission. As NPP Krško did not employ new staff, there were no nuclear technology courses this year.

There were 25 **radiological protection training** courses for medical, industrial and research uses of radioactive sources.

Four **international courses** were organized; three of them were in collaboration with the Reactor physics division and the Reactor infrastructure centre.

Public information remains an important part of our activities. Groups of visitors (mainly schoolchildren, students and various societies) were regularly attending lectures and visiting the permanent exhibition on nuclear energy, smaller groups also the TRIGA reactor and/or the accelerator. The lectures were offered on electricity from nuclear energy, fusion, isotopes, energy in general, and the use of radiation in industry, medicine and research. Altogether, there were 150 groups or 6040 visitors this year. Since 1993, a total of 187,419 pupils, teachers and others, visited our information centre. We have continued monitoring and analysing media reports on nuclear energy.

In June 2019, we organized in Portorož the *International conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications* (ANIMMA 2019), in collaboration with CEA and Aix-Marseille University (France), SCK-CEN (Belgium), and Reactor physics division from the JSI. The conference was attended by 294 participants from 32 countries and international organizations and was one of the biggest nuclear conferences in the history of Slovenia.

In the autumn, we celebrated the 30th anniversary of the ICJT as a formal unit of the JSI. Several former JSI directors and numerous experts and managers of Slovenian nuclear industry participated in the event. We also published a book with contributions on the history and development of the ICJT, the first architectural design of the training centre, front pages of important documents, and an extensive photographic archive.

On the occasion of the 30th anniversary of the ICJT, a book with contributions on the history and development of ICJT, the first architectural design of the training centre, the front pages of important documents, and an extensive photographic archive was published.

Organization of conferences, congresses and meetings

1. International conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications (ANIMMA 2019), Portorož, Slovenia, June 17–21, 2019

Figure 1: Radioactivity workshop at the visit of the Slovene Gymnasium in Celovec

Figure 2: Energy workshop at the Open Day of the Jožef Stefan Institute

Table of training activities at the Nuclear Training Centre in 2019

Date	Title of the course	Partici-pants	Lecturers	Weeks	Participants × weeks
04.03. - 08.03.	Radiation protection for industrial and other practices (radiography)	3	4	1	3
11.03.	Radiation protection for baggage-screening systems	6	4	0.2	1.2
11.03.	Radiation protection for industrial and other practices	5	4	0.2	1
11.03. - 12.03.	Radiation protection for industrial and other practices (unsealed sources)	3	5	0.4	1.2
11.03. - 13.03.	Radiation protection for medical and veterinary workers - Nuclear medicine workers	2	8	0.6	1.2
14.03.	Radiation protection for industrial and other practices (measurement of road-way density and humidity) - Refresher Course	3	4	0.2	0.6
14.03.	Radiation protection for industrial and other practices (unsealed sources) - Refresher Course	3	5	0.2	0.6
14.03.	Radiation protection for industrial and other practices - Refresher Course	17	4	0.2	3.4
14.03.	Radiation protection for High Activity Sealed Sources - Refresher Course	1	4	0.2	0.2
14.03.	Radiation protection for handheld XRF spectroscopy - Refresher Course	1	0	0.2	0.2
15.04. - 19.04.	Radiation protection for exposed workers in Krško Nuclear Power Plant	10	7	1	10
03.06. - 07.06.	Pilot Training Course on On-Site Emergency Plan for Nuclear Power Plants	26	5	1	26
05.06. - 07.06.	Radiation protection for Nuclear Medicine Dept.	11	9	0.6	6.6
12.06. - 14.06.	Radiation protection for Nuclear Medicine Dept.	6	8	0.6	3.6
30.09. - 02.10.	Uppsala University Dedicated Practical Educational Course "Experimental reac-tor physics"	9	5	0.6	5.4
30.09. - 18.10.	15th EERRI Research Reactor Group Fellowship Training Course	9	10	3	27
07.10. - 09.10.	Radiation protection for High-Activity Sealed Sources - Refresher Course	1	4	0.6	0.6
07.10. - 09.10.	Radiation protection for handheld XRF spectroscopy	5	4	0.6	3
07.10. - 11.10.	Radiation protection for industrial and other practices (radiography)	1	4	1	1
10.10. - 17.10.	Radiation protection for industrial and other practices (radiography) - re-fresher course	1	4	0.4	0.4
14.10.	Radiation protection for baggage-screening systems	8	4	0.2	1.6
14.10.	Radiation protection for industrial and other practices	11	4	0.2	2.2
14.10. - 15.10.	Radiation protection for industrial and other practices (unsealed sources)	8	5	0.4	3.2
14.10. - 17.10.	Radiation protection for Nuclear Medicine Dept.	4	7	0.8	3.2
17.10.	Radiation protection for industrial and other practices (measurement of road-way density and humidity) - Refresher Course	3	4	0.2	0.6
17.10.	Radiation protection for baggage-screening systems - Refresher Course	1	1	0.2	0.2
17.10.	Radiation protection for industrial and other practices	15	4	0.2	3
17.10.	Radiation protection for handheld XRF spectroscopy - Refresher course	2	4	0.2	0.4
11.11.	Puse experiment exercise for students	22	5	0.2	4.4
TOTAL		197	140	15.4	115

R&D GRANTS AND CONTRACTS

1. Strengthening the Competence of Entrepreneurship and Promoting Flexible Transition between Education and the Environment in Primary and lower Secondary Schools
   Tomaž Skobe, M. Sc.
   Ministry of Education, Science and Sport
2. Strengthening the Competence of Entrepreneurship and Promoting Flexible Transition between Education and the Environment in Secondary Schools
   Tomaž Skobe, M. Sc.
   Ministry of Education, Science and Sport
3. ENRAS: Ensuring Radiation S afety for First Responder Teams in Case of Radiological or Nuclear Accidents
   Matjaž Koželj, M. Sc.
   Government Office for Development and European Cohesion Policy
4. Trainings of the RZ for Foreign Market
   Matejka Južnik, M. Sc.
5. Services
   Matejka Južnik, M. Sc.

NEW CONTRACTS

1. Education in the field of power engineering and nuclear power in central Slovenia
   Dr. Igor Jenčič
   Gen Energija, d. o. o.
2. Reload Operational Core Analysis, Post Refuelling Nuclear Design Check Tests, PIS and KFSS Cycle Specific Data for Future Fuel Cycles (Cycle 31)
   Dr. Igor Jenčič
   Nuklearna Elektrarna Krško d. o. o.

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4. Urban Pompe, B. Sc.
5. Tomaž Skobe, M. Sc.
6. Vesna Slapar Borišek, B. Sc.

Technical and administrative staff

7. Saša Bobič
8. Matejka Južnik, M. Sc.
9. Borut Mavec, B. Sc.

Figure 3: Plasma ball at the Fusion Exhibition in the Info Centre

Figure 4: ANIMMA 2019 Conference, Portorož, June 17–21

Figure 5: Front page of the Publication at the 30th anniversary of the ICJT

Figure 6: Ceremony at the 30th anniversary of the ICJT

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1. Tomaž Skobe, Matjaž Leskovar, "Influence of corium composition on ex-vessel steam explosion", *Annals of Nuclear Energy*, 2019, **133**, 359-377.
2. Guliz Inan Akmehmet, Sašo Šturm, Matej Komelj, Zoran Samardžija, Bojan Ambrožič, Meltem Sezen, Miran Čeh, Cleva Ow-Yang, "Origin of long afterglow in strontium aluminate phosphors: atomic scale imaging of rare earth dopant clustering", *Ceramics international*, 2019, **45**, 16, 20073-20077.
3. Bojan Ambrožič, Anže Prašnikar, Nejc Hodnik, Nina Kostevšek, Blaž Likozar, Kristina Žužek Rožman, Sašo Šturm, "Controlling the radical-induced redox chemistry inside a liquid-cell TEM", *Chemical science*, 2019, **10**, 38, 8735-8743.

Published Conference Contribution

1. Tomaž Skobe, Matjaž Koželj, "Feedbacks from radiation protection courses in nuclear training centre", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 807.
2. Radko Istenič, Igor Jenčič, "Public oppinion about nuclear energy - Year 2019 poll", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 1104.
3. Vesna Slapar Borišek, Matjaž Koželj, "Radiation protection training for radiation protection culture: What can and what can not be done", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 1106.
4. Matjaž Koželj, Vesna Slapar Borišek, "Training of radiation protection officers in Slovenia: what are we missing?", In: *Proceedings, 28th International Conference Nuclear Energy for New Europe - NENE 2019, Portorož, Slovenia, September 9-12*, Nuclear Society of Slovenia, 2019, 1110.

RADIATION PROTECTION UNIT SVPIS

Head:
Matjaž Stepišnik, M. Sc.

SVPIS has been involved in ionizing-radiation measurements and radiation protection since the commissioning of the TRIGA MARK II Research reactor in 1966. The responsibility of SVPIS is the radiation control of all the activities at the Institute dealing with ionizing radiation. Our main task is the supervision of work in the reactor with the Hot Cell facility and we are authorised by the regulatory authority to perform environmental monitoring.

SVPIS also controls 17 laboratories that use sources of ionising radiation in their research work. There are different sources of radiation used, such as sealed sources, open sources, X-ray units and the accelerator TANDETRON, which need regulatory control. Furthermore, we are involved in radioactive waste management.

SVPIS is authorized by the Slovenian radiation protection administration and nuclear safety administration to perform control in industrial and research institutions dealing with open or sealed radioactive sources and X-ray units.

The measurements of dose rate, contamination and gamma spectrometry are performed by an accredited method (LP-022, EN ISO/IEC 17025). In this year, we expended the accreditation to radon-concentration measurements.

Personal dosimetry

The personal doses of 125 workers that regularly or occasionally deal with ionizing radiation were monitored with Thermo Luminescent Dosimeters. The maximum individual yearly dose was 0.36 mSv. This is only 1.8 % of the regulatory limit for occupational exposure (20 mSv per year) and 36 % of the limit for the public (1 mSv per year). The collective dose at JSI in 2019 was 2.9 man-mSv.

Supervision of research reactor and laboratories

The controlled area of the Research Reactor, the Hot Cell Facility and the Department of Environmental Sciences, was monitored on a weekly basis. During some activities the constant presence of a radiation-protection worker was needed (i.e., for the opening of activated samples or radioactive-waste management). Measurements of the dose rate, surface contamination, contamination of different objects and personal contamination were performed routinely. In most cases, no or very low contamination levels were measured. Locally elevated radiation levels were measured mostly in the reactor controlled area.

At present, 106 sources of radiation are in use, which require regulatory control and additionally 458 low-activity sources in different laboratories.

In 2019, 20 radiological surveys in other JSI laboratories were performed. An independent inspection by external authorized institution was performed in the SVPIS laboratory and two additional laboratories at the JSI. There were no deficiencies recognized that could be important for radiation protection.

Environmental monitoring of the reactor

The environmental monitoring of the Reactor Center was performed according to an existing programme. The programme consists of effluent measurements and measurements of samples in the environment. Activity concentrations of gamma emitters in water samples, filters, noble gases, soil samples and sediment samples were measured periodically. About 500 different samples for reactor and different laboratories have been measured with gamma spectrometry. Environmental passive dosimeters have been used to monitor the radiation levels in the surroundings of the reactor. Based on the effluent measurements and a conservative environmental transfer model, the effective dose to the reference group of the public was estimated to be less than 1 μSv/year. In 2019 the public exposure due to activities at the Reactor Center was insignificant.

Expert assessments and measurements for outside customers

The Radiation Protection Unit is authorized to make supervision measurements and expert assessments in the field of radiation protection. In the past year, several radiological control investigations were carried out in industrial and research institutions (in total 51). Our group has participated in the evaluation of radiological monitoring of Krško NPP, the research reactor TRIGA and storage for low and intermediate level waste in Brinje.

R&D GRANTS AND CONTRACT

1. ENRAS Slovenia-Croatia Interreg Program
   Government Office for Development and European Cohesion Policy
   Stepišnik Matjaž, M. Sc.

NEW CONTRACTS

1. Radioactive Waste Wonditioning at OVC - Radiation Protection of Work
   ARAO
   Stepišnik Matjaž, M. Sc.
2. Monitoring of Central LILW Storage Facility 2018
   ARAO, Ljubljana
   Stepišnik Matjaž, M. Sc.
3. Survey of Radiation Sources – MORS
   Ministry of Defence
   Stepišnik Matjaž, M. Sc.

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2. **Matjaž Stepišnik, M. Sc., Head**

Technical and administrative staff

3. Thomas Breznik, B. Sc.
4. Tanja Murn, B. Sc.
5. Nina Udir, B. Sc.

CENTER FOR TECHNOLOGY TRANSFER AND INNOVATION CTT

The Office of Technology Transfer was established in 1996 and transformed in January 2011, when an independent Center for Technology Transfer and Innovation (CTT) was created to continue the third-pillar mission at the Jožef Stefan Institute. We assist in the process of technology and knowledge transfer from the JSI to industry, which includes licensing, spin-out creation, associated procedures for the protection of intellectual property. We also assist companies with finding suitable local and international research partners for contract and collaborative research. Also, we support the transfer of knowledge from science to the school system and promote the recognisability of the JSI and science in general among young people and the wider population.

Head:
Dr. Špela Stres, MBA, LLM

The center's success is based on the work of 13 professionals, 7 of which are educated in natural sciences and engineering, 7 in economics, 1 in law. At the same time, one of the experts is also qualified as a patent attorney and a Registered Technology Transfer Professional (RTTP). We are members of the ASTP (Association of Science and Technology Professionals), the LES (Licensing Executives Professionals), and three team members hold the US "Certified Licensing Professional "certificate.

Our essential tool is a created network of contacts with enterprises and other organizations in Slovenia and abroad. **Our services**, fine-tuned towards individual needs, are offered to JSI researchers and external organizations and include analysis of requirements, preparation, registration, and protection of intellectual property, marketing of intellectual property (including secret know-how), negotiations and the development of suitable agreements. Our clients are primarily JSI researchers, although numerous companies and other research organizations have also procured our services in 2019.

In 2019, the Center for technology transfer and innovation was partly funded through **five larger and numerous smaller European and national projects**. Projects belonging to various funding programs and schemes: Enterprise Europe Network (EEN) Slovenia and EU-GIVE (COSME scheme), EEN We4SMESLO, and KET4Clean Production (Horizon 2020), DIHelp (EC), SYNERGY and KETGATE (INTERREG Central Europe), Co-Create (INTERREG MED). CTT was also involved in the project SKOZ (MIZŠ) by connecting JSI researchers with Gimnazija Vič high-school students and their teachers. Project activities were combining and completing our core TT activities.

Marketing of 20 JSI technologies, 107 identified RR topics. Eight licenses and 22 research and development agreements conducted.

In 2019, CTT faced several activity-related challenges, the biggest of which were: (i) KTT project and (ii) SIO project. In KTT, we coordinate, and execute the Technology Transfer (KTT) project, covering all most significant Slovenian PROs. In SIO we perform support services by the innovation ecosystem actors in Slovenia within the SIO 2018-2019 project.

CTT is divided into four groups whose activities mutually interact with and complement each other.

Group for Protection and Marketing of Intellectual Property deals with cases that we obtained through the single entry point (26 cases), gives first advice to researchers (26), prepares assessments of patentability – reviews in-depth state-of-the-art analysis (8). The group also conducts detailed market potential analysis (5), helps develop the invention for disclosure within the institute (12), prepares agreements on the ownership of intellectual property (4), helps to draft the patent applications (9), searches for suitable patent attorneys for filing the applications (13), advises about the strategy of the international (3) and national (10) expansion of patent protection. The group also takes care of passive marketing activities: 10 technology profiles promoted through the Enterprise Europe Network, 11 expressions of interests received, and active marketing activities: 20 technologies promoted directly to 700 companies and other organizations, 13 expressions of interests received. Moreover, the group members arrange for the signing of non-disclosure agreements (4), manage affairs with partners in different consortia (3), take part in negotiations (30), prepare license (8) and research and development agreements (22) and arrange for their signature.

The organization of the 11th International Technology Transfer Conference. More than 100 visitors. The competition of the best innovation idea.

Experts that belong to this group provide individual consulting, regarding all phases of spin-out company formation (2), help with the preparation of business plans (2), manage discussions on the arrangement of the

relationship between the JSI and the researcher (1) and prepare license agreements (1) for the use of technology within the spin-out company. To encourage the researches in their entrepreneurial aspirations, this group's experts organize a contest for the selection of innovations with the highest commercial potential and various workshops (2) for young researchers. Teams from the JSI (3 presented), as well as from other public research organizations (4 presented) are eligible to apply to the call. At the 12th International Conference on Technology Transfer, a ceremony for awarding the best innovations was carried out.

Group for Contractual Collaboration with Industry visits both large and small companies (33 in 2019), organizes their return visits to the JSI (18), organizes sector and regional tours of companies to JSI, and collaborates with other support environment entities. This group's members are trying to find new topics for cooperation within the development projects amongst companies and researchers (132), prepare technology offers, arrange for the signing of non-disclosure agreements, and acquire written consents for further international cooperation with business or technology-research goals (16).

One thousand visitors during the Open Day at the JSI. 45 school visits.

The groups mentioned above work closely together to market technology and business profiles (24) in the Enterprise Europe Network global base and coordinate the market interests (90) for SMEs (79) and researchers (11), making the expression of interests to foreign published profiles (49) for businesses (41) and researchers (8). The groups co-organized 15 international B2B events with the participation of 46 Slovenian SMEs and researches who conducted 264 meetings with foreign partners.

In 2019, the two groups, jointly, concluded 8 licenses and 22 research and development contracts with 19 different companies. The activities of the CTT have increased significantly in the area of contracting over the last year.

Group for Promotion, Education, and Project Management prepared and disseminated lists of Slovenian and EU tenders (12) and foreign partner searches, helped develop project applications, especially in the "Exploitation" and "Dissemination" part. They disseminated information to TT coordinators weekly, which has efficiently contributed to the submission of new projects with foreign partners (4). The group distributed various information through the CTT e-newsletter and CTT's Facebook profile, organized an Open Day at the JSI (1000 visitors), school visits at the JSI (45). They provided two entrepreneurial education sessions for young researchers (25 participants in total) and organized the 12th International Technology Transfer Conference with many participants (more than 110). Besides, the group held and carried out promotional and motivational events (22) and thematic events (9) on the subject of intellectual property, the basics of entrepreneurship, spin-out creation, business planning, and pitching, for high-school students, researchers and potential entrepreneurs, as well as startup companies, within the SIO project.

We collaborate with the United Nations, as members of the 10-member group for support of the Technology Facilitation Mechanism (10MG TFM) and with the World Intellectual Property Office (WIPO) in the context of their international worldwide activities.

Group for Innovation Research

We operate as evaluators and external experts in Slovenia and in the frame of the European Commission for different international institutions (e.g., MGRT, ERC). We were recognized by the JRC as one of the most propulsive technology-transfer offices in the EU and were included in the TTO Circle, the Group of PROs most active in the field of knowledge and technology transfer (including the institutes Max Planck, Weitzman, Fraunhofer, VITO, VTT). We collaborate with the United Nations, as members of the 10-member Group for Support of the Technology Facilitation Mechanism (10MG TFM) and with the World Intellectual Property Office (WIPO) in the context of their international worldwide activities.

Organization of Conferences, Congresses and Meetings

1. Open Days at the Jožef Stefan Institute 2019, JSI, Ljubljana, Slovenia, 23. 3. .2019
2. Daily school visits in the Open Week at the Jožef Stefan Institute 2019, JSI, Ljubljana, Slovenia, 25. - 29. 03. 2019
3. International B2B partnering event at the Hannover Messe, Hannover, Germany, 1. 4. 2019 (co-organizer)
4. Business Stand-Up Breakfast – "Meet your Mentor", JSI, Ljubljana, Slovenia, 16. 4. 2019
5. Visit by the "Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering" representatives from Bucharest, Romania; JSI, Ljubljana, Slovenia, 7.-10. 5. 2019
6. Young Hopes – workshop for entrepreneurship and innovation for young researchers; JSI, Ljubljana, Slovenia, 30. 5. 2019
7. SYNERGY project workshop: Simulated Crowdfunding by use of the Synergic Crowd Innovation Platform (SCIP), JSI, Ljubljana, Slovenia, 13. 9. 2019

8. 12. ITTC – International Technology Transfer Conference, JSI, Ljubljana, Slovenia. 9.-11. 10. 2019
9. EU-GIVE project workshop: Support Services for Collaborative Economy, JSI, Ljubljana, Slovenia, 22. 11. 2019
10. Young Hopes 2 – How to use Research Work for Marketing Purposes, JSI, Ljubljana, Slovenia, 29. 11. 2019

INTERNATIONAL PROJECTS

1. K7, CTT - ID Creations; Rights and Obligations regarding the Development, Use and Commercialization of Hydrothermally Synthetized TiO2 Coatings in Metal Orthopaedic and Dental Implants
   Dr. Špela Stres
   Id Creations Oy
2. COSME; EU-GIVE - Generating Opportunities from Intangible Assets and Value Chains in the Collaborative Economy in Europe
   Dr. Špela Stres
   European Commission
3. Digital Innovation Hubs Enhanced Learning Programme (DIHELP)
   Dr. Špela Stres
   European Commission, Directorate-general For
4. COSME-EEN-SGA3 - EEN Slovenia_3; EEN Slovenia Services in Support of Business and Innovation in Slovenia
   Dr. Špela Stres
   European Commission
5. H2020 - KET4CleanProduction; Pan-European Access for man.SME on tech. services for clean production through a Network of premier KET Technology Centres with one stop shop access incl. EEN and discourse with policy makers on RI3
   Dr. Špela Stres
   European Commission
6. H2020 - We4SMESLO_4; Enhancing the Innovation Management Capacity of SMEs (by EEN), Slovenia
   Dr. Špela Stres
   European Commission

R&D GRANTS AND CONTRACTS

1. Co-Create: Setting up a network of COmpetitive MED Clusters with the contribution of cREATive Industries
   Dr. Špela Stres
   Interreg Med Programme
2. Central European SME Gateway zo Key-enabling Technology Infrastructures - Sparking new Transnational KET Innovation Ecosystem
   Dr. Špela Stres
   Interreg Central Europe Programme
3. Synergic Networking for Innovativeness Enhancement of central european actoRs focused on hiGh-tech industry
   Dr. Špela Stres
   Interreg Central Europe Programme
4. The consortium for technology transfer from the PRO to the economy
   Dr. Špela Stres
   Ministry of Education, Science and Sport
5. SIO: Implementation od support activities for innovation ecosystem actors in Republic of Slovenia in the years 2018-2019
   Dr. Špela Stres
   Ministry of Economic Development and Technology
6. JSI Share of License Revenues related to Exploitation of Inventions - Abroad (JSI License Revenue Share - Abroad)
   Dr. Špela Stres
7. SKOZ: Career Orientation Center – West
   Dr. Špela Stres
   Ministry of Education, Science and Sport

VISITORS FROM ABROAD

1. Dan Enache, Aurel Sima, Adrian Cocioceanu, Calin Stoica and Daniela Zamfir, Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, Bucharest, Romania, 7.-10. 5. 2019
2. Jure Dreo and David Sakić, Braintrip Ltd., St Julian's, Malta, 4. 6. 2019
3. MSc. Jorge Galvan Falcon, Canary Island Digital Innovation Hub, Santa Cruz de Tenerife, Spain, 9.-10. 10. 2019
4. Bernhard Koch, BOKU University, Vienna, Austria, 9. 10. 2019
5. Dolores Modic, Nord University Business School, Bodø, Norway, 9. 10. 2019
6. Giovanni Cristiano Piani, Università degli Studi di Trieste, Trieste, Italy, 9. 10. 2019
7. Tjwan Tan, Netherlands Chamber of Commerce, Rotterdam, The Netherlands, 10. 10. 2019
8. Iiro Eerola, European Commission, Brussels, Belgium, 10. 10. 2019
9. David Secher, Cambridge KT Ltd., Cambridge, UK, 10. 10. 2019
10. Siobhan Horan, Knowledge Transfer Ireland, Dublin, Ireland, 10. 10. 2019
11. Karla Rončević and Hubert Culik, Helios Kansai Group, Osaka, Japan, 18. 11. 2019

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6. Dr. Levin Pal
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9. Marjeta Trobec, M. Sc.

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12. *Maja Ivanišin, M. Sc., left 20.02.19*
13. Gregor Jus, B. Sc.
14. *Gašper Juvančič, B. Sc., left 09.09.19*
15. *Lucija Luetić, B. Sc., left 04.12.19*
16. Matej Mrak, B. Sc.
17. Urška Mrgole, B. Sc.
18. Miha Pitako, B. Sc.
19. *Nataša Požarnik, B. Sc., left 01.05.19*
20. Robert Premk, B. Sc.

BIBLIOGRAPHY

Published Conference Contribution

1. Špela Stres, "Ethics in research issues: development of a situational analysis questionnaire", In: *Professional Ethics: proceedings of the 22nd International Multiconference Information Society - IS 2019, 9 October, 2019, Ljubljana, Slovenia: volume D*, Institut "Jožef Stefan", 2019, 5-8.
2. Špela Stres, "Ethics in research issues, an example of JRC "TTO Circle" organizations", In: *Professional Ethics: proceedings of the 22nd International Multiconference Information Society - IS 2019, 9 October, 2019, Ljubljana, Slovenia: volume D*, Institut "Jožef Stefan", 2019, 9-11.

CENTER FOR SMART CITIES AND COMMUNITIES CSC&C

The Center for Smart Cities and Communities CSC&C was established at the beginning of 2017. On January 1, 2019, Nevenka Cukjati, Ph.D., took over the management of the center.

The main task of the center is to coordinate and operate the Strategic Development and Innovation Partnership of Smart Cities and Communities (SRIP SC&C). In addition, the center also promotes cross-sectoral cooperation within the Jožef Stefan Institute, thus supporting partnerships in the field of state-of-the-art technologies and at the same time actively participating in the creation of national R&D policies for the coming years.

Head:
Dr. Nevenka Cukjati

Strategic Development Innovation Partnership Smart Cities and Communities

Strategic Development Innovation Partnership Smart Cities and Communities is a form of partnership in which stakeholders have joined forces in developing and selling solutions to raise the quality of life in the cities of the future.

The purpose of SRIP SC&C is to connect companies and research institutions in a particular field into value chains, to set priorities for development investments and to coordinate R&D activities. We are building a good support environment for sharing knowledge and experiences in the form of workshops, seminars and joint events; we offer access to test environments, laboratories, databases; and we provide assistance in market analyses, human-resources development, intellectual-property protection and internationalization.

We want to approach the smaller towns in Central and Eastern Europe with solutions, as we consider that due to its size and geostrategic position, Slovenia is very suitable as a reference country for various "smart urban" solutions suitable for implementation in other parts of Central and Eastern Europe.

SRIP SC&C was formally constituted at the Assembly on 23 March 2017, and currently involves more than 130 companies and research institutions from all over Slovenia.

Key areas and technologies

Strategic Research and Innovation Partnership Smart Cities and Communities covers several research areas as well as the ICT horizontal key enabling technologies (Figure 1).

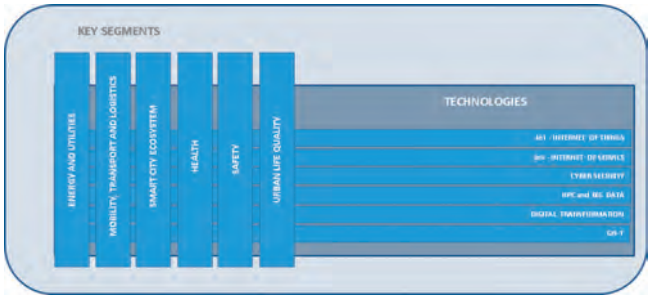

Figure 1: Key areas and technologies

The key objectives of SRIP SC&C are:

Developing globally competitive solutions in the SC&C field

Establishment of a globally recognized ecosystem of partners that permanently and synergistically build and link their competencies in SC&S domains and technologies.

Providing resources and conditions (an open-platform ecosystem) for as short a time as possible from planning to marketing globally competitive high-tech solutions

International promotion of the Slovenian "brand" in Smart Town and Community – Smart Towns

SRIP SC&C creates and supports business and research synergies in smart cities for new products, services and technologies, and helps companies enter the global market by focusing on niche areas, with the aim of making Slovenian companies an important European provider of such solutions.

In 2019 we entered the final period of the second phase of the operation "Strategic Development Innovation Partnership in the field of Smart Cities and Communities", which confirms the SRIP SC&C guidelines set out in the action plans. In the period April-June 2019, an evaluation of the SRIP SC&C was carried out, which included a series of meetings between the SRIP SC&C Office (General Director of SRIP SC&C Operation, N. Cukjati), the evaluator and representatives of vertical and horizontal areas.

Activities within the Organizational Structure od SRIP SC&C

Within the organizational structure of the SRIP SC&C operation, there have been changes in the area of the consortium partnership. The exit of the University of Maribor from the founder member's place demanded the reorganization of the bodies and structures of the SRIP SC&C. The organizational structure of the SRIP SC&C has been made leaner, which makes it easier to monitor, manage and coordinate the more than 130 members of the

SRIP SC&C. On July 1, 2019, at the 5th session of the SRIP SC&C Steering Committee, we adopted the Financial Plan for the current year and confirmed the SRIP SC&C Executive Director. The SRIP SC&C Steering Committee was informed about changes in the Rules of Procedure of SRIP SC&C due to the departure of the founding member. On September 4, 2019, the 2nd session of the assembly was held at the EU House, at which the Rules of Procedure of the SRIP SC&C were adopted (with a deferred condition) and the Report on the Activities Carried Out in 2018 was approved. The Rules of Procedure for SRIP SC&C were approved at the Assembly Correspondence Session, which took place from September 10, 2019 to September 13, 2019. In September, the electoral corps of individual Verticals and the Program Board of SRIP SC&C were convened. On November 4, 2019, the 5th Session of the Program Board of SRIP SC&C was held, at which the content part of the ICT HM Business Plan for 2019 was approved, as well as the preparation of the Vertical and Horizontal Action Plan. From November 12, 2019 to November 15, 2019 the 3rd Correspondence Session of the Steering Committee was held, at which the ICT HM Business Plan for 2019 and the SRIP SC&C Financial Plan for 2019 were adopted. In connection with the preparation for the third phase of the SRIP SC&C operation, we were presented at ICT HM workshop. On December 10, 2019, we organized an Extended Session of the Program Board of SRIP SC&C and a workshop with a newly elected team to review the activities of each Vertical and Horizontal and started preparing a Plan of Activities for the Future.

Cooperation between SRIPs and Ministries

Throughout 2019, meetings of the SRIP Coordinators Working Group (DSKS) have taken place. Both the joint appearance of the DSKS and the appearance of the SRiP PMiS against the state took the form of several coordination meetings with the MGRT and MIZŠ. On June 17, 2019 a meeting was convened with SRIPs and with V. Urlep, M.Sc., at the Prime Minister's Office. As part of the project "Strengthening the Framework for Foreign Direct Investment and Export and Innovation Cooperation in Slovenia", which Deloitte Slovenia is working with the European Commission and MGRT, we participated in interactive workshops on the topic of proactively attracting foreign investment.

Cooperation with other Institutions

In cooperation with other Institutions, we presented our SRIP at a meeting of the Slovenian Association for Energy Economics. We cooperated with the Faculty of Economics, UL at the EIT Digital School 2019 project. We signed a Letter of Intent to cooperate between the Jožef Stefan Institute, SRIP SC&C and the organization Open Agile and Smart Cities OASC. We signed a Letter of Intent for Technology, Research, Education and Business Cooperation, between the Jožef Stefan Institute, SRIP SM&C and Alma Mater Europaea. We have established contacts with the EIT KIC Raw Materials, an Economic Advisor at the Embassy of the Republic of Copenhagen, a representative of Diversify Nevada and a representative of the Japanese Institute for International Socio-Economic Studies. We actively cooperated with the Association of Municipalities of Slovenia, which, as part of the Interreg-Higher project, participated as a co-organizer with SRIP SC&C at the Smart Cities 2019 Conference: Smart Cities 2019: "Resilient Cities: between digital and physical world". At the organizing the conference, we also cooperated with the City of Ljubljana.

Free workshops and seminars for SRIP SC&C members

We have organized a series of free seminars and workshops for SRIP SC&C members: Workshop "Grants in 2019", February 02, 2019; Two-day workshop "Project Management School", April 09 and April 11, 2019; RRI Brokerage Event for SRIP SC&C and SRIP Factories of the Future Members, July 09, 2019; Workshop "360 Marketing in SRIP SC&C and SRIP Factories of the Future, September 06, 2019; How to get a Grant for your TETRAMAX Open Call Project, October 02, 2019; Meeting with the Evaluation Team, the conclusions of the evaluation of all nine SRIPs were presented, October 07, 2019; Leadership Development Workshops "Fundamental Management Skills"; November 08, 2019 and November 21, 2019; Android programming workshop within TETRAMAX project, November 20, 2019.

As part of the promotion and internationalization, we participated in major events in Slovenia and abroad: February 14, 2019: Rome, "Italy & Slovenia: Partnership in investment and innovation, presentation of the SRIP SC&C model; March 04, 2019: Meeting of Economic advisers, Jablje, presentation of the SRIP SC&C by N. Cukjati; April 12, 2019: Workshop on identifying the opportunities of SRIPs in the field of internationalization, Deloitte; April 18, 2019: Presentation at the event New Challenges by N. Cukjati, Brdo pri Kranju; May 20, 2019: Presentation at the event Workshop with expert Pierre Padillo on the topic of SRIP internationalization within the framework of the Industrial Transition Pilot project by N. Cukjati, TP Ljubljana; June 14, 2019: Co-Organization of the Conference En.Municipality & En.management, N. Cukjati is part of Selection Committee of the Energy Advanced Municipality; June 17 - June 18, 2019: Co-organization of the International Conference "Living bits and things 2019", presentation of the SRIP SC&C; September 16, 2019: Organization of International Conference Smart Cities 2019: "Resilient Cities: between digital and physical world", the actions of Municipalities and Cities in case of natural disasters and unexpected events using ICT solutions were presented; October 02 – October 03, 2019: Greenomed / Vanguard Cluster event

and Greenomed methodology presentation; October 21, 2019: It is time to market, University of Ljubljana, Faculty of Economics; October 25, 2019: Horizon Europe Information Day, University of Ljubljana, Faculty of Economics.

In the field of informing the public about the functioning and vision of the SRIP SC&C partnership, a few articles have been published in the journals: *"GG/Digitalizacija gospodarstva", "Eko Dežela"* and *"Časnik Finance«.* An interview was posted on *"Val 202"*.

In 2019 we updated the SRIP SC&C website, on which we regularly publish news and events. We implemented activities to establish a common open-source integration platform for SRIP SC&C members, within SRIP SC&C members will offer various ICT solutions (products and services) to residents of cities and communities.

R&D GRANTS AND CONTRACTS

1. Strategic Research & Innovation Partnership Factories of the Future (SRIP PMIS)
   Dr. Nevenka Cukjati
   Ministry of Economic Development and Technology
2. SRIP (Strategic Research & Innovation Partnership) Smart Cities and Communities
   Dr. Nevenka Cukjati

STAFF

Technical and administrative staff

1. **Dr. Nevenka Cukjati, Head**
2. *Petja Grizilo, B. Sc., left 14.04.19*
3. Tjaša Lazič, B. Sc.
4. *Sabina Ponikvar, B. Sc., left 05.10.19*
5. *Klemen Sojar, B. Sc., left 14.05.19*
6. *Matjaž Šteblaj, B. Sc., left 01.03.19*

CENTER FACTORIES OF THE FUTURE

CFoF

Centre Factories of the Future - CToP, run by Rudi Panjtar, was established in early 2017.

The main task of the newly established centre is to coordinate and operate the Strategic Development and Innovation Partnership of Factory of the Future (SRIP ToP). In addition, the centre also encourages cross-sectoral cooperation within the Jožef Stefan Institute, thereby contributing to the support of the latest technology partnership and at the same time actively participating in the development of R&D policies in the coming years. The centre participates in the field of Blue BIOtechologies innovation. It also participates in the establishment of a virtualized platform for the marketing of services and products within the H2020 project QU4LITY. It also manages the project HIA (High Impact Action), where it will use the pooled Slovenian knowledge to establish a physical and virtual platform for the implementation and demonstration of reconfigurable production cells.

Head:
Rudi Panjtar , B. Sc.

What does the Factory of the Future Strategic Development Innovation Partnership offer?

The SRIP Factory of the Future (SRIP ToP) strategy is to gather and integrate Slovenian research and innovation knowledge and experience in the industrial and academic spheres and highlight the priority breakthroughs of new products, technologies and services for Factories of the Future. We have established a supportive environment with expert services for industry and research organizations, with an emphasis on developing new cutting-edge technologies that combine and build on existing Slovenian research and innovation achievements.

SRIP ToP **creates and supports** business and research synergies in the area of future factories for new products, services and technologies, and helps businesses enter the global market by focusing on niche areas.

The 90 members of SRIP ToP come from various companies, associations or institutions from Slovenia. The operation of SRIP ToP focuses on the greater integration of knowledge and the joint appearance of stakeholders in domestic and foreign markets. The primary goals are to increase the share of high-tech industrial products in exports and to increase the added value of Slovenian industry.

Key areas of activity

The SRIP Factories of the Future includes eight areas (verticals), and horizontal networks with which key technologies are interwoven through all (Figure 1).

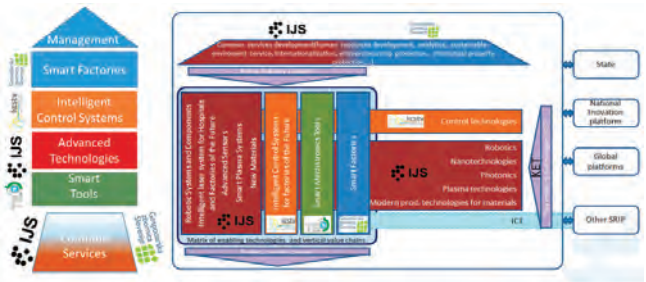

Figure 1: Scheme of SRIP ToP domains

By effectively directing the R&D and introducing knowledge and technologies that enable the production of better-quality products, reducing energy and raw materials, reducing environmental pollution, improving human involvement, etc., SRIP ToP also indirectly contributes to accelerating the transition to a low-energy, energy-efficient economy, to reduced greenhouse-gas emissions and to intensively promote the transition to a low-carbon society and a circular economy. The essence of the concept of Factories of the Future is mainly reflected in the greater potential for the reuse of raw materials, made possible by more flexible and optimally managed production.

In the field of internationalization, we have become full members of EFFRA, the umbrella EU for the Factories of the Future. In the area of S3, we took over the co-leadership of Artificial Intelligence in Production (AI & HMI), and through the Greenomed, BoifoksAlps, SmartSpace projects within Ljubljana Technology Park, we worked with various stakeholders of regions involved in the Vanguard Initiative.

As part of the preparation of the Action Plan and in order to promote networking, the exchange of information and to encourage organizations to become members of SRIP ToP, several SRIP ToP events were held in 2019 (among the most notable were the European Robotics Week 2019, the HC10 Collaborative Robot Workshop at the Days of Industrial Robotics, 16th Slovenian Meeting on Applicative Physics, Workshop on Green Advanced Plasma Technology, Workshop on Innovative Plasma Technologies for Factories of Future, Workshop on Chemical and Structural Analysis of Materials, Workshop on Advanced Mineral Characterization Techniques, National Conference on Nanotechnology, International Workshop on laser systems and photonics, RRI 2 Brokerage event, Tetramax workshops, and Vanguard workshop) We organized several workshops for our members on lean business - LEAN,

review of relevant legislation and other regulations, workshop Internationalization of Photonics, School of Project Management and 360 Marketing. We have co-organized various thematic workshops around Slovenia and co-organized multiple high-profile conferences (MIDEM 2019, 8th Central European Conference on Plasma Chemistry, and NanoApp). We have partnered with KOC-TOP to give our members access to HR workshops and conferences. We have co-organized 10 workshops in elementary schools in the scope of the KUBO programme. We participated in the Future Factories exhibition and organized the presentation of Demo Center - Smart Factory at the Faculty of Mechanical Engineering. We also conducted a workshop "Identification of relevant legislation and regulation and a systematic approach to monitoring its changes".

We have started to prepare the action plan for the third phase, to which we will divert a large part of our resources. In order to renew our business plan and together with our members and beneficiaries make changes and adjustments, we have already organized appropriate workshops.

We have upgraded our communication strategy with members and the wider community. In addition to informing them about our activities and achievements via e-mail, we also publish news on our enhanced website and social networks, with a focus on informing members of important events and workshops. We have also completed and published the SRIP ToP catalogue. It acts as a tool for direct self-marketing and the marketing of our members. We will be updating it on an ongoing basis.

In April 2019 we joined the QU4LITY project in the scope of the H2020 initiative, which is expected to demonstrate, in a realistic, measurable, and replicable way, an open, certifiable and highly standardised, SME-friendly and transformative shared data-driven ZDM (Zero Defects Manufacturing) product and service model for Factory 4.0. In the scope of the project the SRIP FoF is working with the JSI Department for the Automation, Biocybernetics and Robotics as one of the leading partners in Work Package 8 and is collaborating with a consortium of partners to design and implement a virtualized platform that will consist of the projects marketplace, where all the ZDM equipment will be listed and marketed, and the Digital Innovation Hub, which will offer innovation management services.

In December 2018, we joined the Panoramed Interreg Mediteran project as a co-leader in the field of innovation. In 2019, we prepared the first expert meeting held in Ljubljana, where with the help of experts, we collected relevant projects from the Mediterranean area and prepared a comprehensive analysis on "Gaps and Opportunities for Growth". We participated in the second expert meeting and the Innovation Camp organized by the leader of the working group. Together with the leader of the working group we prepared the contents of the call documentation. We have also participated in several international events in the field of Blue and Green technologies.

CToP was successful with the application of the project "Digital technologies as enabler to foster transition to the circular economy by the small and medium enterprises in the Alps", in short CIRCULAR 4.0, which started in the October of 2019. The project is funded in the scope of the Interreg Alpine Space programme. The main objective of the project is to strengthen digitalisation processes by SMEs, to foster innovation processes and accelerate the transition of the economy to the Circular Economy (CE) in the Alpine Space by means of Industry 4.0. The project will deliver a toolkit to assist SMEs with the accelerated adoption of digital and emerging technologies, identify financial instruments needed to assist with transition and adoption of circular business models. It will produce an action plan for the Alpine region. It will enable best practices exchange. SRIP FoF is a work package leader in charge of the Elaboration of the training process, bench learning and good practices exchange, setting up a toolkit to absorb key enabling and digital technologies better into business models as well as with defining investment models and financial incentives needed in the scope of the new EU-funded programmes in period 2021–2027.

In December 2019, the HIA (High Impact Action) project was launched. Its goal is to pilot a "transformative mechanism" that will take the form of a physical and a virtual platform for piloting and demonstrating modular and reconfigurable cells across various industries. The platform will be the channel for public support to technology development and deployment, education for industry, as well as networking, matchmaking, and information diffusion. SRIP FoF will be managing the project through the preparation of multiple open calls, including one for expert-group establishment and one for vouchers, which will be awarded to the eligible SMEs for upgrading their existing production cells. In the first phase of the project the centre will use the Slovenian knowledge within its partnership and with the help of external experts in the field of Industry 4.0, to prepare specifications for the platform.

INTERNATIONAL PROJECT

1. H2020 - QU4LITY; Digital Reality in Zero Defect Manufacturing
   Rudi Panjtar, B. Sc.
   European Commission

R&D GRANTS AND CONTRACTS

1. MED Governance Platform
   Rudi Panjtar, B. Sc.
   Government Office for Development and European Cohesion Policy
2. Circular 4.0: Digital technologies as enabler to foster the transition to the circular economy bythe SME in the Alpine Space area
   Rudi Panjtar, B. Sc.
   Government Office of the Land of Salzburg
3. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
   Rudi Panjtar, B. Sc.
   Ministry of Economic Development and Technology
4. FoF - Factories of the Future; 2nd Phase, Centre FoF SRIP
   Rudi Panjtar, B. Sc.

NEW CONTRACT

1. Modeling of process fluctuations and process parameters variations using the DOE method and performing statistical analysis of influential process parameters
   Rudi Panjtar, B. Sc.
   Tecos

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5. *Petja Grizilo, B. Sc., left 14.04.19*
6. Petra Lavtar, B. Sc.
7. Tina Mrak, B. Sc.
8. **Rudi Panjtar, B. Sc., Head**
9. *Klemen Sojar, B. Sc., left 14.05.19*