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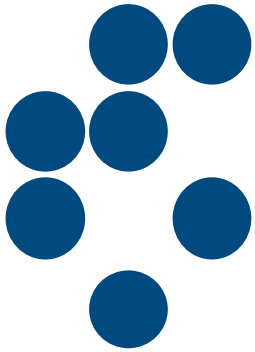
JULY 2016

Annual Report 2015



Jožef Stefan Institute, Ljubljana, Slovenia

Annual Report 2015

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Ljubljana, July 2016

CONTENTS

INTRODUCTION

Prof. Jean-Francois Tassin, Directeur Adjoint Scientifique de l'Institut de Chimie du CNRS, and Prof. Jadran Lenarčič, Director of the Jožef Stefan Institute, signing a cooperation agreement between the French CNRS and the JSI to establish the LIA PACS$_2$ joint research laboratory.

I cannot hide my satisfaction as I read through this new annual report. But at the same time, I keep thinking about how humble the conditions are at the institute, and how we struggle to operate and compete with the world's best scientific and research centres. If it wasn't for all the international connections and exchanges, which are the basis for almost everything we do, our institute would be falling behind. About 15 % of the employees at the institute are foreign researchers, while many of our researchers are abroad, and every day sees some tens of foreign visitors. The Institute is very involved with European projects and is considered as one of the most valued research partners in Europe. Due to the hard work, the vision, the ambitions and its international involvement, the Jožef Stefan Institute is not only a national, but also a European, research centre.

It is in the Slovenian genes, not only to be a poet like France Prešeren, but also to be a physicist, scientist and engineer like Jožef Stefan. Slovenes are not only homesick poets writing ballads to their beautiful homeland or mistress. Slovenes are not only athletes. Slovenes are also researchers, scientists, and intellectuals, contributing our share to society and the world – just like the great nations do – as we form the consciousness and identity of our own nation. The Jožef Stefan Institute is therefore not only a scientific, but also a cultural, institution, just as science is part of the nation's culture.

For this reason I have to point out that the conditions for work in Slovenian science, at the institutes and the universities, are not good. Between 2009 and 2015, public investment in research and development decreased by an incomprehensible 34 %. We lost more than any other socially relevant activity in Slovenia. I keep repeating this, not for the established scientists who are on the right side of the age curve, but for the waves of young people who need suitable conditions to realise their talents, ideas and projects for the benefits of Slovenia, Europe and society as a whole. They need the opportunity to be able to celebrate their own achievements.

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 build 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 Z 23, 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

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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. Boris Frlec, 1975–1984
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Prof. Danilo Zavrtanik, 1992–1996
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Prof. Dušan Turk
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University of Nova Gorica

Jožef Stefan International Postgraduate School

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

Nanotesla Institute Ljubljana

Security Technology Competence Centre (SETTCE)

Development Centre for Hydrogen Technologies

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

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Assistant to the Director
Dr. Romana Jordan

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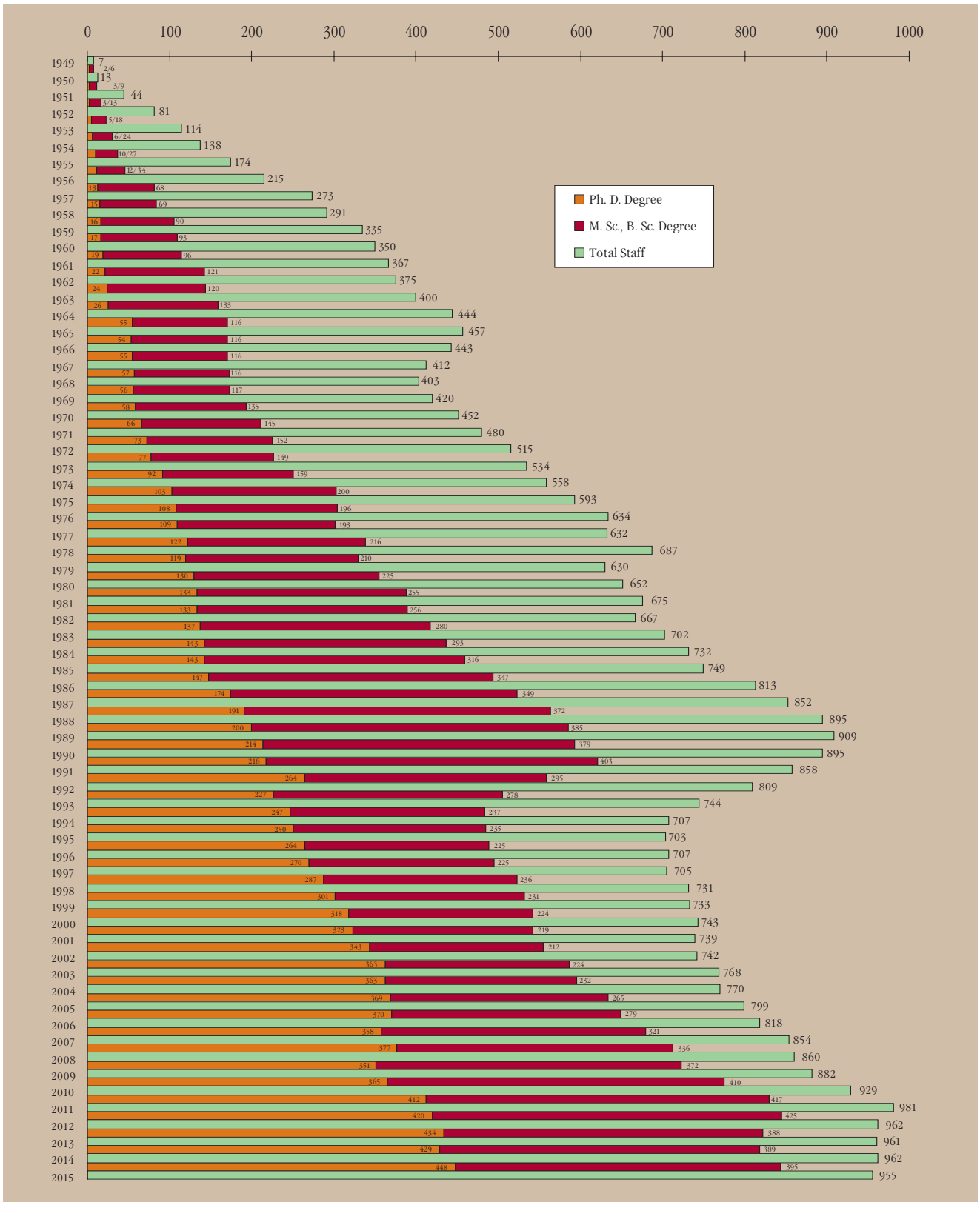
1949-2015



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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)	34
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	75
ESRR	19
OTHERS (COST, IAEA, EIE, IRMM, ESA, NATO, CIP, IPA ADRIATIC, MED, EMRP, WHO, LIFE+, SCOPES, ARTEMIS...)	134
TOTAL	**262**

Bilateral cooperation	No. of projects
Argentine	1
China	7
Montenegro	2
France	8
Croatia	7
India	3
Japan	5

Bilateral cooperation	No. of projects
Russia	5
Serbia	13
Turkey	2
USA	26
Others	4
TOTAL	**83**

INTERNATIONAL COOPERATION AGREEMENTS

In 2015, cooperation agreements were signed between the Jožef Stefan Institute and:

1. Ferrigato Srl, Schio (VI), Italy (F5, CTT)
2. Indesit Company S.p.A., Fabriano (AN), Italy (F5, CTT)
3. Lovalite SAS, Besançon, France (F5, CTT)
4. Whirlpool R&D S.r.l, Biandronno (VA), Italy (F5, CTT)
5. University of Ljubljana, Faculty for Mechanical Engineering, Forming Laboratory, Ljubljana, Slovenia (F5)
6. Fondazione Istituto Italiano di Tecnologia (IIT), Genoa, Italy; Ecole polytechnique federale de Lausanne (EPFL), Lausanne, Switzerland (F7, CTT)
7. Fondazione Istituto Italiano di Tecnologia (IIT), Genoa, Italy (F7, CTT)
8. Cidetec, San Sebastian, Spain (K3, CTT)
9. Ural Federal University, Institute of Natural Sciences, Ekaterinburg, Russia (K5)
10. Polish Academy of Sciences, Institute of Molecular Physics, Poznan, Poland (K5)
11. Ionix Advanced Technologies Limited, Leeds, West Yorkshire, United Kingdom (K5)
12. Palo Alto Research Center Incorporated, Palo Alto, California, USA; Johanson Dielectrics, Sylmar, California, USA (K5)
13. Centre National de la Recherche Scientifique (CNRS), Paris cedex, France; Université de Lorraine (UL), Nancy cedex, France, Institut Jean Lamour (IJL), Nancy cedex, France (K7)
14. University of Wolverhampton, Wolverhampton, Great Britain; University of Ljubljana, Ljubljana, Slovenia; Educell d.o.o., Trzin, Slovenia; Animacel Biotehnologija d.o.o., Ljubljana, Slovenia; Knowledge Economy Network, Slovenia Business and Research Association, Brussels, Belgium (K7, CTT)
15. Hungarian Academy of Sciences, Institute for Geological and Geochemical Research, Research Centre for Astronomy and Earth Sciences, Budapest, Hungary (O2)
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20. Centriair, Saevedalen, Sweden; KTH Royal Institute of Technology, Department of Chemical Engineering and Technology, Stockholm, Sweden (E7, CTT)
21. Time & Data Systems International Ltd., Poole, Dorset, United Kingdom (E9, CTT)
22. Knowledge 4 All Foundation Limited, London, United Kingdom (CT3)
23. Lucid Holdings, Inc., Austin, TX, USA (CT3)
24. Universite Catholique de Louvain (UCL), Louvain-la-Neuve, Belgium (R4)

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30. **Asst. Prof. Saša Prelovšek Komelj**, University of Ljubljana, Faculty of Mathematics and Physics
31. **Prof. Anton Ramšak**, University of Ljubljana, Faculty of Mathematics and Physics
32. **Asst. Prof. Iztok Savnik**, University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies
33. **Prof. John Shawe-Taylor**, University College London, Centre for Computational Statistics and Machine Learning
34. **Prof. Simon Širca**, University of Ljubljana, Faculty of Mathematics and Physics
35. **Prof. Žiga Šmit**, University of Ljubljana, Faculty of Mathematics and Physics
36. **Prof. Borut Štrukelj**, University of Ljubljana, Biotechnical Faculty and Faculty of Pharmacy, University of Maribor, Faculty of Medicine
37. **Asst. Prof. Tanja Urbančič**, University of Nova Gorica
38. **Asst. Prof. Nataša Vaupotič**, University of Maribor, Faculty of Education
39. **Prof. Danilo Zavrtanik**, University of Nova Gorica
40. **Prof. Marko Zgonik**, University of Ljubljana, Faculty of Mathematics and Physics
41. **Asst. Prof. Primož Ziherl**, University of Ljubljana, Faculty of Mathematics and Physics
42. **Prof. Slobodan Žumer**, University of Ljubljana, Faculty of Mathematics and Physics

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1. **Asst. Prof. Marko Bračko**, University of Maribor, Faculty of Chemistry and Chemical Engineering
2. **Dr. Jure Leskovec**, Stanford University, Palo Alto, California, USA
3. **Dr. Tomaž Rejec**, University of Ljubljana, Faculty of Mathematics and Physics
4. **Asst. Prof. Lea Spindler**, University of Maribor, Faculty of Mechanical Engineering

PART-TIME FACULTY MEMBERS

Professors

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2. **Asst. Prof. Ljudmila Benedik**, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Faculty of Mathematics and Physics and IPS, Ljubljana
3. **Asst. Prof. Aleš Berlec**, University of Ljubljana, Faculty of Pharmacy
4. **Asst. Prof. Slavko Bernik**, IPS, Ljubljana
5. **Asst. Prof. Anton Biasizzo**, IPS, Ljubljana
6. **Asst. Prof. Vid Bobnar**, IPS, Ljubljana
7. **Prof. Marko Bohanec**, University of Nova Gorica, School of Enginnering and Management and IPS, Ljubljana
8. **Prof. Leon Cizelj**, University of Ljubljana, Faculty of Mathematics and Physics
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41. **Prof. Spomenka Kobe**, University of Ljubljana, Faculty of Natural Sciences and Technology, IPS, Ljubljana
42. **Prof. Juš Kocijan**, University of Nova Gorica, School of Engineering and Management and IPS, Ljubljana
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45. **Asst. Prof. Anton Kokalj**, IPS, Ljubljana
46. **Asst. Prof. Matej Andrej Komelj**, University of Ljubljana, Faculty of Mathematics and Physics
47. **Asst. Prof. Branko Kontić**, University of Ljubljana, Biotechnical Faculty
48. **Asst. Prof. Dušan Kordiš**, University of Ljubljana, Biotechnical Faculty, Faculty of Chemistry and Chemical Technology, IPS, Ljubljana
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52. **Prof. Tomaž Kosmač**, University of Ljubljana, Faculty of Natural Sciences and Technology, Medical Faculty and IPS, Ljubljana
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54. **Asst. Prof. Janez Kovač**, University of Ljubljana, Faculty of Natural Sciences and Technology and IPS, Ljubljana
55. **Prof. Igor Križaj**, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Biotechnical Faculty, Medical Faculty, IPS, Ljubljana
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57. **Prof. Zdravko Kutnjak**, University of Ljubljana, Faculty of Mathematics and Physics and Faculty of Mechanical Engineering, IPS, Ljubljana
58. **Prof. Nada Lavrač**, University of Nova Gorica, IPS, Ljubljana, University of Ljubljana
59. **Prof. Jadran Lenarčič**, University of Ljubljana, Faculty of Electrical Engineering, University of Nova Gorica, Università degli studi di Bologna
60. **Asst. Prof. Igor Lengar**, University of Maribor, Faculty of Energy Technology
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65. **Prof. Darko Makovec**, University of Maribor, Faculty of Chemistry and Chemical Engineering and Faculty of Medicine, IPS, Ljubljana
66. **Prof. Barbara Malič**, IPS, Ljubljana
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68. **Asst. Prof. Paul McGuiness**, IPS, Ljubljana
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75. **Prof. Dunja Mladenić**, IPS, Ljubljana and University of Zagreb, Croatia, University of Ljubljana, Faculty of Education, University of Nova Gorica, University of Primorska, Koper
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113. **Asst. Prof. Andrej Trkov**, University of Ljubljana, Faculty of Mathematics and Physics and University of Maribor, Faculty of Energy Technology
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117. **Prof. Vito Turk**, University of Ljubljana, Faculty of Chemistry and Chemical Technology, IPS, Ljubljana
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126. **Prof. Eva Žerovnik**, IPS, Ljubljana
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128. **Asst. Prof. Leon Žlajpah**, IPS, Ljubljana
129. **Asst. Prof. Bernard Ženko**, Faculty of Information Studies, Novo Mesto
130. **Asst. Prof. Martin Žnidaršič**, Faculty of Information Studies, Novo Mesto, IPS, Ljubljana
131. **Asst. Prof. Kristina Žužek Rožman**, IPS, Ljubljana

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18. **Dr. Mitja Luštrek**, IPS, Ljubljana
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20. **Dr. Matija Milanič**, University of Ljubljana, Faculty of Mathematics and Physics
21. **Dr. Natan Osterman**, University of Ljubljana, Faculty of Mathematics and Physics
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23. **Vladimir Radulovič**, University of Nova Gorica, School of Applied Sciences
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26. **Dr. Urban Simončič**, University of Ljubljana, Faculty of Mathematics and Physics
27. **Dr. Andrej Studen**, University of Ljubljana, Faculty of Mathematics and Physics
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32. **Asst. Prof. Matjaž Vencelj**, University of Ljubljana, Faculty of Mathematics and Physics
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34. **Dr. Andrija Volkanovski**, University of Ljubljana, Faculty of Mathematics and Physics
35. **Dr. Darko Vrečko**, University of Nova Gorica, School of Environmental Sciences
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37. **Dr. Gašper Žerovnik**, University of Ljubljana, Faculty of Mathematics and Physics
38. **Dr. Dušan Žigon**, IPS, Ljubljana

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INSTITUTE COLLOQUIA

January 29: **Jacob L. Jones**
North Carolina State University, Raleigh, North Carolina, USA
Origins of electromechanical strain ascertained from in situ X-ray and neutron diffraction

February 2: **Tony Donné**
EUROfusion, Garching, Germany and Eindhoven University of Technology, Eindhoven, The Netherlands
Nuclear fusion: From science fiction to science fact

March 11: **Tomaž Javornik**
Jožef Stefan Institute
What can be expected from the next generation of wireles telecommunication systems?

March 23: **Vito Turk**
Jožef Stefan Institute and Jožef Stefan International Postgraduate School
Lysosomal cathepsins and their endogenous inhibitors – 50 years of research

March 24: **Helena Dobrovoljc**
Fran Ramovš Institute of the Slovenian Language, Research Centre of the Slovenian Academy of Sciences and Arts
Social and cultural background of language changes in the electronic age

March 25: **Milena Horvat**
Jožef Stefan Institute
Mercury: From important raw material to dangerous waste

March 27: **Jure Leskovec**
Stanford University, Stanford, California, USA
Computer analysis of large social networks

April 8: **James Gillies**
Conseil Européen pour la Recherche Nucléaire, Geneve, Switzerland
Communicating CERN - what we do and why it matters'

April 22: **Slavko Bernik**
Jožef Stefan Institute
The inverse grain-boundary and grain growth phenomena in zinc-oxide ceramics for surge protection

May 7: **Nigel B. Wilding**
University of Bath, Bath, United Kingdom
Self-assembly and phase behaviour of indented colloids

May 13: **Alan C. Seabaugh**
University of Notre Dame, Notre Dame, Indiana, USA
Ion-doped transition metal dichalcogenide transistors

May 27: **Leon Cizelj**
Jožef Stefan Institute
Simulations of formation of intercrystalline fractures in stainless steels

September 16: **Steven L. Johnson**
Eidgenössische Technische Hochschule Zürich, Zürich, Switzerland
Driving atomic-scale structure with light

September 23: **Janez Ščančar**
Jožef Stefan Institute
Chemical speciation in studies of biological role of trace elements

October 28: **Darko Makovec**
Jožef Stefan Institute
Synthesis of magnetic and multipurpose composite nanoparticles

November 9: **Robin W. Grimes**
Imperial College, London, United Kingdom
Atomic scale simulation in the service of nuclear materials

November 18: **Miha Nemevšek**
Jožef Stefan Institute
Why do neutrinos have mass?

December 2: **Michael Coey**
CRANN and School of Physics, Trinity College, Dublin, Ireland
The zero-moment half metal: How can it change spintronics?

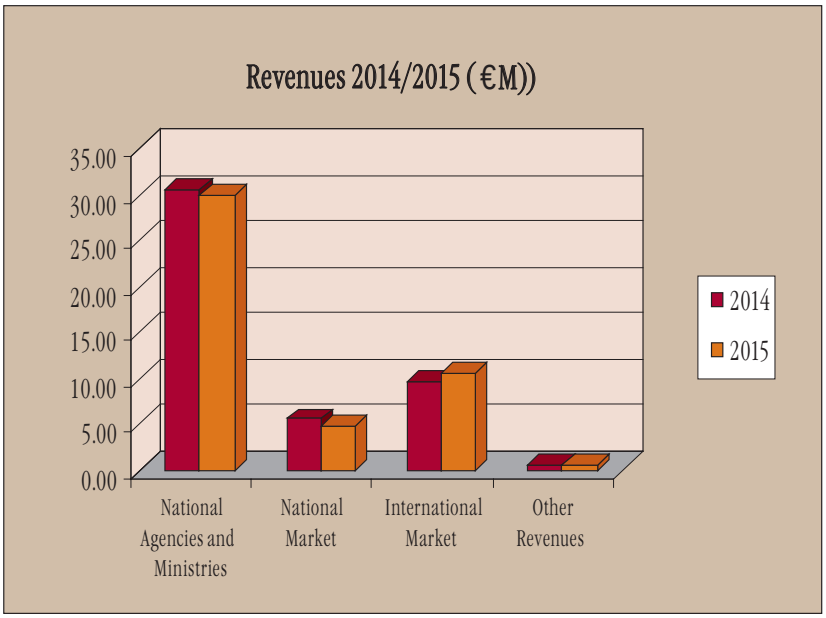
December 9: **Petros Koumoutsakos**
Eidgenössische Technische Hochschule Zürich, Zürich, Switzerland
High-performance computing in the time of uncertainty

December 16: **Ludwig Schultz**
Leibniz Institute of Solid State and Materials Research Dresden, Technical University Dresden, and evico GmbH, Dresden, Germany
Interaction of ferromagnetic and superconducting permanent magnets: Superconducting levitation

FINANCING

REVENUES JSI (€) AND NUMBER OF PROJECTS

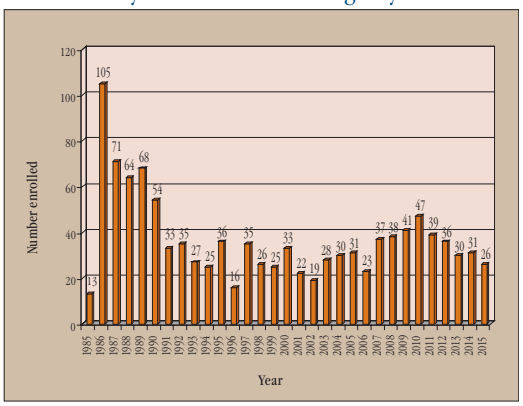
	Contribution 2015	Contribution 2015	Contribution 2014	Contribution 2014	Index 2015/2014	No. of Projects in 2015
National Agencies and Ministries	29,980,897	65.8 %	30,484,535	66.3 %	98.3	405
National Market	4,703,687	10.3 %	5,487,438	11.9 %	85.7	211
International Market	10,535,749	23.1 %	9,602,339	20.9 %	109.7	338
Other Revenues	358,872	0.8 %	402,709	0.9 %	89.1	
TOTAL	**45,579,205**	**100.0 %**	**45,977,021**	**100.0 %**	**99.1**	**954**



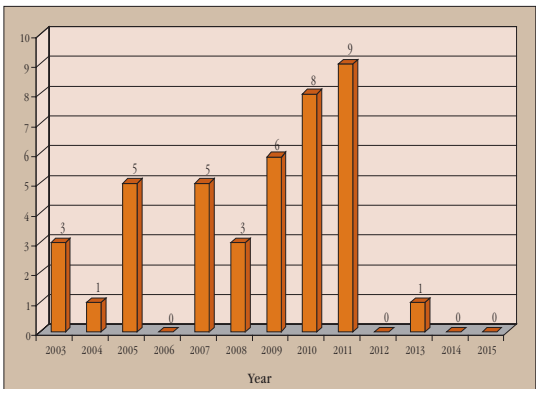
POSTGRADUATES FINANCED

1985-2015

by Slovenian Research Agency



by Industry



JSI UNDERGRADUATE SCHOLARSHIPS

1977-2015

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												
... 1982	115	38	100						50	12				315
1983	10	1	5						9		1			26
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
TOTAL	421	104	429	25	13	8	4	63	472	32	20	11	33	1635

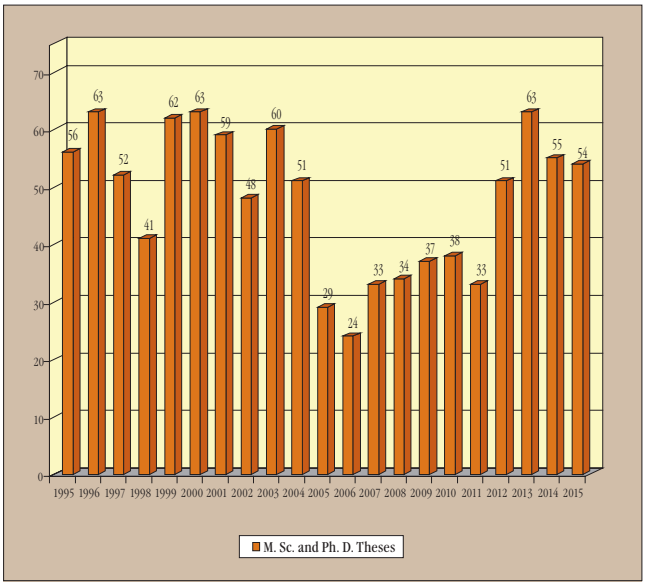
FMF Faculty of Mathematics and Physics, University of Ljubljana
FKKT (Uni-Lj) Faculty of Chemistry and Chemical Technology, University of Ljubljana
FKKT (Uni-Mb) Faculty of Chemistry and Chemical Technology, University of Maribor
NTF Faculty of Natural Sciences and Engineering, University of Ljubljana
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
FRI Faculty of Computer and Information Science, University of Ljubljana
FG Faculty of Civil Engineering, University of Maribor
FERI Faculty of Electrical Engineering and Computer Science, University of Maribor
UNG University of Nova Gorica
IPS Jožef Stefan International Postgraduate School
Other UNI LJ Faculty of Pharmacy, Faculty of Mechanical Engineering, Faculty of Economics, Faculty of Medicine, University of Ljubljana

COMPLETED THESES

UNTIL 2015

Year	Ph. D. Theses	M. Sc. Theses	Total
...1962	15	6	21
1963	7		7
1964	7	2	9
1965	16		16
1966	2		2
1967		8	8
1968	4	8	12
1969	3	6	9
1970	2	12	14
1971	7	6	13
1972	11	24	35
1973	8	14	22
1974	21	10	31
1975	10	20	30
1976	6	31	37
1977	5	16	21
1978	10	20	30
1979	7	11	18
1980	13	10	23
1981	12	15	27
1982	13	18	31
1983	5	10	15
1984	14	17	31
1985	6	14	20
1986	8	15	23
1987	18	21	39
1988	12	26	38
1989	15	33	48
1990	16	41	57
1991	22	47	69
1992	19	42	61
1993	28	36	64
1994	27	37	64
1995	34	22	56
1996	38	25	63
1997	29	23	52
1998	21	20	41
1999	33	29	62
2000	36	27	63
2001	31	28	59
2002	29	19	48
2003	41	19	60
2004	31	20	51
2005	22	7	29
2006	22	2	24
2007	26	7	33
2008	29	5	34
2009	30	7	37
2010	33	5	38
2011	31	2	33
2012	47	4	51
2013	56	7	63
2014	51	4	55
2015	44	10	54
TOTAL	1083	868	1951



PATENTS GRANTED

1. Rodrigo Ferrão De Paiva Martins, Elvira Maria Correia Fortunato, Pedro Miguel Candido Barquinha, Nunes Pereira, Gonçalo Gonçalves, Danjela Kuščer, Marija Kosec, Maria Silvina Vieira Pereira Ferreira
   Amorphous multicomponent dielectric based on the mixture of high band gap and high K materials, respective devices and manufacture
   US8987097 (B2), US Patent Office, 24. 03. 2015.
2. James William West, Jason Sagert, Paul H. Bessette, Henry Berbard Lowman, Nancy E. Stagliano Stagliano, Olga Vasiljeva, Elizabeth Menendez
   Anti-jagged 1/jagged 2 cross-reactive antibodies, activatable anti-jagged antibodies and methods of use thereof
   US9127053 (B2), US Patent Office, 8. 09. 2015.
3. Maja Remškar, Ivan Iskra, Marko Viršek, Mark Pleško, Damjan Golob
   Method and capacitive sensor for counting aerosol nanoparticles
   US9151724 (B2), US Patent Office, 6. 10. 2015.
4. Robert Jeraj, G. Liu
   System and method for evaluation of disease burden
   US9161720 (B2), US Patent and Trademark Office, 20. 10. 2015.
5. Marko Marinček, Jožica Kranjec, Matjaž Lukač
   Manually guided articulated arm
   US9186222 (B2), US Patent Office, 17. 11. 2015.
6. Aleš Mrzel, Maja Remškar, Adolf Jesih, Marko Viršek
   Process for the synthesis of nanotubes and fullerene-like nanostructures of transition metal dichalcogenides, quasi one-dimensional structures of transition metals and oxides of transition metals
   EP2132142 (B1), European Patent Office, 5. 08. 2015.
7. Matjaž Lukač, Marko Kazič
   Laser system for treatment of body tissue
   EP2618768 (B1), European Patent Office, 14. 01. 2015.
8. Igor Muševič, Matjaž Humar
   Spherical liquid-crystal laser
   EP2638604 (B1), European Patent Office, 18. 03. 2015.
9. Maja Remškar, Janez Jelenc, Andrej Kržan
   Fluoro-polymer nanocomposites with tailored friction properties
   SI24472 (A), Slovenian Intellectual Property Office, 31. 03. 2015.
10. Matjaž Gams, Rok Piltaver, Hristijan Gjoreski
    Method for Identification of Persons Entering a Room
    SI24485 (A), Slovenian Intellectual Property Office, 31. 03. 2015.
11. Jana Erjavec, Tanja Dreo, Jerica Sabotič, Jože Brzin, Janko Kos, Maja Ravnikar
    Composition and method for plant protection
    SI24489 (A), Slovenian Intellectual Property Office, 30. 04. 2015.
12. Jože Vižintin, Jose Miguel Marques Querido Salgueiro, Boris Kržan, Gabrijel Peršin, Đani Juričić, Pavle Boškoski, Gregor Dolanc
    Apparatus and method for on-line monitoring of oil condition and debris concentration
    SI24579 (A), Slovenian Intellectual Property Office, 30. 06. 2015.
13. Damir Vrančić, Marko Nerat, Samo Krančan
    Procedure of rapid signal filtering of rotational speed with automatic elimination of periodic deviation
    SI 24580 (A), Slovenian Intellectual Property Office, 30. 06. 2015.
14. Andraž Rešetič, Jerneja Milavec, Blaž Zupančič, Boštjan Zalar
    Polymer dispersed liquid crystal elastomers
    SI24658 (A), Slovenian Intellectual Property Office, 30. 09. 2015.
15. Miran Mozetič, Nikolas Panagiotopoulos, Giorgos A. Evangelakis
    Method for tetragonal zirconia oxide thin films growth suitable for catalytic devices
    SI24659 (A), Slovenian Intellectual Property Office, 30. 09. 2015.
16. Ana Mladenovič, Primož Oprčkal, Nina Kržišnik, Radmila Milačič, Janez Ščančar, Andrijana Sever Škapin
    Process for obtaining health- and environment acceptable construction materials from the soil containing water soluble compounds of heavy metals
    SI24681 (A), Slovenian Intellectual Property Office, 30. 10. 2015.
17. 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
    SI24727 (A), Slovenian Intellectual Property Office, 30. 11. 2015.
18. Marko Matkovič, Iztok Tiselj, Ivo Kljenak, Andrej Prošek, Matjaž Leskovar, Ljubo Fabjan, Leon Cizelj
    Method and apparatus for assessing the state of a spent-fuel facility
    SI24756 (A), Slovenian Intellectual Property Office, 31. 12. 2015.

ART EXHIBITIONS AT THE JSI

Jože Ciuha, 26 January-19 February
Brina Torkar, 23 February-19 March
Vida Fakin, 23 March-16 April
Jana Vizjak, 20 April-14 May
Boštjan Pucelj, 18 May-11 June
Taja Ivančič, 15 June -9 July
Ciril Velkovrh, 13 July-3 September
Polde Oblak, 7 September-8 October
Janez Mišo Knez, 12 October-5 November
Tina Dobrajc, 9 November-3 December
Vesna Čadež, 7 December-21 January 2016

Acedemician Prof. Milček Komelj at the opening of Vida Fakin's exhibition

AWARDS AND APPOINTMENTS

AWARDS MADE TO JSI RESEARCHERS BY THE REPUBLIC OF SLOVENIA

Zois Award and Zois Certificate of Recognition

Borut Štrukelj
Presented with the Zois Award for outstanding achievements in modern sustainable development of pharmaceutical biotechnology in the Republic of Slovenia

Alenka Mertelj and Darja Lisjak
Presented with the Zois Certificate of Recognition for discovery of ferromagnetic liquid-crystal suspensions

Puh Certificate of Recognition

Ines Bantan, Silvo Drnovšek (JSI), Danjela Kuščer (JSI), Helena Razpotnik
Presented with the Zois Certificate of Recognition for inventions, development achievements and use of the scientific discoveries in the development of cordierite ceramics with a stable low coefficient of linear thermal expansion

JSI AWARDS AND APPOINTMENTS

The Jožef Stefan Golden Emblem Prize

presented to the following for doctoral theses with high impact :

Aljaž Godec
Many-body correlations in hydrophobic interactions

Erik Štrumbelj
An efficient explanation of regression and classification models' predictions

The winner of Zois Award: Prof. Borut Štrukelj

SELECTED OTHER AWARDS TO JSI RESEARCHERS

Danfoss Trata d. o. o. and the Systems and Control research group (JSI), the TARAS award for the most successful cooperation between research teams and organisations on one side and development teams in industry on the other side for the year 2015 at the 7th Industrial forum of Innovation, R&D and Technology - IRT 2015 held in Portorož

The winners of the Jožef Stefan Golden Emblem Prize: Dr. Aljaž Godec and Dr. Erik Štrumbelj

Blaž Belec, Best contribution at the Conference of Jožef Stefan International Postgraduate School, Jožef Stefan International Postgraduate School, Ljubljana, "Magnetic properties of nanoplatelet composite nanoparticles composed of hard-magnetic hexaferrite and soft-magnetic maghemite".

The winners of Zois Certificate of Recognition and Puh Certificate of Recognition: Asst. Prof. Darja Lisjak, Helena Razpotnik, M. Sc., Asst. Prof. Danjela Kuščer Hrovatin, Silvo Drnovšek, B. Sc., Ines Bantan, B. Sc. and Asst. Prof. Alenka Mertelj

Bojan Cestnik, **Marko Bohanec in Tanja Urbančič**, Best paper award at the 6th International Conference on Computer Systems and Technologies 2015, Dublin, Ireland, "QTvity: advancing students' engagement during lectures by using mobile devices".

Božidara Cvetković, **Vito Janko**, **Mitja Luštrek**, Recognition for API for Motion Analysis, Slovenian Innovation Forum 2015, Šempeter pri Novi Gorici, 17.–18. 11. 2015

Andrej Debenjak, "Golden award" for his doctoral thesis "Condition monitoring of PEM fuel cells" in 2015 at the 25th Slovenian Trade Fair and Conference on Technical Maintenance, Otočec

Gorazd Frontini, **Janez Holc**, **Danjela Kuščer**, **Irena Ramšak**, **Marija Raspotnik**, **Helena Razpotnik**, Silver national recognition for the inovation, Brdo pri Kranju, Chamber of Commerce and Industry of Slovenia and Golden recognition for the inovation, Trbovlje, Chamber of Commerce and Industry of Slovenia, Regional Chamber Zasavje, Recognition for inovation: The development of the new steatite materials

Andrej Gams, ICRA CEB Best Reviewer Award, IEEE Int. Conf. on Robotics and Automation (ICRA), Seattle, Washington, USA. Awarded by the IEEE International Conference On Robotics and Automation Conference Editorial Board (CEB). This award is established to recognize the four Best Reviewers from the RAS Conference Editorial Board for a job well-done during the ICRA review process.

Hristijan Gjoreski, **Rok Piltaver**, **Matjaž Gams**, Best Paper Award for "Person identification by analyzing door accelerations in time and frequency domain", 12th European Conference on Ambient Intelligence, AmI 2015, Athens, Greece, 11.–13. 11. 2015

Matjaž Humar, Name of the week (VAL 202)

Matjaž Humar, Personality of Primorska region for the month of July 2015

Vanja Jordan, "Hydrothermal synthesis of highly branched rutile-type TiO_2," (co-authors, Goran Dražić, Aleksander Rečnik). Best Young Lecturer Award, 12th Multinational Congress on Microscopy 2015, Eger, Hungary, 23-28 August 2015

Đani Juričić, **Pavle Boškoski**, **Bojan Musizza**, **Janko Petrovčič**, **Boštjan Dolenc**, **Stanislav Černe**, the first prize for the innovation with the greatest economic potential that was created in PROs (public research organizations) in 2015 at the 8th International Conference on Technology Transfer and Innovation Day 2015, Brdo pri Kranju, September 2015

Miha Kavčič, The Prešeren award for academic degree with title: The influence of oxygen and ammonia plasma treatment of cotton on adsorption of natural curcumin dyestuff (Marija Gorjanc and Miran Mozetič). The award was given by the Faculty of Natural Sciences and Engineering.

Rok Kocen, Viscoelastic properties of hydrogel - "ceramic" composites for tissue-engineering scaffolds (co-authors: Ana Gantar, Sasa Novak, Christian Hellmich, Michael Gasik). Award for the Best Scientific Work, Bulgarian Society of Biorheology, 4 September 2015, presented at the 5th Euro Summer School on Biorheology, Varna, Bulgaria, 1–5 September 2015

Rok Kocen, Measuring viscoelasticity of hydrogel-BAG composites (co-authors, Ana Gantar, Saša Novak, Christian Hellmich, Michael Gasik). Best Oral Presentation Award, 23rd International Conference on Materials and Technology, Portorož, 28–30 September 2015

Dragi Kocev, best paper award at the 16th International Conference on Intelligent Data Engineering and Automated Learning (IDEAL), Wroclaw, Poland, October 2015

Mario Konecki, **Alen Lovrenčić**, **Matjaž Gams**, Award for excellent paper, best presentation and best content, Using customized reports in introductory programming courses, 3rd International Academic Conference on Development in Science and Technology, IACDST 2015, Paris, France, 11. 10. 2015

Samo Kralj, Reward for outstanding educational achievements and constantly highest marks in students' assessments from Faculty of Natural Sciences and Mathematics, University of Maribor, 2015

Samo Kralj, Golden Reward from Society for Technical Culture of Slovenia for outstanding achievements in the field of education, 2015

Samo Kralj, Distinguished referee reward of the European Physical Journal in 2015

Jurica Levatić, Best ICT paper on the 7th Jožef Stefan International Postgraduate School Students' Conference, Ljubljana, May 2015

Martina Lorenzetti, European Doctoral Award 2015, European Society for Biomaterials, 2 September 2015

Gjorgji Madjarov, **Vedrana Vidulin**, **Ivica Dimitrovski and Dragi Kocev**, Best paper award at the 16th International Conference on Intelligent Data Engineering and Automated Learning 2015, Wroclaw, Poland, Web genre classification via hierarchical multi-label classification.

Blaž Mikuž, Young author awards (International Conference Nuclear Energy for New Europe: Portorož, Slovenia, 14.-17.09.2015) - Nuclear Society of Slovenia ... Accurate wall-resolved Large Eddy Simulation of a turbulent flow in 5×5 fuel rod bundle

Dunja Mladenić, FOI Varaždin, Croatia; Friend of the faculty of organization and informatics charter recognizing the outstanding long-term contribution to the international affirmation of the faculty in the higher education and scientific area

Aljaž Osojnik, "Carl Smith" award for the best student paper at the 18th International Conference on Discovery Science 2015, Banff, Canada, Multi-label Classification via Multi-target Regression on Data Streams.

Jerca Pahor, Best Poster Award on International Conferences on Current Challenges in Drug Discovery Research, Jaipur, India, November 2015

Tanja Pečnik, Award for the best oral presentation among young researchers at the 23rd International Conference on Materials and Technologies, Portorož, Dielectric properties of the solution-derived $Ba_{0.5}Sr_{0.5}TiO_3$ thin films, Portorož, September 2015

Gregor Primc, Award for outstanding achievements in the year 2014, awarded by the Jožef Stefan Institute International Postgraduate School for developing an innovative sensor with highest commercial potential and for the establishment of a spin-out company Plasmadis Ltd.

Johanna Amalia Robinson, Best Student Poster Presentation Award, Eindhoven, The Netherlands, Healthy Buildings Europe 2015, University of Technology, Empowering students to improve their indoor school environment with the help of low-cost air quality sensors – CITI-SENSE project

Pia Škodlar, The Krka award for students' research work with title Methods for improving hemocompatibility of vascular implants (Ita Junkar). The award was given in Pharmaceutical Corporation Krka, 21. September, Novo mesto.

Roman Trobec, HiPEAC Tech Transfer Award 2015, University of Gent, Gent, Belgium, December 2015.

Janja Vidmar, **Radmila Milačič**, **Janez Ščančar**: Best ECO paper, The 7th Jožef Stefan International Postgraduate School Students' Conference, Sizing of nanoscale titanium dioxide and its quantification in the presence of dissolved titanium by single particle inductively coupled plasma mass spectrometry, Ljubljana, May 2015

Barbara Volarič, Best Student Presentation on ISE-Satellite Student Symposium of the Regional Symposium on Electrochemistry, South-East Europe 2015, Pravets, Bulgaria, June 2015

Janja Vrzel, **Goran Vižintin**, **Nives Ogrinc**, Best ECO paper, The 7th Jožef Stefan International Postgraduate School Students' Conference, Conceptual model of Ljubljansko polje aquifer, Ljubljana, May 2015

Matevž Vučnik, **Johana Robinson**, **Miha Smolnikar**, **David Kocman**, **Milena Horvat**, **Mihael Mohorčič**, Outstanding Student Poster Award at EGU General Assembly 2015 to, "Portable air quality sensor unit for participatory monitoring: an end-to-end VESNA-AQ based prototype", Geophysical Research Abstracts, Vol. 17, European Geosciences Union General Assembly 2015, Vienna, Austria, April 2015.

Simon Žurga, Dean's Award 2015, for paper "Biochemical properties of lectin from parasol mushroom (*Macrolepiota procera*) and its effects on model nematode *Caenorhabditis elegans*", published in Federation of European Biochemical Societies (FEBS) Journal, Ljubljana, Faculty of Pharmacy, University of Ljubljana

REVIEW OF PUBLICATIONS

FOR 2015

Department	Original Articles*	Books	Patent Appl. and Grants	Theses
Department of Theoretical Physics (F-1)	106			3
Department of Low and Medium Energy Physics (F-2)	69	2		1
Department of Thin Films and Surfaces (F-3)	14			
Department of Surface Engineering and Optoelectronics (F-4)	64		5	2
Department of Solid State Physics (F-5)	122		8	9
Department for Complex Matter (F-7)	58	1	6	5
Department of Reactor Physics (F-8)	185	2	2	3
Department of Experimental Particle Physics (F-9)	147	1		2
Department of Inorganic Chemistry and Technology (K-1)	35	1	3	1
Department of Physical and Organic Chemistry (K-3)	24		1	1
Electronic Ceramics Department (K-5)	59		1	1
Engineering Ceramics Department (K-6)	6			
Department for Nanostructured Materials (K-7)	55		2	2
Department for Synthesis of Materials (K-8)	29		1	1
Department for Advanced Materials (K-9)	24			1
Department of Biochemistry, Molecular and Structural Biology (B-1)	42		2	3
Department of Molecular and Biomedical sciences (B-2)	16			1
Department of Biotechnology (B-3)	31	1	4	1
Department of Environmental Sciences (O-2)	94	3	2	3
Department of Automation, Biocybernetics and Robotics (E-1)	42			5
Department of Systems and Control (E-2)	47	2	2	1
Artificial Intelligence Laboratory (E-3)	33	1		
Laboratory for Open Systems and Networks (E-5)	23			1
Department of Communication Systems (E-6)	54	1	1	
Computer Systems Department (E-7)	27			1
Department of Knowledge Technologies (E-8)	89			3
Department of Intelligent Systems (E-9)	62	1	2	2
Department of Reactor Engineering (R-4)	55	1	1	1
Reactor Infrastructure Centre (RIC)	5			
Networking Infrastructure Centre (NIC)	3	1		
Energy Efficiency Centre (EEC)	10			
Milan Čopič Nuclear Training Centre (ICJT)	3			
Radiation Protection Unit (SVPIS)	1			
Centre for Technology Transfer and Innovation (CTT)	4	1		
Jožef Stefan Institute	1641	19	44	54

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

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.

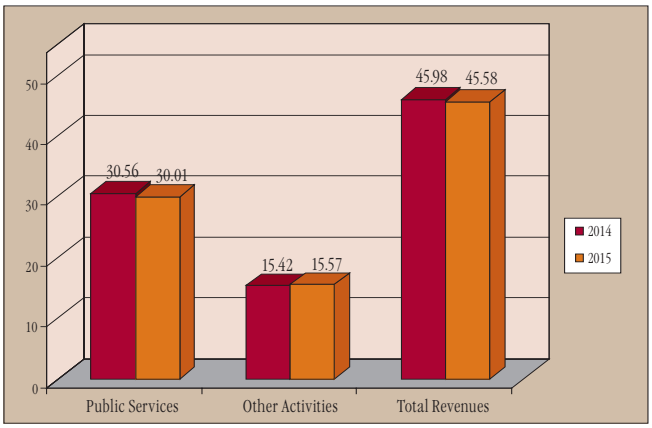
R & D PROJECT PARTNERS

1. Abak.Net, d. o. o., Murska Sobota
2. Acies Bio, d. o. o., Ljubljana
3. Alpineon, d. o. o., Ljubljana
4. Amebis, d. o. o., Kamnik, Kamnik
5. ARAO-Slovenian Agency For Radioactive Waste Management, Ljubljana
6. Bioiks, d. o. o., Ljubljana
7. Časnik Finance, d. o. o., Ljubljana
8. CDT Group, d. o. o., Kropa
9. Central Technological Library At the University of Ljubljana, Ljubljana
10. Chemicals Office of the Republic of Slovenia, Ljubljana
11. Cosylab, d. d., Ljubljana
12. Danfoss Trata, d. o. o., Ljubljana
13. Domel, d. o. o., Železniki
14. Ecological Engineering Institut, d. o. o., Maribor, Maribor
15. Ecot, d. o. o., Ljubljana
16. Ektimo, d. o. o., Medvode
17. Eles, d. o. o., Ljubljana
18. Elgoline, d. o. o., Cerknica
19. Energetika Ljubljana, d. o. o., Ljubljana
20. Energy Agency, Maribor, Maribor
21. Entia, d. o. o., Ljubljana
22. Gama System, d. o. o., Ljubljana
23. Gen Energija, d. o. o., Krško
24. Golea, Nova Gorica, Nova Gorica
25. Hyb, d. o. o., Šentjernej
26. Inea , d. o. o., Ljubljana
27. Informa Echo, d. o. o., Ljubljana
28. Institute of Microbial Sciences and Technologies, d. o. o., Domžale
29. Institute of Oncology, Ljubljana
30. Intech - Les, d. o. o., Rakek
31. Intersocks, d. o. o., Kočevje
32. Iolar, d. o. o., Ljubljana
33. IPD Med, d. o. o., Šentjernej
34. Istrabenz plini, d. o. o., Koper
35. JP CČN Domžale-Kamnik, d. o. o., Domžale
36. JP Vodovod-Kanalizacija D.O.O, Ljubljana
37. Keko - Oprema, d. o. o. Žužemberk
38. Knauf Insulation, d. o. o., Škofja Loka
39. Kolektor Group, d. o. o., Idrija
40. Kolektor KFH, d. o. o., Idrija
41. Kolektor Sikom, d. o. o., Idrija
42. Komunala Novo mesto, d. o. o., Novo mesto
43. Kovinos, d. o. o., Horjul
44. Krka, d. d., Novo mesto
45. Krško Nuclear Power Plant, d. o. o., Krško
46. Lek, d. d., Ljubljana
47. Luka Koper, d. d., Koper
48. Meis, d. o. o., Šmarje Sap
49. Metrology Institute of the Republic of Slovenia, Celje
50. Milan Vidmar Electric Power Research Institute, Ljubljana
51. Ministry of Agriculture, Forestry and Food of the Republic of Slovenia, Ljubljana
52. Ministry of Defence of the Republic of Slovenia, Ljubljana
53. Ministry of Education, Science and Sport of the Republic of Slovenia, Ljubljana
54. Ministry of Finance of the Republic of Slovenia, Ljubljana
55. Ministry of Infrastructure of the Republic of Slovenia, Ljubljana
56. Ministry of the Environment and Spatial Planning of the Republic of Slovenia, Ljubljana
57. Ministry of the Interior of the Republic of Slovenia, Ljubljana
58. National Institute of Biology, Ljubljana
59. Optacore, d. o. o., Ljubljana
60. Optotek, d. o. o., Ljubljana
61. Panna Plus, d. o. o., Ljubljana
62. Petrol d. d., Ljubljana
63. Petrol Energetika, d. o. o., Ravne na Koroškem
64. Plinovodi, d. o. o., Ljubljana
65. Quintelligence, d. o. o., Ljubljana
66. Razvojni center ENEM Novi materiali, d. o. o., Zagorje ob Savi
67. Robotina, d. o. o., Kozina
68. S2p, d. o. o., Ljubljana
69. Saving, d. o. o., Ljubljana
70. Simed, d. o. o., Ljubljana
71. Slovenian Radiation Protection Administration, Ljubljana
72. Slovensko društvo ljubiteljev kemije, Ljubljana
73. Splošna Bolnišnica "Dr. Franca Derganca", Šempeter pri Gorici
74. Splošna Bolnišnica Novo mesto, Novo mesto
75. Statistical Office of the Republic of Slovenia, Ljubljana
76. Tela Merilni Sistemi, d. o. o., Ljubljana
77. Telekom Slovenije, d. d., Ljubljana
78. Unior kovaška industrija d. d., Zreče
79. University of Ljubljana, Biotechnical Faculty, Ljubljana
80. Ustna medicina, d. o. o., Ljubljana
81. Velenje Coal Mine, d. d., Velenje
82. Xenya, d. o. o., Ljubljana
83. Xlab, d. o. o., Ljubljana
84. Žito, d. d., Ljubljana
85. ZRMK Building and Civil Engineering Institute, Ljubljana
86. ZVD - Institute of Occupational Safety, d. o. o., Ljubljana

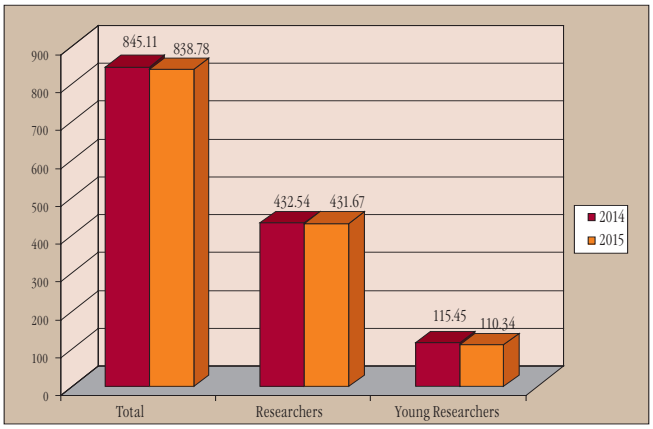
INSTITUTE IN NUMBERS

2014–2015

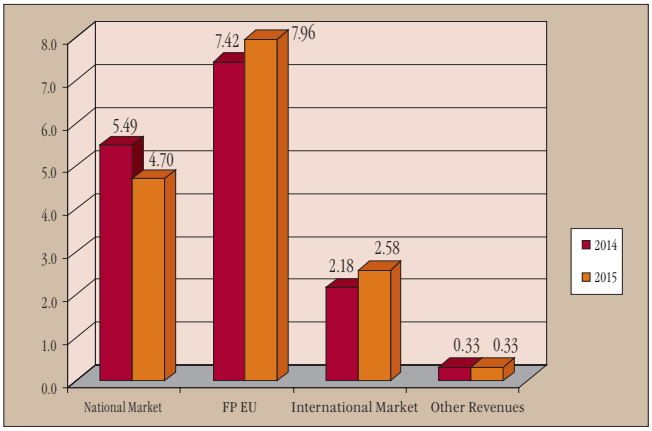
COMPARISON OF REVENUES (€M)



EMPLOYEES (FTE)



REVENUES FROM OTHER ACTIVITIES (€M)



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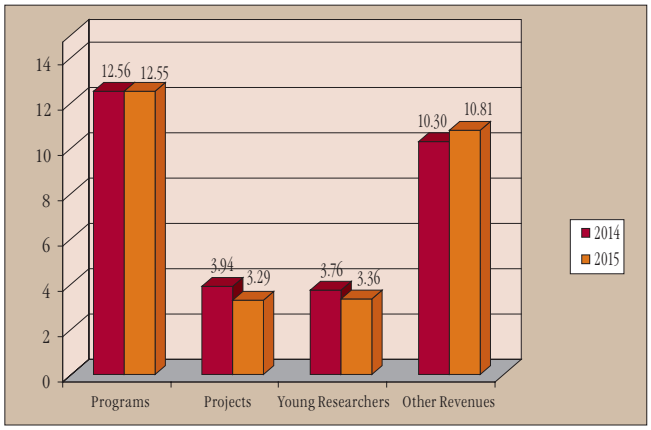
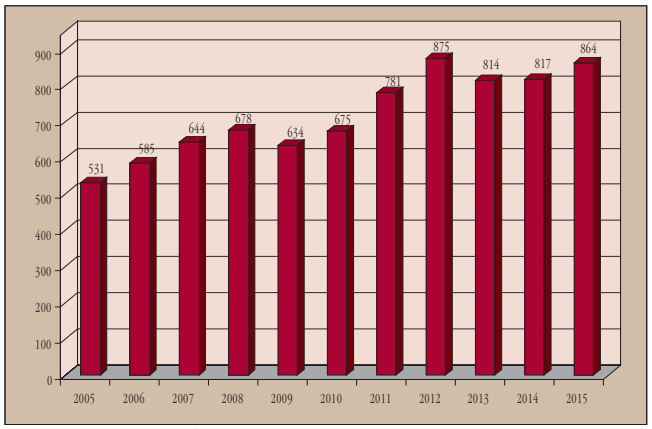
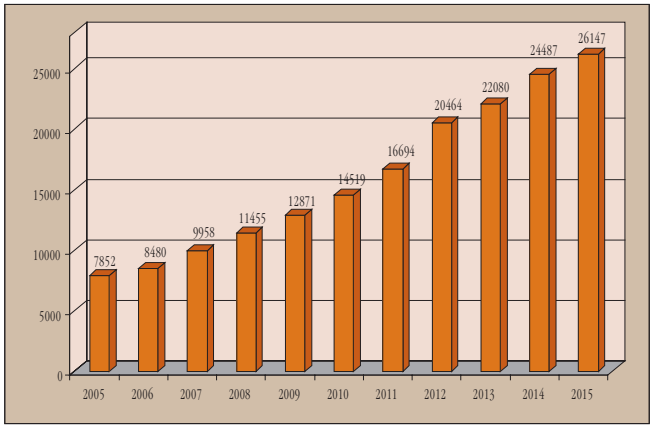


NUMBER OF PUBLICATIONS IN THE WEB OF SCIENCE*



* retrieved 9 August 2016

NUMBER OF CITATIONS IN THE WEB OF SCIENCE*



* retrieved 9 August 2016

RESEARCH DEPARTMENTS

DEPARTMENT OF THEORETICAL PHYSICS F-1

In 2015 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 calculations in three-body systems.

Head:
Prof. Svjetlana Fajfer

In the area of hadronic physics we have calculated, using the coupled-channel approach, the photo-production of eta mesons and kaons and concluded that the dominant amplitudes in the S11, P11, P13, and P33 partial waves are well described in a SU(3) extended chiral quark model. In addition, the model explains the origin of an apparent resonance in the production of eta mesons off the neutron and its absence on the proton target.

The charmonia above the open charm threshold were simulated in lattice QCD taking into account their strong decays for the first time. The resulting decay width and resonance mass agree with the experiment. The mass predictions for as yet unobserved scalar and axial B s mesons were made, taking into account the effect of nearby thresholds. We simulated the channels where the exotic experimental candidates Zc $^{+}$ (bar c c d bar u) and Y (4140) (bar c c s bar s) reside. The first evidence for X(3872) was found in a simulation that also employed diquark- antidiquark interpolating fields.

In the part of the research program devoted to particle physics we have investigated the phenomenology of flavoured dark matter (DM). DM stability is guaranteed by an accidental Z3 symmetry. We considered an explicit realization where the quark part of the SM flavour group is fully gauged. We classified weak-scale extensions of the Standard Model, which automatically preserve its accidental and approximate symmetry structure at the re-normalisable level and which are hence invisible to low-energy indirect probes. By requiring the consistency of the effective field theory up to scales of 10^{15} GeV and after applying cosmological constraints, we arrived at the finite set of possibilities that we analysed in detail.

We revisited constraints on the new physics contributions coming from charm meson leptonc and semileptonic decays to strange mesons processes. Using an effective theory approach, we investigated new physics effects that might appear in the differential distributions for the longitudinally and transversely polarised vector strange meson in the semileptonic decays of D to K*. In the case of D→Klν we identify observables that are sensitive to the new physics contribution coming from the scalar Wilson coefficient, i.e., the forward-backward and the transversal muon asymmetries.

Positive parity meson states $D^*_{s0}(2317)$ and $D_{s1}(2460)$ have masses slightly below the DK threshold. Therefore, both states can strongly decay only into isospin-violating decays $D_{s1}(2460) \to D_s \varpi \varpi$, $D_{s1}(2460) \to D_s^* \varpi$ and $D^*_{s0}(2317) \to Ds \varpi$. The pion states have rather small energies, which makes these decays appropriate to study within the heavy meson chiral perturbation theory and calculate the loop contributions. We found that chiral loop contributions might be important in both cases. We explore the experimentally known ratio of the decay widths for these two decay modes to estimate the size of the counter-terms' contributions.

We have explored the possibility of Higgs boson decay to a muon and a tauon in the effective theory framework, as well as in complete models of new physics. We have shown that the Two Higgs doublet model can explain h → tau mu with a branching ratio of 1 %. We have proposed a light scalar leptoquark, which is a weak doublet and with hypercharge 1/6 that can explain the observed violation of lepton universality in B → K mu mu and B → K e e decays.

We showed that R-parity violating terms in the minimal re-normalisable supersymmetric SU(5) can describe all the fermion masses with a large mixing between the electron and the Higgsino. We proposed the minimal supersymmetric re-normalisable E_6 with the Higgs sector made of 27, 351 and 78 dimensional representations, and matter in three copies of 27-plets.

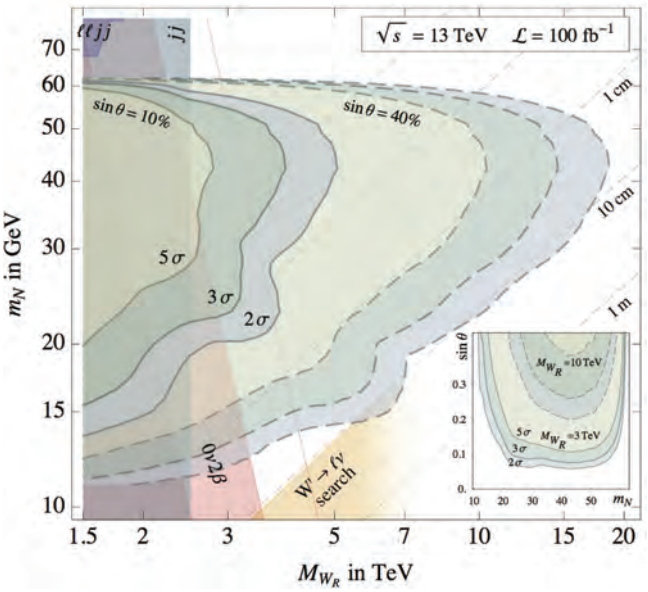


Figure 1: Discovery reach of the lepton number violating Higgs decay to a pair of heavy neutrinos.

We proposed a novel way to search for the breaking of the lepton number in exotic Higgs decays at the LHC. In the context of the minimal Left-Right symmetric model, where the neutrino mass results from a spontaneous breaking, we show that the Standard Model Higgs can decay to a pair of right-handed neutrinos. This results in a signal with same-sign leptons and jets that can be searched for at the LHC. Collider simulation with a sensitivity study shows this may be a very sensitive probe of new physics.

We studied the application of quasi-linearization recast in the form of a discrete optimization problem using linearized approximations to propagation equations. Possible applications are the Schrödinger equation and minimal principles via their Euler equations.

We have shown that cosmological dark-matter stability can be ensured by an accidental quark flavour symmetry, already present in the standard model, where it coincides with a subgroup of the baryon number.

We have proposed a light scalar leptoquark that is a weak doublet and with hypercharge 1/6, which can explain the observed violation of lepton universality in B → K mu mu and B → K e e decays. Also, we studied the minimal supersymmetric theory of E6 unification.

We proposed a novel way to search for the neutrino mass origin in exotic Higgs decays.

Some outstanding publications in the past three years

1. Maiezza, Alessio, Nemevšek, Miha, Nesti, Fabrizio. Lepton number violation in Higgs decay at LHC. Physical review letters, ISSN 0031-9007. [Print ed.], 2015, vol. 115, no. 8, str. 081802-1-081802-7, doi: 10.1103/PhysRevLett.115.081802. [COBISS.SI-ID 28795175]
2. Bečirević, Damir, Fajfer, Svjetlana, Košnik, Nejc. Lepton flavor nonuniversality in b → sl$^+$l$^-$ process. Physical review. D, Particles, fields, gravitation, and cosmology, ISSN 1550-7998, 2015, vol. 92, no. 1, str. 014016-1-014016-11, doi: 10.1103/PhysRevD.92.014016. [COBISS.SI-ID 28735015]

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 correlated electrons we continued studies of many-body quantum states close to inegrability, the investigations of Mott insulators and with the analyses of disordered quantum systems. Together with co-workers we developed a numerical method that allows the systematic search for local and quasi-local conserved quantities in one-dimensional systems. Using the example of the anisotropic Heisenberg model we established, besides the known local conserved operators, the proposed quasilocal ones, but also some novel ones, in particular one within the isotropic model. With an analogous approach we show that adding a small generic perturbation to the model leads to the regular decay of previously conserved quantities. In the study of Mott insulators we showed that the recombination in one-dimensional organic systems must happen via the multi-phonon emission, which can be put in agreement with experimentally observed pressure dependence. We also developed a novel approach to the insulator-metal Mott transition based on the view-point of binding vs. unbinding of holon-doublon pairs. Dealing with the disordered spin systems we showed that at elevated temperatures the transport properties of classical spin chains are qualitatively similar to the quantum ones, i.e., showing no strict localization. In the case of weakly coupled disordered spin chains the relevant question is how the disorder influences the transition temperature and ordered local moments. Here, we presented an analysis that applies to existing materials with random spin chains.

By studying the ultrafast dynamics of strongly correlated cuprate superconductors we showed that we can model the primary relaxation mechanism within a model that assumes energy transfer from excited charge carriers to antiferromagnetic fluctuations.

We studied the ultrafast dynamics of strongly correlated cupratesuperconductors. In collaboration with experimental optics groups in Brescia and Milano we managed to analyse the transient response of the material in the 10 fs time window. We showed that we can model the primary relaxation mechanism within a model that assumes energy transfer from excited charge carriers to bosonic fluctuations. By means of a comparison with exact numerical simulations we concluded that antiferromagnetic degrees of freedom very likely represent the dominant mechanism.

Thermopower is a powerful but mostly untouched spectroscopic probe of electronic states in mesoscopic devices. Recently, differential thermopower spectroscopy was used to study quasibound states that form on top of a quantum point contact. We performed density functional theory calculations within the local spin density approximation that explain the magnetic field dependence of the experimental results. We investigated the magnetism and optical properties of pseudocubic ruthenium perovskites. In the framework of dynamical mean-field theory and the density-functional theory we successfully explained the occurrence of magnetism in $SrRuO_3$ and its absence in $CaRuO_3$.

An exact solution is presented for the time-dependent wavefunction of an initial ground-state Kramer's-doublet qubit, which is driven around a quantum ring. We show that the initial qubit may be transformed to an arbitrary point on the Bloch sphere for an integral number of revolutions around the ring. The prospects and challenges for possible realizations are discussed, for which rings based on InAs quantum wires are promising candidates.

We have proposed a theoretical model for an antiferroelectric system, characterized by an intermediate ferroelectric phase between the antiferroelectric phase and the high-temperature paraelectric phase. We have calculated the dielectric susceptibility and the electrocaloric temperature change, which is negative in the antiferroelectric region.

Within the research on the statistical physics of complex systems and networks, in 2015 we studied self-organized processes of knowledge creation through questions and answers in online portals. Based on a physics description of two-scale processes, we developed an approach that includes an analysis of empirical data, information theory, and agent-directed modelling. We have determined the fractal properties of these processes and the characteristics of the communities in the co-evolving bipartite networks, depending on the expertise of individual participants. With the help of an algebraic topology graph, we have investigated the higher topological structure and introduced quantities that characterize the "social capital" of individuals in social networks. Furthermore, using higher combinatorial structures of graphs representing the time series of the transport on networks, we determined new characteristics of the collective dynamics near the phase transition into the congested traffic phase.

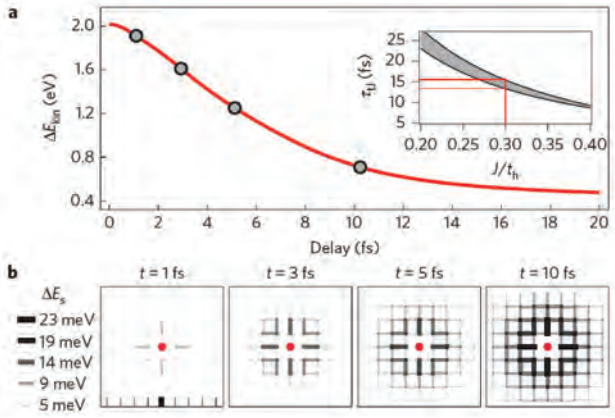


Figure 2: Energy transfer (a) of the photo-excited carrier to local spin degrees of freedom (spin bonds) (b).

Some outstanding publications in the past three years

1. Dal Conte, S., Vidmar, Lev, Golež, Denis, Bonča, Janez, et al. Snapshots of the retarded interaction of charge carriers with ultrafast fluctuations in cuprates. *Nature Physics*, ISSN 1745-2473, 2015, vol. 11, no. 5, str. 421-426, ilustr. doi: 10.1038/nphys3265. [COBISS.SI-ID 2794596]
2. Mitrović, Marija, Melnik, Roderick, Tadić, Bosiljka. The dynamics of meaningful social interactions and the emergence of collective knowledge. *Scientific Reports*, ISSN 2045-2322, 2015, vol. 5, str. 12197-1-12197-10, doi: 10.1038/srep12197. [COBISS.SI-ID 28758567]
3. Hung T. Dang, Jernej Mravlje, Antoine Georges, Andrew J. Millis, "Band Structure and Terahertz Optical Conductivity of Transition Metal Oxides: Theory and Application to CaRuO3,". *Phys. Rev. Lett.* 115, 107003 (2015).

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

Our work in the field of theoretical biophysics and soft-condensed-matter physics included a number of studies dedicated to problems in physical virology, the physics of proteins as well as DNA and RNA. We investigated the macromolecular interactions of the electrostatic and van der Waals type, the Casimir effect in the context of non-equilibrium processes, and the effects of disorder in electrostatic interactions in soft matter. Using computer simulations, we studied the nature of hydration and the hydrophobic forces between various biological membranes and surfaces in water environments as well as the nature of nanodroplets on various surfaces and the influence of their size on the shape. By combining simulations, self-consistent field theory and two continuum models we explored the deformation of a polymeric nanocolloidal particle trapped between parallel walls, finding that its behaviour may be likened to the small compressible liquid droplet.

We measured the compressibility of the modulated nematic liquid-crystalline phases and we found that it is orders of magnitude larger than predicted by continuum models. Also quantified was the thermal diffusivity in a homolog series of thermotropic liquid crystals. We showed that the influence of the molecular length on the magnitude of the thermal conductivity is consistent with the molecular model. We theoretically analysed the interactions that could lead to the complex 3D structure of the tetragonal phase found in materials that also exhibit an antiferroelectric phase. A series of liquid-crystals demonstration experiments for the lay audience was developed.

Using a surface-tension-based mechanical model we quantitatively explained a detailed measurement of the deformation of the epithelium tissue in the fruit fly embryo during gastrulation, concluding that

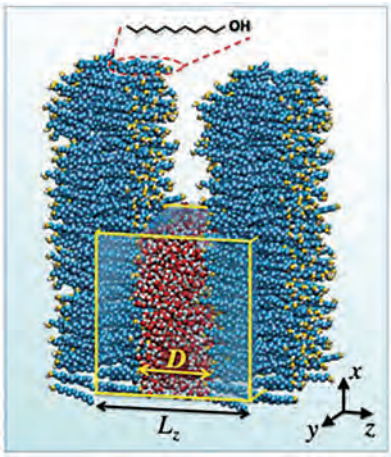


Figure 3: A computer simulation snapshot of a polar (hydrophilic) and a non-polar (hydrophobic) surface, where a strongly bound water layer to the polar layer prevents their close contact.

We have introduced a new computational model for van der Waals interactions and we developed a method of electrostatic identification for different types of viral capsids.

the elastic properties of the different parts of the tissue are rather dissimilar. Also proposed was a continuum theory of the shape of epithelial tissue, which elucidates the previously barely noticed coupling between local tissue thickness and curvature. We developed a mathematical model of arachidonic acid degradation to prostaglandins and leukotrienes, which are implicated in the processes of inflammation and hypersensitivity to non-steroidal anti-inflammatory drugs.

Some outstanding publications in the past three years

1. Górecka, Ewa, Vaupotič, Nataša, Zep, Anna, Pociecha, Damian, Yoshioka, Jun, Yamamoto, Jun, Takezoe, Hideo. A twist-bend nematic (NTB) phase of chiral materials : Ewa Gorecka ... [et al.]. Angewandte Chemie, ISSN 1433-7851. [Print ed.], 2015, vol. 54, no. 35, str. 10155-10159, doi: 10.1002/anie.201502440. [COBISS.SI-ID 28844839]
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Organization of conferences, congresses and meetings

1. Particle Phenomenology From the Early Universe to High Energy Colliders, Portorož, 7.-10. 4. 2015
2. Nonequilibrium Phenomena in Complex Matter: new observations and new theories, Krvavec, 13.-16. 12. 2015 (co-organisation with F-7)

INTERNATIONAL PROJECTS

1. H2020 - ITN - COLLDENSE; Hybrid Colloidal Systems with Designed Response
   Prof. Primož Ziherl
   European Commission
2. Higgs Boson at the Junction of Flavor Physics and Dark Matter
   Asst. Prof. Jernej Fesel Kamenik
   Slovenian Research Agency
3. Relaxation Dynamics and Thermalization of Quantum Many-body Systems
   Prof. Janez Bonča
   Slovenian Research Agency

RESEARCH PROGRAMS

1. Theory of the condensed matter and statistical physics
   Prof. Janez Bonča
2. Biophysics of polymers, membranes, gels, colloids and cells
   Prof. Rudolf Podgornik
3. Theoretical physics of nuclei, particles and fields
   Prof. Svjetlana Fajfer

R & D GRANTS AND CONTRACTS

1. Integrability and ergodic theory of non-equilibrium quantum many-body systems
   Dr. Jernej Mravlje

VISITORS FROM ABROAD

1. Prof. Ilja Doršner, University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Arch, Split, Croatia, 1.-6. 1., 27. 1.-4. 2., 19. 7.-14. 8., 13. 11.-22. 11. and 27.-30. 12. 2015
2. Prof. Junji Hisano, Nagoya University, Nagoya, Japan, 28.-30.1. 2015
3. Dr. Jacobo Lopez-Pavon, SISSA, Trieste, Italy, 4.-8.2. 2015
4. Dr. Gianluca Giovannetti, SISSA, Trieste, Italy, 9.-10.2. 2015
5. Prof. Masayuki Imai, Ochanomizu University, Tokyo, Japan, 16.-19. 2. 2015
6. Prof. John H. Jefferson, University of Lancaster, Lancaster, Great Britain, 21.-28. 2. 2015
7. Dr. Luca Merlo, Instituto de Física Teórica CSIC/UAM, Universidad Autónoma de Madrid, Madrid, Spain, 4.-6. 3. 2015
8. Dr. Guillermo Silva, IFLP-Departamento de Física, UNLP, La Plata, Argentina, 4. 3. 2015
9. Dr. Jacek Herbrych, University of Heraklion, Heraklion, Greece, 23. 3.-1. 4. 2015
10. Dr. Roberto Percacci, SISSA, Trieste, Italy, 2. 4. 2015
11. Dr. Jakša Vučičević, University of Belgrade, Belgrade, Serbia, 6.-8. 4. 2015
12. Dr. Admir Greljo, Universität Zürich, Physik-Institut, Zürich, Switzerland, 6.-15. 4., 17.-22. 8. in 16.-20. 11. 2015
13. Dr. Taegeun Song, ICTP, Trieste, Italy, 14.-15. 4. 2015
14. Prof. Marcin Mierzejewski, University of Silesia, Katowice, Poland, 15.-25. 4. 2015
15. Prof. Geoff J. Rodgers, Brunel University, London, Great Britain, 24.-30. 5. 2015
16. Dr. Daniel Mohler, Fermi National Accelerator Laboratory, Batavia, Illinois, USA, 31. 5.-4. 6. 2015
17. Dr. Jure Zupan, University of Cincinnati, Ohio, USA, 2.-8. 6. 2015
18. Prof. Osor Slaven Barišić, Institut za fiziko, Zagreb, Croatia, 29. 6.-2. 7. 2015
19. Dr. Rusa Mandal, The Institute of Mathematical Sciences, Chennai, India, 28. 6.-1. 7. 2015
20. Dr. Fabrizio Nesti, Institut Ruđer Bošković, Zagreb, Croatia, 1.-2. 7. 2015
21. Prof. Andrey Mishchenko, Strong Correlation Theory Research Group, RIKEN Center for Emergent Matter Science, Hirosawa, Japan, 1.-5. 7. 2016
22. Dr. Roni Harnik z University of Cincinnati, Ohio, USA, 13.-17. 7. 2015
23. Prof. Takami Tohyama, Tokyo University of Science, Tokyo, Japan, 7.-9. 9. 2015
24. Dr. Alaska Subedi, Max-Planck-Institute, Stuttgart, Germany, 20.-26.9. 2015
25. Prof. Ian Afleck, Department of Physics and Astronomy, University of British Columbia, Vancouver, Canada 2. 10. 2015
26. Dr. Tin Sulejmanpašić, North Carolina State University, Raleigh, USA, 15. -18.10. 2015
27. Prof. Veljko Zlatić, Institut za fiziko, Zagreb, Croatia, 19.10.-20. 11. 2015
28. Dr. Roberto Anibal Morales, University of Buenos Aires, Buenos Aires, Argentina, 15. 10.-15. 11. 2015
29. Dr. Daniele Fausti, University of Trieste and Elettra - Sincrotrone Trieste, Italy, 20. 10. 2015
30. Dr. Alessio Maiezza, IFIC, Universitat de València-CSIC, València, Spain, 28. 10.-5. 11. 2015
31. Prof. Jan Olav Eeg, Oslo University, Oslo, Norway, 1. -16.11. 2015
32. Dr. Jordy de Vries, Forschungszentrum Jülich GmbH, Jülich, Germany, 2.-7. 11. 2015
33. Prof. Axel Maas, Institute for Physics, University of Graz, Graz, Austria, 13.-14. 11. 2015
34. Prof. Robin Steinigeweg, University of Osnabrück, Osnabrück, Germany, 30. 11.-4. 12. 2015
35. Dr. Jorge Ovalle, Universidad Simón Bolívar, Caracas, Venezuela, 4. 12. 2015
36. Miroslav Andjelković, Institut Vinča, Belgrade, Serbia, 7.-17. 12. 2015
37. Prof. Stuart A. Trugman, Los Alamos National Laboratory, Los Alamos, USA, 12.-18. 12. 2015
38. Dr. Joan Elias Miro, SISSA, Trieste, Italy, 16.-18. 12. 2015

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1. Prof. Borut Bajc
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39. Jan Kogoj, B. Sc.
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42. *Dr. Zala Lenarčič, left 01.10.15*
43. *Dr. Luka Leskovec, left 01.09.15*
44. Žiga Osolin, B. Sc.
45. Urša Skerbiš, B. Sc.

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46. Lamprini Athanasopoulou, B. Sc.

Technical and administrative staff

47. Nevenka Hauschild

Note:

* part-time JSI member

BIBLIOGRAPHY

Original Article

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4. AUGER Collaboration, A. Aab *et al.*, "The Pierre Auger Cosmic Ray Observatory", *Nucl. instrum, methods phys res., Sect. A, Accel.*, vol. 798, pp. 172-213, 2015.
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17. Alexandru Botan *et al.* (17 authors), "Toward atomistic resolution structure of phosphatidylcholine headgroup and glycerol backbone at different ambient conditions", *J. phys. chem., B Condens. mater. surf. interfaces biophys.*, vol. 119, no. 49, pp. 15075-15088, 2015.
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19. Jože Buh, Viktor V. Kabanov, Vladimir V. Baranov, Aleš Mrzel, Andrej Kovič, Dragan Mihailović, "Control of switching between metastable superconducting states in δ-MoN nanowires", *Nature communications*, vol. 6, pp. 10250-1-10250-6, 2015.
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effect on miscibility of lipid mixtures in multicomponent membranes", *J. phys., Condens. matter*, vol. 27, art. no. 214004, 10 pp., 2015.
24. Luca Di Luzio, Ramona Gröber, Jernej Kamenik, Marco Nardecchia, "Accidental matter at the LHC", *J. high energy phys.*, vol. 2015, no. 7, pp. 74-1-74-55, 2015.
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Published Conference Contribution (invited lecture)

1. Saša Prelovšek, "Hadron spectroscopy", In: *The 32nd International Symposium on Lattice Field Theory, LATTICE 2014, 23-28 June, 2014, Columbia University, New York*, (Proceedings of science, 214), Trieste, Sissa, 2015, 20 pp.

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Mentoring

1. Jože Buh, *Investigation of properties of nanowires produced by transformation from MoSI nanowires:* doctoral dissertation, Ljubljana, 2015 (mentor Dragan Mihailović).
2. Dejan Arzenšek, *Physics of colloidal interactions in protein aggregation processes:* doctoral dissertation, Ljubljana, 2015 (mentor Rudolf Podgornik).
3. Zala Lenarčič, *Nonequilibrium properties of Mott insulators:* doctoral dissertation, Ljubljana, 2015 (mentor Peter Prelovšek).
4. Luka Leskovec, *Hadronic resonances from lattice QCD:* doctoral dissertation, Ljubljana, 2015 (mentor Saša Prelovšek Komelj; co-mentor Daniel Mohler).
5. Adil Begić, *Measuring muscle endurance in health care workers by means of EMG health care workers:* master's thesis, Ljubljana, 2015 (mentor David Haložan; co-mentors Jadranka Stričević, Milan Brumen).
6. Luka Čurović, *Konformacije DNA skozi ray tracing:* master's thesis, Ljubljana, 2015 (mentor Rudolf Podgornik).
7. Alenka Juhant, *Tekoči dušik in obravnava lastnosti snovi v 3. razredu osnovne šole:* master's thesis, Ljubljana, 2015 (mentor Mojca Čepič).
8. Marjanca Komar, *Conceptions of shadows by finite light sources:* master's thesis, Ljubljana, 2015 (mentor Mojca Čepič).
9. Alenka Mehle, *The influence of previous independent experimenting on the understanding of light:* master's thesis, Ljubljana, 2015 (mentor Mojca Čepič).

DEPARTMENT OF LOW AND MEDIUM ENERGY PHYSICS F-2

Research in atomic and nuclear physics and a wide spectrum of applications: this is a short description of the activities of the Department of Low and Medium Energy Physics. Dedicated basic research and the resulting extensive accumulated knowledge of physics provides an excellent basis to address interdisciplinary research problems in materials research, fusion, biology, medicine, pharmacy, environment and archaeology and for the engineering of innovative devices. We invest a lot of effort in the development of research instrumentation, which is frequently used by visiting researchers from abroad. The research involving our instrumentation, covering ion accelerators, advanced detectors for ionizing radiation and calibrated radiation fields, is complemented with visiting experiments at large research facilities worldwide, including particle accelerators, synchrotrons, free-electron lasers and fusion-research tokamaks.

Head:
Prof. Primož Pelicon

In the A1 Collaboration at the MAMI facility (Mainz, Germany) we measured quasi-elastic electron scattering on carbon nuclei with a polarimeter to detect the recoil proton polarization components. We wanted to answer the question, whether the nuclear environment influences the elastic form factors of the nucleons and whether the polarization transfer to the outgoing proton is driven by some kinematic quantity, for example, the amount of the proton being off its relativistic mass shell. We have also completed the first planned measurements of elastic scattering cross-sections on the proton in order to determine the magnetic form factor at high momentum transfers. In this effort, we contributed to the solution of the so-called "proton radius puzzle". The analysis of experimental results on the virtual Compton scattering at low momentum transfer, dedicated to the determination of generalized polarizabilities of the proton, and the analysis of the electro-production of neutral pions in the energy region of the Roper resonance is in its final stage. We completed two production beam-times devoted to measurements of parity-violating electron scattering in which transversely polarized electrons are used and which offer a completely different sensitivity to the strange-quark content in the protons and their contribution to the electromagnetic form factors.

We have completed the first measurements of elastic scattering cross-sections on the proton in order to determine the magnetic form factor at high momentum transfers, contributing to the solution of the so-called "proton radius puzzle".

At the Thomas Jefferson National Accelerator Facility (Jefferson Lab) we have continued our measurements of real Compton scattering on the protons at high momentum transfers in the regime of the large Mandelstam variables s, t, and u. We participated in the experiment to determine the magnetic form factor of the proton at high momentum transfers (up to 18 GeV^2). In this case, after the recent CEBAF accelerator upgrade to 12 GeV, the experimental conditions for full production quality have not been optimized yet.

We have published several papers in the field of hadronic physics; the most important among them are the results of our study of single-spin asymmetries on ^{3}He involving a transverse polarization of the target (Zhang et al., Phys. Rev. Lett. 2015), the report on the measurements of A=4 hyper-hydrogen by using decay-pion spectroscopy in electron scattering (Esser et al., Phys. Rev. Lett. 2015), as well as the measurements of neutral-pion electro-production off the proton close to the pion production threshold (Chirapatpimol et al., Phys. Rev. Lett. 2015).

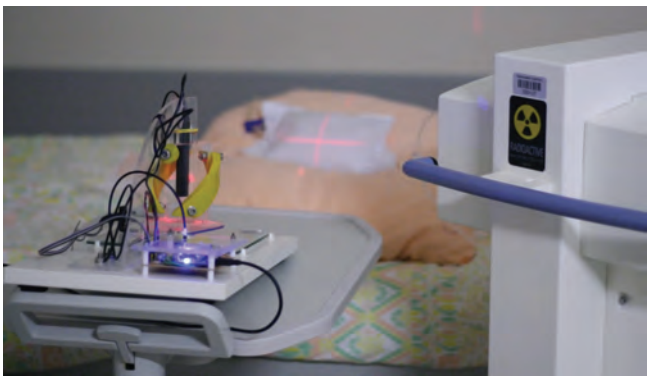

Figure 1: Angular-sensitive gamma-ray camera with a rotational coding mask for monitoring radiotherapeutical surgery and for nuclear security applications. The camera concept has been filed as a Great Britain and PCT patent application. Image shows its characterization at the Ljubljana Institute of Oncology.

The dependence of electron screening in nuclear reactions on the projectile or target atomic number has been studied by bombarding different hydrogen-containing targets with beams of ^{7}Li, ^{11}B, and ^{19}F. The largest electron-screening potentials were obtained in a graphite target containing hydrogen as an impurity. Some measured potentials are almost two orders of magnitude above the theoretical predictions. To explain the measurements, a new concept of electron screening is introduced (Cvetinović et al, Phys. Rev. C, 2015).

We have developed an angular-sensitive gamma camera with a rotational coding mask for the monitoring and quality assurance of several radio-therapeutic modalities in clinical oncology. The camera design is also useful in homeland-security applications, such as the prevention of terrorist attacks and nuclear non-proliferation efforts. The

camera concept has been filed as a UK patent and as a PCT application. We have started a detailed characterization of the camera at the Ljubljana Institute of Oncology.

The Laboratory for Radioactivity Measurements was conducting the environmental radioactivity monitoring of the living environment in Slovenia, off-site environmental radioactivity monitoring of the Krško Nuclear Power Palnt (KNPP), monitoring of radioactivity in fodder and radiological monitoring of the Central Radioactive Waste Repository in Brinje. Personal doses were measured for professionals in the country, as well as in the environment, using thermo-luminescent dosimeters (TLDs). The Laboratory for Dosimetry Standards calibrated a number of measuring devices for radiation dose and ensured measurement traceability in the region. In 2015 the Laboratory for Liquid Scintillation Spectrometry started a long-term study of the drinking-water network in Slovenia, as the control of the total alpha/beta activity in drinking water is recommended by the EU directive on waters 2013/51/EURATOM. In the frame of radiation monitoring programmes we analysed the contents of tritium in water, as well as the content of the ^{14}C isotope in fuel. Within a collaboration with Scottish enterprise IARMA, reference materials were prepared and characterized. All the listed laboratories are accredited according the standard SIST EN ISO/IEC 17025 and performed very successfully during international inter-comparisons in 2015.

We developed a continuous, on-line, early-warning portable system consisting of a high-flow air pump to transport aerosol particles to a filter cartridge where the radioactivity is continuously measured with a $CeBr_3$ scintillation detector, following the experience of the Fukushima plume detection in 2011.

As a designated institution and holder of the national etalon for the field of ionizing radiation, we cooperate with the Metrology Institute of the Republic of Slovenia (MIRS) and actively participate in the European Metrology Research Programme (EMRP). In the scope of the EMRP project "Metrology for radiological early-warning networks in Europe" (ENV57 MetroERM), we developed an innovative radioactive aerosol particulate monitoring device with a continuous on-line measurement capability and 3G networking to enable the data to be relayed from remote field stations to a centralized system. The device consists of a high-flow air pump (200 m3/h) to transport the particles to an innovative filter-cartridge housing where the radioactivity is measured with a $CeBr_3$ scintillation detector. The device will be used as a portable early-warning system in the case of a nuclear or radiological emergency. Within the collaboration with the MIRS, in 2015 we received a new set of equipment dedicated to the dose calibration of mammography scanners, financed by the European Regional Development Fund.

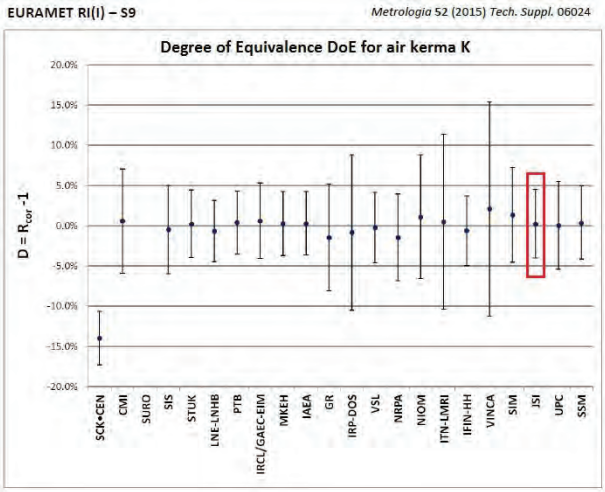

Figure 2: On the basis of excellent intercomparison results (JSI results in red rectangle) in the x-ray radiation qualities of the N-series, ^{137}Cs, ^{60}Co and ^{241}Am, for kerma in the x-ray radiation qualities of the N-series, as well as in the x-ray radiation field of RQR and RQA qualities, the best Calibration and Measurement Capabilities (CMC) of the Laboratory for dosimetry standards were approved and reported by the Bireau International de Poids et Mesures (BIPM) http://kcdb.bipm.org/appendixC/RI/SI/RI_SI.pdf.

In the first half of 2015 we were preparing for an experiment with the free-electron laser FERMI, where we planned to trigger the stimulated emission of doubly excited states in He. We built a state-of-the-art EUV spectrometer for the detection of photons with energies of about 40 eV with excellent contrast in the forward direction. To generate a temporarily localized high-density target region we used, for the first time, a pulsed Even-Lavie valve without the skimmer reaching a pressure of about 1 bar at the exit of the valve. We recorded the fluorescence spectra, which show a nonlinear intensity trend with respect to the intensity of the incoming light pulse that went up to 10^{14} W/cm^2 at a photon energy of 64 eV. The acquired data is now being modelled to describe the behaviour in a dense gas upon the passage of a highly intense, 100-fs-long light pulse. After last year's publication on two-photon absorption into the doubly excited states, we completed a more complete analysis of the metastable atom yield depending on the parameters of the two-photon excitation, such as the intensity, polarization, higher harmonics contribution and chirp (A. Mihelič in M. Žitnik, PRA 2015), and we were invited to publish a resumé for Elettra Highlights.

At the Maxlab 2 synchrotron light source we measured the degree of vibrational excitation of fragments after 2p hole creation on chlorine in chlorohydrocarbons. The experiment is the third one in a series performed in collaboration with researchers from Oulu University, so far dealing with the detection of fragment types emitted upon the photo-excitation of a 2p electron into unoccupied molecular orbitals and the (coincidence) detection of the corresponding L-VV resonant Auger spectra. An extrapolation of our quantum-chemical calculations of the initial dissociation dynamics suggests a high level of vibrational excitations for the fragments. We set to detect it by combining the absorption of IR light (the FTIR method to detect vibrations) with the synchrotron light absorption employed to create a 2p hole on the chlorine atom. The main difficulty affecting the efficiency of such

Li-S batteries were studied *in-operando* using the synchrotron radiation techniques XANES, EXAFS and RIXS to monitor the valence of sulphur and the formation of Li-polysulfide chains dissolved in the electrolyte.

an experiment is the two-orders-of-magnitude difference in the cross-sections, which could only be compensated by the corresponding difference in the absorption paths for the IR and EUV photons.

Measurements of the KM satellite lines in the photo-excited KLL Auger spectra of Ar with the photon excitation energy scanned in the near-threshold region for the double 1s3p and 1s3s photo-excitation were carried out at the Galaxies beamline of the Soleil synchrotron in Paris, together with the group from UPMC. The measurements were performed with a gas-phase electron spectrometer providing a total instrumental resolution of 460 meV at the energy of the Ar K absorption edge, which is below the lifetime broadening of the 1s core-hole state. The line-narrowing characteristic for the resonant process will make it possible to extract double excitation spectra with a sub-natural linewidth resolution. At the same beamline, we recorded a high-resolution spectrum of an exotic Two-Electron One Electron (TEOE) Auger decay of a double 2p hole in Ar where only one Auger electron is emitted. We determined its branching ratio of 2.2×10^{-3} with respect to the dominant sequential Auger decay and reproduced the spectrum of such a three-body decay in the lowest order of the perturbation scheme (Žitnik et al., accepted for publication in Rapid Communications PRA).

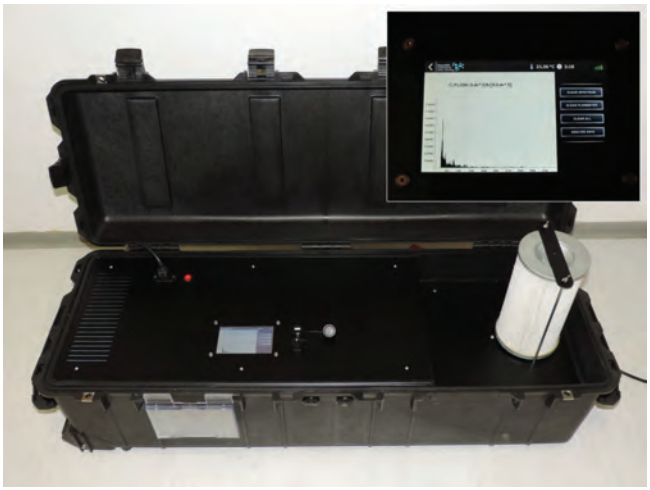

Figure 3: Portable radioactive aerosol particulate monitoring device with a continuous on-line measurement capability. The device was developed in the scope of the project MetroERM within the EMRP 2013 programme and features continuous on-line measurement capability, 3G networking enables data relay from remote field stations to a centralized system. The device consists of a high-flow air pump (200 m^3/h) to transport the particles to an innovative concertinaed filter cartridge housing where the radioactivity is measured with a $CeBr_3$ scintillation detector. The device is used as a portable system in the case of a nuclear or radiological emergency.

In collaboration with UPMC, Paris, we published a paper on resonant inelastic x-ray scattering (RIXS) on the CS_2 molecule investigating its dependence on energy detuning. On the resonance, the effective scattering time is of the order of the core hole lifetime (~ 1 fs for the S K hole) and then goes down, reaching a sudden limit at a few hundred eV detuning. We also demonstrated core hole localisation, which leads to the violation of symmetry-based selection rules in the emission (Marchenko et al. PRX 5, 2015). We published the results on a single-resonant double excitation KK-V detected by the magnetic bottle in water and nitrogen molecule (S. Carniato et al, J. Chem. Phys. 2015).

In collaboration with the Laboratory for Material Research at the University of Nova Gorica we report on a cation order-disorder transition in Fe-doped 6H-$BaTiO_3$ for dilute room-temperature ferromagnetism (Zorko et al, Scientific rep. 2015, Mikulska et al, *Jour. Amer. Ceram. Soc. 2015*). The Fe EXAFS and XANES revealed the source of ferromagnetism in the crystal structure of the Fe^{3+}-doped material. We continued a long-term project in collaboration with the National Institute of Chemistry, which involves XAS measurements on catalytic mesoporous molecular sieves doped with Ca, Ti Cr, Mn, Fe, Ni in Cu, also containing organic building units. In collaboration with researchers from the JSI Department for Inorganic Chemistry and Technology we discovered a unique silver compound containing the mixed valences Ag^{1+} and Ag^{2+}. The relative amount of each Ag valance was determined with a Ag XANES analysis (Mazej et al, Dalton trans. 2015). In collaboration with University Ca' Foscari, Venice, we applied EXAFS for research on Fe and Pd in nanostructured polysacharides, produced by a strain of Klebsiella oxytoca (Arčon et al., Jour. synch. rad. 2015). This biomaterial is potentially interesting as a bio-catalyst for the hydrodechlorination reaction.

We completed the construction of a new, parallel-beam, wavelength-dispersive x-ray spectrometer (PBWDS) employing a polycapillary x-ray half-lens and Bragg diffraction on a flat crystal.

Li-S batteries are considered as one of the most promising candidates for future batteries in applications where a high energy density is required. In collaboration with the National Institute for Chemistry, Ljubljana, we executed a series of *in-operando* studies with synchrotron radiation. XANES and EXAFS experiments on high-energy-density Li-sulphur batteries applying various cathode materials and electrolytes were performed at Elettra and ESRF. The XAS spectra were recorded during the charging and discharging of the battery. In this way we were able to monitor with high precision the change of the valence of sulphur, and the formation of Li-polysulphides (Li_2S_x) compounds and finally crystalline Li_2S during discharge, and the reversibility of the process during charging. This key information on the battery dynamics opened the way to an optimization of the synthesis of the material with maximum capacity (Dominko et al, Jour. Phys. Chem. C, 2015). The same approaches were applied for studies of Mg-sulphur batteries. In the same research efforts to understand and optimize the operation of the Li-sulphur batteries, an alternative approach employing resonant x-ray emission spectroscopy (RIXS) was used at the ID26 beamline of the ESRF synchrotron to characterize the electronic structure of sulphur in a cathode material. By performing

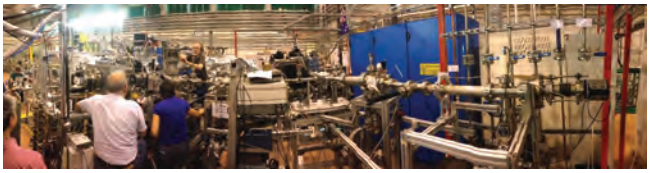

Figure 4: Set-up of the experiment to detect spontaneously triggered stimulated emission from doubly excited states of He at the LDM beamline of the free-electron laser facility FERMI in Trieste.

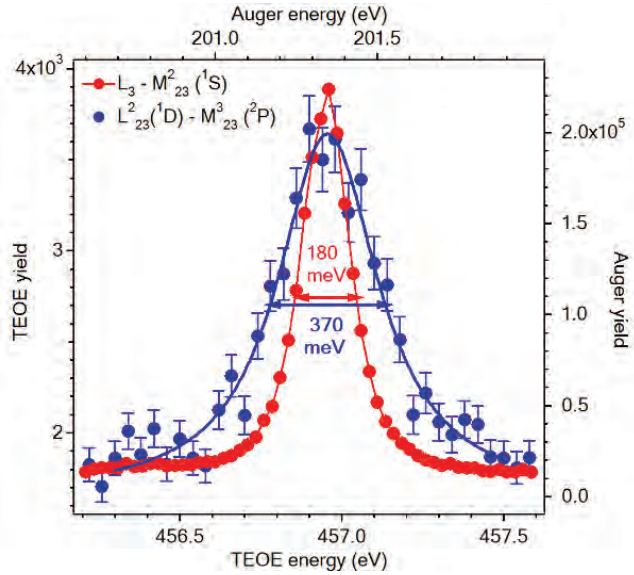

Figure 5: Comparison of an exotic Two-Electron One-Electron (TEOE) Auger decay line of a double 2p hole in Ar with the normal Auger line. Linewidths indicate that a double 2p hole in Ar decays about 2.8-times faster than a single 2p hole. (Žitnik et al., accepted for publ. in Rapid Communications PRA).

in-operando resonant x-ray emission measurements while discharging the battery, we were able to directly study the sulphur reduction within the cathode, which proceeds through the formation of long- and short-chain polysulphides dissolved in the electrolyte, finally reaching the completely reduced sulphur in the form of insoluble crystalline Li_2S. The measured data will further improve the understanding of polysulfide formation in the cathode and its interactions with the host matrix and the electrolyte within the lithium sulphur (Li-S) battery. This is crucial to achieving long-term cycling stability. The cathode material's properties for lithium batteries were also studied with measurements of the magnetic and electric hyperfine fields using Mössbauer spectroscopy. The measurements took place at the synchrotron facilities Petra in Hamburg and APS in Chicago. We determined the charge states in single particles in the electrodes during lithiation and delithiation.

In 2015 we published an experimental and theoretical analysis of the electronic structure of phosphorus in various compounds. The analysis was performed by high-energy-resolution X-ray emission measurements combined with quantum chemical calculations based on the density functional theory (Petric et al., Anal. Chem. 2015). In collaboration with colleagues from the Department of Chemistry of Technical University Munich we have published results on resonant inelastic x-ray scattering (RIXS) for several reference Mo oxides and sulphides, which represents a benchmark for the analysis of the local electronic and geometrical structure of 4d metals in various materials (Thomas et al., J. Phys. Chem. 2015).

In 2015 we completed the construction of a new, parallel-beam, wavelength-dispersive, x-ray spectrometer (PBWDS) employing a polycapillary x-ray half-lens and Bragg diffraction on the flat crystal was completed at the Microanalytical Center within the EU Marie Curie project SPRITE. The spectrometer was installed in the vacuum chamber of the high-energy-resolution x-ray emission spectrometer and coupled to the proton microprobe beamline of our Tandem accelerator. The PBWDS spectrometer provides a high collection efficiency together with an energy resolution of 10–30 eV, which will significantly enhance the energy resolution of micro-PIXE measurements and, consequently, lower the detection limits of PIXE.

In collaboration with the Biotechnical Faculty of the University of Ljubljana, Université catholique de Louvain (Belgium), Universitaet Bayreuth, Lehrstuhl Pflanzenphysiologie (Germany), ESRF Grenoble (France), National Agri-Food Biotechnology Institute (India), we performed XAS experiments to determine the distribution of pollutant elements (Se, Hg, Cd, Pb) and essential elements (Zn. Cu, Ni, Mn, Fe) in the cells to elucidate the molecular and cellular mechanisms that induce the tolerance to the noxious metal cations, or the mechanism of accumulation for essential elements in edible parts of the plants. Prior to the synchrotron radiation experiments, we conducted series of complementary analyses of these samples at the instrumentation of the Department by X-ray florescence (XRF) and micro-PIXE.

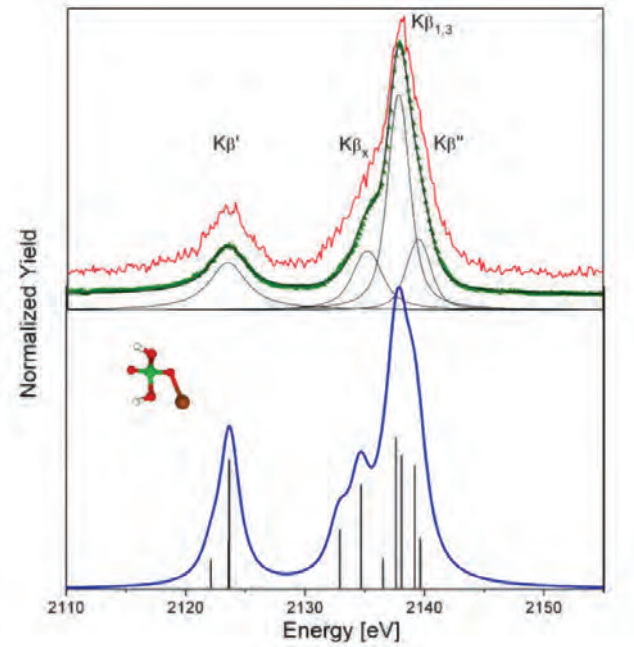

Figure 6: High-energy resolution phosphorus Kβ emission spectrum of NaH_2PO_4 induced with monochromatic synchrotron radiation and 2-Mev protons compared to the theoretical model spectrum (Petric et al., Anal. Chem. 2015).

At the tandem accelerator, intense research activities were taking place. Overall, more than 4000 beamtime hours were delivered to the users.

The Micro-PIXE method was applied in close collaboration with the Biotechnical Faculty of the University of Ljubljana in the field of tissue-processing technology. A recently developed technology to preserve frozen hydrated tissue was further improved and implemented in the biomedical research of external users (Vavpetič et al., NIM B 2015). A series of measurements in collaboration with Wageningen University on the *Gomphrena claussenii*, a novel metal-hypertolerant plant species, revealed the process of cadmium sequestration in vacuolar oxalate crystals (Villafort Carvalho et al., *The new phytologist*, 2015). In collaboration with the Department of Orthopaedics of the University Medical Centre Maribor, we investigated the clinical cases of hip prosthesis failure. Using micro-PIXE we revealed the type and occurrence of wear microparticles in the removed tissue after the failure follow-up surgery. The wear of the Ti-V-Al alloy resulted in the presence of microparticles in the hip-surrounding tissue, which exhibit an aluminium leaching into the

surrounding regions. We established contacts with the Pediatric Hospital Burlo Garofolo in Trieste and investigated ovary and liver tissue using micro-PIXE microscopy.

We continued with intense work on MeV-SIMS development and the application of this novel analytical method. In collaboration with the Department of Surface Engineering and Optoelectronics, we compared the performance of MeV-SIMS applying a 5.8 MeV $^{35}Cl^{6+}$ primary ion beam with a state-of-the-art TOF SIMS apparatus applying 25 keV Bi_3 ions as a primary beam. For the samples containing organic molecules with masses (m/Z) over 300, MeV-SIMS with a 5.8 MeV $^{35}Cl^{6+}$ beam features up to two-orders-of-magnitude higher sensitivity, which makes it an excellent method for the imaging mass spectroscopy of biological materials. The imaging capabilities and the chemical sensitivity of MeV-SIMS were nicely demonstrated in a study of cannabis, where we detected unfragmented THCA molecules, the precursor for THC, in trichomes of the plant (Jenčič et al., NIM B in press). We initiated the upgrade of the existing MeV-SIMS system in order to enable its operation in continuous primary-beam mode, which offers a much higher lateral resolution and an improved mass resolution, with a trade-off related to the demanding preparation of thin tissue sections with a thickness below 4 micrometres.

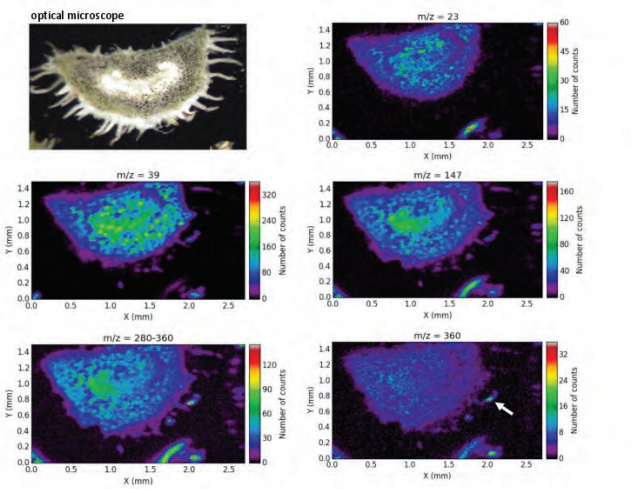

Figure 7: Imaging mass spectrometry of a cannabis-leaf cross-section with MeV-SIMS. Primary beam of 5.8 MeV $^{35}Cl^{6+}$ is used to desorb molecular species from the sample. Mass images with (m/Z) values of 23 and 39 correspond to sodium and potassium distribution. THCA molecules (m/Z=360), precursors for THC, were detected at the positions of broken trichomes (see white arrow mark in m/Z=360) only (Jenčič et al., NIM B, in press).

Fusion research at the ion accelerator laboratory was coordinated by EUROfusion within the Work Package "Preparation of efficient Plasma-Facing Component (PFC) operation for ITER and DEMO" and by the Slovenian Fusion Research Association (SFA). Our main focus in 2015 was to study: i) The influence of neutron-like damage on D retention by simultaneous W-ion damaging and D-atom loading of polycrystalline W at different sample temperatures and ii) The temperature dependence of the atom beam loading of damaged W and model the resulting depth profiles to obtain the kinetic parameters for the hydrogen atom uptake into W. The work was performed in collaboration with IPP, Garching, Germany. In a fusion reactor (ITER, DEMO) both the implantation of energetic hydrogen ions and neutrals as well as the damage creation by the neutron irradiation will take place at the same time. To take a step forward towards a more realistic situation we executed the first study of simultaneous tungsten irradiation by 10.5 MeV W ions and D atom loading at three different temperatures, 450 K, 600 K and 800 K, over a period of 4 hours, yielding a maximum 0.5 dpa damage dose. Comparing the maximum concentrations, as shown in Fig. 1, we observed a difference between the sequential (Založnik et al., Phys. Scripta 2015) and simultaneous damage. In the sequential study where the samples were damaged, annealed and exposed to D atoms, we obtained an almost linear decrease in the maximum concentration with the increasing annealing temperature. For the simultaneous damage and exposure there is a decrease from 450 K to 600 K, but for 800 K the concentration is similar to the 600 K case. This indicates that the atoms that diffused into the layer at 800 K during the irradiation prevented the defect recovery during the irradiation/damage. The capabilities of in-situ measurements using ion-beam methods (Založnik et al., NIM B in press) enabled us to study the isotope exchange on the surface and in the bulk of self-ion-damaged W by exposure to neutral hydrogen atoms, where both combinations of isotope exchange were measured (Markelj et al. J. Nucl. Mater. 2016). We made a simple modelling of the isotope exchange on the surface and in the bulk, obtaining the recombination coefficient, reflection coefficient for the surface and also an estimate of the potential barrier for surface-to-bulk transport. These parameters will be used in the Rate Equation Model to model the atom interaction and loading of tungsten. In collaboration with the National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania, we studied the influence of nitrogen co-deposition in ITER-relevant mixed layers on the retention and release dynamics of deuterium in situ by Nuclear Reaction Analysis (NRA) and thermo-desorption spectroscopy (Založnik et al., J. Nucl. Mater. 2015).

We executed the first *in-situ* study of simultaneous tungsten irradiation by 10.5-MeV tungsten ions to induce neutron-like material damage and simultaneous exposure to atomic deuterium in order to simulate fusion plasma fuel uploading in tungsten during the ITER operation.

We published a study dealing with indoor-air quality in a particular case of one-month non-stop measurements of atmospheric parameters at the student gym Rožna dolina. The humidity, temperature, and PM10 concentration were monitored with a minute time resolution, recoding also the number of active people and their type of activity. It turned out that the amount of inhalable dust when practicing in closed rooms can be higher compared to quasi-static conditions on the outside for two main reasons: due to exercises the concentration of dust is higher as well as the respiratory activity. The detected six-fold increase in inhalable input on average could be reduced by more efficient cleaning of the air (Žitnik et al., Indoor Air 2015).

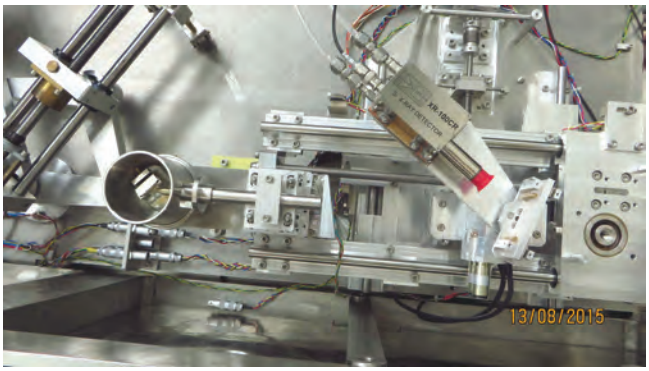

Figure 8: A photograph of the new, parallel-beam, wavelength-dispersive x-ray spectrometer (PBWDS), developed by the department and constructed in the JSI workshops. PBWDS combines polycapillary x-ray lens optics with Bragg diffraction on the flat analyzer crystal. The spectrometer combines a wide acceptance angle and high-energy resolution. It enables micro-PIXE studies with an energy resolution ranging from 6 to 20 eV, which is much higher than the standard 140 eV with silicon detectors.

Archaeometric measurements with the in-air PIXE method were devoted to a study of brass coins minted during the first c. BC outside the Roman world. The investigation involved Greek coins of Mithradates VI from Asia Minor and Celtic coins from Gaul. According to the trace elements, notably selenium, it was possible to trace the distribution of the material from the eastern part of the classical world towards the west. Technically, we improved our mapping system with the in-air proton beam and measured the distribution of silver and other elements on Roman coins from the 3rd c. AD. We confirmed that during this century, they still tried to imitate the massive silver coins, but by the end of the century, mere silvering was adopted. With the use of the in-air beam we also confirmed the type of pigments in the book of Sigmund Herberstein, printed in 1560 in Vienna. The issue kept at the library in Ptuj is hand-coloured. We pointed out that certain pigments were based on iron-gall ink and copper compounds that act corrosively on the paper. We also identified some interesting pigments, like the yellow made of fine gold dust. We further studied the recently discovered photography that was potentially artwork of the inventor Janez Puhar. The measurements on the photographic emulsion confirmed the presence of sulphur. From the attenuation of the X-ray lines from the underlying glass plate it was possible to conclude that the sulphur was embedded in a thicker emulsion layer, possibly of organic origin.

Organization of conferences, congresses and meetings

1. Nuclear Structure and Dynamics III, 14–19 June 2015, Portorož

INTERNATIONAL PROJECTS

1. Calibrations
   Matjaž Mihelič, M. Sc.
2. TLD Dosimetria
   Boštjan Črnič
3. Provision of Testing Services for Filter Media used in IMS Radionuclide Stations
   Dr. Benjamin Zorko
   The Preparatory Commission For The Comprehensive
4. Micro-PIXE: Plant Sample Analysis
   Prof. Primož Pelicon
5. Extraction of Tantalum and Niobium from Ores
   Dr. Marijan Nečemer
   Prg Ltd.
6. 7FP - SPRITE; Supporting Postgraduate Research with Internships in Industry and Training Excellence
   Asst. Prof. Matjaž Kavčič
   European Commission
7. 7FP - PREPARE; Innovative Integrative Tools and Platforms to be Prepared for Radiological Emergencies and Post-accident Response in Europe
   Dr. Benjamin Zorko
   European Commission
8. MetroNORM; Metrology for Processing Materials with High Natural Radioactivity
   Branko Vodenik, M. Sc.
   Euramet E.v.
9. MetroERM; Metrology for Radiological Early Warning Networks in Europe
   Denis Glavič Cindro, M. Sc.
   Euramet E.v.
10. IAEA Training Fee for Ms Irma Kadic (BOH/15002) for the period from 10 May 2015 to 5 June 2015
    Dr. Benjamin Zorko
    IAEA - International Atomic Energy Agency
11. RC 18186/R0; Application of Synchrotron Radiation in Studies of Environmental Impact on Biological Organisms; Experiments with Synchrotron Radiation for Modern Environmental and Industrial Applications
    Dr. Peter Kump
    IAEA - International Atomic Energy Agency
12. RC 18353/R1; Dual Imaging of Biological Samples with MeV SIMS and PIXE Analysis; Development of Molecular Concentration Mapping Techniques using MeV Focussed Ion Beams
    Prof. Primož Pelicon
    IAEA - International Atomic Energy Agency
13. COST CM1204: XUV/X-ray Light and Fast Ions for Ultrafast Chemistry (XLIC)
    Prof. Matjaž Žitnik
    Cost Office
14. Hydrogen Retention in Self-damaged and He Irradiated Tungsten Alloys in Fusion Devices; Plasma-Wall Interaction for Irradiated Tungsten and Tungsten Alloys in Fusion Devices
    Asst. Prof. Sabina Markelj
    IAEA - International Atomic Energy Agency
15. Plasma Facing Components-1-IPH-FU, EUROFUSION
    Asst. Prof. Sabina Markelj
    European Commission
16. Double Core Hole Formation by Photon and Proton Impact
    Prof. Matjaž Žitnik
    Slovenian Research Agency
17. Molecular Imaging of Biological Samples Using MeV Ions and keV Clusters for TOF-SIMS Spectrometry
    Prof. Primož Pelicon
    Slovenian Research Agency
18. Electromagnetic Structure of the Proton at High Momentum Transfers
    Prof. Simon Širca
    Slovenian Research Agency

RESEARCH PROGRAMS

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

R & D GRANTS AND CONTRACTS

1. Nanostructured cathodes for lithium sulphur batteries
   Dr. Darko Hanžel
2. Vegetation and hydrology of Ljubljansko barje in the past, present and future a consequence of succession, human impact or climatic fluctuations?
   Dr. Marijan Nečemer
3. Evaluation of quality and safety parameters of vegetables produced on different systems in Slovenia and abroad with aim to establish national quality scheme for vegetables
   Dr. Marijan Nečemer
4. Evaluation of quality and safety parameters of vegetables produced on different systems

in Slovenia and abroad with aim to establish national quality scheme for vegetables
Dr. Marijan Nečemer
5. Electron screening in metals
Dr. Jelena Vesić
6. EMRP, MetroERM - Metrology for Radiological Early Warning Networks in Europe
Denis Glavič Cindro, M. Sc.
7. Different Analyses
Dr. Jasmina Kožar Logar
8. Training Course Fee for the Trainee Mr. Ali Salim Mohammed Al-Zaabi at JSI, Ljubljana, Slovenia from 31 August 2015 to 11 September 2015
Dr. Benjamin Zorko
9. COST CM1204: XUV/X-ray Light and Fast Ions for Ultrafast Chemistry (XLIC)
Prof. Matjaž Žitnik
Cost Office
10. Hydrogen Retention in Self-damaged and He Irradiated Tungsten Alloys in Fusion Devices; Plasma-Wall Interaction for Irradiated Tungsten and Tungsten Alloys in Fusion Devices
Asst. Prof. Sabina Markelj
IAEA - International Atomic Energy Agency

NEW CONTRACTS

1. Annex No. 12 to the contract on performing activities and fulfillment of obligations of holder of national standard in the field of ionising radiation
Matjaž Mihelič, M. Sc.
Ministry of Education, Science and Sport, Ljubljana
2. Maintenance of radiological emergency preparedness for a period of 5 years (2012-2017)
Asst. Prof. Matej Lipoglavšek
Krško Nuclear Power Plant, Krško
3. Off-site radiological monitoring of NPP Krško 2014 and 2015
Dr. Benjamin Zorko
Krško Nuclear Power Plant, Krško
4. Measurement of gaseous effluents in 2015,2016 and 2017
Dr. Benjamin Zorko
Krško Nuclear Power Plant, Krško
5. Monitoring of the Radioactivity in Drinking Water in Republic of Slovenia in 2015
Dr. Benjamin Zorko
Ministry of Health, Ljubljana
6. Monitoring of Central LILW Storage Facility at Brinje
Dr. Marijan Nečemer
ARAO, Ljubljana
7. Environmental radioactivity monitoring of living environment in Slovenia in 2015
Dr. Benjamin Zorko
Ministry of the Environment and Spatial Planning, Ljubljana
8. Gross alpha and betta emitters in drinking water of Slovenia - review study
Dr. Jasmina Kožar Logar
Ministry of Health, Ljubljana
9. Construction and dispatch of XRF Analyzer
Dr. Peter Kump
University of Ljubljana
10. Calibration of probes for measurement doserate in ambient air
Matjaž Mihelič, M. Sc.
Ministry of the Environment and Spatial Planning, Ljubljana

VISITORS FROM ABROAD

1. Lidija Matjačić, University of Surrey, Guildford, United Kingdom, 10–20 February 2015
2. prof. dr. Ron Heeren, Univerza of Maastrichtu, Maastricht, Kingdom of the Netherlands, 2–3 April 2015
3. Dr. István Rajta, István Vajda, Szabolcs Szilasi and Zoltán Perduk, Institute for Nuclear Research, ATOMKI, Debrecen, Hungary, 12-15. April 2015
4. Irma Kadić, Institute for Public Health of Federation of Bosnia and Herzegovina, Sarajevo, Bosnia and Herzegovina, 11. May to 5. June 2015
5. Arnoud Terpstra, HVEE, Amersfoort, Kingdom of the Netherlands, 18–22 May 2015
6. Dr. Francis Penet and Dr. Pascal Lablanquie , LCPMR, Paris, France, 19–23 May 2015
7. Dr. Ashley Stowe, Y-12 National Security Complex and Dr. Jake Livesay, Mason Livesay Scientific, Oak Ridge, USA, 20–24 May 2015
8. Dr. Jerome Paladoux, LCPMR, Paris, France, 21–23 May 2015
9. Dr. Milko Jakšić, IRB, Zagreb, Croatia, 15. July 2015
10. Dr. Saroe Rozas Guinea, The University of the Basque Country UPV / EHU, Bilbao, Spain, 10 June to 11 September 2015
11. Prof. Dr. Lorella Pascolo, Francesca Cammisuli and Irene Venturin, University of Trieste, Trieste, Italy, 22–25 September 2015
12. Dr. Dimosthenis Sokaras, SLAC, Stanford, USA, 1–3 October 2015
13. Hassan Ahmadi, University of Bayreuth, Bayreuth, Germany, 25–31 October 2015
14. Dr. Ines Krajcar Bronić and Dr. Jadranka Barešić, IRB, Zagreb, Croatia, 8–10 December 2015

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Professional Monograph

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1. Katarina Kovačič, *Radioactive isotopes in ground waters of Slovenia:* doctoral dissertation, Nova Gorica, 2015 (mentors Matej Lipoglavšek, Jasmina Kožar Logar).
2. Romana Krištof, *Quantification of biocomponents in fuels by ^{14}C:* doctoral dissertation, Nova Gorica, 2015 (mentors Jasmina Kožar Logar, Cristina Otero Hernandez).
3. Nina Ogrinc Potočnik, *Elemental and molecular characterization of biological tissue with a focused high-energy ion beam:* doctoral dissertation, Ljubljana, 2015 (mentor Marjan Veber; co-mentor Primož Pelicon).
4. Jure Beričič, *Measurement of generalized polarizabilities of the proton by virtual Compton scattering:* doctoral dissertation, Ljubljana, 2015 (mentor Simon Širca).
5. Aleksandra Cvetinović, *The influence of the electronic structure in different environments on the nuclear reaction probability:* doctoral dissertation, Ljubljana, 2015 (mentor Matej Lipoglavšek).
6. Luka Jeromel, *Development of MeV SIMS imaging mass spectrometry based on time-of-flight measurement:* doctoral dissertation, Ljubljana, 2015 (mentor Primož Pelicon).
7. Mojca Miklavec, *In-vivo dosimetry by PET in γ-ray radiotherapy:* doctoral dissertation, Ljubljana, 2015 (mentor Simon Širca).
8. Žiga Barba, *Spektrometer za fotone z energijskim oknom v smeri vpadnega žarka:* master's thesis, Ljubljana, 2015 (mentor Matjaž Žitnik).
9. Nataša Debeljak, *Influence of selenium on uptake and distribution of mercury in corn:* master's thesis, Ljubljana, 2015 (mentor Katarina Vogel-Mikuš).
10. Larisa Hosnar, *Kotno občutljiva kamera gama z rotacijsko zaslonko:* master's thesis, Ljubljana, 2015 (mentor Matej Lipoglavšek; co-mentor Matjaž Vencelj).
11. Špela Kržišnik, *Influence of selenium on mercury transport along the food chain:* master's thesis, Ljubljana, 2015 (mentor Katarina Vogel Mikuš; co-mentor Primož Zidar).

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. As part of the applied research, different coatings are developed for the protection of tools for various production processes in industry.

Head:
Asst. Prof. Miha Čekada

A few years ago, we implemented in Slovenian industry a nanocomposite coating based on TiAlSiN, which is composed of TiAlN nanometer-sized grains in a Si_3N_4 amorphous matrix. In collaboration with the University of Bartin (Turkey) and the University of Novi Sad (Serbia) we conducted several analyses of the mechanical and tribological properties of this coating, with an emphasis on the study of hard milling. This was the topic of a PhD thesis that was successfully defended by Dr Aleksandar Miletić at the University of Novi Sad under the co-mentorship of Dr Peter Panjan from our department. The majority of the experimental work was carried out in our labs.

In recent years we investigated the nanolayer coatings CrN/CrAlN and CrN/CrVN, where we varied the ratio of the metallic elements Cr:Al and Cr:V. Vanadium oxide is known to have good lubricating properties at elevated temperature, thus it is potentially applicable for the protection of tools that operate under these conditions. A typical example is hot forging, which is the topic of an applied project with the company Unior. At the scientific level we analyzed the oxidation mechanisms for the coating CrN/CrVN and found that the formation of a thin chromium oxide layer effectively slows down the diffusion of vanadium towards the surface. However, at the locations of growth defects the vanadium keeps diffusing at a high rate and forms dendritic structures at the surface. At the applied level of this project, in collaboration with the other project partner, the Institute of Metals and Technologies, we determined the optimum deposition parameters for the application of this coating in conditions of hot forging, simulated in a lab. The last step was the deposition of this coating on real tools. Industrial testing is pending.

We set up an experimental system to follow the first phase of wear in a tribological contact, where we are able to follow the behavior at a selected growth defect.

The coatings CrN/CrVN and CrN/CrVN were extensively analyzed from the tribological point of view, while as a reference we also analyzed the standard coatings TiN, CrN and TiAlN. In contrast to most publications, which typically use standard lab conditions, we put an emphasis on the aspect of the surrounding atmosphere. We found important differences between ordinary air, oxygen (the main point being the absence of moisture) and nitrogen (the main point is the absence of oxidation). The lowest wear volume was measured for the above-mentioned multilayer coatings.

In the field of tribology, we experimented in two additional less-known directions. One is the study of wear at the microlevel at the very beginning of the tribological test. We concentrated our study on a few selected growth defects; first we analyzed them with a scanning electron microscope, then we made a short tribological test, initially only one passage. Consequently, we analyzed the same defect and repeated the procedure several times (after four passages, after eight passages, etc.). In this way we traced the wear evolution on selected defects. The other direction of the study included the use of MoS_2 multi-wall nanotubes as an additive to classic lubricants. There is some data on the application of MoS_2 nanoparticles; however, our experiments proved that by using nanotubes rather than nanograins there is a substantial improvement in the tribological properties.

Low-friction coatings based on amorphous carbon were a topic of the recently concluded project "research voucher". We developed and optimized a coating for the protection of cemented carbide saws for the cutting of copper commutators; in the previous year we implemented this coating in serial production at the company Koletor Sikom.

For the deposition of thin films by magnetron sputtering, it is very important to understand the basic physical processes in the plasma. Until recently, common knowledge about the magnetron plasma was based on the assumption that it was distributed evenly along the circle.

Figure 1: This figure from the paper of our coworker Dr Matjaž Panjan was selected as a cover image for the journal Plasma Sources Science and Technology. It shows plasma structures in DC magnetron sputtering, recorded using a high-speed camera (exposure time 500 ns).

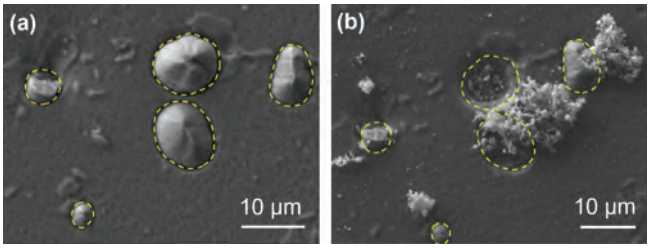

Figure 2: A group of growth defects at the TiAlN coating surface after deposition (a) and after 128 passages of the tribological test (b); the same area is shown.

However, using a high-speed camera Dr Matjaž Panjan proved that in DC magnetron sputtering the plasma is not evenly distributed, but localized in small areas with regular shapes. These areas resemble elongated arrows and form different symmetrical patterns that change their shape depending on the working pressure and the sputtering parameters. The plasma areas rotate on the magnetron plain with an angular velocity of 2–10 km/s. They also have an important influence on the electron and ion transport in the magnetron plasma. The research of non-homogeneous rotating plasma areas initiated a lot of interest in the plasma community. The editors of *Plasma Sources Science and Technology* selected Dr Panjan's paper: "*Non-uniform plasma distribution in dc magnetron sputtering: origin, shape and structuring of spokes*" as one of the most interesting publications in their journal and emphasized its importance on their home page. One of our figures was even chosen as the title page of the issue. This research was done in collaboration with researchers from the Polytechnique Montreal.

To a lesser extent, our work was conducted outside the field of hard coatings. At the beginning of the European project Eurofusion, we developed a process to deposit WN thin films on tungsten and silicon substrates. The reason for studying this coating is due to the spontaneous formation of nitrides at the first wall of the divertor during ammonia injection. In the previous year, we deposited this coating on test plates, which will be mounted into the ASDEX tokamak.

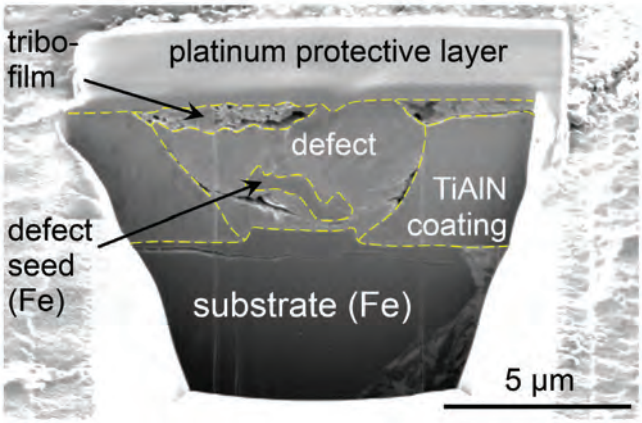

Figure 3: Cross-section of a growth defect after 128 passages, acquired using the focused-ion-beam technique.

The following additional studies should also be mentioned:

influence of hard coatings and electrolytic nickel deposition parameters on the oxidation resistance of rare-earth magnets (in collaboration with the company Magneti)

study of growth-defect formation in ultra-high vacuum (in collaboration with the Ruđer Bošković Institute)

analysis of the dependence of steel toughness on coating properties (in collaboration with the Institute of Metals and Technologies)

deposition of multilayer structures for laser modification, and a study of NiO magnetic nanoparticles (both in collaboration with the Vinča Institute of Nuclear Sciences)

In addition to the above-mentioned research projects we also conducted several analyses for various companies: Cetis, Domel, EMO Orodjarna, Kovinos, Lama, Mahle Letrika, Phos, TIK and Tosama.

In the previous year dr. Vladan Mladenovič successfully defended his PhD thesis under the mentorship of asst. prof. Miha Čekada; he was a young researcher from industry at the company Cetis. He systematically analyzed surface structuring using different methods (scratching, micromilling, laser treatment), and statistically evaluated the influence of various treatment parameters on the geometrical properties of microscratches.

Some outstanding publications in the past year

1. M. Panjan, S. Loquai, J. E. Klemberg-Sapieha, L. Martinu, Non-uniform plasma distribution in dc magnetron sputtering: origin, shape and structuring of spokes, Plasma sources science & technology, 24 (2015) 6, 065010-1–065010-16
2. A. Drnovšek, P. Panjan, M. Panjan, S. Paskvale, J. Buh, M. Čekada, The influence of surrounding atmosphere on tribological properties of hard protective coatings, Surface & coatings technology, 267 (2015), 15–20

INTERNATIONAL PROJECTS

1. Plasma Facing Components-1-IPH-FU, EUROFUSION
   Dr. Matjaž Panjan
   European Commission
2. JET Campaigns-JET1-FU, EUROFUSION
   Dr. Matjaž Panjan
   European Commission
3. Medium Size Tokamak Campaigns-MST1-FU, EUROFUSION
   Dr. Matjaž Panjan
   European Commission
4. Self-organized Plasma Structures in Magnetron Sputtering
   Dr. Matjaž Panjan
   Slovenian Research Agency
5. Study of Growth Defects in Nanolayer Structures
   Asst. Prof. Miha Čekada
   Slovenian Research Agency

RESEARCH PROGRAM

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

R & D GRANTS AND CONTRACTS

1. Development and production of taylor made milling tools, coatings and corresponding manufacturing technologies in individual tooling industry
   Asst. Prof. Miha Čekada
2. Self-lubricating and wear resistant PVD hard coatings based on (V,Cr,Al,Ti)N for hot-working processes
   Dr. Peter Panjan
3. Reduction of friction and tool wear using advanced lubricants and protective PVD coatings
   Dr. Srečko Paskvale

NEW CONTRACTS

1. Study of functional properties of PVD-hard coatings in the system (Cr,Al)N
   Dr. Peter Panjan
   Kovinos d. o. o.
2. Characteristics of gaseous plasma in gaps
   Dr. Peter Panjan
   Kolektor Sikom d. o. o.

VISITORS FROM ABROAD

1. Saša Kovačić, University of Zagreb, Zagreb, Croatia, 11. 6. 2015
2. Saša Kovačić, University of Zagreb, Zagreb, Croatia, 15. 7. 2015
3. Aleksandar Miletić, Pal Terek, University of Novi Sad, Novi Sad, Serbia, 2.–10. 8. 2015
4. Pal Terek, University of Novi Sad, Novi Sad, Serbia, 16.–25. 9. 2015
5. Suzana Petrović, Davor Peruška, Vinča Nuclear Institute, Belgrade, Serbia, 25.–28. 11. 2015

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3. Dr. Peter Panjan
4. Dr. Matjaž Panjan

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5. Dr. Srečko Paskvale

Postgraduate
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Technical and administrative staff
7. Jožko Fišer
8. Damjan Matelič
9. Andrej Mohar
10. Tomaž Sirnik

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Original Article

1. Aljaž Drnovšek, Peter Panjan, Matjaž Panjan, Srečko Paskvale, Jože Buh, Miha Čekada, "The influence of surrounding atmosphere on tribological properties of hard protective coatings", *Surf. coat. technol.*, vol. 267, pp. 15-20, 2015.
2. Dobrica Nikolić, Matjaž Panjan, Graeme R. Blake, Marin Tadić, "Annealing-dependent structural and magnetic properties of nickel oxide (NiO) nanoparticles in a silica matrix", *J. Eur. Ceram. Soc.*, vol. 35, issue 14, pp. 3843-3852, 2015.
3. Matjaž Panjan, Simon Loquai, Jolanta Ewa Klemberg-Sapieha, Ludvik Martinu, "Non-uniform plasma distribution in dc magnetron sputtering: origin, shape and structuring of spokes", *Plasma sources sci. technol.*, vol. 24, no. 6, pp. 065010-1- 065010-16, 2015.
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5. Bojan Podgornik, Marko Sedlaček, Miha Čekada, Staffan Jacobson, Boštjan Zajec, "Impact of fracture toughness on surface properties of PVD coated cold work tool steel", *Surf. coat. technol.*, vol. 277, pp. 144-150, 2015.
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7. Milan Trtica, J. Limpouch, G. Gavrilović, L. Gemini, Peter Panjan, Jelena Stasić, D. Milovanović, Goran Branković, "Surface modification of a-CN/TiAlN double layer coating on ASP 30 steel induced by femtosecond laser with 10^{13}-10^{14} W/cm^2 intensity in vacuum", *Laser part. beams*, vol. 33, issue 3, pp. 551-559, 2015.

Published Conference Contribution (invited lecture)

1. Peter Panjan, Aljaž Drnovšek, "Influence of growth defects in PVD hard coating on their wear, corrosion and oxidation resistance", In: *Proceedings*, The Thirtheenth International Symposium on Sputtering Plasma Processes, ISSP 2015, July 8-10, 2015, Kyoto, Japan, [S. l., s. n.], 2015, pp. 323-328.

Published Conference Contribution

1. Marko Berginc, Andrej Čampa, Katarina Vojisavljević, Barbara Malič, Peter Panjan, Marko Topič, "Relation between sputtering parameters and optical and electrical properties of Ga doped ITO transparent conductive oxide", In: *Proceedings of EMRS 2015 Spring Meeting - Symposium C on Advanced Inorganic Materials and Structures for Photovoltaics*, (Energy procedia, vol. 48), E-MRS, Lille, France, May 11-15, 2015, Ivan Gordon, ed., et al, Amsterdam, Elsevier, 2015, pp. 183-189.
2. Halil Çalişkan, E. Altas, Peter Panjan, "Experimental investigation of surface integrity of hardened AISI D2 steel at cutting conditions from conventional to high speed machining", In: *8th International Conference and Exhibition on Design and Production of Machine and Dies/Molds & 11th International Conference on Barkhausen Noise and Micromagnetic Testing, (Joint event), June 18-21, 2015, Aydin, Turkey*, Metin Akkök, ed., Ankara, Atilim University, 2015, pp. 217-221.
3. Marko Jošt, Marko Berginc, Andrej Čampa, Janez Krč, Peter Panjan, Barbara Malič, Marko Topič, "Nanoimprinted textures on glass as a substrate for GITO deposition", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 23-28.
4. Bojan Podgornik, Marko Sedlaček, Miha Čekada, Staffan Jacobson, Boštjan Zajec, "Load-carrying capacity and impact wear resistance of coated tool steel - influence of fracture toughness", In: *Proceedings of the 11th International Tribology Conference, University of Pretoria Conference Centre, Pretoria, South Africa, 10-12 March, 2015*, Philip de Vaal, ed., Pretoria, South African Institute of Tribology, University of Pretoria, 2015, pp. [1-10].
5. Pal Terek, Dragan Kukuruzović, Aleksandar Miletić, Peter Panjan, Lazar Kovačević, Branko Škorić, "Mechanical and tribological properties of nanolayered TiAlN/TiSiN coating", In: *Serbiatrib '15: proceedings*, 14th International Conference on Tribology SERBIATRIB '15, May 13-15, 2015, Belgrade, Serbia, Aleksandar Vencl, ed., Kragujevac, Serbian

Tribology Society, Belgrade, University, Faculty of Mechanical Engineering, 2015, pp. 137-142.
6. Pal Terek, Dragan Kukuruzović, Aleksandar Miletić, Peter Panjan, Lazar Kovačević, Branko Škorić, "Surface roughness and its effect on tribological performance of magnetron sputtered nitride coatings", In: *Serbiatrib '15: proceedings*, 14th International Conference on Tribology SERBIATRIB '15, May 13-15, 2015, Belgrade, Serbia, Aleksandar Vencl, ed., Kragujevac, Serbian Tribology Society, Belgrade, University, Faculty of Mechanical Engineering, 2015, pp. 143-148.

MENTORING

1. Aleksandar Miletić, *Design of nanolayered and nanocomposite metal-nitride coatings:* doctoral dissertation, Novi Sad, 2015 (mentor Branko Škorić; co-mentor Peter Panjan).
2. Vladan Mladenovič, *Influence of surface structuring parameters on mechanical and structural properties of stainless steel:* doctoral dissertation, Ljubljana, 2015 (mentor Miha Čekada).

DEPARTMENT OF SURFACE ENGINEERING AND OPTOELECTRONICS F-4

The research program is associated with vacuum science, technology and applications. The main activities are focused on plasma science, the modification of advanced biomedical materials and products for improved biocompatibility, the characterization of inorganic, polymer and composite materials with different thin films on the surface, the modification and characterization of fusion-relevant materials, the thermodynamics of trapped gases and methods for sustaining ultra-high-vacuum environment, vacuum optoelectronics, and basic research in the field of surface and thin-film characterization by electron and ion spectroscopy techniques.

Head:
Prof. Miran Mozetič

Non-equilibrium gaseous plasma created in molecular gases is a rich source of neutral reactive gaseous species. An electron temperature of several 10,000 K ensures the frequent dissociation of gaseous molecules upon inelastic collisions with fast electrons. The neutral atoms are often stable in the gas phase since the association with parent molecules requires three-body collisions, which are unlikely to appear at pressures below 100 Pa. The major loss mechanism for neutral reactive particles in low-pressure plasma is therefore heterogeneous surface recombination. The recombination coefficient depends on the ability of the surface facing the gaseous media rich in neutral atoms to bond to them chemically. Depending on the type of atoms it can be very low for many glasses, some polymers and several types of ceramics, but much larger for materials that chemisorb atoms. Systematic research on the interaction between neutral oxygen atoms and selected nanostructured materials enabled the discovery of a material with the highest coefficient ever reported in the scientific literature. The recombination coefficient was determined experimentally in the early afterglow of oxygen plasma created by an electrodeless radiofrequency discharge. Extremely high values of the atomic oxygen loss coefficient on a carbon nanowall (CNW) surface were observed. CNW layers consisting of interconnected individual nanostructures with an average length of 1.1 μm, average thickness of 66 nm and surface density of 3 CNW/μm^2 were prepared by plasma-jet-enhanced chemical vapour deposition using C_2H_2/H_2/Ar gas mixtures at the National Institute for Laser, Plasma and Radiation Physics in Bucharest, Romania. An image obtained with our atomic force microscope is shown in Figure 1. The surface-loss coefficient for oxygen atoms was determined at various densities of oxygen atoms in the experimental chamber up to 1.3×10^{21}m^{-3}. CNWs and several different samples of known coefficients for the heterogeneous surface recombination of neutral oxygen atoms have been placed separately in the afterglow chamber and the oxygen-atom density in their vicinity was measured with calibrated catalytic probes. A comparison of the measured results allowed us to determine the loss coefficient for CNWs and the obtained value of 0.59 ± 0.03 makes this material an extremely effective sink for oxygen atoms [1].

The group of Prof. Janez Kovač invented an analytical solution for the convolutional integral describing depth profile analyses of thin films.

In many cases the oxygen atoms should be preserved since they are useful for both functionalization with polar functional groups and the controlled etching of polymers. Surface saturation with polar oxygen-rich groups is achieved in a fraction of a second, providing the plasma is sustained in a chamber made from inert materials, typically quartz or borosilicate glasses [2]. Further exposure of polymer materials to an oxygen plasma leads to etching. The etching is often non-uniform and results in nano-structuring of the surface morphology. A combination of a rich morphology and saturation with polar functional groups allows for the super-hydrophilic character of originally hydrophobic materials. Polymer composites are etched selectively so that the polymer component is removed from the sample surface, leading to modified surface properties. Furthermore, such a treatment makes it possible to distinguish the distribution and orientation of fillers inside the polymer matrix. A systematic treatment of advanced thermochromic prints used in the food industry was performed. The prints contain a polymer matrix and a-few-μm-large capsules containing thermochromic ink. The quality of the prints depends on the distribution of the capsules inside the polymer matrix. The prints were

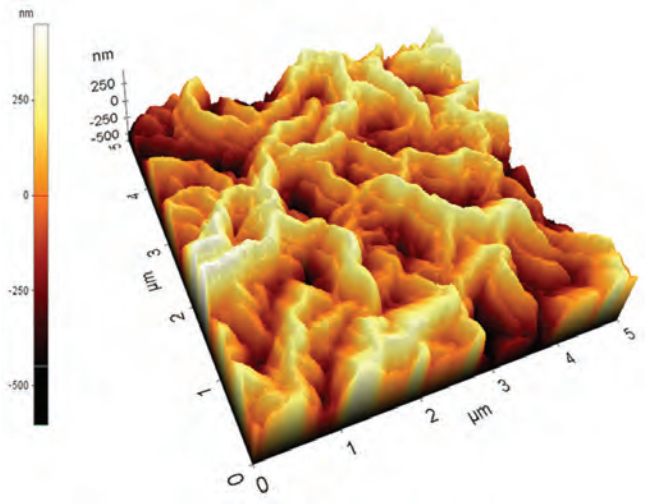

Figure 1: An AFM image of plasma-assisted synthesized carbon nanowalls of highest recombination coefficient for neutral oxygen atoms [1].

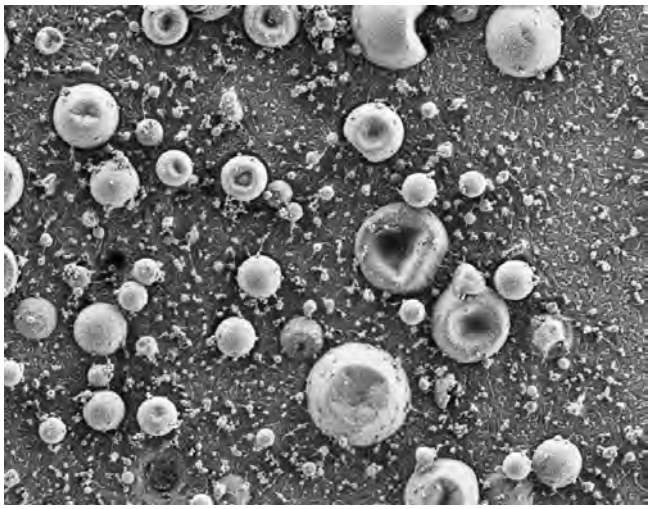

Figure 2: A SEM image of oxygen-plasma treated sample reveals distribution of capsules inside the thermochromic print [2].

treated using oxygen plasma for different periods in order to remove the surface polymer of a certain thickness. After several seconds of plasma treatment the uppermost capsules became visible by imaging the print surface with a scanning electron microscope. As the treatment proceeded more capsules were revealed, thus enabling a determination of the capsule's lateral distribution. After a prolonged treatment some capsules themselves were etched, as revealed in Figure 2. Knowing the etching rate for the specific polymer it was possible to estimate even the distribution of the capsules versus the depth of the print.

Textiles need to be treated prior to dyeing with natural dyes, which is usually done with the use of mordants (metal salts), with many of them being ecologically unsafe. The plasma treatment of cotton was used for improving the adsorption of the extracted dye of curcuma. Dyeing was performed on 100 % cotton fabric, both raw and bleached. The raw cotton was pre-treated using a classic wet-chemical scouring process and treated with an oxygen and ammonia low-pressure radiofrequency plasma. The chemical changes on the substrate surface were analysed using X-ray photoelectron spectroscopy and the morphological changes of samples, with a scanning electron microscope. Raw untreated, raw soured, raw plasma treated and bleached cotton were all dyed in the extracted dye of curcuma. CIEL*a*b* colour values and K/S values were measured using a reflectance spectrophotometer Spectraflash 600 Plus. The UV permeability was measured using spectrophotometer Cary 1E UV/VIS. The samples were also tested after a repetitive wash to examine the wash fastness. The results showed that the selection of gas for creating plasma is crucial for increasing the adsorption of natural dye of curcuma onto the cotton. The classic wet-chemical modifications of scouring and bleaching, and the use of oxygen plasma, were unsuitable methods for increasing the adsorption of curcuma onto cotton. The K/S values of those samples were lower than of those of the untreated sample. Treating raw cotton with ammonia plasma not only increased the adsorption of curcuma, it also increased the washing fastness of the dyed cotton. The effect was explained by the formation of nitrogen functional groups that were introduced onto the cotton's surface. In addition, these samples also had the highest ultraviolet protection factor, which was not significantly reduced after washing. This study was the subject of diploma work by Miha Kavčič, who received the Prešeren award for his thesis "The influence of oxygen and ammonia plasma treatment of cotton on adsorption of natural curcumin dyestuff".

Miha Kavčič received the Prešeren award for his diploma "The influence of oxygen and ammonia plasma treatment of cotton on adsorption of natural curcumin dyestuff".

The application of TiO_2 nanoparticles in textile finishes is attracting interest due to its relatively straightforward immobilization onto cotton fabrics, enabling the fabrication of cotton fabrics with excellent protection against UV radiation and its photocatalytic bacteriostatic effects. In collaboration with the National Institute of Chemistry in Ljubljana and the University of Ljubljana, we proposed a new route for the functionalization of cotton fibres with organic–inorganic hybrid materials using titanium tetraisopropoxide (TiP) and aminopropyltriethoxysilane (APTES) for the preparation of sol-gel TiP/APTES coatings. The presence of TiP and TiP/APTES hybrids on cotton fibres was established using X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM) and infrared attenuated total reflectance (ATR) analyses. Our XPS and ATR investigations showed the chemical interaction of the TiP and TiP/APTES hybrids with the cellulose fibres. From XPS spectra of O 1s, Si 2p and C 1s we identified the formation of the Si-O-C covalent bonds on treated samples indicating a reaction between the cellulose and APTES molecules [3].

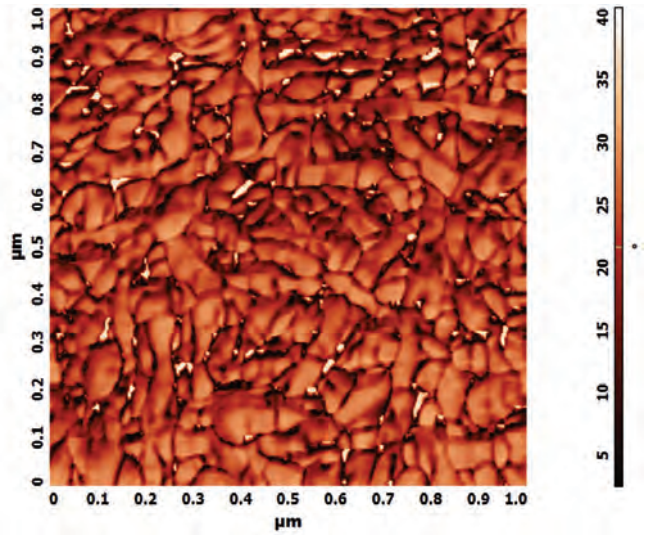

Figure 3:. AFM image of rod-shaped cellulose nanofibrils obtained from sisal [4].

The production of innovative materials from renewable and abundant bio-resources, such as nano-celluloses obtained from cellulosic sources, is becoming an important area of research, since it offers a unique combination of good physical properties producing a variety of high-value products with a low impact on the environment. Nano-cellulose can be classified into two types: cellulose nanofibrils (CNFs) and cellulose nanocrystals (CNCs), which are different in terms of morphology. These novel forms of cellulose come from abundant and renewable natural sources, thus having low-cost, being economically beneficial in replacing synthetic fibres like carbon

and glass. CNFs exhibit attractive properties such as the large specific surface area, a very high elastic modulus, a high aspect ratio, a low thermal expansion, a non-abrasive nature, a non-toxic character and their ability to act as a significant reinforcement at low filler-loading levels stimulates their use as reinforcing agents in the polymer-nanocomposites sector. CNFs have great potential application in various fields, such as regenerative medicine, tissue engineering scaffolds, catalysis, textiles, surface coatings, drug delivery, food packaging and green nanocomposite materials. Nano-cellulose was successfully extracted from different lignocellulosic biomass sources using a combination of chemical treatments such as alkaline treatment, bleaching and acid hydrolysis. The shape, size and surface properties of the nano-cellulose generally depend on the source and hydrolysis conditions. A comparative study of the fundamental properties of raw material, bleached and nanocellulose was carried out by means of Fourier-transform infrared spectroscopy, scanning electron microscopy, atomic force microscopy, transmission electron microscopy, birefringence, X-ray diffraction, inverse gas chromatography and thermogravimetric analyses. Through the characterization of the nano-cellulose obtained from different sources, the isolated nano-cellulose showed an average diameter of less than 50 nm, high crystallinity, high thermal stability and a great potential to be used with acid coupling agents due to a predominantly basic surface [4].

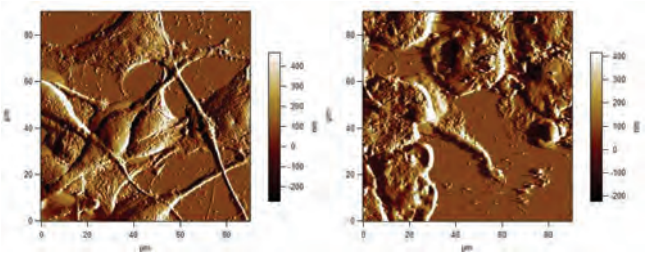

Figure 4: Deflection signal images of fixed human-brain glioblastoma (U87) cells before (left) and after (right) plasma treatment [5].

Plasma medicine is a rapidly growing field of interdisciplinary science. In this case plasma is often created at atmospheric pressure because the biological materials are usually destroyed upon exposure to a vacuum environment. Because the probability of a three-body collision at atmospheric pressure is very high the life-time of neutral reactive species is very short. This effect limits the application of atmospheric pressure plasma to small volumes of high electric field where the dissociation of gaseous molecules occurs. The reactive gaseous species interact with biological matter as well as the medium. The reactive species, such as OH, H_2O_2, NO and O_2^-, are the main components of the cold plasma jet that provides for therapeutic effects, not only with cancer, but also with biological disinfection, viral destruction and wound healing. It is well known that NO is an omnipresent intercellular messenger in all vertebrates, modulating blood flow, thrombosis, neuronal activity, immune response, inflammation, and plays a critical role in tumorigenesis by modulating the apoptotic machinery. Both NO radical and superoxide can form peroxynitrite once they collide or even locate within a few cell diameters of each other. Peroxynitrite is a powerful oxidant and nitrating agent that is known to be much more damaging to the cells than NO or superoxide, because cells readily remove superoxide and NO to reduce their harmful effects, while they fail to neutralize peroxynitrite. The morphological characteristics and differences of the cell membrane between normal human astrocytes and glial tumour cells are not well explored. Following a treatment with cold atmospheric plasma, evaluation of the selective effect of plasma on cell viability of tumour cells is poorly understood and requires further evaluation. Using atomic force microscopy we imaged the morphology of glial cells before and after cold atmospheric plasma treatment. To look more closely at the effect of plasma on cell membranes, high-resolution imaging was used. We report on the differences between normal human astrocytes and human glioblastoma cells by considering the membrane surface details. Our data, obtained for the first time on these cells using atomic force microscopy, argue for an architectural feature on the cell membrane, i.e., brush layers, different in normal human astrocytes to glioblastoma cells. The brush layer disappears from the cell-membrane surface of normal E6/E7 cells and is maintained in the glioblastoma U87 cells after plasma treatment. This work was performed in collaboration with George Washington University, USA [5].

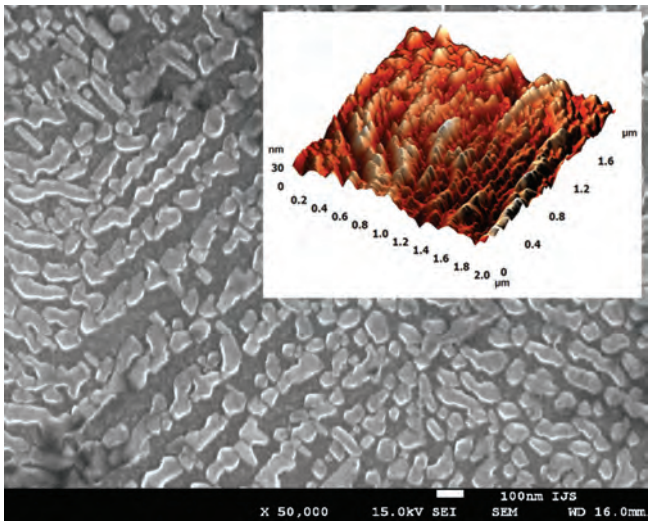

Figure 5: SEM and AFM images of stainless-steel sample treated subsequently by oxygen and hydrogen plasmas [6]

Our group is also involved in the European project IP4Plasma: Industrial innovations based on EU intellectual property assets in the field of atmospheric pressure plasma technology, funded by European Union under the 7th Framework Programme for Research and Innovation. In the IP4Plasma project, plasma equipment manufacturers and end-users work with leading experts in research to demonstrate the suitability of the atmospheric pressure plasma technology for existing and new industrial applications in the advanced medical diagnostics sector and healthcare products. In the project nine European partners from research and industry areas are involved: Spinverse Ltd (Finland), Fraunhofer Institute for Surface Engineering and Thin Films IST (Germany), IMA (Belgium), Jozef Stefan Institute (Slovenia), LIONEX GmbH (Germany), 2B (Italy), SOFTAL Corona & Plasma GmbH (Germany), Tosama (Slovenia), VITO - Flemish

Institute for Technological Research (Belgium). In the project a new type of plasma equipment has been developed, capable of the cost- and resource-efficient deposition of coatings. The IP4Plasma project aims to improve the properties of wound dressings produced by Tosama by improving the wound draining behaviour and add anti-bacterial properties to the surface of materials by plasma deposition of non-silver-containing chemistries. Our group performs detailed analyses of the surface composition and the chemical structure of treated materials by XPS and time-of-flight secondary-ion mass spectrometry (ToF-SIMS) methods supporting the optimization of an atmospheric-pressure plasma treatment process.

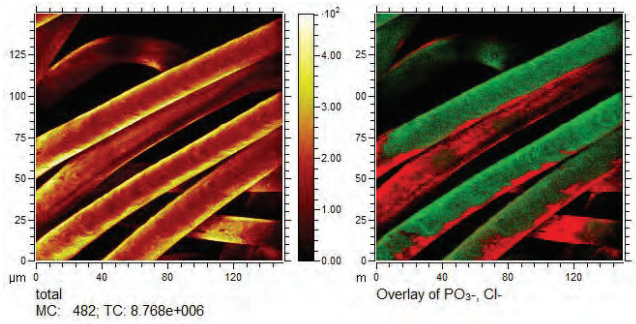

Figure 6: ToF-SIMS images of wound dressing treated in Tosama by a new atmospheric pressure plasma technology. Left - morphology of polymer fibres, right - distribution of the Cl-ions on the fibres.

Gaseous plasma is also useful for tailoring the surface properties of inorganic materials. Metal oxides are formed upon the exposure of metals to oxygen plasma, while hydrogen plasma causes a reduction of the oxides. The metal oxides often do not grow as thin films, which is typically for thermal oxidation, but rather in the form of one- or two-dimensional nanostructures. The method for the rapid synthesis of large quantities of metal oxide nanowires was invented by our group a decade ago and the technique is nowadays used in many laboratories worldwide. Both oxygen and hydrogen plasma were used in order to reveal the oxidation and reduction kinetics during the treatment of stainless steel. The experiments were performed in collaboration with the Solar Centre Font Romeu, France, where samples are heated upon exposure to plasma independently of the plasma parameters using concentrated solar radiation. Approximately 500-nm-thick oxide films of rich morphology formed on the surface of AISI 316L stainless steel samples upon brief exposure to oxygen plasma, which was created by microwave discharge. During the plasma treatment, the samples were simultaneously heated by concentrated solar radiation such that the temperature increased almost linearly to approximately 1100 K, after which the heating was abruptly turned off. After oxidation, the samples were exposed to hydrogen plasma in the same experimental chamber using the same heating regime to reduce the oxide films. The sample temperature was monitored using an infrared pyrometer. The results showed several knees in the signal versus treatment time due to chemical reactions between the oxidised stainless steel and the hydrogen plasma. Scanning electron microscopy, atomic force microscopy and Auger electron spectroscopy (AES) depth profiling were used to determine the surface and thin-film modifications. The oxidation by oxygen plasma caused the formation of densely packed oxide crystallites rich in Fe and Mn on the surface, followed by a rather thick chromium oxide subsurface film. The removal of the oxygen from the surface film was indicated by a sudden decrease in the material's emissivity that occurred in a few seconds at approximately 1300 K. Subsequent oxidation and reduction cycles caused nanostructuring of the surface morphology because evenly distributed islets of uniform lateral dimensions (approximately 100 nm) were observed on the surface after the treatments [6].

Solar energy is the cleanest renewable natural resource available since it does not produce air pollutants or CO_2. The world's energy demands are growing rapidly and the development of coatings with a high absorption of solar radiation and low thermal emittance is thus a driving force for the development of absorber coatings with spectral selectivity. Thickness Sensitive Spectrally Selective (TSSS) paint coatings made by the deposition of black paints with controlled thickness on metallic substrates are a cheap alternative to vacuum-based coatings. In collaboration with the National Institute of Chemistry in Ljubljana, we prepared and characterized a new type of TSSS paint coating using a paint made of black manganese spinel pigment dispersed in polysiloxane resin binder with the help of (3-aminopropyl)triethoxy silane (APTMS), which served as a dispersant. Absorber coatings gave a solar absorbance of 0.91 and a thermal emittance of 0.12, excellent homogeneity and good stability up to 400 °C. The coatings were investigated by infrared spectroscopy and XPS, AES and AFM surface analyses. The thermal stability and the improvement of th espectral selectivity of the TSSS coatings were explained by changes in the surface chemical composition and by the oxidation states of the elements observed in XPS spectra of Mn 2p, Fe 2p, O 1s and Si 2p and by the depth distribution of elements measured by AES depth profiling [7].

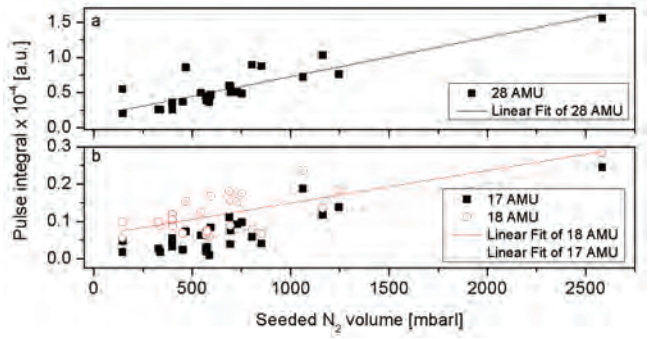

Figure 7: Response of pulse-integrated intensities of MS signals to nitrogen seeding at a) 28 AMU (nitrogen) and b) 17 and 18 AMU (ammonia) [9].

The miniaturization of modern sealed vacuum devices and greater demands for their stable operation require an accurate determination of the gas composition in the early stage of their operation or after a long operational period. Among a few highly gas-sensitive methods, quadrupole mass spectrometry (QMS) and ion-

trap mass spectrometry (ITMS) seem to be the most appropriate ones for this task as the gas amounts are well below $1x10^{-4}$ mbar L. We continue with the QMS experiments and have started with evaluations of the ITMS, which is a relatively new instrument. A new approach, how to prepare any type of mass spectrometer for routine quantitative analysis of small gas amounts, was elaborated. In the first stage, it was calibrated by an innovative *in-situ* procedure using four different gases: nitrogen, hydrogen, argon and neon. Each gas was admitted into a chamber with a precisely determined volume, equipped by a capacitance manometer. By opening the variable leak valve and setting it to a small and constant conductance to the mass spectrometer, an exponential decay of the gas flow rate was generated. Simultaneously, ion currents versus flow rate were determined over three orders of magnitude. A non-linear response at very low flow rates was detected. In the second stage, gas quantities from $3x10^{-5}$ mbar L to $6x10^{-7}$ mbar L of pure gas were admitted, which proved that, after the numerical correction, the achieved accuracy was still rather high. Finally, small amounts of mixtures with two gases were prepared and analysed. Various unexpected mutual effects within both instruments, the QMS and ITMS, greatly modified the instrument's response, which resulted in a substantially lower accuracy [8]. The observed anomalies need to be considered carefully in the evaluations of very small amounts of gas mixtures with unknown gas ratios.

Figure 8: Miha Kavčič received the Prešeren award. From left to right: M. Mozetič (co-supervisor), M. Kavčič and M. Gorjanc (supervisor).

Pia Škodlar, a student of Medical College from Ljubljana, supervised by Dr. Ita Junkar, received an award granted by the pharmaceutical company Krka for the research work: "Methods for improving hemocompatibility of vascular implants".

In the development of commercially viable fusion-energy exploitation, the upcoming experimental ITER will no doubt be a crucial milestone. ITER will be a tokamak-type reactor, in which the burning fusion fuel is contained by magnetic fields. However, the operation of the reactor is also in a great many sway determined by plasma-wall interaction (PWI), which takes place in a specially designated part of the reactor, called the divertor. Impurities from the wall which enter the plasma core limit the performance of the reactor, while the impurities in the plasma edge promote sputtering and thereby determine the life time of the plasma-facing components (PFCs). The PFCs were traditionally made out of carbon-based materials, however due to the problems of the in-vessel accumulation of hydro-carbon deposits, larger tokamaks have recently been fitted with all-metallic divertors. Similarly, ITER will operate with a tungsten divertor, while the remaining plasma-facing surfaces will be covered with beryllium. Because of the limited power-handling capabilities of the metallic PFCs, a significant fraction of the energy in the plasma edge will have to be dissipated by radiation. To promote this radiation, impurities are seeded into the plasma edge. Among the impurities tested so far, nitrogen has shown to have the most beneficial effect on the plasma performance; however, before nitrogen seeding is implemented in ITER, mechanisms of in-vessel nitrogen retention must be studied thoroughly. This is especially true for ammonia formation, which acts as an unpredictable source of fuel retention and can have serious safety and operational consequences for ITER. The research was performed at the JET fusion reactor, which, besides being the largest currently operating tokamak, is the only reactor with the same composition of the plasma walls as ITER. Besides the intrinsic impurities, N_2, Ne and Ar are routinely injected into the vessel during impurity seeding. Moreover, Ar is also injected as part of the disruption-mitigation gas to quell oncoming disruptions. The impurities were analysed with a mass spectrometer (MS), located below the divertor cryopumps. The MS is magnetically shielded, which allows for data acquisition in all phases of the reactor's operation. As the plasma pulses at JET are characteristically 20 s long, the MS is set up to record the spectral intensities at discrete masses during the discharges, which results in a sampling time between 1 and 1.5 s. Between discharges, the MS acquires full spectra, typically in the 0–60 AMU range. The results outline as deuterated methane and nitrogen as the most prominent impurities in non-seeded pulses, while their dependency on discharge parameters indicate PWI as their most likely source. Nitrogen seeding gives rise to a significant increase in nitrogen; however, also to ammonia production, which is confirmed by the response in intensities at ammonia-related masses to the amount of seeded nitrogen, as shown in Figure 8. This publication is the first report of such analysis in any tokamak with an ITER-like inner wall. Moreover it is also the first instance of participation at the JET experimental campaigns for our department, as well as the Slovenian Fusion Association.

Figure 9: Pia Škodlar (left) supervised by Dr. Ita Junkar (right) received the Krka award.

Some outstanding publications in the past year

1. Mozetič, Miran, Vesel, Alenka, Stoica, Silviu-Daniel, Ionut Vizireanu, Sorin, Dinescu, Gheorghe, Zaplotnik, Rok. Oxygen atom loss coefficient of carbon nanowalls. Applied Surface Science, ISSN 0169-4332, 2015, vol. 333, p. 107-213.
2. Mozetič, Miran, Primc, Gregor, Vesel, Alenka, Zaplotnik, Rok, Modic, Martina, Junkar, Ita, Recek, Nina, Klanjšek Gunde, Marta, Guhy, Lukus, Sunkara, Mahendra K., Gorjanc, Marija, Stana-Kleinschek, Karin. Application of extremely non-equilibrium plasmas in the processing of nano and biomedical materials. Plasma sources science & technology, ISSN 0963-0252, 2015, vol. 24, no. 1, p. 015026-1-015026-12.
3. Tomšič, Brigita, Jovanovski, Vasko, Orel, Boris, Mihelčič, Mohor, Kovač, Janez, Francetič, Vojmir, Simončič, Barbara. Bacteriostatic photocatalytic properties of cotton modified with TiO2 and TiO2/aminopropyltriethoxysilane. Cellulose, ISSN 0969-0239, 2015, vol. 22, no. 5, p. 3441-3463.
4. Deepa, B., Abraham, Eldho, Cordeiro, Nereida, Mozetič, Miran, Mathew, Aji P., Oksman Niska, Kristina, Faria, Marisa, Thomas, Sabu, Pothan, L. A. Utilization of various lignocellulosic biomass for the production of nanocellulose: a comparative study. Cellulose, ISSN 0969-0239, 2015, vol. 22, no. 2, p. 1075-1090.
5. Recek, Nina, Cheng, Xiaoqian, Keidar, Michael, Cvelbar, Uroš, Vesel, Alenka, Mozetič, Miran, Sherman, Jonathan H. Effect of cold plasma on glial cell morphology studied by atomic force microscopy. PloS one, ISSN 1932-6203, 2015, vol. 10, issue 3, p. 1-14.
6. Mozetič, Miran, Vesel, Alenka, Kovač, Janez, Zaplotnik, Rok, Modic, Martina, Balat-Pichelin, Marianne. Formation and reduction of thin oxide films on a stainless steel surface upon subsequent treatments with oxygen and hydrogen plasma. Thin Solid Films, ISSN 0040-6090, 2015, vol. 591, part B, p. 186-193.
7. Mihelčič, Mohor, Francetič, Vojmir, Kovač, Janez, Šurca Vuk, Angela, Orel, Boris, Kunič, Roman, Peros, Dimitrios. Novel sol-gel based selective coatings: from coil absorber coating to high power coating. Solar energy materials and solar cells, ISSN 0927-0248, 2015, vol. 140, p. 232-248.
8. Nemanič, Vincenc, Žumer, Marko, Lakner, Mitja. Ultimate limits in the gas composition determination within small sealed volumes by quadrupole mass spectrometry. Vacuum, ISSN 0042-207X, 2015, vol. 119, p. 112-118 Vacuum.
9. Jet Efda Contributors, Drenik, Aleksander, Mozetič, Miran, et al. Mass spectrometry analysis of the impurity content in N[sub]2 seeded discharges in JET-ILW. Journal of nuclear materials, ISSN 0022-3115, 2015, vol. 463, p. 684-687.

Awards and appointments

1. Dr Gregor Primc: Award for outstanding achievements in the year 2014, awarded by the Jožef Stefan Institute International Postgraduate School for developing an innovative sensor with highest commercial potential and for the establishment of a spin-out company Plasmadis Ltd.
2. Miha Kavčič: The Prešeren award for academic degree with title: *The influence of oxygen and ammonia plasma treatment of cotton on adsorption of natural curcumin dyestuff* (doc. dr. Marija Gorjanc and prof. dr. Miran Mozetič). The award was given in Faculty of Natural Sciences and Engineering.
3. Pia Škodlar: The Krka award for students' research work with title: *Methods for improving hemocompatibility of vascular implants* (dr. Ita Junkar). The award was given in Pharmaceutical Corporation Krka.

Patents granted

1. Miran Mozetič, Nikolas Panagiotopoulos, Giorgos A. Evangelakis, Method for tetragonal zirconia oxide thin films growth suitable for catalytic devices, SI24659 (A), Slovenian Intellectual Property Office, 30. 09. 2015.
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, SI24727 (A), Slovenian Intellectual Property Office, 30. 11. 2015.

INTERNATIONAL PROJECTS

1. Services
   Asst. Prof. Janez Kovač
2. 7FP - IP4Plasma; Industrial Innovations Based on EU Intellectual Property Assets in the Field of Atmospheric Plasma Technology
   Asst. Prof. Janez Kovač
   European Commission
3. EFDA-JET 2013 Experimental Campaigns
   Dr. Aleksander Drenik
   Ministry of Education, Science and Sport, Ljubljana
4. COST TD1208; Electrical Discharges with Liquids for Future Applications; COST Training School on Liquid Discharges
   Prof. Uroš Cvelbar
   Cost Office
5. NATO Grant; SPS 984555; Atmospheric Pressure Plasma Jet for Neutralisation of CBW
   Prof. Uroš Cvelbar
   Nato - North Atlantic Treaty Organisation
6. COST MP1101; Biomedical Applications of Atmospheric Pressure Plasma Technology
   prof. dr. Uroš Cvelbar
   Cost Office
7. Plasma Facing Components-1-IPH-FU, EUROFUSION
   Dr. Aleksander Drenik
   European Commission
8. JET Campaigns-JET1-FU, EUROFUSION
   Dr. Aleksander Drenik
   European Commission
9. Medium Size Tokamak Campaigns-MST1-FU, EUROFUSION
   Dr. Aleksander Drenik
   European Commission
10. Characterization of Gaseous Plasma for Nanoparticle Synthesis
    Asst. Prof. Alenka Vesel
    Slovenian Research Agency
11. Deposition of Coatings on Plasma prepared Medical Stents
    Prof. Uroš Cvelbar
    Slovenian Research Agency
12. Molecular Imaging of Biological Samples Using MeV Ions and keV Clusters for TOF-SIMS Spectrometry
    Asst. Prof. Janez Kovač
    Slovenian Research Agency
13. Advanced Physical Techniques for Modification of Polymer and Composite Functionalities for Biomedical Applications
    Prof. Miran Mozetič
    Slovenian Research Agency
14. Guided Nanoherding of Quantum Dots
    Prof. Uroš Cvelbar
    Slovenian Research Agency
15. Synthesis and Characterization of Pt Nanocatalysts at Metal Oxide based Supports for Fuel Cells Application
    Asst. Prof. Alenka Vesel
    Slovenian Research Agency
16. Ion and Laser Beam induced Formation of Biocompatibile Alloys in Multilayered Thin Film Structures
    Asst. Prof. Janez Kovač
    Slovenian Research Agency
17. Measurements of Plasma Parameters in Capacitive and Inductive RF Discharges
    Prof. Uroš Cvelbar
    Slovenian Research Agency
18. Sniffing for Carcinogenic Substances - Research for Toxic Gas Molecule Sensing with Networks of Carbon Nanowalls
    Prof. Uroš Cvelbar
    Slovenian Research Agency
19. Advanced Photo-electrochemical Cells with Nanostructured Iron Oxide Electrodes
    Prof. Miran Mozetič
    Slovenian Research Agency
20. Irradiation of Metal Oxide Nanowires
    Prof. Uroš Cvelbar
    Slovenian Research Agency
21. ECS Electrochemical Society
    Prof. Uroš Cvelbar
    Slovenian Research Agency

RESEARCH PROGRAMS

22. Vacuum technique and materials for electronics
    Dr. Vincenc Nemanič
23. Thin film structures and plasma surface engineering
    Prof. Miran Mozetič

R & D GRANTS AND CONTRACTS

1. Development of the functional textiles used fot the treatment of diabetic foot (malum perforans)
   Prof. Miran Mozetič
2. New materials for printed sensors and indicators and their integration in smart printed matter
   Asst. Prof. Alenka Vesel
3. Self-lubricating and wear resistant PVD hard coatings based on (V,Cr,Al,Ti)N for hot-working processes
   Asst. Prof. Janez Kovač
4. Interaction between fully dissociated moderately ionized ammonia plasma and glass-fiber reinforced polymers
   Prof. Miran Mozetič
5. Nanostructures and related composites for detection of hazardous gaseous molecules
   Prof. Uroš Cvelbar
6. Functionalization of polymer cardiovascular implants for optimal hemocompatibility
   Asst. Prof. Alenka Vesel

NEW CONTRACT

1. Characteristics of gaseous plasma in gaps
   Prof. Uroš Cvelbar
   Kolektor Sikom d. o. o.

VISITORS FROM ABROAD

1. Dr Mahendra Sunkara, University of Louisville, Louisville, USA, 17–20 January 2015
2. Prof. Marian Lehocky, Tomas Bata University, Zlin, Czech Republic, 3–5 February 2015
3. Dr Petr Stloukal, Tomas Bata University, Zlin, Czech Republic, 3–5 February 2015
4. Prof. Slobodan Milošević, Institute of Physics, Zagreb, Croatia, 2 April 2015
5. Dr Nevena Puać, Institute of Physics, Belgrade, Serbia, 7–12 May 2015
6. Kosta Spasić, Institute of Physics, Belgrade, Serbia, 7–20 May 2015
7. Dr Davor Peruško, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 24–29 May 2015
8. Dr Maja Obradović, University of Belgrade, Belgrade, Serbia, 5–8 July 2015
9. Dr Marian Lehocky, Tomas Bata University, Zlin, Czech Republic, 14–20 July 2015
10. Prof. Michael J. Gordon, University of California, Santa Barbara, USA, 17–20 September 2015
11. Dr Robert Olejnik, Tomas Bata University, Zlin, Czech Republic, 23–30 September 2015
12. Jiri Matyas, Tomas Bata University, Zlin, Czech Republic, 23–30 September 2015
13. Prof. Petr Slobodian, Tomas Bata University, Zlin, Czech Republic, 23–30 September 2015
14. Prof. Masaru Hori, Nagoya University, Nagoya, Japan, 27–30 September 2015
15. Prof. Makoto Sekine, Nagoya University, Nagoya, Japan, 27–30 September 2015
16. Prof. Hiroki Kondo, Nagoya University, Nagoya, Japan, 27–30 September 2015
17. Shun Imai, Nagoya University, Nagoya, Japan, 27–30 September 2015
18. Hyungjun Cho, Nagoya University, Nagoya, Japan, 27–30 September 2015
19. Dr Marko Karlušić, Ruđer Bošković Institute, Zagreb, Croatia, 5–6 October 2015
20. Dr Zdravko Siketić, Ruđer Bošković Institute, Zagreb, Croatia, 5–7 October 2015
21. Dr Nevena Puać, , Institute of Physics, Belgrade, Serbia, 15–20 October 2015
22. Nikola Škoro, Institute of Physics, Belgrade, Serbia, 15–20 October 2015
23. Dr Danijela Vujošević, Institute for Public Health of Montenegro, Podgorica, Montenegro, 21–25 October 2015
24. Dr Davor Peruško, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 15–20 November 2015
25. Dr Suzana Petrović, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 15–20 November 2015
26. Dejan Pjević, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 30 November–3 December 2015

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BIBLIOGRAPHY

Original Article

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2. Xinqun Cheng, K. Rajjoub, Jonathan H. Sherman, Jerome Canady, Nina Recek, Dayun Yan, Ka Bian, Ferid Murad, Michael Keidar, "Cold plasma accelerates the uptake of gold nanoparticles into glioblastoma cells", *Plasma processes polym.*, vol. 12, iss. 12, pp. 1364-1369, 2015.
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11. Petr Humpolíček, Zdenka Kucekovà, Věra Kašpárková, Jana Pelková, Martina Modic, Ita Junkar, Miroslava Trchová, Patrycja Bober, Jaroslav Stejska, Marián Lehocký, "Blood coagulation and platelet adhesion on polyaniline films", *Colloids surf., B Biointerfaces*, vol. 133, pp. 278-285, 2015.
12. Roghayeh Imani, Barbara Drašler, Veno Kononenko, Tea Romih, Kristina Eleršič, Janez Jelenc, Ita Junkar, Maja Remškar, Damjana Drobne, Veronika Kralj-Iglič, Aleš Iglič, "Growth of a novel nanostructured ZnO urchin: control of cytotoxicity and dissolution of the ZnO urchin", *Nanoscale research letters*, vol. 10, pp. 1-10, 2015.
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Review Article

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Patent

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Mentoring

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2. Metod Kolar, *Improving biocompatibility of poly(ethylene terephthalate) surfaces by immobilization of heparin:* doctoral dissertation, Ljubljana, 2015 (mentor Miran Mozetič; co-mentors Alenka Vesel, Karin Stana-Kleinschek).
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DEPARTMENT OF SOLID STATE PHYSICS F-5

Our research program is focused 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 hand, 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 magnetic resonance, magnetic resonance imaging, fluorescence microspectroscopy, scanning tunnelling, electronic and atomic force microscopy, as well as dielectric relaxation spectroscopy and dynamic specific-heat measurements.

Head:
Prof. Igor Muševič

The experimental techniques used are:

- One (1D) and two (2D) dimensional nuclear magnetic resonance (NMR) and relaxation, as well as quadrupole (NQR) resonance and relaxation,
- Multi-frequency NMR in superconducting magnets of 2T, 6T and 9T, as well as the dispersion of the spin–lattice relaxation time T_1 via field cycling,
- Nuclear double resonance and quadrupole double resonance such as ^{17}O–H and ^{14}N-H,
- Fast field cycling NMR relaxometry,
- Frequency-dependent electron paramagnetic resonance (EPR) and 1D and 2D pulsed EPR and relaxation
- MR imaging and micro-imaging
- Measurement of the electronic transport properties
- Magnetic measurements.
- Fluorescence microscopy and microspectroscopy
- Linear and non-linear dielectric spectroscopy in the range 10^{-2} Hz to 10^{9} Hz,
- Electron microscopy and scanning tunnelling microscopy,
- Atomic force microscopy and force spectroscopy,
- Dynamic specific heat measurements.

The research program of the Department of Solid State Physics at the Jožef Stefan Institute is performed 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 J. Stefan International Postgraduate School. In 2015, the research was performed within three research programs:

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

The group discovered unconventional superconductivity in a molecular "Jahn-Teller" metal, synthesized the first hexagonal high-entropy alloy based on rare-earth elements and determined its complex magnetic phase diagram, studied new quantum effects in the magnetism of low-dimensional spin systems, the physical properties of nanostructures, materials with the giant electrocaloric and thermomechanical effect, and multiferroic and relaxor phases. The research included pharmaceutical and biological substances.

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,
- Measurements of electrical and thermal transport coefficients,
- Magnetic measurements.

The research program was performed 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 2015, members of the program group published 51 original scientific papers in international peer-reviewed scientific journals. Among these, one paper was published in *ACS Nano*, one in *Adv. Funct. Mater*., one in *Nature Commun*., one in *Phys. Rev. Lett*., one in *ACS Appl. Mater. & Interf*., two in *Sci. Rep*., two in *J. Phys. Chem. C*, one in *RSC Advances*, seven in *Phys. Rev. B* and eight in *Appl. Phys. Lett*. We also published one paper in *Science Advances*, which does not have an impact factor as yet.

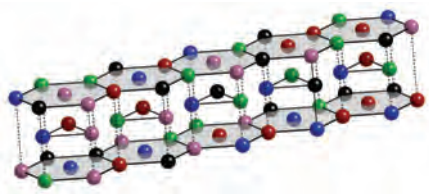

Figure 1: Structure of the Ho-Dy-Y-Gd-Tb hexagonal high-entropy alloy.

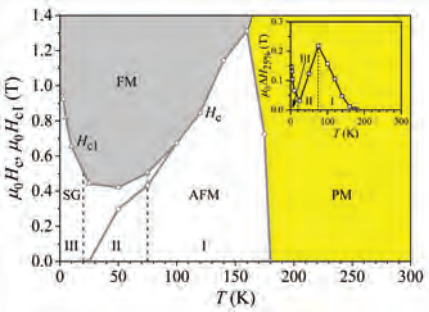

Figure 2: Magnetic phase diagram of the Ho-Dy-Y-Gd-Tb hexagonal high-entropy alloy.

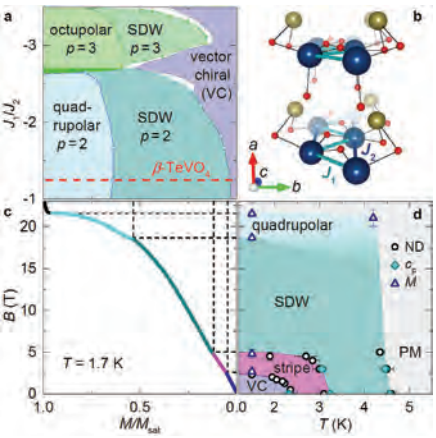

Figure 3: Comparison of the theoretical and experimental phase diagrams. (a) Schematic phase diagram of the frustrated ferromagnetic spin-1/2 chain model as a function of J1/J2 and M/Msat. (b) The crystal structure of β-$TeVO_4$. Small, medium and large spheres denote O, Te and magnetic V ions, respectively. (c) Normalized magnetization measured in the magnetic field along the a axis. (d) The experimental magnetic phase diagram of β-$TeVO_4$, signifying the novel spin-stripe phase.

The investigations were focused on the following research fields:

1. High-entropy alloys

In the publication "Complex magnetism of Ho-Dy-Y-Gd-Tb hexagonal high-entropy alloy" (J. Lužnik et al., *Phys. Rev. B* **92**, 224201 (2015)) we have reported on physical properties of the first hexagonal high-entropy alloy Ho-Dy-Y-Gd-Tb (Fig. 1). We have determined the magnetic phase diagram, which in a zero magnetic field shows a transition to a helical antiferromagnetic state at high temperatures, whereas at low temperatures a new kind of spin-glass phase appears. In a magnetic field, discontinuous metamagnetic phase transitions to exotic spin phases occur (Fig. 2).

2. Quantum magnetism

Matej Pregelj, Andrej Zorko in Denis Arčon have, in collaboration with partners from Switzerland, France and Japan, performed a comprehensive study of the β-$TeVO_4$ system. An impressive correspondence between a broad variety of experimental results, e.g., neutron diffraction and magnetization measurements in pulsed high-magnetic fields, with theory emphasizes the β-$TeVO_4$ compound as a model system of a frustrated spin chain with a rich phase diagram. The main result is the discovery of a magnetic stripe structure on the nano-scale, which appears at the transition between the spiral and collinear magnetic orders. In contrast to known strongly-correlated electron systems, here the stripes are stabilized in the absence of long-range magnetic interactions and are likely driven by weak frustrated interchain interactions. The presented model system thus allows a better understanding of the origin of the analogous nanometre-sized modulation in other systems, e.g., high-temperature superconductors. Their results were published in a paper by M. Pregelj et al., "Spin-stripe phase in a frustrated zigzag spin-1/2 chain", *Nat. Commun.* **6**, 7255 (2015).

Matej Pregelj, Andrej Zorko and Matjaž Gomilšek have in collaboration with partners from Switzerland, Germany and Moldova studied a mixed ferro/antiferromagnetic phase in the $Cu_3Bi(SeO_3)_2O_2Br$ system. Their results reveal the ability of metamagnetic materials to absorb the electromagnetic radiation across an extremely broad frequency range. The effect is controlled by the external magnetic field, which actuates a mixed ferro/antiferromagnetic phase, where the absorption in the $Cu_3Bi(SeO_3)_2O_2Br$ system extends over at least nine orders of frequency scale. Considering that artificial metamagnets (magnetic multilayers) allow for a direct control over the required magnetic field, a novel way of tuning the material's functional properties is imminent. Their work was published in the article by M. Pregelj et al., "Controllable broadband absorption in the mixed phase of metamagnets", *Adv. Func. Mat.* **25**, 3634 (2015).

Andrej Zorko and Denis Arčon collaborated with partners from Slovenia, Greece and Switzerland in studying the inhomogeneous magnetic states of triangular spin lattices. Combining various local-probe experiments and numerical calculations they discovered crucial differences between isostructural α-$NaMnO_2$ and $CuMnO_2$ compounds and demonstrated that the ground state of the

former compound is phase separated, while the latter is much more homogeneous. Such behaviour was believed to arise from the competition between the magnetic exchange and the elastic energies. Their discovery was published in the paper by A. Zorko et al., "Magnetic inhomogeneity on a triangular lattice: the magnetic-exchange versus the elastic energy and the role of disorder", *Sci. Rep.* **5**, 9272 (2015).

Martin Klanjšek, Tilen Knaflič and Denis Arčon, in collaboration with German colleagues, studied the structurally simple quantum antiferromagnet CsO_2 where the interplay of spin degrees of freedom with lattice vibrations and orbital ordering nevertheless leads to complex and interesting physics. Using magnetic resonance techniques, they showed that the system exhibits an exotic Tomonaga-Luttinger-liquid state at low temperatures where orbital ordering takes place. Sizeable lattice vibrations at higher temperatures lead to the huge temperature dependence of the exchange interaction, providing the first clear demonstration of this effect, predicted three decades ago. The work has been published in the papers M. Klanjšek et al., "Phonon-Modulated Magnetic Interactions and Spin Tomonaga-Luttinger Liquid in the *p*-Orbital Antiferromagnet CsO_2", *Phys. Rev. Lett.* **115**, 057205 (2015), and T. Knaflič et al., "One-dimensional quantum antiferromagnetism in the *p*-orbital CsO_2 compound revealed by electron paramagnetic resonance", *Phys. Rev. B* **91**, 174419 (2015).

Martin Klanjšek, in collaboration with French colleagues, studied the system of antiferromagnetic spin chains $BaCo_2V_2O_8$, which exhibits a very interesting phase diagram when a magnetic field is applied along the magnetic exchange easy axis. Because of the competition between the two types of spin fluctuations, present when the spin chains realize a Tomonaga-Luttinger-liquid state at low temperatures, two magnetically ordered phases are expected. A surprising observation of three magnetic phases leads to the conclusion of a giant magnetic field dependence of the exchange coupling. The work was published in the papers M. Klanjšek et al., "Giant magnetic field dependence of the coupling between spin chains in $BaCo_2V_2O_8$", *Phys. Rev. B* **92**, 060408(R) (2015), and B. Grenier et al., "Neutron diffraction investigation of the *H-T* phase diagram above the longitudinal incommensurate phase of $BaCo_2V_2O_8$", *Phys. Rev. B* **92**, 134416 (2015).

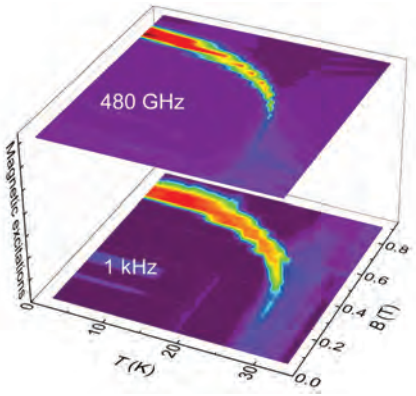

Figure 4: The imaginary part of the ac susceptibility, χ'' (bottom panel), and electron magnetic resonance at 480 GHz (top panel) plotted as a function of field and temperature. The red and the violet regions correspond to the highest and lowest absorption intensities, respectively.

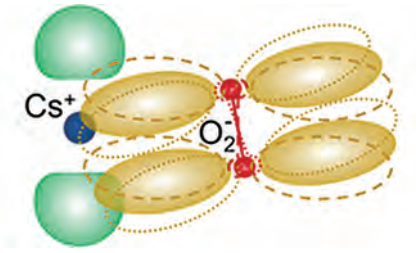

Figure 5: Schematic of the varying overlap of Cs p_z orbitals and O_2^- π^* orbitals in the process of O_2^- librations, which leads to the modulation of the exchange interaction.

3. Diluted magnetic systems

Andrej Zorko, Matej Pregelj and Matjaž Gomilšek collaborated with partners from Slovenia, Croatia and Great Britain in investigations of high-temperature ferromagnetism in the Fe-doped 6H-$BaTiO_3$. Although in this material the high-temperature ferromagnetism was previously widely accepted as an intrinsic property, they proved this conjecture to be wrong. A combination of bulk magnetization and complementary in-depth local-probe electron spin resonance and muon spin relaxation measurements clearly revealed that multiple magnetic instabilities occurring in this material coincide with the electronic instabilities of the Fe-doped 3C-$BaTiO_3$ pseudocubic polymorph. They thus demonstrated that the intricate magnetism of the hexagonal phase is not intrinsic, but is rather due to sparse strain-induced pseudocubic regions. Their discovery was published in the paper by A. Zorko et al., "Strain-Induced Extrinsic High-Temperature Ferromagnetism in the Fe-Doped Hexagonal Barium Titanate", *Sci. Rep.* **5**, 7703 (2015).

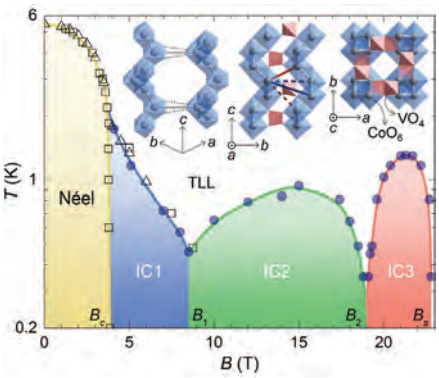

Figure 6: Phase diagram of the system of antiferromagnetic spin chains $BaCo_2V_2O_8$ in a magnetic field applied along the magnetic exchange easy axis.

4. Unconventional superconductivity

Denis Arčon, Peter Jeglič and Anton Potočnik contributed some crucial experimental evidence for a new type of metallic state of matter, discovered by an international team of researchers from England, Slovenia, Japan and Hungary when studying a superconductor made from C_{60} molecules. The team found the new state after changing the distance between the neighbouring C_{60} molecules by doping the parent Cs_3C_{60} compound with rubidium. The study reveals that the material has a remarkably rich combination of insulating, magnetic, metallic and superconducting phases – including the hitherto unknown state, which the researchers have dubbed a "Jahn–Teller metal". These studies are extremely important for our understanding of how superconductivity evolves in cases when several degrees of freedom are intertwined – in our case these are electronic, spin and molecular degrees of freedom. The article has been published in *Science Advances* (Zadik et al., *Sci. Adv.* **1**, e1500059 (2015)), a new research journal of *AAAS (Science)*, and has been picked up by several news

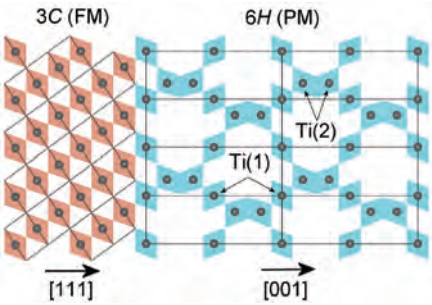

Figure 7: Schematic interface of the two crystallographic phases in $BaTiO_3$, the pseudocubic (3C) and the hexagonal (6H) crystallographic polymorphs. High-temperature ferromagnetism (FM) is ascribed to sparse regions of the 3C phase, while the majority 6H phase remains paramagnetic (PM).

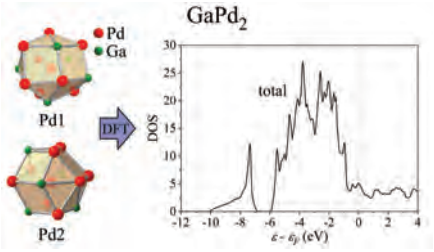

Figure 8: Structure of GaPd2 and the electronic density of states.

outlets, including physicsworld.com. Moreover, the article was ranked as the 6th most viewed article in this journal in 2015.

Peter Jeglič, Martin Klanjšek and Denis Arčon studied a hyper-interlayer-expanded FeSe-based material with a very high superconducting critical temperature T_c = 45 K. The study, a joint investigation between several groups from Japan and Slovenia, revealed a complete decoupling of the interlayer units from the conduction electrons in FeSe layers, the non-negligible concentration of Fe impurities present in the insulating interlayer space, and most importantly, the absence of the electronic nematic order and spin fluctuations down to T_c. Despite these findings, the results imply that the Cooper pairing is mediated by spin fluctuations. The study has been published in M. Majcen Hrovat et al., *Phys. Rev. B* **92**, 094513 (2015).

5. Complex metallic alloys

M. Klanjšek, M. Krnel, S. Vrtnik, P. Koželj, A. Jelen and J. Dolinšek studied an interesting intermetallic compound $GaPd_2$ using a combination of thermal, electrical and magnetic property measurements, and nuclear magnetic resonance. The compound, which represents a highly selective catalytic material for the semi-hydrogenation of acetylene, was studied in the single-crystal morphology as well as in the nanoparticle morphology, which is used in catalysis. They found that the electronic properties of the compound are not much different in both morphologies, while the behaviour of the compound is very similar to the behaviour of the related compound GaPd. The work is published in the paper by M. Wencka et al., "Physical properties of the $GaPd_2$ intermetallic catalyst in bulk and nanoparticle morphology", *Intermetallics* **67**, 35 (2015).

6. Study of nanostructured materials and materials with a large electrocaloric effect and its application in a solid-state cooling device

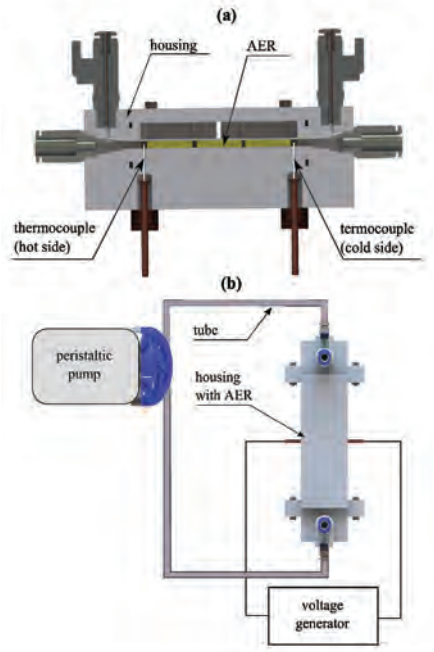

Figure 9: Prototype of electrocaloric cooling device based on the regeneration principle. The regenerator block is presented in (a), here AER denotes the ceramic electrocaloric elements. The complete device is shown in (b).

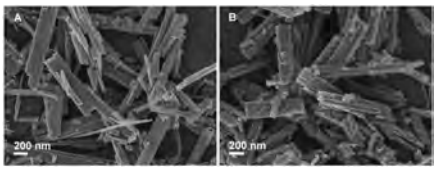

Figure 10: SEM images of TiO_2 nanoribbons transformed from protonated titanate nanoribbons with calcination in air (a) and hydrothermal treatment in water (b).

Using direct measurements we demonstrated the existence of the positive and negative electrocaloric effects in antiferroelectric material doped with barium. With indirect and direct experiments, we showed a large electrocaloric effect in lead-free ferroelectric relaxors. First, we made, in cooperation with the Engineering Faculty, a working prototype of an electrocaloric solid-state cooling device that is based on ceramic cooling elements and does not use cooling gases. We were invited to write an article about the electrocaloric effect in the distinguished Wiley Encyclopedia of Electrical and Electronics Engineering. The above results have been published in 11 articles in international scientific journals (e.g. U. Plaznik et al., *Appl. Phys. Lett.*, 2015, vol. 106, pp. 1-4; B. Asbani et al., *Appl. Phys. Lett*, 2015, vol. 106, pp. 042902-1-042902-4; J. Korzua et al., *Appl. Phys. Lett.*, 2015, vol. 106, pp. 202905-1-202905-4) and an article in an encyclopaedia (Z. Kutnjak et al.: "Electrocaloric effect : theory, measurements, and applications. *Wiley Encyclopedia of Electrical and Electronics Engineering*." 2015, pp. 1-19). Recently published works on electrocalorics and the stabilization of the TGB and blue phases have been cited more than 100 times in 2015 alone.

Large electrocaloric effect in grain-size-engineered ceramics

We have shown that a substantial enhancement of the electrocaloric (EC) effect can be achieved with a properly engineered ceramic microstructure. In particular, a significant impact of the grain size on the EC effect in the $0.9Pb(Mg_{1/3}Nb_{2/3})O_3$–$0.1PbTiO_3$ system was demonstrated. The single-phase perovskite ceramics with grain sizes ranging from 2.8 to 9.4 μm were prepared. The largest EC coefficient was obtained for ceramics with 5.8 μm grains, as a consequence of its large saturation polarization. The EC response is limited by the breakdown strength of the material, which is higher than 160 kV/cm for the fine-grained ceramics. For the material with a 98 % relative density and 3.6-μm grains, a large EC temperature change of 3.45 K was achieved, which is the highest reported value so far for Pb-based perovskites and is comparable to best results obtained by multi-critical-point enhancement. The findings were published in a paper by M. Vrabelj et al., "Large electrocaloric effect in grain-size-engineered $0.9Pb(Mg_{1/3}Nb_{2/3})O_3$–$0.1PbTiO_3$ ceramics", *J. Eur. Ceram. Soc.* 36, 75 (2016).

7. Synthesis and physical properties of nanomaterials

Melita Rutar, Matej Pregelj and Polona Umek have together with partners from the Slovenian National Building and Engineering Institute, the University of Ljubljana and the University of Mons studied the impact of reaction conditions on the photocatalytic properties of TiO_2 nanoribbons (NRs). The TiO_2 NRs were synthetized from protonated titanate nanoribbons (HTiNRs) under different reaction conditions in order to improve the photocatalytic activity of the TiO_2 NRs. The transformation from HTiNRs to TiO_2 NRs was performed with calcination in air or a reductive NH_3 atmosphere, and

with hydrothermal treatment in water or NH_3(aq). The key factors that influence the material's photoactivity are the crystal phase, the degree of crystallinity, the specific surface area and the width of the bandgap. A calcination in the air provided anatase NRs with the highest crystallinity. A transformation under hydrothermal conditions resulted in an increase of the specific surface area of the material, and reactions in NH_3 media (atmosphere or aqueous solution) led to N-doping. The photocatalytic activity of the products was evaluated from the photo-oxidation of the isopropanol to acetone. The best results were obtained from the anatase NRs that were firstly hydrothermally transformed from HTi NRs in water and were additionally calcinated in air. With this we synthetized anatase NRs with an increased specific surface area and high crystallinity. N-doping led to light absorption also in the visible region; however, the photocatalytic activity was supressed as the doping sites acted also as recombination sites. The work was published in a paper by M. Rutar et al., *Belstein J. Nanotechnol.,* 6, (2015), 831.

Melita Sluban, Polona Umek and Denis Arčon performed, in collaboration with colleagues from the JSI and partners from Belgium, France and Germany a synthesis study of titanium oxyntride nanostructures. In this study the authors demonstrated that the slow anion diffusion in anion exchange reactions can be efficiently used to tune the disorder strength and the related electronic properties of nanoparticles. This paradigm was applied to the high-temperature formation of titanium oxynitride nanoribbons, Ti(O,N), transformed from hydrogen titanate NRs in an ammonia atmosphere. The nitrogen content, which determines the chemical disorder through a random O/N occupancy and ion vacancies in the Ti(O,N) composition, increases with the reaction time. The presence of disorder has important effects on the resistivity of Ti(O,N) NRs. Atypically for metals, the resistivity increases with decreasing temperature due to the weak localization effects. From this state superconductivity develops below considerably or completely suppressed critical temperatures, depending on the disorder strength. Their results were published in a paper by M. Sluban et al., "Controlling disorder and superconductivity in titanium oxynitride nanoribbons with anion exchange", *ACS nano,* 9 (2015), 10133.

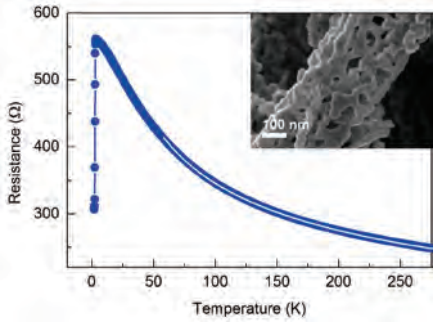

Figure 11: Temperature dependence of resistivity of superconducting titan oxynitride nanoribbons. Inset: SEM image shows a mesoporous structure of a titan oxynitride nanoribbon.

With partners from Spain, Belgium and Germany, Polona Umek collaborated in research on a gas-sensitive hybrid material consisting of Cu_2O nanoparticle-decorated WO_3 nanoneedles. The material was successfully grown for the first time in a single step via aerosol-assisted chemical vapour deposition. Morphological, structural, and composition analyses show that our method is effective for growing single-crystalline, n-type WO_3 nanoneedles decorated with p-type Cu_2O nanoparticles at moderate temperatures (i.e., 380 °C), with cost effectiveness and short fabrication times, directly onto micro-hot-plate transducer arrays with a view to obtaining gas sensors. The gas-sensing studies performed show that this hybrid nanomaterial has excellent sensitivity and selectivity to hydrogen sulphide (7-fold increase in response compared with that of pristine WO_3 nanoneedles) and a low detection limit (below 300 ppb of H_2S), together with unprecedented fast response times (2 s) and high immunity to changes in the background humidity. The results were published in the paper by F. E. Annanouch et al., "Aerosol assisted CVD grown WO_3 nanoneedles decorated with copper oxide nanoparticles for the selective and humidity resilient detection of H_2S", *ACS applied materials & interfaces,* 7(2015), 6842.

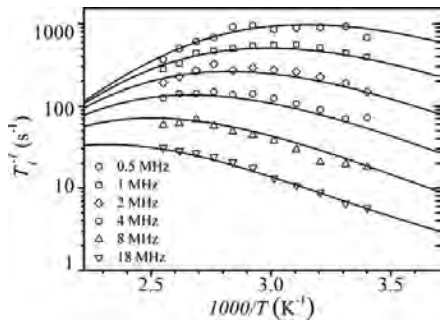

Figure 12: Proton spin-lattice relaxation dispersion in a $Zr_{69.5}Cu_{12}Ni_{11}Al_{7.5}$ quasicrystal.

8. Hydrogen dynamics in $Zr_{69.5}Cu_{12}Ni_{11}Al_{7.5}$ hydrogen storage alloy

We studied the hydrogen dynamics in a partially quasicrystalline hydrogen/storage alloy $Zr_{69.5}Cu_{12}Ni_{11}Al_{7.5}$ by a combination of fast-field-cycling nuclear magnetic relaxometry and diffusometry in a static fringe field. We demonstrate that proton spin–lattice relaxation cannot be explained using a single activation energy for the proton hopping between the interstitial sites. Instead, the behaviour is better explained using a Gaussian distribution of activation energies, with the average value closely matching the one obtained in independent direct diffusion measurements. Knowing the diffusion constant and the correlation times for proton jumps, we can directly estimate the average jump length. The findings were published in a paper by A. Gradišek and Apih, T, "Hydrogen dynamics in partially quasicrystalline $Zr_{69.5}Cu_{(12)}Ni_{(11)}Al_{(7.5)}$: fast field cycling relaxometry study", *The Journal of Physical Chemistry C*, vol. 119, no. 19, 10677-10681.

9. Quantitative Analysis of Hydration Using ^{14}N Nuclear Quadrupole Resonance

In the paper by A. Gregorovič, *Anal. Chem.* 87, 6912-6918, 2015, we present the use of ^{14}N NQR spectroscopy to quantitatively analyse the hydration of a model compound 5-aminotetrazole. This method utilizes the fact that by hydrating a molecular crystal we shift the characteristic ^{14}N NQR frequency by a large amount (~ 100 kHz) so that the anhydrate and the hydrate resonances are easily distinguished in the spectrum of a partially hydrated compound. Thus, the spectrum can be used to determine the integral intensities of the two peaks that are directly proportional to the amounts of each phase. ^{14}N NQR has several advantages over other techniques used to study hydration (like

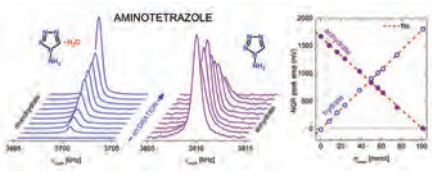

Figure 13: (left, centre) The ^{14}N NQR spectrum of aminotetrazole and its hydrate for several samples with a different degree of hydration. (right) Correlation between the water amount in the samples obtained with ^{14}N NQR and by heating to constant mass.

XRD, NIR, ^{35}Cl NQR, etc.). First, the ^{14}N NQR spectrum is very simple, and second, a single-point calibration is also sufficient. On the other hand, the method's great disadvantage is low sensitivity, which limits the use of the technique to large samples. Nevertheless, we have achieved accuracies <1% for samples whose temperature was carefully stabilized by extending the experimental time.

10. Polymer-dispersed liquid-crystalline elastomers

We have developed polymer-dispersed liquid-crystal elastomers (PDLCE) with a composite structure of aligned liquid-crystal elastomer (LCE) microparticles embedded in a conventional elastomer matrix. These composites exhibit an increased thermomechanical response, in analogy to the increase of the electric conductivity in polymers doped with conductive particles. We have demonstrated that, by aligning the LCE microparticles in the magnetic field during the polymerization phase, structures with arbitrary spatial configurations of thermomechanical anisotropy can be prepared, which determine the mechanical deformation mode during thermal actuation of the specimen. Based on our discoveries, we applied for the patent "Polymer dispersed liquid crystal elastomers (PDLCE)", A. Rešetič et al., PCT/EP2015/055527, publication number WO2015/140149 A1, publication date 24 September 2015.

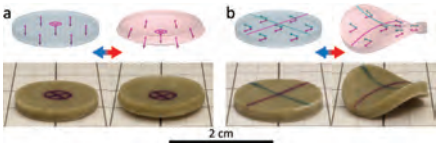

Figure 14: Thermal actuation of PDLCE samples with a double-layer configuration of LCE microparticles: a) out-of-plane alignment in the bottom layer, no alignment in the top layer, resulting in a concave deformation and b) in-plane alignment with crossed directors, resulting in a saddle-like deformation of the specimen on heating.

After the linear and particularly nonlinear dielectric experiments revealed that ferroelectric and relaxor states coexist in blends of relaxor P(VDF-TrFE-CFE) terpolymer and ferroelectric P(VDF-TrFE) copolymer (such a coexistence strongly enhances the electrocaloric response of a system), differential scanning calorimetry confirmed that both components form separate crystalline phases. Moreover, calorimetric experiments revealed the influence of blending on the crystallinity and melting points of both components. Finally, the relative crystallinity data, obtained from the normalized enthalpy changes during melting, appropriately explain the variation of the dielectric constant in developed blends. The findings were published in a paper by G. Casar et al., "Impact of structural changes on dielectric and thermal properties of vinylidene fluoride-trifluoroethylene-based terpolymer/copolymer blends", *Physica B: Condens. Matter* 461, 5 (2015).

11. Unusual structural-disorder stability of mechanochemically derived $Pb(Sc_{0.5}Nb_{0.5})O_3$

Relaxors are of great interest for a wide range of applications as they exhibit high dielectric and electromechanical responses over broad temperature ranges as well as a large electrocaloric effect. In collaboration with the Electronic Ceramics Dept., the Institute of Chemistry, and researchers from France, Austria, and the USA, we have demonstrated the important effect of processing on the B-site ordering in well-known relaxor $Pb(Sc_{0.5}Nb_{0.5})O_3$ ceramics. In contradiction to previous observations on ceramics prepared from solid-state synthesis powders, which show a distinctive B-site cation ordering when annealed below 1200 °C, in mechanochemically derived ceramics sintered much below this temperature, no such ordering was observed, regardless of the thermal post-annealing conditions. Accordingly, atomic-scale transmission electron microscopy revealed nanometre-sized B-site ordered regions in mechanochemically derived ceramics, in contrast to the larger regions extending through the whole grains in a solid-state-derived system. The results of the work have established an understanding of the relationship between the synthesis method, the B-site cation ordering in the relaxor ceramics, and its functional properties, particularly the dielectric response and electrical polarization. The findings were published in a paper by H. Uršič et al., "Unusual structural-disorder stability of mechanochemically derived- $Pb(Sc_{0.5}Nb_{0.5})O_3$", *J. Mater. Chem. C* 3, 10309 (2015).

12. Pharmaceutical substances

^{14}N NQR represents a useful tool to characterize pharmaceutical substances and the method of their preparation. In combination with quantum chemical calculations the electronic structure of these molecules and the properties of the functional groups can be determined. These discoveries were published in a paper by J. N. Latosińska et al. "Unusual case of desmotropy. Combined spectroscopy (^{1}H-^{14}N NQDR) and quantum chemistry (periodic hybrid DFT/QTAIM and Hirshfeld surface-based) study of solid dacarbazine (anti-neoplastic)", *Solid State Nuclear Magnetic Resonance* 68-69, 13–24 (2015).

The antineoplastic chemo-therapeutic drug 5-(3,3-dimethyl-1-triazenyl)imidazole-4-carboxamide (Dacarbazine, DTIC) has been studied experimentally in the solid state by ^{1}H-^{14}N NQDR double resonance at 295K and theoretically by the Density Functional Theory (DFT)/ Quantum Theory of Atoms in Molecules (QTAIM) and Hirshfeld surfaces analysis. Only one set of eighteen resonance frequencies was found in the experiment. This indicates the presence of six non-equivalent nitrogen sites: $-N(CH_3)$, $-NH_2$, -NH- and three -N= (of which one is a ring, two are from triazene) in the DTIC molecule. This contradicts the X-ray data, which revealed the multiplication of nitrogen sites due to unusual desmotropism. The averaging of the NQR frequencies caused by the fast NQR time-scale exchange of protons in a double-well potential combined with the oscillations of twisted supramolecular synthons was proposed

as a potential mechanism responsible for this apparent contradiction. An effective improvement in the quality of the spectrum reproduction was achieved when the calculations were performed assuming the periodic boundary conditions, BLYP functional, the DNP basis set and taking the 3×3×3 k-point separation. The ordering of the nitrogen sites according to the increasing quadrupole coupling constant (QCC):N(3)<N (2)<N(6)<N(1)<N(4)<N(5) reflects the metabolic pathway of DTIC. Two sites N(5) and N(4) with the highest QCC are responsible for the first step – conversion to MTIC (5-[3-methyl-triazen-1-yl]-imidazole-4-carboxamide) required for effective processes of binding dacarbazine to DNA (demethylation of N(5)), and the second step – fast conversion of MTIC to 5-amino-1H-imidazole-4-carboxamide (AIC; remove – N(4)-N(5)HCH_3). N(5) does not participate in any, while N(4) participates in a weak C(2)H···N(4) interaction that can be readily broken. The four remaining nitrogen atoms N(1), N(2), N(3) and N (6) participate in strong intermolecular N(1)H···N(2) and intramolecular N(3)–H···N(6) bonds, which stiffen the crystalline structure. These findings were published in a paper by J. N. Latosińska et al., "Impact of structural differences in carcinopreventive agents indole-3-carbinol and 3,3'-diindolylmethane on biological activity. An X-ray, ^{1}H–^{14}N NQDR, ^{13}C CP/MAS NMR, and periodic hybrid DFT study", *European Journal of Pharmaceutical Sciences* 77, 141–153 (2015).

Three experimental techniques ^{1}H–^{14}N NQDR, ^{13}C CP/MAS NMR and X-ray and Density Functional Theory (GGA/BLYP with PBC) and Hirshfeld surfaces were applied for the structure–activity-oriented studies of two phyto-antioxidants and anticarcinogens: indole-3-carbinol, I3C, and 3,30-diindolylmethane, DIM, (its bioactive metabolite). One set of ^{14}N NQR frequencies for DIM and I3C was recorded. The multiplicity of the NQR lines reveal the high symmetry (chemical and physical equivalence) of both the methyl indazole rings of the DIM. Carbonyl ^{13}C CSA tensor components were calculated from the ^{13}C CP/MAS solid-state NMR spectrum of I3C recorded under fast and slow spinning. At room temperature the crystal structure of I3C is orthorhombic: space group Pca21, Z = 4, a = 5.78922(16), b = 15.6434(7) and c = 8.4405(2) A. The I3C molecules are aggregated into ribbons stacked along [001]. The oxygen atoms are disordered between the two sites of different occupancy factors. It implies that the crystal is built of about 70% trans and 30% gauche conformers, and apart from the weak O-H–O hydrogen bonds (O–O = 3.106 A) the formation of alternative O'-H–O bonds (O'–O = 2.785 A) is possible within the 1D ribbons. The adjacent ribbons are further stabilised by O'-H–O bonds (O'–O = 2.951 A). The analysis of spectra and intermolecular interactions pattern using experimental techniques was supported by solid (periodic) DFT calculations. The knowledge of the topology and competition of the interactions in the crystalline state shed some light on the preferred conformations of -CH_2OH in I3C and the steric hindrance of methyl indole rings in DIM. A comparison of the local environment in the gas phase and the solid permitted drawing some conclusions on the nature of the interactions required for effective processes of recognition and binding for a given anticarcinogen to the protein or nucleic acid.

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

The investigations of the research program "Physics of Soft Matter, Surfaces, and Nanostructures" are focused on novel complex soft-matter systems and surfaces with specific functional properties. We investigated in particular liquid-crystalline elastomers and dendrimers as novel multifunctional materials, nematic colloids, molecular motors, soft-matter photonic crystals and novel synthetic or self-assembled micro- and nano-structures. The aim of the program is to understand the 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 program combines both experimental and theoretical investigations, supported by modelling and simulations. Special emphasis is given to the possible electro-optic and medical applications.

The group explored topological defects and their topological charge as well as the topology of knots and links in liquid crystals. We studied the ultrafast optical response of soft matter and molecular motors. We explored new types of nanowires and the surfaces of superconductors at the single-atom level.

Light-controlled topological charge in a nematic liquid crystal

Like the electric charges in electromagnetism, topological charges are sources of a physical field, which are observable in superconductors, superfluids, cold atoms, ferromagnetic materials and even light. Whereas in these systems the topological charge is difficult to create and control, it is an easy task to create and manipulate topological charges in liquid crystals. Here, the topological charge is attributed to topological defects, which are singularities of the orientational field describing the liquid-crystal alignment. In a paper entitled "Light-controlled topological charge in a nematic liquid crystal", published by M. Nikkhou et al. in *Nat. Phys.* 11, 183 (2015), the authors demonstrated full control over the creation, manipulation and analysis of topological defects that are pinned

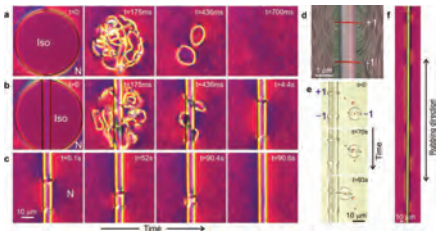

Figure 15: Creation and annihilation of topological charges on a fibre. (a) The NLC is heated into the isotropic phase by the strong light of the laser tweezers, thus creating an isotropic island (Iso). At t = 0 the light is switched off and the NLC is quenched into the nematic phase (N). The dense tangle of defects annihilates in less than a second. (b) The NLC is quenched from the isotropic island surrounding a fibre. A pair of defects is created, each carrying an opposite topological charge. (c) If let free, the pair annihilates into the vacuum. (d) LdG simulation of the Saturn ring and the Saturn anti-ring with opposite charges and windings. (e) The sign of the charge is tested using the repulsive force between like topological charges. (f) An arbitrary number of ring–anti-ring pairs can be created on a fibre. Images (a–c, f) were taken between crossed polarisers and the red plate that shows the average molecular orientation in different colours.

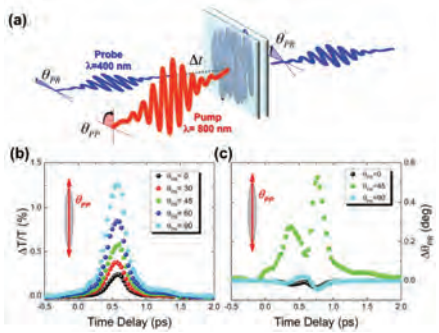

Figure 16: Scheme of the pump-probe experiment and time dependence of the optically induced birefringence.

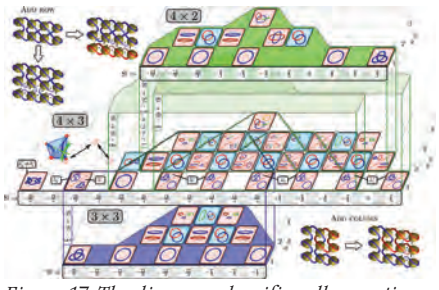

Figure 17: The diagram classifies all nematic disclination configurations (from simple loops to links and knots) on a 4 × 3 colloidal grid, with marked structures that are just extensions of structures on sub-grids of dimensions 3 × 3 (blue outline) and 4 × 2 (green outline).

to a microfibre immersed in a nematic liquid crystal. Using the laser tweezers, they created pairs of defects carrying opposite topological charges, which were manipulated and moved by the force of the laser tweezers. They observed long-lived pairs of oppositely charged rings or points that either attracted and annihilated, or formed long-lived, charge-neutral loops made of two segments with a fractional topological charge (Figure 15).

In a follow-up publication entitled "Topological binding and elastic interactions of microspheres and fibres in a nematic liquid crystal" published by Nikkhou, Škarabot and Muševič in *Eur. Phys. J.* E 38, 15023-6 (2015), the authors present an analysis of the topological binding of microspheres to a fibre in a nematic liquid crystal. They observed the entanglement and topological charge interaction between the various types of defects on the ring and microspheres and observed strong pair-interaction forces. These forces were explained with a simple topological rule: like topological charges repel each other and opposite topological charges attract. This article was highlighted in the *European Physical Journal* published in September 2015 and the cover image of that issue was taken from this article.

Topological defect transformation across the nematic-to-smectic-A phase transition

We studied the topological defects associated with small microspheres with perpendicular surface anchoring of the liquid-crystal molecules across the nematic-to-smectic-A phase transitions. Because the topological defects are regions of strong electric deformation, it is expected that any variation in the elastic constants should strongly influence the defect structure. We observed that a nematic hyperbolic hedgehog defect, which accompanies a microsphere in a nematic liquid crystal, is gradually transformed into a focal conic line in the smectic-A phase.

This defect transformation has a strong influence on the structural force between a pair or several colloidal particles in the nematic and smectic-A phase. The pre-transitional behaviour of the defect is well supported by the Landau-de Gennes numerical modelling published in *Physical Review E* 92, 052501(2015) by Zuhail et al. The transformation of the Saturn ring defects associated with spherical microparticles across the nematic-to-smectic-A phase transition were studied by Zuhail et al. and published in Physical Review E 92, 052501(2015). It was observed that the director structure around each microparticle changes rapidly with temperature and has a strong impact on the pair-interaction colloidal forces. The onset of the smectic order influences not only the interparticle separation but also the angular dependence. As a consequence, 2D colloidal crystals are not stable in the smectic-A phase as the crystal dissolves irreversibly across the nematic–smectic-A transition.

Ultrafast control of light by light in a nematic liquid crystal

A significant advancement was achieved with respect to the ultrafast all-optical response of a nematic liquid crystal. Two important experiments were reported by our group in 2015, in two publications in *Optics Express*. In collaboration with Radboud University, Nijmegen, the Netherlands, we measured the ultrafast optical response of a nematic liquid crystal, which is induced by an intense femtosecond optical impulse. It was observed in a pump-probe experiment (Figure 16), that a 100 fs optical pulse induces changes of the refractive index of the nematic liquid crystal, which are as fast as 500 fs. This is due to the optical Kerr effect and refractive-index changes of the order of 10^{-4} were observed at a fluence of 4 mJ/cm^2. The effect is strongly polarisation dependent and opens up new routes to all-optical liquid-crystal photonics. Published by Cattaneo et al., *Optics Express* 23, 14010 (2015).

Nanosecond control of light by stimulated emission depletion in a liquid crystal

Stimulated emission depletion is used in STED microscopes to achieve the super-resolution of an optical microscope by manipulating the fluorescence emissions from dye molecules dissolved in a material. We have used the STED technique to control the emission of light in the smectic-A and nematic liquid crystal and observed strong attenuation of the optical signals on the nanosecond timescale. The STED effect is strongly polarisation dependent in liquid crystals because of the orientational order of fluorescent dies. This allows for gigahertz control of light, including light-gating and optical pulse-shaping with sub-nanosecond resolution. Published by Vitek and Muševič in *Optics Express* 23, 16921 (2015).

Knot-theory realizations in nematic colloids

Knot theory is a branch of topology that deals with the study and classification of closed loops in 3D Euclidean space. The creation and control of knots in physical systems is the pinnacle of technical expertise, pushing forward state-of-the-art experimental approaches as well as a theoretical

understanding of the topology in a selected medium. We showed how several abstract concepts manifest elegantly as observable and measurable features in nematic colloids with knotted disclination lines. The construction of medial graphs, surfaces, and Jones polynomials (Figure 17) was showcased directly on experimental images, and adapted for the specific system of colloidal crystals in a twisted nematic cell. Discussing the correspondence between topological concepts and experimental observation is essential for building the bridge between mathematical and physical communities. (S. Čopar et al., "Knot theory realizations in nematic colloids", *Proc. Natl. Acad. Sci.* 112, 1675 (2015)).

Templated blue phases

Microscopic properties of templated liquid-crystal blue phases were demonstrated. Specifically, the role of surface anchoring on the microscopic ordering was explored, showing novel liquid-crystalline structures. The predicted structures exhibit the Kerr constant, which is several times larger than currently known in these materials, making templated blue phases interesting for optic and photonic applications. The work was performed as part of the Japanese JSPS Short-term invitation fellowship (M. Ravnik, 1.5 months), which was also the basis for a series of 9 invited seminars across Japan (Tokyo, Kyoto, Osaka, Kyushu, AIST). The paper (M. Ravnik and Jun-ichi Fakuda, "Templated blue phases", *Soft Matter* **11**, 8417 (2015)) was also announced by the inside cover of the Soft Matter journal (Figure 18).

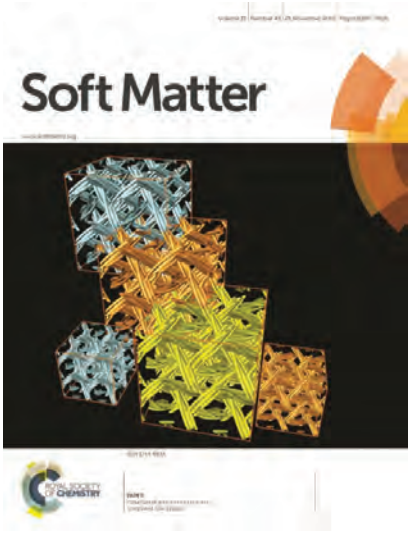

Figure 18: Templated blue phases as a new photonic material, which is based on the micro-organisation of a nematic liquid crystal. The figure is the inside cover of one of the November issues of Soft Matter.

Topological defects within nematic shells

We have studied theoretically and numerically the impact of curvature on the position and the number of topological defects (TDs) in orientational ordering in effectively two-dimensional (2D) films. We used a 2D Landau-type mesoscopic approach, which we developed in 2013, in terms of nematic tensor order parameter. For illustrative purposes we considered mostly cylindrically symmetric dumb-bell and toroidal geometries. We demonstrated that curvature can impose geometric frustration, which enforces topological defects (Figure 19). Furthermore, interactions between the TDs in 2D display remarkable similarity with electrostatic interactions among the electric charges. Using the electrostatic analogy we derived a critical curvature induced condition at which pairs (defect, anti-defect) are created. The results are interesting both from the fundamental perspective as well as for potential applications in nano-photonics. The results were presented in several publications and in a plenary conference lecture. The key paper was D. Jesenek et al., *Soft Matter Soft* **11**, 2434–2444 (2015).

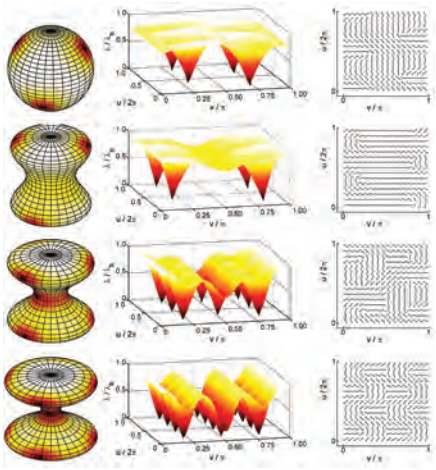

Figure 19: Curvature-induced unbinding of topological defects in nematic shells. Geometry of the shells (the 1st row) and the corresponding order parameter (the 2nd row) and mesoscopic molecular field (the 3rd row) spatial variations.

New method of realignment in liquid-crystal displays

A new method for the realignment of nematic liquid crystals in surface-stabilized displays was presented. The realignment is carried out by controlled movement of an IR laser beam, which reorients LC molecules and consequently the aligning polymer layer due to the surface-memory effect. (G. Mirri et al., *Soft Matter*, 11, (2015), 3347). This method can be separately applied to both substrates of a LC display in different directions and small homogenous and twist-nematic domains can be created in planar cells (Figure 20).

Stability of nanometre-sized colloidal liquid-crystal dispersions

We studied the motion of individual 20-nm nanoparticles in a nematic liquid crystal using dark-field microscopy and analysed particle pair interactions (Figure 21). We have shown that the stability of the dispersion of nanoparticles in a LC is a result of the balance of an attractive LC-mediated elastic force with a very weak interaction potential (below 10 k_BT) and a repulsive electrostatic force, which prevents the formation of permanent colloidal assemblies of a nanometre size (A. Ryzhkova et al., *Phys. Rev. E*, 91, (2015), 042505).

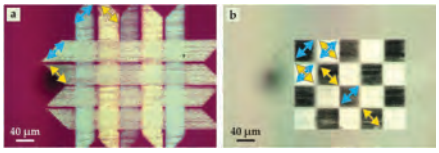

Figure 20: LC realignment in a planar cell. (a) For one substrate alternating rows with molecular orientations of 45° and -45° with respect to the original horizontal LC alignment (blue and yellow arrows) were imprinted by laser realignment. For the other substrate, alternating columns of 45° and -45° were imprinted. (b) When the cell is backlit and viewed between crossed optical polarizers, the squares with a parallel orientation appear dark and the squares with a perpendicular orientation appear bright.

Molecular motors

In 2015 we investigated the hydrodynamic synchronization of autonomous oscillators in collaboration with researchers from the University of Ljubljana. As oscillators we used ellipsoidal particles, which can spontaneously oscillate in a focused laser beam. We have shown that two particles in general synchronize in-phase and that the level of synchronization is stronger when the particles are arranged parallel to the direction of oscillations rather than perpendicular. In a narrow parameter range, anti-phase synchronization is also possible. A longer chain of oscillators shows correlations, but no complete synchronization of all the particles (Figure 22). We explained the results by describing the oscillating particles with a simple phenomenological model and calculating the hydrodynamic coupling numerically using a boundary-element method. Our study shows that

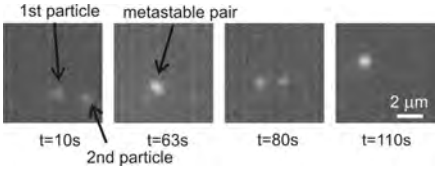

Figure 21: Formation of a metastable pair of 20-nm silica particles in a nematic liquid crystal observed by dark-field microscopy.

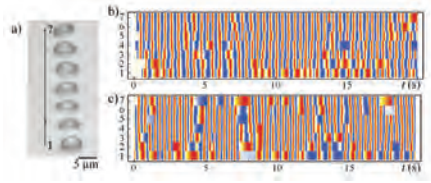

Figure 22: a) A chain of 7 autonomous oscillators in a row. b) Measured phase profile of oscillations. c) Result of the theoretical model.

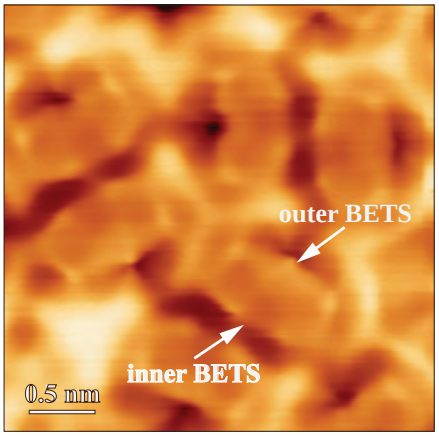

Figure 23: High-resolution STM image showing details with the organic BETS molecules packed into a Kagome lattice on the Ag(111) surface (10.5 × 10.5 nm², T=1.1K, functionalized tip).

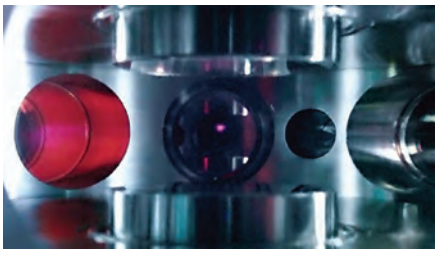

Figure 24: View through one of the viewports into the UHV chamber, where due to fluorescence light about 50 million cold Cs atoms can be seen as a small pink ball.

self-oscillating particles can act as a model system for the synchronization between biological cilia. Although several model systems for hydrodynamic synchronization were published previously, ours was the first to use truly autonomous microscopic oscillators. The results were published in *Physical Review E (Rapid Communication)*, where the paper was also highlighted as the Editor's suggestion.

MoO_3 nanowires and nanotubes

We synthesized MoO_3 nanowires and nanotubes from $Mo_6S_2I_8$ nanowires via oxidation in air. The orthorhombic α-MoO_3 phase has been determined from XRD data and Raman spectroscopy. The porosity of the nanowires and faceting tendency of the nanotubes were explained by the density and molar mass change during oxidation and the layered structure of α-MoO_3, respectively. An additional broad Raman band at 1004 cm^{-1} was clearly observed and attributed to missing oxygen. An EPR investigation showed that the extent of oxygen deficiency is large enough for the appearance of crystal shear planes typical for Magneli phases (A. Varlec et al., *Materials Chemistry and Physics* 170 (2016) 154-161), which strongly influence the physical properties of these nanomaterials. A high specific surface (14.3 m2/g) and water solubility enable the application of these nanomaterials in anti-bacterial coatings.

MoS_2 nanotubes in field-effect transistors

MoS_2 nanotubes and nanoribbons synthesized by a chemical transport reaction two decades ago at the JSI found their application in a new generation of field-effect transistors (FETs) due to the very low density of structural defects. Devices demonstrated n-type characteristics with ON/OFF current ratios of more than 10^3, greatly exceeding the best prior report of 60 in the MoS_2 nanotubes prepared in other ways. Current densities were 1.02 μA/μm and 0.79 μA/μm at V_{DS}=0.3V and V_{BG}=1V, respectively. Photocurrent measurements conducted on a MoS_2 nanotube FET using Ti/Au contacts revealed a short-circuit photocurrent of tens of nano-amps under an excitation optical power of 78 μW and a 488-nm wavelength, which corresponds to a responsivity of 460 μA/W (S. Fathipour, et al., Applied Physics Letters 106 (2015) 022114).

Nanoscale organic superconductors

The ability to fabricate crystalline monolayers of confined superconducting condensates on surfaces is a key issue to realize new functionalities and understand the nature of competing orders in these materials at the nanoscale. The epitaxial growth of insulating or superconducting monolayer islands of an organic charge-transfer salt $(BETS)_2GaCl_4$ on Ag(111) has been achieved at various growth temperatures. Below 125 K the BETS molecules form chain-like or regular two-dimensional networks. Above 125 K, the BETS dimers start to alternate regularly along the three equivalent orientations of the <110> packing directions, forming an insulating Kagome lattice with a triangular nanoporous network (Figure 23). When the deposition is carried out at room temperature and at low deposition currents (monolayer) islands showing a superconductive gap in the density of states are grown (A. Hassanien et. al, *Phys. Stat. Sol. (B)*, 252 (2015), 2574).

Ultra-cold atoms

For the first time Cs atoms were trapped and cooled in the Laboratory for Cold Atoms. Using 852-nm laser light hot Cs atoms are first slowed down and then trapped in a magneto-optical trap using a quadrupole magnetic field (Figure 24). In a process called Raman sideband cooling their temperature is decreased to below 500 nK. In the next steps these atoms will be loaded into a strong dipole trap where they will be compressed and additionally evaporatively cooled to temperatures below 50 nK. At such low temperatures a transition to the Bose-Einstein condensate will be achieved.

III. Research programme Experimental biophysics of complex systems

In the program "**Experimental biophysics of complex systems**", processes and structures of various complex biological systems are investigated, ranging from model systems to the structures in living cells, tissues and small animals. Investigations also comprise studies of the impact of numerous bioactive substances such as toxins and drugs as well as a variety of materials from materials to medical materials on such biological systems. The research is lately focused on a better understanding of the structure of membrane compartments, domains, proteins, glyco- saccharides clusters, molecular structures of polymer gels, etc. and their interaction, accompanying the interaction of cell structures with new materials that enter into their natural environment. New spectroscopic

and micro-spectroscopic techniques contribute to a better understanding of the organization of these supramolecular systems, complex cellular and tissue responses and open up new possibilities for the design of medical materials, especially for tissue regeneration, which is one of the main health issues among the aging population of the developed world. In addition, the research field is also directed to optimization methods for the treatment of tumours, magnetic resonance imaging and the mathematical modelling of thrombolysis, and the use of high-resolution magnetic resonance imaging to study materials. This method allows us to study different problems in forestry, the wood industry, and food safety. We expect a lot from the development of new methods for measuring diffusion in porous materials with which we will be able to tell a lot about the microscopic structure of porous materials.

The cell-adhesion dynamics was quantitatively studied via optical-tweezers force-induced displacements of loosely bound cells which reveal that the adhesion strength correlates with the scaffold's polymer molecular mobility and has a direct impact on further cell growth, measured on a scale of days. We have developed new methods to monitor food processing and food quality control based on multiparametric MR imaging. In addition, a new method that allows an accurate determination of the deformation tensor of soft samples has also been developed.

The **cell-material interaction studies**, especially from the viewpoint of bioactivity and biocompatibility, are undoubtedly one of the hottest biophysics research topics. Based on new micro-spectroscopies we efficiently address the problem of nanoparticles and nanofibers uptake into the cell or the model membrane. Uptake into and through the membrane was proven by the FMS-FRET-experiments acquired on model membranes. We also explored the effect of the properties of nanoparticles, such as their size and their surface properties, on the interaction of the nanoparticles with biological systems. As a result, some methods to control the size and the surface properties of the nanoparticles have also been undertaken.

Based on our previous research focused on measuring the impact of the physical properties of 3D porous biopolymer scaffolds as tissue-engineering materials on cell growth, published last year in a journal with an impact factor of 5.9 (*ACS Appl. Mater. Interfaces*, 2014; 6 (18), pp 15980 to 15990), the focus in 2015 was on the interaction between scaffold surfaces and cells in real time. With the **optical-tweezers system** for optical micro-manipulation built within the **confocal fluorescence microscope system**, the adhesion dynamics of the cells on the surfaces of different biocompatible tissue engineering scaffolds with different surface molecular physical properties was investigated (Figure 25). The time window and the dynamics of the adhesion sites' formation on the cell-material interface was quantitatively determined by submicron-resolution, optical-tweezers, force-induced, displacement analysis of a loosely bound cell. It was found that the adhesion strength on the surfaces of different scaffolds correlates with the scaffolds' polymer molecular mobility and has a direct impact on further cell growth, measured on a scale of days. The study was published in a journal with an impact factor of 6.7 (*ACS Appl. Mater. Interfaces*, 2015, 7 (12), pp 6782-6791). The developed experimental system for studying the direct contact of cells with tissue-engineering materials in real time could, with some additional future optimizations, contribute to a better understanding of the biocompatibility of materials, which is one of the main challenges in the field of tissue engineering and regenerative medicine.

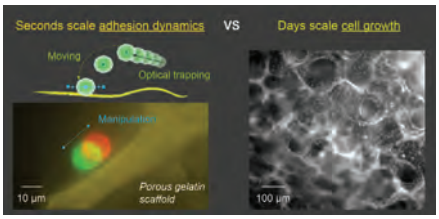

Figure 25: Real-time cell-adhesion dynamics analysis on the surfaces of tissue-engineering scaffolds using optical micromanipulation and fluorescence detection (left) serves as an efficient method for studying scaffolds' biocompatibility (right).

Fluorescence microspectroscopy (FMS) reveals the physical properties of the molecular environment of fluorescent probes. In this respect specific probes can be designed and synthesized to enhance the sensitivity to a particular property, for example, a local pH value. This approach was applied to **study the internalization in dendritic cells** (DCs) the most potent antigen-presenting cells. DC-SIGN, an antigen-uptake receptor in DCs, has a clear **role in the immune response** but can, conversely, also facilitate infection by providing the entry of pathogens to DCs. The key action in both processes is internalization to acidic endosomes and lysosomes. Molecular probes that bind to DC-SIGN could thus provide a useful tool to study internalization and, at the same time, constitute potential antagonists against pathogens. Our strategy, therefore, was to **develop a smart fluorescent probe** with an affinity for DC-SIGN (Figure 26). Two particular properties of the probe were exploited: **activation in a low-pH environment and an aggregation-induced spectral shift**. The results indicate that our probe is successfully internalized in DCs. Moreover, the concentration of the probe increases inside the cells with the time of incubation leading to aggregation. Since the expected spectral shifts due to aggregation are small – in the range of a few nanometres – conventional fluorescence microscopy with broad band-pass emission filters is not an appropriate experimental approach. In contrast, a spectrally highly sensitive FMS method permits the detection of highly precise shapes of emission spectra. In this way, the features of the smart probe could be exploited to monitor its targeting to and aggregation in low-pH cell structures.

In an article published in *PLOSONE* we explored **the role of serum proteins in the phototoxicity of TiO_2 nanoparticles**. We measured the viability of the exposed cells depending on the nanoparticle and serum protein concentrations. Our data indicate that the phototoxicity only becomes substantial when the protein concentration is too low to completely coat the nanotubes' surface. These results imply that TiO_2 nanoparticles should be applied with ligands such as proteins when phototoxic effects are not desired – for example, in the cosmetics industry. On

the other hand, the nanoparticles should be used in a serum-free medium or any other ligand-free medium, when phototoxic effects are desired – like for efficient photodynamic cancer therapy (PLoS One 2015 10 (6):e012957).

Our unpublished results indicate that the formation of a lipid corona is possible, where the nanoparticle is wrapped with a lipid membrane. We hypothesize that such lipid-wrapped nanoparticles may resemble lipid vesicles derived from platelets, usually known as "microparticles". An important characteristic of microparticles is that the key reaction of **blood coagulation** takes place on them, the **activation of factor Xa**. Last year we published our work showing that the regulation of the activity of Factor Xa depends critically on the concentration of calcium in the plasma and that this process is likely to be physiologically important in the initial stage of blood clotting. This year we continued our collaboration with prof. Lentz's laboratory from the University of North Carolina, resulting in another publication in the *Biochemical Journal*, which is one of the world's leading bioscience journals (Impact Factor (2013): almost 5 (ranked 61st out of 291 journals in the Biochemistry and Molecular Biology category, established 1906). We showed that at Ca^{2+} concentrations found in the maturing platelet plug (2–5 mM), fVa can compete fXa off of inactive fXa dimers to significantly amplify thrombin production, both because it releases dimer inhibition and because of its well-known cofactor activity. This suggests a novel, hitherto unanticipated, mechanism by which PS-exposing platelet membranes can regulate the amplification and propagation of blood coagulation (*Biochem. J.* 2015 (467):37).

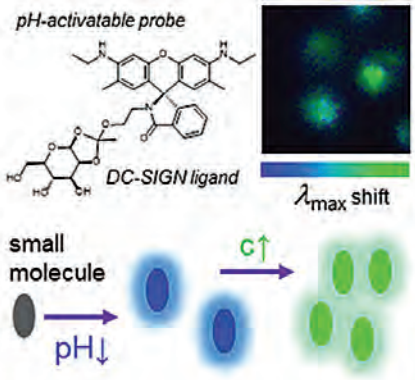

Figure 26: A smart fluorescent probe was synthesized to monitor internalization by the DC-SIGN receptor in dendritic cells (DCs). Its activation and accumulation in low-pH cell structures were spectrally detected. Such molecules could compete with pathogens for binding both outside and inside DCs.

In cooperation with researchers from the Agricultural Institute of Slovenia we published a paper entitled "Use of multiparametric magnetic resonance microscopy for discrimination among different processing protocols and anatomical positions of Slovenian dry-cured Hams." in the journal *Food Chemistry*. The paper deals with the possibility of using new methods of **characterization for the dry-curing process of meat products**, which are based on the use of **multiparametric magnetic resonance (MR) imaging**. More specifically, relaxation time T1 and T2 mapping, and the apparent diffusion constant (ADC) mapping were used to find the differences between two different ham muscles (biceps femoris and semi-membranosus) at two different stages of salting (low and high). In this paper, we showed that the maps can be converted into one-dimensional distributions of the parameters T1, T2 and ADC and in two-dimensional correlations between the parameters ADC-T2, ADC-T1, T1-T2, which show characteristic peaks in the distribution. The location and distribution of these peaks are very sensitive to both types of tissue, as well as the influence of the salting. The characterization was better with a two-dimensional correlation than with one-dimensional distributions. We concluded that these methods having greater accessibility to NMR/MRI systems can serve as an effective tool for monitoring the processing of dry-cured meat products, as well as to control their quality. In the field of MR imaging in food science we have also published an article "MR microscopy for noninvasive detection of water distribution during soaking and cooking and the common bean". The paper deals with the role of water in the soaking and cooking of legumes. The water in the seeds of legumes is bound, and therefore has a short T2 relaxation time, while the surrounding water has a long T2 relaxation time. These two different types of water can be detected by different NMR/MRI methods. In the study we used the SPI method to detect the bound water and the RARE method to detect free water. Both methods were used for dynamic imaging, so that we were able to monitor the changing role of water in the process of soaking and cooking the seeds.

We developed a method for **high-resolution MR imaging of mechanical deformations**. The method is based on the use of the pulsed magnetic field gradients that can encode the initial (before deformation) and the final (after deformation) position of each volume element of the studied sample. It turns out that the difference in the positions is proportional to the phase shift of the signal (Figure 27). With this method we measured the strain tensor of the gelatin sample. In addition to the pulse sequence we also developed a special deformational device that was used to dynamically trigger a sample deformation of the desired magnitude. The device had to perform sample deformations synchronously with the imaging sequence. The method was presented in an article "Magnetic Resonance Imaging of mechanical deformations" published in the journal *Magnetic resonance imaging*.

The cooperation with the group of prof. Eung Je Woo from Kyung Hee University in the Republic of Korea continued in 2015. With this group, we published an article entitled "Frequency-dependent conductivity contrast for tissue characterization using a dual-frequency range conductivity mapping magnetic resonance method", which was published in the renowned journal IEEE Transactions on Medical Imaging. In this paper we introduced a new method of conductivity imaging, which can simultaneously acquire two sets of data that are then used for the calculation of conductivity images at two different frequency ranges. One at low (DC) frequencies and the other at high radio (RF) frequencies.

In 2015 we also started using our new 400-MHz system for MR microscopy of more challenging samples. On the system we carried out extensive measurements for the determination of the effect of impregnation on water penetration in wood. The measurements were carried out with different types of wood (pine, spruce, chestnut, etc.)

as well as with various wood treatments (oiling, waxing, etc.). This study is a result of our cooperation with the group of Prof. Miha Humar from the Department of Biotechnical Faculty in Ljubljana. The second half of the year was marked by the visit of two visitors from Norway, namely, Prof. John G. Seland and Dr. Tina Pavlin. Prof. Seland was in our laboratory on sabbatical. The theme of his scientific work was measurements of restricted diffusion in porous materials for which he used the method of modulated magnetic field gradients (MGSE), which was developed in our laboratory.

Our research has been supported by a number of international projects financed by the European Union within the 6th and 7th Frameworks. It was also supported within the bilateral Slovenia–USA, Slovenia–Germany, Slovenia–Greece and other scientific cooperations. In 2015, the Department had cooperations with 108 partners from Slovenia and abroad. Among them:

- The high-magnetic-field centres in Grenoble, France, and Nijmegen, The Netherlands
- The high-magnetic-field centre at the University Florida, Tallahassee, Florida, USA
- The ETH, Zürich, Switzerland
- The Ioffe Institute in St. Petersburg, Russia
- The University of Duisburg, the University of Mainz and the University of Saarbrucken in Germany
- The University of California, the University of Utah and the Liquid Crystal Institute, Kent, Ohio, USA,
- National Institute for Research in Inorganic Materials, Tsukuba, Japan
- NCSR Demokritos, Greece
- Institut für Biophysik und Nanosystemforschung OAW, Graz, Austria
- Bioénergétique et Ingénierie des Protéines, CNRS Marseille, France
- Architecture et Fonction des Macromolécules Biologiques, CNRS Marseille, France
- The Max Delbruck Center for Molecular Medicine in Berlin
- The Dartmouth Medical School, Hanover, NH, USA
- The Mayo Clinic, Rochester, USA
- Kyung Hee University, Suwon, Korea
- Technische Universität Ilmenau, Ilmenau, Germany
- Elettra Sincrotrone Trieste, Trieste, Italy
- University if North Carolina at Chapel Hill
- Max-Delbrück-Centrum für Molekulare Medizin (MDC)

made the above studies possible.

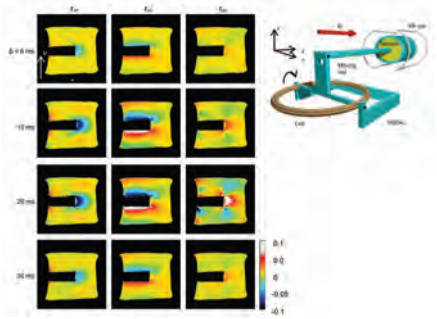

Figure 27: Maps of normal (ε_{zz}, ε_{yy}) and shear (ε_{yz}) strain components of the deformed sample for different deformation times Δ = 6, 10, 20, 30 ms. A colour-coded scale represents strains in the range -0.1–0.1. The sample deformations were induced by a deformational device shown in the upper-right corner.

Some outstanding publications in 2015

1. M. Pregelj, A. Zorko, O. Zaharko, H. Nojiri, H. Berger, L. Chapon, D. Arčon. Spin-stripe phase in a frustrated zigzag spin-1/2 chain. *Nature Communications* 6, 7255(2015).
2. M. Klanjšek, D. Arčon, A. Sans, P. Adler, M. Jansen, C. Felser. Phonon-modulated magnetic interactions and spin Tomonaga-Luttinger liquid in the p-orbital antiferromagnet CsO_2. *Physical Review Letters* 115, 057205(2015).
3. R. H. Zadik, A. Potočnik, P. Jeglič, D. Arčon, et al. Optimized unconventional superconductivity in a molecular Jahn-Teller metal. *Science Advances* 1, e1500059(2015).
4. M. Pregelj, A. Zorko, M. Gomilšek, et al. Controllable broadband absorption in the mixed phase of metamagnets. *Advanced Functional Materials* 25, 3634 (2015).
5. M. Nikkhou, M. Škarabot, S. Čopar, M. Ravnik, S. Žumer, I. Muševič. Light-controlled topological charge in a nematic liquid crystal. *Nature Physics* 11, 183 (2015).
6. S. Čopar, U. Tkalec, I. Muševič, S. Žumer. Knot theory realizations in nematic colloids. *Proc. Natl. Acad. Sci.* 112, 1675 (2015)).
7. R. Podlipec, J. Štrancar. Cell-scaffold adhesion dynamics measured in first seconds predicts cell growth on days scale - optical tweezers study. *ACS Applied Materials & Interfaces* 7, 6782(2015).
8. T. Koklič, R. Chattopadhyay, R. Majumder, B. R. Lenz. Factor Xa dimerization competes with prothrombinase complex formation on platelet-like membrane surfaces. *Biochemical Journal* 467, 37(2015).
9. Z. Arsov, U. Švajger, J. Mravljak, S. Pajk, A. Kotar, I. Urbančič, J. Štrancar, M. Anderluh. Internalization and accumulation in dendritic cells of a small pH-activatable glycomimetic fluorescent probe as revealed by spectral detection. *ChemBioChem* 16, 2660(2015).

Some outstanding publications in 2014

1. A. Zorko, O. Adamopoulos, M. Komelj, D. Arčon, A. Lappas. Frustration-induced nanometre-scale inhomogeneity in a triangular antiferromagnet. Nature Comms 5, 3222 (2014).
2. P. Koželj, S. Vrtnik, A. Jelen, S. Jazbec, Z. Jagličić, S. Maiti, M. Feuerbacher, W. Steurer, J. Dolinšek, Phys. Rev. Lett. **113**, 107001 (2014).
3. R. Pirc, B. Rožič, J. Koruza, B. Malič, Z. Kutnjak, Negative electrocaloric effect in antiferroelectric $PbZrO_3$. Europhysics Letters 107, 17002-1-5(2014).
4. A. Martinez, M. Ravnik, B. Lucero, R. Visvanathan, S. Žumer, and I.I. Smalyukh Mutually tangled colloidal knots and induced defect loops in nematic fields, Nature Mater. 13, 258-263 (2014).
5. D. Seč, S. Čopar and S. Žumer, Topological zoo of free-standing knots in confined chiral nematic fluids, Nature Comms. 5, 3057 (2014).
6. J. Dontabhaktuni, M. Ravnik and S. Žumer, Quasicrystalline tilings with nematic colloidal platelets, Proceedings of the National Academy of Sciences of the United States of America 111, 2464 (2014).
7. S. Čopar, Topology and geometry of nematic braids, Phys. Rep. 538, 1-37 (2014).
8. A. Vilfan, Myosin directionality results from coupling between ATP hydrolysis, lever motion, and actin binding. Proceedings of the National Academy of Sciences of the United States of America 111, E2076 (2014).
9. Urbančič, I., Ljubetič, A. & Štrancar, J. Resolving Internal Motional Correlations to Complete the Conformational Entropy Meter. J. Phys. Chem. Lett. 5, 3593–3600 (2014).
10. Podlipec, R. et al. Molecular Mobility of Scaffolds' Biopolymers Influences Cell Growth. ACS Appl. Mater. Interfaces 6, 15980–15990 (2014).
11. Mikhaylov, G. et al. Selective targeting of tumor and stromal cells by a nanocarrier system displaying lipidated cathepsin B inhibitor. Angew. Chem. Int. Ed Engl. 53, 10077–10081 (2014).

Some outstanding publications in 2013

1. S. Vallejos, P. Umek, T. Stoycheva, F. Annanouch, E. Llobert, X. Correig, P. de Marco, C. Bittencourt, Ch. Blackman. Single-step deposition of Au- and Pt-nanoparticle-functionalized tungsten oxide nanoneedles synthesized via aerosol-assisted CVD, and used for fabrication of selective gas microsensor arrays. Advanced Functional Materials 23, 1313-1322(2013).
2. A. Gradišek, D. Bomholdtravnsbaek, S. Vrtnik, A. Kocjan, J. Lužnik, T. Apih, T. Jensen, A. V. Skripov, J. Dolinšek. NMR study of molecular dynamics in complex metal borohydride $LiZn_2 BH_{45}$. Journal Phys. Chem. C 117, 21139-21147(2013).
3. M. Pregelj, A. Zorko, O. Zaharko, P. Jeglič, Z. Kutnjak, Z. Jagličič, S. Jazbec, H. Luetkens, A. D. Hillier, H. Berger, D. Arčon. Multiferroicity in the geometrically frustrated $FeTe_2O_5Cl$. Phys. Rev. B 88, 224421-1- 10(2013).
4. A. Nych, U. Ognysta, M. Škarabot, M. Ravnik, S. Žumer, I. Muševič. Assembly and control of 3D nematic dipolar colloidal crystals. Nature Communications 4, 1489-1-8 (2013) doi: 10.1038/ncomms2486. 2013,
5. V. S. R. Jampani, M. Škarabot, S. Čopar, S. Žumer, I. Muševič. Chirality screening and metastable states in chiral nematic colloids. Phys. Rev. Lett.110, 177801-1-5(2013).
6. S. Novak, D. Drobne, L. Vaccari, M. P. Kiskinova, P. Ferraris, G. Birarda, M. Remškar, M. Hočevar. Effect of ingested tungsten oxide (WO_X) nanofibers on digestive gland tissue of Porcellio scaber (Isopoda, Crustacea) : fourier transform infrared (FTIR) imaging. Env. Sci. & Tech. 47, 11284-11292(2013).
7. F. Bajd, I. Serša. Mathematical modeling of blood clot fragmentation during flow-mediated thrombolysis. Bioph. Journal 104, 1181-1190(2013).
8. I. Urbančič, A. Ljubetič, Z. Arsov, J. Štrancar. Coexistence of probe conformations in lipid phases: a polarized fluorescence microspectroscopy study. Bioph. Journal 105 919-927(2013).

Awards and appointments

1. Samo Kralj: Reward for outstanding educational achievements and constantly highest marks in students' assessments from Faculty of Natural Sciences and Mathematics, University of Maribor, 2015
2. Samo Kralj: Golden Reward from Society for Technical Culture of Slovenia for outstanding achievements in the field of education, 2015
3. Samo Kralj: Distinguished referee reward of the European Physical Journal in 2015
4. Matjaž Humar: Name of the week (VAL 202)
5. Matjaž Humar: Personality of Primorska region for the month of July 2015

Organization of conferences, congresses and meetings

1. Training School "Bottom-up Approaches of Hybrid materials: Preparation and Design", 26. 5. – 28. 5. 2015

Patents granted

1. Andraž Rešetič, Jerneja Milavec, Blaž Zupančič, Boštjan Zalar, Polymer dispersed liquid crystal elastomers, SI24658 (A), Slovenian Intellectual Property Office, 30. 09. 2015.
2. Maja Remškar, Janez Jelenc, Andrej Kržan, Fluoro-polymer nanocomposites with tailored friction properties, SI24472 (A), Slovenian Intellectual Property Office, 31. 03. 2015.
3. Maja Remškar, Ivan Iskra, Marko Viršek, Mark Pleško, Damjan Golob, Method and capacitive sensor for counting aerosol nanoparticles, US9151724 (B2), US Patent Office, 6. 10. 2015.
4. Aleš Mrzel, Maja Remškar, Adolf Jesih, Marko Viršek, Process for the synthesis of nanotubes and fullerene-like nanostructures of transition metal dichalcogenides, quasi one-dimensional structures of transition metals and oxides of transition metals, EP2132142 (B1), European Patent Office, 5. 08. 2015.
5. Igor Muševič, Matjaž Humar, Spherical liquid-crystal laser, EP2638604 (B1), European Patent Office, 18. 03. 2015.

INTERNATIONAL PROJECTS

1. MERCK - AFM Investigations
   Asst. Prof. Miha Škarabot
   Merck Kgaa
2. Development of Curved LCD Shutter
   Prof. Igor Muševič
   Kimberly-Clark
3. Kimberly-Clark-2015 - Development of Prototype Curved LCD Shutter
   Prof. Igor Muševič
   Kimberly-Clark
4. 7FP - LEMSUPER; Light Element Molecular Superconductivity: An Interdisciplinary Approach
   Prof. Denis Arčon
   European Commission
5. 7FP - ESNSTM; Electron Spin Noise Scanning Tunneling Microscopy
   Prof. Janez Dolinšek
   European Commission
6. 7FP - NanoMag; Magnetic Nanoparticles and Thin Films for Spintronic Applications and High Performance Permanent Magnets
   Prof. Janez Dolinšek
   European Commission
7. 7FP - SIMDALEE2; Sources, Interaction with Matter Detection and Analysis of Low Energy Electrons 2
   Prof. Maja Remškar
   European Commission
8. 7FP - NEMCODE; Controlled Assembly and Stabilisation of Functionalised Colloids in Nematic Liquid Crystals
   Prof. Igor Muševič
   European Commission
9. 7FP - LIVINGLASER; A Laser made Entirely of Living Cells and Materials derived from Living Organisms
   Prof. Igor Muševič
   European Commission
10. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
    Prof. Maja Remškar
    European Commission
11. COST MP1202; HINT School
    Dr. Polona Umek
    Cost Office
12. COST MP1103; Nanostructured materials for solid-state hydrogen storage
    Dr. Anton Gradišek
13. Low Dimensional Structures of Metal Sulfides and Selenides for Use in Transistor Electronics
    Prof. Maja Remškar
    Slovenian Research Agency
14. Local Studies of Frustrated Quantum Antiferromagnets
    Dr. Andrej Zorko
    Slovenian Research Agency
15. Key Role of Magnetic Anisotropy in Low-dimensional Spin Systems
    Dr. Andrej Zorko
    Slovenian Research Agency
16. Hybrid Solar Cell Based on Conducting Polymers and 1D Nanostructured TiO2
    Dr. Polona Umek
    Slovenian Research Agency
17. Spin-liquid Ground State of Quantum Kagome Antiferromagnets from a Local-probe Perspective
    Dr. Andrej Zorko
    Slovenian Research Agency
18. Controlled Nanoparticle Assemblies in Complex Soft Matrices
    Prof. Samo Kralj
    Slovenian Research Agency
19. Crystal and Electronic Structure of Quasi One-dimensional Transition-metal Chalcogenides
    Dr. Erik Zupanič
    Slovenian Research Agency
20. Radiative forcing of desert mineral dust and PM10 concentrations over Southern Europe
    Prof. Maja Remškar
    Slovenian Research Agency

RESEARCH PROGRAMS

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

R & D GRANTS AND CONTRACTS

1. Topology and Photonics of Liquid Crystal Colloids and Dispersions
   Prof. Igor Muševič
2. Intra-pocket-targeted nanomedicines for treatment of periodontal disease
   Prof. Maja Remškar
3. The textural analysis of spatiotemporal changes for breast lesions diagnosis on ultrafastbreast MRIs
   Prof. Igor Serša
4. Optimization strategies in biological and artificial microfluidic systems
   Asst. Prof. Andrej Vilfan
5. Thermophoretic guidance, accumulation and sorting of biomolecules in microfluidic devices
   Asst. Prof. Andrej Vilfan
6. New advanced electrocaloric materials for novel environmentally-friendly dielectric refrigeration technology
   Prof. Zdravko Kutnjak
7. Role of Calcium and lipid membranes in survival of critically ill patients
   Dr. Tilen Koklič
8. Selective and hipersensitive microcapacitive sensor system for targetted molecular detection in the atmosphere
   Prof. Igor Muševič

9. Water exclusion efficacy, measure for prediction of wood performance against wood decay fungi
   Prof. Igor Serša
10. Micro-electromechanical and electrocaloric layer elements
    Prof. Zdravko Kutnjak
11. Light-controlled layer-by-layer formation of scaffolds for faster tissue regeneration
    Dr. Iztok Urbančič
    Ministry of Education, Science and Sport
12. New polymer and ceramic materials for potential use in capacitors
    Dr. Andreja Eršte
    Ministry of Education, Science and Sport
13. SCOPES; Spin-liquid and Spin-ice States in Frustrated Rare-earth and Transition Metal Spinels
    Dr. Matej Pregelj
    SNF- Swiss National Science Foundation
14. Nanomaterials and Scaffolds preparation and characterization
    Prof. Janez Štrancar
    Ministry of Education, Science and Sport
15. Irradiation and Analysis of Nano Si Samples
    Prof. Vid Bobnar
    Institute Of Radiation Problems Of Aznas
16. Irradiation and Analysis of Nano SiC Samples
    Prof. Vid Bobnar
    National Nuclear Research Center

VISITORS FROM ABROAD

1. Prof. dr. Myung-Hwa Jung, Sogang University, Department of Physics, Seoul, South Korea, 1. 1. 2015-31. 8. 2015
2. Dr. Anna Ryzhkova, ASML, Eindhoven, Netherlands, 26.1.2015 - 22.2.2015, 18. 10. 2015 – 15. 11. 2015
3. Mag. Marketa Havrdova, Palacky University Olomouc, Department of Science, Czech Republic, 30.1.2015 – 20.2.2015, 29.3.2015 – 30.4.2015, 2.10. 2015 – 12.11.2015
4. Prof. dr. Sergey Lushnikov, IOFFE Physical-Technical Institute of the Russian Academy of Sciences, St. Petersburg, Russia, 2.2.2015 – 30.6.2015
5. Dr. Amal Kasry, Austrian Institute of Technology (AIT), Biosensor Technologies Department, Vienna, Austria, 5.2.2015 – 7.2.2015
6. Prof. dr. Igor Lukyanchuk, University of Picardie Jules Verne, Amiens, France, 15.2.2015 – 21.2.2015
7. Dr. Carla Bittencourt, Universite de Mons, Belgium, 10.3.2015 – 15.3.2015
8. Dr. Valentina Domenici, Dipartimento di Chimica e Chimica Industriale, University of Pisa, Pisa, Italy, 23.3.2015 – 28.3.2015, 14.12. – 18.12.2015
9. Vanessa Cresta, University of Pisa, Pisa, Italy, 1. 4. 2015 – 31. 8. 2015
10. Prof. Horst Beige, Martin Luther University, Halle, Germany, 21.4. – 26.4.2015
11. Dr. Ioannis Lelidis, University of Athens, Department of Physics, Athens, Greece, 22.4.2015 – 26.4.2015
12. Dr. George Nounesis, NCSR Demokritos, Athens, Greece, 22.4.2015 – 26.4.2015, 24.11.2015 – 27.11.2015
13. Mag. Katarina Jovanović, Institute for Oncology and Radiology of Serbia, Belgrade, Serbia, 4. 5. 2015 - 3. 7. 2015
14. Dr. Mirta Herak, Institute of Physics, Zagreb, Croatia, 8. 5. 2015, 8. 6. 2015 – 11. 6. 2015, 3. 11. 2015, 17.12. – 22.12.2015
15. Prof. dr. Alan C. Seabaugh, Notre Dame University, Department for Electrical Engineering, Indiana, USA, 10. 5. 2015 – 17. 5. 2015
16. Mag. Bouchra Asbani, Universite de Picardie Jules Verne, Laboratorie de Physique de la Mateiere Condensee, Amiens, France, 10. 5. 2015 – 31. 5. 2015
17. Dr. Marko Gosak, Fakulteta za narovoslovje in matematiko, Inštitut za fiziologijo Univerze v Mariboru, Maribor, 14. 5. 2015
18. Prof. Siegfied Dietrich, Max–Planck Institut für Intelligente Sisteme & Institut für Theoretische Physik IV, Universität Stuttgart, Stuttgart, Germany, 1. 6. 2015
19. Dr. Magdalena Wencka, Institute of Molecular Physics, Polish Academy of Sciences, Poznan, Poland, 1.6.2015 – 15.6.2015, 20. 9. 2015 – 20. 10. 2015
20. Dr. Nina Kravets, Nonlinear Optics and Optoelectronics Laboratory, Roma Tre University, Rome, Italy, 3. 6. 2015 – 7. 6. 2015
21. Etienne Brasselet, University of Bordeaux, France, 14.6.2015 – 17.6.2015
22. Dr. Ivana Capan, Ruđer Bošković Institute, Zagreb, Croatia, 10. 7. 2015 – 12. 7. 2015
23. Mateo Palleo, Stelar s.l.r., Mede, Italy, 20.7.2015 – 22.7.2015
24. Prof. John Georg Seland, University of Bergen, Bergen, Norway, 1. 8. 2015 – 31. 12. 2015
25. Dr. Tina Pavlin, University of Bergen, Bergen, Norway, 1. 8. 2015 – 31. 12. 2015
26. Dr. Yishay Feldman, Weizmann Institute of Science, Rehovot, Israel, 3. 8. 2015
27. Dr. Mutsuo Igarashi, Gunma National college of Technology, Maebashi, Japan, 12. 8. 2015 – 24. 8. 2015, 19. 10. 2015 – 27. 10. 2015
28. Prof. Aysegul Oksuz, Suleyman Demirel University, Faculty of Arts and Science, Isparta, Turkey, 21. 8. 2015 – 28. 8. 2015
29. Prof. Lutfi Oksuz, Suleyman Demirel University, Faculty of Arts and Science, Isparta, Turkey, 21. 8. 2015 – 28. 8. 2015
30. Prof. Qiming Zhang, The Pennsylvania State University, Pennsylvania, USA, 23. 9. 2015 – 25. 9. 2015
31. Prof. Francesca Ferlaino, University of Innsbruck, Research department, Innsbruck, Austria, 28. 9. 2015 – 29. 9. 2015
32. Adrien Chauvin, Institut des Materiaux Jean Rouxel, Nantes, France, 3. 10. 2015 – 11. 10. 2015
33. Dr. Vadim Pokrovskii, V.A. Kotelnikov Institute of Radioengineering and Electronics of Russian Academy of Sciences, Moskow, Russia, 26. 10. 2015 – 31. 10. 2015
34. Dr. Sergey Zybtsev, V.A. Kotelnikov Institute of Radioengineering and Electronics of Russian Academy of Sciences, Moskow, Russia, 26. 10. 2015 – 31. 10. 2015
35. Dr. Irina Gorlov, V.A. Kotelnikov Institute of Radioengineering and Electronics of Russian Academy of Sciences, Moskow, Russia, 26. 10. 2015 – 31. 10. 2015
36. Prof. dr. Philippe Mendels, Laboratoire de Physique des Solides, Universite Paris – Sud 11, Orsay, France, 16.12. – 18.12.2016
37. Prof. dr. Fabrice Bert, Laboratoire de Physique des Solides, Universite Paris – Sud 11, Orsay, France, 16.12. – 18.12.2016

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29. Prof. Aleksander Zidanšek
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31. Prof. Slobodan Žumer

Postdoctoral associates

32. Dr. Franci Bajd
33. *Dr. Andreja Eršte, left 01.09.15*
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38. Dr. Maryam Nikkhou
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40. Dr. Stane Pajk*
41. Dr. Rok Podlipec
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45. Dr. Jernej Vidmar*
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48. *Dr. Goran Casar, left 01.06.15*
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50. Matjaž Gomilšek, B. Sc.
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52. Dr. Matjaž Humar
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55. Primož Koželj, B. Sc.
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71. Dr. Luka Drinovec*
72. Dr. Andreja Jelen
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75. Jože Luzar
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77. Dr. Griša Močnik*

Technical and administrative staff

78. Dražen Ivanov
79. Janez Jelenc, B. Sc.
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83. Silvano Mendizza
84. Janja Milivojević
85. Iztok Ograjenšek
86. Ana Sepe, B. Sc.
87. Marjetka Tršinar

Note:
* part-time JSI member

BIBLIOGRAPHY

Original Article

1. Andreja Abina, Uroš Puc, Anton Jeglič, Jana Kemperl, Rimvydas Venckevičius, Irmantas Kašalynas, Gintaras Valušis, Aleksander Zidanšek, "Qualitative and quantitative analysis of calcium-based microfillers using terahertz spectroscopy and imaging", *Talanta (Oxford)*, vol. 143, pp. 169-177, 2015.
2. Andreja Abina, Uroš Puc, Anton Jeglič, Aleksander Zidanšek, "Structural characterization of thermal building insulation materials using terahertz spectroscopy and terahertz pulsed imaging", *NDT E int.*, vol. 77, pp. 11-18, 2015.
3. Matias Acosta, Nasser Khakpash, Takumi Someya, Nikola Novak, Wook Jo, Hajime Nagata, George A. Rossetti, Jürgen Rödel, "Origin of the large piezoelectric activity in $(1-x)Ba(Zr_{0.2}Ti_{0.8})O_3 - x(Ba_{0.7}Ca_{0.3})TiO_3$ ceramics", *Phys. rev., B, Condens. matter mater. phys.*, no. 91, no. 10, pp. 104108-1-104108-11, 2015.
4. Matias Acosta, Nikola Novak, George A. Rossetti, Jürgen Rödel, "Mechanisms of electromechanical response in $(1-x)Ba(Zr_{0.2}Ti_{0.8})O_{3-x}(Ba_{0.7}Ca_{0.3})TiO_3$ ceramics", *Appl. phys. lett.*, vol. 107, no. 14, pp. 142906-1-142906-6, 2015.
5. Fatima Ezahra Annanouch, Zouhair Haddi, Stella Vallejos, Polona Umek, Peter Guttmann, Carla Bittencourt, Eduard Llobet, "Aerosol assisted CVD grown WO_3 nanoneedles decorated with copper oxide nanoparticles for the selective and humidity resilient detection of H2", *ACS appl. mater. interfaces*, vol. 7, issue 12, pp. 6842-6851, 2015.
6. Zoran Arsov, Urban Švajger, Janez Mravljak, Stane Pajk, Anita Kotar, Iztok Urbančič, Janez Štrancar, Marko Anderluh, "Internalization and accumulation in dendritic cells of a small pH-activatable glycomimetic fluorescent probe as revealed by spectral detection", *ChemBioChem*, vol. 16, iss. 18, pp. 2660-2667, Dec. 2015.
7. B. Asbani, J. -L. Dellis, Y. Gagou, H. Kaddoussi, A. Lahmar, M. Amjoud, D. Mezzane, Zdravko Kutnjak, M. El Marssi, "Electrocaloric effect in $Ba_{0.2}Ca_{0.8}Ti_{0.95}Ge_{0.05}O_3$ determined by a new pyroelectric method", *Europhys. lett.*, vol. 111, no. 5, pp. 57008-1-57008-5, 2015.
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Review Article

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Published Conference Contribution (invited lecture)

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DEPARTMENT FOR COMPLEX MATTER F-7

The research within the department for Complex Matter encompasses a variety of research fields, ranging from the synthesis of new materials to fundamental investigations of elementary excitations in complex systems. These include anything from nano-biosystems to exotic magnetic systems and superconductors. The experimental methods used are suitably diverse, from synthetic chemistry to femtosecond laser spectroscopy. Last year's research achievements are thus quite diverse, but we are able to report on important discoveries in a number of areas.

Head:
Prof. Dragan D. Mihailović

The activities in the department can be grouped together into a number of thematically inter-related research areas. Nanomaterials science research is focused on investigations into the fundamental properties and applications of semiconducting transition-metal dichalcogenides and molecular nanowires, crossing into the physics and nanoscience of macromolecular biological systems, venturing also into fields of quantum molecular electronics and nanoelectronics. These and other materials, such as strongly correlated systems, electronically ordered systems and superconductors were investigated using advanced femtosecond spectroscopy techniques. In many areas we have introduced new materials, technologies and techniques.

The most prospective field of research in 2015 is related to non-equilibrium phase transitions into a hidden state of tantalum disulphide with a publication in Science Advances, where we reported on research leading to an understanding of the mechanisms that stabilize the hidden state, on the one hand, and a device with electrical switching to the hidden state opening up the possibility of a new type of ultrafast memory element, on the other. This discovery was also included in an international patent application for a record-speed memory element. A significant part of this activity was within an ERC project. A diploma work on the subject by Ian Mihailovic was awarded with the **University Prešern Prize**.

An important achievement that should be mentioned is a determination of the mechanism leading to the photo-excited quasiparticle localization in a high-temperature superconductor published in **Nature Communications**. By means of a new method we were able to determine the size of the localized state, advancing our understanding of these materials. Additional publications in **Physical Review B** in **Nature Scientific Reports** on different aspects of the ultrafast phenomena in different pnictide superconductors led to a better understanding of the fundamental electron dynamics.

An original achievement was experimental investigations of 1D MoN superconductors, which were in-house synthesized from a MoSI nanowire precursor. In MoN superconducting nanowires we discovered the existence of non-equilibrium metastable states, which can be, despite the nonlinearity of the system, controlled deterministically by means of an electric current. The results of the work were published in **Nature Communications**.

Using photomodulation spectroscopy we identified the charge-carrier characteristics and exciton dissociation in MoS_2, as published in **Advanced Materials**. Polymer composites with WS_2 were successfully exfoliated, as confirmed by means of Raman spectroscopy (**Adv. Funct. Materials**).

Cascade centrifuges were used to fabricate nanolayer dispersions with a high monolayer content (**ACS Nano**). We also found the relaxation dynamics of the exfoliated MoS_2 nanosheets to be insensitive to surfactant adsorption (**J. Nanophotonics**).

Theoretical research is an important part of our activity supplementing the experimental work. Some results from the field of spintronics were published in **New J. of Physics** and **Physical Review B**.

A long-lasting, exhaustive study of MoSI nanowire properties in solutions was published in the reputable **Nano Letters**. The results present an important advancement in the understanding the self-doping phenomena of these materials in solution.

Research in the field of soft-matter was focused on ferromagnetic liquid crystals and on the development of new methods for liquid-crystal alignment in contact with polymer layers (**Opt. Lett., patent application WO2015139353-A**). Alenka Mertelj, together with Darja Lisjak from the Department for Materials Synthesis, was awarded with the **Zois Certificate of Recognition** for the discovery of ferromagnetic liquid-crystalline suspensions.

The work of Matjaž Ličen on colloidal crystals with added superparamagnetic nanoparticles lead to the **Prešern prize for students** at FMF.

Biomedical optics represents an important applied activity in collaboration with Fotona and the Beckman Laser Institute.

European Research Council
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Ultrafast studies of electron dynamics in correlated systems

Ferromagnetism and superconductivity are antagonistic phenomena. Their coexistence implies either a modulated ferromagnetic order parameter on a length scale shorter than the superconducting coherence length or a weak exchange coupling between the itinerant superconducting electrons and the localized ordered spins. In some iron-based pnictide superconductors the coexistence of ferromagnetism and superconductivity has been clearly demonstrated. The nature of the coexistence, however, remains elusive, since no clear understanding of the spin structure in the superconducting state has been reached and the reports on the coupling strength are controversial. We showed in $Eu(As,P)_2Fe_2$, using a direct optical pump-probe experiment, that the coupling is weak, since the transfer of the excess energy from the itinerant electrons to ordered, localized spins is much slower than the electron-phonon relaxation, implying the coexistence without the short-length-scale ferromagnetic order parameter modulation. Remarkably, the polarization analysis of the coherently excited spin-wave response points towards a simple ferromagnetic ordering of the spins with two distinct types of ferromagnetic domains, as reported in a manuscript accepted for publication in **Scientific Reports 5, 7754 (2015)**.

Controllable switching between metastable macroscopic quantum states under non-equilibrium conditions induced either by light or with an external electric field is rapidly becoming of great fundamental interest. We investigated the relaxation properties of a "hidden" (H) charge density wave (CDW) state in thin single crystals of the layered dichalcogenide 1*T*-TaS_2, which can be reached by either a single 35-fs optical laser pulse or an ~30-ps electrical pulse. From measurements of the temperature dependence of the resistivity under different excitation conditions, we found that the metallic H state relaxes to the insulating Mott ground state through a sequence of intermediate metastable states via discrete jumps over a "devil's staircase." In between the discrete steps, an underlying glassy relaxation process is observed, which arises because of the reciprocal-space commensurability frustration between the CDW and the underlying lattice. We showed that the metastable state's relaxation rate may be externally stabilized by the substrate strain, thus opening the way to the design of non-volatile ultrafast high-temperature memory devices based on the switching between CDW states with large intrinsic differences in the electrical resistance, as reported in a manuscript accepted for publication in **Science Advances 1, e1500168, (2015)**.

The temperature and fluence dependence of the optical transient reflectivity in superconducting $BaFe2(As_{1-x}P_x)_2$ was measured and analysed in the low and high excitation density limit. The effective magnitude of the superconducting gap of ~5 meV obtained from the low-fluence-data phonon bottleneck model fit was found to be consistent with the angle-resolved photoemission spectroscopy results for the γ- and β-hole Fermi surfaces. The superconducting state's non-thermal optical destruction energy was determined from the fluence-dependent data. The planar optical destruction energy density scales well with T_c^2 and is found to be similar in a number of different layered superconductors, as published in **Phys. Rev. B 92, 144503 (2015).**

A 'pseudogap' was introduced by Mott to describe a state of matter that has a minimum in the density of states at the Fermi level, deep enough for the states to become localized. It can arise either from the Coulomb repulsion between electrons, and/or incipient charge or spin order. We employed ultrafast spectroscopy to study the dynamical properties of the normal-to-pseudogap state transition in the prototype high-temperature superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$. We performed a systematic temperature- and doping-dependence study of the pseudogap photo destruction and recovery in coherent quench experiments, revealing a marked absence of critical behaviour for the elementary excitations, which implies an absence of collective electronic ordering beyond a few coherence lengths on short timescales. The data imply ultrafast carrier localization into a textured polaronic state arising from a competing Coulomb interaction and lattice strain, enhanced by a Fermi-surface instability, as reported in **Nature Communications 6, 6958 (2015)**.

We conducted a systematic study of the single-particle and collective excitations by femtosecond transient-reflectivity measurements in single crystals of η-Mo_4O_{11}, investigating the dynamics as a function of temperature with two different pump photon energies (3.1 eV and 1.55 eV). A remarkable slowing down of the relaxation dynamics was observed for the first charge density wave (CDW) transition at T_{CDW1} = 105 K, associated with hidden one-dimensional Fermi surface (FS) nesting. In contrast, the appearance of the second transition at T_{CDW2} associated with further CDW ordering is barely perceptible. The coherent response can be described well by the displacive coherent excitation model of Zeiger et al. assuming a coupling of the phonons to the photo-excited quasi-particles. The coupling of the collective modes to the electronic order parameter was found to be weak. The exponential relaxation was discussed in terms of single-particle relaxation and an overdamped collective mode. The manuscript has been submitted to Phys. Rev. B.

Systems that rapidly evolve through symmetry-breaking transitions on timescales comparable to the fluctuation timescale of the single-particle excitations may behave very differently than under controlled, near-ergodic conditions. A real-time investigation with a high temporal resolution may reveal new insights into the ordering through the transition that are not available in static experiments. We investigated the system trajectory through a normal-to-superconductor transition in a prototype high-temperature superconducting cuprate in which such a

situation occurs. Using a multiple pulse femtosecond spectroscopy technique we measured the system trajectory and the time evolution of the single-particle excitations through the transition in $La_{1.9}Sr_{0.1}CuO_4$ and compared the data to a simulation based on time-dependent Ginzburg-Landau theory, using laser excitation fluence as an adjustable parameter controlling the quench conditions in both experiment and theory. The comparison revealed the presence of significant superconducting fluctuations that precede the transition on short timescales. By including superconducting fluctuations as a seed for the growth of the superconducting order we can obtain a satisfactory agreement between theory and experiment. Remarkably, the pseudogap excitations apparently play no role in this process. The manuscript has been submitted to Phys. Rev. X

Theoretical studies on the nanoscale

We have derived kinetic equations describing the injection and transport of spin-polarized carriers in organic semiconductors with hopping conductivity via an impurity level. The model predicts a strongly voltage-dependent magnetoresistance, defined as a resistance variation between devices with parallel and antiparallel electrode magnetizations (spin-valve effect). The voltage dependence of the magnetoresistance splits into three distinct regimes. The first regime matches well-known inorganic spintronic regimes, corresponding to the well-known conductivity mismatch case. The second regime at intermediate voltages corresponds to strongly suppressed magnetoresistance. The third regime develops at higher voltages and accounts for a novel paradigm. It is promoted by the strong nonlinearity in the charge transport. This nonlinearity, depending on device conditions, can lead to significant enhancement or to an exponential suppression of the spin-valve effect in organic devices. (New Journal of Physics 17, 023019 (2015).

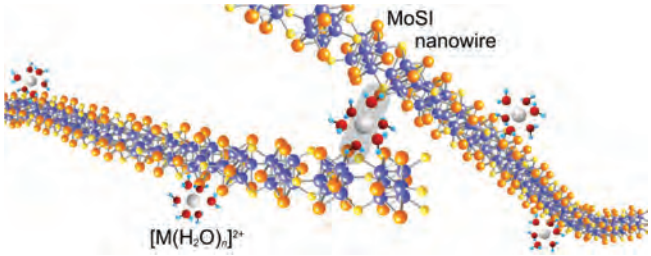

Figure 1: MoSI nanowires with adsorbed $[M(H2O)n]^{2+}$ complexes (where M stands for Mg, Ni, or Zn). These complexes facilitate the aggregation of nanowires and enhance their conductivity.

We have derived the kinetic equations for hopping transport that take into account the electron spin and the possibility of double occupation. In the ohmic regime, the equations are reduced to the generalized Miller-Abrahams resistor network. We have applied these equations to the problem of the magnetic-moment relaxation due to the interaction with the random hyperfine fields. It was shown that for a wide range of parameters the relaxation rate is governed by the hops with similar rates to the spin precession frequency. We demonstrated that for the large time scale the spin relaxation is non-exponential. We argue that the non-exponential relaxation of the magnetic moment is related to the spin of the electrons in the slow-relaxing traps. Interestingly, the traps can significantly influence the spin relaxation in the infinite conducting cluster at large times. (Physical Review B 92, 014206 (2015).

Nanomaterials

One of our fields of study is research on transition-metal chalcogenides and chalcohalides in various low-dimensional forms, in particular nanowires, nanotubes, and nanoflakes.

To improve the functionalization of $Mo_6S_{9-x}I_x$ cluster polymers we have studied the effects of adsorption doping on the electrical transport, aggregation, and optical absorption spectra. The doping results in both enhanced conductivity and aggregated bundles in the dispersion. Thanks to this finding, the previously observed different electronic properties of different bundle diameters can be ascribed to self-doping during the synthesis. Doping shifts, the characteristic absorption peaks and transfers the oscillator strength to lower energies. Femtosecond optical spectroscopy shows that the spectral signature of the adsorption and self-doping indeed originates from the population of electronic levels that are empty or absent in the undoped sample. This work has been published in **Nano Letters 15 (2015) 813-818.** One of our fields of study is research on transition-metal chalcogenides and chalcohalides in various low-dimensional forms, in particular nanowires, nanotubes, and nanoflakes. In the area of thin-film synthesis we are developing disulphide molecular beam epitaxy capabilities.

We have measured the optical spectra of doped MoSI nanowires, while the spectra of self-doped and adsorption-doped nanowires were compared to the results from femtosecond spectroscopy.

Recent progress in the exfoliation of layered materials, and the nanofabrication of functional structures, has revived the interest in two-dimensional materials with properties complementary to graphene, in particular transition-metal dichalcogenides, such as MoS_2. Their potential in electronics has become evident by the realization of a field-effect transistor and a logic circuit device based on a single monolayer flake. MoS_2 in its mono- and few-layer forms has a significant exciton binding energy of several 100 meV, leading to the consensus that excitons are the primary photo-excited species. Nevertheless, even single layers show a strong photovoltaic effect and work as the active material in high-sensitivity photodetectors, thus indicating efficient charge-carrier photogeneration (CPG). By using continuous wave photo-

Charge-carrier photogeneration via exciton dissociation is very efficient in few-layer MoS_2 flakes.

modulation spectroscopy we could identify the optical signature of long-lived charge carriers and then study the CPG dynamics with femtosecond pump-probe spectroscopy. We found that initial photo-excitation creates excitons, which dissociate with a time constant of 700 fs. These findings help with the design of more efficient MoS_2 photovoltaic and photodetector devices. This work has been published in **Advanced Materials 25 (2015) 3351–3358**.

We produced highly monolayer-enriched dispersions of liquid-exfoliated nanosheets by liquid cascade centrifugation.

While liquid-phase exfoliation can be used to produce nanosheets stabilized in polymer solutions, very little is known about the resultant nanosheet's size, thickness, or monolayer content. The present study uses semi-quantitative spectroscopic metrics based on extinction, Raman, and photoluminescence (PL) spectroscopy to investigate these parameters for WS_2 nanosheets exfoliated in aqueous poly(vinyl alcohol) (PVA) solutions. By measuring the Raman and PL simultaneously, the monolayer content can be tracked via the PL/Raman intensity ratio while varying the processing conditions. The PL is found to be maximized for a stabilizing polymer concentration of 2 g/L. In addition, the monolayer content can be controlled via the centrifugation conditions, exceeding 5% by mass in some cases. These techniques have allowed tracking the ratio of PL/Raman in a droplet of polymer-stabilized WS_2 nanosheets as the water evaporates during composite formation. No evidence of nanosheet aggregation is found under these conditions, although the PL becomes dominated by trion emission as the drying proceeds and the balance of doping from the PVA/water changes. Finally, bulk PVA/WS_2 composites are produced by freeze drying where >50% of the monolayers remain unaggregated, even at WS_2 volume fractions as high as 10%. This work has been accepted for publication in 2016 in **Adv. Funct. Mater., DOI: 10.1002/adfm.201503863**.

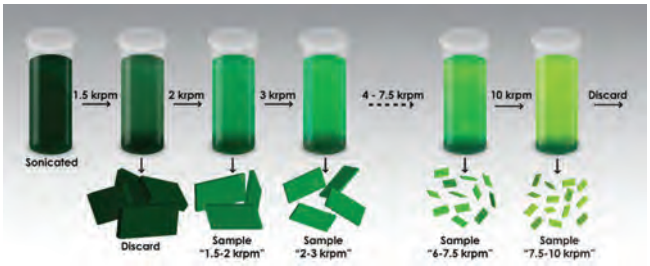

Figure 2: Schematic describing the centrifugation cascade. Sequential centrifugations at increasingly higher rotational frequencies act as a size-selection mechanism for separating differently sized exfoliated crystallites from the original sample.

While liquid exfoliation is a powerful technique to produce defect-free nanosheets in large quantities, its usefulness is limited by broad nanosheet thickness distributions and low monolayer contents. We demonstrated liquid processing techniques, based on iterative centrifugation cascades, which can be designed to achieve either highly efficient nanosheet size selection and/or monolayer enrichment. We used the resultant size-selected dispersions to establish quantitative metrics to determine the monolayer volume fraction, as well as mean nanosheet size and thickness, from standard spectroscopic measurements. Such metrics allowed us to design and optimize centrifugation cascades to enrich liquid exfoliated WS_2 dispersions up to monolayer contents of 75%. Monolayer-rich dispersions show relatively bright photoluminescence with narrow line widths (<35 meV) indicating the high quality of the nanosheets. The enriched dispersions display extinction spectra with distinct features, which also allow the direct estimation of monolayer contents. This work has been accepted for publication in **2016 in ACS Nano, DOI: 10.1021/acsnano.5b07228**.

The electronic and photophysical properties of a material depend crucially on the electron relaxation behaviour. Ionic surfactants, which are widely used to stabilize nanomaterials in dispersions, can drastically alter the nanomaterial's photophysical properties. Here, we used femtosecond optical spectroscopy to study the dynamics of the excitons and charges in few-layer flakes of the two-dimensional semiconductor MoS_2. We compare samples obtained via exfoliation in water with different amounts of adsorbed sodium cholate, obtained by repeated washing of the dried flakes. We find that the femtosecond dynamics is remarkably robust against the surfactant adsorption, with a slight increase in the initial exciton quenching that occurs during the first few picoseconds as the only appreciable effect. The work has been published in **Journal of Nanophotonics 10 (2015), 012508-1-8** and was among the top ten downloads from that journal in November and December 2015.

The electron relaxation dynamics in liquid-exfoliated MoS_2 flakes is remarkably robust against the adsorption of surfactants.

Nanowires and nanotubes decorated with platinum nanoparticles are known for their excellent sensing and catalytic properties. However, the decoration of transition-metal dichalcogenide nanotubes can be very complex. We have found a simple procedure that enables the efficient production and purification of thin bundles of MoSI nanowires decorated with platinum nanoparticles and a simple procedure for the direct decoration of MoS_2 nanotubes. First, we isolated several hundred milligrams of nanowire bundles that were several microns long with average diameters of around 40 nm, and formed a stable dispersion in water without added surfactants. Platinum nanoparticles were directly deposited on the nanowire bundles in a solution at room temperature in a single-step reaction without any additional reducing reagents. A stable and uniform decoration was observed with average particle diameters of around 2 nm and a controllable surface density, covering up to 80% of the nanowire surface. A similar decoration also takes place on MoS_2 nanotubes dispersed in water. Sulphurisation of the decorated nanowires was performed, during which the platinum nanoparticles aggregated into larger formations, and partial

encapsulation of elongated platinum nanorods in the obtained multi-wall MoS_2 nanotubes was observed. These results are reported in **Materials Letters 159 (2015) 333–336**.

We have grown epitaxial WO_3 films on single-crystal substrates using radio-frequency magnetron sputtering. While a pronounced surface roughness is observed in films grown on $LaSrAlO_4$ substrates, films grown on $YAlO_3$ substrates show atomically flat surfaces, as demonstrated by atomic force microscopy and X-ray diffraction (XRD) measurements. The crystalline structure has been confirmed to be monoclinic by symmetric and skew-symmetric XRD. This work is reported in **APL Materials 3 (2015) 096012-1–5**.

The creation of local charged states on the surface of the lanthanum-strontium manganite single crystals by means of bias application via a conducting atomic force microscope tip is strongly affected by the magnetic field. Both the charge and the size of created structures increase significantly with the application of the magnetic field during the induction. The observed phenomenon originates from the known tendency of manganites towards charge segregation and its intimate relation to magnetic ordering. Our research is published in **Applied Physics Letters 107 (2015) 192906-1–4**.

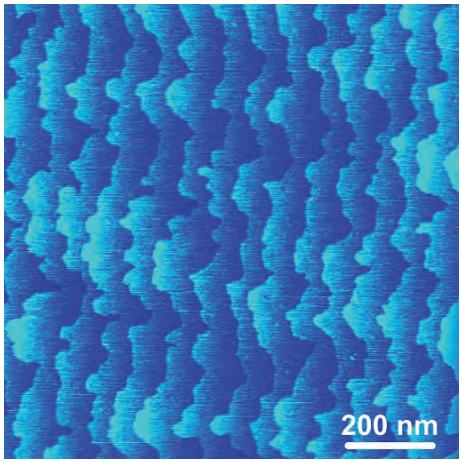

Figure 3: A 512×512 AFM height image of an atomically flat, epitaxially grown WO_3 monocrystal. Each measured step height is about 0.4 nm, which corresponds well to the WO_3 structure.

We have achieved a remarkable 52% relative increase in power-conversion efficiency (PCE) of solar cells embedded with small amounts of MoSI nanowires dispersed in a P3HT:PCBM matrix. We have presented a detailed and systematic investigation of the numerous factors influencing this breakthrough increase. Raman spectroscopy and photocurrent imaging are used to investigate the spatial inhomogeneity of the solar-cell parameters and correlate them with the device's performance. The effect is strongly correlated to the regio-regularity of P3HT with highly regio-regular P3HT having the largest effect. Our work was accepted for publication in 2016 in **Synthetic Metals, DOI: 10.1016/j.synthmet.2015.12.009**.

The superconducting state in one-dimensional nanosystems is very delicate. While fluctuations of the phase of the superconducting wave function lead to the spontaneous decay of persistent supercurrents in thin superconducting wires and nanocircuits, discrete phase-slip fluctuations can also lead to more exotic phenomena, such as the appearance of metastable superconducting states in current-bearing wires. We have shown that switching between different metastable superconducting states in δ-MoN nanowires can be very effectively manipulated by introducing a small-amplitude electrical noise. Furthermore, we were able to show that deterministic switching between metastable superconducting states with different numbers of phase-slip centres can be achieved in both directions with small electrical current pulse perturbations of the appropriate polarity. The observed current-controlled bistability is in remarkable agreement with the theoretically predicted trajectories of the system switching between different limit cycle solutions of a model one-dimensional superconductor. This work has been published in **Nature Communications 6, 10250 (2015)**.

Soft Matter

In cooperation with Nankai University in China we investigated liquid-crystal alignment at the interface with thin polymeric walls that are oriented in a direction perpendicular to the glass substrates. The walls are fabricated by a direct laser writing process based on two-photon polymerization. This method provides microstructured liquid-crystal alignment in practically oblique configurations, which opens up several possibilities for application in liquid-crystalline optical modulators and spatial light filters, microfluidic units based on liquid crystals, etc. The results of this work were reported in a paper published in ***Optics Letters***. The described alignment approach is also the main topic of an international patent application (***WO2015139353 (A1)***).

- **We have demonstrated how to apply a ferromagnetic nematic liquid crystal for the visualisation of magnetic fields.**
- **We have shown that ferromagnetic liquid crystals exhibit a significant magneto-viscous response to small magnetic fields.**

In cooperation with the University of Luxembourg we investigated the optical properties of periodic arrangements of droplets and shells made of cholesteric liquid crystals. We found that the shells exhibit optical reflection patterns with much better quality than the droplets. We also demonstrated that the addition of a photo-polymerizable moiety to such structures results in optical materials exhibiting reversibly changing optical properties, even for relatively large mechanical deformations. This makes them very promising for application in authentication tags for the protection of products against imitation. The results on the droplets were reported in a paper published in ***SPIE Proceedings***, while the results obtained with the shells were recently submitted for publication in ***Nature Communications***.

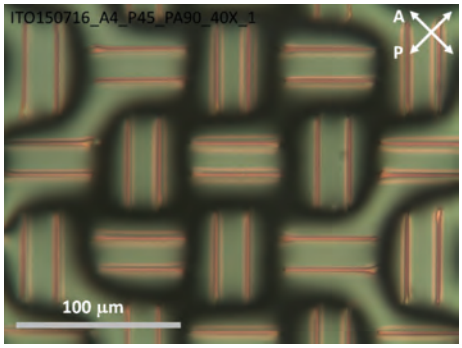

Figure 4: Optical polarization microscopy of the aligned regions of a nematic liquid crystal in contact with pairs of parallel polymer walls.

We continued investigations of the self-assembly of lipophilic guanosine derivatives in thin films formed at the air-water interface and on solid substrates. We demonstrated that the addi-

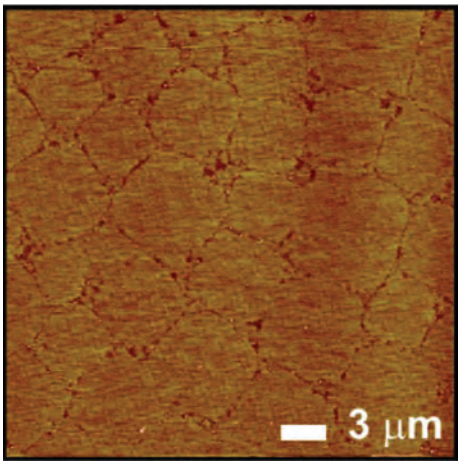

Figure 5: Mosaic surface texture of a LB film of guanosine derivative on mica that is characteristic for KCl addition to the water sub-phase.

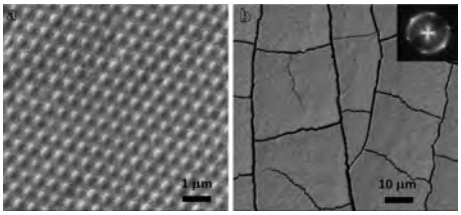

Figure 6: SEM image of a colloidal crystal from polystyrene spheres. The intermediate space between the spheres is filled with maghemite-based superparamagnetic nanoparticles.

tion of a small amount of different ions to the water sub-phase can strongly affect intramolecular organization in such films. The results were reported in a paper published in ***Langmuir***.

In cooperation with University of Vienna we continued our investigations of composite materials incorporating superparamagnetic nanoparticles aiming at the manipulation of a spin state (polarization) of cold neutrons. The structural homogeneity of colloidal crystals from polystyrene spheres, to which different amounts of maghemite-based nanoparticles were added, was analysed. The optimal conditions for the fabrication of samples with good diffraction properties were determined. A member of our group, Matjaž Ličen, was awarded the ***Prešeren prize for students of the Faculty of Mathematics and Physics*** for his M.Sc. work in this field.

We have continued studies of the properties of a ferromagnetic phase in suspensions of magnetic platelets in liquid crystals. In this phase, in addition to the orientational order of the liquid crystal, also the polar magnetic ordering of the platelets is present, which also makes the suspensions sensitive to magnetic fields, leading to a very large magneto-optic effect. We have demonstrated how to apply such a ferromagnetic nematic liquid crystal for the visualisation of magnetic fields. The material exhibits a strong optical response to both external electric and magnetic fields, which gives us an opportunity to use it for the detection of an area of the magnetic vector field in a way that both the magnitude and the direction of a given field can be simultaneously measured (*Liquid Crystals*, 2015, **42**, 1684–1688).

In collaboration with the University of Hyderabad, India we have shown that ferromagnetic liquid crystals exhibit a significant magneto-viscous response to small magnetic fields (*Applied Physics Letters*, 2015, **106**, 161905). In collaboration with the same university we also studied the behaviour of the suspensions of ferroelectric particles in liquid crystals. We found that apart from the nanoparticles, the free oleic acid molecules also significantly affect the phase transition and the physical properties of the suspensions (*Liquid Crystals*, 2015, **42**, 1059–1067).

Nonlinear optics

In the Nonlinear optics laboratory we study new materials and their interactions with laser light. Integrated optics is a promising technology; however, better materials will increase its potential. In cooperation with North Carolina State University in Raleigh, USA, we study new concepts of compact light sources on the basis of a nonlinear optical conversion of existing lasers into the spectral regions where lasers are not yet available. AlGaN grown by metal-organic chemical vapour deposition (MOCVD) has a great potential for optoelectronic devices emitting and detecting light in the ultraviolet spectrum. It is also transparent for THz frequencies, making it interesting for new THz applications.

We study AlGaN waveguides in various geometries that allow for phase-matched, second-harmonic generation into the UV spectral region.

We study AlGaN waveguides in various geometries that allow for phase-matched, second-harmonic generation and therefore give a high efficiency. We study modal dispersion in multimode waveguides and specially prepared waveguides with alternating sign of the nonlinear coefficient that allows quasi phase matching.

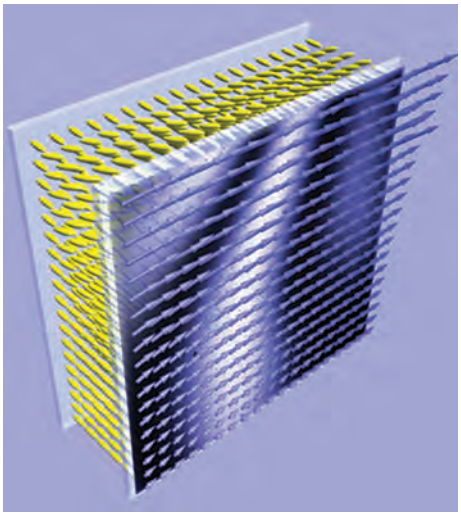

Figure 7: Ferromagnetic nematic liquid crystal for the visualisation of magnetic fields

Biomedical optics

We have continued with the development of novel applications based on pulsed photo-thermal radiometry (PPTR). By combining such non-contact measurements of laser-induced radiometric transients with a dedicated numerical model of light transport in strongly scattering human skin, we have developed a unique approach to the quantitative assessment of haemoglobin mass diffusion and biochemical decomposition rate in traumatic bruises (hematomas). The obtained knowledge and developed methodology could enable a significantly more accurate and reliable determination of the time of injury in forensic science in the near future.

The same experimental technique was also applied to research on the interaction between strong laser pulses and blood vessels in an animal model. The study's ultimate aim is to enable objective guidance of dermatologic laser therapy on an individual patient basis. (Collaboration with the Beckman Laser Institute, University of California at Irvine.) Both studies were supported by equipment loans from Fotona, d.o.o., Ljubljana.

We have also studied the potential of non-contact tissue characterization based on diffuse reflectance spectroscopy (DRS) using an integrating sphere. This technique was applied in conjunction with PPTR and linked to the same numerical models of optical transport and multi-dimensional optimization algorithms, as applied in the analysis of bruises mentioned above. (Collaboration with Norwegian University for Sciences and Technology, Trondheim.)

We have developed a three-dimensional Monte Carlo (MC) model of light transport in spatially heterogeneous biological organs, with a rigorous treatment of curved and/or oblique tissue boundaries. In contrast to most common implementations where the tissue boundaries are approximated according to a rectangular spatial grid, the results of our model do not vary with the discretization step or the re-positioning of the grid.

Using pulsed photo-thermal radiometry and a dedicated numerical model of light transport in human skin, we have assessed the coefficients of hemoglobin mass diffusion and biochemical decomposition in traumatic bruises, with a great potential for future advancements in forensic science.

We have participated in the optical characterization of inorganic nanoparticles such as Yb^{3+},Tm^{3+}:$NaYF_4$, which exhibit so-called up-conversion fluorescence, and in studies of its dependence on the specifics of the nanoparticle synthesis. Upon further improvement of their fluorescence yield and biocompatibility, such nanoparticles have great potential for the development of novel approaches to diagnostic imaging and/or the cell-specific therapy of cancer. (Collaboration with Department for Materials Synthesis, IJS)

Colloidal systems

Research on colloidal and microfluidic systems was conducted in close collaboration with the Laboratory of Experimental Soft Matter at the Faculty of Mathematics and Physics, University of Ljubljana. The experiments were performed mainly on magneto-optical tweezers, which were developed and built in the same laboratory for our specific research. We studied the appearance of vortices in microfluidic channels, the creation of a micro-pump based on thermo-viscous pumping and anomalous diffusion in anisotropic fluids.

Microfluidic samples often comprise micro-cavities, tiny extrusions running perpendicular to the fluid flow. We systematically experimentally investigated the fluid flow in elongated micro-cavities in the low-Reynolds-number regime and compared the observations to a numerical model. We found that the flow properties depend decisively on the depth/width ratio of the cavity. For large aspect ratios, counter-flow vortices emerge, whereas below the critical aspect ratio the flow velocity decreases exponentially from the cavity entrance. The research was performed in collaboration with the Institute of Biophysics, Medical Faculty, University of Ljubljana and the results were published in *Microfluidics and Nanofluidics.*

An important part of microfluidic arrays are the micro-pumps. In our laboratory we successfully demonstrated a working micro-pump based on thermo-viscous fluid pumping. By locally heating the fluid a local change in viscosity is observed enhanced by local thermal expansion. By rapidly changing the heated area, fairly large fluid-flow velocities can be obtained, forming the basis of the so-called thermophoretic separation or characterisation of molecules. The experiments were done as a part of a bachelor's thesis, which was successfully defended by Luka Pirker.

We also studied anisotropic and anomalous diffusion in liquid crystals. When a microparticle moves in a liquid crystal, the intrinsic anisotropy of the medium results in two diffusion coefficients: one for the motion parallel to the director and another for motion in the perpendicular direction. For very short times even sub-diffusion is observed, caused by the elastic properties of the liquid crystal. In a ferromagnetic liquid crystal, the diffusion is even more complex. It is perturbed by the magnetic nanoplatelets, which are added to the liquid crystal to make it ferromagnetic, but can also be influenced by external magnetic fields. The study of how the magnetic field influences the diffusion is still ongoing.

Some outstanding publications in the past year

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Organization of conferences, congresses and meetings

1. Nonequilibrium Phenomena in Complex Matter: new observations and new theories, Ambrož pod Krvavcem, Slovenia, organizers, 13.12.-16.12.2015
2. Symposium "Light and Matter infinite challenges", Jožef Stefan Institute and Faculty of Mathematics and Physics, Ljubljana, Slovenia, organizers, 3.12. - 4.12.2015

Patents granted

1. Aleš Mrzel, Maja Remškar, Adolf Jesih, Marko Viršek, Process for the synthesis of nanotubes and fullerene-like nanostructures of transition metal dichalcogenides, quasi one-dimensional structures of transition metals and oxides of transition metals, EP2132142 (B1), European Patent Office, 5. 08. 2015.
2. Matjaž Lukač, Marko Kazič, Laser system for treatment of body tissue, EP2618768 (B1), European Patent Office, 14. 01. 2015.
3. Marko Marinček, Jožica Kranjec, Matjaž Lukač, Manually guided articulated arm, US9186222 (B2), US Patent Office, 17. 11. 2015.

INTERNATIONAL PROJECTS

1. Kimberly-Clark-2015 - Development of Prototype Curved LCD Shutter
   Prof. Martin Čopič
   Kimberly-clark
2. 7FP - MoWSeS; Nanoelectronics based on Two-dimensional Dichalcogenides
   Prof. Christoph Gadermaier
   European Commission
3. 7FP - TRAJECTORY, Coherent Trajectories through Symmetry Breaking Transitions
   Prof. Dragan Dragoljub Mihailović
   European Commission
4. JET Campaigns-JET1-FU, EUROFUSION
   Dr. Natan Osterman
   European Commission
5. Medium Size Tokamak Campaigns-MST1-FU, EUROFUSION
   Dr. Natan Osterman
   European Commission
6. Individual Guidance of Medical Laser Treatments Using Photothermal Radiometry
   Prof. Boris Majaron
   Slovenian Research Agency
7. Nonlinear Optical Spectroscopy and Electron Paramagnetic Resonance Study of Valley-polarized Charges in the Monolayer Molybdenum Disulfide
   Prof. Christoph Gadermaier
   Slovenian Research Agency
8. Time Resolved Optical Spectroscopy and Manipulation of Ectronically Ordered States in Iron Based Superconductors
   Asst. Prof. Tomaž Mertelj
   Slovenian Research Agency
9. COST MP1205; Advances in Optofluidics: Integration of Optical Control and Photonics with Microfluidics
   Dr. Natan Osterman
   Cost Office
10. COST MP1302; NanoSpectroscopy
    Prof. Christoph Gadermaier
    Cost Office

RESEARCH PROGRAMS

1. Medical physics
   Dr. Matija Milanič
2. Theory of the condensed matter and statistical physics
   Prof. Svjetlana Fajfer
3. Light and Matter
   Prof. Martin Čopič
4. Dynamics of complex nano-systems
   Prof. Dragan Dragoljub Mihailović

R & D GRANTS AND CONTRACTS

1. Symmetry breaking in real time
   Prof. Dragan Dragoljub Mihailović
2. Optimization strategies in biological and artificial microfluidic systems
   Dr. Mojca Vilfan
3. Thermophoretic guidance, accumulation and sorting of biomolecules in microfluidic devices
   Dr. Natan Osterman
4. Development of new ultrafast change memory devices by femtosecond multi-pulse spectroscopy (ULTRA-MEM-DEVICE)
   Dr. Ljupka Stojčevska Malbašić
5. Irradiation and Analysis of Nano SiC Samples
   Miloš Borovšak, B. Sc.
   National Nuclear Research Center

VISITORS FROM ABROAD

1. Dr. Tibor Toth Katona, Hungarian Academy of Sciences, Budapest, Hungary, 12.1.-16.1.2015
2. Dr. Yeong Ah-Soh, Dartmouth College Hanover, NH, USA, 14.1.-16.1.2015
3. Prof. dr. Fulvio Parmigiani, University of Trieste, Trieste, Italy, 19.1.2015
4. Dr. Bojana Višić, Weizmann Institute of science Rehovot, Israel, 14.2.-3.4.2015
5. Dr. Wolfgang Kern, Montanuniversitat Leoben, Austria, 14.4.2015
6. Dorian Alden, NC State University, Raleigh, North Carolina, USA, 7.6.-13.6.2015
7. Prof. dr. Sergei Zaitsev-Zotov, Russian Academy of Sciences, Moscow, Russia, 23.6.-25.6.2015
8. Prof. dr. Lise Lyngsnes Randberg, NTNU, Trondheim, Norway, 7.7.-10.7.2015
9. Dr. Venera F. Nasretdinova, Institute of Radioengenieering and Electronics of the Russian Academy of Sciences, Moscow, Russia, 18.8.-21.8.2015
10. Dr. Yaroslav Gerasimenko, Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia, 18.8.-21.8.2015
11. Dr. Andrei Shumilin, Ioffe Physical-Technical Institute of the Russian Academy of Sciences, St. Petersburg, Russia, 2.9.-30.11.2015
12. Dr. Satoshi Tsuchiya, Faculty of Engineering, Hokkaido University, Japan, 3.9.-6.9.2015
13. Dr. Serquei in Dr. Natasha Brazovskii, LPS CNRS& University Paris-Sud, Paris, France, 9.9.-3.9.2015
14. Dr. Steven Johnson, ETH-Institute for QUANTUM Electronics, Zürich, Switzerland, 16.9.-19.9.2015
15. Prof. dr. Alexey V. Kimel, Radbound University, Nijmegen, The Netherlands, 17.9.-19.9.2015
16. Prof. dr. Michael Bauer, Christian-Albrechts- Univeristatzu Kiel, Germany, 23.9.-25.9.2015
17. Ivana Sremački, University of Novi Sad, Serbia, 9.10.-10.10.2015
18. Dr. Bojana Višić, Weizmann Institute of science Rehovot, Israel, 9.11.-22.11.2015
19. Dr. Venera F. Nasretdinova, Institute of Radioengenieering and Electronics of the Russian Academy of Sciences, Moscow, Russia, 28.11.-31.12.2015
20. Dr. Yaroslav Gerasimenko, Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia, 28.11.-31.12.2015
21. Prof. dr. Joseph Maclennan, University of Colorado, Boulder, USA, 1.12.-6.12.2015
22. Prof. dr. Noel Clark, University of Colorado, Boulder, USA, 1.12.-6.12.2015
23. Prof. dr. Peter Palffy-Muhoray, Kent University, Ohio, USA, 1.12.-6.12.2015
24. Dr. Steven Conradson, Los Alamos National Laboratory, New Mexico, USA, 28.12.-30.12.2015

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University, Higher Education or Higher Vocational Education Textbook

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Patent Application

1. Andrej Kovič, Adolf Jesih, Aleš Mrzel, *Process for the synthesis of quasi one-dimensional structures of molybdenum carbides in the form of microwires, nanowires, nanobelts and microbelts,* P-201500049, Urad RS za intelektualno lastnino, 27. 02. 2015.
2. Ljupka Stojchevska, Tomaž Mertelj, Igor Vaskivskyi, Dragan Mihailović, *Ultrafast nonvolatile memory*, US2015340089 (A1), US Patent Office, 26. 11. 2015.
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2. Marko Marinček, Jožica Kranjec, Matjaž Lukač, *Manually guided articulated arm*, US9186222 (B2), US Patent Office, 17. 11. 2015.
3. Aleš Mrzel, Maja Remškar, Adolf Jesih, Marko Viršek, *Process for the synthesis of nanotubes and fullerene-like nanostructures of transition metal dichalcogenides, quasi one-dimensional structures of transition metals and oxides of transition metals*, EP2132142 (B1), European Patent Office, 5. 08. 2015.

MENTORING

1. Ivan Madan, *Photoinduced non-equilibrium phase transitions in cuprate superconductors:* doctoral dissertation, Ljubljana, 2015 (mentor Dragan Mihailović).
2. Anna Pogrebna, *Time-resolved optical study of quasiparticle and collective dynamics in iron pnictides:* doctoral dissertation, Ljubljana, 2015 (mentor Tomaž Mertelj).
3. Anastasia Samodurova, *Ageing of zirconia ceramics for dental applications:* doctoral dissertation, Ljubljana, 2015 (mentor Tomaž Kosmač; co-mentor Andraž Kocjan).
4. Jože Buh, *Investigation of properties of nanowires produced by transformation from MoSI nanowires:* doctoral dissertation, Ljubljana, 2015 (mentor Dragan Mihailović).
5. Lucija Čoga, *Self-assembling properties of lipophilic nucleoside derivatives on surfaces:* doctoral dissertation, Ljubljana, 2015 (mentor Irena Drevenšek-Olenik).
6. Igor Vaskivskyi, *Light induced phase transitions to hidden states in strongly correlated systems:* doctoral dissertation, Ljubljana, 2015 (mentor Dragan Mihailović).
7. Luka Vidovič, *Characterization of bruises using pulsed photothermal radiometry and diffuse reflectance spectroscopy:* doctoral dissertation, Ljubljana, 2015 (mentor Boris Majaron).
8. Matjaž Ličen, *Colloidal crystals by the addition of magnetic nanoparticles:* master's thesis, Ljubljana, 2015 (mentor Irena Drevenšek-Olenik).
9. Ana Marin, *Determination of fatty acid monolayer thickness on water surface and solid substrates:* master's thesis, Ljubljana, 2015 (mentor Irena Drevenšek-Olenik).
10. Luka Pirker, *Micropump on the principle of thermal viscous pumping:* master's thesis, Ljubljana, 2015 (mentor Natan Osterman).
11. Tomaž Suhovršnik, *The influence of the structure of shock laser Er: YAG and water spray on enamel ablation:* master's thesis, Ljubljana, 2015 (mentor Boris Majaron; co-mentor Matjaž Lukač).
12. Blaž Tašič, Light-sensitive composite materials based on polymers and liquid crystals: master's thesis, Ljubljana, 2015 (mentor Irena Drevenšek Olenik).
13. Tanja Tesovnik, *Study of diffusion properties of Bacillus subtilis biofilms:* master's thesis, Ljubljana, 2015 (mentor David Stopar; co-mentor Natan Osterman).

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***
- ***physics of semiconductors***
- ***medical physics***

Head:
Asst. Prof. Luka Snoj

In the field of **reactor physics** our research was continued mainly towards the development of new methods for the analysis of research and power reactors. The preparation for a new experimental campaign at the TRIGA reactor in collaboration with researchers from CEA, Cadarache, was initiated. Fission chambers with neptunium and plutonium serving as the active materials will be studied during this campaign, scheduled for 2016. Preliminary calculations were made to investigate the fission chambers' response with respect to their location in the reactor core, to control the rod positioning, the type of active material and the use of transmission filters (e.g., cadmium, gadolinium, boron). In collaboration with researchers from CEA, Bruyers Les Chateles, we have designed and implemented a device for irradiation with thermal neutrons from our TRIGA reactor. In 2015, an important upgrade to our deterministic code GNOMER (a part of the core design system CORD-2) was performed, allowing us to simulate nuclear reactor transients.

In the framework of the international collaboration coordinated by OECD/NEA we continued with the tasks in the working group WPEC SG-41, with the objective of "Improving nuclear data accuracy of ^{241}Am and ^{237}Np capture cross-sections". In 2015, an analysis was made on the sub-thermal region of the ^{241}Am and ^{237}Np capture cross-section and its impact on the integral parameters. We have improved the methodology used to analyse cold-neutron measurements in cases of large samples and low-energy resonances and/or bound states. The influence of the Am cross-section uncertainties on the multiplication factor uncertainty was studied as a typical example.

In the framework of the European project CHANDA we collaborated in the process of nuclear data improvements for the MYRRHA Generation IV concept reactor. An analysis of the reactor's computational model uncertainties was made, as well as an analysis of the integral parameters' (i.e., the multiplication factor and the effective delayed neutron fraction) uncertainty and sensitivity to the nuclear data. Based on the findings of this study, we listed the materials and nuclear reactions that importantly affect the uncertainty of the integral parameters and the improvement of whose data would lead to the best reduction in this uncertainty. For these materials/reactions a comparison of the evaluated nuclear data libraries and experimental data libraries was made.

We also collaborated in the international project CIELO (coordinated by OECD/NEA in the framework of the WPEC SG-40 working group), namely, in the evaluation and validation of the reaction cross-sections for ^{56}Fe (in collaboration with the IAEA) and ^{238}U (in collaboration with the IRMM) using neutrons.

With an international comparative study on the sensitivity- and uncertainty-methods and programs we participated in the OECD/NEA projects Uncertainty Analysis in Modelling (UAM) and WPEC SG39.

Researchers at the Reactor Physics Department also provided technical support for the safe operation of the Krško nuclear power plant (NPP) in 2015. We have independently confirmed the nuclear design calculations for the fuel cycle 28 and performed start-up tests after the fuel reloading. In the field of criticality safety we determined the limiting burn-up for safe spent-fuel storage in the old rack of the spent-fuel pool, assuming the loss of boric acid. We initiated calculations to determine the neutron dose fields in the containment building, consequently determining the basic characteristics of the neutron shields for primary pipes aiming to reduce the neutron dose rate in the cubicles in the vicinity of the reactor. As an authorized expert organization in the field of radiation and nuclear safety, we have finalized an independent expertise on a Krško NPP reload safety evaluation for cycle 28.

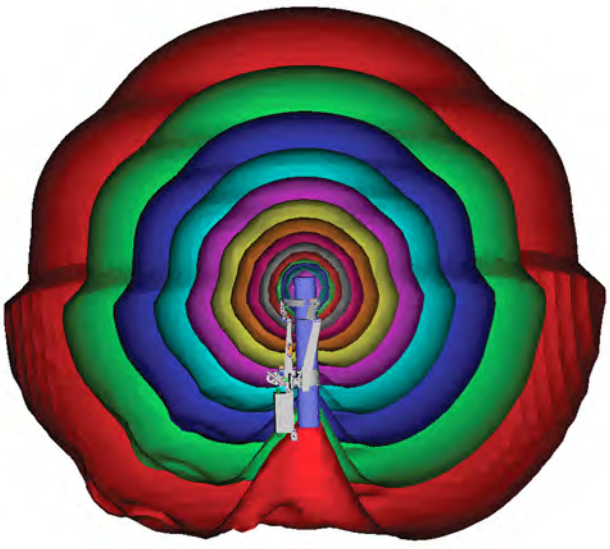

Figure 1: A model of the DT neutron generator and the surfaces of constant neutron flux.

In the field of **plasma physics** we increased our involvement in fusion-related topics. In collaboration with colleagues from the University of St. Kliment Ohridski, Sofia, we worked on research of the impact of interactions between electrons and neutral particles on the properties of edge plasma (scrape-off-layer, SOL) in fusion devices. The emphasis was on a study of the electronic energy distribution function with the FDPT method in the COMPASS tokamak in Prague and on the stellarator TJ-II in Madrid. We participated in the model development for the ionization of neutral particles in the radial direction in the SOL and added the calculations of the radial dependence of the heat flux in the SOL. We continued our work on the development of the triple Langmuir probe method for magnetized plasma and on the interpretation of certain phenomena during measurements with the "ball-pen" probe in weakly-magnetized plasma. In our laboratory we successfully developed and implemented the first measurements with a new ion-sensitive probe with the working name "bunker probe". The work was carried out together with the University of Innsbruck. As part of the EUROfusion consortium we are working on the WP15-MST2-14 project in the scope of which we help in the development of the probe-head and the adapter, which will enable the same probe-head to be used in three different Tokamak Programs of the EUROfusion MST. In addition, we are also involved in the experiment WP15-MST1-AUG / TCV15-2.2-3 in the field of the filamentary transport in the SOL. In the field of theoretical research, we managed to analyse the layer formation in front of the negative electrode in an oblique magnetic field with the use of a fluid model. The Boltzmann relation was used for the electrons in the first approximation, whereas for the improved model the electrons were also modelled with hydrodynamic equations. We studied, in particular, the effect of different source terms for the continuity equation. Last year we completed the project "Determination of computational framework gas discharge treatment in case of surge protection device on a large scale", in which we have used the upgraded 1d3v and 2d3v particle codes for the successful simulation of various processes at the time of discharge. The particle codes have proven to be a useful tool, which is however computationally very demanding and will in future require further research, especially in the field of boundary conditions.

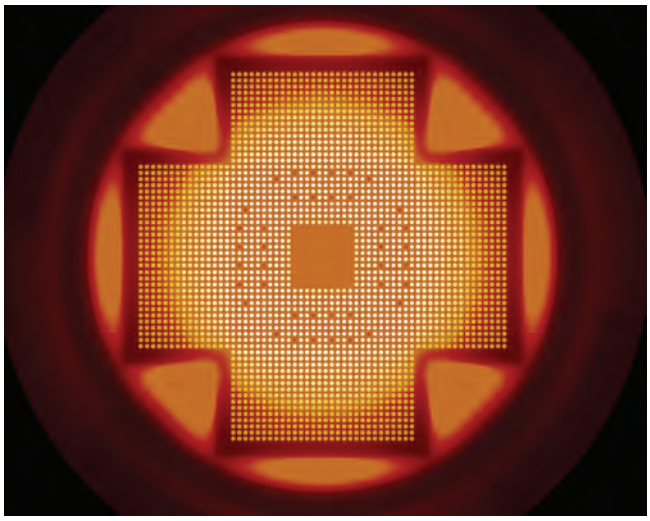

Figure 2: Relative distribution of the thermal flux and fission rate for the VENUS-2 benchmark.

In the field of **neutron transport calculations for fusion reactors** co-workers of the Reactor Physics division have, in collaboration with colleagues from Culham Centre for Fusion Energy, United Kingdom, participated in the preparations for the calibration of neutron detectors to 14-MeV neutrons. As part of these preparations a DT neutron generator was modelled. A comprehensive analysis of the impact of various uncertainties in the composition of the neutron generator on the neutron flux and the spectrum in its surroundings was performed. The DT neutron generator will be used as a calibration source in the calibration of the JET tokamak, for which it is necessary to know its characteristics. For this reason the generator was experimentally characterized in November 2015 using a large set of different detectors (two diamond detectors, various activation foils, two long counters, scintillation counter, etc.) and co-workers of F8 are involved in the computational support. This support for the characterization of the neutron generator and the subsequent calibration procedure are crucial for the successful calibration of the detectors with a target uncertainty under 10 %.

Co-workers from the F8 department have performed calculations of the neutron field inside the torus and determined the expected damage rate in samples of structural materials to be irradiated at specific locations in the JET torus during the upcoming DT campaign. The expected damage rate in the highest exposed position is 10^{-5} DPA, which is comparable to the damage near the vacuum port of the ITER reactor. Members of the IJS staff are co-responsible for the maintenance of a model for transport calculations with the Monte Carlo method, needed as support for the calibration of detector systems. This cooperation is positioned within the framework of the new EUROfusion project under H2020.

The parametric neutron source, used to model the plasma neutron source, was expanded in 2015 by the addition of the simulation of a TT (tritium + tritium) plasma source, as will be used in the TT campaign at the JET tokamak. The neutrons generated in this reaction are of particular interest since the reaction has three important channels for the generation of neutrons with different energies. The relative intensity of each channel is, however, poorly known. A determination of the relative intensities of these three channels will be an important outcome of the TT campaign and the co-workers of F8 are engaged in the computational support for the experiment. Our task is therefore to find suitable detectors (mainly activation foils) for the experimental determination of the importance of these channels. In 2015 we started the preparations for the calculations associated with the TT campaign.

Within the European fusion framework (Fusion for Energy projects) we were involved in the following activities:

- Preparation and analysis of a benchmark experiment, which included irradiation of a copper block (60 × 60 × 70 cm^3) with 14-MeV D-T neutrons. The purpose is the validation of the neutron cross-sections for copper.
- The TRIGA reactor was used for irradiation and analyses of Mn samples for the control of tritium production.
- We evaluated and validated iron neutron cross-sections.
- Based on SINBAD benchmarks we validated photon libraries.
- We analysed and validated the MCUNED program, used for the modelling of a DT neutron source.
- In 2015 we started work on the ITER reactor, our responsibility was the calculation of the impact of runaway electrons on the production of gamma rays and the potential impact on the detection of gamma radiation from the plasma. The majority of the work was devoted to the modification of the MCNP numerical code in order to be able to make calculations with asymmetrical sources of runaway electrons by using the existing ITER model. In the frame of the same project we are also involved in planning of the neutron attenuator, needed to protect the hard x-rays monitor.

In the field of **medical physics** we continued the research on the subjects of our greatest interest: positron emission tomography (PET) image analysis, image-guided therapy of cancer and tumour modelling. We dealt with a kinetic analysis of images from DCE-MRI (dynamic contrast-enhanced magnetic resonance imaging) and FMISO PET (fluoromisonidazole) in order to deduce whether both methods could be used to survey the same subject, i.e., if the dynamic FMISO PET imaging could be replaced by a simultaneous static FMISO PET and DCE-MRI imaging. The results will be presented at this year's ESTRO meeting and also published in a scientific journal. In collaboration with the Institute of Oncology we continued with the radiomic analysis of the FDG PET/CT (fluorodeoxyglucose) response to radiotherapy and chemotherapy in patients with ORL cancer and in patients with lung cancer. Preliminary results indicate that, based on radiomic parameters from FDG PET/CT images taken before therapy, it can be roughly predicted whether the patient will respond to the treatment or not. We have begun to model the combined treatment with immunotherapy and radiotherapy. Clinical cases show that with this treatment combination it is possible to achieve total healing, even for patients with metastases; however, there are numerous open questions (dose, fractionation way, immunotherapy schedule, etc.) to which we hope to provide answers using the computational model. Similar to previous years, we collaborated closely with the University of Wisconsin – Madison. In 2015 we also collaborated on the foundation and formation of a new research program group at the Faculty of Mathematics and Physics (University of Ljubljana), named Medical physics, which includes researchers from four Slovenian research institutes: the Faculty of Mathematics and Physics, Jožef Stefan Institute (departments F7, F8 and F9), the Institute of Oncology and the University Medical Centre Ljubljana.

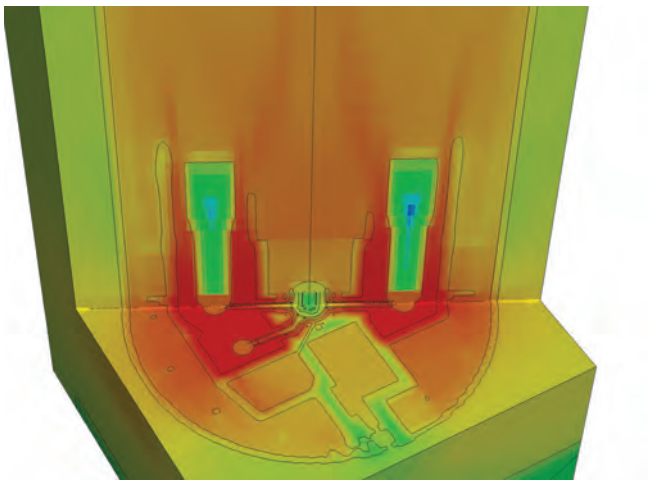

Figure 3: Adjoint flux for tallies in the first and second cubicle of NEK, visualized with VisIt

Some outstanding publications in the past year

1. Gyergyek, Tomaž, Kovačič, Jernej. Fluid model of the sheath in front of a floating electrode immersed in a magnetized plasma with oblique magnetic field: Some comments on ion source terms and ion temperature effects. *Physics of plasmas*, ISSN 1070-664X, Apr. 2015, vol. 22, no. 4, str. 043502 ilustr. doi: 10.1063/1.4916318.
2. Gyergyek, Tomaž, Kovačič, Jernej. A self-consistent two-fluid model of a magnetized plasma-wall transition. *Physics of plasmas*, ISSN 1070-664X, Sep. 2015, vol. 22, no. 9, str. 093511 ilustr. doi: 10.1063/1.4931169.
3. Popov, Tsviatko K., Dimitrova, Miglena, Pedrosa, M. A., Lopez-Bruna, D., Horáček, J., Kovačič, Jernej, Dejarnac, Renaud, Stöckel, Jan, Aftanas, M., Böhm, P., Bilkova, P., Hidalgo, C., Panek, Radomir. Bi-Maxwellian electron energy distribution function in the vicinity of the last closed flux surface in fusion plasma. *Plasma physics and controlled fusion*, ISSN 0741-3335, 2015, vol. 57, str. 115011. http://stacks.iop.org/0741-3335/57/i=11/a=115011.
4. I. Kodeli, K. Kondo, R.L. Perel, U. Fischer, Cross-Section Sensitivity and Uncertainty Analysis of the FNG Copper Benchmark Experiment, Fusion Engineering and Design (2015), doi: 10.1016/j.fusengdes.2015.11.058.

Patent granted

1. Robert Jeraj, G. Liu, System and method for evaluation of disease burden, US9161720 (B2), US Patent and Trademark Office, 20. 10. 2015.

INTERNATIONAL PROJECTS

1. Specific Grant Agreement; Cu Experiment and TBM Nuclear Instrumentation
   Prof. Ivan Aleksander Kodeli
   European Commission
2. 7FP - CHANDA; solving CHAllenges in Nuclear Data
   Prof. Ivan Aleksander Kodeli
   European Commission
3. F4E-GRT-168.02; Specific Grant Agreement: Nuclear Data Improvements and Development of Tools - Nuclear Data Evaluation
   Prof. Ivan Aleksander Kodeli
   European Commission
4. F4E-FPA-327 (PMS-DG): SG04; Conceptual Design and Interface Definitions for the Enabled ITER Radial Gamma-Ray Spectrometer Diagnostic
   Dr. Igor Lengar
   The European Joint Undertaking For The Development
5. 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
6. Integral Measurements for the Validation of the Dosimetry Cross Sections; F41031 Testing and Improving the IAEA International Dosimetry Library for Fission and Fusion (IRDFF)
   Prof. Ivan Aleksander Kodeli
   IAEA - International Atomic Energy Agency
7. H2020 - AIDA-2020; Advanced European Infrastructures for Detectors at Accelerators
   Dr. Vladimir Radulović
   European Commission
8. RU-FU, EUROFUSION; Research Unit - Administration and Services
   Asst. Prof. Luka Snoj
   European Commission
9. Plasma Facing Components-1-IPH-FU, EUROFUSION
   Dr. Jernej Kovačič
   European Commission
10. Exploatation of DT Operation for ITER-JET3-FU, EUROFUSION
    Asst. Prof. Luka Snoj
    European Commission
11. JET Enhancements-JET4-FU, EUROFUSION
    Dr. Igor Lengar
    European Commission
12. Medium Size Tokamak Campaigns-MST1-FU, EUROFUSION
    Dr. Jernej Kovačič
    European Commission
13. Neutron Transport in Fusion and Fission Reactors by Coupling of Deterministic and Monte Carlo Methods
    Dr. Igor Lengar
    Slovenian Research Agency
14. Development and Application of Kinetic Analysis for PET for Optimization of Antiangiogenic Targeted Cancer Therapies
    Prof. Robert Jeraj
    Slovenian Research Agency
15. Experimental on-line neutron spectra adjustment method using various fission chambers with adequate fissile isotopes
    Dr. Gašper Žerovnik
    Slovenian Research Agency

RESEARCH PROGRAM

1. Medical physics
   Prof. Robert Jeraj
2. Reactor Physics
   Asst. Prof. Luka Snoj

R & D GRANTS AND CONTRACTS

1. Neutron calculations for use with neutron diagnostics - application to the JET fusion reactor
   Dr. Igor Lengar
2. Development of methodology for calibration of neutron detectors with a 14.1 MeV neutron generator - JET fusion reactor case
   Asst. Prof. Luka Snoj
3. Analysis of material damage and activation in large scale fusion reactors - application to the reactor JET
   Dr. Igor Lengar
4. Determination of computational framework for treating gas discharges in case of surge protection gas discharge tubes
   Dr. Jernej Kovačič
   Ministry of Education, Science and Sport of the Republic of Slovenia
5. Development of Radiation Resistant Cameras
   Asst. Prof. Luka Snoj
   Isec Industrial Security Ab
6. Irradiation of Piezoelectric Transducers
   Asst. Prof. Luka Snoj
   Commissariat A L'energie Atomique Et

NEW CONTRACTS

1. Reload Operational Core Analysis, Post Refueling nuclear design check tests, PIS and KFSS cycle specific data for future fuel cycles
   Dr. Marjan Kromar
   Krško Nuclear Power Plant, Krško
2. Development of advanced methods for the description of dynamic processes in a nuclear reactor"
   Asst. Prof. Luka Snoj
   Krško Nuclear Power Plant, Krško
3. Reload operational core analysis, post refueling nuclear design check tests, PIS and KFSS cycle specific data for future fuel cycles
   Dr. Marjan Kromar
   Krško Nuclear Power Plant, Krško
4. Independent Evaluation of the NPP Krško Cycle 28 Reload Safety Evaluation
   Dr. Marjan Kromar
   Krško Nuclear Power Plant, Krško
5. Independent Evaluation of Modified Krško 16x16 VANTAGE+Fuel design fully in accordance with NEK Technical Specification SP-ES1250 Rev.0
   Dr. Marjan Kromar
   Krško Nuclear Power Plant, Krško
6. Neutron Streaming Analysis and Shielding Determination
   Asst. Prof. Luka Snoj
   Krško Nuclear Power Plant, Krško

VISITORS FROM ABROAD

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2. Judy Vyshniauskas, Research Reactor Section, Division of Nuclear Fuel Cycle and Waste Technology, Dept. Of Nuclear Energy, International Atomic Energy Agency, Vienna, Austria, 16. 2.–3. 3. 2015
3. Antonio Tejero Del Caz, Departamento de Física, Facultad de Ciencias, Universidad de Córdoba, Córdoba, Spain, 1. 3.–31. 5. 2015
4. Stefan Costea, University of Innsbruck, Innsbruck, Austria, 20. 4.–24. 4. 2015
5. Prof. Tsviatko K. Popov, Faculty of Physics, University St. Kliment Ohridskiy, Sofia, Bulgaria, 4. 5.–15. 5. 2015
6. Dr. Loic Barbot, Damien Fourmentel, Christophe Destouche, Christian Jammes, CEA Cadarache, France, 20. 5.–21. 5. 2015
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8. Niklas Barringer, ISEC - Industrial Security AB, Sweden, 1. 12.-3. 12. 2015

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Note:
* part-time JSI member

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Original Article

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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 cost, both in terms of money and human resources, has 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:

In 2015 the upgraded Large Hadron Collider (LHC) began its operation at CERN and reached the record centre-of-mass energy of 13 TeV, which marks the beginning of "Run 2" of the LHC's operation.

- ATLAS at the Large Hadron Collider (LHC) at CERN (3000 researchers, 174 institutions from 38 countries),
- Belle at the asymmetric electron-positron collider (KEK-B) at KEK (409 researchers, 62 institutions from 15 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 km²) observatory near Malargue in Argentina for the 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 2015's activities follows, focused on the contributions of our researchers:

ATLAS experiment

In 2015 the upgraded Large Hadron Collider (LHC) began operating at CERN and reached the record centre-of-mass energy of 13 TeV, which marks the beginning of the "Run 2" of LHC operation. Despite the fact that 2015 at CERN was planned as the LHC commissioning year, the ATLAS experiment already managed to record a sufficient quantity of data to be able to perform the first analyses [1]. The results of some of these analyses in certain areas of New Physics searches are already competitive with the results of the analyses of the data collected in the period 2009–2013 (the so-called "Run 1" period). Consequently, the scientists in the ATLAS collaboration performed the first analyses of New Physics searches on Run 2 data in addition to finishing the analyses on Run 1 data. In the analysed data (Figure 1) a considerable number of different theories were excluded and there are some indications of potential new discoveries in particle physics – however, for confirming or refuting these a larger amount of data needs to be recorded and analysed. Subsequently, the next 2 years will be full of challenges and expectations of pivotal events.

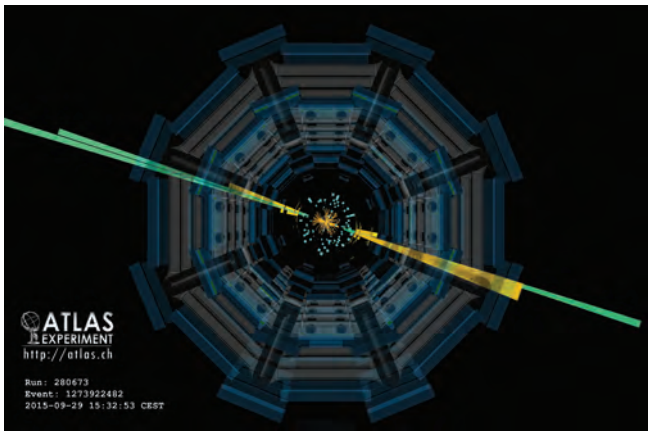

Figure 1: The event display of a proton-proton collision at the centre-of-mass energy of 13 TeV with the highest invariant mass of two jets in the resonance searches in the data collected in 2015 (Event 1273922482, Run 280673). The two central jets have an invariant mass of 6.9 TeV

The group from Ljubljana took a leading role in designing, building and operating the ATLAS Beam Condition Monitor (BCM), Beam Loss Monitor (BLM), Radiation Monitor (RADMON) and Diamond Beam Monitor (DBM). The BCM was built to monitor the conditions of the LHC beams and issue warnings during unexpected and potentially dangerous situations. In Run 1 of the Large Hadron Collider (LHC) it served as the main luminosity monitor for the great majority of almost 30 fb^{-1} that were delivered to ATLAS. The BLM, on the other hand, acted solely as a safety system and protected the ATLAS Inner Detector from potential damage by LHC beams that fired and extracted LHC beams twice in summer 2011. 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, but it is still in the commissioning phase. It is built from a pCVD diamond sensor and pixel readout chip with pixels of size 250×50 um^2. It will provide luminosity measurements complementary to the BCM and other luminosity monitors in ATLAS. It has the potential to become the main luminosity monitor with increasing luminosity when other detectors start to saturate.

The upgraded ATLAS detector will be able to record the data even at the highest luminosity delivered by the HL-LHC collider.

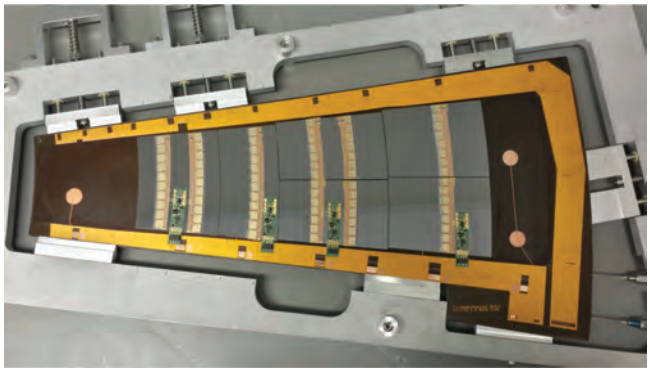

Figure 2: Thermomechanical model of the detector module support structure (petal). This will be a building block of the forward tracker in the upgraded ATLAS spectrometer. Flexible circuits covering the carbon core structure have been fabricated in ELGOLINE from Podskrajnik.

The ATLAS collaboration intends to upgrade the detector in the next decade. This upgraded detector will be able to record data even at the highest luminosity ($5\ 10^{34}\ cm^2s^{-1}$) delivered by the HL-LHC collider (High Luminosity LHC). The inner part of the detector will be replaced by a new tracker of charged particles with sensors based on semiconductor technology. Our department is involved in the development of sensors, readout electronics and support structures. The company ELGOLINE from Podskrajnik is fabricating multilayer flexible circuits, which will serve as the interface between the detector modules and the control electronics. The first thermomechanical prototypes were designed, fabricated (Figure 2) and tested. The results of the measurements were compared with numerical simulations.

In 2015 the ATLAS collaboration published more than 110 scientific papers in the most distinguished scientific journals, bringing the total number of scientific papers published by the collaboration to 472, with more than a hundred more papers in preparation.

Belle detector at the asymmetric electron positron collider KEKB at KEK

The data collected by the Belle detector at the electron-positron collider KEKB in Tsukuba, Japan, are being exploited by members of the department to carry out precise measurements of rare processes in the world of subatomic particles. By comparing the results of measurements and theoretical predictions it is possible to check for possible contributions from New Physics, the yet unknown particles and processes. These processes are – among others – also responsible for the fact that we live in a universe in which matter (particles) completely dominates over antimatter (antiparticles).

Measurements with the Belle detector also allow searches for dark-matter particles, which constitute about 25% of the universe, but have not been observed

In 2015, researchers from the international research group Belle (495 researchers from 85 institutions and 20 countries) published an important result. They studied B+ meson decays into the τ lepton and its neutrino [2]. This rare decay (only one out of 10,000 B+ mesons decays in this way) is interesting, as its probability could be modified due to the potential contribution of the hitherto unknown charged Higgs boson.

Figure 3: Installation of one of the 16 TOP detector modules in the experimental hall of the Belle II spectrometer. This detector system is being prepared by physicists from Japan, the US, Italy and Slovenia.

Measurements carried out using the data collected with the Belle detector also allow for searches of dark matter particles, which constitute about 25% of the universe, but have not been observed. In one of the studies [3] they searched for the presence of the so-called dark photon, a particle like a photon that interacts with the hypothetical particles that make up the dark matter. No evidence was found for the dark photon; it was shown that the probability of its interaction with an ordinary photon is less than $8 \cdot 10^{-4}$. With the follow-up Belle II detector it will be possible to look for dark photons with a ten-times smaller interaction probability. Significant excitement in the particle-physics community was recently caused by a measurement of the probability of $B \rightarrow D\ \tau\ \nu$ and $B \rightarrow D^*\ \tau\ \nu$ decay, as the measured values did not agree with the theoretical predictions, and could therefore point to a New Physics contribution. Scientists from the Belle collaboration have performed new measurements of these decays and found that while their probabilities do not deviate significantly from the Standard

Model expectations, the measurements can also be explained with a contribution from a charged Higgs boson.

A large fraction of the activity of the Ljubljana Belle team was devoted to the preparation of the follow-up Belle II experiment. Belle II is again an international collaboration with 680 scientists from 96 institutions and 23 countries. In 2015, the group reached several important milestones. The electromagnetic calorimeter and the muon detector were tested in situ. The central drift chamber, intended for the detection of tracks of charged particles, with more than 14,000 thin wires has successfully started with the operation; the first tracks of cosmic muons could be observed, showing that the accuracy of the measurements is already very close to the design values.

In 2015 the group successfully started with the assembly of one of the most delicate parts of the detector, i.e., the TOP (Time-Of-Propagation) counter. This detector component is intended for the identification of charged particles through the detection of Cherenkov light; this light is emitted by very fast particles in a 2-cm-thick quartz plate. Figure 3 shows the transportation of one of the modules in the experimental hall. In the meantime, we also completed preparations for the assembly of the detector to identify particles in the forward region, i.e., the ARICH (Aerogel Ring Imaging Cherenkov) counter. We completed the development of the read-out electronics. The corresponding printed circuit board will be manufactured in Slovenia, and is expected to be ready in March 2016, for the first installation in the detector (Figure 4).

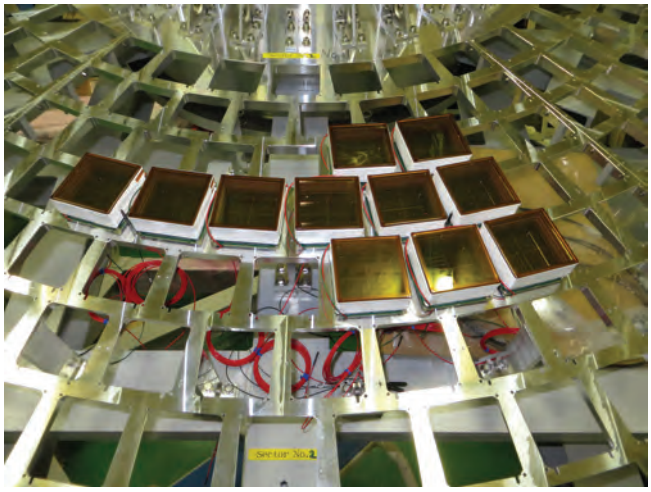

Figure 4: Assembling the detector to identify charged particles in the forward direction (Aerogel Ring Imaging Cherenkov counter, ARICH): the main components are the light sensors and the associated read-out electronics, designed and produced in Slovenia.

Pierre Auger observatory

The Earth is exposed to a permanent shower of cosmic particles from outer space. Most of the particles are fully ionized atomic nuclei, moving with relativistic energies. The bulk of them with energies up to 10^{17} eV originate from within our Milky Way. Some particles have a thousand times higher energies, *i.e.*, around 10^{20} eV. To clarify the origin of the highest-energy particles, their properties like energy, arrival direction and the particle type (photons, protons, atomic nuclei) have to be measured. The highest-energy cosmic rays are extremely rare. On Earth one particle is registered in an area of 100 square kilometres, once in a hundred years. The measurement of such particles requires a huge measurement device that is operated for a long time.

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 Observatory is the largest-aperture cosmic-ray observatory at present, built to reach large statistics for the low flux of Ultra High Energy Cosmic Rays (UHECRs). Constructed in the province of Mendoza, Argentina, the observatory is the first hybrid air-shower experiment combining two independent observation techniques. It consists of 1660 water Cherenkov stations with a 1.5 km spacing on a triangular grid (the surface detector, SD), overlooked by 24 fluorescence telescopes housed in four buildings (fluorescence detector, FD). It covers an area of 3000 square kilometres of Pampa and has a hexagonal footprint with a diameter of about 60 kilometres.

The advent of the Pierre Auger Observatory has dramatically advanced our understanding of UHECRs. A strong flux suppression at the highest energies, similar to the one expected from cosmic-ray energy losses in the CMB (GZK-effect), has been observed beyond any doubt. Moreover, strong flux limits have been placed on the photon and neutrino components at EeV energies disfavouring exotic particle physics models for the origin of the most energetic cosmic rays. Finally, there are indications of the presence of a large-scale anisotropy both below and above the energy of the ankle, and for an anisotropy on smaller angular scales at $E > 5.5 \cdot 10^{19}$ eV.

The all-particle cosmic-ray energy spectrum carries combined information about the UHECR sources and about the galactic and/or intergalactic media through which the cosmic rays propagate. The flux suppression due to energy losses by photo-pion production and photo-disintegration in the CMB (GZK-effect) is the only firm prediction ever made concerning the shape of the UHECR spectrum. The first observations of a cut-off were reported by Auger. However, at present we cannot be sure whether this flux suppression is an imprint of the aforementioned GZK energy losses or whether it is related to the maximum cosmic-ray acceleration energy at the sources. Despite the high level of precision reached, the all-particle energy spectrum by itself does not allow us to conclude unambiguously about the origin of the spectral structures and thereby about the origin of the cosmic rays from the ankle to the highest energies. Additional key information is obtained from the mass composition of the cosmic rays. Unfortunately,

the measurement of primary masses relies on comparisons of data to extensive air shower (EAS) simulations, with the latter serving as a reference. EAS simulations, however, are subject to uncertainties mostly because the hadronic interaction models need to be employed at energy ranges much beyond those accessible to man-made particle accelerators. Therefore, the advent of LHC data, particularly those measured in the extreme forward region of the collisions, is of great importance to cosmic-ray and air-shower physics and have already helped to tune the hadronic interaction models. The data from the Pierre Auger Observatory suggest an increasingly heavier mass composition above $4 \cdot 10^{18}$ eV when compared to post-LHC interaction models. These data complement those of the energy spectrum in a remarkable way: the change of the composition starts just above the ankle and the composition becomes increasingly heavy towards the flux-suppression region, which is exactly the behaviour expected from the maximum energy scenario.

Further important information about the nature and origin of UHECRs is contained in the distribution of their arrival directions over the sky. Unlike energies or primary mass, the arrival directions of cosmic-ray events are practically free from systematic errors. Apart from the (unknown) distribution of sources over the sky, the two main factors that determine the UHECR anisotropy are the deflections in cosmic magnetic fields and the attenuation due to the interactions with the background radiations. The Pierre Auger Collaboration has performed a number of anisotropy searches on different angular scales and by applying different techniques. No significant deviations from the isotropic expectations were found throughout the analyses performed, which provides constraints on the production of cosmic rays above 10^{18}eV if they were emitted from stationary galactic sources densely distributed in the galactic disk. At high energies (around and above the cut-off in the spectrum) the situation is more interesting. The Auger collaboration has reported an excess of UHECR events with $E > 55$ EeV around the direction towards the Centaurus supercluster at a distance of about 60 Mpc and Centaurus A, a close AGN at a distance of about 3.5 Mpc. The largest excess was found for a circular region of the angular size 18^{o}. This region includes 10 out of 60 events above 55 EeV in the data set of this analysis, while 2.44 are expected from isotropy.

By now, the Auger Observatory has collected 10 years of data, 6 years of which were with the fully instrumented observatory. The results obtained so far have dramatically advanced our understanding of ultra-high-energy cosmic rays. However, despite more than 40,000 km^2sr yr of high-quality data being analysed, it is still not possible to determine whether the observed flux suppression is due to the GZK-effect or due to the limited accelerating power of the sources. It is evident that this puzzle must be resolved in order to identify the sources or source regions. The key lies in a better identification of the primary composition, especially extending to the highest energies. The most promising way to obtain further composition-sensitive information is the discrimination between the electromagnetic and muonic components of the shower with ground-array measurements. Intense R&D efforts thus have been started in this direction and five different options for complementing the surface detector array have been investigated. They include placing scintillators or resistive plate chambers with a pad readout beneath the tanks or into the ground, placing scintillators on top of the tanks, or segmenting the existing water Cherenkov detectors into a top and bottom layer. The principle is always the same: the top detector samples more of the electromagnetic component, while the response of the bottom detector becomes more pronounced to muons.

The different technical realizations have been assessed under considerations of performance, technical complexity, robustness, deployment, and costs, with the result that the scintillators to be placed on top of the tanks were given priority for realization. The detector will be further optimized and new surface-detector electronics be produced to facilitate the readout of the extra channels and to provide more powerful triggers and better monitoring. Another small PMT to be placed into the water Cherenkov tank is considered for increasing the dynamic range of the detector stations, enabling us to measure signals more closely to the shower core than has been possible up to now. The R&D phase and prototyping ended in 2015. The construction will start in 2016 and will last for about 2 years. The upgraded observatory would then take data into 2023, thereby doubling the statistics that have been collected with the present setup.

Distributed computing

The SiGNET Tier-2 distributed computing centre with a computing power of 4200 cores and a storage capacity of 3000TB continued to provide resources to the ATLAS, Belle II and Pierre Auger experiments. During the ATLAS Run-2 data taking that started in 2015, the cluster also participated in the prompt reconstruction that is usually performed on the Tier-0 centre at CERN. Due to the high computing demands of data reconstruction, part of the data processing was executed on reliable distributed sites, SiGNET being amongst them. A dedicated production on 1000 cores has been executing throughout 2015 as a part of the first large-scale Monte-Carlo production campaign of the Belle II experiment. The SiGNET storage remains integrated as a part of the NDGF-T1 data centre, providing a first-class storage endpoint to the ATLAS experiment. A dedicated dCache storage endpoint for Belle II was set-up with a capacity of 500TB. The SiGNET cluster was partially moved to a new building dedicated to the common computing infrastructure of the Jožef Stefan Institute.

Detector development

We continued the research on particle detectors developed in HV-CMOS technology, which enables the cost-effective and large-series production of sensors. The HV processes allow the connection of the substrate to a high voltage, which makes charge drift the dominant component contributing to the signal. The ability to integrate first the amplification and further processing stages in the sensor allows for an excellent signal-to-noise ratio and so a very efficient operation. The investigation of their radiation hardness was the main activity in 2015. It was shown that the HV-CMOS sensors are very radiation hard and those with a low-resistivity substrate exhibit an improvement of the charge-collection efficiency after neutron irradiations (irradiations performed at the JSI reactor facility). We were first to introduce the model that explained their performance after irradiation.

We continued the research on particle detectors developed with HV-CMOS technology, which enables the cost-effective and large-series production of sensors.

A large part of the research in 2015 was devoted to studies of Low Gain Avalanche Detectors, which are of great interest in particle physics and medicine. Large numbers of sensors were tested after irradiation with different particles, which showed that the gain decreases with irradiation [LGAD]. The decrease of the gain was attributed to a decrease in the initial dopant concentration (boron) in the multiplication layer, which leads to lower electric fields.

A multichannel system for the simultaneous readout of different dosimetric sensors was developed and tested in 2015. Apart from its use in medical applications, the systems will also be used in the future irradiation centre at the JSI research reactor facility.

We participated in the second round of the European Commission call for new detection methods in medicine (H2020-PHC-2015). In a potential collaboration COMPAXS, composed of researchers from Germany, Israel, France, Spain and Slovenia, the group from the JSI would be in charge of building a detector for X-ray fluorescence. Within the international CIMA collaboration, with members from University of Michigan, Ohio State University, IFIC Valencia and JSI, we built a prototype of a high-resolution PET detector at OSU and continued its evaluation. Also, the analysis of collected images was further developed.

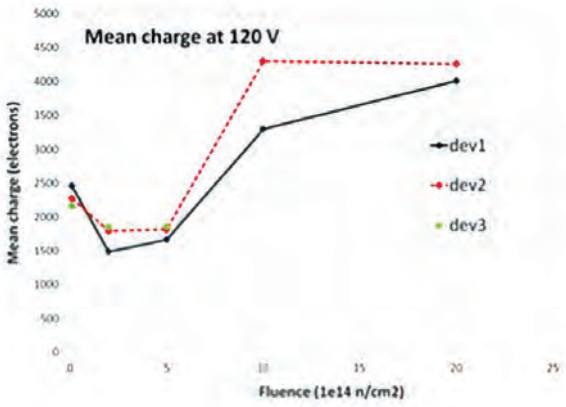

Figure 5: Signal measured in CMOS sensor after irradiations with neutrons.

We also continued with the development of new methods for the detection of annihilation gamma rays in positron emission tomography (PET), one of the most important medical imaging methods. We have already shown that the difference in the time of flight of the two gamma rays can be measured with a very high precision of 80ps (FWHM) if a Cherenkov radiator is used as a gamma-ray converter instead of a scintillator. With such a resolution, we can directly obtain three-dimensional information on the emission point of the two gamma rays, which substantially reduces the time needed to determine the activity distribution in the patient. While this first result was achieved with a microchannel plate photomultiplier tube (MCP PMT) as the low-level light sensor, in 2015 we have examined the possibilities offered by silicon photomultipliers (SiPM), semiconductor-based sensors that are much easier to handle, are relatively compact, work in a magnetic field (important for multimodal imaging), and would be much cheaper. The results are very encouraging; with cooled sensors we have achieved an excellent signal-over-noise ratio and a time-of-flight resolution very close to the desired value (200 ps FWHM).

An ultra-fast method was developed for the detection of annihilation gamma rays; this breakthrough could have a major impact on progress in positron emission tomography (PET).

Within the framework of the European project AIDA 2020 (Advanced European Infrastructures for Detectors at Accelerators) more than 120 irradiations using neutrons were performed at the reactor centre at the request of 18 different institutions. The focus was on the development of components for planned upgrades of the ATLAS , CMS and Belle detectors.

Organization of Conferences, Congresses and Meetings

1. XXVII International Symposium on Lepton Photon Interactions at High Energies, Exhibition and Congress Centre in Ljubljana, 17 – 22 August 2015

INTERNATIONAL PROJECTS

1. Design, Procurement and QA of Flex-rigid Hybrids
   Prof. Marko Mikuž
   European Organization For Nuclear Research
2. Irradiations in TRIGA Nuclear Reactor
   Prof. Vladimir Cindro
3. 7FP - AIDA; Advanced European Infrastructures for Detectors at Accelerators
   Prof. Marko Mikuž
   European Commission
4. H2020 - JENNIFER; Japan and Europe Network for Neutrino and Intensity Frontier Experimental Research
   Prof. Peter Križan
   European Commission
5. H2020 - AIDA-2020; Advanced European Infrastructures for Detectors at Accelerators
   Prof. Marko Mikuž
   European Commission
6. Development and Tests of a Method for Particle Identification with a TOP Counter
   Prof. Marko Starič
   Slovenian Research Agency
7. Methods and Accuracies of the Mixing and CP Violation Measurements of the Charmed Hadrons at the Belle II Experiment
   Prof. Boštjan Golob
   Slovenian Research Agency
8. Study of Silicon Detectors and Structures by using Scanning Transient Current Tecnique
   Dr. Gregor Kramberger
   Slovenian Research Agency
9. Measurement of Rare Semileptonic B Meson Decays and Construction of Belle II Detector
   Asst. Prof. Anže Zupanc
   Slovenian Research Agency
10. Development of New Detectors for Medical Imaging
    Prof. Marko Mikuž
    Slovenian Research Agency
11. Development of Silicon and Diamond Semiconductor Detectors for Particle Physics Experiments and Medical Imaging
    Prof. Vladimir Cindro
    Slovenian Research Agency

RESEARCH PROGRAMS

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

R & D GRANTS AND CONTRACTS

1. ATLAS Diamond Beam Monitor
   Prof. Marko Mikuž
2. Search for microscopic black hole signatures with ultra-high energy cosmic rays
   Prof. Marko Zavrtanik
3. Novel detection methods based on Cherenkov radiation
   Prof. Peter Križan
4. Novel scintillation detectors for precision particle physics experiments
   Prof. Peter Križan
5. Development of in-vivo dosimetry for applications in radiotherapy
   Dr. Gregor Kramberger
6. COST TD1401; Fast Advanced Scintillator Timing (FAST)
   Prof. Peter Križan
   Cost Office

NEW CONTRACT

1. Data-storage system
   Prof. Andrej Filipčič
   Xenya, d. o. o.

VISITORS FROM ABROAD

1. Prof. Pierr Savard, University of Toronto, Toronto, USA, 22. 2. – 24. 2. 2015
2. Marko Mark Andjelković, Faculty of Electronic Engineering Niš, Serbia, 2. 3.–20. 3. 2015
3. Prof. Hermann Kolanoski, University of Berlin, DESY, Germany, 16. 3. – 20. 3. 2015
4. Dr. James Giles, CERN, Genève, Switzerland, 8. 4. 2015
5. Prof. dr. Tom Browder, University of Hawaii, USA, 16. 8. – 23. 8. 2015
6. Prof. dr. Alan Guth, Massachusetts Institute of Technology, Cambridge USA, 18. 8. – 22. 8. 2015
7. Koto Noguchi, University of Tokyo, Tokyo, Japan, 23. 9. – 15. 10. 2015
8. Kazuho Kobayashi, University of Nagoya, Nagoya, Japan, 2. 11. – 27. 11. 2015
9. Prof. dr. Toru Iijima, University of Nagoya, Nagoya, Japan, 17. 11. – 18. 11. 2015
10. Prof. dr. William Barletta, Massachusetts Institute of Technology, Cambridge, USA, 7. 12. 2015

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26. Manca Mrvar, B. Sc.
27. Miha Muškinja, B. Sc.
28. Tara Nanut, B. Sc.
29. Grygorii Sokhrannyi, B. Sc.
30. Tina Šfiligoj, B. Sc.
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34. Dejan Lesjak
35. Erik Margan
36. *Dr. Eva Ribežl, left 01.11.15*

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

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1. Gregor Tomc, Erik Margan, *Posoda minevanja: mišljenje prostora in časa v fiziki in znanostih o življenju*, (Knjižna zbirka Humanistika in naravoslovje), Ljubljana, Fakulteta za družbene vede, Založba FDV, 2015.

Mentoring

1. Maksym Deliyergiyev, *Search for exotic particles with correlated leptons in the final state with the ATLAS detector:* doctoral dissertation, Ljubljana, 2015 (mentor Marko Mikuž).
2. Nejc Mekiš, *Influence of patient shielding on dose in selected projections during conventional radiography:* doctoral dissertation, Ljubljana, 2015 (mentor Dejan Žontar).
3. Eva Ribežl, *Search for X(3872) production in e^+e^- collisions with Belle:* doctoral dissertation, Ljubljana, 2015 (mentor Rok Pestotnik; co-mentor Anže Zupanc).
4. Ruben Verheyden, *Development of a PET module with DOI encoding using silicon photomultipliers:* doctoral dissertation, Ljubljana, 2015 (mentor Samo Korpar).
5. Nina Djurić, *Quality control for magnetic resonance image scanner:* master's thesis, Ljubljana, 2015 (mentor Dejan Žontar; co-mentor Janez Podobnik).
6. Aljoša Polšak, *Študija razpadov $B^0\nu D^* \to \pi^+\pi^0\pi^0$ z detektorjema Belle in Belle II:* master's thesis, Ljubljana, 2015 (mentor Anže Zupanc).
7. Mitja Predikaka, *Karakterizacija modulov za detektor obročev Čerenkova pri spektrometru Belle II:* master's thesis, Ljubljana, 2015 (mentor Rok Pestotnik).
8. Urša Skerbiš, *Testiranje detektorja TOP s kozmičnimi mioni:* master's thesis, Ljubljana, 2015 (mentor Peter Križan).

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 and the synthesis of new inorganic materials with special properties. A great deal of the activity of the group has been devoted to technological, ecological and safety problems 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

Compounds with noble gases are still an important part of the research activities of the department. Some "unexpected" results were found very recently. A layer type of structural arrangement in $[Mg(XeF_2)_2](BiF_6)_2$ does not follow the previous typical examples of $[Mg(XeF_2)_2](AF_6)_2$ (A= As, Sb, Ta, Nb) with a chain arrangement. In $[Ca(XeF_2)_2](BiF_6)_2$ a complicated three-dimensional network was observed. Kristian Radan, Evgeny Goreshnik, Boris Žemva, a member and former members of the Department of Inorganic Chemistry and Technology, received the award of the Slovenian Research Agency (ARRS) for an exceptional scientific achievement in 2014 in the field of chemistry (Xenon(II) Polyfluoridotitanates(IV): synthesis and structural Characterization of $[Xe_2F_3]^+$ and $[XeF]^+$ Salts) in the scope of "Excellence in Science", awarded in 2015.

Kristian Radan, Evgeny Goreshnik and Boris Žemva received the award of the Slovenian Research Agency (ARRS) for an exceptional scientific achievement in 2014 in the field of chemistry.

$Pb_2F_2(HF)(SbF_6)_2$ and $Ba(HF)(AF_6)_2$: (A = As, Sb) are structurally characterized examples of the compounds $M(AF_6)_2$ and $MFAF_6$ in which HF molecules can also be bonded directly to the metal centre. The main feature of $Pb_2F_2(HF)(SbF_6)_2$ is the formation of the ribbon-like $[Pb_4F_4]^{4+}$ units, which are further connected by SbF_6^- units into a three-dimensional framework.

The silver(II) compounds exhibit a broad range of peculiar physico-chemical properties that are described in the review "Chemistry of Silver(II): a Cornucopia of Peculiarities" written by Wojciech Grochala (University of Warsaw) and Zoran Mazej (JSI). The review has been published in the journal Philosophical Transactions A, published by the Royal Society (London). This is the oldest journal in the world dedicated only to science. The first issue appeared in March 1665, and this year the journal celebrates its 350th anniversary of publication. Each issue presents a stand-alone topic. The issue, in which the mentioned contribution is published, has the title "The new chemistry of the elements" and it is dedicated to the importance of the periodic table.

Chemical compounds with an element in more than one oxidation state have been labelled as "mixed-valence" systems. A contribution involving a detailed examination of the green $Ag^{I}_2Ag^{II}(SbF_6)_4$ compound, written by leading authors Z. Mazej (JSI) and W. Grochala (Univesity in Warsaw) together with co-workers (T. Michałowski and J. Szydłowska, University in Warsaw; E. Goreshnik, JSI; Z. Jagličić, University in Ljubljana; I. Arčon, JSI, University of Nova Gorica), has been reported in Dalton Transactions. It is the first example of a Ag compound with a random distribution of Ag(I) and Ag(II) cations on the same crystallographic sites in the crystal lattice with the preserved localized-valence character. The contribution has been selected for the inside front cover of Dalton Transactions.

Research on MF_3 (M=As in Sb) compounds with N-heterocyclic carbenes revealed new and rare properties of this system. Neutral coordination compounds are formed in the solution, while an increase of the temperature causes auto-ionization and the formation of the rare SbF_2^+ cation and the, up to now unknown, isolated AsF_2^+ cation. The reaction proceeds through the rearrangement of the imidazole ring and the subsequent formation and coordination of mezoionic carbene to the metal centre.

In 2015 the direct synthesis of copper compounds was performed. Dissolving elemental copper in a CCl_4-DMSO mixture in the presence of hexamethylenetetramine (hex) resulted in the formation of the

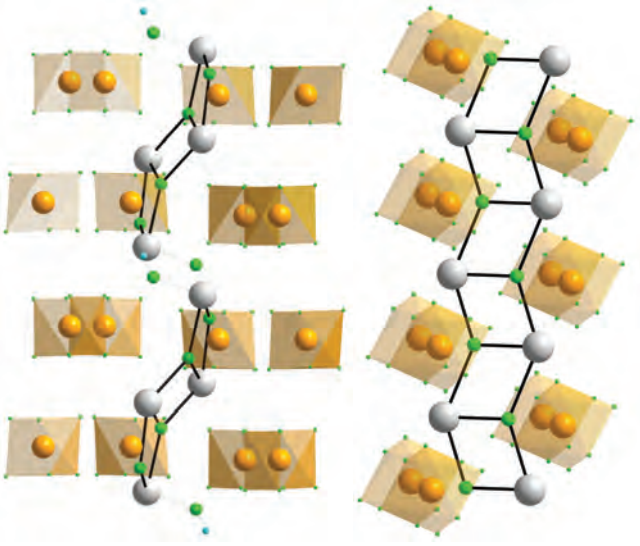

Figure 1: $[Pb_4F_4]^{4+}$ units in $Pb_2F_2(HF)(SbF_6)_2$ and ribbon-like polymers in the structure of $PbFSbF_6$

Figure 2: Inside cover of the journal Dalton Transaction and cover of IJS Novice presents $Ag^{I}_{2}Ag^{II}(SbF_6)_4$ (covers designed by M. Mazej)

hex$[CuCl_2(DMSO)_2]_4$ compound. Its decomposition in mother liquor led to the unknown cis- $CuCl_2(DMSO)_2$ compound. Using *dabco* (1,4-diaza- bicyclo [2.2.2] octane) instead of hex, the $[dabcoH_2]^{2+}Cu^{I}Cl_3$ and $[dabcoH_2]_3Cl_4CuCl_4(DMSO)$ compounds were obtained.

The crystallization of guanazole (3,5-diamino-1,2,4-triazole) and hydrazine from 40% or anhydrous HF resulted in the formation of hybrid salts containing HF_2^- and $H_3F_4^-$ anions. Hydrazinium salts with HF_2^-, $H_3F_4^-$, TaF_7^{2-} and TaF_8^{3-} anions were also synthesized and studied. All the mentioned complexes were investigated by X-ray single-crystal diffraction and Raman spectroscopy.

The single synthesis step composite, containing MoS_2 inorganic fullerenes (IF) interconnected with carbon, exhibited a higher activity than commercial MoS_2 powder in the hydrodeoxygenation of liquefied wood, as revealed through a cooperation with the National Institute of Chemistry, Slovenia. Composite materials comprised of amorphous carbon, carbon fibres and transition-metal sulphides were also developed in cooperation with the National Academy of Sciences of the Ukraine. The thermally processed carbons from agricultural sources with a specific surface area in the range from 980 to 2100 m^2/g and total pore volumes in the range from 0.44 to 0.77 cm^3/g were used to accommodate the transition-metal sulphide nanoparticles.

In the area of process safety we continued with the EU 7FP project TOSCA (Total Operations Management for Safety Critical Activities) in which we participate as a partner. The project deals with the integration of the individual management aspects of industrial operations as a total safety, quality and productivity management system (at the company level), covering the whole life cycle of the product. We led the implementation, testing and evaluation of the efficiency of TOSCA products (methods and tools) in 12 case studies. The general conclusion is that the use of integrated products can lead to substantial improvements in the production processes and their supporting activities (the assessment came from the industrial partner's representatives, and in some cases we were also able to perform a monetary evaluation of the savings).

In 2015 the IPA Adriatic project Adriacold was finished, connecting six solar cooling power plants in three Adriatic countries into an integrated automatic operational data-collection system.

A cooperation with the international company PRG was established for the refining of tantalite and columbite ore to tantalum and niobium oxide. The first tests of leaching showed a good yield under heavily acidic conditions. The laboratory experiments were later expanded and a pilot plant in Macedonia was built, which is expected to operate with 100 kg of ore per day.

We continued and concluded our work within the EU COST action ES 1006 - Evaluation, improvement and guidance for the use of local-scale emergency prediction and response tools for airborne hazards in built environments. Within this action we participate in the assessment of the accuracy of the existing hazardous substances' atmospheric dispersion models into the ambient air in a complex/urban environment, as well as in the preparation of the best-practice guideline for modelling (co-authors of the guidelines on "Best practice guidelines: COST action ES1006 evaluation, improvement and guidance for the use of local-scale emergency prediction and response tools for airborne hazards in built environments").

Figure 3: Tantalite leaching pilot plant

In this year we were in the end-user platform of the EU 7FP project EDEN (End User Driven Demo for CBRNe), which started in September 2013. In the project, which deals with the assessment of and preparedness for terrorist risks (aspects of security), we participate on the basis of our previous experiences in the assessment of such threats to industrial operations.

For the Slovenian Environmental Agency (ARSO) we continued to take part in the reviewing of Safety Case reports for lower-tier establishments (according to the Seveso directive) as part of the licensing procedures.

We have successfully finished the international project EMILIE (Enhancing Mediterranean Initiatives Leading Innovation and SMEs to Building Energy Efficiency Technologies, www.emilieproject.eu). The project involved the building of the pilot facility Infrasun, designed as a research and educational energy polygon based on the integration of the most advanced solar thermal technologies into a unified system of heating and cooling using solar energy, thus showing an example of the use 'of the sun as infrastructure'. Different workshops for small and medium-sized enterprises and administrative bodies that are responsible for the promotion of energy efficiency and the use of renewable energy sources were organized as part of the project, together with visits to other related pilot facilities in Italy and Croatia that were part of the project. The pilot facility is designed as a basic platform for testing and the development of new designs of solar thermal technologies.

In October 2015 the IPA project Adriacold "Diffusion of cooling and refreshing technologies using the solar energy resource in the Adriatic regions" (http://adriacold.eu) was successfully finished with partners from Italy, Slovenia, Croatia, Bosnia & Herzegovina and Albania. The JSI led the Work Task "Monitoring and data mining", within which we performed the organisation, consolidation and analysis of the installed plants' operational data, and in cooperation with the external partner Enekom d.o.o. we established the automatic transfer of the absorption solar cooling plants' operational data to the lead partners' server, and the web application for the display and analysis of the operational data. Some of the six pilot plants (three in Italy (Bari, Rimini, Bazovica), two in Croatia (Crikvenica and Dubrovnik) and one in Slovenia (Piran)) did not manage to provide quality operational data by the end of the project, so the best data collections are available for the Dubrovnik, Crikvenica and Piran pilot plants. The data will be collected automatically until October 2017 and are available to interested parties (scientific institutions, engineering companies, energy managers, local communities, etc.).

The activity in the field of education and the promotion of sciences should be mentioned. Five co-workers 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 schools, secondary schools and even kindergartens through experimental courses performed in a specialised laboratory or through direct demonstrations at the schools. With demonstrations of chemical experiments we participated at the 21st Slovenian Science Festival, organized by the Slovenian Science Foundation and at the Researchers' Night in Ljubljana and other events.

Some outstanding publications in the past year

1. Mazej Z., Goreshnik E. A., $[XeF_5]^+$/metal and $[XeF_5]^+$/non-metal mixed-cation salts of hexafluoridoantimonate(V), Europ. J. of Inorg. Chem., (2015) 1453-1456.
2. Štefančič A., Primc D., Tavčar G., Skapin T., Direct solvothermal preparation of nanostructured fluoride aerogels based on AlF_3, Dalton Trans., 44 (2015) 20609-20617.
3. Mazej Z., Michałowski T., Goreshnik E. A., Jagličić Z., Arčon I., Szydłowska J., Grochala W., The first example of a mixed valence ternary compound of silver with random distribution of Ag(I) and Ag(II) cations, Dalton Trans., 44 (2015) 10957-10969.
4. Grilc M., Veryasov G., Likozar B., Jesih A., Levec J., Hydrodeoxygenation of solvolysed lignocellulosic biomass by unsupported MoS_2, MoO_2, Mo_2C and WS_2 catalysts. Applied Catal. B, Environmental, 162 (2015) 467-477
5. Vižintin A., Lozinšek M., Kumar Chellappan R., Foix D., Krajnc A., Mali G., Dražić G., Genorio B., Dedryvère R., Dominko R.. Fluorinated reduced graphene oxide as an interlayer in Li-S batteries, Chemistry of Materials, 27 (2015) 7070-7081.

Organization of conferences, congresses and meetings

1. Support for small and medium-sized enterprises in the development of eco-innovative solutions and the financing of measures of URE and OVE: Jožef Stefan Institute organizes the meeting, Ljubljana, Slovenia, 18. 3. 2015
2. EUREM meeting (EMILIE): Jožef Stefan Institute organizes meeting of managers from energetics, Ljubljana, Slovenia, 26. 3. 2015
3. Trends in energy efficiency and renewable energy sources: Jožef Stefan Institute organizes meeting as project partner, Ljubljana, Slovenia, 7. 5. 2015

Patent granted

1. Aleš Mrzel, Maja Remškar, Adolf Jesih, Marko Viršek, Process for the synthesis of nanotubes and fullerene-like nanostructures of transition metal dichalcogenides, quasi one-dimensional structures of transition metals and oxides of transition metals, EP2132142 (B1), European Patent Office, 5. 08. 2015.

INTERNATIONAL PROJECTS

1. Extraction of Tantalum and Niobium from Ores
   Asst. Prof. Gašper Tavčar
   Prg Ltd.
2. 7FP - TOSCA; Total Operations Management for Safety Critical Activities
   Asst. Prof. Marko Gerbec
   European Commission
3. 7FP - FluoCoorChem; Fluorinated Weakly Coordinating Anions for Coordination Chemistry of Unusual Ligands
   Prof. Boris Žemva, Dr. Matic Lozinšek
   European Commission
4. IPA ADRIATIC; ADRIACOLD - Diffusion of Cooling and Refresing Technologies using the Solar Energy resources in the Adriatic Regions
   Asst. Prof. Gašper Tavčar
   Consorzio Per L"area Di Ricerca Scientifica
5. MED - EMILIE; Enhancing Mediterranean Initiatives Leading SMEs to Innovation in Building Energy Efficiency Technologies
   Asst. Prof. Gašper Tavčar
   Stc Programme Med

6. EU Cost Action ES 1006 Meeting
   Asst. Prof. Marko Gerbec
   Cost Office

RESEARCH PROGRAM

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

R & D GRANTS AND CONTRACTS

1. IPA ADRIATIC; ADRIACOLD - Diffusion of Cooling and Refresing Technologies using the Solar Energy resources in the Adriatic Regions
   Asst. Prof. Gašper Tavčar
   Ministry of Economic Development and Technology of the Republic of Slovenia
2. COST ES1006; Evaluation, Improvement and Guidance for the Use of Local-scale Emergency Prediction and Response Tools for Airborne Hazards in Built Environments
   Asst. Prof. Marko Gerbec
   Cost Office

NEW CONTRACTS

1. Update of the threat assessment for natural gas distribution pipeline network and preparation of the threat assessment for planned pipeline network expansion
   Asst. Prof. Marko Gerbec
   Plinovodi d. o. o.
2. Preparation of the risk reduction plan for the environment for the planned technical gases production plant at land parcel 4d, industrial zone Štore II.
   Asst. Prof. Marko Gerbec
   Istrabenz Plini d. o. o.
3.

VISITORS FROM ABROAD

1. Franjo Skuber, Guenter Zweiner, Franz Krauts, Gottfreid Eder, Peter Kaut, Visit to the pilot plant EMILE 19. 8. 2015
2. Dr. Rodolfo Taccani, University of Trieste, Trieste, Italy, 3. 9. 2015
3. Ray Power, Biljana Mishevska, Dragica Daova, PRG, Skopje, Macedonia, 7. 9. 2015
4. Piotr Połczyński, dr. Rafael Jurczakowski, Delovni obisk, University of Warsaw, Warsaw, Poland, 13. 9. – 18. 9. 2014
5. Dr. Roberto Jodice, Lucia Gorostidi, Marco Cesaro, Visit from company Cortea, Trieste, Italy 28. 9 . 2015

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5. Dr. Matic Lozinšek
6. Dr. Zoran Mazej
7. Asst. Prof. Maja Ponikvar-Svet
8. Asst. Prof. Tomaž Skapin
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10. Dr. Melita Tramšek

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13. Dona Pavlović, B. Sc.
14. *Kristian Radan, B. Sc., left 01.03.15*
15. Igor Shlyapnikov
16. *Aleš Štefančič, B. Sc., on leave 24.04.13*
17. Žiga Zupanek, B. Sc.

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21. Pero Kolobarić
22. Robert Moravec
23. Mira Zupančič

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Original Article

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2. Norbert Chilingarov, A. V. Knot'ko, Igor Shlyapnikov, Zoran Mazej, Matjaž Kristl, Lev Nikolaevich Sidorov, "Cerium tetrafluoride: sublimation, thermolysis and atomic fluorine migra", *J. phys. chem., A Mol. spectrosc. kinet. environ. gen. theory*, vol. 119, no. 31, pp. 8452-8460, 2015.
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Review Article

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Published Conference Contribution

1. Wojciech Adamczyk, Piotr Połczyński, Andrzej Mika, Tomasz Jaroń, Zoran Mazej, Karol J. Fijalkowski, Rafał Jurczakowski, Wojciech Grochala, "New $Ag(F_{1-x}Cl_x)$ phases for energy storage applications", In: *International Conference on Fluorine Chemistry, May 28-30, 2014, Tokyo, Japan*, (Journal of fluorine chemistry, vol. 174, 2015), Lausanne, Elsevier, 2015, vol. 174, pp. 22-29, 2015.
2. Marko Gerbec, Nora Balfe, Maria C. Leva, S. Prast, M. Demichela, "Risk assessment and optimization for new or novel processes: combining task analysis with 4D process simulation - framework and case study", In: *Safety and reliability of complex engineered systems: proceedings of the 25th European Safety and Reliability Conference, ESREL 2015, Zürich, Switzerland, 7-10 September 2015*, Luca Podofillini, ed., Boca Raton, CRC Press, London, Taylor & Francis, cop. 2015, pp. 387-394.
3. Gašper Tavčar, Melita Tramšek, "XeF_2 as a ligand to a metal center, an interesting field of noble gas chemistry", In: *International Conference on Fluorine Chemistry, May 28-30, 2014, Tokyo, Japan*, (Journal of fluorine chemistry, vol. 174, 2015), Lausanne, Elsevier, 2015, vol. 174, pp. 14-21, 2015.

Scientific Monograph

1. T P. Armand *et al.*, *Best practice guidelines: COST action ES1006 evaluation, improvement and guidance for the use of local-scale emergeny prediction and response tools for airborne hazards in built environments*, [S. l.], COST Office, 2015.

Patent Application

1. Andrej Kovič, Adolf Jesih, Aleš Mrzel, *Process for the synthesis of quasi one-dimensional structures of molybdenum carbides in the form of microwires, nanowires, nanobelts and microbelts*, P-201500049, Urad RS za intelektualno lastnino, 27. 02. 2015.
2. Piotr J. Leszczyński, Wojciech Grochala, Zoran Mazej, Adam Budniak, *Proces sprzęgania cząsteczek związków organicznych*, P. 413922, Urząd patentowy Rzeczypospolitej Polskiej, 11. 09. 2015.

Patent

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Mentoring

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DEPARTMENT OF PHYSICAL AND ORGANIC CHEMISTRY K-3

The basic research of the department is focused on experimental and theoretical studies of various physico-chemical processes at surfaces and in atmospheric chemistry. The main attention in the field of organic chemistry is directed to the halogenated – in particular fluorinated – organic molecules.

Head:
Prof. Ingrid Milošev

Experimental research in the field of electrochemistry is oriented to contemporary types of corrosion protection. We concentrated primarily on alloys based on copper, aluminium and steel. Alloys of copper are often used for structures open to the atmosphere, for example, in architecture and for sculptures. We have studied methodologies for their protection by increasing the hydrophobicity of the surface and its protection by corrosion inhibitors. Hydrophobicity was achieved by the self-assembling of a layer of carboxylic acids at the metal surface. The effectiveness of the protection was tested in simulated urban rain. It increases with the length of the aliphatic tail of carboxylic acid. All acids form layers with a contact angle over 90°. The study was complemented by the combination of carboxylic acids and traditional organic inhibitors (i.e., molecules that have the ability to inhibit corrosion), which achieved a more effective and long-lasting protection. We used benzotraizole (BTAH) and 2-mercaptobenzimidazole (SH-BimH) and tested two methodologies: immersion of a metal in an ethanol solution of inhibitor and stearic acid, and the successive immersion in the inhibitor and then stearic acid. The morphology of self-assembled layers differed, from nano-flowers, nano-grains and nano-fibers. The mechanism of inhibition is also dependent on the combination used; whilst BTAH acts like an anodic inhibitor, in the combination with stearic acid the cathodic reaction is also retarded. The combination of SH-BimH and stearic acid is better for long-term protection than that with BTAH, which loses its protection during prolonged immersion. Comparative studies were performed on copper, zinc and brasses, and for each particular method the optimal methodology and inhibitor combination were determined.

Self-assembled layers containing stearic acid and an organic inhibitor, benzotriazole or 2-mercaptobenzimidazole, enable the good corrosion protection of copper and brasses in simulated urban rain.

Studies were also performed on aluminium and steel alloys in order to investigate contemporary methodologies. Due to their beneficial properties aluminium and its alloys are used in numerous applications in civil engineering, the automotive and aerospace industries, as well as the food and electronics industries. For many decades chromate coatings represented the most effective corrosion protection for aluminium alloys. However, in the European Union their use is banned or restricted due to their toxicity. Today, new alternatives for conversion chromate coatings are being investigated, which would achieve comparable corrosion protection, while being environmentally acceptable. In that context the development of sol-gel coatings is important. In our laboratory we are devoted to the development of hybrid sol-gel coatings that enable the effective corrosion protection of aluminium and its alloys. A two-step procedure for synthesizing a new type of hybrid coating was developed. The coatings were synthesized from tetraethyl orthosilicate (TEOS), 3-(trimethoxysilyl)propyl methacrylate (MAPTMS) and zirconium(IV) propoxide (ZTP). Zirconium(IV) propoxide was chelated with methacrylic acid. We have also synthesized hybrid coatings based on TEOS and 3-glycidoxypropyl-trimethoxysilane (GPTMS), enriched with the addition of a colloidal silica suspension and cerium nitrate ($Ce(NO_3)_3$) as the source of Ce(III) ions. The latter act as a corrosion inhibitor, whilst SiO_2 particles improve the barrier properties of the coatings. Another alternative to chromate coatings is conversion coatings based on rare-earth nitrate and chloride salts. The inhibition effectiveness of the coatings is dependent on the bath conditions, i.e., immersion time and temperature. Special attention was devoted to the preparation of mixtures of different salts of cerium and lanthanum.

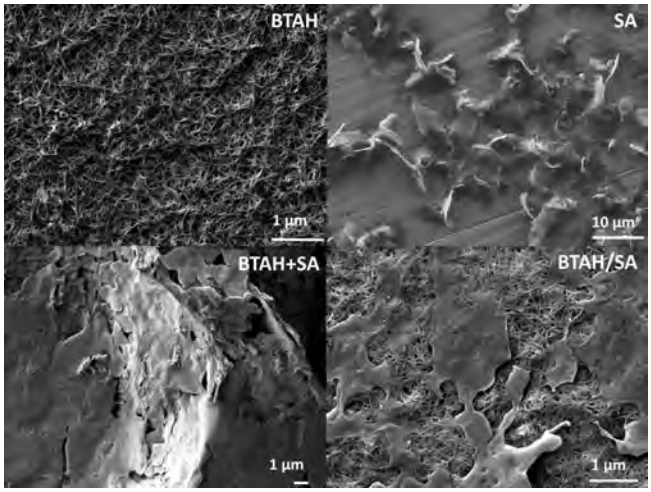

Figure 1: Morphology of self-assembled layers on a copper surface after immersion in an ethynol solution of benzotriazole (BTAH), stearic acid (SA), a mixture of benzotriazole and stearic acid (BTAH+SA) and benzotriazole followed by stearic acid (BTAH/SA).

Our principal aim is to better understand how organic corrosion inhibitors act against corrosion at the molecular level and to discern the fundamental principles that govern their corrosion-inhibition characteristics. In the past few years we have studied by means of first-principle density-functional-theory (DFT) based computer modelling the interaction of several azole-type

On the basis of the insight provided by the first-principle, density-functional-theory-based modelling of azole molecules on oxidized copper surfaces, we infer that the corrosion-inhibition capability of azoles stems, in part, from their ability to passivate reactive surface sites.

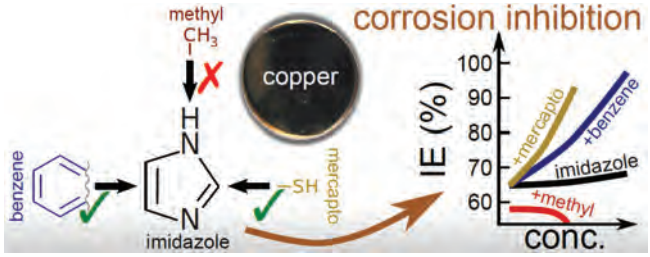

Figure 2: Effect of derivatives of imidazole on the efficiency of corrosion inhibition on copper in a chloride solution.

corrosion inhibitors with reduced surfaces of copper and to a smaller extent iron and aluminium. A combined experimental and computational study on copper was performed. An electrochemical and immersion study, combined with topography and X-ray photoelectron spectroscopy analyses, was carried out in chloride solutions with and without the addition of various imidazole derivatives – imidazole (ImiH), 1-methyl-imidazole (ImiMe), benzimidazole (BimH), 2-mercapto-1-methyl-imidazole (SH-ImiMe), and 2-mercaptobenzimidazole (SH-BimH). Pronounced differences were observed at concentrations ≥ 1mM. While 1-methyl-imidazole was found to be inferior in terms of activity to imidazole, all the other derivatives were superior. At a 1-mM concentration the order of the inhibition efficiency, IE, was: ImiMe < ImiH < BimH < SH-ImiMe < SH-BimH. The mercapto group and benzene group were shown to have a beneficial effect on corrosion inhibition, whereas the effect of the methyl group even accelerated the corrosion at 10 mM. The protective ability of the BimH, SH-ImiMe and SH-BimH inhibitors is based on the formation of cuprous complexes with species originating from inhibitors, mainly carbon and nitrogen, and sulphur in the case of mercapto compounds. An experimental study was supplemented by detailed DFT calculations to (i) explicitly characterize the interactions between the inhibitors and the copper surfaces and to (ii) rationalize the experimentally observed trends. We found that the mercapto-substituted imidazoles are prone to dissociation upon adsorption (S–H or N–H bond cleavage). They bond more strongly to the surface and display a weaker tendency to form soluble complexes with hydrated Cu^{2+} ions than non-mercapto imidazoles. By encapsulating these two interactions into a simple model – the first interaction is deemed as beneficial and the second as detrimental – the inhibition efficiency trend was well captured.

In the past year we addressed the interaction of imidazole, triazole, tetrazole, and benzotriazole – used as archetypal models of azole corrosion inhibitors – with oxidized copper surfaces. Oxidized copper surfaces contain two different kinds of surface Cu sites, coordinatively saturated (CSA) and coordinatively unsaturated (CUS) sites, the latter being thermodynamically deficient. We found that azoles adsorb rather strongly at CUS sites with an adsorption energy of about –1.5 eV, whereas the bonding at CSA sites is about three times weaker, making it similar to metallic Cu(111). A thermodynamic analysis revealed that the azole adsorption at CUS sites is strong enough to compensate for their thermodynamic deficiency, unless the conditions are too oxygen rich and azole lean. This finding may tentatively suggest that the corrosion-inhibition capability of azoles stems from their ability to passivate reactive surface sites. We further found that azole molecules can deprotonate on hydroxylated copper surfaces. This deprotonation proceeds from the azole's N–H interacting with the surface hydroxyl, first forming the N–H···$OH_{(surf)}$ hydrogen bond. Then the proton shifts from azole's N to the hydoxyl's O, thus forming a water molecule.

The HOSO formic-acid–water complex formations progress spontaneously and they are photochemically reasonably stable in the troposphere.

Since it is known that both water molecules and formic acid molecules contribute greatly to the production of secondary aerosols, we have undertaken a computational study to provide the first insight into the stability for complexes of the HOSO radical with one and two formic acid molecules and the hydration of these complexes. Calculations indicated multiple H-bonded cyclic structures for all types of complexes, resulting in strongly bonded complexes. From the calculated vibrational frequencies and the IR intensities it follows that the complex formation through the H-bonding interaction induces a large spectral red-shift and an enhancement of the IR intensities for the H-bonded OH stretching modes relative to these modes in the free monomers. Furthermore, the complexation affects the electronic spectra of the radical within the acid and water complexes on a small scale. For the complexes cannot be expected to photolyze easily under sunlight, implying that these radical-formic acid-water complexes are photochemically rather stable in the troposphere. The atmospheric relevance of the complexes is also analysed by exploring their thermochemical properties. The complexations progress spontaneously and the fraction of HOSO-formic acid complexes near the Earth's surface is computed to be insignificant, but it is estimated that the fraction increases by two orders of magnitude at an atmospheric height of 5 km. However, the fraction of complexes would certainly increase locally with any potential higher emission of formic acid into the atmosphere.

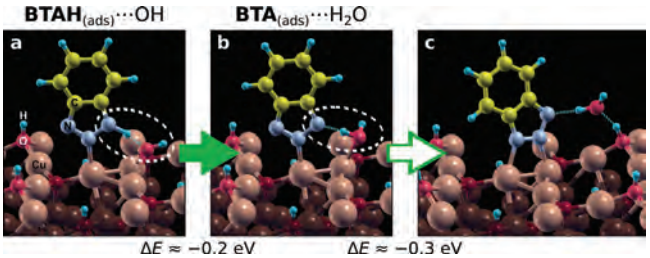

Figure 3: (a,b) Deprotonation of adsorbed benzotriazole (BTAH) involves the proton transfer from its N1 atom to $OH_{(surf)}$; the corresponding process is exothermic by 0.2 eV. (c) Deprotonated benzotriazole–water complex ($BTA_{(ads)}$···$H_2O_{(ads)}$) then further stabilizes by 0.3 eV by forming another N–Cu bond and a H_2O···$OH_{(surf)}$ hydrogen bond (but the H_2O···$Cu_{(surf)}$ bond is lost).

In the framework of the Laboratory for Organic and Bioorganic Chemistry we continued our investigations on the application of principles of green

chemistry to the transformations of organic compounds. We upgraded the research, stressing the development of a new, more eco-friendly approach to the halogenation or oxidation of organic compounds and invented a new method for the aerobic oxidative iodination of organic compounds using the iodo(I) reagent $HICl_2$ as the reagent and nitrogen oxides and hydrochloric acid as the catalysts. Nitrogen oxides and nitric acid were also investigated as the catalysts for the aerobic oxidation of alcohols and we established that perfluoro alcohols could be used for these transformations as template co-catalysts, enhancing the catalytic power of nitric acid. The method is so far limited to the oxidation of benzyl alcohols, while when applying stronger activation, other alcohols could also be oxidised.

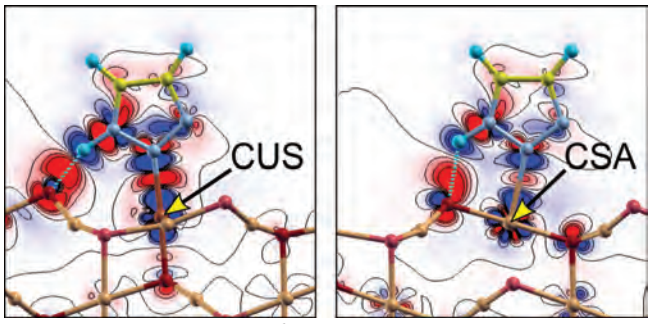

Figure 4: Electronic structure of triazole adsorbed at unsaturated (CUS, left) and saturated (CSA, right) sites on the Cu_2O(111) surface. The blue (red) color represents the electron deficit (excess) regions, i.e., electron charge flows from the blue to red regions.

A new method for the direct catalyst-free and solvent-free nucleophilic substitution of the hydroxyl functional group in alcohols by chlorine or bromine using trimethylsilylhalogenides was developed. The scope of the transformations is currently limited to primary benzyl alcohols with an activated aromatic ring, secondary benzyl alcohols and tertiary alkyl alcohols, while no catalyst is needed only in the cases when the reactions were performed under solvent-free reaction conditions.

We developed a new coupling reaction between benzyl alcohols and phenyl-substituted alkenes catalysed by molecular iodine under solvent-free reaction conditions. The transformations result in the formation of 1-phenyl-2-benzylalkenes.

Using hydrogen peroxide as the oxidant, the azeotrope removal of water from reaction mixtures enables the selective and efficient synthesis of organic peroxides, including those that are very sensitive.

We developed a new method for the synthesis of organic peroxides using hydrogen peroxide, which was activated for the peroxidation of ketones by the azeotrope removal of water from reaction mixtures. The reactions are thus neutral and with this innovation a number of sensitive peroxides, which could not be prepared using the classic methodology, were thus obtained. We further succeeded to isolate the monohydroperoxide or perhydrate intermediates and defined their structure. The method represents an original and up to now unique general approach to the synthesis of perhydrates of cyclic ketones. The results provide an insight into the mechanism of the formation of bioactive cyclic peroxides and to the Baeyer-Villingenr oxidation as well, since the analogue intermediates were till now proposed only for the peroxidations performed using peracids and not using hydrogen peroxide.

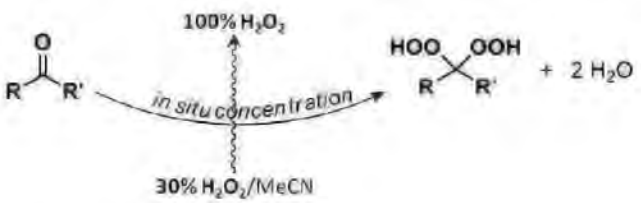

Figure 5: New general method for the synthesis of organic peroxides using hydrogen peroxide.

In the framework of Centre of Excellence CIPKeBiP and our collaboration with the high-tech company ACIS BIO we were continuing investigations into the directed synthesis building blocks of potential bioactive compounds from the family of pantothenic acid and derivatives of maleic acid as precursors in a polyketide biosynthesis. We developed a few new reagents for the phosphorylation of alcohols and one of them was also tested on derivatives of pantothenic acid that carry a potential function as the prodrugs of phosphates. We were developing new products used in non-human cosmetics for the company ECOT. At the Jožef Stefan International Postgraduate School we are engaged in two courses on organic green chemistry and at Faculty for Chemistry and Chemical Technology at the University of Maribor a few undergraduate courses of organic chemistry.

Some outstanding publications in the past year

1. I. Milošev, N. Kovačević, A. Kokalj, The roles of mercapto, benzene and methyl groups in the corrosion inhibition of imidazole on copper, Corrosion Sci. 98 (2015), 107-118
2. A. Kokalj, Ab initio modeling of the bonding of benzotriazole corrosion inhibitor to reduced and oxidized copper surfaces, Faraday Discuss., 180 (2015), 415-438
3. K. Starkl, S. Pečar, J. Iskra, Activation of aqueous hydrogen peroxide for non-catalyzed dihydroperoxidation of ketones by azeotropic removal of water, Org. Biomol. Chem., 36 (2015), 9369-9372

Awards and appointments

1. Barbara Volarič: Best Student Presentation on ISE-Satellite Student Symposium of the Regional Symposium on Electrochemistry, South-East Europe 20155, Pravets, Bulgaria, Hune 2015
2. Jerca Pahor: Best Poster Award on International Conferences on Current Challenges in Drug Discovery Research, Jaipur, India, November 2015

INTERNATIONAL PROJECTS

1. CARISMA; Catalytic Routines for Small Molecule Activation; CMST COST Action CM1205
   Prof. Jernej Iskra
   Cost Office
2. EUSpec, COST MP1306; Modern Tools for Spectroscopy on Advanced Materials: A European Modelling Platform
   Assist. Prof. Anton Kokalj
   Cost Office
3. Exploring Antimalarial Peroxides from Bench-side to Bed-side: Synthesis, Chemistry, Antimalarial Assessment and SAR studies of Novel functionalized 1, 2, 4-Trioxanes and 1, 2, 4, 5-Tetraoxanes against Multi-drug Resistant Malaria
   Prof. Jernej Iskra
   Slovenian Research Agency
4. Study of the Synthesis of Bioactive Furans and their Inhibitory Role in Antimicrobial Hybrid Coatings
   Prof. Jernej Iskra
   Slovenian Research Agency
5. ECICORR Computational modeling and Experimental Characterization of Interfaces relevant for CORRosion: passive films and corrosion
   Assist. Prof. Anton Kokalj
   Slovenian Research Agency
6. Corrosion protection of technologically important materials using environmentally-friendly coatings
   Prof. Ingrid Milošev
   Slovenian Research Agency

RESEARCH PROGRAMS

1. Bioanorganic and bioorganic chemistry
   Prof. Stojan Stavber
2. Advanced materials for low-carbon and sustainable societyAdvanced materials for low-carbon and sustainable society
   Prof. Ingrid Milošev

R & D GRANTS AND CONTRACTS

1. Lightweight alloys based on aluminium as materials with increasing potential in transport industry
   Prof. Ingrid Milošev
2. Development of Molecularly Imprinted Polymers and their application in environmental and bio-analysis
   Prof. Jernej Iskra
3. New technology for design of novel polyketide drug-leads with chemically ameanable moieties
   Prof. Stojan Stavber

VISITORS FROM ABROAD

1. Nicoleta Cotolan, Ph.D. Student, Babes-Bolay University, Cluj-Napoca, Romania, 2 February-28 February 2015
2. Prof. Sandeep Chaudhary, Malaviya National Institute of Technology, Jaipur, India, 7 September-11 September 2015
3. Pauline Cornette, Ph.D. Student, Chemie Paris Tech, Ecole nationale superiore de chemie de Paris, Paris, France, 15 November-4 December 2015

STAFF

Researchers
1. Prof. Jernej Iskra
2. Asst. Prof. Anton Kokalj
3. Dr. Antonija Lesar
4. **Prof. Ingrid Milošev, Head**
5. Prof. Stojan Stavber

Postdoctoral associate
6. Dr. Peter Rodič

Postgraduates
7. Dunja Gustinčič, B. Sc.
8. Jerca Pahor, B. Sc.
9. Matic Poberžnik, B. Sc.
10. Katarina Starkl Renar, B. Sc.
11. Gavrilo Šekularac, B. Sc.
12. Urša Tiringer, B. Sc.
13. Simona Tušar, B. Sc.
14. Barbara Volarič, B. Sc.
15. *Dr. Gregor Žerjav, left 01.06.15*

Technical officer
16. Barbara Kapun, B. Sc.

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2. Njomza Ajvazi, Stojan Stavber, "New method for C - C bond formation following N - halo compound catalysis under solvent - free reaction conditions", In: *Zbornik referatov in povzetkov*, Slovenski kemijski dnevi 2015, Ljubljana, 24. - 25. september 2015 = Slovenian Chemical Days 2015, Ljubljana, September 24 - 25, 2015, Venčeslav Kaučič, ed., et al, Ljubljana, Slovensko kemijsko društvo, 2015, 6 pp.
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1. Gregor Žerjav, *Modified surface of Cu, Zn, Cu10Zn and Cu40Zn with expression of hydrophobic properties for the purpose of corrosion protection:* doctoral dissertation, Maribor, 2015 (mentor Regina Fuchs-Godec; co-mentor Ingrid Milošev).
2. Tjaša Savić, *Polymerization of thiol, vinyl and glycol esters:* master's thesis, Maribor, 2015 (mentor Peter Krajnc; co-mentor Jernej Iskra).

ELECTRONIC CERAMICS DEPARTMENT

K-5

The Electronic Ceramics Department is active in the research of the synthesis, properties and applications of materials for electronics and energetics, mainly complex multifunctional materials and structures. 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 the principles of basic technologies of ceramic pressure sensors, ceramic MEMS and flexible electronics.

Head:
Prof. Barbara Malič

Activities in 2015

In the framework of **lead-free piezoelectric materials** we were particularly interested in alkali-niobate-based ceramics, which are considered as candidates for the replacement of lead-based perovskites in piezoelectric applications. The equilibrium vapour pressures of sodium and potassium over a $K_xNa_{1-x}NbO_3$ solid solution within its whole compositional range at temperatures between 1173 K and 1303 K were determined by Knudsen Effusion Mass Spectrometry in collaboration Eötvös Loránd University, Hungary. The equilibrium vapour pressure of potassium over $K_{0.5}Na_{0.5}NbO_3$ (KNN) is a few times larger than that of sodium, i.e., $8 \cdot 10^{-3}$ Pa as compared to $3 \cdot 10^{-3}$ Pa at 1263 K. The comparison of the obtained results with the well-established lead-based piezoelectric systems revealed that the vapour pressure of alkalis over the respective niobates at 1200 K is almost three orders of magnitude lower than the values reported for lead oxide over $Pb(Zr,Ti)O_3$.

Within the activities on **lead-based piezoelectric ceramics**, in the frame of the 7 **OP EU CERAMPOL** project, and in collaboration with our research partner HIPOT-RR, we modelled and fabricated a vibrating system for waste-water purification applications. The vibrating system consisted of electrical wiring and a protective layer that was screen printed on a porous ceramic substrate (20 cm × 20 cm) and a **piezoelectric $Pb(Zr,Ti)O_3$ actuator**. The tests performed by the project partners showed that the efficiency of water purification achieved with the vibrating system is higher than in conventional systems.

We published a paper "Mobile Domain Walls as a Bridge between Nanoscale Conductivity and Macroscopic Electromechanical Response" in the journal Advanced Functional Materials in collaboration with the Swiss Federal Institute of Technology. Our results link the local conductivity and the macroscopic piezoelectricity via the domain-wall dynamics, revealing that the domain-wall conductivity should be considered when interpreting and controlling the macroscopic electro-mechanical response of piezoelectric ceramics.

With co-workers from Austria, France, USA, the National Institute of Chemistry, Ljubljana and the Department for Condensed Matter Physics, JSI, we demonstrated the important effect of processing on the B-site ordering in $Pb(Sc_{0.5}Nb_{0.5})O_3$ ceramics. In contrast to previous observations on the ceramics prepared from solid-state synthesised powders, which show a distinctive B-site cation ordering when annealed below 1200 °C, we do not observe such ordering in the **mechanochemically derived ceramics**, regardless of the conditions of thermal post-annealing. (Figure 1)

Studies on **multiferroic bismuth ferrite** ($BiFeO_3$) were focused on the complex relationship between the local properties, such as the electrical conductivity at the domain walls and grain boundaries, and the macroscopic electromechanical response. Through a combination of local and macroscopic measurements of the electrical and electromechanical properties we showed evidence of a nonlinear piezoelectric Maxwell-Wagner effect as a new mechanism for explaining the relationship between the local domain-wall conductivity and the macroscopic piezoelectricity in $BiFeO_3$. (Figure 2). In-situ high-energy X-ray diffraction studies revealed a strong post-poling relaxation of the switched non-180° domain walls in $BiFeO_3$ where the conductive nature of the domain walls most probably plays a role. We reported on the development of an efficient and reproducible synthesis technique based on the mechanochemical activation of rare-earth (RE=Sm, Gd, Dy) modified $BiFeO_3$ (RE-BFO) ceramics, and explained the mechanisms involved in the improvement of the perovskite phase formation in RE-BFO relative to the unmodified $BiFeO_3$.

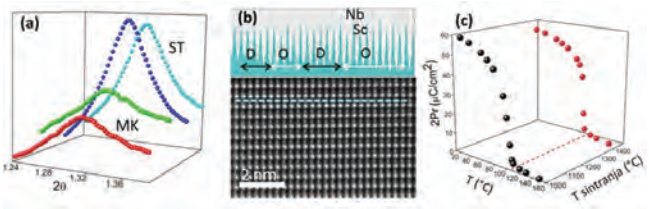

Figure 1: $Pb(Sc_{0.5}Nb_{0.5})O_3$ ceramics prepared from the mechanochemically (MA) activated powder: (a) Synchrotron X-ray diffraction pattern of superstructure peak (½ ½ ½). The pattern of solid-state (SS) ceramics is added for comparison. (b) HAADF-STEM image with the corresponding intensity profile of B site ions (O, D-ordered/disordered area) (c) Temperature dependence of remnant polarization of ceramics sintered at 1000 °C and 1420 °C.

In collaboration with the Condensed Matter Physics Department, JSI, we continued our research on the **electrocaloric (EC) effect**, i.e., the adiabatic and reversible temperature change that occurs in a polar material upon the

application of an external electric field, in **relaxor ferroelectric** $0.9Pb(Mg_{1/3}Nb_{2/3})O_3$–$0.1PbTiO_3$ (PMN-10PT) bulk ceramics. We showed that a substantial enhancement of the EC effect is achieved with a properly engineered ceramic microstructure. Highly dense bulk ceramics with grain sizes in the micron range (≈ 2 μm to ≈ 10 μm) were prepared. The material with an ≈ 98 % relative density and 3.6-mm grains is characterized by a high breakdown strength exceeding 160 kV cm^{-1}, and a large EC temperature change (DT_{EC}) of 3.45 °C. This value is the highest reported so far for Pb-based perovskites and is comparable to the best results obtained by multi-critical-point enhancement. Furthermore, in collaboration with the Faculty of Mechanical Engineering, University of Ljubljana, we explored the applicability of the PMN-10PT ceramics as active elements for the heat regenerator in an EC cooling device. The experimental testing of the cooling device demonstrates the efficient heat regeneration and the establishment of the temperature span between the hot and the cold sides of the regenerator, exceeding several times the electrocaloric temperature change within a single ceramic plate.

A USA patent entitled "Amorphous multicomponent dielectric based on the mixture of high band gap and high K materials, respective devices and manufacture" was granted in 2015, and is the result of collaboration with University Nova, Lisbon, Portugal.

The EC effect of a lead-free relaxor ferroelectric $0.85K_{0.5}Na_{0.5}NbO_3$-$0.15SrTiO_3$ (KNN-STO) ceramic was investigated. A large DT_{EC} exceeding 1.2 K at 300 K and 1.9 K at 340 K at 159 kV/cm was observed, and in a broad temperature range of ≈80 K. Such a high ECE response near room temperature is comparable to that found in lead-based ceramic materials, thus making KNN-STO a strong candidate to replace lead-based materials in future EC applications.

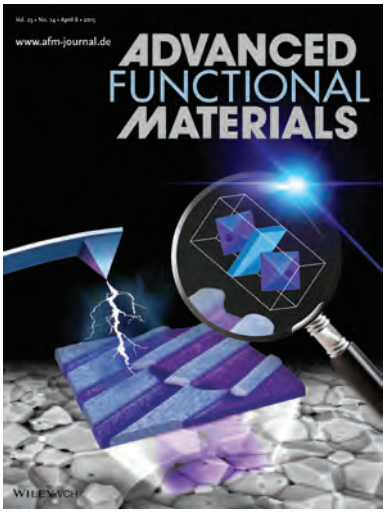

Figure 2: We published a paper entitled "Mobile domain walls as a bridge between nanoscale conductivity and macroscopic electromechanical response" in the high-impact-factor journal Advanced Functional Materials, (IF 11.805). The paper was accompanied with an inside front cover authored by the researchers from K-5.

Within the studies of **environment-friendly lead-free ferrolectric thin films** we demonstrated the relationship between the microstructural details of $(K_{0.5}Na_{0.5})NbO_3$ thin films, synthesized from alkoxide-based solutions, and their leakage-current behaviours. The films deposited from the 10 and 5 mol % excess potassium-acetate solutions and annealed at 750 °C possessed columnar or fine-grained microstructures, respectively. The latter exhibited a current density of 2.9 × 10^{-7} A/cm^2 at 50 kV/cm, whereas the value increased by two orders of magnitude in the films with the columnar grains. Using conductive atomic force microscopy we obtained direct evidence that the current starts to flow initially along the boundaries of the columnar grains, because such grain boundaries provided a direct conduction path between the electrodes. (Figure 3)

In collaboration with the Faculty of Electrical Engineering, University of Ljubljana, Experimental Particle Physics Department, JSI, and the Centre of Excellence SPACE.SI we studied solution-derived tuneable ferroelectric **$Ba_{0.5}Sr_{0.5}TiO_3$ (BST) thin films** for microwave applications. The films deposited on polycrystalline alumina substrates with thicknesses in the range from 90 to 400 nm were rapid thermally annealed at 900 °C. The microstructures of the films were uniform and dense, consisting predominantly of columnar grains. As the thickness increased from 90 nm to 240 nm, the dielectric permittivity, measured at 100 kHz, increased from 650 to 1250, respectively. Improved dielectric properties were explained by the grain size effect together with the effect of the increased film thickness. As the film thickness increased further to 400 nm, the dielectric permittivity dropped to around 900, which was explained by the existence of nano-cracks, formed via the relaxation of the tensile biaxial stress in thin films as a consequence of the thermal expansion mismatch. The dielectric properties also exhibited similar thickness and grain-size dependences in the GHz frequency range. The influence of neutron and gamma-ray irradiation on the kilohertz- and microwave-range dielectric properties of $Ba_{0.5}Sr_{0.5}TiO_3$ thin films was also investigated. We observed that microstructural features, such as grain boundaries, pores and cracks, as well as crystal-lattice defects have an effect on the irradiation-damage accumulation rate, and we concluded that the microstructure of the pristine films is decisive for the irradiation hardness of ferroelectric thin films used for microwave applications.

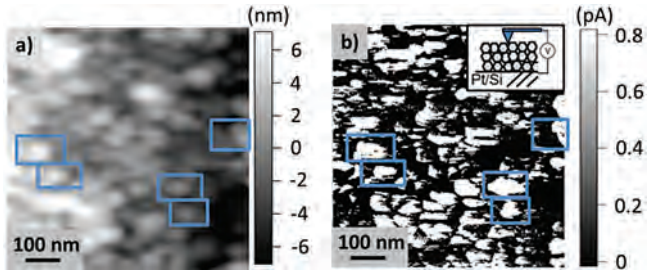

Figure 3: Direct imaging of the leakage mechanisms vs. the microstructure in the (K0.5Na0.5)NbO3 thin film via the conductive atomic force microscope (c-AFM). (a) AFM topography and (b) current image at an electric field of 190 kV/cm. For clarity, the inserted boxes highlight the individual grains on the topography and current images.

The $Pb(Zr,Ti)O_3$ (PZT) thick films were processed by **electrophoretic deposition (EPD)**. Numerical analyses predicted a non-uniform current-density distribution on the electrodes, which was higher at the edges, which was in agreement with the experiments. We found that the thickness uniformity of the deposit could be improved by extending the deposition times and reducing the conductivity of the suspensions. Homogeneous and uniform layers were prepared from ethanol-butanol-based suspensions with a conductivity of 20 μS/cm (Figure 4).

In collaboration with François-Rabelais University, Tours, France, the electromechanical properties of PZT thick films with a thickness of 20 μm and relative density of 85 % were measured, The films with a thickness

coupling coefficient of 50 % and an acoustic impedance of 15 MRa can be used for the fabrication of high-frequency ultrasound transducers for medical applications.

We studied the stability of lead zirconate titanate powder (PZT) in water at various pHs. We found that the water-soluble acetate complexes formed on the PZT surface in the acidic conditions that consequently lead to a lead-lean surface of PZT. The ceramic formed from this powder is multiphase with a porosity of 40 %. The density, dielectric and piezoelectric properties of the ceramic processed from the powders aged at pH 7 and 10 were similar to the properties of the reference ceramic, which indicates that the aqueous PZT suspensions have to be prepared at neutral or alkaline pHs.

Danjela Kuščer and Silvo Drnovšek together with collaborators from the company ETI Elektroelement d.d., Izlake, were awarded the Puh recognition for inventions, development achievements and the use of scientific discoveries in the development of cordierite ceramics with a stable low coefficient of linear thermal expansion.

We prepared **$BiFeO_3$ thick films** on different substrates by screen-printing and studied the influence of the annealing temperature on the densification and interface reactions. The key parameters that need to be controlled in order to obtain high-quality films in terms of phase composition and microstructure were identified and include the annealing temperature and the substrate purity. Taking into account such processing parameters, we prepared compositionally improved and highly dense $BiFeO_3$ thick films on Ag metal foils, which were sintered at temperatures as low as 740 °C. While the local ferroelectric behaviour of the $BiFeO_3$ film was confirmed by the piezo-response force microscopy analysis, the films were macroscopically still electrically conductive.

We continued investigations of **LTCC** (Low Temperature Co-fired Ceramics), thick-film materials and processes, used for the fabrication of three-dimensional structures for different micro-electro-mechanical systems (MEMS) and chemical microsystems. The traditional co-operation with our partners **HIPOT-RR** and the Centre of Excellence **NAMASTE** continued in the research related to thick-film and LTCC technology. In cooperation with the above mentioned research partners, we evaluated new LTCC tapes developed at the company **KEKO Equipment**. Several three-dimensional structures were fabricated with both commercial and new LTCC tapes, and the processes and products were benchmarked. **Electrochemical sensors** with an integrated microfluidic structure were fabricated on the basis of a compatibility study of different electrode and LTCC materials in the frame of the M-ERA.NET INTCERSEN project.

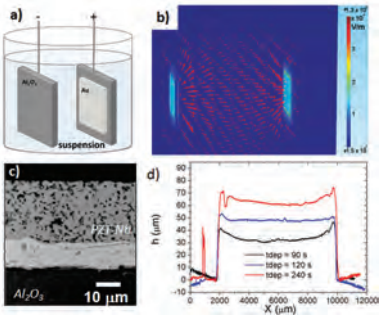

Figure 4: a) Schematic of the electrophoretic set-up. b) The electric field and the current flow between the electrodes. c) Sintered Nb-doped PZT thick film, d) Cross-sectional profiles of the deposits after different deposition times.

The influence of the fraction of the glass-fibre (EGF) reinforcement, from 0 to 15 wt%, on the thermal properties of the polymer-matrix composites with the $CaCO_3$ mineral filler was studied in collaboration with the company **DOMEL**. The proper ratio of glass-fibres and mineral filler is important for obtaining good mechanical, and at the same time good thermal, properties of the composites used in the production of high-quality components in the electro industry.

In collaboration with the company **ETI Elektroelement d.d.** from Izlake we developed an advanced procedure for processing steatite ceramics. The procedure includes the selection of the appropriate raw materials, the milling of steatite suspensions, spray-drying, dry pressing and sintering of the products. The newly developed steatite materials have superior mechanical and electrical properties that significantly exceed the characteristics required according to the standards. For the invention "Development of new steatite material" the researchers from Jožef Stefan Institute and ETI Elektroelement, d. d., were awarded the Silver recognition by the Chamber of Commerce and Industry of Slovenia in September 2015. The researchers also developed a non-porous cordierite ceramic C410 with controlled thermal and mechanical properties and transferred the process to production. The cordierite ceramic with a low and reproducible thermal expansion coefficient combined with excellent mechanical properties was manufactured by selecting the alumina reagent with a given particle size. For this invention the researchers from the Jožef Stefan Institute and ETI Elektroelement, d. d., were awarded the **Puh recognition**.

We organised the international conference PIEZO 2015: Electroceramics for End-Users VIII (January 25-28, 2015, Maribor). The event with almost 100 participants from 19 countires, out of which one-third were from industry, included conntributions on electroactive, mainly piezoelectric materials and devices.

Some outstanding publications in the past year

1. Walker, Julian, Bryant, Peter, Kurusingal, Valsala, Sorrell, Charles C., Kuščer, Danjela, Dražić, Goran, Benčan, Andreja, Valanoor, Nagarajan, Rojac, Tadej. Synthesis-phase-composition relationship and high electric-field-induced electromechanical behavior of samarium-modified BiFeO[sub]3 ceramics. Acta materialia, ISSN 1359-6454. [Print ed.], 2015, str. 149-159, doi: 10.1016/j.actamat.2014.09.058. [COBISS.SI-ID 28038439]
2. Rojac, Tadej, Uršič, Hana, Benčan, Andreja, Malič, Barbara, Damjanović, Dragan. Mobile domain walls as a bridge between nanoscale conductivity and macroscopic electromechanical response. Advanced

functional materials, ISSN 1616-301X, 2015, vol. 25, no. 14, str. 2099-2108, doi: 10.1002/adfm.201402963. [COBISS.SI-ID 28359975]
3. Uršič, Hana, Benčan, Andreja, Dražić, Goran, Esteves, Giovanni, Jones, Jacob L., Usher, Tedi-Marie, Rojac, Tadej, Drnovšek, Silvo, Deluca, Marco, Jouin, Jenny, Bobnar, Vid, Trefalt, Gregor, Holc, Janez, Malič, Barbara. Unusual structural-disorder stability of mechanochemically derived-Pb(Sc[sub](0.5)Nb[sub](0.5))O[sub]3. Journal of materials chemistry. C, Materials for optical and electronic devices, ISSN 2050-7526. [Print ed.], 2015, vol. 3, no. 39, str. 10309-10315, doi: 10.1039/C5TC02205C. [COBISS.SI-ID 28843815]
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Awards and Appointments

1. Tanja Pečnik: Award for the best oral presentation among young researchers at the 23rd International Conference on Materials and Technologies, Portorož: Dielectric properties of the solution-derived Ba0.5Sr0.5TiO3 thin films
2. Marko Vrabelj: 2nd place at the competition of young researchers at the 23rd International Conference on Materials and Technologies, Portorož: Electrocaloric Effect in 0.9Pb(Mg1/3Nb2/3)O3-0.1PbTiO3 Bulk Ceramics with Grain Sizes in Micron Range
3. Gorazd Frontini, Janez Holc, Danjela Kuščer, Irena Ramšak, Marija Raspotnik, Helena Razpotnik: Golden recognition for the innovation, Trbovlje, Chamber of Commerce and Industry of Slovenia, Regional Chamber Zasavje, Recognition for innovation: The development of the new steatite materials
4. Gorazd Frontini, Janez Holc, Danjela Kuščer, Irena Ramšak, Marija Raspotnik, Helena Razpotnik: Silver national recognition for the innovation, Brdo pri Kranju, Chamber of Commerce and Industry of Slovenia: Recognition for innovation: The development of the new steatite materials
5. Ines Bantan, Silvo Drnovšek, Danjela Kuščer, Helena Razpotnik: Puh Acknowledgement, Portorož, Republic of Slovenia, The Government of the Republic of Slovenia, Puh Acknowledgement for inventions, development achievements and use of the scientific discoveries in the development of cordierite ceramics with a stable low coefficient of linear thermal expansion

Organization of Conferences, Congresses and Meetings

1. Piezo 2015: Electroceramics for End-Users VIII, Maribor, Slovenia, January 25 – 28, 2015
2. 3rd Central and Eastern European Conference on Thermal Analysis, and Calorimetry, Ljubljana, Slovenia, August 25 – 28, 2015
3. 51th International Conference on Microelectronics, Devices and Materials with the Workshop on Terahertz and Microwave Systems – MIDEM 2015, Bled, Slovenia, September 23 – 25, 2015

Patent granted

1. Rodrigo Ferrão De Paiva Martins, Elvira Maria Correia Fortunato, Pedro Miguel Candido Barquinha, Nunes Pereira, Gonçalo Gonçalves, Danjela Kuščer, Marija Kosec, Maria Silvina Vieira Pereira Ferreira, Amorphous multicomponent dielectric based on the mixture of high band gap and high K materials, respective devices and manufacture, US8987097 (B2), US Patent Office, 24. 03. 2015.

INTERNATIONAL PROJECTS

1. Feasibility Study and Fabrication of LTCC based PCB Multilayer
   Prof. Barbara Malič
   Ctr Carinthian Tech Research Ag
2. 7FP - CERAMPOL; Ceramic and Polymeric Membrane for Water Purification of Heavy Metal and Hazardous Organic Compound
   Asst. Prof. Danjela Kuščer Hrovatin
   European Commission
3. 7FP - PI; The Piezo Institute - European Expertise Centre for Multifunctiona and Integrated Piezoelectric Devices
   Prof. Barbara Malič
   European Commission
4. Processing-properties Relationship in Lead-free (K,Na)NbO3-based Piezoelectric Materials
   Asst. Prof. Tadej Rojac
   Slovenian Research Agency
5. Study on the Process and Mechanism of Novel Electronic Ceramics
   Prof. Barbara Malič
   Slovenian Research Agency

6. Multiferroic Composites for Novel Applications
   Asst. Prof. Andreja Benčan Golob
   Slovenian Research Agency
7. Functional Heterogeneity in Complex Oxides: Chemical Clustering, Atomic Displacements, and Polar Nanoregions
   Dr. Hana Uršič Nemevšek
   Slovenian Research Agency
8. Towards Oxide Based Electronics
   Dr. Katarina Vojisavljević
   Cost Office

RESEARCH PROGRAM

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

R & D GRANTS AND CONTRACTS

1. Nanostructures for high-efficiency solar cells and photovoltaic
   Prof. Barbara Malič
2. Tunable ferroelectric thin film capacitors for agile microwave antennas
   Prof. Barbara Malič
3. High-performance piezoelectric materials for sensors and actuators in high-temperature applications
   Asst. Prof. Tadej Rojac
4. New advanced electrocaloric materials for novel environmentally-friendly dielectric refrigeration technology
   Prof. Barbara Malič
5. Micro-electromechanical and electrocaloric layer elements
   Prof. Barbara Malič
6. Processing of stable aqueous suspensions for fabrication of electrotechnical elements based on steatite ceramic
   Dr. Katja Makovšek
7. Integrated sensors with microfluidic features using LTCC technology
   Dr. Hana Uršič Nemevšek
8. Piezoelectric MEMS for efficient energy harvesting
   Prof. Barbara Malič
9. International Conference PIEZO 2015, Maribor, Slovenia, 25.-28.01.2015
   Prof. Barbara Malič
10. Programme for Students and Early Stage Researchers at PIEZO 2015: Microstructure-properties Relationship in Piezoelectric Ceramics which will take Place from January 25th to January 28th, 2015
    Prof. Barbara Malič

NEW CONTRACTS

1. Research of compatibility of LTCC materials and conductive pastes, with the emphasis on appropriate adhesion of the conductive material on LTCC and on simultaneous densification of both materials
   Prof. Barbara Malič
   Keko - Oprema d. o. o. Žužemberk
2. Research of silicate based technical ceramics
   Prof. Barbara Malič
   Razvojni Center Enem Novi Materiali d. o. o.

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1. Marco Deluca, Institut für Struktur-und Funktionskeramik, Montanuniversität Leoben, Leoben, Austria, January 15 – 16, 2015
2. Dragan Damjanovic, Ceramics Laboratory, Swiss Federal Institute of Technology-EPFL, Lausanne, Switzerland, January 23 – 26, 2015
3. Jacob L. Jones, North Carolina State University, Raleigh, USA, January 25 – February 1, 2015
4. Arai Takashi, Shizuoka University, Shizuoka, Japan, March 24 – 29, 2015
5. Adis Dzunuzović, Institute for Multidisciplinary Research, University of Belgrade, Belgrade, Serbia, March 23 – April 3, 2015
6. Hisao Suzuki, Research Institute of Electronics, Shizuoka University, Shizuoka, Japan, April 21 – 23, 2015
7. Andrei Rotaru, National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania, May 15, 2015
8. Marko Budimir, Institute for Nuclear Technology-INETEC, Zagreb, Croatia, June 4 – 5, 2015
9. Camilla Baratto, CNR National Institute of Optics, Brescia, Italy, June 4 – 5, 2015
10. Isabella Concina, Department of Information Engineering, University of Brescia, Brescia, Italy, June 4 – 5, 2015
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14. Hugo Mercier, GREMAN UMR CNRS 7347-François Rabelais, University of Tours, Tours, France, October 1 – December 31, 2015
15. Antonio Petošić, Department of Electroacoustics, Faculty of Electrical Engineering and Computing, Zagreb, Croatia, October 15, 2015
16. Marko Hrovat, Department of Electroacoustics, Faculty of Electrical Engineering and Computing, Zagreb, Croatia, October 15, 2015
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20. Jochen Bardong, Carinthian Tech Research, Villach, Austria, November 4, 2015
21. Alfred Binder, Carinthian Tech Research, Villach, Austria, November 4, 2015
22. Brienne Johnson, North Carolina State University, Raleigh, USA, November 8 – 17, 2015
23. Mateo Markov, Technical College Bjelovar, Bjelovar, Croatia, November 9 – December 31, 2015
24. Nikola Ilić, Institute for Multidisciplinary Research, University of Belgrade, Belgrade, Serbia, November 21 – 28, 2015
25. Jelena Bobić, Institute for Multidisciplinary Research, University of Belgrade, Belgrade, Serbia, November 29 – December 4, 2015
26. Biljana Stojanović, Institute for Multidisciplinary Research, University of Belgrade, Belgrade, Serbia, November 29 – December 3, 2015
27. Jurij Koruza, Technical University Darmstadt, Darmstadt, Germany, December 18, 2015

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Researchers
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2. Asst. Prof. Goran Dražić*
3. Asst. Prof. Danjela Kuščer Hrovatin
4. **Prof. Barbara Malič, Head**
5. Asst. Prof. Tadej Rojac
6. Dr. Hana Uršič Nemevšek

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7. *Dr. Mara Bernardo Sacristan, left 01.04.15*
8. Dr. Raluca-Camelia Frunza
9. *Dr. Alja Kupec, left 01.04.15*
10. Dr. Kostja Makarovič*
11. *Dr. Katja Makovšek, left 01.07.15*
12. Dr. Katarina Vojisavljević
13. Dr. Julian Bradley Walker

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14. *Tina Bakarič, B. Sc., left 01.11.15*
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18. Evgeniya Khomyakova, B. Sc.
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22. Darko Belavič, B. Sc.
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BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Andre-Pierre Abellard, Danjela Kuščer, Marc Lethiecq, Barbara Malič, Franck Levassort, "Processing and electromechanical properties of lead zirconate titanate thick films by electrophoretic deposition", *Advances in applied ceramics*, vol. 114, no. 4, pp. 198-204, 2015.
2. D. O. Alikin, A. P. Turygin, Julian Walker, Tadej Rojac, Vladimir V. Shvartsman, V. Ya. Shur, Andrei L. Kholkin, "Quantitative phase separation in multiferroic $Bi_{0.88}Sm_{0.12}FeO_3$ ceramics via piezoresponse force microscopy", *J. appl. phys.*, vol. 118, no. 7, pp. 072004-1-072004-5, 2015.
3. Robin Amisse, Moulay Tahar Sougrati, Lorenzo Stievano, C. Davoisne, Goran Dražić, Bojan Budič, Robert Dominko, Christian Masquelier, "Singular structural and electrochemical properties in highly defective $LiFePO_4$ powders", *Chem. mater.*, vol. 27, iss. 12, pp. 4261-4273, Jun. 2015.
4. Tina Bakarič, Bojan Budič, Barbara Malič, Danjela Kuščer, "The influence of pH dependent ion leaching on the processing of lead-zirconate-titanate ceramics", *J. Eur. Ceram. Soc.*, vol. 35, no. 8, pp. 2295-2302, 2015.
5. C. Baratto, Ramesh Kumar, G. Faglia, Katarina Vojisavljević, Barbara Malič, "p-Type copper aluminum oxide thin films for gas-sensing applications", *Sens. actuators, B, Chem.*, vol. 209, pp. 287-296, 2015.
6. Darko Belavič, Andraž Bradeško, Marina Santo-Zarnik, Tadej Rojac, "Construction of a piezoelectric-based resonance ceramic pressure sensor designed for high-temperature applications", *Metrol. Syst. Pomiarowe*, vol. XXXII, no. 3, pp. 331-340, 2015.
7. Darko Belavič, Marko Hrovat, Kostja Makarovič, Gregor Dolanc, Andrej Pohar, Stanko Hočevar, Barbara Malič, "3D LTCC structure for a large-volume cavity-type chemical microreactor", In: *Special issue IMAPS Poland 2014, 38th International IMAPS - CPMT Poland Conference & Exhibiton, September 21-24, 2014, Rzeszów-Czarna, Poland*, (Microelectronics international, Vol. 32, no. 2, 2015), Port Erin, Wela Publications, 2015, vol. 32, no. 3, pp. 133-137, 2015.
8. Mara Bernardo, Barbara Malič, Danjela Kuščer, "PZT-based thick films prepared by electrophoretic deposition from suspensions with different alcohol-based solvents", *J. Electrochem. Soc.*, vol. 162, iss. 11, pp. D3040-D3048, 2015.
9. Barbara Bertoncelj, Katarina Vojisavljević, Marko Vrabelj, Barbara Malič, "Thermal properties of polymer-matrix composites reinforced with E-glass fibers", *Inf. MIDEM*, vol. 45, no. 3, pp.216-221, 2015.
10. Goran Brovč, Goran Dražić, Blaž Karpe, Igor Đorđević, Gorazd Lojen, Borut Kosec, Milan Bizjak, "Synthesis and characterization of hardened Cu-Fe-Ni-P alloy", *Metalurgija (Sisak)*, vol. 54, no. 1, pp. 51-54, 2015.
11. Elena Buixaderas, Ivan Gregora, Maxim Savinov, J. Hlinka, Li Jin, Dragan Damjanović, Barbara Malič, "Compositional behavior of Raman-active phonons in $Pb(Zr_{1-x}Ti_x)O_3$ ceramics", *Phys. rev., B, Condens. matter mater. phys.*, vol. 91, no. 1, pp. 014104-1-014104-9, 2015.
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13. Goran Casar, Xinyu Li, Barbara Malič, Qiming M. Zhang, Vid Bobnar, "Impact of structural changes on dielectric and thermal properties of vinylidene fluoride-trifluoroethylene-based terpolymer/copolymer blends", *Phys., B Condens. matter*, vol. 461, pp. 5-9, 2015.
14. Jovana Ćirković, Katarina Vojisavljević, Nenad Nikolić, Predrag J. Vulić, Zorica Branković, Tatjana Srećković, Goran Branković, "Dielectric and ferroelectric properties of BST ceramics obtained by a hydrothermally assisted complex polymerization method", *Ceram. int.*, vol. 41, no. 9, part A, pp. 11306-11313, 2015.
15. Vladimir Furlan, Sebastjan Glinšek, Brigita Kmet, Tanja Pečnik, Barbara Malič, Matjaž Vidmar, "Influence of numerical method and geometry used by Maxwell's equation solvers on simulations of ferroelectric thin-film capacitors", *IEEE trans. microwave theor. tech.*, vol. 63, no. 3, pp. 891-896, 2015.
16. Sebastjan Glinšek, Tanja Pečnik, Vladimir Cindro, Brigita Kmet, Brigita Rožič, Barbara Malič, "Role of the microstructure in the neutron and gamma-ray irradiation stability of solution-derived $Ba_{0.5}Sr_{0.5}TiO_3$ thin films", *Acta mater.*, vol. 88, pp. 34-40, 2015.
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18. Neamul H. Khansur, Tadej Rojac, Dragan Damjanović, Christina Reinhard, Kyle Webber, Justin A. Kimpton, John E. Daniels, "Electric-field-induced domain switching and domain texture relaxations in bulk bismuth ferrite", *J. Am. Ceram. Soc.*, vol. 98, iss. 12, pp. 3884-3890, 2015.
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27. Raša Pirc, Brigita Rožič, Jurij Koruza, George Cordoyiannis, Barbara Malič, Zdravko Kutnjak, "Anomalous dielectric and thermal properties of Ba-doped $PbZrO_3$ ceramics", *J. phys., Condens. matter*, vol. 27, no. 45, pp. 455902-1-455902-7, 2015.
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29. Uroš Plaznik, Marko Vrabelj, Zdravko Kutnjak, Barbara Malič, Alojz Poredoš, Andrej Kitanovski, "Electrocaloric cooling: the importance of electric-energy recovery and heat regeneration", *Europhys. lett.*, vol. 111, nr. 5, pp. 57009-1-57009-6, 2015.
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34. Ankica Šarić, Goran Štefanić, Goran Dražić, Marijan Gotić, "Solvothermal synthesis of zinc oxide microspheres", *J. alloys compd.*, vol. 652, pp. 91-99, Dec. 2015.
35. Ana P. M. Tavares, Cláudia G. Silva, Goran Dražić, Adrián M. T. Silva, José M. Loureiro, Joaquim Luís Faria, "Laccase immobilization over multi-walled carbon nanotubes: kinetic, thermodynamic and stability studies", *J. colloid interface sci.*, vol. 454, pp. 52-60, 2015.

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37. Hana Uršič, Marko Vrabelj, Lovro Fulanović, Andraž Bradeško, Silvo Drnovšek, Barbara Malič, "Specific heat capacity and thermal conductivity of the electrocaloric $(1-x)Pb(Mg_{1/3}Nb_{2/3})O_3 - xPbTiO_3$ ceramics between room temperature and 300° C", *Inf. MIDEM*, vol. 45, no. 4, pp.260-265, 2015.
38. Alen Vižintin, Matic Lozinšek, Rajesh Kumar Chellappan, Dominique Foix, Andraž Krajnc, Gregor Mali, Goran Dražić, Boštjan Genorio, Rémi Dedryvère, Robert Dominko, "Fluorinated reduced graphene oxide as an interlayer in Li-S batteries", *Chem. mater.*, vol. 27, no. 20, pp. 7070-7081, Oct. 2015.
39. Julian Walker, Peter Bryant, Valsala Kurusingal, Charles C. Sorrell, Danjela Kuščer, Goran Dražić, Andreja Benčan, Nagarajan Valanoor, Tadej Rojac, "Synthesis-phase-composition relationship and high electric-field-induced electromechanical behavior of samarium-modified $BiFeO_3$ ceramic", *Acta mater.*, pp. 149-159, 2015.
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Review Article

1. Barbara Malič, Jurij Koruza, Jitka Hreščak, Janez Bernard, Ke Wang, John Gerard Fisher, Andreja Benčan, "Sintering of lead-free piezoelectric sodium potassium niobate ceramics", *Materials (Basel)*, vol. 8, no. 2, pp. 8117-8146, 2015.

Published Conference Contribution

1. Darko Belavič, "Keramični mikrosistemi za povezane sodelujoče sisteme pri nadzoru zdravega bivalnega in delovnega okolja", In: *Delavnica Pametna mesta in skupnosti kot razvojna priložnost Slovenije: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 12. oktober 2015, [Ljubljana, Slovenia]: zvezek H: proceedings of the 18th International Multiconference Information Society - IS 2015, October 12th, 2015, Ljubljana, Slovenia: volume H*, Mihael Mohorčič, ed., Ana Robnik, ed., Dalibor Baškovč, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 20-23.
2. Darko Belavič, Andraž Bradeško, Tadej Rojac, "Design of ceramic packaging for piezoelectric devices in high-temperature applications", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 79-84.
3. Darko Belavič, Kostja Makarovič, Andraž Bradeško, Hana Uršič, "Microfluidic elements in LTCC-based ceramic microsystems", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 68-73.
4. Marko Berginc, Andrej Čampa, Katarina Vojisavljević, Barbara Malič, Peter Panjan, Marko Topič, "Relation between sputtering parameters and optical and electrical properties of Ga doped ITO transparent conductive oxide", In: *Proceedings of EMRS 2015 Spring Meeting - Symposium C on Advanced Inorganic Materials and Structures for Photovoltaics*, (Energy procedia, vol. 48), E-MRS, Lille, France, May 11-15, 2015, Ivan Gordon, ed., et al, Amsterdam, Elsevier, 2015, pp. 183-189.
5. Mara Bernardo, Barbara Malič, Danjela Kuščer, "Piezoelectric elements for multi-element linear-array transducers prepared by electrophoretic deposition", In: *Selected, peer reviewed papers from the 5th International Conference on Electrophoretic Deposition "Fundamentals and Applications", October 5-10, 2014, Hernstein, Austria*, (Key engineering materials, vol. 654), Aldo R. Boccaccini, ed., Aedermansdorf, Trans Tech Publications, 2015, vol. 654, pp. 42-46, 2015.
6. Barbara Bertoncelj, Katarina Vojisavljević, Janez Rihtaršič, Gregor Jelenc, Barbara Malič, "Microstructure, mechanical and electrical properties of Glass Fiber Reinforced Composites (GFRC)", In: *Zbornik: 2. del: part 2*, 7. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 7th Jožef Stefan International Postgraduate School Students' Conference, 20.-22. 5. 2015, Ljubljana, Andraž Rešetič, ed., et al, Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2015, zv. 1, pp. 152-161.
7. Raluca-Camelia Frunză *et al.* (15 authors), "Solution-derived Ta_2O_5 high-K thin films for gate dielectric applications", In: *Zbornik: 2. del: part 2*, 7. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 7th Jožef Stefan International Postgraduate School Students' Conference, 20.-22. 5. 2015, Ljubljana, Andraž Rešetič, ed., et al, Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2015, zv. 1, pp. 188-197.
8. Lovro Fulanović, Marko Vrabelj, Silvo Drnovšek, Hana Uršič, Danjela Kuščer, Kostja Makarovič, Zdravko Kutnjak, Vid Bobnar, Barbara Malič, "Characterization of $0.9Pb(Mg_{1/3}Nb_{2/3})O_3 - 0.1PbTiO_3$ electrocaloric elements prepared by tape casting", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 221-226.
9. Viviana Golja *et al.* (15 authors), "Matrix degradation as a mechanism for nanoparticles release from food contact materials", In: *Zbornik: 2. del: part 2*, 7. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 7th Jožef Stefan International Postgraduate School Students' Conference, 20.-22. 5. 2015, Ljubljana, Andraž Rešetič, ed., et al, Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2015, zv. 1, pp. 198-206.
10. Marko Hrovat, Kostja Makarovič, Darko Belavič, Jena Cilenšek, Barbara Malič, "Evaluation of thick film sensing resistors on novel LTCC", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 74-78.
11. Marko Jošt, Marko Berginc, Andrej Čampa, Janez Krč, Peter Panjan, Barbara Malič, Marko Topič, "Nanoimprinted textures on glass as a substrate for GITO deposition", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 23-28.
12. Katja Makovšek, Irena Ramšak, Barbara Malič, Vid Bobnar, Danjela Kuščer, "Processing of steatite ceramic with a low dielectric constant and low dielectric losses", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 197-202.
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Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 215-220.

Independent Component Part or a Chapter in a Monograph

1. S. A. C. Carabineiro, Adrián M. T. Silva, Cláudia G. Silva, Ricardo A. Segundo, Goran Dražić, José Luís Figueiredo, Joaquim Luís Faria, "Titanium dioxide nanoparticle based materials for photocatalytic conversion of water pollutants", In: *Nanocomposites in wastewater treatment*, Amit Kumar Mishra, ed., Boca Raton, FL, CRC Press, Pan Stanford Publishing, 2015, pp. 247-269.
2. Jurij Koruza, Tadej Rojac, Barbara Malič, "Polar oxide nanopowders prepared by mechanical treatments", In: *Handbook of mechanical nanostructuring*, Mahmood Aliofkhazraei, ed., Weinheim, Wiley-VCH, cop. 2015, zv. 2, pp. 641-661.

Patent

1. Rodrigo Ferrão De Paiva Martins, Elvira Maria Correia Fortunato, Pedro Miguel Candido Barquinha, Nunes Pereira, Gonçalo Gonçalves, Danjela Kuščer, Marija Kosec, Maria Silvina Vieira Pereira Ferreira, *Amorphous multicomponent dielectric based on the mixture of high band gap and high K materials, respective devices and manufacture,* US8987097 (B2), US Patent Office, 24. 03. 2015.

Mentoring

1. Andraž Bradeško, *Design, modelling and characterization of an electrocaloric cooler made from array of cantilevers:* master's thesis, Ljubljana, 2015 (mentor Tadej Rojac; co-mentor Zdravko Kutnjak).
2. Aleksander Matavž, *Inkjet printing of transparent metal oxide-based nano-capacitors:* master's thesis, Ljubljana, 2015 (mentor Barbara Malič).
3. Danijela Pucko, *New analytical methods for determination of TiO_2-based thin film photoactivity:* master's thesis, Ljubljana, 2015 (mentor Goran Dražić; co-mentor Irena Kralj Cigić).

ENGINEERING CERAMICS DEPARTMENT

K-6

The Engineering Ceramics Department is the leading group in the field of structural ceramics and ceramic technologies in Slovenia. The research programme comprises phenomena relevant to materials synthesis and component fabrication as well as mechanisms leading to the degradation of engineering and bio-ceramic structures under operating conditions. The applied research work is focused on new applications of engineering ceramics, the development of novel, high-strength, wear-, corrosion- and/or heat-resistant materials and the development of alternative, cost-effective and environmentally friendly ceramic technologies.

Head (since 1. 6. 2015):
Dr. Andraž Kocjan

Head (until 31. 5. 2015):
Prof. Tomaž Kosmač

In 2015 we continued our research on the hydrolysis of aluminium nitride (AlN) powder and its use in innovative ceramic processing. High-performance, porous γ-alumina monoliths with hierarchical heterogeneities were fabricated by the compaction of the AlN-powder-hydrolysis-derived γ-alumina (MA). The latter consisted of nanocrystalline, yet micron-sized, hierarchically self-assembled, mesoporous bundles of aggregated lamellas with a high surface area. Without any additional calcination or sintering step the as-compacted porous MA bodies exhibited a relatively high stiffness and elasticity, and a low thermal conductivity, as a result of the homogeneous packing of the primary crystallites. By varying the consolidation pressure it was possible to manipulate the pore size distribution in the compacts (monoliths) from bimodal, i.e., combining (hierarchical heterogeneities) macro- and meso-porosity, to a monomodal distribution of meso-pores. Such monolithic porous structures, retaining the original surface properties of the MA powder, are aimed at applications related to catalysis, separation, thermal insulation and filtration.

The research on the development of electrically conductive ceramic composites based on zirconia (ZrO_2) with dispersed titanium nitride (TiN) particles that could be machined with electrical-discharge machining (EDM) was also continued. Homogeneous ZrO_2/TiN powder mixtures with various amounts of TiN were prepared by the controlled in-situ precipitation of titanium oxide on the surface of ZrO_2 particles, followed by calcination and a thermochemical treatment in ammonia (nitridation) to yield TiN. These powder mixtures were consolidated using the spark-plasma sintering (SPS) technique to produce dense composites. The impact of the amount and size of the conductive particles on the densification process and microstructure, as well as on the resulting mechanical and electrical properties of the sintered composites, was studied. By using electron microscopy it was confirmed that upon densification the electrically conductive TiN particles retained their nanometric size and, as a consequence, the materials containing only 13 vol.% of TiN exhibited a sufficiently high electrical conductivity for machining using EDM.

In the frame of a Master's thesis, a translucent, self-reinforced mullite ceramic with anisotropic grains was developed. The material was produced by co-doping a commercial mullite powder with small amounts of yttria and silica, and consolidation in an SPS furnace. The combination of yttria/silica co-doping and SPS provided an enhanced densification, also provoking an anisotropic grain growth at a relatively low sintering temperature of 1370 °C and a contact pressure of ~15 MPa. In this way it was possible to meet the conflicting demands for obtaining a dense mullite ceramic with a certain amount of anisotropic grains, ensuring good mechanical properties, while preserving a remarkable optical transmittance. The manuscript reporting on these results is under consideration for the *Journal of the American Ceramic Society*.

The spark-plasma-sintered, nanosized ZrO_2/TiN composites from powders prepared by the wet chemical route followed by a thermochemical treatment in ammonia exhibit a high electrical conductivity at the lowest TiN content ever reported.

In September 2015 Tjaš Savarin, an undergraduate student from the Department of Physics, Faculty of Mathematics and Physics at the University of Ljubljana, obtained a bachelor degree by defending his diploma work entitled "*Bend Strength of Alumina Ceramics in Uniaxial and Biaxial Test*". In this work he compared the bend-strength values of sintered alumina ceramics measured using the uniaxial, four-point bending test for rectangular samples and the biaxial, pin-on-three-balls flexural test for discs, respectively. A statistical distribution of the measured strength values was described with the commonly used, two-parametric Weibull function, whereby the Weibull parameters were evaluated with the moment's method, a linear regression and the maximum-likelihood method. It was shown that the strength distribution fits the Weibull distribution well and the three methods give similar, but not equal, parameter values. The mean strength of the rectangular samples is smaller than for the discs, and the same holds for the relative standard deviation of the strengths. The Weibull modulus for the rectangular samples is significantly larger than that for the discs.

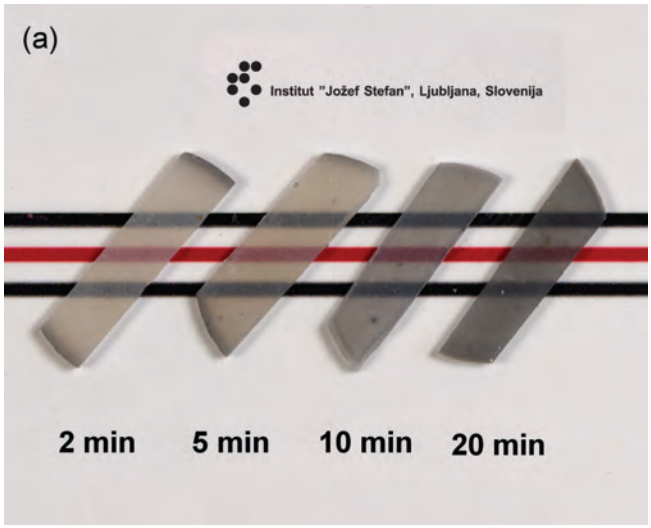

Figure 1: A qualitative comparison of the optical translucencies of yttria- and silica-doped mullite ceramics (1-mm thickness) SPS sintered at 1370 °C with various SPS dwell times.

In November 2015 Anastasia Samodurova successfully defended her doctoral dissertation at the Jožef Stefan International Postgraduate School. The thesis deals with the kinetics and mechanisms of the hydrothermal ageing of 3 mol % yttria-doped tetragonal zirconia polycrystalline (3Y-TZP) ceramic, which is an attractive material for dental restorations due to its unique combination of excellent mechanical properties, biocompatibility and aesthetic appearance. The research was focused on the role of silica and/or alumina-(co)-doping in the phase partitioning and microstructure evolution during sintering, also resulting in the formation of residual internal stresses within the sintered ceramics, thereby influencing the nucleation and propagation of the hydrothermally induced tetragonal-to-monoclinic (*t-m*) transformation. In order to differentiate between the distinct contributions of the two dopants to the overall resistance to ageing, the specimens were prepared by the infiltration of a silica sol into pre-sintered, porous 3Y-TZP discs, which contained 0.00, 0.05 and 0.25 wt. % of alumina. The infiltration technique was chosen for co-doping, since it could be easily included in the CAD/CAM (computer-aided design and computer-aided manufacturing) technology commonly used in the production of dental 3Y-TZP restorations. After the final sintering, the specimens were characterized in terms of their microstructure, phase composition, mechanical properties and accelerated ageing behavior. The kinetics of the low-temperature degradation (LTD) was studied by quantifying the transformed monoclinic fraction from an X-ray diffraction (XRD) analysis as well as by analyzing cross-sections of aged samples using optical microscopy. It was demonstrated that the addition of silica caused the rounding of the zirconia grains and thus reduced the internal stresses affecting the nucleation, while the presence of alumina increased the grain-boundary cohesion, suppressing the propagation of the *t-m* transformation. In addition, the overall partitioning process was found to be the slowest in co-doped material, leaving a larger amount of yttria in the tetragonal grains and thereby decelerating the LTD. The higher thermodynamic stability of these grains, together with the presence of a silica phase at the triple grain junctions and/or grain boundaries, led to a greatly improved LTD resistance of the 3Y-TZP, without compromising its strength and fracture toughness. The results of this doctoral thesis were summarized in two scientific papers published in highly ranked journals. In 2015 papers entitled "*The combined effect of alumina and silica co-doping on the ageing resistance of 3Y-TZP bioceramics*" and "*The sintering-temperature-related microstructure and phase assemblage of alumina-doped and alumina–silica-co-doped 3-mol%-yttria-stabilized tetragonal zirconia*" were published in *Acta Biomaterialia* and *Scripta Materialia*, respectively.

Dr. Anastasia Samodurova successfully defended her doctoral dissertation entitled "Ageing of Zirconia Ceramics for Dental Applications", at the Jožef Stefan International Postgraduate School. The results, published in *Acta Biomaterialia* and *Scripta Materialia*, have a high practical applicability, providing a simple processing modification that yields ageing-resistant zirconia bioceramics without compromising their mechanical properties.

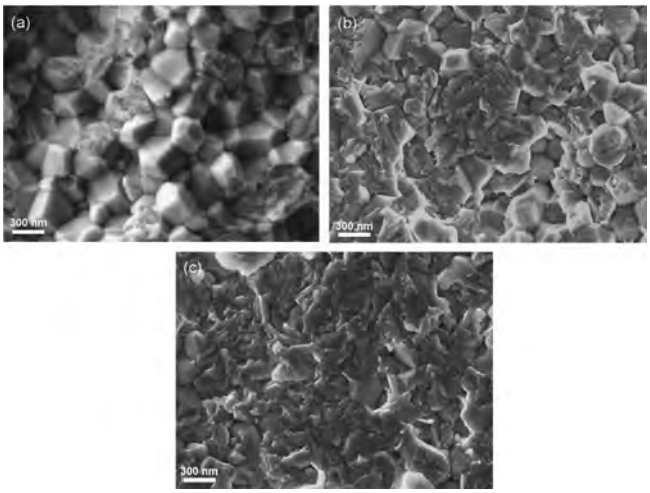

Figure 2: Increase in the amount of transgranular fracture type observed in fractured surfaces after bending as a function of increased alumina (dopant) content in 3 mol% yttria-doped tetragonal zirconia bioceramics (3Y-TZP): (a) 0 wt.%, (b) 0.05 wt.% and (c) 0.25 wt.% of alumina.

In the field of research on dental ceramics we continued addressing some of the major problems concerning the production of full-ceramic dentures with 3Y-TZP as a core material, their cementation and their behaviour in clinical conditions. The work was conducted in close co-operation with the Department of Prosthetic Dentistry, Medical Faculty at the University of Ljubljana. Thus, extensive *in-vitro* experiments were conducted, aimed at a better understanding of the ageing process, i.e., the hydrothermally induced transformation of the metastable tetragonal zirconia into the thermodynamically stable monoclinic structure. In 2015 an extensive study was published in *Dental Materials* on the complexity of the relationships between airborne-particle abrasion, hydrothermal degradation and the strength of the biomedical-grade zirconia 3Y-TZP ceramic. Airborne-particle abrasion is a common surface-modification method to increase the roughness and achieve mechanical retention when bonding dental restorations. As the surface becomes damaged in the process, additional flaws could decrease the strength when subjected to the hydrothermal conditions in the human body. We studied the influence of airborne-particle abrasion and ageing on materials with different grain sizes and therefore different transformabilities. Different grain sizes were obtained by applying two sintering temperatures (1400 °C 2h or 1500 °C 2h) to the nominally identical materials. It was shown

that the pristine, low-temperature-sintered, fine-grained ceramic exhibited superior LTD resistance, while the high-temperature-sintered, coarse-grained material experienced higher surface strengthening and a substantially improved ageing resistance upon airborne-particle abrasion. This finding is important when considering the recommended grain-size values in the currently accepted standard ISO 13356 "Implants for surgery – Ceramic materials based on yttria-stabilized tetragonal zirconia (Y-TZP)" and the producers' tendencies to apply finer grain sizes in order to increase the translucence. As the high-translucency 3Y-TZP ceramic is increasingly applied in the clinical setting, our ongoing clinical trial on its in-vivo ageing is of great importance. The high-translucency Y-TZP ceramic discs are incorporated in the lingual flanges of full lower dentures worn by volunteers. Interim results show that hydrothermal degradation occurs in the oral cavity and is dependent on the surface-modification methods, such as polishing and airborne-particle abrasion. Results after one year were presented at the European Dental Materials Conference in Nürnberg, Germany.

Linked to a former JECS Trust funded post-doctoral project on "*Improved Reliability of Translucent Dental Zirconia and Alumina Ceramics*" a paper entitled "*Processing of zirconia nanoceramics from a coarse powder*" was published in the *Journal of the European Ceramic Society* resulting from Andraž Kocjan's work conducted during his stay at Stockholm University in the period 2011-2013. The present study showed that it is possible to process a dense, zirconia nanoceramic at moderate sintering temperatures using a coarse, mesoporous powder. The consolidation by wet centrifugal slip-casting yielded green bodies with hierarchical heterogeneities (HH) on account of the spherical mesoporous particle packing. The HH had a pronounced effect on both the densification and the grain growth, increasing the overall sintering activity. The intra-particle pore coalescence and a "frozen" inter-particle porosity prolonged the pore-pinning effect, separating the densification and grain growth mechanisms.

Dr. Andraž Kocjan published a paper in the *Journal of the European Ceramic Society* resulting from the work on a recent JECS-Trust-funded post-doctoral project at Stockholm University, showing it is possible to process a dense, zirconia nanoceramic at moderate sintering temperatures using a coarse, mesoporous powder.

A recent collaboration with the Department of Biomaterials and Biomimetics, New York University College of Dentistry yielded a publication in the *Dental Materials* journal entitled "*Effects of cementation surface modifications on fracture resistance of zirconia*". In this work, the impact of two innovative surface-modification techniques, i.e., the glass infiltration (GI) developed at NYU, and alumina coating (AC), developed at IJS, on the four-point bending strength and fracture resistance of monolithic zirconia was investigated. It was shown that both surface-modification techniques can be used to effectively modify the intaglio (cementation) surface of zirconia-based restorations. GI has the potential to significantly improving the flexural strength of zirconia, but the process is rather unpractical and difficult to control. In contrast, an AC has no substantial effect on the load-bearing capacity of zirconia, but it can be reproducibly made in a relatively simple process.

Within another informal collaboration with École Polytechnique Fédérale de Lausanne (EPFL) our former colleague dr. Aleš Dakskobler developed an empirical modification of the Yodel model for the prediction of the yield stress of concentrated, particulate, paraffin-wax suspensions with solids loadings in the range 47–57 vol.%, used in low-pressure powder injection moulding (LPIM). A practical validation of the empirical model, in terms of predicting the yield stress of paraffin-wax suspensions made from several alumina powders and one zirconia powder, yielded excellent agreement with the experimental results. It was shown that it is possible to predict realistic yield stresses across the whole of the solids-loading range suitable for LPIM just by making a single yield-stress measurement for the desired volume fraction of the solids in the paraffin-wax suspension. This collaborative research was finalized by publishing a common scientific paper entitled "*Predicting the Yield Stress of Paraffin-Wax Suspensions*", published in the *Powder Technology* journal.

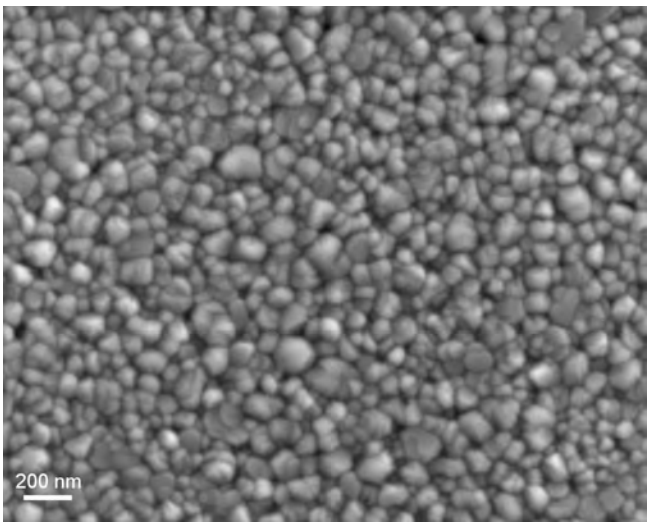

Figure 3: ZrO_2 nanoceramics fabricated by the hot pressing of coarse-grained, mesoporous powder at a relatively low temperature (1150 °C).

In addition to the above-mentioned informal co-operations in 2015, yielding common scientific papers, we have also formally cooperated with several domestic and foreign research institutions and industrial partners. For Omega-air, tovarna nogavic d.o.o., we have analysed the surface properties of some commercially available microporous and mesoporous adsorbent materials by employing a surface-area and pore-size analyser based on nitrogen adsorption. For the CETIS company, analyses of the thermal properties of sensors were made. For Errantech two batches of green and sintered tetragonal zirconia ceramic samples for dental applications produced via colloidal processing were measured and/or analysed – the dilatometric analysis, density by Archimedes, Vickers hardness and indentation toughness, the elastic modulus with an impulse excitation measuring device and coefficient of thermal expansion were performed. We have manufactured

and provided high-quality alumina-based laboratory ceramics to the Lithoz GmbH company, Hidria Rotomatika d.o.o., Brno University of Technology and to Universitat Politecnica de Catalunya.

Some outstanding publications in the past three years

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3. Štefanič, Martin, Milačič, Radmila, Dražič, Goran, Škarabot, Miha, Budič, Bojan, Krnel, Kristoffer, Kosmač, Tomaž. Synthesis of bioactive b-TCP coatings with tailored physico-chemical properties on zirconia bioceramics. Journal of materials science. Materials in medicine, ISSN 0957-4530, DOI 10.1007/s10856-014-5246-9.
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INTERNATIONAL PROJECTS

1. Services
   Asst. Prof. Andraž Kocjan
2. 7FP - CERAMPOL; Ceramic and Polymeric Membrane for Water Purification of Heavy Metal and Hazardous Organic Compound
   Prof. Tomaž Kosmač
   European Commission

RESEARCH PROGRAM

1. Engineering and bio-ceramics
   Asst. Prof. Andraž Kocjan

R & D GRANTS AND CONTRACTS

1. COST MP1301; NEWGEN, New Generation Biomimetic and Customized Implants for Bone Engineering
   Prof. Tomaž Kosmač
   Cost Office

VISITOR FROM ABROAD

1. Dr. Vaclav Pouchly, Central European Institute of Technology (CEITEC), Brno University of Technology, Department of Ceramics and Polymers, Brno, Czech Republic, 10 July-31 July 2015

STAFF

Researchers
1. **Dr. Andraž Kocjan, Head, since 01.06.15**
2. ***Prof. Tomaž Kosmač, Head, retired 01.06.15***
3. Asst. Prof. Kristoffer Krnel

Postgraduate
4. Ana Lazar, B. Sc.

Technical and administrative staff
5. Darko Eterović
6. Mojca Hren
7. Tomislav Pustotnik

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Original Article

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6. Bernd Wicklein, Andraž Kocjan, German Salazar-Alvarez, Federico Carosio, Giovanni Camino, Markus Antonietti, Lennart Bergström, "Thermally insulating and fire-retardant lightweight anisotropic foams based on nanocellulose and graphene oxide", *Nature nanotechnology*, vol. 10, no. 3, pp. 277-283, 2015.

Mentoring

1. Anastasia Samodurova, *Ageing of zirconia ceramics for dental applications:* doctoral dissertation, Ljubljana, 2015 (mentor Tomaž Kosmač; co-mentor Andraž Kocjan).

DEPARTMENT FOR NANOSTRUCTURED MATERIALS K-7

The basic and applied research in the Department for Nanostructured Materials includes ceramic materials, metals, intermetallic alloys and minerals. Our research encompasses conventional processing as well as the development of new technologies and methods for preparing new materials with novel properties. It considers both experimental and theoretical investigations of structures, analyses of chemical compositions at the atomic level, and measurements and calculations of physical properties, all of which help us to improve the properties of micro- and nanostructured materials.

Head:
Prof. Spomenka Kobe

The European project ROMEO (Replacement and Original Magnet Engineering Options) has come to an end and there were many activities before the finalization. The final task of the project was to design and make a prototype of an electric motor in collaboration with two co-operating partners: VALEO (France) and SIEMENS (Germany). A technology for improving the magnetic performance, developed in the Department for Nanostructured Materials, was chosen to be the most appropriate among those proposed by other academic and research-oriented partners. It is based on the grain-boundary diffusion process, which involves the electrophoretic deposition of TbF_3 as the initial step. The implementation of this technology gave the Nd-Fe-B permanent magnets a coercivity of more than 2000 kA/m and a remanence higher than 1.3 T at room temperature. These are the key magnetic properties that allow electric motors to operate at 150 °C. Besides ambitious magnetic properties, the use of essential heavy rare earths, which are identified as critical elements, is minimized down to only 1.37 wt. %, instead of 10–11 wt. % in the current state of the art. In our laboratory, more than 550 magnets were coated with TbF_3 powder prior to the annealing process. The electrophoretic deposition process enabled an even coating on each magnet, which is crucial for avoiding the use of excessive amounts of expensive coating. All of the magnets were then firmly packed into wooden boxes and double sealed in an argon atmosphere to avoid possible oxidation during transportation. The coated magnets were annealed in a vacuum furnace at the Vacuumschmelze company in Hanau (Germany). Those magnets with enhanced magnetic properties were then grinded to their final dimensions and embedded into the rotors of prototype electric motors.

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At the end of the year another EU FP7 project entitled "Nanocrystalline permanent magnets based on hybrid metal-ferrites" (**NANOPYME**) was finished. Within the frame of this project we prepared a hard-soft magnetic composite, which exhibited an increase in maximum energy product of 22 % when compared to the pure hard phase (used in a composite) magnet. For the preparation of the hard-soft magnetic composite we used hydrothermally synthesized Sr-ferrite as the hard magnetic phase and nanoparticles of Co-ferrite as the soft magnetic phase. The powders were compacted with spark-plasma sintering and the increase in the maximum energy product in the sintered composites is due to the exchange coupling between the hard and soft magnetic phases. The composites exhibit enhanced magnetic properties when compared to the single-phase materials used in the composites and had the best magnetic properties among all the materials prepared within the NANOPYME consortium.

In the frame of the European project **REProMag** we are developing and validating an innovative resource-efficient manufacturing route for rare-earth magnets that allows for the economically efficient production of net-shape magnetic parts with complex structures and geometries, while being 100% waste-free along the whole manufacturing chain. We use 100% recycled magnetic powder that is formed into complex shapes by mixing it with a polymer, which is removed after the process in order to achieve a dense sintered magnet. By optimizing the process of debinding and sintering, we have successfully removed the harmful excess of carbon, as a first stage of the project.

The international research project **MAG-DRIVE** is also focused on new permanent magnets for electric-vehicle drive applications. Besides K7 being the coordinator of the project, our scientific task is to perform structural characterization with scanning electron microscopy, magnetic characterization using a vibrating-sample magnetometer, and spark-plasma sintering of recycled powders.

In the frame of LIA - **International Laboratory between CNRS and JSI** - PACS$_2$, the following scientific results were obtained. The $Cu_5(Gd,Ca)$ metastable solid solution was prepared in different forms, including single-grain crystals. This series of compounds was selected from the studies performed within the CalGad-X PICS and was shown to produce an isomorphous, random substitution of Ca for Gd atoms in the hexagonal lattice, which is stabilized by the presence of calcium. The crystal structure of a single grain of composition close to $Cu_5(Gd_{0.5}Ca_{0.5})$ was refined. Transport properties were measured in the low- to room-temperature range. The surfaces were also characterized and we discovered unexpected catalytic properties of the Cu_5Gd allotrope.

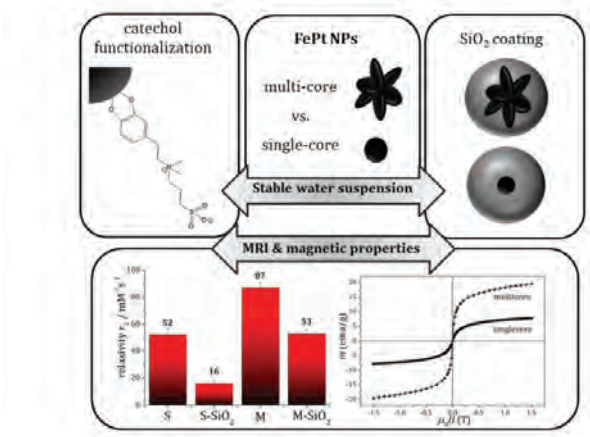

Figure 1: Formation of "multi-core" FePt nanoparticles results in an increased magnetization and consequently in higher MRI relaxivity values in comparison to their "single-core" counterparts. Functionalization with a bio-compatible zwitterionic dopamine ligand or coating with a SiO_2 shell enables the preparation of stable water suspensions, which are a prerequisite for further bio implementation.

A **new bulk glass-forming alloy** was identified from a study of substituting Gd or Ce atoms for Al atoms in the well-known Al-Cu-Fe icosahedral quasicrystal. The interval between the glass transition and crystallization was found to be large enough to allow the preparation of cm-size glassy samples by spark-plasma sintering. This finding is attractive enough to start a PhD thesis about the initiation of crystallization in such glasses and its influence on magnetic properties.

More exploratory research was dedicated to typical push-pull alloys. So far, no new compound with a giant unit cell was discovered, but these studies have enhanced our understanding of the miscibility gaps in the liquid state that characterize such systems.

FePd alloys are of particular interest due to the many possible applications that originate from their different chemical compositions. The electrodeposition process was first studied for single metals: Fe, Pd. In the end a comparison with a Fe–Pd alloy was performed. It was found that the deposition of Fe starts at 50 mV, the deposition of Pd at 200 mV and the deposition of the Fe–Pd alloy at 150 mV at more positive potentials, when instead of a Au electrode as the working electrode Fe, Pd or Fe–Pd monolayered deposits are already present. Furthermore, when Fe is accompanied with Pd, the deposition of Fe starts at more than 500 mV more positive potentials. Using the galvanostatic deposition, it was observed that in the case of the Fe–Pd-alloy deposition, Pd deposits first and due to its catalytic behaviour, it subsequently catalyses the reduction of Fe. These results are important since they reveal the "true" deposition behaviour of the Fe-Pd alloy, which is many times overlooked because the cyclic voltammetry is performed on substrates with different chemical compositions. The obtained electrodeposition conditions were further used to deposit 200-nm-thick and 3.5-μm-long fcc nanowires (NWs) with a consistent composition of $Fe_{48\pm3}Pd_{52\pm3}$ in an AAO template. Magnetic force microscopy (MFM) on a single Fe–Pd NW revealed its single-domain behaviour with the easy axis of magnetization along the long axis of the NW. The magnetization switching behaviour of a single Fe–Pd NW studied with MFM suggested a square-shaped magnetization curve (M/Ms = 1) with $Hc_{II} \approx 3.2$ kA/m. In addition, using in-field MFM techniques, the effects of dipolar interactions in a Fe–Pd array of NWs embedded in the AAO were determined. It was found that the dipolar interactions greatly reduce the parameters of the magnetic hysteresis loop, such as the coercivity, remanence, and switching-field distribution of the Fe–Pd NW array, which are important parameters for the consideration of these NW arrays as magnetic recording media.

In the frame of an ARRS project, **FePt nanoparticles** (NPs) were assessed for their possible bio applications. Since the magnetization value strongly influences the performance of the nanoparticles acting as the contrast-agent material for MRI, we have described processing routes for the synthesis of FePt nanoparticles of different sizes, which possess, consequently, different magnetization values. "Single-core" FePt nanoparticles of different sizes (3–15 nm) were prepared via one-step or two-step synthesis, with the latter exhibiting almost twice the magnetization ($m_{(1.5T)}$ = 14.5 emu/g) as compared to the nanoparticles formed via a one-step synthesis ($m_{(1.5T)}$ < 8 emu/g). Furthermore, we proposed the synthesis of "multi-core" FePt nanoparticles by changing the ratio between the two surfactants (oleylamine and oleic acid), exhibiting much higher magnetizations, i.e., 19.5 emu/g, without exceeding the superparamagnetic limit. Stable water suspensions of FePt NPs were prepared via functionalization with a biocompatible zwitterionic catechol ligand, for the first time, and via a SiO_2 coating. FePt nanoparticles showed promising MRI characteristics, with significant shortening of the transversal relaxation times, i.e., r_2 relaxivities that equal 52 $mM^{-1}s^{-1}$ for "single core" FePt and 87 $mM^{-1}s^{-1}$ for "multi-core"

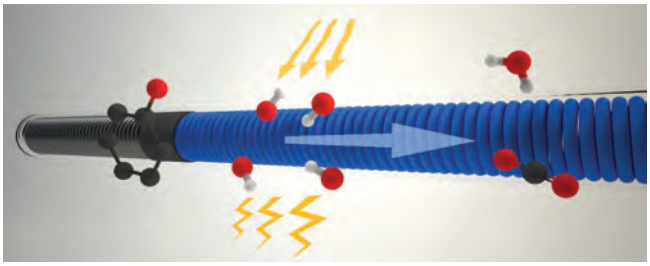

Figure 2: Schematic representation of phenol mineralization inside the continuous-flow photoelectrocatalytic microreactor. Degradation reaction takes place on the surface of the photocatalytically active coil in the presence of UV-light illumination, hydroxyl radicals, and external electrical potential.

FePt NPs, while exhibiting r_2/r_1 ratios above 10, which are ideal for MRI. The nonmagnetic SiO_2 coating "diluted" the magnetic effect of the FePt nanoparticles, resulting in lower MRI performance.

In the frame of the ARRS project "Bioresponsive magnetooptically coupled nanomaterial based systems for innovative skin cancer treatments", we explored the field of multimodal hybrid nanoparticles, which can be used for nanomedical applications by combining the focused localization and extraction of hybrid nanoparticles, using an external magnetic field and photothermally-responsive drug release and treatment. To realize this, we have combined photothermal and magnetic entities in an innovative material based on **FePt/SiO_2/Au hybrid nanoparticles**. The magnetic cores of FePt exhibit the superparamagnetic properties necessary for biomedical purposes, while the gold nano-shells absorb light in the near-infrared range, as predicted by our modelling. Our results showed that superparamagnetic components in the form of a FePt core can be successfully incorporated into silica/gold nano-shells. The multifunctional nature of such materials was successfully demonstrated by measuring their photothermal and magnetic response. We demonstrated that a high photothermal response can be achieved while irradiating a suspension of these hybrid nanoparticles with a low-energy NIR laser. In addition, using a separation/retention experiment under dynamic conditions we confirmed that these hybrid nanoparticles can be extracted using an external magnet. This opens up a "playground" of choices and a range of possibilities for in-vivo applications and confirms our idea that these nanoparticles can be successfully applied in real biological systems.

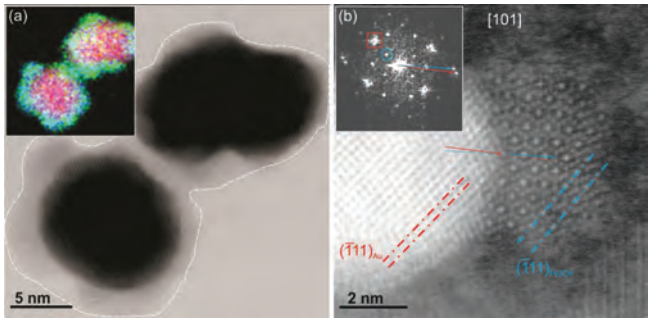

Figure 3: (a) High-resolution BF-STEM image of Au and Fe-oxide NPs. The dashed contour lines distinguish the Fe-oxide particles from the support carbon film. The inset shows the corresponding composed elemental map (Au: red, Fe: green and O: blue). (b) Atomic resolution HAADF-STEM image of the interface between the Au and Fe_3O_4 particles observed in the [101] zone axis. The red and blue dashed parallel lines represent the (1̄11) lattice planes for the Au and Fe_3O_4 crystal structures, respectively.

For the first time, we report on a one-step synthesis and surface functionalization of dumbbell-like **Au/Fe_3O_4 nanoparticles**, which is a key step for their use as hybrid organic-inorganic nanotheranostic systems. The exact morphology of these dumbbell-like gold-iron oxide nanoparticles at the atomic scale was determined by high-resolution HAADF-STEM imaging. We were able to confirm that the dumbbell-like gold-iron oxide nanoparticles were composed of a gold particle with the fcc structure observed in the $[101]_{Au}$ zone axis and cubic Fe_3O_4 with the inverse spinel structure, which was also observed in the $[101]_{Fe3O4}$ crystallographic projection. The interface between the Au and Fe_3O_4 crystal phases was manifested by the {111} faceted gold surface. The analysis of the crystallographic relationship between both structures indicates the epitaxial growth of Fe_3O_4 $(111)_{Fe3O4}$ planes onto the $(111)_{Au}$ Au surface. The observed slight misalignment of the gold and Fe_3O_4 crystal lattices was explained by the small lattice mismatch (~3%) between the theoretical values of Au $2d_{111}$-(0.471 nm) and Fe_3O_4 d_{111}(0.485 nm), which could provoke local structural compensation at the interface, enabling the epitaxial growth of Fe_3O_4 onto the surface of the Au. In the theoretical part of our research, we applied the density-functional theory to investigate the influence of the exchange-correlation effects on the electron-phonon coupling, and consequently on the predicted phase-transition temperature in the superconducting H_3S under high pressure ~ 2GPa. We also worked on the theoretical reconstruction of the twin boundary on some minerals. We developed a method for the calculation of the electron-phonon coupling in the frame of the density-functional and Hartree-Fock theories. It was found that the correct description of the hydrogen phonon states required the presence of the exact correlation term.

In the frame of European programme **EUROFusion** we continued the development of structural materials based on tungsten for the highly thermally loaded structural parts of demonstration fusion reactors. Since the first results revealed critical drawbacks of the reinforcement with SiC or TiC particles, which readily react with a tungsten matrix, we focused our research on the addition of W_2C as a reinforcement. We confirmed that the W_2C particles can be synthesised from added graphene or an organic precursor directly in the tungsten matrix during sintering and that, as proposed, the particles concentrate at the grain boundaries. Moreover, in collaboration with the UK industrial partner TISICS Ltd, the first metal-matrix composite samples with long SiC fibres have been prepared.

Encouraging testing results for a hydrothermally synthesized TiO_2 anatase coating, obtained within the **BioTiNet** (FP7-ITN) project, led us towards a further comprehensive analysis of the effect of the coating on the physico-chemical properties and the biological response. In collaboration with the Biotechnical Faculty and the Faculty for Mechanical Engineering, University of Ljubljana, we confirmed that the topographic characteristics have a more pronounced effect on bacterial attachment than the surface charge and wetting. By tailoring the coating surface, an attachment of bacteria of less than 5% has been achieved. The importance of the obtained results has been reflected in a signed licence agreement for the exploitation of undisclosed knowledge with a foreign partner.

In the final year of **COST Action NAMABIO** ("From nano to macro biomaterials and application to stem cells regenerative orthopaedic and dental medicine"), our main focus was on the characterization of 3D bioactive composite scaffolds for stem cells. In collaboration with Vienna University of Technology and Aalto University we compared several methods for mechanical characterization and concluded that shear rheology and compression

tests are the most appropriate. In collaboration with Belgrade University we have tested the bioactivity of samples with and without bioactive glass particles in a perfusion bioreactor, and proved that the addition of such particles drastically enhances the scaffold's properties. Composite samples with a silk fibroin or gellan gum matrix, which showed the most promising results, have been sterilized in the Triga reactor (in cooperation with the department F8) and tested at the company Animacell d.o.o. Together with Educel d.o.o., bioactive glass/protein scaffolds for the treatment of osteochondral defects were developed and characterized. The positive influence of bioactive glass on the protein structure, solubility and bioactivity were determined in collaboration with the Veterinary Faculty and the Faculty for Chemistry and Chemical Technology. We joined the **COST Action NEWGEN** (New Generation Biomimetic and Customized Implants for Bone Engineering) that will help us to continue our research in the field of tissue engineering.

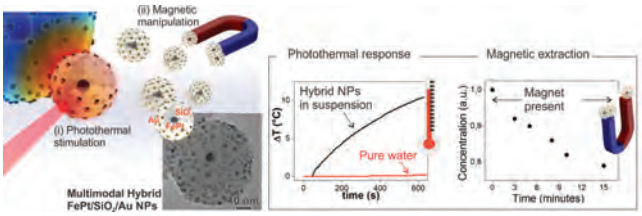

Figure 4: Multimodal hybrid NP functionalities for nanomedical applications by combining photothermal stimulation and manipulation with an external magnetic field.

Great attention has been paid to submicron TiO_2 particles added to food and food-contact materials. Within the project **ISOFood**, various techniques have been tested for the extraction of TiO_2 particles. As a model system, we selected chewing gums available on the Slovenian market. The extracted particles have been proved to be anatase, with a particle size below 200 nm. Similarly, nanoparticles were found in white, non-stick "ceramic" pans. The presence of anatase particles with a size of 100-200 nm and silica particles with a size below 50 nm were confirmed in the used pans.

Since submicron or even nanometric TiO_2 particles are increasingly present in food, many investigations are dealing with questions about the risks to health. However, as various techniques and powders are used in the studies, there is still no agreement about this. In order to shed more light on the importance of the mentioned variations, we performed a comprehensive study of five titania powders in aqueous suspensions. We confirmed that TiO_2 powders significantly differ among each other, not only in terms of particle size and crystal form, but also in surface charge, which affects dispersibility and hence, presumably, also bioavailability. Further investigations will be oriented towards an examination of the effect of TiO_2 nanoparticles on cells.

In the field of **photocatalysis** our research was focused on the degradation of water pollutants inside an in-house-developed photoelectrocatalytic microreactor. We have studied the influence of different operational parameters of the photoelectrocatalytic microreactor on the contaminants' mineralization rate. The most significant change in the pollutants' degradation rate was achieved by applying an external anodic potential to the anode of titania nanotubes. The applied potential significantly reduced the photogenerated electron-hole recombination rate and enabled the complete mineralization of phenol to water and carbon dioxide while consuming very low amounts of electrical energy.

In the field of **thermoelectrics** we studied the influence of niobium doping on the $Sr_3Ti_2O_7$ monocrystal formation and growth. Doped monocrystals were used as seeds in strontium titanate in order to improve its thermoelectric properties. By adding different amounts of niobium we concluded that most of the niobium incorporates on titanium sites in the $Sr_3Ti_2O_7$ crystal lattice. The remaining niobium forms various strontium titanium niobates. Based on our results we proposed a mechanism of titanium incorporation in $Sr_3(Ti,Nb)_2O_7$. We also studied the influence of SrO and CaO additions to $Sr(Ti_{0.8}Nb_{0.2})O_3$ on its thermoelectric properties. It was found that the addition of SrO and/or CaO resulted in the formation of a three-dimensional network of Ruddlesden-Popper-like planar faults along the {001} crystal planes, which lowered the thermal conductivity of the material. Consequently, the material exhibited an increased figure of merit ZT. In cooperation with the German Aerospace Center in Cologne, we tested a new method for the synthesis of thermoelectric strontium titanate: DSP (Direct current sinter press). The Seebeck coefficient, electrical conductivity and thermal conductivity were determined for all the synthesized samples.

In the field of oxide thermoelectric (TE) materials, we also studied the preparation of n-type $(ZnO)_kIn_2O_3$ ceramics using microwave sintering. In a much shorter time of about 1 hour, microwave sintering enabled the preparation of $(ZnO)_kIn_2O_3$ ceramics with TE characteristics similar to the case of classical sintering.

The influence of the synthesis conditions of the $Ca_3Co_4O_9$ p-type thermoelectric phase and different methods for the further processing of Ca349 ceramics (classical sintering, hot pressing, SPS, cold pressing) on the microstructure, morphology of the grains, density and texturing, and consequently their TE characteristics, were studied. The possibilities and limitations of the microstructure tailoring for an improvement in the TE characteristics of the Ca349 ceramics were determined. Ca349 ceramics with the highest ZT of 0.31 at 600 °C reported so far in the literature were successfully produced. Samples of thermoelectic microgenerators were successfully prepared by screen printing on alumina substrates from p-type $Ca_3Co_4O_9$ and n-type $(ZnO)_5In_2O_3$ thermoelectric materials. We were among the first to explore the possibilities and challenges of screen-printing technology in the preparation of TE oxide microgenerators.

Perovskite materials such as $BaTiO_3$ and Fe-$SrTiO_3$ nanostructures are suitable for many applications, such as humidity or oxygen sensing and tuneable HTS (high-temperature superconducting) microwave filters. The potential advantages of the nanostructured forms have been, however, scarcely explored compared to other oxides. The synthesis of perovskite nanostructures via sol-gel electrophoretic deposition (EPD) into anodic aluminium oxide (AAO) membranes has proven to be a very successful and useful method for processing one-dimensional metal oxides that are used for humidity and oxygen sensors.

The influence of WO_3 on the type of Bi_2O_3-rich phase at the grain boundaries and hence the electrical characteristics of ZnO-Bi_2O_3-based varistor ceramics was studied. It showed that the optimal addition of 0.4 mol.% of WO_3 significantly improves the current-voltage (I-U) characteristics of varistor ceramics sintered at 950 °C. The results are important for the preparation of varistor ceramics at a significantly lower sintering temperature than the typically used 1200 °C.

We developed a new type of ZnO-based varistor ceramic with a coefficient of nonlinearity as high as 40 without the addition of Bi_2O_3 as a standard dopant for I-U nonlinearity, which also results in the formation of a liquid phase at the sintering temperature and is highly volatile. Hence, the use of ZnO varistor ceramics doped with small amounts of oxides of Ca, Co and Cr can have an important advantage for the preparation of varistors in comparison to the use of classical varistor ceramics containing Bi_2O_3.

The development of ink with a high solids load of varistor powder of 70%, having the proper rheological properties for screen printing, enabled us to prepare thick-film varistors on alumina substrates with a dense and homogeneous microstructure, and excellent current-voltage (I-U) characteristics with a high coefficient of nonlinearity of 24, after firing for only 15 minutes at a low temperature of 900 °C. From zinc nitrate and sodium hydroxide solutions in a mixture of water and ethylene glycol we prepared, under hydrothermal conditions at 90 °C, ZnO nano-crystals that were functionalized by the chemical binding of ionic liquids. In this way we have prepared materials with a very good antimicrobial activity.

We have successfully completed a project for the VARSI company entitled “Current challenges in the development and manufacture of varistors”.

The second part of the investigation of the mechanism for the topotaxial transformation of ilmenite to rutile and hematite was finished during the past year. The first part of the investigation was studies of naturally oriented rutile/hematite intergrowths, while in the second part we tried to reproduce the transformation of an ilmenite single crystal to rutile and hematite during oxidation in air. Different conditions led to different crystallographic orientation relationships between the rutile and hematite in natural samples and ilmenite samples heated in air. The mechanism of transformation includes the initial oxidation of the Fe^{2+} in ilmenite to Fe^{3+} and its diffusion to the surface that triggers the exsolution of Ti ions within the parent ilmenite structure to form rutile lamellae. The kinetics of the diffusion controls the orientation relationships. However, when the diffusion is slow, the cations have enough time to adopt the energetically most favourable positions and to form a tetragonally deformed rutile structure. In the spinel-chrysoberyl system, we have synthesized ceramic samples of taaffeite, where we detected only one stable phase ($BeMg_3Al_8O_{16}$). Surface analysis of the pellet has indicated, besides taaffeite crystals, also complex spinel twin crystals, in the epitaxial growth of taaffeite crystals on a spinel octahedron. For all these situations, structural models were prepared. Mathematical simulations of high-resolution images and density-functional theory (DFT) to define a rigid model are in progress.

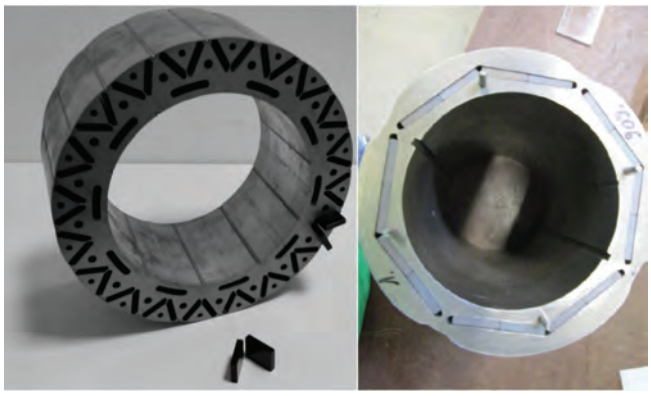

Figure 5: Magnets developed in the department for the ROMEO project inbuilt in the motor of the electric car in the company Valeo. The electric motor test showed 13 % better performance compared to the reference motor, while the torque was increased by 11 % at the ΔT of 95 K. Both parameters contribute to a higher efficiency.

We continued with the synthesis procedures for the enhanced growth of multiply twinned rutile-type TiO_2. For the production of highly branched rutile, we need the following hydrothermal conditions: high temperature, low precursor concentration or low reagent concentration. The final crystals are growing with the attachment of approximately 5-nm-thick rutile fibres (following the oriented attachment mechanism), aggregated more frequently along the {110} (growth) and, less frequently, along the {101} planes, causing the formation of {101} twins. With a TEM analysis we confirmed that branching is achieved by a second generation of twinning. A new area of research, which we opened in 2015, is the study of twinning in cassiterite (SnO_2) in the field of varistor ceramics. Based on microstructural studies of ZnO ceramics, where the grain growth was successfully controlled by the formation of inversion boundaries, we made an attempt to apply the same principle to SnO_2 ceramics. We developed homogenous SnO_2-based varistor ceramics doped with CoO and Nb_2O_5, where we measured a high non-linear coefficient (49.1), matching those of ZnO-based varistors. The highest non-linear coefficient was measured for SnO_2 ceramics, where

the observed density of the twin boundaries appears to be highest. With a TEM investigation we will further explain the role of twin boundaries in SnO_2 grains and their influence on the resulting electrical properties.

We have implemented advanced analytical methods for the characterization of innovative materials on the micrometre and sub-micrometre scales: high-resolution scanning electron microscopy (FEGSEM), qualitative and quantitative elemental electron-probe microanalysis (EPMA) with energy-dispersive and wavelength-dispersive X-ray spectroscopies (EDS, WDS) and electron backscatter diffraction (EBSD). The use of optimized methods made it possible to achieve reliable, precise and accurate analytical results, which are necessary to obtain the ultimate microstructural, microchemical and microcrystallographic characterizations of materials. We have investigated various materials: ceramic and metallic thin films, complex metallic alloys, magnetocalorics, magnetic materials, ferroelectric perovskites, nanorods and nanoparticles, and quasicrystalline alloys.

With the implementation of the EBSD method, we were able to get additional and very important information about the microcrystallographic properties of materials, i.e., the crystallinity, the crystallographic orientation of particular phases and the texture. In this way, using precise EBSD analyses, we have investigated complex Al-Mn-Cu alloys and have successfully directly verified the presence of two quasicrystalline phases in the material, i.e., icosahedral quasicrystals with a 5-fold symmetry and decagonal quasicrystals with a 10-fold symmetry.

We have collaborated with partners from industry and other research institutions by performing analyses on specific materials. The main collaborations were realized with SwatyComet Maribor, Energetika Ljubljana, UL-NTF Department of Materials and Metallurgy, Ljubljana, UL Faculty of Electrical Engineering, Ljubljana.

One of the important research areas of the group is the implementation of various **electron microscopy** analytical techniques within the existing EU project ESTEEM2, such as electron-energy-loss spectroscopy (EELS), high-resolution scanning transmission electron microscopy (STEM, HAADF-STEM), electron holography and mechanical preparation of the TEM samples. The implementation of various electron microscopy analytical techniques and the possibility for the researchers to access the research infrastructure for electron microscopy within the Center for Electron Microscopy and Microanalysis (CEMM) is of utmost importance for the research group.

Some outstanding publications in the past three years

1. Komelj, Matej, Krakauer, Henry. Electron-phonon coupling and exchange-correlation effects in superconducting H3S under high pressure. *Physical review. B, Condensed matter and materials physics*, ISSN 1098-0121, 2015, vol. 92, issue 20, str. 205125-1-205125-5, doi: 10.1103/PhysRevB.92.205125.
2. Kostevšek, Nina, Šturm, Sašo, Žužek Rožman, Kristina, et al. The one-step synthesis and surface functionalization of dumbbell-like gold-iron oxide nanoparticles : a chitosan-based nanotheranostic system. *Chemical communications*, ISSN 1359-7345, [in press] 2015, 4 str., doi: 10.1039/C5CC08275G.
3. Kovič, Andrej, Mrzel, Aleš, Ravnik, Jan, Šturm, Sašo, Vilfan, Mojca. Surface decoration of MoSI nanowires and MoS_2 multi-wall nanotubes and platinum nanoparticle encapsulation. *Materials letters*, ISSN 0167-577X, 2015, vol. 159, str. 333-336, doi: 10.1016/j.mat.let. 2015.07.021.
4. Lorenzetti, Martina, Dogša, Iztok, Stošicki, Tjaša, Stopar, David, Kalin, Mitjan, Kobe, Spomenka, Novak, Saša. The influence of surface modification on bacterial adhesion to titanium-based substrates. *ACS applied materials & interfaces*, ISSN 1944-8244. [Print ed.], 2015, vol. 7, str. 1644-1651, ilustr., doi: 10.1021/am507148n.
5. Rečnik, Aleksander, Stanković, Nadežda, Daneu, Nina. Topotaxial reactions during the genesis of oriented rutile/hematite intergrowths from Mwinilunga (Zambia). *Contributions to Mineralogy and Petrology*, ISSN 0010-7999, 2015, vol. 169, str. 1-22, doi: 10.1007/s00410-015-1107-x.

Organization of conferences, congresses and meetings

1. Opening of "The international associated laboratory Push-Pull AlloyS And Complex CompoundS ($PACS_2$): from bulk properties to surface functions" (LIA $PACS_2$), Ljubljana, 6–9 January 2015
2. Project Meeting, ESTEEM2: Enabling Science and Technology through European Electron Microscopy, Ljubljana, 23–24 February 2015
3. EMAS 2015 - 14th European Workshop on Modern Developments and Applications in Microbeam Analysis, Portorož, 3–7 May 2015
4. Eurofusion: WPMAT-HHFM Project Monitoring Meeting, Ljubljana, 2–3 June 2015
5. Y1 Annual meeting of LIA $PACS_2$: "The international associated laboratory Push-Pull AlloyS And Complex CompoundS ($PACS_2$): from bulk properties to surface functions", Ljubljana, 17–18 December 2015
6. Final project meeting, ROMEO: Replacement and Original Magnet Engineering Options, Ljubljana, 26–27 November 2015
7. 1st Slovenian Meeting of Microscopists, Piran, 18–19 May 2015 (co-organisation)

8. 23rd International Conference on Materials and Technologies, 27–30 September, Portorož (co-organisation)
9. MCM2015, Multinational Congress on Microscopy, Eger, Hungary, 23–28 August 2015 (members of the International Advisory Board)
10. C-MAC Euroschool, Bratislava, Slovakia, 31 May – 5 June 2015 (members of Science Board and General Assembly in European Integrated Center for the Development of New Metallic Alloys and Compounds (C-MAC))

Awards and appointments

1. Martina Lorenzetti, European Doctoral Award 2015, European Society for Biomaterials, 2 September 2015
2. Vanja Jordan, "Hydrothermal synthesis of highly branched rutile-type TiO_2" (co-authors, Goran Dražić, Aleksander Rečnik). Best Young Lecturer Award, 12th Multinational Congress on Microscopy 2015, Eger, Hungary, 23-28 August 2015
3. Rok Kocen, "Viscoelastic properties of hydrogel - 'ceramic' composites for tissue-engineering scaffolds" (co-authors: Ana Gantar, Saša Novak, Christian Hellmich, Michael Gasik). Award for the Best Scientific Work, Bulgarian Society of Biorheology, 4 September 2015, presented at the 5th Euro Summer School on Biorheology, Varna, Bulgaria, 1–5 September 2015
4. Rok Kocen, "Measuring viscoelasticity of hydrogel-BAG composites" (co-authors, Ana Gantar, Saša Novak, Christian Hellmich, Michael Gasik). Best Oral Presentation Award, 23rd International Conference on Materials and Technology, Portorož, 28–30 September 2015

INTERNATIONAL PROJECTS

1. Selective Laser Melting (SLM) and Spark Plasma Sintering (SPS) of Cost Effective Rare-earth based Permanent Magnets for Electrical Machines
   Prof. Spomenka Kobe
   ABB Switzerland Ltd
2. 7FP - ESTEEM 2; Enabling Science and Technology through European Electron Microscopy
   Prof. Miran Čeh
   European Commission
3. 7FP - NANOPYME; Nanocrystalline Permanent Magnets Based on Hybrid Metal-Ferrites
   Asst. Prof. Kristina Žužek Rožman
   European Commission
4. 7FP - ROMEO, Replacement and Original Magnet Engineering Options
   Prof. Spomenka Kobe
   European Commission
5. 7FP - MAG-DRIVE; New Permanent Magnets for Electric-Vehicle Drive Application
   Asst. Prof. Matej Andrej Komelj
   European Commission
6. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Prof. Saša Novak Krmpotič
   European Commission
7. MODEF - Creazione e sperimentazione congiunta di modelli per l"ottimizzazione dell"utilizzo di energia fotovoltaica
   Dr. Zoran Samardžija
   Unindustria Rovigo
8. COST ES1205; The Transfer of Engineered Nanomaterials from Wastewater Treatment & Stormwater to Rivers
   Prof. Saša Novak Krmpotič
   Cost Office
9. COST MP1005, NAMABIO; From Nano to Macro Biomaterials (Design, Processing, Characterization, Modelling) and Applications to Stem Cells Regenerative Orthopedic and Dental Medicine
   Prof. Saša Novak Krmpotič
   Cost Office
10. COST MP1301 NEWGEN; New Generation Biomimetic and Customized Implants for Bone Engineering
    Prof. Saša Novak Krmpotič
    Cost Office
11. H2020 - REProMag; Resource Efficient Production Route for Rare Earth Magnets
    Dr. Benjamin Podmiljšak
    European Commission
12. H2020 - DEMETER; Training Network for the Design and Recycling of Rare-Earth Permanent Magnet Motors and Generators in Hybrid and Full Electric Vehicles
    Asst. Prof. Kristina Žužek Rožman
    European Commission
13. Materials-PPPT-FU: WC and SiC Reinforced Tungsten
    Prof. Saša Novak Krmpotič
    EURATOM
14. Eurofusion Education-ED-FU
    Prof. Saša Novak Krmpotič
    EURATOM
15. Characterisation of Growth Features and Planar Defects in Crystals Grown Under Hydrothermal Conditions
    Asst. Prof. Nina Daneu
    Slovenian Research Agency
16. Biomimetic Characterisation of Bioactive Composit Scaffolds for Bone and Osteochondral Tissue Repair
    Prof. Saša Novak Krmpotič
    Slovenian Research Agency
17. Development of Oxide Thermoelectric Materials for Waste-heat Recovery into Electricity
    Prof. Slavko Bernik
    Slovenian Research Agency
18. Electron Microscopy Study of the Degradation Kinetics of Porous Bioactive Glass based Novel Drug Eluting Implants (Coating/3D Scaffolds) as a Function of Hard Tissue Regeneration for Treatment of Osteoporotic Fractures in Elderly Patients
    Asst. Prof. Nina Daneu
    Slovenian Research Agency
19. Nucleation and Photocatalytic Activity of Nanoparticles Studied in Actual Liquid Environment under Transmission Electron Microscope
    Prof. Sašo Šturm
    Slovenian Research Agency
20. Atomic-scale Studies of Topotaxial Reactions in Minerals with the Rutile and Corundum-type Structures
    Asst. Prof. Nina Daneu
    Slovenian Research Agency
21. Structural and Microstructural Engineering of ZnO Thermoelectrics (SMEZ)
    Prof. Slavko Bernik
    Slovenian Research Agency
22. The Study of Strain in Nonstoichiometric Perovskites by Applying X-Ray Powder Diffraction Methods, Dilatometry and Advanced Techniques of Electron Microscopy
    Prof. Sašo Šturm
    Slovenian Research Agency
23. Advanced Methods and Technologies for Processing of a New Generation of ZnO-based Varistor Ceramics
    Prof. Slavko Bernik
    Chinese Academy Of Sciences
24. Irradiation and Analysis of Nano SiC Samples
    Dr. Aljaž Iveković
    National Nuclear Research Center

RESEARCH PROGRAMS

1. Nanostructured Materials
   Prof. Spomenka Kobe
2. Engineering and Bio-ceramics
   Asst. Prof. Andraž Kocjan

R & D GRANTS AND CONTRACTS

1. Structure and Chemical Composition Study of Surfaces and Interfaces with Highresolution Scanning Transmission Electron Microscopy at Atomic Level
   Prof. Aleksander Rečnik
2. Atomic-scale studies of initial stages of phase transformations in minerals
   Asst. Prof. Nina Daneu
3. Bio-responsive magneto-optically coupled nanomaterial-based systems for innovative skin cancer treatments
   Prof. Sašo Šturm
4. Tridimensional bioactive glass and biopolymer composite scaffolds for treatment of osteochondral defects developed due to the articular cartilage lesions
   Dr. Nataša Drnovšek
   Ministry of Education, Science and Sport of the Republic of Slovenia

NEW CONTRACTS

1. The study of self-cleaning and abrasion resisting properties of carbon-, para-aramid- or glass-fibre-based composite materials by applying photocatalytic and/or mechanical resistant nanoparticles
   Prof. Sašo Šturm
   Cdt Group d. o. o.
2. Multipole magnetisation of NdFeB bonded magnets for rotor application
   Prof. Spomenka Kobe
   Kolektor Kfh d. o. o.
3. Current challenges in developing and producing varistors
   Prof. Slavko Bernik
   RCeNem Novi materiali

VISITORS FROM ABROAD

1. Tian Tian, Chinese Academy of Science – SICCAS, Shanghai, China, 23 July – 18 November 2015
2. Prof. Jean-Marie Dubois, Institut Jean Lamour, Nancy, France, 6–16 January 2015
3. Prof. Jean-Francois Tassin, Dr. Pascal Breuilles, Dr. Francesca Grassia, Centre national de la recherche scientifique, Paris, France, 7–9 January 2015
4. Dr. Julian Ledieu, Dr. Vincent Fournée, Dr. Pascal Boulet, Institut Jean Lamour, Nancy, France, 7–9 January 2015
5. Dr. Goran Branković, Marina Vuković and Sanja Pršić, Institute for Multidisciplinary Research, Belgrade, Serbia, 19–26 January 2015
6. Dr. Milivoj Plodinec, Institut Rudjer Bošković, Zagreb, Croatia, 23–27 February 2015
7. Prof. Jean-Marie Dubois, Institut Jean Lamour, Nancy, France, 14–19 February, 22–26 March, 26 April – 2 May 2015, 1–4 June 2015
8. Dr. Emmanuel Guilmeau and Dr. Etienne Savary, Universite de Caen, Laboratoire de Cristallographie er Sciences des Materiaux, CRISMAT, Caen, France, 22–24 April 2015
9. Dr. Andreja Gajović and Dr. Milivoj Plodinec, Institut Rudjer Bošković, Zagreb, Croatia, 25–27 May 2015
10. Dr. Michael Rieth, Dr. Eberhard Diegele, Dr. Steffen Antusch, Dr. Ermile Gaganidze, Dr. Wolfgang Krauss, Karlsruher Institut für Technologie (KIT), Karlsruhe, Germany, Dr. Freimut Koch, Alexander von Müller, Dipl. Ing., Dr. Johann Riesch, Dr. Hans Maier, Max-Planck-Institut für Plasmaphysik, Garching, Germany, Dr. Carmen García-Rosales, CEIT Centro de Estudios e Investigaciones Técnicas de Gipuzkoa, Gipuzkoa, Spain, Dr. Gerald Pintsuk, Dr. Andrey Litnovsky, Dr. Marius Wirtz, Dr. Jan Willem Coenen, Forschungszentrum Jülich, Jülich, Germany, Dr. Andrei Galatanu, National Institute of Materials Physics, Ilfov, Romania, M.Sc. Vladica Nikolić, Eirch-Schmid – Institut für Materialwissenschaft der Österreichischen Akademie der Wissenschaften, Leoben, Austria, Dr. Marianne Richou, CEA-DSM-IRFM, Service Intégration Plasma-Paroi, SIPP, Cadarache, France, Dr. Marta Dias, Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, Lisbona, Portugal, Prof. Sergei Dudarev, Culham Centre for Fusion Energy, Abingdon, United Kingdom, Prof. María Sánchez Martínez, DCIM - Grupo de Ciencia e Ingeniería de Materiales, Universidad Rey Juan Carlos, Madrid, Spain, Dr. Roberto Coppola, ENEA-Casaccia, FISNUC, Rome, Italy
11. Prof. Guorong Li, Prof. Haosu Luo, Dr. Liaoying Zheng, Shanghai Institute of Ceramics, Chinese Academy of Science - SICCAS, Shanghai, China, and Prof. Jinrong Cheng, University Shanghai, China, 24–31 July 2015
12. Dr. Masahiro Kawasaki, JEOL USA, Inc., Peabody, Massachusetts, USA, 29 June – 9 July 2015
13. Prof. Yilmaz Ozmen, Pamukkale University, Technology Faculty, Biomedical Engineering Dept., Denizli, Turkey, 2 June 2015
14. Dr. Andrea Čobić, Faculty of Science, University of Zagreb, Zagreb, Croatia, 15 June – 30 September 2015
15. Prof. George S. Dulikravich, MAIDROC Laboratory, Department of Mechanical and Materials Engineering, Florida International University, Miami, Florida, USA, 19 June 2015
16. Dr. Goran Branković, Dr. Zorica Branković, Institute for Multidisciplinary Research, Belgrade, Serbia; Prof. Jose Michel Haddad, UNIARA - Centro Universitario de Araraquara, Araraquare, Brazil, 5–9 August 2015
17. Dr. Goran Branković, Marina Vuković in Sanja Pršić, Institute for Multidisciplinary Research, Belgrade, Serbia, 11–18 August 2015
18. Benjamin Pages and Emmanuelle De Clermont Gallerande, Ecole des Mines de Nancy, Nancy, France, 1–31 August 2015
19. Dr. Milivoj Plodinec, Lara Štajner and Iva Buljan, Institut Rudjer Bošković, Zagreb, Croatia, 4–6 August 2015
20. Dr. Yuki Kimura, Dr. Jun Kawano and Dr. Tomoa Yamazaki, Hokkaido University, Sapporo, Shinnosuke Ishizuka, Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan, 29 September – 4 October 2015
21. Dr. Ivna Kavre Piltaver, Department of Physics, University of Rijeka, Croatia, 7 September – 23 October 2015
22. Dr. Pavel Gavryushkin and Dr. Victor Gabrielevich Thomas, Sobolev Institute of Geology and Mineralogy SB, RAS, Novosibirsk, Russia, 31 October – 14 November 2015
23. Dr. Chuck Henager, Nuclear Science Division, Pacific Northwest National Laboratory, Richland, WA, USA, 18–20 October 2015
24. Kaya Aysen, Institute of Natural and Applied Sciences, Hatay, Turkey, 1 October 2015 – 30 June 2016
25. Sayatan Ray, Central Glass & Ceramic Research Institute, Kolkata, India, 8–28 December 2015
26. Dr. Bojana Obradović and Jovana Zvicer, Tehniško metalurški fakultet, University of Belgrade, Belgrade, Serbia, 11–18 November 2015
27. Dr. Nora Dempsey, Anja Backen, Institut Néel, Grenoble, France, Prof. Gutfleisch Oliver and Christoph Schwöbel, Dipl. Eng., Technische Universität Darmstadt, Darmstadt, Germany, Prof. Josef Fidler, M.Sc. Peter Toson, M.Sc. Gregor Zickler, Ahmad Asali, Technische Universität Wien, Vienna, Austria, Ing. Florian Bittner, Torsten Mix, Leibniz-Institut für Festkörper- und Werkstofforschung, Dresden, Germany, Dr. Jean Marc Dubus, VALEO equipements electriques moteur, Creteil, France, Prof. Thomas Schrefl, M.Sc. Alexander Kovacs, Fachhochschule St. Pölten - FHSTP, St. Pölten, Austria, M.Sc. Pelin Tozman, Dr. Munuswamy Venkatesan, Trinity College Dublin, Ireland, Ing. Hristian Naumoski, Daimler, Stuttgart, Germany, Annemarie Gemperli and Dr. Jürgen Höck, TEMAS AG, Arbon, Switzerland, Dr. Matthias Katter, Ing. Kaan Üstüner, Vacuumschmelze GmbH & Co. KG, Hanau, Germany, Dr. Du Van Ann and Dr. Michael Krispin, Siemens AG, Erlangen, Germany, Dr. Boris Saje, Kolektor, Idrija, 26–27 November 2015
28. Prof. Michael Coey, Trinity College, Dublin, Ireland, 25 November – 2 December 2015
29. Prof. Cleva Ow Yang, Sabancı University, Nanotechnology Research and Application Center, Istanbul, Turkey, 9–13 December 2015
30. Prof. Ludwig Schulz, Leibniz-Institut für Festkörper- und Werkstofforschung, Dresden, Germany, 16–18 December 2015
31. Prof. Jean-Marie Dubois, Dr. Julien Zollinger, Dr. Pascal Boulet, Dr. Marie-Cécile de Weerd, Dr. Julian Ledieu and Dr. Alain Hazotte, Institut Jean Lamour, Nancy, France, Prof. Boštjan Markoli and Dr. Iztok Naglič, Faculty for Natural Sciences, University of Ljubljana, Dr. Blaž Likozar, National Institute of Chemistry, Ljubljana, 17–18 December 2015
32. Dr. Andreja Gajovič, Institut Rudjer Bošković, Zagreb, Croatia, 14–18 December 2015

STAFF

Researchers

1. Prof. Slavko Bernik
2. Prof. Miran Čeh
3. Asst. Prof. Nina Daneu
4. Prof. Jean Marie Dubois
5. **Prof. Spomenka Kobe, Head**
6. Asst. Prof. Matej Andrej Komelj
7. *Asst. Prof. Paul John McGuiness, left 01.03.15*
8. Prof. Saša Novak Krmpotič
9. Dr. Benjamin Podmiljšak
10. Prof. Aleksander Rečnik
11. Dr. Zoran Samardžija
12. Prof. Sašo Šturm
13. Dr. Kristina Žagar Soderžnik
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15. Dr. Nataša Drnovšek
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17. Dr. Petra Jenuš
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20. Dr. Matejka Podlogar
21. Dr. Marko Soderžnik

Postgraduates

22. Anže Abram, B. Sc.
23. Bojan Ambrožič, B. Sc.

24. Muhammad Shahid Arshad, B. Sc.
25. Sandra Drev, B. Sc.
26. Ana Gantar, B. Sc.
27. Marja Jerič, B. Sc.
28. Vanja Jordan, B. Sc.
29. Luka Kelhar, B. Sc.
30. Rok Kocen, B. Sc.
31. Nina Kostevšek, B. Sc.
32. Mateja Košir, B. Sc.
33. Mojca Presečnik, B. Sc.
34. *Rok Rudež, B. Sc., left 01.09.15*
35. *Nadežda Stanković, B. Sc., left 01.11.15*
36. Luka Suhadolnik, B. Sc.
37. Sara Tominc, B. Sc.
38. Tomaž Tomše, B. Sc.
39. Špela Trafela, B. Sc.

Technical officers

40. Dr. Jana Ferčič
41. *Medeja Gec, B. Sc., retired 31.12.15*
42. *Špela Klemenčič, B. Sc., left 09.01.15*
43. Martin Topole, B. Sc.
44. Sanja Fidler, B. Sc.

BIBLIOGRAPHY

Original Article

1. Marjeta Čepin, Vasko Jovanovski, Matejka Podlogar, Zorica Crnjak Orel, "Amino- and ionic liquid-functionalised nanocrystalline ZnO via silane anchoring - an antimicrobial synergy", *J. mater. chem. B*, vol. 3, iss. 6, pp. 1059-1067, Feb. 2015.
2. Matej Dolenec, Todor Serafimovski, Nina Daneu, Tadej Dolenec, Nastja Rogan Šmuc, Petra Vrhovnik, Sonja Lojen, "The case of the carbonatite-like dyke of the Madenska River complex at the Kriva Lakavica section in the Republic of Macedonia: oxygen and carbon isotopic constraints", *Turk. j. eart. sci.*, vol. 24, no. 6, pp. 627-639, 2015.
3. Sandra Drev, Matej Komelj, Matjaž Mazaj, Nina Daneu, Aleksander Rečnik, "Structural investigation of (130) twins and rutile precipitates in chrysoberyl crystals from Rio das Pratinhas in Bahia (Brazil)", *Am. mineral.*, vol. 100, no. 4, pp. 861-871, 2015.
4. Nataša Drnovšek, Urška Dragin Jerman, Rok Romih, Miran Čeh, Matevž Gorenšek, Jozef Vleugels, Saša Novak, "Improvement of osseointegration of Ti and Ti-alloys by hydrothermally prepared bioactive anatase coating", *Int. j. nano biomater.*, vol. 6, no. 1, pp. 18-28, 2015.
5. Matjaž Godec, Tatjana Večko Pirtovšek, Barbara Šetina, Paul J. McGuiness, Jaka Burja, Bojan Podgornik, "Surface and bulk carbide transformations in high-speed steel", *Scientific reports*, vol. 5, pp. 1-11, Nov. 2015.
6. Aljaž Iveković, Andrei Galatanu, Saša Novak, "Low-activation W-Si-C composites for fusion application", *Fusion eng. des.*, vol. 100, pp. 638-645, 2015.
7. Aljaž Iveković, Saša Novak, "Electrophoretic (infiltration) deposition of thick conductive fiber preforms", *J. Electrochem. Soc.*, vol. 162, no. 11, pp. D3049-D3056, 2015.
8. Aljaž Iveković, Saša Novak, Marko Lukek, Mitjan Kalin, "Aqueous electrophoretic deposition of bulk polyether ether ketone (PEEK)", *J. mater. process. technol.*, vol. 223, pp. 58-64, 2015.
9. Matej Komelj, "Influence of strain on the properties of CeRuPO and CeOsPO Kondo systems: letter to the editor", *J. magn. magn. mater.*, vol. 393, pp. 175-178, 2015.
10. Matej Komelj, Henry Krakauer, "Electron-phonon coupling and exchange-correlation effects in superconducting H_3S under high pressure", *Phys. rev., B, Condens. matter mater. phys.*, vol. 92, issue 20, pp. 205125-1-205125-5, 2015.
11. Nina Kostevšek, Sašo Šturm, Igor Serša, Ana Sepe, Maarten Bloemen, Thierry Verbiest, Spomenka Kobe, Kristina Žužek Rožman, ""Single- and "multi-core" FePt nanoparticles: from controlled synthesis via zwitterionic and silica biofunctionalization to MRI applications", *J. nanopart. res.*, vol. 17, no. 12, pp. 464-1-464-15, 2015.
12. Nina Kostevšek, Kristina Žužek Rožman, Muhammad Shahid Arshad, Matjaž Spreitzer, Spomenka Kobe, Sašo Šturm, "Multimodal hybrid $FePt/SiO_2$/Au nanoparticles for nanomedical applications ecombining photothermal stimulation and manipulation with an external magnetic field", *The journal of physical chemistry. C, Nanomaterials and interfaces*, vol. 119, issue 28, pp. 16374-16382, 2015.
13. Andrej Kovič, Aleš Mrzel, Jan Ravnik, Sašo Šturm, Mojca Vilfan, "Surface decoration of MoSI nanowires and MoS_2 multi-wall nanotubes and platinum nanoparticle encapsulation", *Mater. lett.*, vol. 159, pp. 333-336, 2015.
14. Matic Krivec, Gerald Mc Gunnigle, Anže Abram, Dieter Maier, Roland Waldner, Johanna M. Gostner, Florian Űberall, Raimund Leitner, "Quantitative ethylene measurements with MO_x chemiresistive sensors at different relative air humidities", *Sensors*, vol. 15, no. 11, pp. 28088-28098, 2015.
15. Mukta Vishwanath Kulkarni, Yogita Patil-Sen, Ita Junkar, Chandrashekhar Kulkarni, Martina Lorenzetti, Aleš Iglič, "Wettability studies of topologically distinct titanium surfaces", *Colloids surf., B Biointerfaces*, vol. 129, pp. 47-53, May 2015.
16. Z. Ž. Lazarević, Čedomir Jovalekić, A. Milutinović, Nina Daneu, Maja J. Romčević, Đorđe Jovanović, Nebojša Romčević, "Spectroscopy investigation of nanostructured nickel-zinc ferrite obtained by mechanochemical synthesis", *Optoelectron. Adv. Mater. Rapid Commun.*, vol. 9, no. 1/2, pp. 102-106, 2015.
17. Zorica Lazarević, Aleksandra Milutinović Živin, Čedomir Jovalekić, Valentin Ivanovski, Nina Daneu, Ivan Mađarević, Nebojša Romčević, "Spectroscopy investigation of nanostructured nickel-zinc ferrite obtained by mechanochemical synthesis", *Mater. res. bull.*, vol. 63, pp. 239-247, 2015.
18. Martina Lorenzetti, Giulia Bernardini, Thomas Luxbacher, Annalisa Santucci, Spomenka Kobe, Saša Novak, "Surface properties of nanocrystalline TiO_2 coatings in relation to the in vitro plasma protein adsorption", *Biomedical materials*, vol. 10, pp. 045012-1-045012-11, 2015.
19. Martina Lorenzetti, Olga Dakischew, Katja Trinkaus, Katrin Susanne Lips, Reinhard Schnettler, Spomenka Kobe, Saša Novak, "Enhanced osteogenesis on titanium implants by UVB photofunctionalization of hydrothermally grown TiO_2 coatings", *J. biomater. appl.*, vol. 30, no. 1, pp. 71-84, 2015.
20. Martina Lorenzetti, Iztok Dogša, Tjaša Stošicki, David Stopar, Mitjan Kalin, Spomenka Kobe, Saša Novak, "The influence of surface modification on bacterial adhesion to titanium-based substrates", *ACS appl. mater. interfaces*, vol. 7, pp. 1644-1651, 2015.
21. Paul J. McGuiness *et al.* (24 authors), "Replacement and Original Magnet Engineering Options (ROMEOs): a European seventh framework project to develop advanced permanent magnets without, or with reduced use of, critical raw materials", *JOM (1989)*, vol. 67, issue 6, pp. 1306-1317, 2015.
22. Darja Pečko, Nina Kostevšek, Boris Pihlar, Zoran Samardžija, Spomenka Kobe, Kristina Žužek Rožman, "Electrochemical studies of Fe and Pd deposition and their influence on the co-deposition of the Fe-Pd alloy", *Journal of electroanalytical chemistry*, vol. 738, pp. 51-60, 2015.
23. Darja Pečko, Sašo Šturm, Spomenka Kobe, Kristina Žužek Rožman, "Potentiostatically electrodeposited hard-magnetic Fe-Pd-based nanowires", *IEEE trans. magn.*, vol. 51, no. 7, pp. 9600204 -1-9600204-4, 2015.
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25. Benjamin Podmiljšak, Paul J. McGuiness, Spomenka Kobe, "Complex metallic alloys for applications in magnetic refrigeration", *Recent patents on materials science*, vol. 8, no. 2, pp. 129-154, 2015.
26. Aleksander Rečnik, Nadežda Stanković, Nina Daneu, "Topotaxial reactions during the genesis of oriented rutile/hematite intergrowths

from Mwinilunga (Zambia)", *Contrib. Mineral. Petrol.*, vol. 169, pp. 1-22, 2015.
27. Rok Rudež, Piotr Markowski, Mojca Presečnik, Mateja Košir, Andrzej Dziedzic, Slavko Bernik, "Development of thick-film thermoelectric microgenerators based on *p*-type $Ca_3Co_4O_9$ and *n*-type $(ZnO)_5In_2O_3$ legs", *Ceram. int.*, vol. 41, iss. 10, part A, pp. 13201-13209, 2015.
28. Rok Rudež, Jernej Pavlič, Slavko Bernik, "Preparation and influence of highly concentrated screen-printing inks on the development and characteristics of thick-film varistors", *J. Eur. Ceram. Soc.*, vol. 35, no. 11, pp. 3013-2023, 2015.
29. Zoran Samardžija, "Quantitative microanalysis of $(1-x)Pb(Mg_{1/3}Nb_{2/3})O_3xxPbTiO_3$ (PMNT) ferroelectric ceramics", *Microsc. microanal.*, vol. 21, iss. 5, pp. 1138-1144, 2015.
30. Michail Samouhos, Janez Zavašnik, Aleksander Rečnik, Anthanasios Godelitsas, Elias Chatzitheodoridis, Yiannis Sanakis, "Spectroscopic and nanoscale characterization of blue-coloured smithsonite ($ZnCO_3$) from Lavrion historical mines (Greece)", *Period. mineral. (Testo stamp.)*, vol. 84, no. 2, pp. 373-388, 2015.
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32. Marian Stingaciu, Martin Topole, Paul J. McGuiness, Mogens Christensen, "Magnetic properties of ball-milled $SrFe_{12}O_{19}$ particles consolidated by Spark-Plasma Sintering", *Scientific reports*, 5, pp. 1-8, 2015.
33. Xiangkai Xiao, Liaoying Zheng, Lihong Cheng, Tian Tian, Xuezheng Ruan, Matejka Podlogar, Slavko Bernik, Guorong Li, "Influence of WO_3-doping on the microstructure and electrical properties of ZnO – $Bi2O_3$ varistor ceramics sintered at 950°C", *J. Am. Ceram. Soc.*, vol. 98, issue 4, pp. 1356-1363, 2015.
34. Maša Zalaznik, Saša Novak, Miroslav Huskić, Mitjan Kalin, "Tribological behaviour of a PEEK polymer containing solid MoS2 lubricants", *Lubr. sci.*, pp. [1-16], 2015.
35. Andrej Zorko, Jure Kokalj, Matej Komelj, Othon Adamopoulos, H. Luetkens, Denis Arčon, Alexandros Lappas, "Magnetic inhomogeneity on a triangular lattice: the magnetic-exchange versus the elastic energy and the role of disorder", *Scientific reports*, vol. 5, pp. 9272-1- 9272-8, 2015.

Published Conference Contribution (invited lecture)

1. Zoran Samardžija, "Electron probe microanalysis of dopant concentrations in complex perovskite ferroelectrics", In: *Book of tutorials and abstracts*, EMAS 2015, 14th European Workshop on Modern Developments and Applications in Microbeam Analysis, Portorož, Slovenia, 3 to 7 May 2015, Antwerpen, EMAS, 2015, pp. 201-213.
2. Sašo Šturm, Elena Tchernychova, Cleva Ow-Yang, Guliz Inan, Marja Jerič, Miran Čeh, "Applications of scanning transmission electron microscopy (STEM)", In: *Book of tutorials and abstracts*, EMAS 2015, 14th European Workshop on Modern Developments and Applications in Microbeam Analysis, Portorož, Slovenia, 3 to 7 May 2015, Antwerpen, EMAS, 2015, pp. 177-186.
3. Sašo Šturm, Kristina Žužek Rožman, Boštjan Markoli, Evangelia Sarantopoulou, Zoe Kollia, Alciviadis-Constantinos Cefalas, Spomenka Kobe, "Physical-metallurgical aspect of formation of core-shell and hollow nanospheres", In: *Proceedings and Book of Abstracts*, Marija Korać, ed., Belgrade, Association of Metallurgical Engineers of Serbia (AMES), 2015, pp. 37- 47.

Published Conference Contribution

1. Muhammad Shahid Arshad, Darja Pečko, Janez Zavašnik, Sašo Šturm, Spomenka Kobe, Kristina Žužek Rožman, et al., "Cobalt-platinum alloy nanostructures as potential candidates for racetrack magnetic data storage devices", In: *Zbornik: 2. del: part 2*, 7. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 7th Jožef Stefan International Postgraduate School Students' Conference, 20.-22. 5. 2015, Ljubljana, Andraž Rešetič, ed., et al, Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2015, zv. 1, pp. 270-277.
2. Slavko Bernik, Matejka Podlogar, Nina Daneu, "Development of low-voltage varistor ceramics doped with pre-reacted Bi_2O_3 – TiO_2 phases for different TiO_2 to Bi_2O_3ratios", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 203-208.
3. Petar Djinović, Tomaž Tomše, Jelka Grdadolnik, Špela Božič, Boštjan Erjavec, Maxim Zabilsky, Albin Pintar, "Natural aluminosilicates for catalytic depolymerization of polyethylene", In: *Conference proceedings*, European Meeting on Chemical Industry and Environment, Tarragona, Spain, 10-12 June 2015, Christophe Bengoa, ed., Tarragona, [s. n.], 2015, pp. 395-396.
4. Petar Djinović, Tomaž Tomše, Jelka Grdadolnik, Špela Božič, Boštjan Erjavec, Maxim Zabilsky, Albin Pintar, "Natural aluminosilicates for catalytic depolymerization of polyethylene to produce liquid fuel-grade hydrocarbons and low olefins", In: *Selected contributions in the field of heterogeneous catalysis and photocatalysis that were presented at the 8th International Conference on Environmental Catalysis (ICEC 2014), [24-27 August 2014 at Asheville, NC,USA]*, (Catalysis today, Vol. 258, pt. 2, (Dec. 2015)), Amsterdam [etc.], Elsevier, 2015, vol. 258, pt. 2, pp. 648-659, Dec. 2015.
5. Viviana Golja *et al.* (15 authors), "Matrix degradation as a mechanism for nanoparticles release from food contact materials", In: *Zbornik: 2. del: part 2*, 7. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 7th Jožef Stefan International Postgraduate School Students' Conference, 20.-22. 5. 2015, Ljubljana, Andraž Rešetič, ed., et al, Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2015, zv. 1, pp. 198-206.
6. Mitjan Kalin, Maša Zalaznik, Saša Novak, "Wear and friction behaviour of poly-ether-ether-ketone (PEEK) filled with graphene, WS_2 and CNT nanoparticles", In: *20th Intenational Conference on Wear Materials*, (Wear, Vol. 330/331), [Amsterdam], Elsevier, 2015, vol. 330/331, pp. 855-862, May-Jun. 2015.
7. Lidija Korat, Vesna Zalar Serjun, Mateja Štefančič, Nina Daneu, Ana Mladenovič, "Characterization of the reaction products formed at the grain/binder interface during the hydration of supplementary cementitious materials", In: *Razprave, poročila*, (Geološki zbornik, 23), 22. posvetovanje slovenskih geologov = 22nd Meeting of Slovenian Geologists, Ljubljana, november 2015, Boštjan Rožič, ed., Ljubljana, Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za geologijo, 2015, pp. 86-92.
8. Nina Kostevšek *et al.* (15 authors), "Controlling the composition of electrodeposited Fe-Pd nanowires and thin films via determination of the diffusion and electrode kinetic parameters", In: *Zbornik: 2. del: part 2*, 7. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 7th Jožef Stefan International Postgraduate School Students' Conference, 20.-22. 5. 2015, Ljubljana, Andraž Rešetič, ed., et al, Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2015, zv. 1, pp. 207-217.
9. Martina Lorenzetti, Thomas Luxbacher, Spomenka Kobe, Saša Novak, "Electrokinetic behaviour of porous TiO_2-coated implants", In: *Special issue of the 26th Annual Conference of European Society for Biomaterials, 31st August - 3rd September 2014, Liverpool*, (Journal of materials science., Materials in medicine, vol. 26, no. 6, 2015), London, Chapman and Hall, 2015, vol. 26, pp. 191-1-191-4, maj 2015.
10. Iztok Naglič, Kemal Delijić, Zoran Samardžija, F. Bikić, Blaž Leskovar, Boštjan Markoli, "Microstructure and mechanical properties of Al-alloys with quasicrystals", In: *Proceedings and Book of Abstracts*, Marija Korać, ed., Belgrade, Association of Metallurgical Engineers of Serbia (AMES), 2015, pp. 67- 71.
11. Milivoj Plodinec, Andreja Gajović, Ana Šantić, Janez Zavašnik, Miran Čeh, "Increased photoconductivity in $Ba TiO_3/TiO_2$ composites", In: *Proceedings*, 3rd Croatian Congress on Microscopy with international participation, April 26-29, Zadar, Croatia, [Zagreb], Ruđer Bošković Institution, Croatian Miroscopy Society, 2015, pp. 67-68.
12. Matejka Podlogar, Marjeta Maček, Aleksander Rečnik, Slavko Bernik, "Morphology of ZnO crystals prepared from $Zn(OH)_2$ and $Zn_5(OH)_8(NO_3)_2(H_2O)_2$ phases", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 209-214.
13. Mojca Presečnik, Aleksander Rečnik, Goran Dražić, Slavko Bernik, "Preliminary study of the stability of thermoelectric $Ca_3Co_4O_9$-based ceramics", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander

Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 215-220.
14. Kristina Žagar, Francisco Hernandez-Ramirez, Miran Čeh, "Okolju prijazne tehnološke aplikacije na osnovi TiO_2", In: *Delavnica Pametna mesta in skupnosti kot razvojna priložnost Slovenije: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 12. oktober 2015, [Ljubljana, Slovenia]: zvezek H: proceedings of the 18th International Multiconference Information Society - IS 2015, October 12th, 2015, Ljubljana, Slovenia: volume H*, Mihael Mohorčič, ed., Ana Robnik, ed., Dalibor Baškovč, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 32-33.

Patent Application

1. Luka Kelhar, Paul J. McGuiness, Spomenka Kobe, *Metal-bonded RE-Fe-B magnets*, US503346378, US Patent and Trademark Office, 11. 06. 2015.
2. Paul J. McGuiness, Marko Soderžnik, Kristina Žagar, Andraž Kocjan, Spomenka Kobe, *Method of manufacturing fully dense Nd-Fe-B magnets with enhanced coercivity and gradient microstructure*, EP2869311 (A1), European Patent Office, 6. 05. 2015.

Mentoring

1. Muhammad Shahid Arshad, *Magnetization distribution and reversal behaviour in 1D ferromagnetic Co-Pt-based nanostructures:* doctoral dissertation, Ljubljana, 2015 (mentor Spomenka Kobe; co-mentor Kristina Žužek Rožman).
2. Bojan Ambrožič, *Metamorphic processes in meteorites Jesenice and Jezersko:* master's thesis, Ljubljana, 2015 (mentor Sašo Šturm).
3. Luka Kelhar, *Metal-bonded Nd-Fe-B magnets:* master's thesis, Ljubljana, 2015 (mentor Spomenka Kobe; co-mentor Paul J. McGuiness).

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 materials.

Head:
Prof. Darko Makovec

In 2015 our investigations have focused on several important materials, i.e., materials containing magnetic nanoparticles, multifunctional nanocomposites, fluorescent materials, and semiconducting materials for the preparation of thermistors.

The research of nanoparticles-based materials is continuously focused on engineering nanoparticles' surface properties. The engineering of the surface properties is of key importance for nanoparticle applications, as well as for their assembly into composite materials. The surface properties are usually engineered by bonding different functionalization molecules onto the nanoparticle surfaces. The functionalization molecules provide specific functional groups for the further (bio)conjugation of different molecules needed for specific applications. The layer of organic molecules also defines the electric charge at the surfaces and the interactions between the nanoparticles in a liquid medium. It also significantly determines the interactions of the nanoparticles with biological systems. A part of research in 2015 was devoted to engineering of the surface properties of superparamagnetic iron-oxide maghemite nanoparticles using adsorption of different amino acids onto their surfaces. The application of different amino acids in the engineering of nanoparticle surface properties and their functionalization is broadly discussed in scientific literature. Usually the change in the surface properties is discussed based on the assumption that the amino acid is bound with the carboxylic group onto the nanoparticle surface in the form of a molecular monolayer. Our study of the adsorption of two amino acids, aspartic acid and lysine, in cooperation with researchers from the Faculty of Chemistry and Chemical Technology, University of Ljubljana, however, showed that the amino acids absorb in much higher surface concentrations than expected for the adsorption in the form of the monolayer. Direct determination of the amino acids present in the supernatants after ultra-centrifugation of the suspensions using HPLC showed very high surface concentrations of the amino acids at the nanoparticles, exceeding several tens of molecules per nm^2. These high surface concentrations can be explained by adsorption in the form of molecular associates. Osmolality determination based on freezing-point depression measurements showed formation of the associates already in the aqueous solutions of the amino acids. The associate is formed by binding the amino-acid molecules together with relatively weak hydrogen or electrostatic bonds. As a result, the layer of the adsorbed molecules at the nanoparticle surfaces is very sensitive to different external conditions, making the adsorption of amino acids less appropriate for use in the modification of nanoparticle surface properties. The adsorption in the form of molecular associates also decisively influences the colloidal properties of their suspensions and, as a result, their possible applications.

Amino acids, like aspartic acid and lysine, adsorb onto magnetic iron-oxide nanoparticles in the form of large molecular associates that decisively influence the colloidal properties of their aqueous suspensions.

An important part of the research of the engineering surface properties was devoted to the development of organic functionalization layers with properties (structure, water tightness, permeability for different ions), which can be tuned by external stimuli, such us increased temperature (heating of magnetic nanoparticles with AC magnetic field), pH, ionic strength or the presence of trigger molecules, such us specific enzymes. For this purpose we selected a special type of polymers: self-immolative polymers (SIPs), which decompose completely to monomer units by an external stimulus via chain reaction. We studied the synthesis of SIP based on poly(benzylcarbamates) (PBC), which were selected due to their suitable decomposition kinetics with typical decomposition times of a few hours. The SIP with a selected composition composed of around 6000 monomer units was synthesized and coupled to a commercial UV- (nitrobenzene) or redox (para-aminobenzyl alcohol) trigger; however, they were not efficient. The synthesis and study of a new UV trigger based on 4-nitrobenzyl phenylcarbamate is currently in progress.

In 2015 we also started to study nanoparticle functionalization with functional RAFT polymers in a collaboration with the Key Centre for Polymers and Colloids, University of Sydney, Australia. The research on the layer-by-layer (LbL) deposition of polymers/proteins on the surface of the magnetic nanoclusters was carried out in collaboration with the Institut de Physique et Chimie des Matériaux (IPCMS), Strasbourg, France.

An important part of the research has been devoted to the testing of clusters of superparamagnetic iron-oxide nanoparticles (superparamagnetic nanoclusters) in applications based on magnetic separation. In the magnetic separation the commercially available superparamagnetic nanoclusters produced by Nanos Sci. (http://nanos-sci.com/), a spin-out company of the JSI, are normally used (Figure 1). The core of the spherical nanocluster represents an assembly of around 100 nanoparticles. Because of its larger volume the magnetic force acting in a magnetic field gradient on the nanocluster is much larger than the force acting on an individual superparamagnetic nanoparticle. The large magnetic force enables effective magnetic separation of the nanoclusters from the suspension, whereas the individual nanoparticles cannot be separated. The nanocluster core is coated with a thin silica shell, which enabled effective covalent bonding of different functionalization molecules onto their surfaces. The fluorescent molecules are incorporated into the silica shell for tracking of the nanoclusters with methods based on fluorescence microscopy.

Immobilization of (bio)catalysts onto superparamagnetic nanoclusters for their magnetic separation.

A typical example of such applications is the use of the superparamagnetic nanoclusters for immobilization of (bio)catalysts, which enables their magnetic separation from the medium after catalytic reactions. Magnetically recoverable nano-biocatalysts prepared with bioconjugation of enzymes onto the superparamagnetic nanoclusters were studied in co-operation with researchers from Universidad Autònoma de Barcelona, Spain. A possible application of the nanoclusters as a support for a metallic ruthenium catalyst has been studied in cooperation with colleagues from the National Institute of Chemistry. Another possible application of the nanoclusters as a support for an organocatalyst, such *N*-methylmorpholine, has been studied in co-operation with colleagues from the Department for Physical and Organic Chemistry.

Besides magnetic separation, the superparamagnetic nanoclusters could also be interesting in many other applications where a relatively large force acting on a nanocluster in a magnetic field gradient could be beneficially exploited. Magnetic drug delivery and cell-transfection (magnetofection) using magnetic nanoclusters are the most promising applications in the biomedical field. In collaboration with researchers from the Faculty of Pharmacy, University of Ljubljana, we have developed various magnetic nanostructured materials that may show significant advantages compared to the known delivery systems. A part of our research in this field was devoted to the preparation of magnetic liposomes. Hydrophilic magnetic nanoclusters were primarily functionalized with various functional groups followed by their incorporation into an aqueous liposome interior. Such magnetically responsive drug-delivery systems are promising materials for the delivery of hydrophilic macromolecules, i.e., therapeutic proteins and gene materials. In parallel we have studied the hollow magnetically responsive delivery systems. The interior of the magnetic nanoclusters were partially removed and the formed void was loaded with active pharmaceutical ingredients. Such magnetically responsive inorganic delivery systems have better chemical stability in a complex body fluids compared to relatively sensitive systems based on phospholipid bilayers such as liposomes.

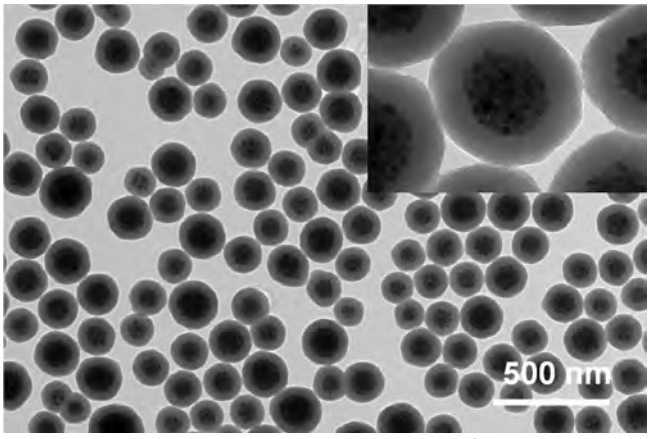

Figure 1: Transmission electron microscopy image of the iNANOvative™ silica-coated nanoparticle clusters. The magnetic cores are coated with a fluorescent 20-nm-thick silica shell, which contains fluorescent dye.

In collaboration with a company Nanos SCI, novel magnetic nanostructures were developed. The nanostructures were synthesized based on a magnetic assembly of the superparamagnetic nanoclusters into one-dimensional nanochains and their further evolution into nanobundles. A developed approach allowed us to synthesize nanochains with well-defined lengths, where the shortest nanochains were composed of only 5 nanoclusters and the longest ones of up to 50 nanoclusters. It is expected that the nanochain lengths have an important impact on their physical properties, which will be a major focus of our research in the field of medicine (short nanochains) and magneto-rheology (long nanochains). Collaboration with a research group from the Technical University of Dresden, Germany, was established in the field of magneto-rheology. The collaboration is based on the preparation of non-aqueous nanochain suspensions. The primary goal is the development of new approaches for the transfer of aqueous suspensions of nanochains into viscous polymer solutions. The short nanochains were used for the synthesis of a novel, magnetically responsive, drug-delivery system in a joint research with a nanotechnology group from the Faculty of Pharmacy.

For the magnetic separation of larger objects, such us microorganisms, non-clustered superparamagnetic nanoparticles can be used. For example, bacteria can be magnetically separated from a liquid medium after the electrostatic adsorption of the superparamagnetic nanoparticles onto their surfaces (Figure 1). Use of the thus prepared magnetically separable bacteria was tested in the malolactic fermentation of wine in cooperation with Prof Marin Berovič from the Faculty of Chemistry and Chemical Technology, University of Ljubljana. During the malolactic fermentation the bacteria transform malic acid into lactic acid and carbon dioxide, thus decreasing the

acidity of the wine. The problem represents the separation of the bacteria after the malolactic fermentation as the unseparated bacteria can have a negative influence on the wine's taste. Adsorption of the magnetic nanoparticles onto the bacteria enables effective magnetic separation of the bacteria from the wine in a desired stage of the fermentation process, contributing to the control of its final composition.

In 2015 a spin-out company InoVine, d. o. o., (http://www.ino-vine.com/) was founded based on innovations related to the use of magnetic nanoparticles in wine technology. On Start up Slovenia competition the company was selected among five finalists and obtained start-up financial resources.

Our long-term research devoted to the synthesis of magnetic iron-oxide nanoparticles has continued. The research was mainly oriented to the nanoparticles with optimized properties for use in cancer treatment using magnetic hyperthermia. The magnetic properties strongly depend on the size and composition of the nanoparticles. A synthesis method that enables good control over the nanoparticle size was developed based on the hydrothermal treatment of iron hydroxides in the presence of ricinoleic acid as a surfactant. The surfactant bonds to the nanoparticle surfaces and partially prevents their growth. The influence of the temperature and the ricinoleic acid concentration on the average size of the nanoparticles has been systematically studied. We were able to control the average size of the nanoparticles in the range between 9 nm and 30 nm. The smaller nanoparticles displayed superparamagnetic properties, whereas the larger were ferrimagnetic. In cooperation with researchers from the Department for Surface Engineering and Optoelectronics and the National Institute of Chemistry we have studied the valence state of Fe cations. We found that the temperature and the ricinoleic acid concentration have a strong influence on the rate of the Fe^{2+} oxidation. Because of the different rate of oxidation the nanoparticles larger than 15 nm contained a substantial amount of incorporated Fe^{2+} and, as the result, exhibited larger values of saturation magnetization. Heating of the magnetic nanoparticles in an AC magnetic field has also been studied. Measurements showed that ferrimagnetic nanoparticles demonstrated optimal properties.

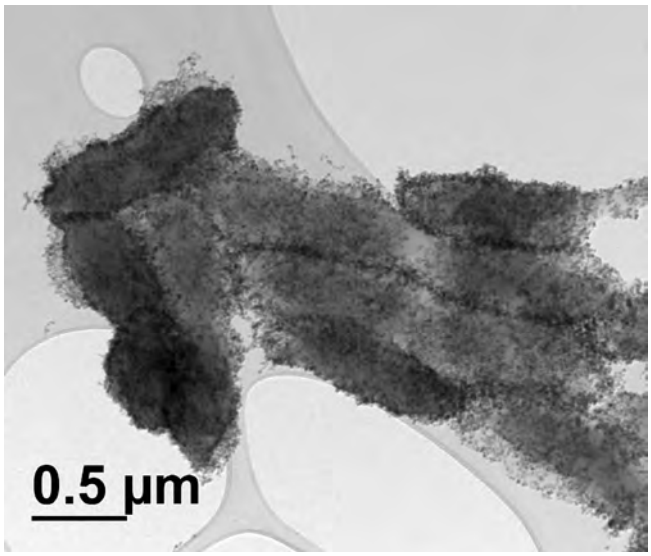

Figure 2: Transmission electron microscopy image of malolactic bacteria with adsorbed magnetic nanoparticles.

The nanocomposites containing the magnetic iron-oxide nanoparticles in a polymer polymethyl methacrylate matrix were also prepared. For efficient heat transfer and good mechanical properties the nanoparticles should be homogeneously dispersed in the polymer matrix. In the polymer solution the depletion flocculation induces rapid flocculation of the colloidal nanoparticles, which limits the possibility to prepare such homogeneous nanocomposites. In cooperation with researchers from the National Institute of Chemistry we developed a method to bond monomer methyl methacrylate to the surface of the magnetic iron-oxide nanoparticles. During the solution polymerization of the methyl methacrylate in the presence of the magnetic nanoparticles the polymer chains also grow from the surface of the nanoparticles and prevent their flocculation. We were able to prepare nanocomposites with a large amount of the homogeneously dispersed magnetic nanoparticles in the polymer matrix. Such nanocomposites are suitable for the fixation of fractured vertebrae and enable additional treatment with magnetically induced hyperthermia.

A part of research was devoted to synthesis of ε-Fe_2O_3 magnetic nanoparticles. Two modifications of iron oxide, i.e., hematite (α-Fe_2O_3) and especially magnetic maghemite (γ-Fe_2O_3), are well known, while much less research has been devoted to a ε modification of Fe_2O_3. Metastable ε-Fe_2O_3 displays an enormous magnetocrystalline anisotropy. The synthesis of the ε-Fe_2O_3 nanoparticles with heating iron-containing silica has already been known. We have studied formation of the ε-Fe_2O_3 nanoparticles during synthesis by applying a completely new method in cooperation with Dr. Marin Tadić from the "Vinča" Institute, Serbia, and researchers from CSPBAT Laboratory, University of Paris, France. The method is based on heating silica-coated akaganeite (β-FeOOH) nanoparticles at temperatures around 1000 °C. In contrast to the known mechanism of the ε-Fe_2O_3 formation from maghemite, the ε-Fe_2O_3 from akaganeite formed in a two-step transformation. First, akaganeite transformed to hematite, which directly transformed into the ε-Fe_2O_3. High-resolution transmission electron microscopy (HREM) showed a topotactic transformation between the two phases (Figure 3). The transformation of the hematite directly into the ε-Fe_2O_3 is very interesting since the hematite represents a thermodynamically stable phase.

Magnetic assembly of superparamagnetic nanoparticle clusters into anisotropic nanostructures such as one-dimensional nanochains and their further assembly into nanobundles.

We continued our research devoted to the synthesis of multifunctional composite nanoparticles using a coating of a magnetic shell onto different core nanoparticles. The magnetic shell is deposited using the simple co-precipitation of iron ions from the aqueous solution. The shell is formed after heterogeneous nucleation of the products at the core surfaces. The key factor is control of a supersaturation of the products. The necessary control of the supersaturation

was achieved with bonding iron (III) ions into a complex with urea, which enables the controlled release of the ions into the reaction mixture with thermal decomposition of the complex. Already for longer period of time the research has been devoted to detailed structural and magnetic characterization of the composite nanoparticles composed of a hard-magnetic barium-hexaferrite ($BaFe_{12}O_{19}$) core that is magnetically coupled with a soft-magnetic shell of iron oxide maghemite (γ-Fe_2O_3). In 2015 the main focus was on the synthesis of the composite nanoparticles with coating the maghemite shell onto the cores of magnetic perovskite manganites ($LaSrMnO_3$) and the cores made of ferroelectric bismuth titanate ($Bi_4Ti_3O_{12}$). The platelet $Bi_4Ti_3O_{12}$ core nanoparticles, approximately 100 nm wide and 10 nm thick, were synthesized using a hydrothermal method. The research of the coating magnetic shell onto the ferroelectric nanoplatelets is aimed at magnetic control of the platelets' orientation in their suspensions.

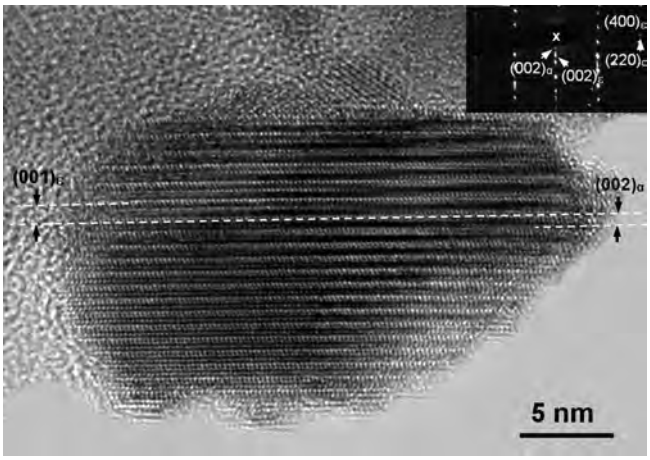

Figure 3: High-resolution transmission electron microscopy image and a corresponding electron diffraction pattern of a nanoparticle composed of hematite (α-Fe_2O_3) and ε-Fe_2O_3 proves a topotactic transformation between the two phases.

We also cooperated in nanotoxicology research with the Biotechnical Faculty, University of Ljubljana, where we provided our expertise in the synthesis, functionalization and characterization of nanoparticles.

The continuing study of $BaFe_{12}O_{19}$ nanoplates and their incorporation in various matrices, like liquid crystals (in cooperation with the Department of Condensed Matter, JSI) and polymers (in cooperation with Faculty of Chemistry and Chemical Technology, University of Maribor) was focused on the concentration of their suspensions. We managed to prepare highly concentrated suspensions (15-30 g/l nanoplates) in n- and t-butanol. They enabled us to develop anisotropic magneto-optic polymer composites and liquid-crystal composites with a significant magento-optic, magneto-rheologic and multiferroic effects. These composites were suitable for the visualization of a magnetic field.

For the preparation of the suspensions of $BaFe_{12}O_{19}$ nanoplates and their functionalization for biomedical applications we studied the synthesis of amorphous silica coatings and their functionalization with amino-silanes. The stability of the suspensions during the silica coating and silanization was carefully studied and controlled. Silanized $BaFe_{12}O_{19}$ nanoplates were subsequently used for the hybridization with peptides. This study, in collaboration, with the University of Trieste, is still in progress.

We continued with the research on fluorescent optical materials. Fluorescent nanoparticles can be applied in various optical elements and are also proposed as alternative bio-markers in imaging diagnostic techniques for medicine. We studied the synthesis of fluoride nanoparticles doped with lanthanides. The main focus was on the control of the particle size, suspension stability and chemical stability of fluorides in an aqueous environment. Namely, the nanoparticles for bio-medicine should be chemically and colloidally stable in aqueous media. We showed that fluoride nanoparticles with different compositions (binary and ternary) partly dissolve in water, which limits their applicability in biomedicine. The dissolution studies were conducted in cooperation with the Department for Inorganic Synthesis and Technology, JSI. The dissolution degree and rate depends strongly on the temperature, the composition of the aqueous media (buffer), pH, chemical composition and crystal structure. The dissolution degree of AYF_4 nanoparticles (A = Na or K), co-doped with Yb^{3+} and Tm^{3+}, increases by several times at 37 °C in comparison to room temperature. The dissolution degree is also higher for A = K and in phosphate buffer than in water or phthalate buffer. The dissolution rate is larger for the nanoparticles with a metastable cubic structure than for those with a thermodynamically stable hexagonal structure of the same composition. Our estimation of the released fluoride ion in a single cell suggest a potential cytotoxicity after a retention time of several hours. The dissolution of the studied nanoparticles is significant enough to affect their optical properties, especially their fluorescent life times. This study was accomplished in cooperation with Bundesanstalt für Materialforschung und prüfung (BAM), Berlin, Germany.

Fluorescent fluoride nanoparticles, alternative biomarkers in biomedicine, dissolve substantially and relatively quickly in aqueous media. A cytotoxic effect only due to the released fluoride ion can be expected within several hours of retention of the fluorescent fluoride nanoparticles in a cell.

The main analytical method used in our studies of the dissolution of fluoride fluorescent nanoparticles was ion-selective electrode combined with potentiometry. Only pure solutions are suitable for this method, which is not suitable for biological samples or even for suspensions of very small nanoparticles that could not be completely eliminated before the analysis. Therefore, we started, in cooperation with Faculty of Pharmacy of University of Ljubljana, the development of fluorescent probes sensitive to fluoride ions. The preliminary studies included molecules based on rhodamine, coumarine, molecules including quarternary ammonium groups and combination of these. The most promising results were obtained with coumarine-based probes, which will be optimized in the following year.

A study related to the protection of $NaYF_4$ nanoparticles against their dissolution in aqueous media was devoted to the development of protective amphiphilic coatings. A significant decrease in the dissolution rate of the $NaYF_4$ nanoparticles has already been proven by a coating based on poly(maleic anhydride-alt-1-octadecen) (PMAO) crosslinked with bis(hexamethylene) triamine (BHMT). Our preliminary *in vitro* study showed no significant cytotoxic effect for the $NaYF_4$ nanoparticles coated with PMAO-BHMT.

The basic research of semiconducting ceramics was devoted to the origin of the positive-temperature coefficient of resistivity (PTCR) effect in BaTiO3 ceramics. We have shown that it is possible to prepare PTC thermistors on the basis of $BaTiO_3$ ceramics without donor-doping when a composite of conductive and non-conductive phases is formed. Due to dimensional changes in $BaTiO_3$ ceramics at the Curie temperature there is an interruption of the connections in the conductive phase that leads to the PTCR anomaly.

We have also continued the research of PTC resistors preparation based on ferroelectric ceramics in the system $BaTiO_3$–$Na_{0,5}Bi_{0,5}TiO_3$. The PTC resistors displaying a Curie temperature of 180 °C and low room-temperature specific resistivity were developed. Unlike the high-temperature PTC resistors available in the market, the developed material contains no toxic lead.

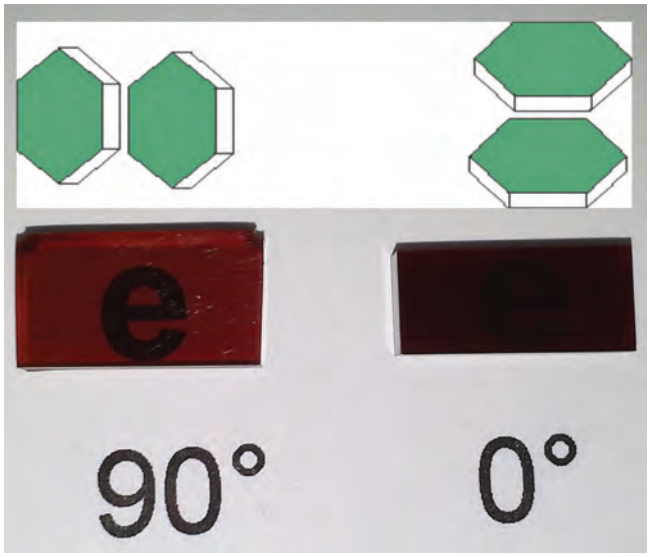

Figure 4: A photograph of anisotropic magneto-optic composites. Nanoplatelets of $BaFe_{12}O_{19}$ are incorporated in PMMA and oriented with respect to the basal plane of samples as presented in the scheme above.

Some outstanding publications in the past year

1. Lisjak, Darja, Jenuš, Petra, Mertelj, Alenka. The influence of the morphology of ferrite nanoparticles on the directed assembly into magnetically anisotropic hierarchical structures. *Langmuir*, 2014, 30, 6588-6595.
2. Jenuš, Petra, Lisjak, Darja, Kuščer, Danjela, Makovec, Darko, Drofenik, Mihael. The low-temperature cosintering of cobalt ferrite and lead zirconate titanate ceramic composites. *Journal of the American Ceramic Society*, 2014, 97, 74-80.
3. Kralj, Slavko, Makovec, Darko. The chemically directed assembly of nanoparticle clusters from superparamagnetic iron-oxide nanoparticles. *RSC advances*, 2014, 4, 25, 13167-13171.

Awards and appointments

1. Blaž Belec: Best contribution at the Conference of Jožef Stefan International Postgraduate School, Ljubljana, Jožef Stefan International Postgraduate School, Title: *B.Belec, D. Makovec; Magnetic properties of nanoplatelet composite nanoparticles composed of hard-magnetic hexaferrite and soft-magnetic maghemite.*
2. Darja Lisjak: Zois Recognition: Committee of the Republic of Slovenia for Zois Award, Zois Recognition, Science Ambassador Recognition of Republic of Slovenia and Puh Recognition, *Discovery of ferromagnetic liquid-crystal suspensions.*

INTERNATIONAL PROJECTS

1. COST IC1208; Integrating Devices and Materials: A Challenge for New Instrumentation in ICT
   Prof. Darko Makovec
   Cost Office
2. The European Upconversion Network - from the Design of Photon-upconverting Nanomaterials to Biomedical Applications
   Asst. Prof. Darja Lisjak
   Cost Office
3. Superparamagnetic Iron-oxide Nanoparticles and Nanoclusters: Synthesis, Inter-particle and Inter-cluster Interactions, Magnetic Moment and Practical Applications
   Prof. Darko Makovec
   Slovenian Research Agency

RESEARCH PROGRAM

1. Advanced inorganic magnetic and semiconducting materials
   Prof. Darko Makovec

R&D GRANTS AND CONTRACTS

1. COST RADIOMAG: Multifunctional Nanoparticles for Magnetic Hyperthermia and Indirect Radiation Therapy
   Prof. Darko Makovec
   Cost Office

NEW CONTRACTS

1. Optical fibers doped with fluorescent nanoparticles
   Asst. Prof. Darja Lisjak
   Optacore d. o. o.
2. Analytical and scientific support in development of ferric carboxymaltose process
   Prof. Darko Makovec
   Lek d. d.

VISITORS FROM ABROAD

1. Prof. Markus Niederberger, ETH Zurich, Zurich, Switzerland, 23. 4. 2015
2. Gerard Masdeu, Universitat Autonoma de Barcelona, Barcelona, Spain, 1. 5.-31. 7. 2014
3. Prof. Josep Lopez Santin, Universitat Autonoma de Barcelona, Barcelona, Spain, 6.-9. 5. 2015
4. Dr. Silvia Marchesan, Università degli Studi di Trieste, Italy, 9. 6. 2015
5. Dr. Marin Tadić, Vinca Institute, Condensed Matter Physics Laboratory, University of Belgrade, Belgrade, Serbia, 27.6.2015 - 19.7.2015 and 6. 12. 2015 - 11. 12. 2015

STAFF

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2. Asst. Prof. Darja Lisjak
3. **Prof. Darko Makovec, Head**
4. Dr. Igor Zajc

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5. Dr. Slavko Kralj

Postgraduates
6. Blaž Belec, B. Sc.
7. *Dr. Peter Dušak, left 01.05.15*
8. Tanja Goršak, B. Sc.
9. Helena Macut, B. Sc.
10. Olivija Plohl, B. Sc.
11. Klementina Pušnik, B. Sc.

Technical and administrative staff
12. Bernarda Anželak, B. Sc.

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Original Article

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Published Conference Contribution (invited lecture)

1. Darja Lisjak, "Ferrite nanoparticles: from synthesis to new advanced materials", In: *Processing and Properties of Advanced Ceramics and Composites VII: [MS&T'14, Materials Science & Technology Conference 2014, October 12-14 2014, Pittsburgh, PA, USA]*, (Ceramic transactions, vol. 252), K. M. Nair, ed., Shashank Priya, ed., Hoboken, Wiley, 2015, pp. 335-347.

Published Conference Contribution

1. Blaž Belec *et al.* (15 authors), "Magnetic properties of nanoplatelet composite nanoparticles composed of hard-magnetic hexaferrite and soft-magnetic maghemite", In: *Zbornik: 2. del: part 2*, 7. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 7th Jožef Stefan International Postgraduate School Students' Conference, 20.-22. 5. 2015, Ljubljana, Andraž Rešetič, ed., et al, Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2015, zv. 1, pp. 135-151.
2. Blaž Belec, Darko Makovec, "Magnetic properties of plate-like composite nanoparticles combining soft-magnetic iron oxide with hard-magnetic barium hexaferrite", In: *Zbornik referatov in povzetkov*, Slovenski kemijski dnevi 2015, Ljubljana, 24. - 25. september 2015 = Slovenian Chemical Days 2015, Ljubljana, September 24 - 25, 2015, Venčeslav Kaučič, ed., et al, Ljubljana, Slovensko kemijsko društvo, 2015, 9 pp.
3. Klementina Pušnik, Gregor Marolt, Sašo Gyergyek, Darko Makovec, "Amino-acid-iron-oxide-nanoparticles: adsorption studies and colloidal properties", In: *Zbornik: 2. del: part 2*, 7. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 7th Jožef Stefan International Postgraduate School Students' Conference, 20.-22. 5. 2015, Ljubljana, Andraž Rešetič, ed., et al, Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2015, zv. 1, pp. 228-240.

Patent Application

1. Peter Dušak, Marin Berovič, Darko Makovec, *Postopek za uravnavanje mlečnokislinske fermentacije pri proizvodnji vina z magnetnim izločanjem bakterij*, P-201500118, Urad RS za intelektualno lastnino, 6. 05. 2015.

Mentoring

1. Peter Dušak, *Magnetic nanoparticles for selective magnetic separation in biotechnology:* doctoral dissertation, Ljubljana, 2015 (mentor Darko Makovec; co-mentor Marin Berovič).
2. Tanja Goršak, *Preparation and characterization of magnetoliposome formulation with superparamagnetic iron oxide nanoparticle clusters:* master's thesis, Ljubljana, 2015 (mentor Petra Kocbek; co-mentor Slavko Kralj).
3. Kristjan Kraševec, *Kinetics of metabolism magnetized yeast Saccharomyces bayanus and possible applications in technology sparkling wines:* master's thesis, Ljubljana, 2015 (mentor Marin Berovič; co-mentor Darko Makovec).

DEPARTMENT FOR ADVANCED MATERIALS K-9

In the Department for Advanced Materials 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 micro-scale precision are used to prepare pre-designed structural ceramics, 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 oxide materials for various electronic applications, ii) new materials with improved antibacterial and photocatalytic effects, and iii) new oxide materials for efficient high-temperature thermoelectric energy conversion.

Head:
Prof. Danilo Suvorov

Functionalized oxides for electronic applications

Ferroelectric perovskite nanoparticles with well-defined anisotropic shapes are attracting increasing attention because of their unique shape- and size-dependent properties at small dimensions (below 200 nm). In addition, these particles with well-defined shapes and uniform size distributions have the potential to be used as the building blocks for the fabrication of functional nanodevices.

The shape, size and orientation engineering of perovskite ferroelectric particles were the focus of a study of the *in-situ* topochemic transformation in the molten salt from Aurivillious $Bi_4Ti_3O_{12}$ template plates into $BaTiO_3$ perovskite plates with a maintained shape. In the first step we investigated the principles for controlling the size of the $Bi_4Ti_3O_{12}$ plates, with the main emphasis being on the conditions for the preparation of nanoplates with a homogeneous size distribution. In the continuation, we managed to prepare various sizes (100 nm to 2 μm) of plate- and block-like $BaTiO_3$ particles by controlling the size of the initial $Bi_4Ti_3O_{12}$ template plates. We systematically investigated how the conditions of the topotactic transformation, in addition to the initial template size, influenced the shape, size, tetragonality and orientation of the formed $BaTiO_3$ plates. The results showed that the shape of the $Bi_4Ti_3O_{12}$ nanoplates (≤ 500 nm) was the most preserved during the topotactic transformation into $BaTiO_3$ at 650–700°C, while the larger template plates (1 μm) disintegrated into smaller blocks (≤500 nm) at this temperature due to the strains, which are a consequence of the misaligned growth of $BaTiO_3$ on the parent Aurivillious structure. The 1-μm-sized $Bi_4Ti_3O_{12}$ plates transformed into the ‹001› preferentially oriented $BaTiO_3$ plates at 800–900°C **(Figure 1)**. The degree of preferential orientation was higher in the case of a homogeneous size distribution of the parent $Bi_4Ti_3O_{12}$ plates, an excess of Ba, slow cooling and heating rates and a defect-free surface. An understanding of the *in-situ* topotactic transformation from $Bi_4Ti_3O_{12}$ into $BaTiO_3$ represents the basis for engineering the morphology and orientation of other perovskite ferroelectrics ($Ba_{1-x}Sr_xTiO_3$ and $Ba_{1-x}Ca_xTi_{1-y}Zr_yO_3$) with good piezoelectric properties.

Ferroelectric (FE), antiferroelectric (AFE) and relaxor materials with a perovskite lattice all exhibit characteristic domain structures, which are a result of the lattice strains from phase transformations into lower-symmetry phases. When external fields (electrical or mechanical) are applied to these materials, changes to the crystal lattice dimensions (intrinsic contribution) and/or changes to the domain structure (extrinsic contribution) can be detected. In order to determine the extrinsic effects on the tunable materials from the $Pb_{1-x}La_x(Zr_yTi_{1-y})_{1-x/4}O_3$ (PLZT) system, in-situ environmental scanning electron microscopy (ESEM) was employed for the first time. With the *in-situ* ESEM method the movement of domain walls during pressing or applying an electric field can be directly observed. From these experiments we determined that the mechanical force has the most influence on the domain structure of AFE materials, whereas the domains of FE materials are mainly affected by an electric field. Thus, extrinsic effects play an important role in the electromechanical response of FE and AFE materials. In relaxors, on the other hand, the main contribution to the enhanced electromechanical properties was determined to be intrinsic, from the distortion of the crystal lattice.

In the scope of an investigation of the phase relations in ternary oxide systems where new compounds and solid solutions form and exhibit interesting electric properties, we determined the phase equilibria in La_2O_3–TiO_2–GeO_2 at 1000°C. The samples were prepared by the wet-precipitation method from a

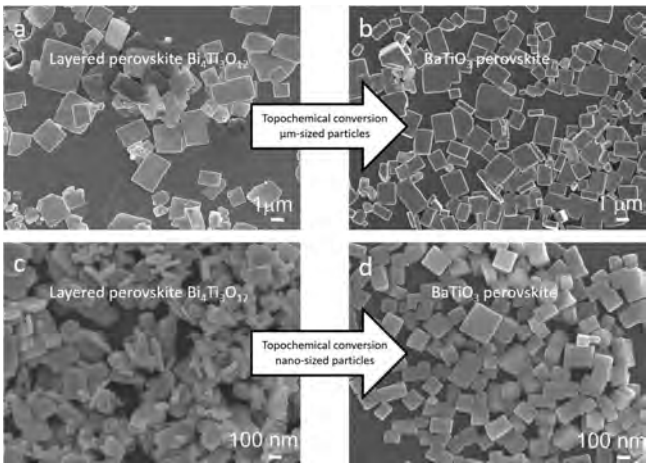

Figure 1: Topochemical conversion from $Bi_4Ti_3O_{12}$ (a,c) into $BaTiO_3$ (b, d) with the retention of the initial particle size at 900°C (a, b) and at 660°C (c, d).

soluble precursor in order to achieve good homogenization of the starting compositions. We identified in the system a new compound and several solid solutions and determined their crystal structures and ranges of solid solubility. We found that in the compound $La_{10-x}Ge_6O_{26\pm\delta}$ with an apatite crystal structure that forms in the La_2O_3–GeO_2 system and exhibits high ionic conductivity, it is possible to incorporate Ti, resulting in the solid solution $La_{9.33}Ge_{6-x}Ti_xO_{26}$ that is stable for $0 \leq x \leq 4$.

We used the pulsed-laser deposition (PLD) technique to grow $Pb[Mg_{1/3}Nb_{2/3}]O_3$–$PbTiO_3$ (PMN-PT) thin films on TiO_2-terminated (001) $SrTiO_3$ (STO) substrates from single-crystal and ceramic targets with compositions in the vicinity of the morphotropic phase boundary (MPB). We prepared the ceramic targets in our laboratories via the columbite method, and we systematically added varying proportions of PbO excess (10–20 %). PbO excess compensates for the loss of highly volatile lead in syntheses at high temperatures, which are necessary for the formation of the perovskite PMN-PT. By using PbO excess and by optimizing the remaining process parameters we managed to avoid the occurrence of the non-ferroelectric pyrochlore phase. Specifically oriented single-phase layers of PMN-PT on STO represent a good starting point for the preparation of multilayered structures for integration into piezoelectric micro-electromechanical systems (piezo MEMS). Namely, the values of the piezoelectric d_{33} constant in rhombohedral PMN-PT single crystals are five times higher than the ones in lead zirconate titanate (PZT). PMN-PT is furthermore distinguished by very low dielectric losses and a high electromechanical factor k_{33}. By optimizing the conditions of the syntheses, and by using appropriate buffer layers and oxide electrodes, these properties can be transferred into the form of thin films.

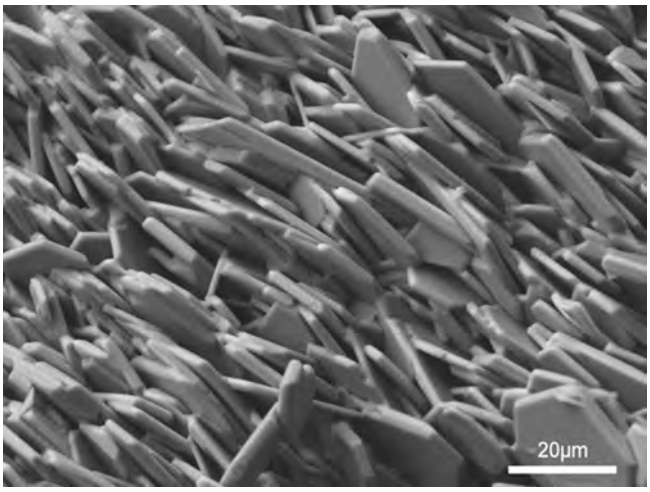

Figure 2: Morphology of trigonal TiS_2 plate-like grains aligned in the (001) direction prepared by a solid-state synthesis of the constituent elements.

In the scope of pulsed-laser deposition (PLD) we focused on the epitaxial integration of $SrTiO_3$ (STO) with Si(001). The high-quality epitaxial growth of STO thin films on a Si platform is essential for many technological applications, since it serves as an excellent template for the growth of different functional oxides. The Si surface is first cleaned by flash annealing up to 1200°C, followed by the deposition of metal Sr. The growth of epitaxial STO on the bare Si(001) surface is not feasible because of the high oxygen reactivity with the clean Si surface. However, the deposition of a Sr ultra-thin layer passivates the Si surface and enables the further epitaxial growth of STO. The process of PLD deposition of a Sr buffer layer with a coverage up to ½ ML has been studied: we have confirmed that Sr grows with the characteristic two-domain (2×3)+(3×2) pattern at 1/6 ML Sr coverage and (1×2)+(2×1) pattern at ½ ML Sr coverage. Furthermore, we have been optimizing the parameters for the epitaxial growth of STO on such a template, using techniques like Reflection High-Energy Electron Diffraction (RHEED), X-Ray Photoelectron Spectroscopy (XPS), Atomic Force Microscopy (AFM) and X-Ray Diffraction (XRD). Satisfactory values for parameters like the Ar background pressure, laser fluency and frequency, as well as the recrystallization temperature and the sample's suitable film thickness for a recrystallization step have been determined. The PLD system has been modified for the use of an ultra-high vacuum (UHV) suitcase that enables in-situ studies of the different stages of the process by surface techniques, like Scanning Tunneling Microscopy (STM) or XPS. A Temperature Programmed Desorption (TPD) system is also being implemented in order to extract additional chemical information about the investigated sample.

Thermoelectric materials

In the scope of the research on new materials for energy conversion we synthesized new thermoelectric materials based on compounds with a layered crystal structure. Weak interlayer bonding in such compounds enables the intercalation of various atoms, ions and molecules, which contributes to lowering the thermal conductivity and consequently to improving the efficiency of the direct conversion of heat to electricity. Layered structures in which individual layers exhibit a high electrical conductivity are thus suitable for the implementation of the phonon glass-electron crystal concept, which is essential for the development of new, efficient thermoelectric materials. We applied ion exchange as a route to new materials based on layered cobaltates and high-pressure pulsed electric current sintering (PECS) to precisely control the nano-stoichiometry and consequently the intercalation of titanium between the layers of titanium disulphide (TiS_2). We were the first to show that using a gas-tight model with PECS, a highly stoichiometric TiS_2 with a high degree of texturing can be synthesized **(Figures 2 and 3)**. Such a material is interesting for the

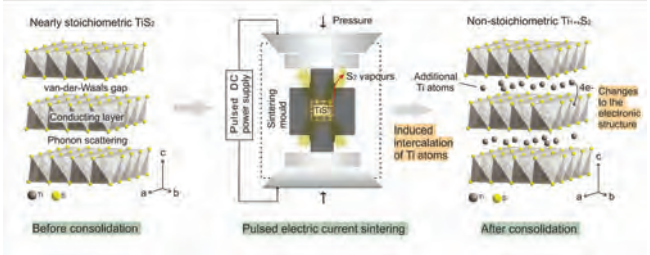

Figure 3: Schematic representation of the pulsed-electric-current-sintering-induced intercalation of Ti atoms in a TiS_2 layered host structure.

development of new thermoelectrics that will replace materials based on rare and toxic elements in near-room- and mid-temperature applications.

Antibacterial and photocatalytic materials

In 2015 the Biomaterials Group was engaged in research work in the following areas:

1. The development of new antimicrobial biomaterials: We have developed new materials based on Ga-apatite and 1D structures of MgO (**Figures 4–6**) and showed that they are very effective against *Escherichia coli* (*E. coli*) and *Pseudomonas aeruginosa*, (*P. aeruginosa*). We showed that they are nontoxic to human fibroblast cells and do not produce reactive oxygen species (ROS).
2. The development of smart scaffolds as suitable carriers of stem cells and applicable in tissue engineering (in this area we have developed apatite doped with Mg^{2+}, Sr^{2+}, Ga^{3+} and Zn^{2+} ions, and functionalized its surface using the BMP-2 protein, which promotes the growth of osteoblastic cells). The material was incorporated within the micro- and nano-porous 3D structure of the PLLA polymer. We showed that the developed material slowly released incorporated bioactive components under physiological conditions and confirmed that the release of doped ions brings a strong antimicrobial activity against *E. coli* and *P. aeruginosa*.
3. The development of innovative nanosensors for the detection of bacteria. In this area we have developed nanomaterials based on Au nanoparticles, functionalized their surface with proteins and confirmed the possibility of their specific interactions with *E. coli* and *P. aeruginosa* bacterial cells.

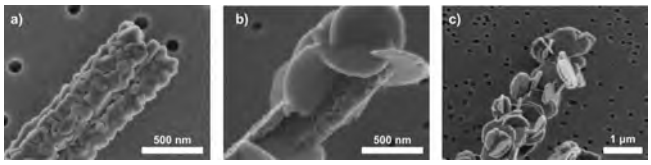

Figure 4: The morphology of a synthesized MgO particle a) before exposure, b) after 2 h of exposure and c) after 24 h of exposure to an aqueous solution. SEM study demonstrates the progress of MgO hydrolysis.

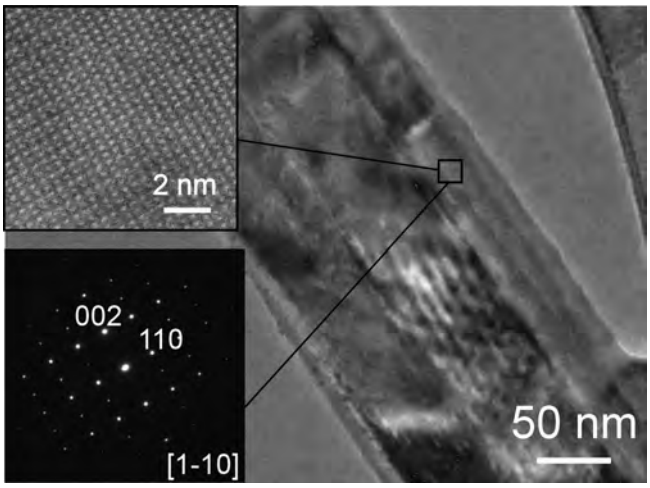

Figure 5: TEM analysis of the hydroxyapatite with incorporated Ga^{3+} ions (4 wt %), which was synthesized by the crystallization of sonochemically prepared hydroxyapatite in the presence of Ga^{3+} ions. This material exhibits an efficient antibacterial activity against P. aeruginosa*, a low toxicity for mammalian cells and good control over the release of Ga^{3+} ions. Ga ions are not incorporated into the crystal structure of hydroxyapatite, but rather into the outer thin amorphous layer, which was shown by the NMR analysis.*

In 2015 we started to work on the development of new antibacterial materials in which we used the antibacterial peptide nisin (Ni) as an antibacterial component. As a carrier of the antibacterial peptide we prepared spherical gold (Au) nanoparticles with an average size of 20 nm. In order to increase the yield of the antibacterial component (Au-Ni), micron-sized carbon spheres (C) were used as supports. Such prepared hybrid materials exhibit improved activity against the bacteria strains *E. coli* in *P. aeruginosa*.

Materials for heat-insulation applications

The aim of our work on foam glass is to develop a new preparation procedure for a foam glass with improved thermal insulation properties. The new method should have a smaller dependence of the foaming process on the composition of the glass cullet. A new preparation procedure was developed that shows a high potential for further improvements. At a density of 150 kg/m^3, we reached a thermal conductivity of 40 mW/(m·K), which is almost 20 % better than in a conventional foam glass. A new project on foam glass aims to reach a thermal conductivity of 37 mW/(m·K). This could be achieved with an understanding of the processes and reactions taking place in the softened glass during the foaming process. We continued with research work focused on the investigation of interactions between foaming additives and glass, and optimizing of the viscosity, surface tension and glass stability at the foaming temperature.

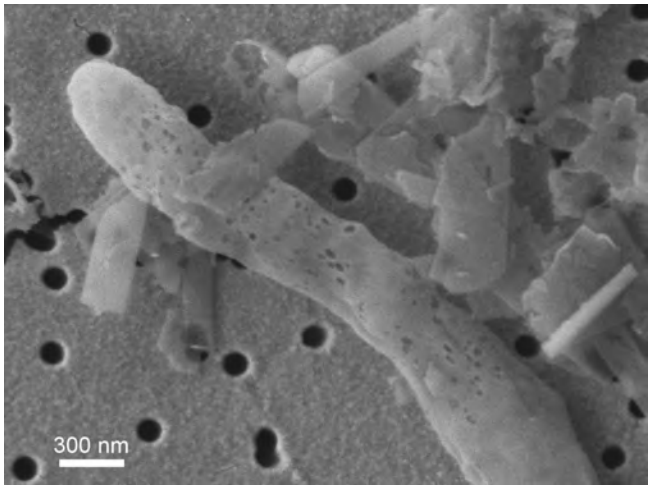

Figure 6: A P. aeruginosa *bacterium in contact with the gallium-containing hydroxyapatite (scanning electron microscope). The bacterium exhibits noticeable holes in the cell wall that most probably lead to bacterial death-cell lysis (destruction of the cell membrane, cell decomposition and release of the intracellular content).*

Projects

TDK-Epcos

For the industrial partner EPCOS OHG, Deutschlandsberg, Austria we work on the project: "Thin-Film-Energy-Storage Devices on the basis of PLZT and Cu-electrodes", the focus of which was to investigate the growth

of $Pb_{(1-x)}La_x(Zr_yTi_{(1-y)})O_3$ (PLZT) thin films using pulsed-laser deposition. The purpose of the project is to develop new materials and technology for advanced energy-storage applications.

ENPIEZO

In the scope of the M-ERA.NET project ENPIEZO we develop piezoelectric-based energy-harvesting (EH) devices to provide a remote source of electricity from waste vibrations with countless applications. For instance, EH devices can be powered by a heartbeat to operate pacemakers or it can provide electricity for sensors at remote locations like wind-turbine air blades. We investigate the fabrication-friendly pulsed-laser deposition of high-quality $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ thin films on silicon, based on the delicate engineering of silicon-oxide interfaces. The study is performed on laboratory- and industrial-scale systems, and it is the first of its kind in the world. In the project, the preparation of EH devices using aerosol deposition is also investigated. The project, which is coordinated by the JSI, brings together four partners with expertise in a very diverse field of research and development.

SCOPES

During the realization of the SCOPES 2014–2017 project, the laboratory for biomaterials purchased new equipment for the processing of biomaterials (liofilizator), equipment for the cultivation of bacteria and the simulation of physiological conditions (incubator shaker) and equipment for biological work under sterile conditions (biological safety cabinet, class 2).

Some outstanding publications in the past year

1. Dejan Klement, Matjaž Spreitzer, Danilo Suvorov, "Formation of a strontium buffer layer on Si(001) by pulsed-laser deposition through the Sr/Si(001)(233) surface reconstruction", *Appl. phys. lett.*, vol. 106, issue 7, str. 071602-1-071602-6, 2015,
2. Marjeta Maček, Dejan Klement, Boštjan Jančar, Danilo Suvorov, "Hydrothermal conditions for the formation of tetragonal BaTiO[sub]3 particles from potassium titanate and barium salt", *Ceram. int.*, vol. 41, no. 10, part B, str. 15128-15137, 2015, [COBISS.SI-ID 28836903]
3. Jakob Koenig, Danilo Suvorov, "Evolution of the electrical properties of $K_{0.5}Bi_{0.5}TiO_3$ as a result of prolonged sintering", *J. Eur. Ceram. Soc.*, vol. 35, no. 10, str. 2791-2799, 2015, [COBISS.SI-ID 28539687]
4. Vojka Žunič, Srečo D. Škapin, Danilo Suvorov, "The assembly of TiO_2 nanoparticles into micrometer-sized structures, photocatalytically active under UV and Vis light", *J. Am. Ceram. Soc.*, vol. 98, iss. 10, str. 2997-3005, 2015, [COBISS.SI-ID 28722983],
5. Vukomanovic Marija, Repnik Urska, Zavasnik-Bergant Tina, Kostanjsek, Rok, Skapin Sreco D., Suvorov Danilo, "Is Nano-Silver Safe within Bioactive Hydroxyapatite Composites? " ACS BIOMATERIALS-SCIENCE & ENGINEERING, Vol 1, Issue 10, pp 935-946, October 2015

Organization of conferences, congresses and meetings

1. Workshop on NATO Sfp 984091 project "Microwave Tuneable Materials, Composites and Devices", Ljubljana, 23. 2. – 27. 2. 2015.
2. Workshop on SCOPES project "Intelligent Scaffolds as a Tool for Advanced Tissue Regeneration", Ljubljana, 26. 5. – 29. 5. 2015.
3. Materials Science & Technology 2015 Conference and Exhibition, Columbus, USA, 4. 10. – 8. 10. 2015 (co-organizers).
4. 23. International Conference on Materials and Technology, Portorož, 27. 9. – 30. 9. 2015 (co-organizers).

INTERNATIONAL PROJECTS

1. Thin-Film-Energy-Storage Device on the basis of PLZT and Cu-Electrodes
   Prof. Danilo Suvorov
   Epcos Ohg
2. Technological Characterisation Test of OGK-5 (RGRES) Ashes for Verification of Usability in the Process of Rock Wool Production
   Prof. Danilo Suvorov
   Enel Ingegneria E Ricerca S.p.a.
3. Investigation of NdDyCoCuFe Rare Earth Alloys and Related Compounds
   Prof. Danilo Suvorov
   Urban Mining Company
4. Production and Characterisation of Coal Ash Fibres
   Prof. Danilo Suvorov
   Enel Ingegneria E Ricerca S.p.a.
5. Microwave Tunable Materials, Composites and Devices
   Asst. Prof. Boštjan Jančar
   Nato - North Atlantic Treaty Organisation
6. 3D Composite Plasmonic Metal/Semiconductor Photo-catalyst for Efficient Solar to Fuel Energy Conversion
   Asst. Prof. Srečo Davor Škapin
   Slovenian Research Agency
7. Biomineralization at the Nanoscale: from the Natural Systems to the Laboratory
   Asst. Prof. Srečo Davor Škapin
   Slovenian Research Agency

RESEARCH PROGRAM

1. Contemporary Inorganic Materials and Nanotechnologies
   Prof. Danilo Suvorov

R & D GRANTS AND CONTRACTS

1. Engineering of structural and microstructural characteristics in contemporary dielectrics and ferroelectrics with perovskite and perovskite-like crystal structures
   Prof. Danilo Suvorov
2. Growth of high quality piezoelectric thin films on silicon using pulsed laser deposition
   Dr. Matjaž Spreitzer
3. SCOPES; Intelligent Scaffolds as a Tool for Advanced Tissue Regeneration
   Dr. Marija Vukomanović
   SNF- Swiss National Science Foundation
4. Cleantech Block II - Energy Saving Cladding
   Dr. Jakob König
   EDDP (EUDP) Energy Technology Development
5. Enabling technology for high-quality piezoMEMS
   Dr. Matjaž Spreitzer

NEW CONTRACTS

6. Development and characterisation of mineral wool fibres
   Prof. Danilo Suvorov
   Knauf Insulation, d. o. o., Škofja Loka
7. Development and characterisation of mineral wool fibres
   Prof. Danilo Suvorov
   Knauf Insulation, d. o. o., Škofja Loka

VISITORS FROM ABROAD

1. Dr. Christoph Auer, TDK EPCOS, Deutschlandsberg, Austria, 10. 2. 2015.
2. Dr. Kerstin Schmoltner, TDK EPCOS, Deutschlandsberg, Austria, 10. 2. 2015.
3. Dr. Manfred Schweinzger, TDK EPCOS, Deutschlandsberg, Austria, 10. 2. 2015.
4. Dr. Anatolii Bilous, V. I. Vernadskii Institute of General and Inorganic Chemistry, Kiev, Ukraine, 23. 2. – 27. 2. 2015.
5. Dr. Tim Jackson, University of Birmingham, Birmingham, Great Britain, 23. 2. – 27. 2. 2015.
6. Dr. Oleg Ovchar, V. I. Vernadskii Institute of General and Inorganic Chemistry, Kiev, Ukraine, 23. 2. – 27. 2. 2015.
7. Dr. Kerstin Schmoltner, TDK EPCOS, Deutschlandsberg, Austria, 2. 3. - 4. 3. 2015.
8. Prof. dr. Heli Jantunen, Microelectronics and Materials Physics Laboratories, University of Oulu, Oulu, Finland, 25. 3. – 27. 3. 2015.
9. Dr. Jari Juuti, Microelectronics and Materials Physics Laboratories, University of Oulu, Oulu, Finland, 25. 3. – 27. 3. 2015.
10. Dr. Dmytro Durylin, V. I. Vernadskii Institute of General and Inorganic Chemistry, Kiev, Ukraine, 6. 4. – 30. 4. 2015.
11. Dr. Oleg Ovchar, V. I. Vernadskii Institute of General and Inorganic Chemistry, Kiev, Ukraine, 6. 4. – 30. 4. 2015.
12. Dr. Kerstin Schmoltner, TDK EPCOS, Deutschlandsberg, Austria, 7. 4. – 10. 4. 2015.
13. Prof. dr. Yun Liu, Research School of Chemistry, Australian National University, Canberra, Australia, 15. 6. – 19. 6. 2015.
14. Dr. Hua Chen, Research School of Chemistry, Australian National University, Canberra, Australia, 15. 6. – 19. 6. 2015.
15. Dr. Smilja Marković, Institut tehničkih nauka Srbske Akademije Znanosti i Umetnosti, Belgrade, Serbia, 15. 6. – 23. 6. 2015.
16. Prof. dr. Dragan Uskoković, Institut tehničkih nauka Srbske Akademije Znanosti i Umetnosti, Belgrade, Serbia, 8. 7. – 13. 7. 2015.
17. Dr. Kerstin Schmoltner, TDK EPCOS, Deutschlandsberg, Austria, 13.7. – 15.7. in 20. 7. – 24. 7. 2015.
18. Dr. Oleg Ovchar, V. I. Vernadskii Institute of General and Inorganic Chemistry, Kiev, Ukraine, 26. 7. – 13.8. 2015.
19. Olexander Suslov, B. Sc., V. I. Vernadskii Institute of General and Inorganic Chemistry, Kiev, Ukraine, 26. 7. – 13.8. 2015.
20. Dr. Chun-Liang Kuo, National Taiwan University, Taipei City, Tajvan, 23. 8. – 5. 9. 2015.
21. Dr. Chao-Ting Chen, National Taiwan University, Taipei City, Taiwan, 23. 8. – 5. 9. 2015.
22. Dr. Kerstin Schmoltner, TDK EPCOS, Deutschlandsberg, Austria, 31. 8. – 4. 9. 2015.
23. Prof. dr. Anatolii Bilous, V. I. Vernadskii Institute of General and Inorganic Chemistry, Kiev, Ukraine, 10. 9. – 15. 9. 2015.
24. Prof. dr. Wen-Jong Wu, National Taiwan University, Taipei City, Taiwan, 10. 9. -14.9. 2015.
25. Prof. dr. Gertjan Koster, MESA+ Institute for Nanotechnology, University of Twente, Enschede, Netherlands, 29. 10. – 30. 10. 2015.
26. Dr. Jari Juuti, Microelectronics and Materials Physics Laboratories, University of Oulu, Oulu, Finland, 2. 11. – 11. 12. 2015.
27. Dr. Kerstin Schmoltner, TDK EPCOS, Deutschlandsberg, Austria, 7. 12. – 9. 12. 2015

Visiting Researchers

1. Prof. dr. Jianjiang Bian, Department of Inorganic Materials, Shanghai University, Shanghai, China, 2. 6. – 28. 8. 2015.
2. Dr. Jyoti Prosad Guha, Missouri University of Science and Technology, Rolla, USA, 14. 7. – 30. 9. 2015.
3. Dr. Daniel Diaz Fernandez, Universidad Autónoma de Madrid, Madrid, Spain, 1. 10. 2015 – 30. 9. 2016.

STAFF

Researchers

1. Asst. Prof. Boštjan Jančar
2. Dr. Špela Kunej
3. Dr. Marjeta Maček Kržmanc
4. Dr. Matjaž Spreitzer
5. **Prof. Danilo Suvorov, Head**
6. Asst. Prof. Srečo Davor Škapin
7. Dr. Marija Vukomanović

Postdoctoral associates

8. Dr. Jakob König
9. Dr. Mojca Otoničar
10. Dr. Vojka Žunič

Postgraduates

11. Nemanja Aničić, B. Sc.
12. Urška Gabor, B. Sc.
13. *Dr. Dejan Klement, left 01.11.15*
14. Mario Kurtjak, B. Sc.
15. Tjaša Parkelj, B. Sc.
16. Tilen Sever, B. Sc.

Technical officers

17. David Fabijan, B. Sc.
18. Dr. Jana Ferčič
19. Damjan Vengust, B. Sc.

Technical and administrative staff

20. Maja Šimaga, M. Sc.
21. Silvo Zupančič

BIBLIOGRAPHY

Original Article

1. Una Bogdanović, Vesna Vodnik, Miodrag Mitrić, Suzana Dimitrijević, Srečo D. Škapin, Vojka Žunič, Milica Budimir, Milovan Stoiljković, "Nanomaterial with high antimicrobial efficacy-copper/polyaniline nanocomposite", *ACS appl. mater. interfaces*, vol. 7, no. 3, pp. 1955-1966, 2015.
2. M. Bošković, G. F. Goya, S. Vranješ-Djurić, N. Jović, Boštjan Jančar, Bratislav Antić, "Influence of size distribution and field amplitude on specific loss power", *J. appl. phys.*, vol. 117, no. 10, pp. 1-6, 2015.
3. Dejan Klement, Matjaž Spreitzer, Danilo Suvorov, "Formation of a strontium buffer layer on Si(001) by pulsed-laser deposition through the Sr/Si(001)(233) surface reconstruction", *Appl. phys. lett.*, vol. 106, issue 7, pp. 071602-1-071602-6, 2015.
4. Jakob Koenig, Rasmus R. Petersen, Yuanzheng Yue, "Fabrication of highly insulating foam glass made from CRT panel glass", *Ceram. int.*, vol. 41, no. 8, pp. 9793-9800, 2015.
5. Jakob Koenig, Danilo Suvorov, "Evolution of the electrical properties of $K_{0.5}Bi_{0.5}TiO_3$ as a result of prolonged sintering", *J. Eur. Ceram. Soc.*, vol. 35, no. 10, pp. 2791-2799, 2015.
6. Nina Kostevšek, Kristina Žužek Rožman, Muhammad Shahid Arshad, Matjaž Spreitzer, Spomenka Kobe, Sašo Šturm, "Multimodal hybrid $FePt/SiO_2$/Au nanoparticles for nanomedical applications ecombining photothermal stimulation and manipulation with an external magnetic field", *The journal of physical chemistry. C, Nanomaterials and interfaces*, vol. 119, issue 28, pp. 16374-16382, 2015.
7. Mario Kurtjak, Tomaž Urbič, "A simple water model in the presence of inert Lennard-Jones obstacles II: the hydrophobic effect", *Mol. Phys.*, vol. 113, issue 7, pp. 727-738, 2015.
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9. Smilja Marković, Miodrag Lukić, Srečo D. Škapin, Boban Stojanović, Dragan Uskoković, "Designing, fabrication and characterization of nanostructured functionally graded HAp/BCP ceramics", *Ceram. int.*, vol. 41, issue 2, part B, pp. 2654-2667, 2015.
10. Rasmus R. Petersen, Jakob Koenig, Yuanzheng Yue, "The mechanism of foaming and thermal conductivity of glasses foamed with MnO_2", *J. non-cryst. solids*, vol. 425, pp. 74-82, 2015.
11. Aleksandra A. Rakić, Marija Vukomanović, Snežana Trifunović, Jadranka Travas-Sejdić, Omer Javed Chaudhary, Jiřy Horský, Gordana Ćirić-Marjanović, "Solvent effects on dopant-free pH-falling polymerization of aniline", *Synth. met.*, vol. 209, pp. 279-296, 2015.
12. Maja Remškar, Gašper Tavčar, Srečo D. Škapin, "Sparklers as a nanohazard: size distribution measurements of the nanoparticles released from sparklers", *Air quality, atmosphere & health*, vol. 8, no. 2, pp. 205-211, 2015.
13. Anastasia Samodurova, Damjan Vengust, Andraž Kocjan, Tomaž Kosmač, "The sintering-temperature-related microstructure and phase assemblage of alumina-doped and alumina–silica-co-doped 3-mol%-yttria-stabilized tetragonal zirconia", *Scr. mater.*, vol. 105, 50-53, 2015.
14. Andrijana Sever Škapin, Luka Škrlep, Danilo Suvorov, Vojka Žunič, Srečo D. Škapin, "Photocatalytic activity of hierarchically structured, thermally stable, anatase particles", *RSC advances*, vol. 5, issue 34, pp. 26769-26776, 2015.
15. Melita Sluban, Nejc Rozman, Matej Pregelj, Carla Bittencourt, Romana Cerc Korošec, Andrijana Sever Škapin, Aleš Mrzel, Srečo D. Škapin, Polona Umek, "ransformation of hydrogen titanate nanoribbons to TiO_2 nanoribbons and the influence of the transformation strategies on the photocatalytic performance", *Beilstein j. nanotechnol.*, vol. 6, pp. 831-844, 2015.
16. Gorazd Šebenik, Miroslav Huskić, Damjan Vengust, Majda Žigon, "Properties of epoxy and unsaturated polyester nanocomposites with polycation modified montmorillonites", *Appl. clay sci.*, vol. 109/110, pp. 143-150, Jun. 2015.
17. Srečo D. Škapin, Vida Čadež, Danilo Suvorov, Ivan Sondi, "Formation and properties of nanostructured colloidal manganese oxide particles obtained through the thermally controlled transformation of manganese carbonate precursor phase", *J. colloid interface sci.*, vol. 457, pp. 35-42, 2015.
18. Srečo D. Škapin, Urša Pirnat, Boštjan Jančar, Danilo Suvorov, "Microwave dielectric properties, crystal structure, and microstructure of the $Bi_3Nb_{1-x}Ta_xO_7$ solid solution", *J. Am. Ceram. Soc.*, vol. 98, no. 12, pp. 3818-3823, 2015.
19. Peter Topolovšek, Christoph Gadermaier, Damjan Vengust, Martin Strojnik, Jure Strle, Dragan Mihailović, "Unlocking the functional properties in one-dimensional MoSI cluster polymers by doping and photoinduced charge transfer", *Nano lett.*, vol. 15, issue 2, pp. 813-818, 2015.
20. Maja Vidmar, Amalija Golobič, Anton Meden, Danilo Suvorov, Srečo D. Škapin, "Sub-solidus phase relations and a structure determination of new phases in the $CaO - La_2O_3 - TiO_2$ system", *J. Eur. Ceram. Soc.*, vol. 35, iss. 10, pp. 2801-2814, 2015.
21. Marija Vukomanović, Urška Repnik, Tina Zavašnik-Bergant, Rok Kostanjšek, Srečo D. Škapin, Danilo Suvorov, "Is nano-silver safe within bioactive hydroxyapatite composites?", *ACS biomater. sci. eng.*, vol. 1, no. 10, pp. 935-946, 2015.
22. Vojka Žunič, Srečo D. Škapin, Danilo Suvorov, "The assembly of TiO_2 nanoparticles into micrometer-sized structures, photocatalytically active under UV and vis light", *J. Am. Ceram. Soc.*, vol. 98, iss. 10, pp. 2997-3005, 2015.

Published Conference Contribution

1. T Vida Čadež, Srečo D. Škapin, Suzana Šegota, Branka Salopek-Sondi, Ivan Sondi, "Biomineral structures of aragonite in marine mollusks at the nanoscale: FESEM and AFM studies", In: *Proceedings*, 3rd Croatian Congress on Microscopy with international participation, April 26-29, Zadar, Croatia, [Zagreb], Ruđer Bošković Institution, Croatian Miroscopy Society, 2015, pp. 56-57.
2. Matejka Podlogar, Marjeta Maček, Aleksander Rečnik, Slavko Bernik, "Morphology of ZnO crystals prepared from $Zn(OH)_2$ and $Zn_5(OH)_8(NO_3)_2(H_2O)_2$ phases", In: *Conference proceedings 2015*, 51th International Conference on Microelectronics, Devices and Materials and the Workshop on Terahertz and Microwave Systems, September 23 - 25 2015, Bled, Slovenia, Janez Trontelj, ed., Marko Topič, ed., Aleksander Sešek, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2015, pp. 209-214.

Mentoring

1. Dejan Klement, *Growth of strontium titanate on silicon by pulsed laser deposition technique:* doctoral dissertation, Ljubljana, 2015 (mentors Danilo Suvorov, Matjaž Spreitzer).
2. Maja Vidmar, *Structural characterization of lanthanum-titanate ceramics with powder diffraction:* doctoral dissertation, Ljubljana, 2015 (mentor Amalija Golobič; co-mentor Srečo D. Škapin).

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 structure. 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 an 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 of this regulation can lead to pathologies such as auto-immune, neurological and cardiovascular disorders, cancer and osteoporosis. However, protease signalling pathways are only partially understood. Currently, only a minor subset of physiological substrates for a limited number of proteases has been identified, and their physiological regulation is still not well understood.

Major work has been done on the identification of physiological substrates of extracellular cysteine, which are known to drive cancer progression, as well as numerous other inflammation-associated diseases. One of the major mechanisms used by other extracellular proteases to facilitate cancer progression is the proteolytic release of the extracellular domains of transmembrane proteins or ectodomain shedding. In the first non-biased study we showed, using a mass-spectrometry-based approach, that the cathepsins L and S act as sheddases and cleave extracellular domains of CAM adhesion proteins and transmembrane receptors from the surface of cancer cells. In cathepsin S-deficient mouse pancreatic cancers, the processing of these cathepsin substrates was greatly reduced, pointing to the essential role of cathepsins in extracellular shedding. In addition to influencing cell migration and invasion, the shedding of surface proteins by extracellular cathepsins impacts on the intracellular signaling, as demonstrated for the regulation of Ras GTPase activity, thereby providing a putative mechanistic link between extracellular cathepsin activity and cancer progression (Figure 1). Moreover, the identified substrates also have a biomarker potential in cancer diagnostics.

In addition, we focused on the role of cysteine cathepsins in chemokine processing, which has been only very poorly understood. We evaluated the cleavage of CXC ELR (CXCL1, -2, -3, -5, and -8) and non-ELR (CXCL9-12) chemokines by cysteine cathepsins B, K, L, and S at neutral pH using mass spectrometry. Whereas cathepsin B cleaved chemokines especially in the C-terminal region, cathepsins K, L, and S cleaved chemokines at the N terminus with glycosaminoglycans modulating the cathepsin processing of chemokines. The functional consequences of the cleavages were determined by Ca^{2+} mobilization and chemotaxis assays. We showed that cysteine cathepsins inactivate and in some cases degrade non-ELR CXC chemokines CXCL9-12. In contrast, cathepsins were found to specifically process the ELR CXC chemokines CXCL1, -2, -3, -5, and -8 N-terminally to the ELR motif, thereby generating agonist forms. This study thus suggests that cysteine cathepsins regulate chemokine activity and thereby leukocyte recruitment during protective or pathological inflammation.

In collaboration with the groups of dr. J. Kos (Department of Biotechnology) and dr. G. Serša (Institute of Oncology) we have shown that an established antibiotic nitroxoline, which is a potent and selective inhibitor of cathepsin B, also displays anti-tumor properties in in-vitro and in-vivo tumor models. Nitroxoline thus markedly decreased tumor-cell invasion monitored in real time and reduced the invasive growth of multicellular tumor spheroids, used as a 3D in-vitro model of tumor invasion. Additionally, endothelial tube formation was significantly reduced by nitroxoline in an in-vitro angiogenesis assay. Finally, nitroxoline significantly abrogated tumor growth, angiogenesis and metastasis in vivo in LPB fibrosarcoma and MMTV-PyMT breast-cancer mouse models, classifying nitroxoline as a promising drug candidate for anti-cancer treatments. In collaboration with dr. G. Blum (Hebrew University, Jerusalem), several new photodynamic quenched cathepsin activity-based probes for cancer detection that simultaneously enable macrophage-targeted therapy were developed. This is the first such theranostic approach, where the activity-based probe is used for targeting, whereas the attached photosensitizer is activated by light, resulting in the oxidative stress-mediated killing of cancer cells. In addition, we also collaborated with dr. Blum on the development of novel cathepsin activity-based probes, which revealed that cathepsin B is significantly elevated

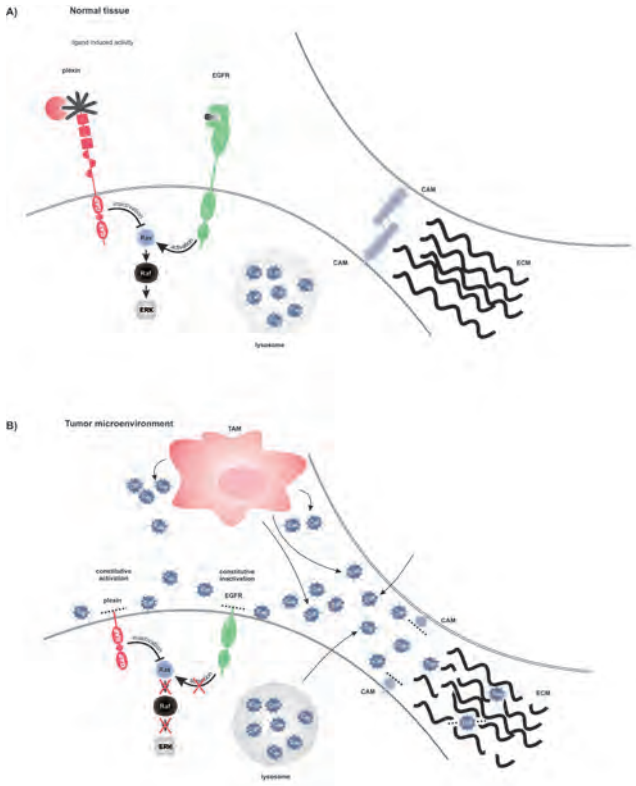

Figure 1: Molecular mechanism of extracellular cathepsin involvement in tumorigenesis.
A) Normal tissue. Plexins are inactive and only semaphorin ligand binding can trigger their GAP activity. EGFR can increase Ras activity upon ligand stimulation. Cell-cell contacts formed by CAM proteins are intact, as well as the extracellular matrix. Cysteine cathepsins are mainly localized within the endo/lysosomal compartments.
B) Tumor microenvironment. Infiltrated immune cells and tumor cells secrete cathepsins, which cleave the receptor ectodomains. Plexin cytosolic GAP activity is constitutively activated and inactivates Ras proteins. Simultaneously, removal of the EGFR ectodomain inactivates the receptor, which loses the capability for Ras activation. Shedding of CAM proteins and degradation ECM destroys cell-cell contacts and increases the migration and invasion of cancer cells.

with osteoarthritis severity in serum and synovial fluid, whereas the levels of cathepsin S are more correlated with synovitis and rheumatoid arthritis.

Another protease that we focused on was cathepsin K, which is a major target in osteoporosis treatment. In collaboration with colleagues from the Institute of Chemistry (dr. M. Novič), we developed a series of cathepsin K inhibitors based on an N-(functionalized benzoyl)-homocycloleucyl-glycinonitrile scaffold, using a combination of virtual combinatorial chemistry, QSAR modeling, and molecular docking studies. In order to avoid previous problems of cathepsin K inhibitors associated with lysosomotropism of compounds with a basic character that resulted in off-target effects, a weakly-to-non-basic moiety was incorporated into the P3 position. Three compounds were highly selective for cathepsin K when compared with cathepsins L and S, with the Ki values in the range 10–30 nM. Kinetic studies revealed that the new compounds exhibited reversible tight binding to cathepsin K, while the X-ray structural studies showed covalent and noncovalent binding between the nitrile group and the catalytic cysteine (Cys25) site (Figure 2). This work thus shows a potential for the development of novel osteoporosis inhibitors that would also have therapeutic potential *in vivo*. Together with colleagues from the University of Ljubljana and the University of Vienna (dr. K. Djinovic Carugo) we also continued our studies on Trop2, a transmembrane signaling glycoprotein upregulated in stem and carcinoma cells, which is structurally related to thyropins, endogenous inhibitors of cysteine cathepsins. Via its cytosolic part, Trop2 influences the expression of cell-proliferation-linked genes. We determined the structure of its cytosolic part in two forms (non-phosphorylated and phosphorylated) and showed how phosphorylation (also observed in vivo) affects its structure and potentially affects the interactions of Trop2 with other signaling proteins. Since the cytosolic part undergoes such considerable conformational changes we termed it a structural switch. The results are important for understanding the signaling processes as well as for the development of therapies targeting the signaling complexes of Trop2.

Another inhibitor that we focused on was stefin B, the major general cytosolic protein inhibitor of cysteine cathepsins. Its main function is to protect the organism against the activity of endogenous potentially hazardous proteases accidentally released from lysosomes. In this study, we investigated the possible effect of endosomal/lysosomal aspartic cathepsins D and E on stefin B after membrane permeabilization. A loss of membrane integrity of the lysosomes and endosomes was induced by a lysosomotropic agent L-Leucyl-L-leucine methyl ester (Leu-Leu-OMe). Permeabilization of acid vesicles from FRTL-5 cells induced the degradation of stefin B. The process was inhibited by pepstatin A, a potent inhibitor of aspartic proteases. However, the degradation of stefin B was only prevented by the siRNA-mediated silencing of cathepsin D expression, but not cathepsin E, suggesting that cathepsin D and not cathepsin E degrades stefin B. It can therefore be concluded that the presence of cathepsin D in the cytosol affects the inhibitory potency of stefin B, thereby preventing the regulation of cysteine cathepsin activities in various biological processes.

Finally, we focused on the autophagy-related cysteine proteases Atg4.1 and Atg4.2 from the parasite Trypanosoma cruzi. The causative agent of the Chagas disease T. cruzi autophagin-2 (TcAtg4.2) carries the majority of the proteolytic activity and is responsible for processing the Atg8 proteins near the carboxyl terminus, exposing a conserved glycine. This enables the progression of autophagy and the differentiation of the parasite, which is required for the successful colonization of humans. Using the positional scanning-substrate combinatorial library (PS-SCL) we determined that TcAtg4.2 tolerates a broad spectrum of amino acids in the P4 and P3 positions, similar to the human orthologue autophagin-1 (HsAtg4B). In contrast, both human and trypanosome Atg4 orthologues exhibited an exclusive preference for aromatic amino acid residues in the P2 position, and for Gly in the P1 position, which is absolutely conserved in the natural Atg8 substrates. We generated the highly selective tetrapeptide substrates acetyl-Lys-Lys-Cha-Gly-AFC (Ac-KKChaG-AFC) and acetyl-Lys-Thr-Cha-Gly-AFC (Ac-KTChaG-AFC) that were not recognized by the human orthologue in vitro, thereby providing excellent tools for the in-vitro screening of potential inhibitors of T. Cruzi autophagin 2 as a potential target for Chagas disease treatment.

Our department has, partially through the help of the Center of Excellence for Integrative approaches for Chemistry and Biology of Proteins (CIPKEBIP), established several technological platforms that are all unique in Slovenia and include a structural biology platform, a proteomics platform and a whole-body imaging platform, based on the IVIS Spectrum imaging system. All three platforms are open for external collaborations and several works resulting from these collaborations have already been published.

We participated in the FP7 project Alexander and were also involved in the Slovenian Center of Excellence CIPKEBIP, which we also coordinate. In addition, there are numerous other international collaborations with excellent research teams from different countries including Belgium (a joint project through FWO), France, Germany, Sweden, Switzerland, UK, USA, Australia and Japan, which resulted in joint publications.

In addition, several members of the department were invited to give lectures at international symposia and foreign universities.

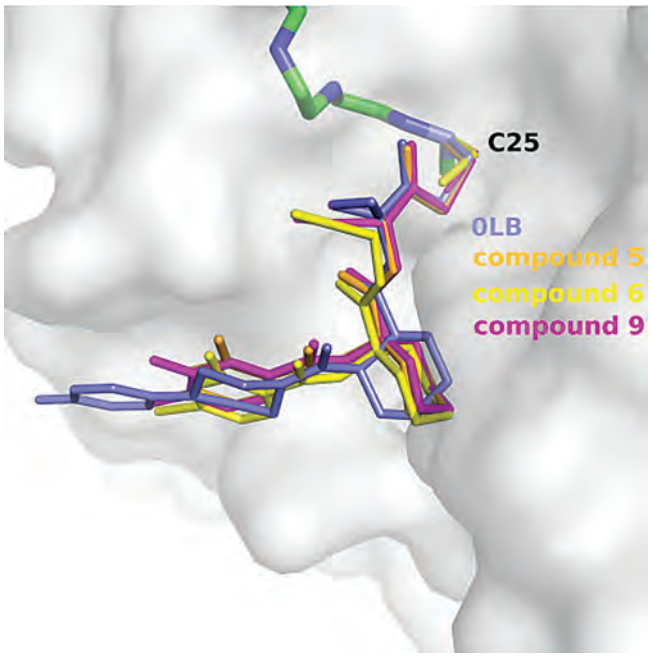

Figure 2: Superposition of the crystal structures of cathepsin K with nitrile inhibitors compounds 5, 6 and 9

Some outstanding publications in the past year

1. Sobotič B, Vizovišek M, Vidmar R, Van Damme P, Gocheva V, Joyce JA, Gevaert K, Turk V, Turk B*, Fonović M*. (2015) Proteomic identification of cysteine cathepsin substrates shed from the surface of cancer cells. Mol Cell Proteomics. 14, 2213-2228. (*shared last authors)
2. Repnik U, Starr AE, Overall CM*, Turk B.* (2015) Cysteine cathepsins activate ELR chemokines and inactivate non-ELR chemokines. J. Biol. Chem. 290, 13800-13811. (*shared last authors)
3. Rajković J, Poreba M, Caglič D, Vidmar R, Wilk A, Borowik A, Salvesen G, Turk V, Drag M, Turk B. (2015) Biochemical characterization and substrate specificity of autophagin-2 from the parasite Trypanosoma cruzi. J Biol Chem. 290, 28231-28244.
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5. Mirković B*, Markelc B*, Butinar M*, Mitrovič A, Sosič I, Gobec S, Vasiljeva O, Turk B, Čemazar M, Serša G, Kos J. (2015) Nitroxoline impairs tumor progression in vitro and in vivo by regulating cathepsin B activity. Oncotarget 6, 19027-19042. (*shared first authors).
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7. Pavšič M, Ilc G, Vidmar T, Plavec J, Lenarčič B. (2015) The cytosolic tail of the tumor marker protein Trop2–a structural switch triggered by phosphorylation. Sci Rep. 5:10324. doi: 10.1038/srep10324.

Organisation of conferences, congresses and meetings

1. 32th Winter School on Proteases and their Inhibitors, Tiers, Italy, 25 February – 1 March 2015, co-organisers

Patent granted

1. James William West, Jason Sagert, Paul H. Bessette, Henry Berbard Lowman, Nancy E. Stagliano Stagliano, Olga Vasiljeva, Elizabeth Menendez, Anti-jagged 1/jagged 2 cross-reactive antibodies, activatable anti-jagged antibodies and methods of use thereof, US9127053 (B2), US Patent Office, 8. 09. 2015.

INTERNATIONAL PROJECTS

1. Supply of DPPI Enzyme and the Non-exclusive License Rights
   Prof. Dušan Turk
   Prozymex A/s
2. 7FP - ALEXANDER; Mucus Permeating Nanoparticulate Drug Delivery Systems
   Asst. Prof. Olga Vasiljeva
   European Commission
3. The Association Between Breast Cancer and Cathepsins and its Related Gene Expression
   Prof. Vito Turk
   Slovenian Research Agency
4. MD Simulations of the Initial Steps in Oligomerization of an Amyloidogenic Protein Human Stefin B; Complex of Stefin B Oligomers with A-beta
   Prof. Eva Žerovnik
   Slovenian Research Agency

RESEARCH PROGRAMS

1. Structural biology
   Prof. Dušan Turk
2. Proteolysis and its regulation
   Prof. Boris Turk

R & D GRANTS AND CONTRACTS

1. Nitroxoline and its derivatives as new antitumour drugs
   Asst. Prof. Olga Vasiljeva
2. The role of micro RNA-21 and cathepsins in delayed preconditioning to acute kidney injury
   Prof. Boris Turk
3. Role of cysteine proteases in the process of cancerogenesis
   Prof. Marko Fonović
4. Role of cysteine cathepsins in inflammation-associated diseases
   Prof. Boris Turk
5. Proteases in inflammation and cell death
   Prof. Boris Turk
6. Lysosomotropic agents and polyketide compounds as potential therapeutics for cancer treatment
   Dr. Maruša Hafner Česen
7. In Vitro Studies to evaluate the Antitumor Activity and Toxicity of Low-Dimensional Al-Hydroxide
   Prof. Boris Turk
8. Study in Vitro the Antitumor Activity and Toxicity of Low-Dimensional Biocomponent Nanostructures
   Prof. Boris Turk

NEW CONTRACT

1. Mass spectromety analysis
   Prof. Boris Turk
   Krka, Tovarna Zdravil, d. d.

VISITORS FROM ABROAD

1. Andrey Kadin, Shemyakin and Ovchinnikov Institute of Bioorganic Chemistry, Russian Academy of Science, Moscow, Russia, 1 January – 31 December 2015 (IJS fellowship holder)
2. Prof. Gareth Wyn Griffiths, Section for Physiology and Cell Biology, University of Oslo, Oslo, Norway, 2 February 2015
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4. Dr Heinz Schwarz, Max Planck Institute for Developmental Biology, Tübingen, Germany, 2 February 2015
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46. Gregor Pretnar
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Note:
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Original Article

1. Pavel Afonine, Nigel W. Moriarty, Marat Mustyakimov, Oleg V. Sobolev, Thomas Charles Terwilliger, Dušan Turk, Alexandre Urzhumtsev, Paul D. Adams, "FEM: feature-enhanced map", *Acta crystallogr., D, Biol. crystallogr.*, vol. 71, part 3, pp. 646-666, 2015.
2. Stefan Baumeister, Preetish Gangopadhyay, Urška Repnik, Klaus Lingelbach, "Novel insights into red blood cell physiology using parasites as tools", *Eur. j. cell biol.*, vol. 94, no. 7/9, pp. 332-339, 2015.
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5. Aleš Berlec, Janja Završnik, Miha Butinar, Boris Turk, Borut Štrukelj, "In vivo imaging of Lactococcus lactis, Lactobacillus plantarum and Escherichiacoli expressing infrared fluorescent protein in mice", *Microb Cell Fact*, vol. 14, no. 181, pp. 1-14, 2015.
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9. Sandra Kissing *et al.* (12 authors), "Vacuolar ATPase in phagosome-lysosome fusion", *J Biol Chem*, vol. 290, no. 22, str. 14166-14180, 2015.
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14. Bojana Mirković, Boštjan Markelc, Miha Butinar, Ana Mitrović, Izidor Sosič, Stanislav Gobec, Olga Vasiljeva, Boris Turk, Maja Čemažar, Gregor Serša, Janko Kos, "Nitroxoline impairs tumor progression in vitro and in vivo by regulating cathepsin B activity", *Oncotarget*, vol. 6, no. 22, pp. 19027-19042, 2015.
15. Narges Naseri, Aji P. Mathew, Lenart Girandon, Mirjam Fröhlich, Kristiina Oksman Niska, "Porous electrospun nanocomposite mats based on chitosan-cellulose nanocrystals for wound dressing: effect of surface characteristics of nanocrystals", *Cellulose (Lond.)*, vol. 22, no. 1, pp. 521-534, 2015.
16. Melanie Niemer, Urlich Mehofer, Maria Verdianz, Andreas Porodko, Philipp Schähs, Daniel Kracher, Brigita Lenarčič, Marko Novinec, Lukas Mach, "Nicotiana benthamiana cathepsin B displays distinct enzymatic features which differ from its human relative and aleurain-like protease", *Biochimie (Paris)*, pp. 1-7.
17. Lovrenc Novak, Benjamin Bizjan, Jure Pražnikar, Boris Horvat, Alen Orbanić, Brane Širok, "Numerical modeling of dust lifting from a complex-geometry industrial stockpile", *Stroj. vestn.*, vol. 61, no. 11, pp. 621-631, Nov. 2015.
18. Miha Pavšič, Gregor Ilc, Tilen Vidmar, Janez Plavec, Brigita Lenarčič, "The cytosolic tail of the tumor marker protein Trop2 - a structural switch triggered by phosphorylation", *Scientific reports*, vol. 5, pp. 1-14, May 2015.
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20. Katja Pirc, Miha Škarabot, Lea Pogačnik, Eva Žerovnik, Nataša Poklar Ulrih, "The effect of tyrosine residues on [alpha]-synuclein fibrillation", *Acta chim. slov.*, vol. 62, no. 1, pp. 181-189, 2015.
21. Jelena Rajković, Marcin Poreba, Dejan Caglič, Robert Vidmar, Aleksandra Wilk, Agata Borowik, Guy S. Salvesen, Vito Turk, Marcin Drag, Boris Turk, "Biochemical characterization and substrate specificity of autophagin-2 from the parasite trypanosoma cruzi", *J Biol Chem*, vol. 290, iss. 47, pp. 28231-28244, 2015.
22. Urška Repnik, Preetish Gangopadhyay, Sven Bietz, Jude M. Przyborski, Gareth Griffiths, Klaus Lingelbach, "The apicomplexan parasite Babesia divergens internalizes band 3, glycophorin A and spectrin during invasion of human red blood cells", *Cell. microbiol.*, vol. 17, no. 7, str. 1052-1068, 2015.
23. Urška Repnik, Amanda E. Starr, Christoper M. Overall, Boris Turk, "Cysteine cathepsins activate ELR chemokines and inactivate non-ELR chemokines", *J Biol Chem*, vol. 290, no. 22, pp. 13800-13811, 2015.
24. Nataša Resnik, Urška Repnik, Mateja Erdani-Kreft, Kristina Sepčić, Peter Maček, Boris Turk, Peter Veranič, "Highly selective anti-cancer activity of cholesterol-interacting agents methyl-beta-cyclodextrin and ostreolysin A/pleurotolysin B protein complex on urothelial cancer cells", *PloS one*, vol. 10, iss. 9, pp. 1-19, 2015.
25. Amrita Roy Choudhury, Emilia Sikorska, Johannes van den Boom, Peter Bayer, Łukasz Popenda, Kosma Szutkowski, Stefan Jurga, Massimiliano Bonomi, Andrej Šali, Igor Zhukov, Sabina Passamonti, Marjana Novič, "Structural model of the bilitranslocase transmembrane domain supported by NMR and FRET data", *PloS one*, vol. 10, iss. 8, pp. 1-16, e0135455, Aug. 2015.
26. Barbara Sobotič, Matej Vizovišek, Robert Vidmar, Petra Van Damme, Vasilena Gocheva, Johanna A. Joyce, Kris Gevaert, Vito Turk, Boris Turk, Marko Fonović, "Proteomic identification of cysteine cathepsin substrates shed from the surface of cancer cell", *Molecular & cellular proteomics*, vol. 14, no. 8, pp. 2213-2228, 2015.
27. Marko Šnajder, Marko Mihelič, Dušan Turk, Nataša Poklar Ulrih, "Codon optimisation is key for pernisine expression in Escherichia coli", *PloS one*, vol. 10, no. 4, pp. 1/16-16/16, e0123288, 2015.
28. Nataša Tešić, Urška Kamenšek, Gregor Serša, Simona Kranjc, Monika Štimac, Urša Lampreht Tratar, Véronique Préat, Gaëlle Vandermeulen, Miha Butinar, Boris Turk, Maja Čemažar, "Endoglin (CD105) silencing mediated by shRNA under the control of Endothelin-1 promoter for targeted gene therapy of Melanoma", *Mol. ther., Nucleic acids*, no. 4, May 2015.
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31. Marija Vukomanović, Urška Repnik, Tina Zavašnik-Bergant, Rok Kostanjšek, Srečo D. Škapin, Danilo Suvorov, "Is nano-silver safe within bioactive hydroxyapatite composites?", *ACS biomater. sci. eng.*, vol. 1, no. 10, pp. 935-946, 2015.
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34. Matjaž Žganec, Eva Žerovnik, Brigita Urbanc, "Assembly of Stefin B into polymorphic oligomers probed by discrete molecular dynamics", *J. chem. theory comput.*, vol. 11, issue 5, pp. 2355-2366, 2015.

Review Article

1. Nataša Kopitar-Jerala, "Innate immune response in brain, NF-kappa B signaling and cystatins", *Front. mol. neurosci.*, vol. 8, pp. 73-1-73-9, 2015.
2. Nataša Kopitar-Jerala, "The role of stefin B in neuro-inflammation", *Front. cell. neurosci.*, vol. 9, pp. 458-1-458-8, 2015.

Published Conference Contribution

1. Lovrenc Novak, Benjamin Bizjan, Jure Pražnikar, Boris Horvat, Alen Orbanić, Brane Širok, "Numerično modeliranje vetrovnih razmer in zmanjšanja prašenja na deponiji premoga in železove rude v Luki Koper", In: *Zbornik del*, Kuhljevi dnevi 2015, Moravske Toplice, 24.-25. september, 2015, Matjaž Hriberšek, ed., Jure Ravnik, ed., Ljubljana, Slovensko društvo za mehaniko, 2015, pp. 113-120.
2. Katarina Starkl, Lovro Kramer, Boris Turk, Jernej Iskra, "Sinteza in protitumorsko delovanje nesimetričnih 1,2,4,5 - tetraoksanov", In: *Zbornik referatov in povzetkov*, Slovenski kemijski dnevi 2015, Ljubljana, 24. - 25. september 2015 = Slovenian Chemical Days 2015, Ljubljana, September 24 - 25, 2015, Venčeslav Kaučič, ed., et al, Ljubljana, Slovensko kemijsko društvo, 2015, 6 pp.

Independent Component Part or a Chapter in a Monograph

1. Urška Repnik, Maruša Hafner Česen, Boris Turk, "Strategies for assaying lysosomal membrane permeabilization", In: *Cell death techniques: a laboratory manual*, Ricky W. Johnstone *et al.*, ed., New York, Cold Spring Harbor Laboratory Press, [2015], pp. 225-229.
2. Urška Repnik, Maruša Hafner Česen, Boris Turk, "The use of lysosomotropic dyes to exclude lysosomal membrane permeabilization", In: *Cell death techniques: a laboratory manual*, Ricky W. Johnstone *et al.*, ed., New York, Cold Spring Harbor Laboratory Press, [2015], pp. 230-235.
3. Urška Repnik, Maruša Hafner Česen, Boris Turk, "Measuring cysteine cathepsin activity to detect lysosomal membrane permeabilization", In: *Cell death techniques: a laboratory manual*, Ricky W. Johnstone *et al.*, ed., New York, Cold Spring Harbor Laboratory Press, [2015], pp. 236-241.
4. Urška Repnik, Maruša Hafner Česen, Boris Turk, "Studying lysosomal membrane permeabilization by analyzing the release of preloaded BSA-golc particles into the cytosol", In: *Cell death techniques: a laboratory manual*, Ricky W. Johnstone *et al.*, ed., New York, Cold Spring Harbor Laboratory Press, [2015], pp. 242-247.

Patent Application

1. Gopal Datta, Carsten Schultz, Oliver Plettenburg, Michael Kurtz, Michael Podeschwa, Guenter Billen, Herbert Kogler, Boris Turk, Matej Vizovišek, *Caspase-1 imaging probes*, EP2848696 (A1), European Patent Office, 18. 03. 2015.

Patent

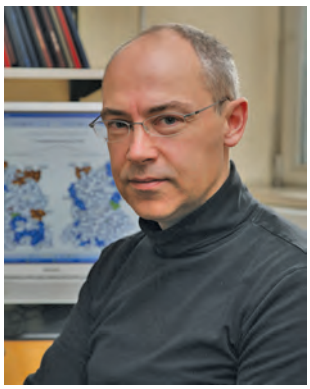
1. James William West, Jason Sagert, Paul H. Bessette, Henry Berbard Lowman, Nancy E. Stagliano Stagliano, Olga Vasiljeva, Elizabeth Menendez, *Anti-jagged 1/jagged 2 cross-reactive antibodies, activatable anti-jagged antibodies and methods of use thereof,* US9127053 (B2), US Patent Office, 8. 09. 2015.

Mentoring

1. Barbara Jerič, *Functional characterization of human cathepsin F pathophysiological mutations:* doctoral dissertation, Ljubljana, 2015 (mentor Veronika Stoka).
2. Jelena Rajković, *The role of autophagins and Atg8 ubiquitin-like conjugation system in the parasite Trypanosoma cruzi and mammals:* doctoral dissertation, Ljubljana, 2015 (mentor Boris Turk).
3. Barbara Sobotič, *Role of cysteine cathepsins in extra- and intracellular signalization:* doctoral dissertation, Ljubljana, 2015 (mentor Boris Turk; co-mentor Marko Fonović).
4. Tajana Zajc, *Vpliv katepsina E na aktivnost cisteinskih katepsinov:* doctoral dissertation, Ljubljana, 2015 (mentor Vito Turk).
5. Blaž Andlovic, *Cloning and expression of the protein RANKL gene and its effect on the secretion of lysosomal cathepsins:* master's thesis, Ljubljana, 2015 (mentor Boris Turk).
6. Tjaša Berčič, *Vpliv cistatina C na rast tumorjev pri alograftnem transplantiranem mišjem modelu raka mlečne žleze:* master's thesis, Ljubljana, 2015 (mentor Boris Turk).
7. Andreja Bratovš, *Ciljanje katepsina S z liposomi konjugiranimi s stefinom A pri vnetjih:* master's thesis, Ljubljana, 2015 (mentor Boris Turk).
8. Tamara Marić, *Preučevanje interakcije med človeškim prokatepsinom B in lahko verigo heterotetramernega kompleksa aneksin A2 (p11):* master's thesis, Ljubljana, 2015 (mentor Boris Turk).
9. Dino Šćuk, *Priprava rekombinantnega človeškega prokatepsina F:* master's thesis, Ljubljana, 2015 (mentor Brigita Lenarčič).
10. Andreja Urlaub, *Binding of tick cystatin OmC2 to cathepsin C in differentiated MUTZ-3 cells:* master's thesis, Ljubljana, 2015 (mentor Boris Turk; co-mentor Tina Zavašnik Bergant).

DEPARTMENT OF MOLECULAR AND BIOMEDICAL SCIENCES B-2

The research program of the Department of Molecular and Biomedical Sciences is focused mainly 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

New substances, molecular tools and procedures to improve human and animal health.

Toxinology

Secreted phospholipases A2

One of the major research topics of the department is secreted phospholipases A_2 ($sPLA_2$s) originating from animal venoms that are toxic to humans. We are studying the molecular mechanisms of the toxic actions of these molecules, particularly their presynaptic neurotoxicity. The knowledge gained from working on snake venom $sPLA_2$s is a valuable tool for studying the pathological and physiological roles of the mammalian $sPLA_2$ orthologues.

Ammodytoxin A (AtxA) is a presynaptically neurotoxic $sPLA_2$ from the venom of the nose-horned viper (*Vipera ammodytes ammodytes*). In order to gain a further insight into the role of the phospholipase activity of this molecule in its toxicity we produced a recombinant, enzymatically inactive form of AtxA, AtxA(D49S). This mutant was shown to co-localize with synaptotagmin 1 (Syt1), cytochrome c oxidase subunit II (CcO), protein disulphide isomerase (PDI) and 14-3-3p in PC12 cells, which are used as a model in our laboratory to study the cellular dynamics of AtxA. Compared to the enzymatically active AtxA, the level of co-localization of the enzymatically inactive AtxA was lower with all of the proteins mentioned. In the case of CcO and Syt1, this effect was far more pronounced in the non-differentiated (ND) cells compared to the differentiated (NGFD) cells, indicating that the phospholipase activity enhances the internalization and intracellular trafficking of AtxA to synaptic vesicles and mitochondria to a greater extent in ND cells than in NGFD cells. This suggests that in NGFD cells, the mechanisms leading to the co-localization of both AtxA and AtxA(D49S) with the above-mentioned binding proteins, utilize more specific processes than in ND cells. NGFD cells seem to have specific pathways of AtxA internalization and intracellular trafficking that are not dependent on the AtxA's enzymatic activity. Additionally, the release of cytochrome c from mitochondria isolated from PC12 cells, caused by AtxA, was determined to be clearly PLA_2-activity dependent, since the enzymatically inactive mutant AtxA(D49S) was unable to elicit this effect.

AtxA also binds the PDI in the lumen of the endoplasmic reticulum (ER) of PC12 cells *in vivo*. In a recently published paper we suggested that this interaction is important for the translocation of AtxA from the extracellular space into the cytosol of the cell (J. Oberčkal et al., *PLoS One*, 10 (2015), e0120692). Besides assisting the AtxA to migrate retrogradely from the Golgi apparatus to the ER, PDI can also help the AtxA to translocate across the ER membrane. The results reported here also strongly support the hypothesis that PDI partakes in the retrograde cellular transport of mammalian $sPLA_2$s, structurally related to AtxA. The $sPLA_2$–PDI model that we present provides a detailed structural insight into the interaction between these proteins (Figure 1), enabling a targeted study of the $sPLA_2$ cell-internalization process.

The Springer publishing company invited us to prepare a chapter for their monograph Snake Venoms, which is currently in press (D. Kordiš and I. Križaj, Handbook on Toxinology, Springer (2015), ISBN: 78-94-007-6648-8). Amongst other things, we presented in the article a critical overview of all the important results on the action of presynaptically neurotoxic $sPLA_2$s, and based on them proposed a hypothesis about the mechanism of action for these toxins and suggested experimental approaches to test it.

As experts from the field of toxinology, we have been invited as lecturers on expert meetings and scientific conferences. Most worthy of mention are the invitations to the very well attended Toxicology 2015 meeting organized

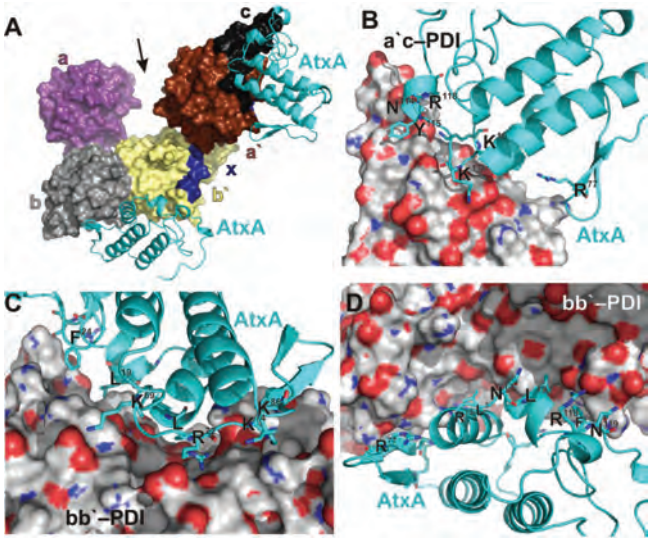


*Figure 1: **Three-dimensional model of the complex between AtxA and PDI.** (A) Molecular modelling resulted in two solutions for AtxA binding to PDI. Both solutions are displayed on the same molecule of PDI. Arrow points towards the active side of PDI. According to the first solution (B), AtxA binds to PDI between domains a' and c of PDI (a'c-model or binding site), while according to the second solution (C and D), AtxA binds at domains b and b' (bb'-model or binding site). In the case of human PDI only the bb'-model is possible.*

by the Slovenian Medical Society in Ljubljana (I. Križaj) and to the World Congress of the International Society on Toxinology–IST in Oxford (I. Križaj).

Other pharmacologically active components from natural venoms

In 2015 we continued with the systematic analysis of the venom components (venom proteomics or venomics) of the nose-horned viper (*Vipera ammodytes ammodytes*) and the common adder (*Vipera berus berus*) venoms. We have been analysing proteomic data and complemented them with the transcriptomic data obtained by an analysis of the nose-horned viper venom gland cDNA library. Two publications are in preparation.

Figure 2: ***From the 45th Krka Award ceremony for the best high-school research achievements.*** *The awarded team of students from the Jurij Vega High School in Idrija with their tutor from our department Dr. Adrijana Leonardi and the High School Headmaster. Dr. Toni Petan, the co-tutor from the Jožef Stefan Institute, did not attend the ceremony. Source: Archive of Krka pharmaceutical company, Novo mesto.*

We intensively studied the snake venom proteins that affect the blood coagulation process–haemostasis. In this area of research, we succeeded in publishing a structural and biochemical description of a monomeric alfa-fibrinogenolytic metalloproteinase, VaF1 (A. Leonardi et al., *Biochimie* 109 (2015), 78–87). VaF1 would be expected to exert an anticoagulant action due to its hydrolysis of fibrinogen, factor X, prothrombin and plasminogen, *i.e.*, plasma proteins involved in blood coagulation. In standard experimental conditions, VaF1 was not recognised by antiserum against the whole venom; therefore, it tentatively contributes to post-serotherapy complications, such as ineffective blood coagulation, in the envenomed patient.

In 2015, two additional interesting groups of molecules from the venom of the nose-horned viper attracted our attention, namely disintegrins and CRISPs (Cysteine RIch Secretory Proteins). Disintegrins are polypeptides that bind to integrin molecules and impair in this way their function. This subject was a research topic of a student team from the Jurij Vega High School in Idrija that worked at the department under our supervision. Our results demonstrated that these molecules efficiently prevent migration and thus the spreading of cancer cells. This confirms their anti-metastatic potential and gives a good perspective for their development in the direction of a new anti-cancer drug. The high-school research work has been recognised with the prestigious Krka Award (Figure 2) and achieved also a resounding international success by winning the first place at the South America's largest international natural sciences and technology contest Mostratec in Brazil.

CRISPs are toxic and they block ion channels in different cells, causing, for example, the paralysis of peripheral smooth muscles and hypothermia. In this year we looked for the physiological effects of CRISPs isolated from the nose-horned viper venom in different experimental settings in collaboration with our colleagues at the Veterinary Faculty, University of Ljubljana (UL) and Strathclyde University in Glasgow (Scotland, UK). Unfortunately, we still do not have a clear interpretation of the action of these proteins.

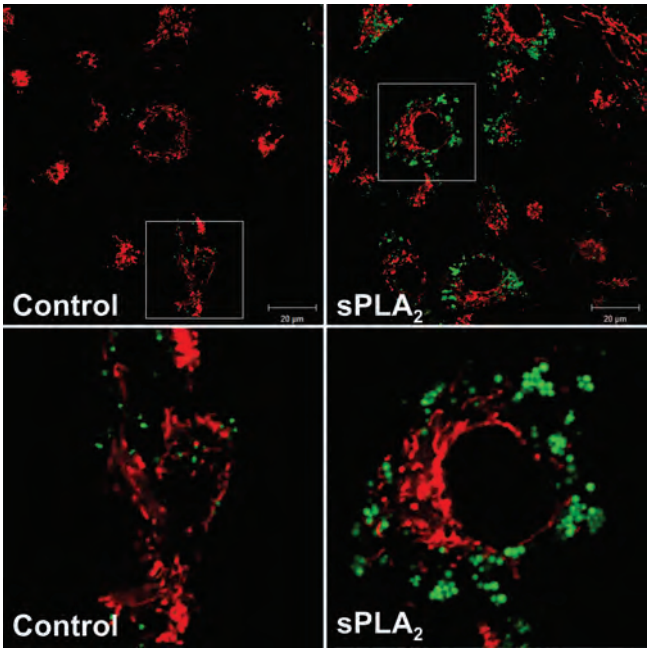


Figure 3: ***The human sPLA$_2$-X enzyme induces the formation of lipid droplets in breast-cancer cells.*** *Control cells are on the left-hand side and sPLA$_2$-treated cells on the right. Mitochondria were stained with Mitotracker Red (red signal), while lipid droplets were visualized using neutral-lipid specific staining with the BODIPY 493/503 fluorescent dye. The photographs were acquired using a Zeiss LSM 710 confocal microscope.*

Lipid metabolism and signalization

Changes in lipid metabolism in cancer are novel therapeutic targets

Dysregulated lipid metabolism is a fundamental metabolic alteration that enables cancer-cell survival and sustains rapid growth and proliferation. An increased availability of fatty acids (FAs), either through *de novo* synthesis in tumour cells or from exogenous sources, is needed for the synthesis of membranes and signalling molecules that are indispensable for tumour growth, and limiting FA supply may prevent cell proliferation in tumours. The transformed properties of cancer cells depend on changes in lipolysis, FA oxidation, membrane phospholipid hydrolysis and reacylation pathways, and the provision of FAs from the circulation. Discovering the weakest points in the core of these metabolic requirements in lipid metabolism has thus a strong therapeutic potential.

Mammalian sPLA$_2$s are lipolytic enzymes that hydrolyse membrane phospholipids to liberate free FAs and lysophospholipids. The group X sPLA$_2$ (sPLA$_2$-X) is the most potent mammalian sPLA$_2$ in hydrolysing cell membranes and its activity leads to the release of a mixture of mono- and polyunsaturated FAs (PUFAs), including omega-6 and omega-3 PUFAs, which have many downstream signalling and metabolic effects. We have recently reported a novel mechanism of action of sPLA$_2$-X in cancer, describing for

the first time a relationship between membrane hydrolysis, changes in lipid accumulation and breast-cancer cell survival. We have found that $sPLA_2$-X induces lipid droplet (LD) formation (Figure 3), stimulates FA oxidation and suppresses lipogenesis. These metabolic changes in turn augment cell proliferation and prevent cell death during metabolic stress. LDs are newly recognized organelles composed of a core of neutral lipids, including triacylglycerol (TAG) and cholesterol esters, and are covered with a phospholipid monolayer and LD-associated proteins. They are not passive repositories of energy, but act as platforms integrating cell signalling and metabolism, and elevated amounts of LDs have been discovered in the tumour tissue of cancer patients. Our recent unpublished data show that, besides breast cancer, $sPLA_2$-X induces LD formation in other cancer cells *in vitro*, such as colorectal, ovarian, endometrial, neuroblastoma, leukaemia and cervical cancer cells. This suggests that its effects on lipid metabolism are not restricted to breast-cancer cells. We have also found that the exogenous addition of PUFAs to cancer cells mimics the effect of $sPLA_2$-X on lipid accumulation, but in contrast to oleic acid and $sPLA_2$-X, they are toxic to highly invasive cells. Currently, we are using quantitative PCR and proteomic analyses to identify changes in the amount and composition of LD-associated proteins in breast-cancer cells with large amounts of $sPLA_2$-induced LDs. We have also identified two inhibitors with therapeutic potential for the simultaneous reduction of LD accumulation and cancer-cell survival.

The activity of our group in the field of $sPLA_2$ is also evidently well known to the editors of the *Digestive Diseases and Sciences* as they invited us to write an editorial about the role of enzyme $iPLA_2\beta$ in the maintenance of intestinal homeostasis and its possible association with the occurrence of the ulcerative colitis (T. Petan and I. Križaj, *Dig. Dis. Sci.*, 60 (2015), 3504–3506).

High-throughput genetics and functional genomics in yeast *Saccharomyces cerevisiae*

The recent development of genomics enabled the transfer of the polygenic trait analysis methods into biotechnological applications of new cell factories' design. In 2015 we continued coordinating a European consortium whose aim is to combine these methods with metabolic engineering and synthetic biology tools to develop a new generation cell factories (M. Kavšček et al., *Microb. Cell Fact.*, 14 (2015), 94). Such cell factories will play an important role in the development of a bioeconomy for the production of biofuels (U. Petrovič, *Yeast*, 32 (2015), 583–593) and other compounds that are currently made from non-sustainable feedstocks.

In the field of inter-organelle communication, currently one of the hottest topics within cell biology, we demonstrated a new way of interaction between mitochondria and peroxisomes (Figure 4), based on the interaction between the ERMES complex and the peroxisomal protein Pex11 (M. Mattiazzi Ušaj et al., *J. Mol. Biol.*, 427 (2015), 2072–2087). The paper attracted a lot of attention and paved the way for some additional interpretations of the organization of eukaryotic cells that until now were considered non-conventional.

We also published the results of the longer-term study on the physiological interconnection between zinc and yeast adiponectin receptor homolog (M. Mattiazzi Ušaj et al., *Metallomics*, 7 (2015), 1338–1351). It is expected that the results of this study on the model organism will spur new ideas for the control or treatment of metabolic syndrome and type-2 diabetes, two of the currently most severe medical problems of our civilization in which the adiponectin receptor plays an important role.

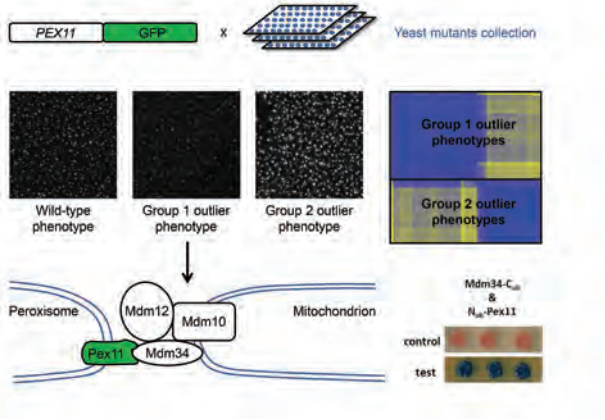


Figure 4: ***Genome-wide study was performed to analyse the localization of Pex11, a peroxisomal protein.*** *Bioinformatics algorithms were used to predict the molecular basis for the observed phenotypes and a corresponding model. Validity of the model of the interaction between Pex11 and ERMES complex components was confirmed with follow-up experiments.*

Analysis of genomes

Evolutionary genomics

Early evolutionary analyses of $sPLA_2$ toxins in venomous animals took place in the "pre-genomic era", and were based on a small sample of taxonomic diversity and diversity within the $sPLA_2$ toxins. Since then, the number of representatives has increased significantly, largely due to the accumulation of the venom transcriptomic resources since the large genomic data regarding $sPLA_2$ toxins in venomous animals are still very sparse. In the book chapter (D. Kordiš and I. Križaj, *Handbook on Toxinology*, Springer (2015), ISBN: 78-94-007-6648-8) we highlighted how the progress in the past decade has increased our understanding of the evolution of $sPLA_2$ toxins in venomous animals (Figure 5).

RNA viruses are common pathogens of humans, animals and economically important plants, which is why they have a large influence on the economy, medicine, agriculture and technology. Numerous studies have been conducted about the RNA viruses in insects since they represent major vectors for the transmission of these viruses. The knowledge about RNA viruses in butterflies and moths (Lepidoptera) was until now quite limited. In the lepidopteran transcriptomes we found 12 novel families of RNA viruses. We found two new families of double

stranded RNA viruses (*Partitiviridae* and *Totiviridae*), seven new families of single stranded RNA(+) viruses (*Betaflexiviridae*, *Dicistroviridae*, *Narnaviridae*, *Negevirus*, *Potyviridae*, *Tombusviridae* and *Virgaviridae*) and three new families of single stranded RNA(-) viruses (*Bunyaviridae*, *Nyamiviridae* and *Orthomyxoviridae*). Only single stranded RNA viruses (*Nyamiviridae*, *Orthomyxoviridae*, *Rhabdoviridae*, *Negevirus*, *Virgaviridae*) have been found endogenised in the lepidopteran genomes. We found that lepidopterans can transmit five families of plant-specific RNA viruses. Analysis of the transcriptomes and genomes has shown that butterflies contain numerous novel families of RNA viruses.

In the field of cysteine proteases and their inhibitors (cystatins) we studied the origin and evolution of 11 orthologous gene families that are present in evolutionary older lineages of vertebrates. The cystatin superfamily contain 20 orthologous families in vertebrates and we analysed the following orthologous gene families: cystatin C, cystatin F, cystatin E/M, latexin, TIG1, cathelicidin, Spp24, fetuin A, fetuin B, HRG and kininogen. Functional diversification of the cystatin superfamily in vertebrates was connected to the loss of their inhibitory activity and the gain of novel biological roles. To explain the functional diversification of the cystatin superfamily, we clarified the origin and evolution of the above-mentioned orthologous gene families. We found that the cystatin superfamily was involved in several "vertebrate innovations", such as skeletogenesis and adaptive immune system, and important roles were gained in innate immunity and reproduction. Novel vertebrate cathepsins also adopted important roles in adaptive immune system and skeletogenesis. We explained the co-evolution of orthologous gene families of the cystatin superfamily with their interaction partners (cathepsins and some novel proteins) and their involvement in the newly gained systems of vertebrates.

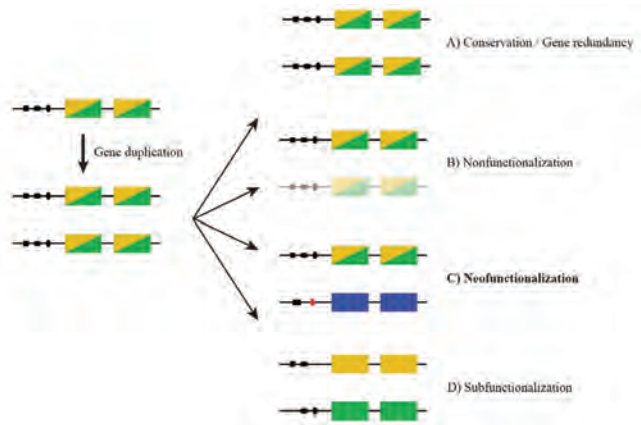


Figure 5: ***Evolutionary fates of gene copies after duplication.*** *On the left-hand side, schematic representation of a gene undergoing gene duplication (exons are depicted as yellow/green blocks and regulatory elements as geometric forms). On the right-hand side, the four major possible evolutionary fates of the copies are represented: (a) both copies remain essentially unchanged and functionally redundant (conservation/gene redundancy). (b) One of the gene copies is deleted from the genome (or pseudogenized), restoring the initial situation (nonfuntionalization). (c) One of the copies accumulates mutations in its coding sequence and/or associated regulatory elements (in red and blue), thereby acquiring new gene functions (neofunctionalization). (d) Coding sequences and regulatory elements may also evolve and be partitioned according to the specific roles played by each subfunctionalized gene copy (exons indicated as yellow or green only) (subfunctionalization).*

Cysteine peptidases that belong to the family C1A peptidases are one of the largest groups among the peptidases. Their biological roles are much better known in eukaryotes than in prokaryotes. Peptidases in prokaryotes can participate in the process of pathogenesis, but the mechanisms are still quite unknown. The protein domains that are associated with the peptidases can have a role of virulence factors. The availability of a huge number of prokaryotic genomes and proteomes has allowed us to analyse the diversity of the C1A peptidases in prokaryotes. We investigated the distribution and domain architectures in the C1A papain superfamily in prokaryotes. Distribution of C1A peptidases in prokaryotes is rather limited, which explains their intended specific function. The number of multidomain C1A proteins in prokaryotes is much greater than one would expect given their distribution. Even their domain architectures are extremely structurally diverse. The connections of multidomain C1A peptidases with the exceptionally large number of different protein domains have confirmed that these domains are relevant to microbial adaptations for survival in the host. The analysis of the structural diversity of the C1A peptidases in prokaryotes has provided a new insight into their biological roles that are not limited just to the pathogenesis.

Other subjects

In 2015 we also participated at several research projects out of the thematic scope of our department.

With structural identification we collaborated with our colleagues from the Department of Biology, the Biotechnical Faculty of UL (BF UL), on comparative composition analysis of protein corona of three different carbon-based nanoparticles after their exposure to human serum (M. Sopotnik et al., *Carbon*, 95 (2015), 560–572). Similar analysis, just with nanoparticles of different structure, we conveyed in collaboration with the team from the Faculty of Electrical Engineering of UL. In this study we related the protein corona composition of nanoparticles and their physical characteristics with the mode of preparation of these nanoparticles, meaning steps between their synthesis and application in one of the biologically relevant systems.

In collaboration with another group from the Department of Biology at BF UL, we analysed the toxin Cdt (cytolethal distending toxin) from bacteria *Aggregatibacter actinomycetemcomitans* associated with a severe form of periodontal disease. We confirmed the existence of a shorter form of the B subunit of this trimeric toxin (CdtB) on the protein level also in patients with periodontal disease. This finding may result in new insights about this disease and its treatment.

In a consortium coordinated by colleagues from the Institute of Biochemistry, the Medical Faculty of UL (MF UL), we participated in a similarity-based virtual screening and synthesis of new benzoic acid-derived antifungal

compounds directed against cytochrome P450 monooxygenase CYP53 enzymes of animal and plant pathogenic fungi (S. Berne et al., *Bioorg. Medic. Chem.*, 23 (2015), 4264–4276).

In collaboration with another group from the MF UL we successfully applied our $sPLA_2$ expertize. In this study we discovered that the patients suffering from ovarian endometriosis have elevated expression of the group IIA $sPLA_2$ (PLA2G2A) on both the mRNA and protein levels. Our data indicate that PLA2G2A is implicated in the pathophysiology of ovarian endometriosis, but that it cannot be used as a diagnostic biomarker (V. Kocbek et al., *Gynecol. Endocrinol.*, 31 (2015), 214–218).

By performing surface plasmon resonance (SPR) measurements, we collaborated with our colleagues from the NMR Centre of Utrecht University, the Netherlands, at establishing the mechanism of binding the structure-specific endonuclease ERCC1/XPF on DNA in the process of its repair (M. Faridounnia et al., *J. Biol. Chem.*, 290 (2015), 20541–20555).

With structural analyses we participated in the optimization of the expression of mouse perforin in insect cells and purification of the recombinant protein in a project led by colleagues from the National Institute for Chemistry in Ljubljana (O. Naneh et al., *J. Immunol. Methods*, 426 (2015), 19–28).

We are partners in the targeted research project (CRP) "Definition of molecular parameters for protection of carniolan honeybee" that is coordinated by the Zootechnical Department at BF UL. In 2015, we accomplished comparative proteomic analysis of haemolymph, royal jelly and venom of the local populations of carniolan honeybee (*Apis mellifera carnica*). We also contributed to the bioinformatic analysis of the collected data.

Some outstanding publications in the past year

1. Oberčkal, J., Kovačič, L., Šribar, J., Leonardi, A., Dolinar, K., Pucer Janež, A. and Križaj, I.: On the role of protein disulphide isomerase in the retrograde cell transport of secreted phospholipases A_2. PLoS One, 10 (2015), e0120692
2. Leonardi, A., Sajevic, T., Latinović, Z., Pungerčar, J., Lang Balija, M., Trampuš Bakija, A., Vidmar, R., Halassy, B. and Križaj, I.: Structural and biochemical characterisation of VaF1, a P-IIIa fibrinogenolytic metalloproteinase from *Vipera ammodytes ammodytes* venom. Biochimie, 109 (2015), 78–87
3. Mattiazzi Ušaj, M., Prelec, M., Brložnik, M., Primo, C., Curk, T., Ščančar, J., Yenush, L. and Petrovič, U.: Yeast *Saccharomyces cerevisiae* adiponectin receptor homolog Izh2 is involved in the regulation of zinc, phospholipid and pH homeostasis. Metallomics, 7 (2015), 1338–1351
4. Mattiazzi Ušaj, M., Brložnik, M., Kaferle, P., Žitnik, M., Wolinski, H., Leitner, F., Kohlwein, S.D., Zupan B. and Petrovič, U.: Genome-wide localization study of yeast Pex11 identifies peroxisome-mitochondria interactions through the ERMES complex. J. Mol. Biol., 427 (2015), 2072–2087
5. Petrovič, U.: Next generation biofuels: a new challenge for yeast. Yeast, 32 (2015), 583–593

Organization of conferences and meetings

1. Organization of the annual meeting of co-workers of the research program "Toxins and Biomembrans" from the Department of Molecular and Biomedical Sciences at the Jožef Stefan Institute, and the Department of Biology, Biotechnical Faculty University of Ljubljana, 25 November 2015

INTERNATIONAL PROJECT

1. 7FP - YeSVitE; Yeasts for the Sustainability in Viticulture and Oneology
   Prof. Uroš Petrovič
   European Commission

RESEARCH PROGRAM

1. Toxins and biomembranes
   Prof. Igor Križaj

R&D GRANTS AND CONTRACTS

1. Integrativne raziskave evolucije spolnega dimorfizma Integrative research of sexual dimorphism evolution
   Prof. Dušan Kordiš
2. Thermophoretic guidance, accumulation and sorting of biomolecules in microfluidic devices
   Prof. Igor Križaj
3. Crosstalk betwen lipid and central carbon metabolism
   Prof. Uroš Petrovič
4. Definition of molecular parameters for protection of Carniolan honeybee
   Prof. Igor Križaj
5. Definition of molecular parameters for protection of Carniolan honeybee
   Prof. Igor Križaj

VISITORS FROM ABROAD

1. Assist. Prof. Klaus Natter, University of Graz, Austria, 15–16 April 2015
2. Dr. Svetla Petrova-Cankova, "St. Kliment Ohridski", University of Sofia, Bulgaria, 18–26 April 2015
3. Ana Temprano, Hospital Universitario Joan XXIII, Tarragona, Spain, 14 September –21 December 2015

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4. Prof. Uroš Petrovič
5. Prof. Jože Pungerčar

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11. Mojca Ogrizović, B. Sc.

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12. Igor Koprivec
13. Darja Žunič Kotar

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Original Article

1. Sabina Berne, Lidija Kovačič, Matej Sova, Nada Kraševec, Stanislav Gobec, Igor Križaj, Radovan Komel, "Benzoic acid derivatives with improved antifungal activity: design, synthesis, structure-activity relationship (SAR) and CYP53 docking studies", *Bioorg. med. chem.*, vol. 23, iss. 15, pp. 4264-4276, Aug. 2015.
2. Maryam Faridounnia, Hans Wienk, Lidija Kovačič, Gerd Folkers, Nicolaas G. J. Jaspers, Robert Kaptein, Jan H. J. Hoeijmakers, Rolf Boelens, "The Cerebro-Oculo-Facio-Skeletal (COFS) syndrome point mutation F231L in the ERCC1 DNA repair protein causes dissociation of the ERCC1-XPF complex", *J Biol Chem*, vol. 290, no. 33, pp. 20541-20555, 2015.
3. Patti Hayes *et al.* (23 authors), "Defects in NADPH oxidase genes NOX1 and DUOX2 in very early onset inflammatory bowel disease", *CMGH*, vol. 1, issue 5, pp. 489-502, 2015.
4. Vida Kocbek, Nick A. Bersinger, Vesna Brglez, Michael D. Mueller, Toni Petan, Tea Lanišnik-Rižner, "Phospholipase A2 group IIA is elevated in endometriomas but not in peritoneal fluid and serum of ovarian endometriosis patients", *Gynecol. endocrinol.*, vol. 31, iss. 3, pp. 214-218, Mar. 2015.
5. Adrijana Leonardi, Tamara Sajevic, Zorica Latinović, Jože Pungerčar, Maja Lang Balija, Alenka Trampuš-Bakija, Robert Vidmar, Beata Halassy, Igor Križaj, "Structural and biochemical characterisation of VaF1, a P-IIIa fibrinogenolytic metalloproteinase from Vipera ammodytes ammodytes venom", *Biochimie (Paris)*, vol. 109, pp. 78-87, 2015.
6. Mojca Mattiazzi, Mojca Brložnik, Petra Kaferle, Marinka Žitnik, Heimo Wolinski, F. Leitner, Sepp D. Kohlwein, Blaž Zupan, Uroš Petrovič, "Genome-wide localization study of yeast Pex11 identifies peroxisome-mitochondria interactions through the ERMES complex", *J. mol. biol.*, vol. 427, no. 11, pp. 2072-2087, Jun. 2015.
7. Mojca Mattiazzi, Metod Prelec, Mojca Brložnik, Cecilia Primo, Tomaž Curk, Janez Ščančar, Lynne Yenush, Uroš Petrovič, "Yeast Saccharomyces cerevisiae adiponectin receptor homolog Izh2 is involved in the regulation of zinc, phospholipid and pH homeostasis", *Metallomics*, vol. 7, iss. 9, pp. 1338-1351, 2015.
8. Omar Naneh, Apolonija Bedina Zavec, David Pahovnik, Ema Žagar, Robert J. Gilbert, Igor Križaj, Gregor Anderluh, "An optimized protocol for expression and purification of murine perforin in insect cells", *J. immunol. methods*, vol. 426, pp. 19-28, 2015.
9. Jernej Oberčkal, Lidija Kovačič, Jernej Šribar, Adrijana Leonardi, Klemen Dolinar, Anja Pucer Janež, Igor Križaj, "On the role of protein disulfide isomerase in the retrograde cell transport of secreted phospholipases A_2", *PloS one*, vol. 10, no. 3, pp. e0120692-1-e0120692-20, 2015.
10. Toni Petan, Igor Križaj, "Is $iPLA_2\beta$ a novel target for the evelopment of new strategies to alleviate inflammatory bowel disease?", *Dig. dis. sci.*, vol. 60, iss. 12, pp. 3504-3506, 2015.
11. Uroš Petrovič, "Next generation biofuels: a new challenge for yeast", *Yeast (Chichester Engl.)*, vol. 32, iss. 9, pp. 583-293, 2015.
12. Maja Sopotnik, Adrijana Leonardi, Igor Križaj, Peter Dušak, Darko Makovec, Tina Mesarič, Nataša Poklar Ulrih, Ita Junkar, Kristina Sepčić, Damjana Drobne, "Comparative study of serum protein binding to three different carbon-based nanomaterials", *Carbon (N. Y.)*, vol. 95, pp. 560-572, 2015.

Review Article

1. Martin Kavšček, Martin Stražar, Tomaž Curk, Klaus Natter, Uroš Petrovič, "Yeast as a cell factory: current state and perspectives", *Microb Cell Fact*, vol. 14, pp. 94-1-94-10, 2015.

Published Conference Contribution (invited lecture)

1. Igor Križaj, Jernej Šribar, Adrijana Leonardi, "Molekularni vidik toksičnosti slovenskih kač", In: *Toksikologija 2015: piki in ugrizi strupenih živali: zbornik prispevkov, Plaza Hotel Ljubljana, 10. april 2015*, Miran Brvar, ed., Ljubljana, Slovensko zdravniško društvo, Sekcija za klinično toksikologijo, Univerzitetni klinični center, Center za zastrupitve, Interna klinika, 2015, pp. 10-14.

Independent Component Part or a Chapter in a Monograph

1. Dušan Kordiš, Igor Križaj, "Secreted phospholipases A_2 with β-neurotoxic activity", In: *Snake venoms*, P. Gopalakrishnakone, ed., Dordrecht, Springer, 15 pp.
2. Adrijana Leonardi, "Proteomika", In: *Eksperimentalna biohemija*, Aida Smailović, Tuzla, Univerzitet u Tuzli, 2015, str. 289-314.

Mentoring

1. Jernej Oberčkal, *On the role of enzymatic activity of ammodytoxin and its interaction with some intracellular proteins in the process of β-neurotoxicity:* doctoral dissertation, Ljubljana, 2015 (mentor Igor Križaj).
2. Sofia Dashko, *Exploring biodiversity potential of wine associated yeasts:* doctoral dissertation, Nova Gorica, 2015 (mentors Lorena Butinar, Uroš Petrovič).
3. Luka Bevc, *Genomska in transkriptomska analiza cistatinske naddružine pri vretenčarjih:* master's thesis, Ljubljana, 2015 (mentor Dušan Kordiš).
4. Nuša Kapušin, *Bioinformatic analysis of interactome of genes involved in regulation of lipid metabolism in eucarionts:* master's thesis, Ljubljana, 2015 (mentor Uroš Petrovič; co-mentor Simon Horvat).
5. Katja Uršič, *The role of Tum1 protein in the lipid methabolism of yeast:* master's thesis, Ljubljana, 2015 (mentor Uroš Petrovič).
6. Margareta Žlajpah, *Karakterizacija CRISP - sekretornih proteinov, bogatih s cisteini - iz strupa modrasa (Vipera ammodytes ammodytes):* master's thesis, Ljubljana, 2015 (mentor Igor Križaj).

DEPARTMENT OF BIOTECHNOLOGY
B-3

At the Department of Biotechnology we investigate the 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, preparation of quality and safe food and for the protection of the environment, contributing to an improvement of peoples' health and of the environment in which we live. Our research work is focused on the processes of cancer progression and immune response, neurodegenerative processes, biology of fungi, plant stress response and in the search for new biotechnological approaches and products.

Head:
Prof. Janko Kos

Prof. Borut Štrukelj was a recipient of a Zois Award for outstanding scientific achievements

As in previous years, in 2015 we studied the structure and function of various fungal enzymes, inhibitors and lectins. With regard to structural similarities we investigated the interactions between the inhibitors and lectins, and demonstrated that they represent an important mode of molecular recognition being relevant under physiological conditions. In cooperation with the National Institute of Biology we have shown the insecticidal activity of clitocypin, the cysteine protease inhibitor from clouded agaric, against Colorado potato beetle larvae. As shown previously for macrocypins, cysteine protease inhibitors from parasol mushroom, clitocypin also inhibits digestive cysteine proteases, intestains, and it does not elicit the adaptive response in larval guts. This establishes mushrooms as an attractive source for novel biopesticides.

We continued our research of the enzyme L-aminooxidase (LAO) from Amanita phalloides and Clitocybe geotropa. Both enzymes, ApLAO and CgLAO, reveal a cytotoxic action on human T lymphocytes, activating apoptosis through the activation of caspase pathways. We showed that the intrinsic pathway is a predominant one. The results could be important for the application of LAO as antitumor drugs.

Figure 1: Amanita muscaria as a source of various potential anti-tumour compounds

The studies in the field of glycobiology in 2015 focused on lectins from different mushrooms and their effects on different cell lines, with the emphasis on immune cells as well as on their application as tools for targeted drug delivery. For the latter we prepared different fusion proteins consisting of lectins and cysteine protease inhibitors. We showed that lectin MpL, isolated from Macrolepiota procera, rapidly enters targeted lymphocytes by means of clatrin-dependent endocytosis. Inside the cell it triggers either lysosomes or Golgi apparatus. Fusion proteins consisted of MpL and cystatin C, a potent inhibitor of cysteine proteases, internalized targeted tumour cells and accumulated in lysosomes, where it significantly impaired the degradation of the extracellular matrix and consequently the invasiveness of tumour cells. On the other hand, a similar lectin CNL, isolated from Clitocybe nebularis, showed a different effect: by binding to membrane CD markers on lymphocytes it triggered the cell apoptosis. The results confirm the great potential of lectins for direct anti-tumour treatment or as a part of systems for the delivery of other anti-tumour drugs.

Investigating the role of proteolytic enzymes in the regulation of the cytotoxic activity of immune cells we published in Oncotarget the results on the direct link between the activities of cystatin F, cathepsin C and granzyme B and the cytotoxicity of natural killer cells (NK cells). By using different cystatin F mutants we showed that the monomeric form of cystatin F, which is truncated at N-terminal end and fully glycosylated, is a key regulator of cytotoxicity. Additionally, we evaluated the contribution of other cells, in particular immune ones, which secrete cystatin F, on the function of NK cells and on their reduced cytotoxicity. A similar mechanism was observed for cytotoxic T lymphocytes, which after the contact with tumour cells also lose their cytotoxicity. We implemented a new method for an assessment of cytotoxicity by using calcein and proximity ligation assay for the assessment of the co-localisation and interaction between proteins. Using the latter we confirmed the interactions between cystatin F, cathepsin C and granzyme B in cytotoxic T lymphocytes.

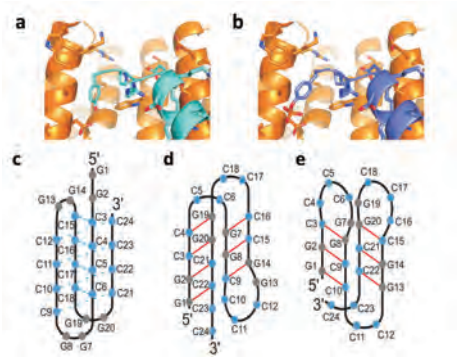

Figure 2: Structural model of the binding of unphosphorylated (a) and phosphorylated (b) C-terminal tyrosine of FUS to the transporting portein TNPO1 and i-motif (c) and two possible protonated hairpins (d and e) formed form the CCCCGG repeat DNA.

In the field of molecular neurobiology, we published five research studies in reputable journals on molecular processes underlying frontotemporal dementia (FTD) and amyotrophic lateral sclerosis (ALS). We presented the atypical DNA secondary structures formed by the hexanucleotide repeat GGGGCC, which is found in the C9orf72 gene. The expansion mutation of this hexanucleotide repeat is the most common genetic cause of ALS and FTD (Neurobiology of Ageing) and the

- **Cystatin F regulates the function of natural killer (NK) cells**
- **Lectins from mushrooms can be used in anti-tumour therapy**

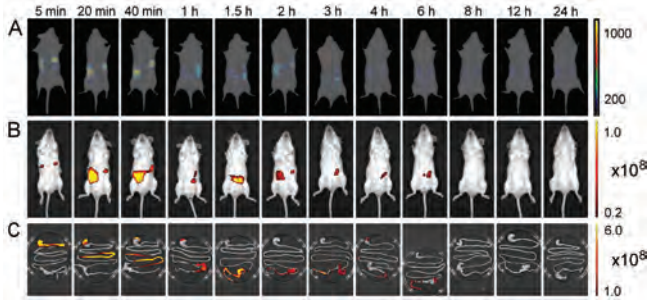

Figure 3: Imaging of mice at different time points after administration of 5.0×1010 cells of IRFP713-expressing L. lactis using trans-illumination and fluorescence imaging tomography (a) or epifluorescence (b) and ex vivo epifluorescence imaging of isolated intestines (c). Colour bars indicate radiant efficiency or total fluorescent yield.

- **Mutation in hexanucleotide repeat GGGGCC in the C9orf72 gene, which results in repeat expansion, is the most common genetic cause of frontotemporal dementia and amyotrophic lateral sclerosis**
- **Fluorescent tomography was confirmed as a suitable method for the spatial localization of bacteria in mice**
- **A review paper was published in Trends in Biotechnology**

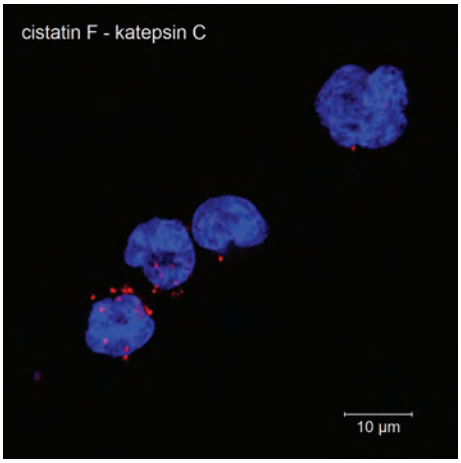

Figure 4: Co-localisation of cathepsin C and cystatin F in TALL-104 cells obtained by proximity ligation method.

reverse complement sequence, CCCCGG forms protonated hairpins and i-motifs (Scientific Reports). Of special interest was our observation that the equimolar mix of sense and anti-sense hexanucleotide repeat sequences preferentially forms single stranded G-quadruplex or i-motif structures instead of the expected DNA double helix. Additionally, we have shown that the C-terminal tyrosine of FUS can be phosphorylated, which may have implications for FUS-related FTD (Journal of Cell Science). We have also published the effect of the loss of TDP-43 on the proteome (Neuroscience) and screening of the Slovenian ALS patient population for the most common mutations (Neurobiology of Ageing).

In the field of the research of lactic acid bacteria we expressed infrared fluorescent protein IRFP713 in the bacteria Lactococcus lactis, Lactobacillus plantarum and Escherichia coli. IRFP713 has absorption and excitation maxima in the infrared part of the spectrum. The characteristic of infrared light is better penetration into the tissue in comparison to visible light. This has enabled us to monitor the bacteria in living mice with the use of fluorescence. We have determined that there are no major differences in intestinal transit times between different species of bacteria. Bacteria passed through the stomach and small intestine during the first hour after administration and were retained in the caecum and the large intestine for 6–8 h. The spatial localization of bacteria was confirmed by imaging of the isolated intestine and by cultivating of the intestinal content. We have also confirmed the suitability of fluorescent tomography for the spatial localization of bacteria in mice. Additionally, we have expressed another fluorescent protein, IRFP682, which has enabled concomitant in-vivo imaging of two different species of bacteria. With this work we laid the foundation for in-vivo imaging of lactic acid and commensal bacteria, as well as confirmed the suitability of the developed method for the acquisition of the information on temporal and spatial distribution of bacteria in the intestinal tract. This represents a basis for future therapeutic studies of probiotics.

We have also published a review article entitled "Non-immunoglobulin scaffolds: a focus on their targets" in which we reviewed 20 different types of binding proteins that can be randomized and that were not derived from the molecule of immunoglobulin. In the article we focused on an overview of more than 100 proteins that have served as targets for the selection of binding proteins. The review article was published in one of the top journals in the field of biotechnology, Trends in Biotechnology, with an impact factor of 11.9.

The results of the research work at the Department of Biotechnology in the year 2015 were published in 30 scientific papers in journals with an impact factor. Two patent applications were filed and a national patent was granted. We also received two research grants from the Slovenian Research Agency. A member of the department prof. Borut Štrukelj received a Zois Award for outstanding scientific achievements. Ph.D. student Simon Žurga received FEBS fellowship and Ph.D. students Ana Bajc Česnik and Simona Darovic Ad Futura fellowships, all for visiting foreign laboratories. Simon Žurga also received the Dean's Award for scientific achievement at the Faculty of Pharmacy, University of Ljubljana. The results of the study on cellular signalling of cathepsin X in cancer (Kos, J., Vižin, T., Pečar-Fonović, U., Pišlar, A., Seminars in Cancer Biology) have been selected and presented by the Slovenian Research Agency as Excellent in Science for the year 2015. Head of department prof. Janko Kos was elected as a member of European Academy of Sciences and Arts. The members of the department co-organized several scientific meetings (CITIM 2015, FEBS3+) and were also very active in pedagogical work as lecturers and mentors to students preparing diploma and doctoral theses at universities in Slovenia and abroad.

Some outstanding publications in the past year

1. Škrlec, Katja, Štrukelj, Borut, Berlec, Aleš. Non-immunoglobulin scaffolds: a focus on their targets. Trends in biotechnology, ISSN 0167-7799. [Print ed.], 2015, vol. 33, iss. 7, str. 408-418, IF 11,9
2. Pišlar, Anja, Perišić, Milica, Kos, Janko. Lysosomal cysteine peptidases - molecules signaling tumor cell death and survival. Seminars in cancer biology, ISSN 1044-579X, 2015, vol. 35, str. 168-179, IF 9,3

3. Magister, Špela, Tseng, Han-Ching, Bui, Vickie T., Kos, Janko, Jewett, Anahid. Regulation of split anergy in natural killer cells by inhibition of cathepsins C and H and cystatin F. Oncotarget, ISSN 1949-2553, Sep. 2015, vol. 6, no. 26, str. 22310-22327, IF 6,4

Awards and appointments

1. Borut Štrukelj: Zois Award 2015 for outstanding achievements in modern sustainable development of pharmaceutical biotechnology in the Republic of Slovenia, Portorož, Government of the Republic of Slovenia
2. Simon Žurga: Dean's Award 2015, for the paper "Biochemical properties of lectin from parasol mushroom (Macrolepiota procera) and its effects on model nematode Caenorhabditis elegans", published in the Federation of European Biochemical Societies (FEBS) Journal, Ljubljana, Faculty of Pharmacy, University of Ljubljana

Organization of conferences and meetings

1. Organization of the annual meeting of co-workers of the research programme "Pharmaceutical Biotechnology: Knowledge for Health" from the Department of Biotechnology, Jožef Stefan Institute, and the Chair of Pharmaceutical Biology, Faculty of Pharmacy, University of Ljubljana, Slovenia, 19 November 2015

Patent granted

1. Jana Erjavec, Tanja Dreo, Jerica Sabotič, Jože Brzin, Janko Kos, Maja Ravnikar, Composition and method for plant protection, SI24489 (A), Slovenian Intellectual Property Office, 30. 04. 2015.

INTERNATIONAL PROJECTS

1. Disrupted RNA Processing in Amyotrophic Lateral Sclerosis
   Prof. Boris Rogelj
   Slovenian Research Agency
2. Mechanism of C9orf72 extended Repeat Pathogenicity in ALS and FTD
   Prof. Boris Rogelj
   Slovenian Research Agency

RESEARCH PROGRAM

1. Pharmaceutical Biotechnology: Knowledge for Health
   Prof. Janko Kos

R & D GRANTS AND CONTRACTS

1. Dysregulation of TDP-43 expression in amyotrophic lateral sclerosis and frontotermoral lobar degeneration
   Prof. Boris Rogelj
2. Genetics and pharmacogenomics of inflammatory bowel diseases and genetically related chronic immune diseases
   Prof. Boris Rogelj
3. Pathogenic mechanism of the C9orf72 expanded hexanucleotide repeat mutation in neurodegeneration
   Prof. Boris Rogelj
4. Nitroxoline and its derivatives as new antitumour drugs
   Dr. Jerica Sabotič
5. Post-transcriptional regulatory networks in neurodegenerative diseases
   Prof. Boris Rogelj
6. Protein engineering of recombinant probiotic lactic acid bacteria for treatment of irritative bowel disease
   Prof. Borut Štrukelj
7. The role of cysteine protease inhibitors in NK cell mediated lysis of tumour cells
   Prof. Janko Kos

VISITORS FROM ABROAD

1. Prof. Pavle Andjus, Milena Milošević, Prof. Dušanka Savić Pavićević, Jovan Petrović, University of Belgrade, Faculty of Biology, Serbia, 14–17 May 2015.
2. Dr. Milena Milošević, University of Belgrade, Faculty of Biology, Serbia, 8–15 December 2015.

STAFF

Researchers
1. **Prof. Janko Kos*, Head**
2. Prof. Boris Rogelj
3. Dr. Jerica Sabotič
4. Prof. Borut Štrukelj*

Postdoctoral associates
5. Asst. Prof. Aleš Berlec
6. *Dr. Maruška Budič, left 01.03.15*
7. Dr. Anja Kovanda
8. Dr. Milica Perišić Nanut
9. Dr. Sonja Prpar Mihevc
10. Dr. Anja Pucer Janež
11. *Dr. Simon Žurga, left 01.10.15*

Postgraduates
12. Ana Bajc Česnik, B. Sc.
13. Simona Darovic, B. Sc.
14. Mateja Prunk, B. Sc.
15. Katja Škrlec, B. Sc.

Technical and administrative staff
16. Darja Žunič Kotar

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Original Article

1. Aleš Berlec, Janja Završnik, Miha Butinar, Boris Turk, Borut Štrukelj, "In vivo imaging of Lactococcus lactis, Lactobacillus plantarum and Escherichiacoli expressing infrared fluorescent protein in mice", *Microb Cell Fact*, vol. 14, no. 181, pp. 1-14, 2015.
2. Simona Darovic, Sonja Prpar Mihevc, Vera Župunski, Gregor Gunčar, Maja Štalekar, Youn-Bok Lee, Christopher E. Shaw, Boris Rogelj, "Phosphorylation of C-terminal tyrosine residue 526 in FUS impairs its nuclear import", *J Cell Sci*, vol. 128, no. 22, pp. 4151-4159, 2015.
3. Gorazd Drevenšek, Mojca Lunder, Eva Tavčar Benković, Ana Mikelj, Borut Štrukelj, Samo Kreft, "Silver fir (Abies alba) trunk extract protects guinea pig arteries from impaired functional responses and morphology due to an atherogenic diet", *Phytomedicine (Stuttg.)*, vol. 22, issue 9, pp. 856-861, 2015.
4. Natalia Guzior, Marek Bajda, Mirosław Skrok, Katarzyna Kurpiewska, Krzysztof Lewiński, Boris Brus, Anja Pišlar, Janko Kos, Stanislav Gobec, Barbara Malawska, "Development of multifunctional, heterodimeric isoindoline-1,3-dione derivatives as cholinesterase and ß-amyloid aggregation inhibitors with neuroprotective properties", *Eur. j. med. chem.*, vol. 92, pp. 738-749, 2015.
5. Anja Kovanda, Matjaž Zalar, Primož Šket, Janez Plavec, Boris Rogelj, "Anti-sense DNA d(GGCCCC)$_n$ expansions in C9ORF72 form i-motifs and protonated hairpins", *Scientific reports*, vol. 5, pp. 17944 -1-17944 -7, 2015.
6. Špela Magister, Han-Ching Tseng, Vickie T. Bui, Janko Kos, Anahid Jewett, "Regulation of split anergy in natural killer cells by inhibition of cathepsins C and H and cystatin F", *Oncotarget*, vol. 6, no. 26, pp. 22310-22327, Sep. 2015.
7. Bojana Mirković, Boštjan Markelc, Miha Butinar, Ana Mitrović, Izidor Sosič, Stanislav Gobec, Olga Vasiljeva, Boris Turk, Maja Čemažar, Gregor Serša, Janko Kos, "Nitroxoline impairs tumor progression in vitro and in vivo by regulating cathepsin B activity", *Oncotarget*, vol. 6, no. 22, pp. 19027-19042, 2015.
8. Jernej Oberčkal, Lidija Kovačič, Jernej Šribar, Adrijana Leonardi, Klemen Dolinar, Anja Pucer Janež, Igor Križaj, "On the role of protein disulfide isomerase in the retrograde cell transport of secreted phospholipases A_2", *PloS one*, vol. 10, no. 3, pp. e0120692-1-e0120692-20, 2015.
9. Jernej Ogorevc, Sonja Prpar Mihevc, Jakob Hedegaard, Dušan Benčina, Peter Dovč, "Transcriptomic response of goat mammary epithelial cells to Mycoplasma agalactiae challenge - a preliminary study", *Anim. Sci. Pap. Rep.*, vol. 33, no. 2, pp. 155-163, 2015.
10. Mitja Ogrizek, Samo Turk, Samo Lešnik, Izidor Sosič, Milan Hodošček, Bojana Mirković, Janko Kos, Dušanka Janežič, Stanislav Gobec, Janez Konc, "Molecular dynamics to enhance structure-based virtual screening on cathepsin B", *J. comput.-aided mol. des.*, vol. 29, iss. 8, pp. 707-712, 2015.
11. Urša Pečar Fonović, Janko Kos, "Cathepsin X cleaves profilin 1 C-Terminal Tyr139 and influences clathrin-mediated endocytosis", *PloS one*, vol. 10, no. 9, pp. 1-14, 2015.
12. Matjaž Ravnikar, Matic Terčelj, Damjan Janeš, Borut Štrukelj, Samo Kreft, "Antibacterial activity of endophytic fungi isolated from conifer needles", *Afr. j. biotechnol.*, vol. 14, no. 10, pp. 867-871, 2015.
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14. Primož Šket, Jure Pohleven, Anja Kovanda, Maja Štalekar, Vera Župunski, Matja Zalar, Janez Plavec, Boris Rogelj, "Characterization of DNA G-quadruplex species forming from C9ORF72 G_4C_2 expanded repeats associated with amyotrophic lateral sclerosis and frontotemporal lobar degeneration", *Neurobiol. aging*, vol. 36, no. 2, pp. 1091-1096, 2015.
15. Ida Šmid, Ana Rotter, Kristina Gruden, Jože Brzin, Meti Buh Gašparič, Janko Kos, Jana Žel, Jerica Sabotič, "Clitocypin, a fungal cysteine protease inhibitor, exerts its insecticidal effect on Colorado potato beetle larvae by inhibiting their digestive cysteine proteases", *Pestic. biochem. physiol.*, vol. 122, pp. 59-66, 2015.
16. Maja Štalekar, Xiaoke Yin, Katja Rebolj, Simona Darovic, Claire Troakes, Manuel Mayr, Christopher E. Shaw, Boris Rogelj, "Proteomic analyses reveal that loss of TDP-43 affects 3 RNA processing and intracellular transport", *Neuroscience*, vol. 293, pp. 157-170, 2015.
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18. Petra Zadravec, Borut Štrukelj, Aleš Berlec, "Heterologous surface display on lactic acid bacteria: non-GMO alternative?", *Bioengineered*, vol. 6, issue 3, pp. 179-183, 2015.
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1. Janko Kos, Tjaša Vižin, Urša Pečar Fonović, Anja Pišlar, "Intracellular signaling by cathepsin X: molecular mechanisms and diagnostic and therapeutic opportunities in cancer", *Semin. cancer biol.*, vol. 31, pp. 76-83, 2015, .
2. Anja Pišlar, Milica Perišić, Janko Kos, "Lysosomal cysteine peptidases - molecules signaling tumor cell death and survival", *Semin. cancer biol.*, vol. 35, pp. 168-179, 2015.
3. Katja Škrlec, Borut Štrukelj, Aleš Berlec, "Non-immunoglobulin scaffolds: a focus on their targets", *Trends biotechnol. (Regul. ed.)*, vol. 33, iss. 7, pp. 408-418, 2015.
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1. Jovan Miljković, Uroš Potočnik, Matjaž Deželak, Aleksandar Godić, Mateja Dolenc-Voljč, Iztok Holc, Liljana Mervic, Vesna Tlaker Žunter, Borut Štrukelj, Vita Dolžan, Žiga Rotar, *Monografija o luskavici*, Maribor, Združenje slovenskih dermatovenerologov, 2015.

Patent Application

1. Jana Erjavec, Tanja Dreo, Jerica Sabotič, Jože Brzin, Janko Kos, Maja Ravnikar, *Composition and method for plant protection*, WO2015058944 (A1), World Intellectual Property Organization, 30. 04. 2015.
2. Tadej Rejc, Uroš Petrič, Dora Debeljak, Toni Bremec, Polonca Ferk, Mojca Lunder, Irena Roškar, Borut Štrukelj, Samo Kreft, *Zmes naravnih polifenolov iz lesa bele jelke za zmanjšanje postprandialne glukoze*, P-201500116, Urad RS za intelektualno lastnino, 12. 5. 2015.
3. Miha Vodnik, Mojca Lunder, Borut Štrukelj, Eva Knuplež, Valentina Kubale, *Peptidi za farmakološko poseganje v grelinski sistem*, P-201500141, Urad RS za intelektualno lastnino, 8. 6. 2015.

Patent

1. Jana Erjavec, Tanja Dreo, Jerica Sabotič, Jože Brzin, Janko Kos, Maja Ravnikar, *Composition and method for plant protection*, SI24489 (A), Urad RS za intelektualno lastnino, 30. 04. 2015.

Mentoring

1. Urša Pečar Fonović, *Vloga katepsina X pri uravnavanju delovanja profilina 1 v tumorskih celičnih linijah:* doctoral dissertation, Ljubljana, 2015 (mentor Janko Kos).
2. Maja Štalekar, *Regulatory function of TDP-43 and implications in pathological changes in neurodegenerative diseases:* doctoral dissertation, Ljubljana, 2015 (mentor Boris Rogelj).

3. Tjaša Vižin, *The role of gamma-enolase in cancer and its regulation by proteolytic enzymes:* doctoral dissertation, Ljubljana, 2015 (mentor Janko Kos).
4. Simon Žurga, *Biochemical properties and function of ricin B like lectin from mushroom Macrolepiota procera:* doctoral dissertation, Ljubljana, 2015 (mentor Janko Kos; co-mentor Jerica Sabotič).
5. Sara Božič, *Comparison of bioluminiscent Escherichia coli K-12/pTetLux and WZM120/pCGLS-11 strains in the evaluation of antibacterial activity:* master's thesis, Ljubljana, 2015 (mentor Janko Kos; co-mentor Päivi Tammela).
6. Sara Redenšek, *Validation of a non-invasive screening test for diagnostics of Down syndrome from whole blood samples of pregnant women:* master's thesis, Ljubljana, 2015 (mentor Borut Štrukelj).
7. Gregor Vidovič, *Testing of plasmid DNA containing collagen promoter for gene delivery to selected tissue:* master's thesis, Ljubljana, 2015 (mentor Borut Štrukelj; co-mentor Gregor Serša).

DEPARTMENT OF ENVIRONMENTAL SCIENCES O-2

The research of the Department of Environmental Sciences deals with fundamental scientific questions about natural environmental systems and processes on various scales, their interactions and responses to human activities, and with the development of technical solutions for environmental problems and environmental management issues. Our research is inter- and multidisciplinary: Environmental analytical chemistry, Biogeochemical cycles, Environment, nutrition and health, Environmental technologies, Risk and environmental assessment, and Environmental monitoring.

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

In the field of elemental speciation, a novel analytical procedure was developed for the simultaneous speciation of chromate (CrO_4^{2-}), molybdate (MoO_4^{2-}), tungstate (WO_4^{2-}) and vanadate (VO_4^{3-}) by anion-exchange HPLC-ICP-MS. The developed procedure was successfully applied to the analysis of manual metal arc-welding fumes loaded on filters.

The speciation of platinum (Pt) in environmental waters is becoming an issue of great concern due to the widespread use of Pt-based chemotherapeutics, where Pt metabolites that are excreted with urine end-up in hospital and municipal wastewaters. A procedure for the separation of cisplatin and its hydrolysed complexes by the use of zwitterionic hydrophilic interaction liquid chromatography (ZIC-HILIC) was optimized. The analysis of environmental water samples, to which the relevant concentrations of suspended particulate matter (SPM) or humic acids (HAs) were added, and were spiked with cisplatin, revealed that about 75% of Pt species were adsorbed by SPM or HAs.

Two new radiochemical methods for the determination of ^{210}Pb and ^{226}Ra were developed. ^{210}Pb was determined using a liquid scintillation counter with the novel application of ICP-MS for the determination of the chemical recovery of radiochemical separation. The method utilizes ^{210}Bi to improve the detection efficiency and consequently improves the minimum detectable activity compared to conventional methods. The method for determining the ^{226}Ra in water samples with high, stable barium concentrations is based on selective precipitation and extraction chromatography.

Figure 1: In the framework of the European Fund for Regional Development and through the co-funding of the Ministry of Education, Science and Sport we obtained a new research infrastructure, including 803 m² of new and 1145 m² of renovated laboratory and office space with high-tech instrumentation

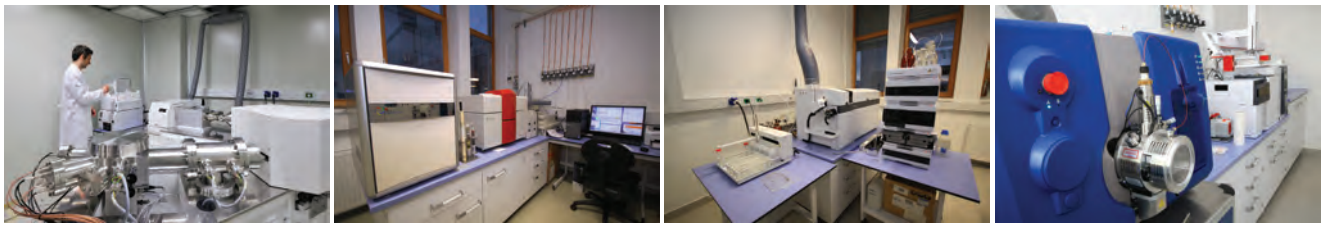

Figure 2: New research equipment acquired in 2015 opens numerous new research activities at the department

***Nu Instruments Multicolector ICP MS** is used for the determination of the stable isotope composition of heavier elements.*

***IsoPrime100 - Vario PYRO Cube (OH/CNS Pyrolyser/Elemental Analyser)** is a mass spectrometer with an elemental analyser and pyrolysis unit for the analysis of the stable isotopes O, H, C, N, S in solid and liquid samples.*

***In the Agilent 8800 instrument**, a collision reaction cell is placed between two quadrupole mass analysers. Such instrumental designed allows precise control over the reaction processes during tandem MS/MS operations and ensures the reliable determination of traces of elements, including those with m/z ratios ≤80 amu, even in samples with highly complex matrices.*

***LC-QTap Liquid Chromatograph with hybrid Mass Spectrometer** for the analysis of polar organic compounds. Instrument includes Liquid Chromatograph, UV-VIS Detector, ESI and APCI Ion Sources and Tandem Mass Spectrometer (Q1-Q2-Q3).*

In the field of the analysis of organic compounds, the fate of pharmaceutical and personal care product residues (e.g., tranquilisers, antidepressants, cytostatics, and industrial compounds that produce an endocrine disrupting effect) in environmental and wastewater samples with an emphasis on advanced sampling/extraction was analysed. We developed a series of analytical procedures for determining cytostatics (Cyclophosphamide, Ifosfamide, Methotrexate, Imatinib, Vincristin and Etoposide) and their commercially available metabolites in waste and environmental water samples. We showed the presence of detectable quantities of these compounds in wastewaters from hospitals, where cancer therapies are being conducted, in wastewater treatment plant (WWTP) influents and also in some effluents. None of the studied cytostatics were detected in their receiving waters. We also performed a series of photodegradation experiments on the antidepressant sertraline. The effect of several secondary compounds that simulate the natural environment was studied. In addition, in collaboration with the Faculty of Pharmacy, University of Ljubljana we developed an analytical method for its determination in surface waters. While we were not able to determine any sertraline in surface waters, the compound was found to be present in wastewaters. In order to improve the performance of sertraline analysis, we started to develop molecularly imprinted polymers with sertraline as the target compound. This work was done in collaboration with the Faculty of Chemistry and Chemical Engineering at the University of Maribor.

In the area of non-target analysis, we continued with the identification of transformation products of cytostatics (Cyclophosphamide, Ifosfamide, Methotrexate) and identified numerous transformation products for the first time using advanced instrumentation like an LTQ Orbitrap XL mass spectrometer in collaboration with our partner institutes (Curtin University, Perth, Australia; CSIC, Barcelona, Spain). In collaboration with the Faculty of Chemistry and Chemical Engineering at the University of Ljubljana, several of the identified transformation products were also synthesised and applied as standards in our research.

With a high-resolution tandem mass spectrometer QTof Premier, LC-MS and GC-MS analysis were identified and we structurally characterized numbers of organic compounds, organic-metal complexes, biopolymers and similar, mostly organic, compounds. The wide application of mass spectrometry has enabled support for CMS in the research and development of new synthesized organic compounds, pharmaceuticals, proteins and other biomolecules, materials in ceramics, electronics, energy, quality control of food, monitoring pollutants in the environment and assessing their impact on human health, etc.

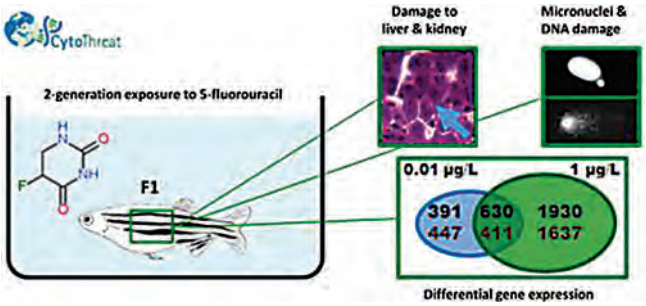

Figure 3: Residues of anti-neoplastic drugs are emerging pollutants in aquatic environments where missing chronic ecotoxicity data constitute a critical knowledge gap. In our investigation of zebra fish, a two-generation chronic toxicity study of 5-fluorouracil was performed and genotoxic effects were detected at environmental concentrations.

Several applications were made in the CMS during the past year, such as a quantitative determination of the metal-organic complexes of nickel hyperaccumulator plants for the remediation of soil enriched with toxic metals. The LC-MS chromatographic methods were used for a determination of the components present during the hydrolysis and polycondensation reactions of $Ti(O\text{-}n\text{-}C4H9)_4$. The electrospray negative ionization with LC-MS was applied for the MS analysis of lipidoms: some organic fatty acids, cholesterol and sphingolipids in cell membranes. The instrumental parameters of the electrospray ionization for the LC-MS analysis of the herbicide glyphosate in food were optimized. The LC-MS methods for the identification and quantification of air pollution with the pharmaceuticals bromocriptine, budesonide, quinolone derivate and ascomycin were validated. With GC-MS and LC-MS we comparatively analysed traces of contaminants in the ground water of the Ljubljana water-supply system. With tandem mass spectrometric measurements at a high mass resolution several benzotriazols were determined in water in trace amounts.

In the field of bioanalytics we developed an analytical method to determine the bleomycin fractions in serum and tumour tissue and studied the formation of chelates between bleomycin and several metals. The determined concentrations and pharmacokinetics of bleomycin in animal and human tissues are important for designing pharmacotherapy in cancer patients.

In parallel, we conducted, in collaboration with the National Institute of Biology, Ljubljana, a series of genotoxicity and ecotoxicity studies of cytostatic residues (pure compounds and their mixtures) contributing to a better understanding of the potential consequences of acute and chronic exposure of environmental organisms to low concentrations of anti-neoplastic drug residues. The results indicate the importance of a toxicological evaluation and monitoring of the drug metabolites/transformation products as they may be more hazardous than the parent compounds for certain aquatic species, while mixtures may also show synergistic and potentiating effects.

In the framework of the EU project GLOBAQUA we optimised our in-house passive sampling method (Polar Organic Chemical Integrative Sampler, POCIS) to improve the sampling for selected pharmaceuticals. Optimised POCIS were applied to surface waters (Sava River, from the source to the Danube River).

Metrology

The department organised a key inter-laboratory comparison CCQM-K127 "Contaminant and other elements in soil" for As, Cd, Mn, Pb and Fe, in cooperation with CENAM, Mexico and CCQM-K124 "Trace Elements in Drinking Water" for B, Ca, As, Mo, Cd and Hg, and the first inter-laboratory comparison addressing a determination of selected anti-cancer drug residues in surface water, hospital wastewater and wastewater-treatment-plant effluents. We participated in the certification of four new reference materials for the EU JRC Institute of Reference Materials and Measurements (IRMM, Geel, Belgium), i.e., mass fractions in Low-Density Polyethylene (ERM-EC680m and ERM-EC681m) and the trace elements' mass fraction in electrolytic copper ERM-EB074A, B, C and ERM-EB075A, B, C.

We also participated in several inter-laboratory comparisons organised by WEPAL, IAEA, NPL, BfS, GEOTRACES and PROCORAD.

In the framework of the European Metrology Research project MeTra, a method for the semi-continuous determination of dissolved elemental mercury and divalent mercury was optimized and applied in surface marine waters and industrial waters of a flue-gas desulfurization slurry. The latter can be applied as a diagnostic tool for the efficiency of Hg removal in the coal-burning sector for energy production.

Biogeochemical cycles

In the field of water-cycle investigations we continued our study of the isotopic composition of precipitation at seven stations in Slovenia, in cooperation with the IAEA and the Slovenian Environmental Agency (ARSO), and its influence on the isotopic composition of surface run-off and groundwater in Slovenia. The relationship between the isotopic composition of the precipitation and the atmospheric circulation patterns was studied in collaboration with colleagues from the University of Ljubljana and the Institute of Geography of the Russian Academy of Sciences. A mathematical model based on a linear combination of the δ^2H and $\delta^{18}O$ values, and on the precipitation amount weighted average related to elementary air circulation mechanisms was proposed and its application demonstrated on the long-term (1981–2010) isotope and precipitation record for the Ljubljana GNIP station. The model provides new insights into our understanding of isotopes' spatial and temporal distribution in precipitation, which is a basis for understanding terrestrial climate proxies based on the isotopic characteristics of the precipitation.

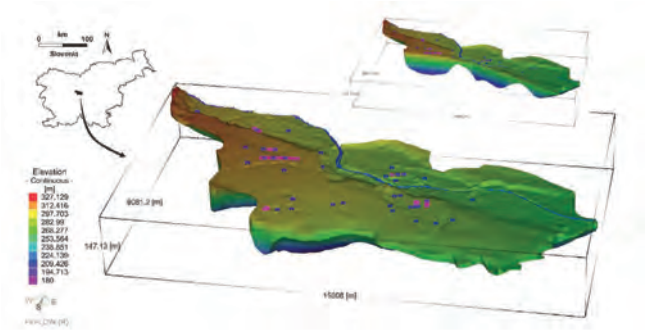

Figure 4: Physical framework of the Ljubljansko polje aquifer system model and its profile with wells (pink symbols) and piezometers (blue symbols).

In the frame of several national and international research projects we continued isotopic hydrogeochemical research on the Sava and Idrijca river systems and selected springs. In collaboration with the National Institute of Biology, interactions between reach- and catchment-scale drivers (physicochemical properties of water, composition of riverbed sediment, channel morphology, catchment land use and nutrient inputs) affecting the Kamniška Bistrica River metabolism and their relationship to biofilm respiratory activity by applying machine-learning methods, i.e., the induction of decision trees, were investigated.

In addition, the isotopic and hydrochemical parameters were investigated at two outlets of the same karstic aquifer: a temporary and a perennial spring characterised by different invertebrate drifts. A canonical correspondence analysis showed the presence of two distinct groups of samples, with Ca^{2+} as the only significant explanatory variable for differences in the drift composition. Some species from the drift were found to be useful tracers for distinguishing between the phreatic and the epikarst and vadose zones as the origin of spring water.

Figure 5: As part of the EU project GLOBAQUA in September 2015, co-workers from the Department of Environmental Sciences performed the sampling of water, biota and sediments of the Sava River from Mojstrana to Belgrade. The sampling was performed with the use of the new, fully equipped van of the Ecological Mobile Unit Laboratory.

The research performed within the GLOBAQUA project comprised (1) a GIS-based prediction of the stable isotope composition of surface river water in the Sava River Basin; (2) an evaluation of the long-term water-quality trends at selected locations along the entire Sava River and (3) a study of the surface-groundwater interactions in the Ljubljansko polje aquifer using hydrological, geochemical and modelling approaches. A great deal of effort has been put into the construction of the geometry of the five-layer model, especially in the interpolation of the Sava River channel and linking it to the extended alluvial aquifer. For the modelling, the WaSiM, MIKE11 and FEFLOW software packages were used.

In the framework of our cooperation with the Institute of Oceanography and Fisheries in Split, Croatia, mercury speciation in seawater and microbiological abundance in the central Adriatic were studied on a monthly basis. In

the framework of the EU GMOS project, mercury speciation in the surface and deep waters of the Antarctic was also studied.

In cooperation with Velenje Coalmine Company d.d., deep groundwater and coalbed gases in active excavation fields were studied in the scope of the evaluation of the geological sequestration of CO_2 in natural analogues in the Velenje Basin.

A study of the sources of CO_2 in cave atmospheres and the conditions that cause cave ventilation was conducted in a dead-end passage of Postojna cave (SW Slovenia) and on the ground surface area above the passage. Preliminary results suggest that the cave's CO_2 originates from soil CO_2 transported directly into the cave, and that there is no statistically significant correlation between the cave's ventilation and the soil's CO_2 concentration or isotopic composition.

Sedimentological and geochemical analyses (stable carbon, nitrogen and oxygen isotopes), pollen and microcharcoal analysis, associated radiocarbon and short-lived radionuclides were used to reconstruct the historical climate and precipitation patterns, flood and earthquake events, soil erosion, vegetation changes and human impact in the lake Bohinj catchment area.

Figure 6: The Department co-organized the 22nd International Symposium on Environmental Biogeochemistry (ISEB) that was held in Piran, September 28 – October 2, 2015 (www.iseb22.ijs.si). The symposium continues its tradition of strong international representation, with more than 100 participants from 23 countries.

The deposition and distribution of trace metals in the surface sediments of the transient environment of the Neretva River delta and the adjacent coastal sediments were studied in collaboration with the Ruđer Bošković Institute and the Faculty of Science of the University of Zagreb (Croatia). It was shown that the presence of sedimentary organic matter of terrestrial origin exerts a significant effect on the sediments' surface properties and processes, influencing the distribution of some trace metals, particularly Cd, Pb and Cu, whereas Ni, Co and Zn are mainly bonded to Fe and Mn oxide and oxyhydroxide coatings at the clay mineral surfaces.

An extensive study of the content of natural radionuclides in the Bay of Trieste was performed in cooperation with the Marine Biological Station, Piran. The activity concentrations of uranium, thorium and radium isotopes and ^{210}Pb and ^{210}Po were determined in seawater, sediments, plankton and mussels. The main emphasis was on a study of the biogeochemical processes in relation to the sources and accumulation of both radionuclides. Lipid biomarkers and their isotope signatures were determined in the Piran salt pans (Sečovlje and Strunjan salt pans), which are the most northern still-active salt pans in the Adriatic and amongst the very few in the Mediterranean region using traditional procedures for salt production. The results revealed the differences in the petola lipid composition due to the different microbial communities present and the selective diagenetic transformations of specific microbial compounds.

Stable isotopes of C and O in carbonate minerals were applied in a petrological study of carbonatite-like dykes in Macedonian magmatic complexes, so as to estimate their origin (igneous vs. sedimentary). The isotopic compositions' plot between primary unaltered carbonatites and marine carbonates pointed towards melted sedimentary carbonates, associated with an unexposed, deep-seated, causative magmatic body.

Environment, nutrition and health

A paleodietary investigation was performed on the animal burial remains from a late Bronze-Iron Age period site in Ljubljana. Particular attention was paid to a canine penile bone. The morphology, metrics and genetic analysis of its source were inconclusive, so that it could have originated either from a wolf (*Canis lupus*) or a dog (*C. familiaris*), while the isotope analysis of carbon and nitrogen in collagen indicated different dietary habits and confirmed our assumption that the bone originated from a dog. This finding has important implications for understanding the relationship between man and dog in early societies.

An investigation of pumpkin-seed oils was performed in collaboration with the Slovenian Institute of Hop Research and Brewing. A $\delta^{13}C$ analysis of pumpkin-seed oils from pumpkins of different regions in Europe and of particular fatty acids combined with chemometrics were found to be an excellent tool for evaluating the geographical and botanical origin. The research performed in cooperation with the Biotechnical Faculty, University of Ljubljana, is related to honey adulteration. The main objective was to determine whether comb reversing from the brood chamber to the honey super and spring bee colonies feeding might cause honey adulteration. On the basis of our study the most successful analyses for revealing the honey's adulteration are the activity of foreign enzymes in honey and also a determination of the $\delta^{13}C$ values in honey and proteins. The geographical origins of apple juices and dairy products were investigated, too. A data evaluation of goat, sheep and cow milk and cheese was performed using a combination of elemental and stable isotope analyses of products originating from different regions in Slovenia. Using a multivariate analysis it was possible to distinguish between the origin of cow, goat and sheep milk and cheese and to discriminate between milk and cheese according to the geographical origin within

each animal species. The estimated prediction ability to separate goat, cow and sheep milk was 95.2% with Ca, Cl, Zn, K and $\delta^{13}C$ values being the most significant variables. A statistical model of authentic Slovenian apple juices was established and tested on apple juices available on the Slovenian market. Thirty-six 100 % apple juices from European countries were purchased, 13 of which were exclusively from Slovenian producers. Successful separation was obtained between authentic Slovenian apple juices and commercial juices from other EU countries. The most significant variables were the concentration of sucrose, the $\delta^{18}O$ and $\delta^{2}H$ values, and the overall prediction ability was 90%.

In collaboration with the Biotechnical Faculty we investigated the effect of different compounds of selenium and iodine on selected biochemical and physiological characteristics in common buckwheat and pumpkin sprouts to reveal possible interactions between selenium and iodine in plants. Seeds of common buckwheat and pumpkins were soaked in solutions of selenite or selenate and iodide or iodate and their combinations. Then the content of chlorophyll a and b, and carotenoids were measured to reveal possible effects of different treatments on the potential photochemical efficiency. The concentrations used in the present study generally had no negative effects on the biochemical and physiological characteristics of the sprouts.

In laboratory-based conditions, the soil-to-plant transfer of uranium and radium for Chinese cabbage was investigated on soils contaminated with uranium-mill tailings. Different levels of soil contamination under various growth conditions were applied in a pot experiment to simulate different contamination scenarios. The results showed an increased accumulation of ^{226}Ra and a low accumulation of ^{238}U in cabbage leaves in the more contaminated soil. New data on the activity concentrations of the isotopes of U, Th and ^{226}Ra in dominant species of plants, growing on territories contaminated by the uranium industry in Kazakhstan, were obtained. The results showed a significant variability between the different plant species and also the intra-plant variability of activity concentrations between the above-ground parts and the roots. Higher concentrations of radionuclides in the root system are attributed to the root barrier, which was the highest in the rough cocklebur (*Xanthium strumarium*), especially for U isotopes, while the highest accumulation ability was determined for the *Artemisia serotina*.

The content of radionuclides in cigarettes from the Slovenian market and the importance of the ^{210}Po and Th isotopes for a radiation-dose assessment due to smoking were investigated. To accurately assess the amount of ^{210}Po and thorium isotopes actually inhaled by a smoker during smoking, a novel smoking experiment was introduced. It is well known that the ^{210}Po in cigarette smoke significantly contributes to the radiation dose of smokers, but in our work it was found that the contribution of Th isotopes is comparable to or even larger than that of ^{210}Po due to the relatively large dose-conversion factors.

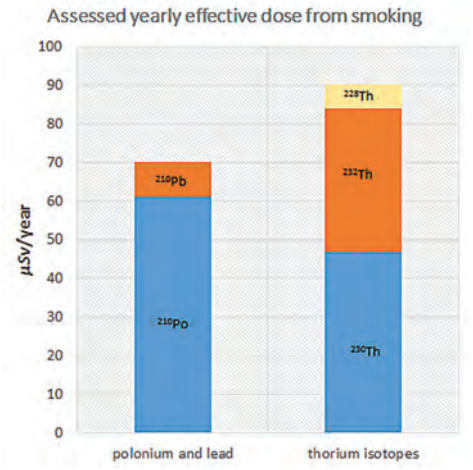

Figure 7: During research related to the radionuclide content in cigarettes and their effect on the smoker's radiation dose it was found that the contribution of the thorium isotopes to the radiation dose is even larger than the radiation dose due to polonium, which was until now considered as the radionuclide with the highest importance in the dose assessments from smoking. A novel smoking experiment was performed in this framework, where, with the voluntary participation of smokers, we simulated as close as possible a realistic assessment of the radionuclide intake into the lungs.

We have been participating in a European research 'personal radon dosimeter' within which Rn has been measured simultaneously in nine countries, using solid-state nuclear track detectors as personal dosimeters and as room detectors. It was shown that the addition of a personal dosimeter to the generally accepted approach of using radon concentrations in living and working environments for dose estimates is an important contribution to justify this method and evaluate its accuracy.

In collaboration with the University of Nova Gorica, the number concentration and the size distribution of nano aerosol particles (size range 10–1100 nm) in the Ljubljana basin and the Vipava valley were determined. Our research on nano aerosols and positive and negative air ions (size range 0.36–1.6 nm) indoors was focused on the characterization of particles produced by wood burning in stoves, cooking and smoking. Correlations have also been sought between the concentrations of nanoparticles, ions, and radon and thoron, strong ionisation sources (in a bilateral collaboration with Serbia).

Within two "exposome" projects funded by the EU (Life CROME and HEALS), a comprehensive review of a selection of the most appropriate biomarkers for exposure to toxic and potentially toxic chemicals for "exposome" research studies was prepared. One of the important objectives of HEALS and CROMEe is the efficient use of existing databases and biological samples from biobanks. An example of such use is the genotyping of apoproteins E (apo E) performed in 2015 in the Slovenian-Croatian population of pregnant women and their newborns, where the correlation between the presence of genotype apo E4 and levels of mercury and selenium in individual tissues (mother's hair, milk, urine, peripheral and umbilical blood during pregnancy and/ or at child birth and child's urine at birth) was examined.

Methodological documents for biomonitoring the human population's exposure to mercury (Hg) using human biomonitoring (HBM) for the World Health Organization (WHO), the WHO Regional Office for Europe, were prepared. Standard operating procedures (SOPs) for the collection of biological samples and laboratory analyses have been prepared previously for the existing standardized WHO methodology for HBM surveys, while in 2015

additional documents were elaborated: (1) critical evaluation of human biological matrices that can be used in HBM surveys of prenatal exposure to organic and elemental/inorganic mercury; (2) SOPs for alternative analytical procedures; (3) a questionnaire for participants in the WHO survey of prenatal Hg exposure; and (4) survey design considerations including recommendations for selecting biomarkers for specific survey sites. The documents were presented at a WHO technical meeting in Bonn, Germany, in June 2015.

The national human biomonitoring study implemented in collaboration with the Chemical Office of the Republic of Slovenia, the University Medical Centre Ljubljana, regional institutes of public health, regional hospitals and health centres was completed. According to the results, the exposure of the general population to toxic elements such as lead, mercury, cadmium and arsenic is low and generally does not pose a risk to the population under investigation. The results of the analyses for essential elements (selenium, copper and zinc) are within the ranges given by international organizations and are comparable to studies elsewhere in the world, showing that there was no noticeable lack or excess of these elements in participating subjects, except in some individuals. An analysis of persistent organic pollutants (dioxins, furans, organochlorine pesticides, PCBs, polybrominated flame retardants) in blood and breast milk showed that the levels in most of the samples are below the reference value for a non-contaminated environment. The burden of the entire study population with selected organic pollutants is generally low, with a few isolated cases of higher values.

In biomedical research, the functional link between zinc (Zn) homeostasis and membrane-related processes, including lipid metabolism regulation was also investigated in collaboration with the Biochemistry Department. In collaboration with co-workers from the Oncology Institute the possibility of adjuvant tumour necrosis factor (TNF-) therapy to potentiate the antitumor effectiveness of electro-chemotherapy with intravenous cisplatin administration in murine sarcoma was investigated. The results demonstrated that the adjuvant intratumoural TNF- therapy synergistically contributes to electro-chemotherapy with intravenous cisplatin administration.

Environmental technologies

Different water-treatment technologies for the successful removal of pharmaceutical residues during water treatment were investigated. We studied the bio- (suspended and attached biomass) and photodegradation of selected pharmaceuticals and personal care products (anti-inflammatory drugs, antidepressants, cytostatics and their metabolites, UV filters based on the benzophenone structure) and endocrine-disrupting compounds (BPA, parabens, triclosan). We were the first to identify some novel transformation products formed during these processes. In collaboration with the Faculty of Mechanical Engineering (University of Ljubljana) we studied cavitation – a novel advanced oxidation process as a viable option to remove organic micro-pollutants like cytostatics and endocrine-disrupting compounds (BPA, parabens and triclosan) from wastewaters. Tests were performed on the laboratory- and pilot-scales.

In the frame of the RusaLCA project and in collaboration with the Slovenian Building and Civil Engineering Institute (ZAG), we continued with the optimization of the remediation of wastewater from small biological treatment plants. The procedure is based on the use of Fe^0 nanoparticles (nZVI) in combination with an ion-exchange column and adsorbing agents. It enables the efficient remediation of wastewater, which fulfils the requirements for drinking water. Different methods of remediation for highly contaminated soil from the Celje basin were also investigated.

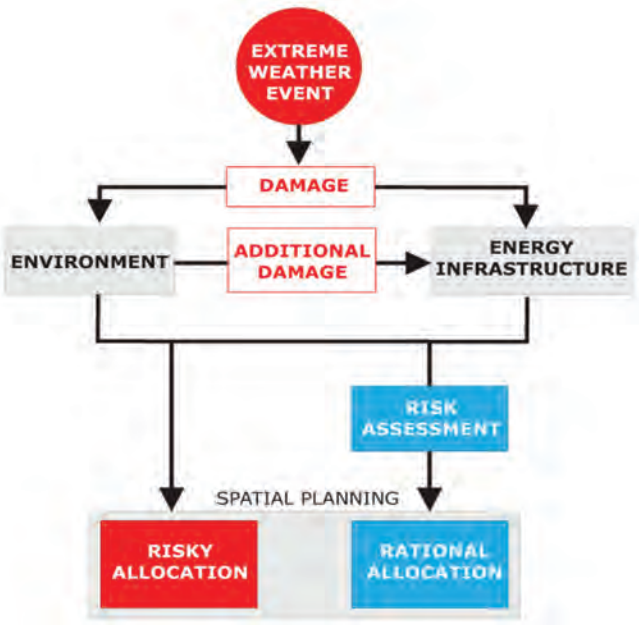

Figure 8: Consideration of extreme-weather events in spatial planning – approach

As part of new research activities, the fate of nanoparticles in the environment was investigated, such as the agglomeration of FeNPs after the remediation of wastewaters using single-particle (SP)-ICP-MS analysis.

In collaboration with ZAG, cements with the addition of ladle slag were investigated for their chemical and physico-mechanical properties. Long-term leaching experiments (180 days) with water and saline solutions revealed that Cr(III) and Cr(VI) were immobilized by the hydration products formed in the cement composites with the addition of ladle slag. The Cr(VI) content originating from the cement was also appreciably reduced by Fe(II) from the minerals present in the added ladle slag, which thus had significant positive environmental effects. Among the metals, only Mo and Ba were leached in elevated concentrations, but solely in ground cement composites with the addition of ladle slag. It was demonstrated that the presence of ladle slag in cement composites can even contribute to an improved mortar resistance.

The adsorption and degradation processes of tributyltin (TBT) and trimethyltin (TMeT) in a landfill leachate sample treated with different iron nanoparticles (FeNPs), i.e., Fe^0 (nZVI), FeO and Fe_3O_4, were investigated to find the conditions for their efficient removal.

Studies of the physico-chemical conditions affecting mercury redox reactions in wet flue-gas desulfurization equipment were made in laboratory pilot-plant conditions in collaboration with the Department of Inorganic Chemistry and Technology (K1).

Environmental management, environmental impact assessment and risk assessment

Within the CITI-SENSE project various air-quality (AQ) sensing devices were tested in order to develop a dense monitoring network that will give an insight into the spatial distribution of pollutants in Ljubljana in real time and enable individual exposure assessments. The general public and city authorities are involved in the project by hosting some of the sensor devices, as well as providing feedback on the developed tools and applications. Workshops, information days, activities in the nature as well as in the city centre of Ljubljana were organised so as to raise an awareness of air-quality issues in general and about the novel technologies in AQ sensing.

Technical support in the permit process for Slovenian Seveso lower-tier establishments has been provided to the Ministry of the Environment and Spatial Planning – The Environmental Agency. Additionally, the first phases of the site-suitability evaluation for the new liquid-petroleum-gas storage facilities for Butanplin d.d. Ljubljana and Steklarna Hrastnik d.o.o. have been made. In terms of international collaboration, the emphasis was on the finalization of the IAEA Coordinated Research Project "Techno-economic Evaluation of Options for Adapting Nuclear and Other Energy Infrastructure to Long-term Climate Change and Extreme Weather".

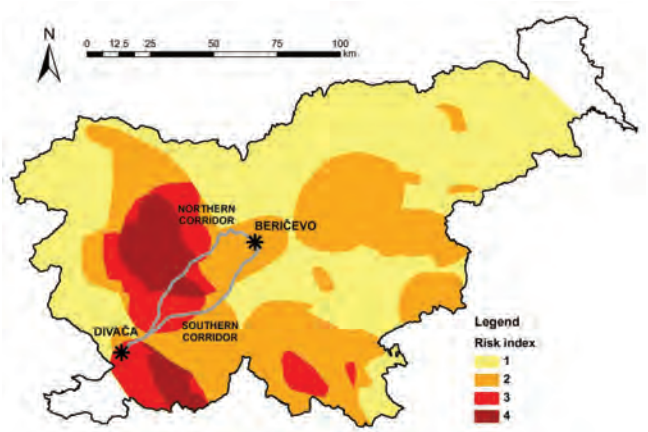

Figure 9: Risk due to Ice Storm: analysis of two alternatives for the planned 400-kV transmission power line Divača-Beričevo.

Environmental monitoring

In collaboration with the Environmental Agency of the Republic of Slovenia the monitoring of organotin compounds in surface and sea water was continued in 2015. 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. The monitoring of tritium and radiocarbon in gas effluents from the NPP was also performed. With analyses of strontium and tritium we also participated in the monitoring of the 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 in the monitoring purposes are accredited by the Slovenian accreditation body (SA LP-090).

Infrastructure activities

The infrastructural Centre for Mass Spectrometry (CMS) participated in many research projects and programs, providing facilities and know-how for studies of the circulation of substances in the environment, chemistry for sustainable development, functional foods and dietary supplements, the synthesis and transformation of organic compounds, and bioinorganic and bioorganic chemistry, design, synthesis and evaluation of active planning and preclinical development of new active pharmaceutical compounds, pharmaceutical biotechnology, the chemistry and structure of biologically active compounds, functional genomics and biotechnology for health, toxins and biomembranes, proteolysis and its regulation, and molecular biotechnology. In these areas the CMS supported researchers at the JSI, the National Institute of Chemistry, the National Institute of Biology, the Universities of Ljubljana, Maribor and Nova Gorica, and a number of Centres of Excellence: En-fist, CIPKeBiP, Namaste, etc.

The mobile chemical laboratory ELMU (Ecological Laboratory with a Mobile Unit) is organized as part of the system for Slovenian Civil Protection as a unit for intervention in ecological accidents with hazardous substances and materials. The new vehicle of ELMU was upgraded into a modern mobile laboratory and is always ready to intervene in ecological accidents or for the sampling of water, air or soil from the environment.

ERA CHAIR ISO-FOOD

The ISO-FOOD ERA Chair for isotope techniques in food safety, quality and traceability was established in 2014. Over the past year research has been focused on isotope and elemental fingerprinting for a determination of foods' authenticity and geographical origin, the analysis of trace-element speciation, radionuclides and new and emerging contaminants, such as organic compounds or nanoparticles, and food compositional databases.

Work is ongoing in a study of potential robust indicators for determining the geographical origin and discrimination between various types of production regimes for vegetables (lettuce, sweet pepper, tomato, potato, garlic). Stable isotopes of nitrogen and carbon, as well as elemental composition (P, S, Cl, K, Ca, Zn, Br, Rb and Sr), were analysed. The preliminary results show a good potential for multiproxy analysis with respect to the discrimination

of organic production from conventional and hydroponic production regimes, although vegetables respond differently to the application of fertilisers with different isotopic compositions.

With respect to metal speciation, the total concentrations of selected trace elements in Neem powder and in Neem tea were determined by ICP-MS. The data revealed that despite high total concentrations of the potentially toxic elements Al and Ni in the Neem powder, their amounts dissolved in Neem tea were low. The total concentrations of the other toxic elements, Pb, As and Cd, were very low and do not represent a health hazard. In contrast, the total concentrations of the essential elements Fe, Cu, Zn, Se Mo and Cr in Neem powder were high and considerable in Neem tea. Consuming one cup of Neem tea covers the recommended daily intakes for Cr and Se and represents an important source of Mo and Cu. A speciation analysis of Cr by high-performance liquid chromatography (HPLC)-ICP-MS with the use of enriched Cr isotopic tracers to follow species interconversions during the analytical procedure demonstrated that toxic Cr(VI) was not present in either Neem powder or Neem tea.

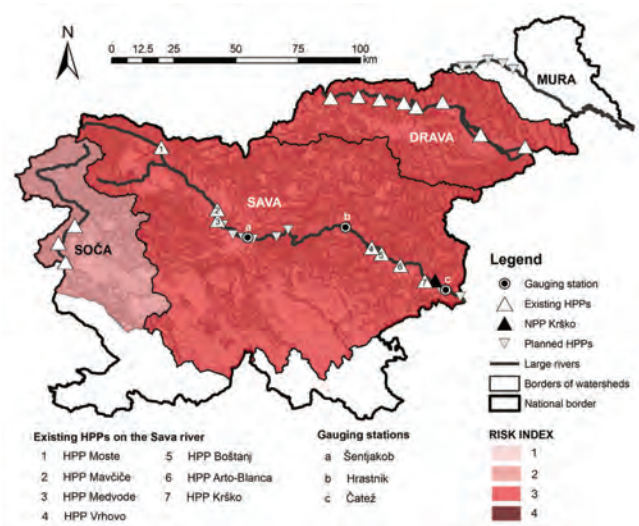

Figure 10: Risks to HPPs on the Sava and Drava due to heavy rain storms

Bisphenols as BPA alternatives (BPs) in honey and their migration from food contact material (FCM) have been studied. A range of honey samples from European countries (e.g., Greece, Italy and Slovenia) and China were analysed. Bisphenol A was present in all the samples, but it was significantly higher in a honey product obtained from China and a honey labelled EU & non-EU. Other bisphenols (BPC, BPE, BPF and BPAP) were present in four samples. Based on the exposure to observed maximum levels of BPA, we estimated that any consumer health risk from consuming honey is unlikely, but the cumulative health effects of these substances should be explored in the future.

Research on nanoparticles (NPs) as food contaminants was focused on verifying the presence of NPs in processed food and characterizing the physico-chemical properties of NPs for a biological risk assessment. The work has involved investigating matrix degradation as a mechanism for nanoparticles released from food contact materials, including the extraction and characterization of TiO_2 (E171) from chewing gums and whitening ingredients. The physico-chemical characteristics of TiO_2 under dry and colloidal conditions were investigated by employing biologically relevant media as the solvents. The aim is to mimic the behaviour of nanomaterials during their consumption.

The research on radionuclides in foodstuffs involved the development of fast digestion methods, the optimization of radiochemical separation procedures and the determination of low-level concentrations of uranium by neutron-activation analysis. The activity concentrations of various radionuclides in cabbage and soil collected in the vicinity of the former Žirovski vrh uranium mine were determined. Preliminary results show that in the case of uranium (^{234}U, ^{235}U, ^{238}U) and polonium (^{210}Po) radioisotopes, biomagnification is not an issue. Also, the activity concentrations of both U and Po are comparable with the results for cabbage found at other locations in Slovenia.

Also this year, ISO-FOOD organized its first international stakeholder event entitled "Recent Advances in Mass Spectrometry in Food, Environment and Health" and held its first training course entitled "Quality assurance for Hg measurements in food and environmental samples". The course was designed for early-stage researchers and application scientists, i.e., from the National Reference Laboratories and the Official Control Laboratories from the EU network on 'heavy metals' involved in food and feed analyses and environmental monitoring.

Some outstanding achievements

1. A study of the adsorption and degradation processes of TBT and TMeT in landfill leachate treated with different iron nanoparticles contributed significantly to understanding the mechanisms of TBT and TMeT removal from the leachate.
2. As a holder of the national etalon for the amount of substance for trace elements in organic and inorganic materials the department entered 11 CMCs (Calibration and Measurement Capabilities) in the BIPM Key Comparison database (KCDB). This ensures measurement traceability to the highest metrological level or SI units in the areas for which the department acts as a Designated Institute.
3. Residues of anti-neoplastic drugs are emerging pollutants in aquatic environments, where missing chronic ecotoxicity data represent a critical knowledge gap. 5-fluorouracil was investigated in a chronic two-generation toxicity study on zebrafish (*Danio rerio*) and genotoxic effects were detected at low levels for environmental exposure relevant concentrations.

4. A book on the Sava river was published, edited by Milačič, R., Ščančar, J., Paunović, M. (Eds). The Sava river, The Handbook of Environmental Chemistry, ISSN 1867-979X, vol. 31, Heidelberg [etc.]: Springer, 2015, 506 pp.

Some outstanding publications in the past year

1. Peeters, K., Lespes G., Milačič R., Ščančar, J. 2015. Adsorption and degradation processes of tributyltin and trimethyltin in landfill leachates treated with iron nanoparticles. Environmental Research, 142, 511-521.
2. Kristan, U., Planinšek, P., Benedik, L., Falnoga, I., Stibilj, V. 2015. Polonium-210 and selenium in tissues and tissue extracts of the mussel *Mytilus galloprovincialis* (Gulf of Trieste). Chemosphere 119, 231-341.
3. Brenčič, M., Kononova, N., Vreča, P. 2015. Relation between isotopic composition of precipitation and atmospheric circulation patterns. Journal of Hydrology 529 (3), 1422-1432.
4. Kotnik, J., Horvat, M., Ogrinc, N., Fajon, V., Žagar, D., Cossa, D., Sprovieri, F., Pirrone, N. 2015. Mercury speciation in the Adriatic Sea. Marine pollution bulletin 96 (1/2), 136-148.
5. Kovács, R., Csenki, Z., Bakos, K., Urbányi, B.. Horvath, A., Garaj-Vrhovac, V., Gajski, G., Gerić, M., Negreira, N., Lopez de Alda, M., Barceló, D., Heath, E., Kosjek, T., Žegura, B., Novak, M., Zajc, I., Baebler, Š., Rotter, A., Ramšak, Ž., Filipič, M. 2015. Assessment of toxicity and genotoxicity of low doses of 5-fluorouracil in zebrafish (Danio rerio) two-generation study. Water Research 77, 201-212.
6. Dominguez-Villar, D., Lojen, S., Krklec, K., Baker, A., Fairchild, I.J. 2015. Is global warming affecting cave temperatures? Experimental and model data from a paradigmatic case study. Climate Dynamics 45 (3-4), 569-681.
7. Covaci, A., Horvat, M., Heath, E., Kosjek, T., Mazej, D., Snoj Tratnik, J., et al. 2015. Urinary BPA measurements in children and mothers from six European member states: overall results and determinants of exposure. Environmental Research 141, 77-85.
8. Kovács, R., Csenki, Z., Bakos, K., Urbányi, B., Horvath, A., Garaj-Vrhovac, V., Gajski, G., Gerić, M., Negreira, N., Lopez de Alda, M., Barceló, D., Heath, E., Kosjek, T., Žegura, B., Novak, M., Zajc, I., Baebler, Š., Rotter, A., Ramšak, Ž., Filipič, M. 2015. Assessment of toxicity and genotoxicity of low doses of 5-fluorouracil in zebrafish (Danio rerio) two-generation study. Water Research 77, 201-212.
9. Den Hond, E., Govarts, E., Willems, H.., Smolders,R., Casteleyn, L. Kolossa-Gehring, M. Schwedler, G. Seiwert, M. Fiddicke, U. Castaño, A. Horvat .M. Mazej,D., Snoj Tratnik,J. et al. 2015. First steps toward harmonized human biomonitoring in Europe: Demonstration project to perform human biomonitoring on a European scale. *Environmental health perspectives*, 123(3), 255-263.
10. Vidmar, J, Martinčič, A., Milačič, R., Ščančar, J. 2015. Speciation of cisplatin in environmental water samples by Hydrophilic interaction liquid chromatography coupled to inductively coupled plasma mass spectrometry. *Talanta*, 138, 1-7.
11. Kotnik, J., Horvat, M., Ogrinc, N., Fajon, V., Žagar, D., Cossa, D., Sprovieri, F., Pirrone, N. 2015. Mercury speciation in the Adriatic Sea. Marine pollution bulletin 96 (1/2), 136-148.
12. Haneklaus, N., Reyes, R., Lim, W. G., Tabora, E. U., Palattao, B. L., Petrache, C., Vargas, E. P., Kunitomi, K., Ohashi, H, Sakaba, N., Sato, H., Goto, M., Yan, X., Nishihara, T., Harikrishnan, T., Reitsma, F., Tarján, S., Sathrugnan, K., Jaćimović, R., Khaledi, N., Birky, B. K., Schnug, E 2015. Energy neutral phosphate fertilizer production using high temperature reactors - a Philippine case study. Philippine Journal of Science 144, 69-79. (članek je dobil nagrado Oddelka za znanost in tehnologijo in Nacionalne akademije za znanost in tehnologijo Republike Filipini: 2015 DOST International Publication Award, 4.12.2015

Awards and appointments

1. Johanna Amalia Robinson: Best Student Poster Presentation Award, Eindhoven, Nizozemska, Healthy Buildings Europe 2015, University of Technology, "Empowering students to improve their indoor school environment with the help of low-cost air quality sensors – CITI-SENSE project"Janja Vrzel, Goran Vižintin, Nives Ogrinc: Best ECO paper, The 7th International Postgraduate School Students' Conference, Conceptual model of Ljubljansko polje aquifer
2. Janja Vidmar, Radmila Milačič, Janez *Ščančar*: Best ECO paper, The 7th International Postgraduate School Students' Conference, Sizing of nanoscale titanium dioxide and its quantification in the presence of dissolved titanium by single particle inductively coupled plasma mass spectrometry

Organization of conferences, congresses and meetings

1. Nives Ogrinc: 22nd Symposium: "International Society for Environmental Biogeochemistry (ISEB)", 22 September to 2 October 2015, Portorož, Slovenia
2. Milena Horvat: The ISO-FOOD Hg Training Course "Quality assurance for Hg measurements in food and environmental sample", Ljubljana, Slovenia, 25–27 November 2015, Reaktroski center Podgorica, Slovenia

Patent granted

1. Ana Mladenovič, Primož Oprčkal, Nina Kržišnik, Radmila Milačič, Janez Ščančar, Andrijana Sever Škapin, Process for obtaining health- and environment acceptable construction materials from the soil containing water soluble compounds of heavy metals, SI24681 (A), Slovenian Intellectual Property Office, 30. 10. 2015.

INTERNATIONAL PROJECTS

1. Services; Determination of the Isotopic Composition of Carbon in Sugar Samples
   Prof. Nives Ogrinc
2. Different Analyses
   Prof. Sonja Lojen
3. Provision of Testing Services for Filter Media used in IMS Radionuclide Stations
   Prof. Ljudmila Benedik
   The Preparatory Commission For The Comprehensive
4. Small Services in the Years from 2007 to 2016
   Prof. Milena Horvat
5. 7FP - GMOS; Global Mercury Observation System
   Prof. Milena Horvat
   European Commission
6. 7FP - CITI-SENSE; Development of Sensor-based Citizens' Observatory Community for Improving Quality of Life in Cities
   Prof. Milena Horvat
   European Commission
7. 7FP - HEALS; Health and Environment-wide Associations Based on Large Population Surveys
   Prof. Milena Horvat
   European Commission
8. 7FP - GLOBAQUA; Managing the Effects of Multiple Stressors on Aquatic Ecosystems Under Water Scarcity
   Prof. Radmila Milačič
   European Commission
9. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Prof. Milena Horvat
   European Commission
10. LIFE12 ENV/ - CROME-LIFE; Cross-Mediterranean Environment and Health Network
    Prof. Milena Horvat
    European Commission
11. MeTra; EMRP - Traceability for Mercury Measurements
    Prof. Milena Horvat
    Euramet E.v.
12. EMPIR; ENVCRM - Matrix Reference Materialls for Environmental Analysis
    Prof. Milena Horvat
    Euramet E.v.
13. STAWA; Towards the Assessment of Ecological Status of Water Bodies in the Sava River Basin
    Prof. Radmila Milačič
    Eurovienna - Eu-consulting & -management GmbH
14. LIFE RusaLCA-Nanoremediation of water from small waste water tretment plants and reuse of water and solid remains for local needs
    Prof. Janez Ščančar
    European Commission
15. Techno-economic Evaluation of Options for Adapting Nuclear and Other Energy Infrastructure to Long-term Climate Change and Extreme Weather
    Asst. Prof. Branko Kontić
    IAEA - International Atomic Energy Agency
16. Stability Monitoring of BCR-462, BCR-646 and ERM-CE477; Butyl/Phenyltin Compounds in Sediments/Mussel Tissue
    Dr. Tea Zuliani
    Institute For Reference Materials And Measurements
17. Develop Methodological Documents for HBM Surveys of Mercury (Selection of Matrices, Two SOPs, Survey Design)
    Prof. Milena Horvat
    World Health Organization
18. The Stability Study for Br in ERM-EC590 & ERM-EC591
    Dr. Radojko Jaćimović
    Institute For Reference Materials And Measurements
19. Characterisation of the Trace Element Content of Two Plastic Materials by K0-INAA
    Dr. Radojko Jaćimović
    Institute For Reference Materials And Measurements
20. Measurements of Elements for the Characterisation of ERM-CA403: Trace Elements in Seawater
    Dr. Tea Zuliani
    Institute For Reference Materials And Measurements
21. Characterisation Study of ERM-CA400 (Total Hg in Seawater)
    Prof. Milena Horvat
    Institute For Reference Materials And Measurements
22. Stability Monitoring of ERM-EF411, ERM-EF412 & ERM-EF413
    Dr. Radojko Jaćimović
    Institute For Reference Materials And Measurements
23. Training Fees for Ms Delali Tulasi, (Ghana), 1.10. - 31.12.2015
    Prof. Milena Horvat
    Ictp - Centro Internazionale Di Fisica Teorica
24. 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
25. Stability Monitoring of the Certified Reference Material ERM-CZ120
    Dr. Tea Zuliani
    Institute For Reference Materials And Measurements
26. Stability Monitoring of ERM-EC590 and ERM-EC591
    Dr. Radojko Jaćimović
    Institute For Reference Materials And Measurements
27. Develop Training Modules as a Component of a Training Course Mercury and Implementation of the Minamata Convention in the Health Sector
    Prof. Milena Horvat
    World Health Organization
28. COST ES1403 - New and Emerging Challenges and Opportunities in Wastewater Reuse (NEREUS)
    Prof. Ester Heath
    COST office
29. Occurrence and Fate of Mercury in the Marine Environment
    Prof. Milena Horvat
    Slovenian Research Agency
30. Environmental Isotopes in Snow Hydrology
    Dr. Polona Vreča
    Slovenian Research Agency
31. Stabilisation and Incorporation of Waste Materials into Composits based on Cement and Fly Ash
    Prof. Janez Ščančar
    Slovenian Research Agency
32. The Role of Microbial Community Structure on Mercury Speciation in the Open Adriatic Sea
    Prof. Milena Horvat
    Slovenian Research Agency
33. Lake Ecosystems: Vulnerability to Pollution and Sustainable Development
    Prof. Nives Ogrinc
    Slovenian Research Agency
34. Multicontaminant Removal in Wet Flue Gas Desulphurisation (FGD)
    Prof. Milena Horvat
    Slovenian Research Agency
35. Probabilistic Risk Assessment for Mercury Associated with Food Consumption
    Prof. Milena Horvat
    Slovenian Research Agency
36. Determination of Alpha Emitters in Various Samples with Emphasis on Source

Preparation Procedures
Prof. Ljudmila Benedik
Slovenian Research Agency

37. Exposure-response Asessment of Ambient Air Pollution (AAP) and Hg Contamination in Affected Cities of India and Slovenia: A Comparative Study
Prof. Milena Horvat
Slovenian Research Agency
38. The Use of New Methods for Dating Young Groundwater in Slovenia
Prof. Nives Ogrinc
Slovenian Research Agency

RESEARCH PROGRAMS

1. Cycling of substances in the environment, mass balances, modelling of environmental processes and risk assessment
Prof. Milena Horvat
2. Modelling and environmental impact assessment of processes and energy technologies
Prof. Borut Smodiš

R&D GRANTS AND CONTRACTS

1. Vegetation and hydrology of Ljubljansko barje in the past, present and future a consequence of succession, human impact or climatic fluctuations?
Prof. Nives Ogrinc
2. Development of Molecularly Imprinted Polymers and their application in environmental and bio-analysis
Asst. Prof. Tina Kosjek
3. The effect of iodine and selenium on growth and quality of crops
Prof. Vekoslava Stibilj
4. In-situ remediacija onesnažene zemljine na področju stare Cinkarne In-situ remediation of polluted grouns in the area of the Zink-works at Celje
Prof. Janez Ščančar
5. Optimization and validation of new indicator systems in complex environmental matrices
Prof. Milena Horvat
6. Evaluating geological sequestration of CO2 in low rank coals; Velenje basin, Slovenia as a natural analogue
Dr. Tjaša Kanduč
7. Pharmaceutical and personal care product residues in the environment: Occurence, sources, treatment and effects
Prof. Ester Heath
8. Comparative study of ecosystem management and services in contrasting Slovenian freshwater systems
Dr. David Kocman
9. Evaluation of quality and safety parameters of vegetables produced on different systems in Slovenia and abroad with aim to establish national quality scheme for vegetables
Prof. Nives Ogrinc
10. Evaluation of quality and safety parameters of vegetables produced on different systems in Slovenia and abroad with aim to establish national quality scheme for vegetables
Prof. Nives Ogrinc
Ministry of Agriculture and Environment
11. Geomicrobial factors influencing mercury transformations in transition zone of middle and south Adriatic Sea
Dr. Arne Bratkič
12. Observe, Infer, Act
Dr. David Kocman
13. EMRP; MeTRA - Traceability for Mercury Measurements
Prof. Milena Horvat
14. Determining Elemental Content in Environmental Samples Using k0-INAA
Dr. Radojko Jaćimović
15. Irradiation and Analysis of Nano SiC Samples
Dr. Radojko Jaćimović
National Nuclear Research Center

NEW CONTRACTS

1. Determination of alpha emmiters
Prof. Ljudmila Benedik
Krško Nuclear Power Plant, Krško
2. Evaluating gelogical sequestration of CO2 in low rank coals; Velenje basin, Slovenia as a natural analogue
Dr. Tjaša Kanduč
Velenje Coal Mine, Velenje
3. Technical support in the permitting processes for Seveso lower tier establishments in Slovenia
Asst. Prof. Branko Kontić
Ministry of Agriculture and Environment
4. Analysis of tributyl and dibutyltin compounds in Slovene marine environment in the year 2014
Dr. Tea Zuliani
Ministry of Agriculture and Environment
5. Human biomonitoring - chemical analysis of metals
Prof. Milena Horvat
Ministry of Health of the Republic of Slovenia
6. Operational imission monitoring in the surrounding of NEK in 2014 and 2015
Prof. Milena Horvat
Krško Nuclear Power Plant, Krško
7. Preparation of the risk reduction plan for the environment for the planned technical gases production plant at land parcel 4d, industrial zone Štore II.
Dr. Davor Kontić
Istrabenz Plini d. o. o.
8. Measurements of gaseous effluents in 2015, 2016 and 2017
Dr. Marko Štrok
Krško Nuclear Power Plant, Krško
9. Monitoring of radioactivity of drinking water for year 2015
Dr. Marko Štrok
Ministry of Health of the Republic of Slovenia
10. Monitoring of radioactivity in living environment in RS for year 2015
Dr. Marko Štrok
Ministry of the Environment and Spatial Planning of the Republic of Slovenia

VISITORS FROM ABROAD

1. Giada Zanuttini, University of Udine, Udine, Italy, 9–27 February 2015
2. Prof. dr. Akagi Hirokatsu, Japan, 9 February to 6 March 2015
3. Niko Bačić, Institut Ruđer Bošković, Zagreb, Croatia, 15–19 June 2015
4. Dr. Maria Ângela de B.C. MENEZES, Nuclear Technology Development Centre/Brazilian Commission for Nuclear Energy (CDTN/CNEN), Belo Horizonte, Minas Gerais, Brazil, 22–26 June 2015
5. Dr. Patricia Badregal, Instituto Peruano de Energia Nuclear, Direccion de Investigacion y Desarrollo, Laboratorio de Tecnicas Analiticas, Lima, Peru, 29 June to 1 July 2015
6. Giada Zanuttini, University of Udine, Udine, Italy, 24 August to 1 September 2015
7. Taichi Nakamura, Hokkaido University, Sapporo, Japan, 10 August to 27 December 2015
8. Dr. Bojan Šešlak, doc. dr. Ivana Vukanac, Institut za nuklearne nauke „Vinča“, Belgrade, Serbia, 23 August to 5 September 2015 and 30 August to 5 September 2015
9. Natalija Velić, University of Osijek, Faculty of Food Technology Osijek, Department of Process Engineering, Subdepartment of Bioprocess Engineering, Osijek, Croatia, 23 August to 5 September 2015
10. prof. dr. Xiang Gao, Yi Wang, doc. dr. Chenghang Zheng, Jun Zhang, Zhejiang University, Hangzhou, Zhejiang, China, 2–5 September 2015
11. prof. dr. Tamar Barkay, Cook College, Rutgers University, Biochemistry and Microbiology, New Brunswick, New York, United States of America, 27 September to 2 October 2015
12. dr. Kathleen Brannen-Donnelly, University of Tennessee, Knoxville, United States of America, 27 September to 2 October 2015
13. dr. Arijit Chowdhuri in dr. Charu K. Gupta, Acharya Narendra Dev College, University of Delhi, Kalkaji, Govindpuri, New Delhi, India, 27 September to 8 October 2015
14. prof. dr. Chunlei Song, prof. dr. Yiyong Zhou, Siyang Wang, Zijun Zhou, Institute of Hydrobiology, Chinese Academy of Sciences, Hubei, Wuhan, China, 27 September to 9 October 2015
15. prof. dr. Ryoko Fujiyoshi, Hokkaido University, Sapporo, Japan, 27 September to 4 October 2015
16. Marianthi Sykiotou, Aristotle Univesity of Thessaloniki, Department of Chemistry, Greece, 1. 10.–31. 12. 2015
17. Delali Tulasi, School of Nuclear and Allied Sciences, University of Ghana, Legon, Accra, Ghana, 2 October to 24 December 2015
18. prof. dr. Takashi Tomiyasu, Ryusuke Imura, Hitoshi Kodamatani, Faculty of Science, Kagoshima University, Kagoshima, Japan, 4.–11 November 2015
19. Danijela Djukić Ćosić, Marijana Ćurčić, ..., Serbia, 24–27 November 2015
20. Jiating Zhao, Yu Feng Li, ..., Shandong, China, 23–28 November 2015
21. Peidong Ji, Cunjie Li, Dingling Tang in Xuewei Geng, Zhejiang University, Hangzhou, China, 21 November to 5 December 2015

STAFF

Researchers
1. Prof. Ljudmila Benedik
2. Asst. Prof. Ingrid Falnoga
3. Dr. David John Heath
4. Prof. Ester Heath
5. **Prof. Milena Horvat, Head**
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9. Asst. Prof. Branko Kontić
10. Asst. Prof. Tina Kosjek
11. Dr. Jože Kotnik
12. Prof. Sonja Lojen
13. Dr. Darja Mazej
14. Prof. Radmila Milačič
15. Prof. Nives Ogrinc
16. Prof. Borut Smodiš
17. *Prof. Vekoslava Stibilj, retired 16.01.15*
18. Prof. Janez Ščančar
19. Asst. Prof. Zdenka Šlejkovec
20. Dr. Marko Štrok
21. Prof. Janja Vaupotič
22. Dr. Polona Vreča
23. Dr. Tea Zuliani
24. Dr. Dušan Žigon

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27. Dr. Davor Kontić
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29. Dr. Miha Trdin

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31. Marjeta Česen, B. Sc.
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34. Ana Kroflič, B. Sc.
35. Petra Novak, B. Sc.
36. Majda Pavlin, B. Sc.
37. Petra Planinšek, B. Sc.
38. Johanna Amalia Robinson, B. Sc.
39. Janja Snoj Tratnik, B. Sc.
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42. Janja Vidmar, B. Sc.
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47. Janja Smrke
48. Barbara Svetek, B. Sc.
49. Zdenka Trkov, B. Sc.
50. Stojan Žigon

BIBLIOGRAPHY

Original Article

1. Ljudmila Benedik, Leja Rovan, Hiacinta Klemenčič, Ivan Gantar, Helena Prosen, "Natural radioactivity in tap waters from the private wells in the surroundings of the former Žirovski Vrh uranium mine and the age-dependent dose assessment", *Environ. sci. pollut. res. int.*, vol. 22, issue 16, 12062-12072, 2015.
2. Marika Berglund *et al.* (53 authors), "Exposure determinants of cadmium in European mothers and their children", *Environ. res. (N.Y.)*, vol. 141, pp. 69-76, 2015.
3. Mihael Brenčič, Nina Kononova, Polona Vreča, "Relation between isotopic composition of precipitation and atmospheric circulation patterns", *J. Hydrol. (Amst.)*, vol. 529, part 3, pp. 1422-1432, 2015.
4. Richard J. C. Brown, Paul J. Brewer, Hugo Ent, Paola Fisicaro, Milena Horvat, Ki-Hyun Kim, Christophe R. Quetel, "Who should take responsibility for decisions on internationally recommended datasets?, The case of the mass concentration of mercury in air at saturation", *Metrologia*, vol. 52, no. 5, pp. L25-L30, 2015.
5. Francesca Cateni, Tiziano Altieri, Marina Zacchigna, Guiseppe Procida, Jelena Zilić, Dušan Žigon, Angelo Cichelli, "Lipid metabolites from the mushroom Meripilus giganteus", *Natural product communications*, vol. 10, no. 11, str- 1833-1838, 2015.
6. Adrian Covaci *et al.* (36 authors), "Urinary BPA measurements in children and mothers from six European member states: overall results and determinants of exposure", *Environ. res. (N.Y.)*, vol. 141, pp. 77-85, 2015.
7. Maja Čemažar, Vesna Todorović, Janez Ščančar, Urša Lampreht Tratar, Monika Štimac, Urška Kamenšek, Simona Kranjc, Andrej Cör, Gregor Serša, "Adjuvant TNF-a therapy to electrochemotherapy with intravenous cisplatin in murine sarcoma exerts synergistic antitumor effectiveness", *Radiol. oncol.*, vol. 49, no. 1, pp. 32-40, III, Mar. 2015.
8. Marjeta Česen, Tina Kosjek, Maria Laimou-Geraniou, Boris Kompare, Brane Širok, Dimitra Lambropolou, Ester Heath, "Occurrence of cyclophosphamide and ifosfamide in aqueous environment and their removal by biological and abiotic wastewater treatment processes", *Sci. total environ.*, vol. 527/528, pp. 465-473, 2015.
9. Z. Ćurguz *et al.* (11 authors), "Long-term measurements of radon, thoron and their airborne progeny in 25 schools in Republic of Srpska", *J. environ. radioact.*, vol. 148, pp. 163-169, 2015.
10. Elly Den Hond *et al.* (52 authors), "First steps toward harmonized human biomonitoring in Europe: eemonstration project to perform human biomonitoring on a European scale", *Environ. health perspect.*, vol. 123, no. 3, pp. 255-263, 2015.
11. Matej Dolenec, Todor Serafimovski, Nina Daneu, Tadej Dolenec, Nastja Rogan Šmuc, Petra Vrhovnik, Sonja Lojen, "The case of the carbonatite-like dyke of the Madenska River complex at the Kriva Lakavica section in the Republic of Macedonia: oxygen and carbon isotopic constraints", *Turk. j. eart. sci.*, vol. 24, no. 6, pp. 627-639, 2015.
12. David Domínguez-Villar, Sonja Lojen, Kristina Krklec, Andy Baker, Ian J. Fairchild, "Is global warming affecting cave temperatures?, Experimental and model data from a paradigmatic case study", *Clim. dyn.*, vol. 45, issue 3-4, pp. 569-681, 2015.
13. Marta Esteban *et al.* (40 authors), "Mercury analysis in hair: comparability and quality assessment within the transnational COPHES/DEMOCOPHES project", *Environ. res. (N.Y.)*, vol. 141, pp. 24-30, 2015.
14. Karen Exley *et al.* (19 authors), "Pilot study testing a European human biomonitoring framework for biomarkers of chemical exposure in children and their mothers: experiences in the UK", *Environ. sci. pollut. res. int.*, vol. 22, iss. 20, pp. 15821-15834, 2015.
15. Ulrike Fiddicke *et al.* (50 authors), "Lessons learnt on recruitment and fieldwork from a pilot European human biomonitoring survey", *Environ. res. (N.Y.)*, vol. 141, pp. 15-23, 2015.
16. Ž. Fiket, Martina Rožmarić, Matea Krmpotić, Ljudmila Benedik, "Levels of major and trace elements, including rare earth elements, and ^{238}U in Croatian tap waters", *Environ. sci. pollut. res. int.*, iss. 9, vol. 22, pp. 6789-6799, 2015.
17. A. Fucić, Milena Horvat, Darja Mazej, Janja Snoj Tratnik, "Gender differences in cadmium and cotinine levels in prepubertal children", *Environ. res. (N.Y.)*, vol. 141, pp. 125-131, 2015.
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Independent Component Part or a Chapter in a Monograph

1. Nives Ogrinc, Tjaša Kanduč, David Kocman, "Integrated approach to the evaluation of chemical dynamics and anthropogenic pollution sources in the Sava river basin", In: *The Sava river*, (The handbook of environmental chemistry, vol. 31), Avdul Adrović, et al, Heidelberg [etc.], Springer, cop. 2015, pp. 75-94.
2. Janez Ščančar, Ester Heath, Tea Zuliani, Milena Horvat, Jože Kotnik, Silva Perko, Radmila Milačič, "Elements and persistent organic pollutants in the sediments of the Sava river", In: *The Sava river*, (The handbook of environmental chemistry, vol. 31), Avdul Adrović, et al, Heidelberg [etc.], Springer, cop. 2015, pp. 95-121.

Scientific Monograph

1. Dimosthenis Sarigiannis *et al.* (17 authors), *Human biomonitoring: facts and figures*, Andrey I. Egorov (urednik), Copenhagen, WHO = World Health Organization, 2015.

Professional Monograph

1. Teja Gerbec, Mira Strmčnik-Gulič, Metka Culiberg, Maja Gutman, Nina Zupančič, Nives Ogrinc, *Hotinja vas pri Mariboru*, (Zbirka Arheologija na avtocestah Slovenije, 45), Ljubljana, Zavod za varstvo kulturne dediščine Slovenije, 2015.
2. Andrej Trkov, Tanja Kaiba, Gašper Žerovnik, Z. Revay, R.B. Firestone, Radojko Jaćimović, Vladimir Radulović, *Supplementary data for neutron activation analysis*, (INDC(NDS), 0693), Vienna, IAEA, 2015.

Patent Application

1. Ana Mladenovič, Primož Oprčkal, Nina Kržišnik, Radmila Milačič, Janez Ščančar, Andrijana Sever Škapin, *Process for obtaining health- and environment acceptable construction materials from the soil containing water soluble compounds of heavy metals*, WO2015160313 (A1), World Intellectual Property Organization, 22. 10. 2015.

Patent

1. Ana Mladenovič, Primož Oprčkal, Nina Kržišnik, Radmila Milačič, Janez Ščančar, Andrijana Sever Škapin, *Process for obtaining health- and environment acceptable construction materials from the soil containing water soluble compounds of heavy metals*, SI24681 (A), Urad RS za intelektualno lastnino, 30. 10. 2015.

Mentoring

1. Kelly Peeters, *Investigations of the fate of organotin compounds in landfill leachates:* doctoral dissertation, Ljubljana, 2015 (mentor Radmila Milačič; co-mentors Marjan Veber, Gaetane Lespes).
2. Petra Štrekelj, *Uptake of metals and selenium in tartary buckwheat (Fagopyrum tataricum Gaertn.) and its role in the soil remediation:* doctoral dissertation, Ljubljana, 2015 (mentor Vekoslava Stibilj; co-mentor Ivan Kreft).
3. Johanna A. Robinson, *Empowerment initiative in air quality:* master's thesis, Ljubljana, 2015 (mentor Milena Horvat; co-mentor Hans Heune).
4. Tjaša Brcar, *A study of photodegradation kinetics of sertraline in the water:* master's thesis, Ljubljana, 2015 (mentor Jurij Trontelj; co-mentor Tina Kosjek).
5. Špela Gregorin, *Petrological, isotopic and geochemical characteristics of lignite and carbonate mineralization in Velenje basin from mining area - 50C Pesje:* master's thesis, Ljubljana, 2015 (mentor Mirijam Vrabec; co-mentor Tjaša Kanduč).
6. Anja Krajnc, *Simulating the photodegradation of sertraline in the aquatic enviroment:* master's thesis, Ljubljana, 2015 (mentor Robert Roškar; co-mentor Tina Kosjek).
7. Davor Kubalek, *Radioactivity of tobacco products and estimated radioactivity dose due to smoking:* master's thesis, Ljubljana, 2015 (mentor Gregor Serša; co-mentors Zvonka Jeran, Ljudmila Benedik).
8. Urša Remic, *Selenium content in Veronica anagallis-aquatica growing in selected Slovenian streams:* master's thesis, Ljubljana, 2015 (mentor Mateja Germ; co-mentor Vekoslava Stibilj).
9. Klara Skočajić, *Artificial and natural radionuclides in the Adriatic Sea:* master's thesis, Portorož, 2015 (mentor Jadran Faganeli; co-mentor Ingrid Falnoga).
10. Žiga Šmidhofer, *Development and validation of analytical method on the basis of liquid chromatography coupled with mass spectrometry for determination of sertraline in surface and waste waters:* master's thesis, Ljubljana, 2015 (mentor Robert Roškar; co-mentor Tina Kosjek).
11. Ajda Trdin, *Connection between mutations in the gene for apolipoprotein E with concentrations of mercury in the mothers and newborns:* master's thesis, Ljubljana, 2015 (mentor Janja Marc; co-mentor Ingrid Falnoga).

DEPARTMENT OF AUTOMATION, BIOCYBERNETICS AND ROBOTICS E-1

Head:
Prof. Aleš Ude

The research strategy within our department is unique, as it supports a variety of multi- and interdisciplinary research projects. Specifically, our research combines the fields of robotics (including intelligent control, humanoids, cognitive robotics, and robot learning and vision), automation, 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. Recently, we have added "human-robot partnership" as an additional goal of our research programme. By combining engineering sciences and life sciences, we have been able to make significant contributions to the development of new methods for sensorimotor learning by imitation and coaching, a planetary-habitat simulation facility, humanoid vision systems, 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 several EU projects in the area of cognitive systems, robotics and space technologies. We are also active in transferring our research results to various applications through direct collaborations with industry. By maintaining a critical mass of researchers in all areas within one programme group, we have managed to foster exciting multidisciplinary projects.

Research in the area of humanoid and cognitive robotics as well as 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 capable of helping people and interacting with them in natural environments.

During the past year, our research focused on the development of cognitive robotic systems, new robot-learning methodologies, including programming by demonstration and autonomous exploration, contact modelling, humanoid robot vision, robotic assistive devices, the automation of industrial manufacturing, studies of human physiology in extreme environments, an evaluation of protective equipment, and the development of biomedical methods. In the past year we began three new projects in the scope of Horizon 2020. Through these projects we will widen our research programme to include new areas such as intelligent factories and exoskeletons.

Historical note: Since its inception the department has maintained an inter- and multidisciplinary research focus. The scientific inheritance of its founders includes pioneering research culminating in the first demonstration of how functional electrical stimulation can assist paraplegics to walk and the development of the first industrial robots in our region. The common denominator in the robotics and biomedical research is improving the quality of life.

Robotics

In 2015 we continued our successful collaboration in the FP7 integrated project **Xperience** (Robots bootstrapped through learning from experience, http://www.xperience.org/). The goal of Xperience is to demonstrate that state-of-the-art cognitive robotic systems can be significantly extended using the concept of structural bootstrapping to generate new knowledge. This process is founded on explorative knowledge acquisition, and subsequently validated through experience-based generalization. In 2015 we experimentally evaluated the developed methodologies including a new approach to robot learning that combines **programming by demonstration and autonomous exploration**. With the proposed system, a robot can exploit the existing sensorimotor knowledge, which is provided as a database of example movement patterns, to efficiently search for new motor patterns. We also investigated a new representation of robot movements, which is based on dynamic movement primitives parameterized by arc length. We showed the effectiveness of the proposed representation for action recognition and statistical robot learning. Furthermore, we analysed the previously developed

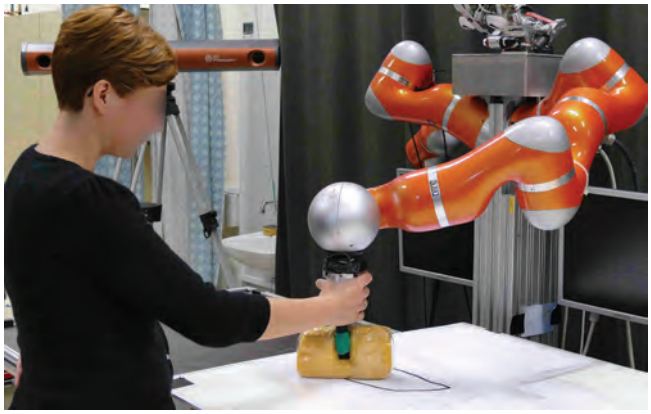

Figure 1: Robot coaching

In 2015 we successfully concluded the integrated EU project Xperience. Our main result was that the existing motor knowledge can be exploited to structure the learning space and accelerate robot motor learning based on autonomous exploration and coaching.

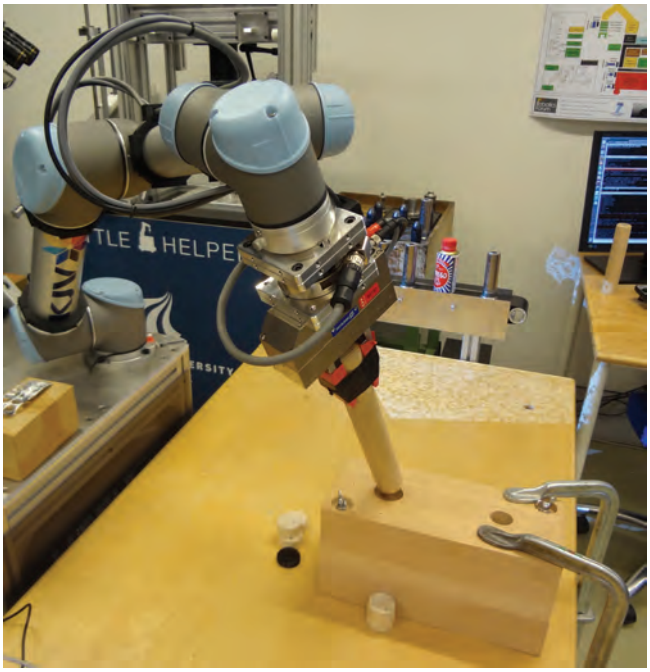

Figure 2: Statistical learning of assembly tasks.

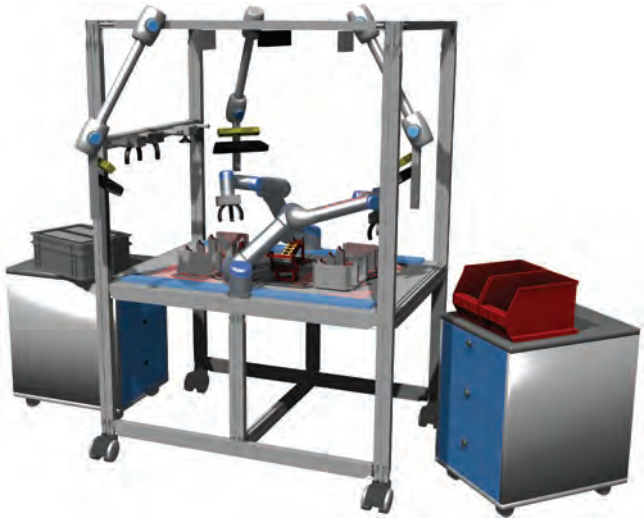

Figure 3: A reconfigurable robot workcell for the fast setup of assembly tasks.

Using a novel probabilistic trajectory model approach we showed that postural control precedes and predicts volitional motor control in humans.

system for interactive robot coaching, where the user shows to the robot which part of the motion to change and how. We found that force-based coaching methods have a clear advantage compared to visual interaction.

In Xperience we also studied the application of learning by demonstration for dual-arm systems, taking into account the interaction forces between the arms and manipulated objects. We developed a new concept that supports the programming by a demonstration of dual-arm manipulation in relative and absolute coordinates. The acquired dual-arm behaviours can then be improved by reinforcement learning and/or iterative learning control. Based on the results of the Xperience project we prepared a new research project entitled "Learning and autonomous adaptation of dual arm assembly and service tasks", which will be launched in 2016.

Cognitive robots operating in natural environments should be able to quickly acquire new skills without extensive programming and mathematical modelling. In the FP7 project **ACAT** (Learning and execution of action categories, http://www.acat-project.eu/) we investigated the problem of **statistical learning of robot movements in contact with the environment**, which are described by position and orientation trajectories as well as force-torque profiles. We showed that with statistical learning we could widen the range of robot contact movements. For this purpose we extended the framework of dynamic movement primitives with torque primitives. The applicability of the approach was shown on several problems from automated assembly. The concept of **action data tables** was utilized to store the available sensorimotor patterns and combine them with semantic information, such as the permissible sequences of movements. We performed several experiments related to the model-free learning of robot task dynamics, which enables the compliant execution of robot contact movements. We demonstrated that statistical learning can be used to compute optimal movements for variations of a given task, without the need for time-consuming programming or autonomous learning.

In 2015 we began a new Horizon 2020 project **ReconCell** (A Reconfigurable robot workCell for fast set-up of automated assembly processes in SMEs, http://reconcell.eu). ReconCell develops a new type of robot workcell, its required process infrastructures and the economic framework for automated robot assembly, especially designed for the needs of SMEs. These SMEs would benefit from robotic automation, but often cannot use it due to the set-up & maintenance complexity. This requires expert knowledge and time for the configuration and programming, which is too costly for them. Robotic automation is, thus, normally economically infeasible for SMEs, especially for small batch sizes. ReconCell develops an easy to (re-)configure and (re-)program workcell, making robot solutions commercially viable even for small batch sizes (~1000 units) by reducing the set-up & maintenance effort substantially. Specifically, the ReconCell System is based on a layered concept where we start together with the customer with business modelling the planned product assembly based on the ReconCell System to assess its economic viability and provide decisive Key Performance Indicators (KPIs). On approval, the next layer of the ReconCell System implements assembly with automated testing in simulation. Here we use reconfigurable hardware elements to design the required workcell layout and assembly processes. After verification, product assembly takes place in the real workcell under machine-vision-based monitoring and novel force-based control of the execution to ensure product quality using the KPIs. We demonstrate the capabilities of the layered ReconCell System on three real-use cases provided by the SMEs of our consortium and two more use cases, established through an open call.

We designed a novel method that **arbitrates the control between the human and the robot actors** in a teaching-by-demonstration setting to form a synergy between the two and facilitate effective skill synthesis on the

robot. We employed the human-in-the-loop teaching paradigm to teleoperate and demonstrate a complex task execution to the robot in real-time. To encode the robotic skill we employed Locally Weighted Regression that fits the local models to a specific state region of the task based on the human demonstration. If the robot is in the state region where no local models exist, the control over the robotic mechanism is given to the human to perform the teaching. When local models are gradually obtained in that region, the control is given to the robot so that the human can examine its performance already during the demonstration stage, and take actions accordingly. This contributes to a faster and more efficient teaching.

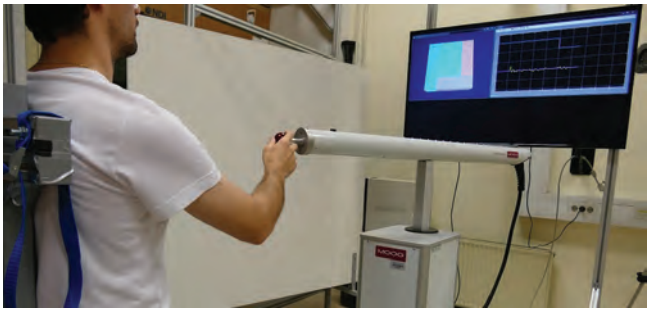

Figure 4: Robot manipulator control interface for shared control between the human and the robot.

In the scope of the FP7 project **CoDyCo** (Whole-body compliant dynamical contacts in cognitive humanoids, http://www.codyco.eu/) we investigated **mechanisms of human motor skill learning** that enable humans to adapt to new situations in the environment. To study the effect of contacts an innovative full-body experimental paradigm was established. A novel probabilistic trajectory model approach was employed to analyse the correlation between the motions of both arms and the trunk. We found that subjects adapted to the perturbations by establishing target-dependent hand contacts. Moreover, we found that the trunk motion adapted significantly faster than the motion of the arms. However, the most striking finding was that observations of the initial phase of the left arm or trunk motion were sufficient to faithfully predict the complete movement of the right arm. Overall, our results suggest that the goal-directed arm movements determine the supportive arm motions and that the motion of heavy body parts adapts faster than the light arms.

In 2015 we began a new project entitled **SPEXOR** (Spinal Exoskeletal Robot for Low Back Pain Prevention and Vocational Reintegration, http://www.spexor.eu). Its main motivation originates from the observation that most of today's robotic assistive devices are in the forms of exoskeletons that augment the motion of legs and arms and neglect the role of the spinal column in transferring load from the upper body and arms to the legs. In SPEXOR we will fill this gap and design a novel and revolutionary spinal exoskeleton to prevent lower-back pain in able-bodied workers and to support workers with lower-back pain in vocational rehabilitation.

Figure 5: Experimental setup for investigating mechanisms of human motor control in contact with the environment.

Automation and industrial robotics

An important mission of our department is to transfer our research results to industrial applications. In the past year, we started an applied R&D project for a Slovenian company, owned by an international food corporation, aimed to set up a **highly flexible production line** for the production and packaging of tea products. In the initial phase, we created the specification of the requirements and solutions. We conceived a system for automatic manufacturing execution, supervision, and control that represents the core of the manufacturing facility. In cooperation with the company specialists, we also synthesized the plant topology, transport and logistical structure, including the selection and configuration of special production devices and machines.

In 2015 we also collaborated with an international manufacturer of industrial robots to develop methods for **efficient dual-arm manipulation programming**. The research work consisted of three phases: 1) development of procedures for dual-arm task programming, 2) development of procedures for efficient dual-arm task execution and 3) development of procedures for the autonomous adaptation of dual-arm tasks. The successful completion of this project provided the basis to extend this collaboration into 2016.

With industry we also collaborated to develop **LCD-based glasses for personal protection** in an environment with welding light sources. The goal of the "Spatial Light Filtering" (SFL) project is to evaluate the potential of using such glasses. For this purpose, a demonstrator model of SFL glasses including a µP-based control system was developed. In 2015 we have developed a new improved version of the SLF glasses, a special simulation-based tool to support the design of the SLF glasses and to verify the algorithms for darkening LCD display segments, and an evaluation system consisting of a simple human-like head model with two cameras simulating the eyes and a computer for capturing the video images from both cameras for the evaluation of the functionality of the SLF glasses.

Environmental physiology and ergonomics

The **Biocybernetics group** in our department focuses primarily on research projects concerning the influence of extreme environmental factors on humans as well as the development and evaluation of technology, and strategies to maintain safety and unhindered performance in such extreme environments.

We investigate the effect of a **simulated planetary habitat environment** on different human physiological systems (http://www.planhab.com). For technical reasons, the environment within future Lunar and Mars habitats will be hypobaric and hypoxic. Prolonged exposure to low gravity results in a deconditioning of vital physiological

Figure 6: Assessing the effect of hypoxia (simulated altitude 3000 m) on muscle strength in children.

systems, and may consequently constitute a threat to the health of the astronauts. However, it is not known how prolonged exposure to both reduced gravity and hypoxia will affect health. For the purpose of this research program we established a Planetary Habitat Simulation Facility at the Olympic Sport Centre Planica. Male and female subjects participated in three trials: hypoxic and normoxic bed rest and hypoxic ambulation. The effects of these interventions were investigated in experiments concerning metabolic, cardiorespiratory, musculoskeletal, haematological, immunological and thermoregulatory functions. We anticipate that the new knowledge gained from these studies will also have clinical implications, since chronic hypoxia and bed rest (inactivity/unloading) constitutes a model of the underlying chronic condition experienced by patients suffering from respiratory insufficiency, cardiac diseases and obesity.

The purpose of our **hypoxic exercise confinement study** was to investigate the additive effects of exercise training during continuous hypoxic exposure on different physiological systems with special reference to appetite regulation, oxidative stress and sleep modulation. Our project was based on recent evidence suggesting that hypoxia *per se* and in combination with exercise influences appetite and body-mass modulation and could therefore provide a viable strategy for inducing weight loss and also for treating different metabolic disorders. This is one of the key priorities of modern research in the field of non-communicable disease prevention, given the fact that the prevalence of obesity is escalating in the modern world. The obtained results indicate that exercise does not significantly influence hormonal appetite regulation or sleep quality during hypoxic confinement. However, we showed that exercise significantly blunts oxidative stress and therefore seems beneficial for an individual's wellbeing during high-altitude sojourns.

We established a research program, funded in part by the European Space Agency (ESA) Programme for European Cooperating States (PECS), the EC FP7 programme, and the Slovenian Research Agency, investigating the separate and combined effects of hypoxia and sustained inactivity/unloading (bed rest) on human physiological systems.

Our research on a **comparison of the effects of normobaric and hypobaric hypoxia**, partly supported by the European Space Agency, examines the acute and chronic effects of living at altitude on several physiological mechanisms: i) central sleep apnea, ii) nocturnal vasodilatation, iii) sleep architecture, and iv) aetiology of acute mountain sickness. The results obtained in normobaric hypoxia at the Olympic Sport Centre Planica have been compared with results obtained during exposure to hypobaric hypoxia. The latter were obtained on staff at the Concordia Antarctic Research Station, and members of the Elbrus 2014 expedition. With regards to the physiological responses monitored, these studies have confirmed the Equivalent Air Altitude Theory. Namely, that it is the partial pressure of oxygen that is the main factor influencing the responses monitored, and not the ambient pressure.

With the support of the Slovenian Sport Foundation we investigated the **effect of simulated altitude conditions** on factors that may affect alpine skiing ability in children. Due to technological developments it is now quite simple for families to travel from sea level to high-altitude ski resorts in one day. The location of some EU ski resorts is at an altitude where the prevailing hypoxia may have detrimental effects on a variety of physiological systems. Together with colleagues from the General Hospital Jesenice (Department of Paediatrics), University Clinical Centre Ljubljana (Eye Clinic and Institute of Neurophysiology) and the Faculty of Sport (University of Ljubljana) we simulated family ski excursions to high-altitude resorts at the Olympic Sport Centre Planica. The preliminary results of this study suggest that while the physical performance of both adults and children is affected by sojourns at 3000 m above sea level, there does not appear to be a significant difference between adults and children in the majority of the physiological factors important for downhill skiing.

Figure 7: Determining the exercise cardiorespiratory responses of children at a simulated altitude of 3000 m.

Despite a plethora of cross-sectional data on foot size in different age periods there is an obvious lack of data regarding longitudinal foot development during childhood. The aim of our project on **foot-growth kinetics in children**, which was undertaken jointly with an industrial partner (UCS), is to obtain high-quality longitudinal data on foot growth during the childhood developmental period. During the course of the two-year project we measured the length, width, and height of the feet of 850 children between the ages of 1 and 15 years, at three-month intervals, using a foot scanner developed by UCS. The project will provide the data necessary to develop an algorithm for

foot growth in children, which will be implemented in a web-based system advising parents on appropriate footwear for their children.

This project evaluated **regional thermal comfort** in males and females. Subjects were requested to regulate the temperature of the water delivered to a water-perfused suit, such that it was thermally comfortable. In separate trials, subjects regulated the temperature of the whole suit, or specific regions of the suit covering different skin areas (arms, legs, front torso, back torso, hands, feet, and head). In the absence of regulation, the temperature changed in a sinusoidal manner from 10°C to 50°C; by depressing a switch, and reversing the direction of the temperature at the limits of the thermal comfort zone (TCZ), each subject defined a TCZ for each body segment investigated.

We have initiated a study with Intersocks d.o.o. to examine the manner in which compression socks may benefit individuals during a variety of sport activities. Specifically, studies will assess the effect of compression socks on delayed onset muscle soreness (DOMS) after outdoor (hiking, running) and training (calf-rise exercise) activities.

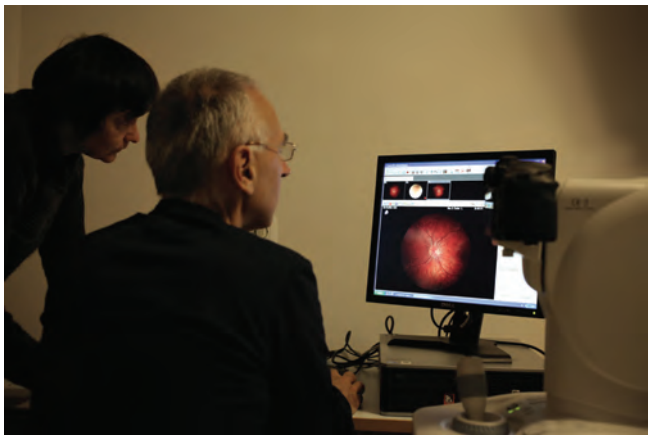

Figure 8: Examination of retinal blood vessels at a simulated altitude of 3000 m.

We continue our development of **thermal manikins** by embedding their control systems with physiological algorithms for simulating the onset and gain of sweating based on the core and shell temperatures. Together with a partner, the University of Maribor, we have developed a whole-body manikin with such capabilities. This work was funded by the Slovenian Research Agency. We are currently developing a thermoregulatory head manikin with such functionality, for the evaluation of helmets. In 2016 this development will be funded by an industrial partner.

Some outstanding publications in the past years

1. F. J. Abu-Dakka, B. Nemec, J. A. Jørgensen, T. R. Savarimuthu, N. Krüger, and A. Ude (2015) Adaptation of manipulation skills in physical contact with the environment to reference force profiles. Autonomous robots, vol. 39, no. 2, pp. 199-217.
2. R. Vuga, E. E. Aksoy, F. Wörgötter, and A. Ude (2015) Probabilistic semantic models for manipulation action representation and extraction. Robotics and autonomous systems, vol. 65, pp. 40-56.
3. F. Wörgötter, C. Geib, M. Tamosiunaite, E. E. Aksoy, J. Piater, H. Xiong, A. Ude, B. Nemec, D. Kraft, N. Krüger, M. Wächter, and T. Asfour (2015) Structural bootstrapping - a novel, generative mechanism for faster and more efficient acquisition of action-knowledge. IEEE Transactions on Autonomous Mental Development, vol. 7, no. 2, pp. 140-154.
4. A. Gams, B. Nemec, A. J. Ijspeert, and A. Ude (2014) Coupling movement primitives: Interaction with the environment and bimanual tasks. IEEE Transactions on Robotics, vol. 30, no. 4, pp. 816-830.
5. L. Peternel, T. Petrič, E. Oztop, and J. Babič (2014) Teaching robots to cooperate with humans in dynamic manipulation tasks based on multi-modal human-in-the-loop approach. Autonomous robots, vol. 46, no. 1, pp. 123-136.
6. F. Tellez, N. Pattyn, O. Mairesse, L. Dolenc-Grošelj, O. Eiken, I. B. Mekjavić, P. F. Migeotte, E. Macdonald-Nethercott, R. Meeusen, and X. Neyt (2015) eAmi: a qualitative quantification of periodic breathing based on amplitude of oscillations. Sleep, vol. 38, no. 3, pp. 381-389.
7. N. Stavrou, A. Mcdonnell, O. Eiken, and I. B. Mekjavić (2015) Psychological strain: examining the effect of hypoxic bedrest and confinement. Physiology & behavior, vol. 139, pp. 497-504.
8. U. Ciuha, O. Eiken, and I. B. Mekjavić (2015) Effects of normobaric hypoxic bed rest on the thermal comfort zone. Journal of Thermal Biology, vol. 49/50, pp. 39-46.

Organization of conferences, congresses and meetings

1. International Society for Gravitational Physiology ISGP 2015, Ljubljana, Slovenia, 7-12 June 2015
2. Workshop at one of the largest robotics conferences IROS 2015: Physical human-robot collaboration: Safety, control, learning and applications, Hamburg, Germany, October 2nd, 2015.
3. Workshop at one of the largest robotics conferences IROS 2015: Transfer of cognitive robotics research to industrial assembly and service robots, Hamburg, Germany, October 2nd, 2015.
4. Kick-off meeting of EU project ReconCell, Ljubljana, November 19th-20th, 2015.
5. Workshop "Factories of the future", Ljubljana, Slovenia, 22 December 2015

Awards and appointments

1. Andrej Gams: ICRA CEB Best Reviewer Award, IEEE Int. Conf. on Robotics and Automation (ICRA), Seattle, Washington, USA. Awarded by the IEEE International Conference On Robotics and Automation Conference Editorial Board (CEB). This award is established to recognize the four Best Reviewers from the RAS Conference Editorial Board for a job well-done during the ICRA review process.

INTERNATIONAL PROJECTS

1. Stimulators and Parts
   Prof. Aleš Ude
2. Yaskawa: Peg Insertion by Dual Arm Manipulation
   Prof. Aleš Ude
   Yaskawa Electric Corporation
3. Kimberly-Clark-2015 - Development of Prototype Curved LCD Shutter
   Asst. Prof. Leon Žlajpah
   Kimberly-clark
4. Yaskawa: Polishing and Grinding by Programming by Demonstration and Autonomous Adaptation
   Prof. Aleš Ude
   Yaskawa Electric Corporation
5. 7FP - Xperience; Robots Bootstrapped through Learning from Experience
   Prof. Aleš Ude
   European Commission
6. 7FP - ACAT; Learning and Execution of Action Categories
   Prof. Aleš Ude
   European Commission
7. 7FP - CoDyCo; Whole-body Compliant Dynamical Contacts in Cognitive Humanoids
   Asst. Prof. Jan Babič
   European Commission
8. 7FP - PlanHab; Planetary Habitat Simulation
   Asst. Prof. Igor Kovač
   European Commission
9. H2020 - ReconCell; A Reconfigurable Robot Workcell for Fast Set-up of Automated Assembly Processes in SME-s
   Prof. Aleš Ude
   European Commission
10. Accelerated Development of Autonomous Behaviors for Humanoid Robots
    Prof. Aleš Ude
    Slovenian Research Agency
11. Advanced Perception and Learning for Heterogeneous Cognitive Robots
    Asst. Prof. Bojan Nemec
    Slovenian Research Agency
12. Learning Compliant Robotic Skills for Safe Industrial Assembly (LeCoRoS)
    Asst. Prof. Andrej Gams
    Slovenian Research Agency

RESEARCH PROGRAM

1. Avtomation, robotics and biocybernetics
   Prof. Igor Mekjavić

R & D GRANTS AND CONTRACTS

1. Methods of algebra and functional analysis in theory and practice of financial mathematics
   Prof. Igor Klep
2. KIDSki
   Asst. Prof. Tadej Debevec
   Fundacija za šport

NEW CONTRACTS

1. Dr. Anton Ružić
   Žito Prehrambena Industrija, d. d.
2. Prevention of delayed onset muscle soreness using compression socks
   Prof. Igor Mekjavić
   Intersocks d. o. o., Kočevje

VISITORS FROM ABROAD

1. Dr. Eiji Fuji, Advanced Research Division, Panasonic Corporation, Seika, Kyoto, Japan, 29. January 2015
2. Prof. Hisao Suzuki, Shizuoka University, Hamatsu, Japan, 29 January 2015
3. Dr. Yoshiaki Tanaka, Corporate Engineering Division, Automotive and Industrial Systems Company, Panasonic Corporation, Seika, Kyoto, Japan, 29 January 2015
4. Dr. Norikazu Sugimoto, NICT National Institute of Information and Communications Technology, Tokyo, Japan, 15-19 February 2015
5. Dr. Tomoyuki Noda, ATR, Kyoto, Japan, , 15-19 February 2015
6. Dr. Tatsuya Teramae, ATR, Kyoto, Japan, , 15-19 February 2015
7. Prof. Erhan Oztop, Ozyegin University, Istanbul, Turkey, 14-16 March 2015
8. Prof. Mikael Gronkvist, KTH, Stockholm, Sweden, 23 March to 6 April 2015
9. Carole House, PhD, Institute of Naval Medicine, Alverstoke, Portsmouth, United Kingdom, 17-21 May 2015
10. Dr. Morteza Azad, University of Birmingham, United Kingdom, 8–12 June 2015
11. Prof. Michael Mistry, University of Birmingham, United Kingdom, 8–12 June 2015
12. Mehmet Can, Özyegin University, Istanbul, Turkey, 2–29. August 2015
13. Prof. Laszlo Balazs with students, University of Budapest, Hungary, 17–18 August 2015
14. Dr. Elmar Ruckert, TUD, Germany, 24-26 August 2015
15. Prof. Mikael Gronkvist, KTH, Stockholm, Sweden, 5–18 October 2015
16. Aleksandar Cosić, Institut Mihailo Pupin, Belgrade, Serbia, 18–30 October 2015
17. Sofija Spasojević, Institut Mihailo Pupin, Belgrade, Serbia, 18 October to 1 November 2015
18. Dr. Freek Stulp, ENSTA – Paris Tech, France, 21–24 October 2015
19. Kai Salminen, New Factory Ltd., Tampere, Finland, 19–25 November 2015
20. Prof. Rüdiger Dillmann, University of Karlsruhe, Germany, 17 December 2015

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7. Asst. Prof. Bojan Nemec
8. Dr. Matjaž Omladič
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1. Tadej Petrič, Andrej Gams, Nejc Likar, Leon Žlajpah, "Obstacle avoidance with industrial robots", In: *Motion and operation planning of robotic systems: background and practical approaches*, (Mechanisms and machine science, 29), Giuseppe Carbone, ed., Fernando Gomez-Barvo, ed., Springer, 2015, Cham [etc.], pp. 113-146.
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Mentoring

1. Urška Ciuha, *Behavioural temperature regulation: the effect of thermal and non-thermal factors:* doctoral dissertation, Ljubljana, 2015 (mentor Igor B. Mekjavić; co-mentor Ola Eiken).
2. Nejc Likar, *Control of cooperating robots by using virtual mechanisms:* doctoral dissertation, Ljubljana, 2015 (mentor Leon Žlajpah).
3. Adam McDonnell, *Lunar habitat simulation: Thermophysiological changes associated with hypoxic inactivity:* doctoral dissertation, Ljubljana, 2015 (mentor Igor B. Mekjavić; co-mentors Ola Eiken, Stylianos N. Kounalakis).
4. Luka Peternel, *Accelerated robotic learning for interaction with environment and human based on sensory-motor learning:* doctoral dissertation, Ljubljana, 2015 (mentor Jan Babič).
5. Polona Kraner Zrim, *Applicable properties of textiles with integrated aerogel composites:* doctoral dissertation, Ljubljana, 2015 (mentor Tatjana Rijavec; co-mentor Igor B. Mekjavić).
6. Rok Vuga, *Motor primitives acquisition in learning by demonstration:* doctoral dissertation, Ljubljana, 2015 (mentor Aleš Ude).
7. Timotej Gašpar, *Control of Mitsubishi PA-10 industrial robot via UDP-ARCNET server:* master's thesis, Ljubljana, 2015 (mentor Matjaž Mihelj; co-mentor Leon Žlajpah).
8. Rok Rezar, *Imitation of elements of human walking in a humanoid robot:* master's thesis, Ljubljana, 2015 (mentor Matjaž Mihelj; co-mentor Aleš Ude).

DEPARTMENT OF SYSTEMS AND CONTROL E-2

The department 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. Vladimir Jovan

Basic and applied research

The basic and applied research in 2015 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 dynamical systems' modelling was pursued in two directions: the development of Gaussian-process models and the development of model-tree ensembles. The developed and improved methods for Gaussian-process modelling were validated on environmental systems, while the methods based on model-tree ensembles were validated with process-engineering processes (Figure 1).

The second topic was *advanced control.* We have been researching the problem of implementing model predictive control (MPC) using fast, online, first-order quadratic programming optimization techniques. Using these techniques and methods for MPC complexity reduction, we have managed to implement a prototype MPC controller for the ITER plasma current and shape controller for the plasma magnetic control of the ITER fusion tokamak reactor, which resulted in a peak computation time of 10 ms on a standard laptop computer. This computation time is considered sufficiently short for practical control implementation at the anticipated sample rate, and is five times faster than the one achieved using the commercial optimization solver CPLEX.

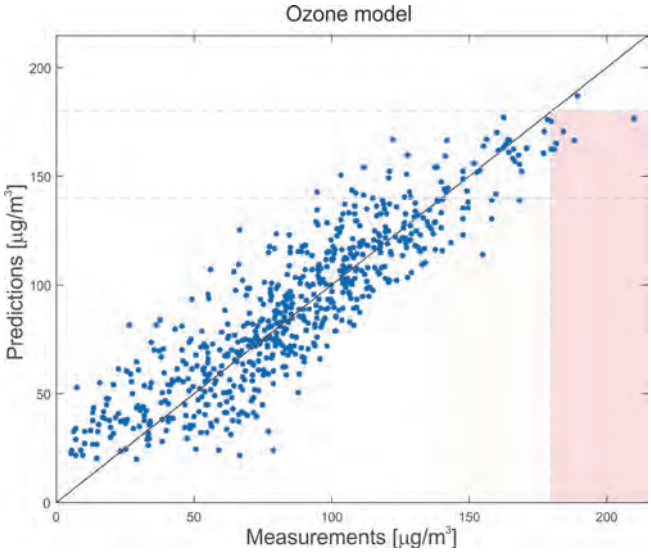

Figure 1. Validation of ozone-model predictions with measurements of maximum daily values

The third topic of interest was *condition monitoring and fault diagnosis*. Here, the focus was on diagnostic decision-making in which the system's condition is inferred from the "distance" between the ensemble of probability density functions (pdfs) of features captured in the current state and the ensemble of features in the nominal fault-free condition. This novel approach is radically different from conventional approaches in which usually one pdf from the current state is compared with a reference pdf in the fault-free state. The main theoretical contribution concerns a relatively simple approximation of the pdf of the Jensen-Reny divergence serving as a distance measure between two ensembles.

In 2015 we continued working on the diagnostics of PEM fuel cells with the use of the newly developed fast electrochemical impedance spectroscopy. The methodology was fused with an in-house-developed DC/DC converter and multi-channel fuel-cell voltage monitor. This fusion enables the seamless utilization of advanced diagnostics for PEM fuel-cell systems in industrial operating conditions. The results of this work were presented in journal papers published in *IEEE Transactions on Industrial Electronics*.

In the area **tools and building blocks for implementation**, the MAGICS methodology for the development and automatic generation of process-control software has been further developed. In the past year a new procedural control entities behaviour model was developed for the domain-specific modelling language *ProcGraph* and the MAGICS methodology for the development and automatic generation of the process-control software. The specifications for a new version of the MAGICS development environment prototype, based on the mentioned new behaviour model, has also been realized.

In 2015 we continued with the development and validation of a software prototype called *ProOpter*, which enables the analysis of production dynamics and supports the optimisation activities within the production process. The influential variable selection module was upgraded with new functionalities that were applied to the problem

of selecting the most relevant variables for the forecasting of ozone concentrations (ARRS project with MEIS d.o.o.). The software prototype was presented in an SCI journal *Computers in Industry*.

Applied research in the priority problem domains was the third sub-area of our interest. A system for monitoring the performance tests of electronically commutated motors was developed. The system allows up to 10 concurrent tests. At each test point the system can acquire vibration signals, temperature, voltage and electrical current. Additionally, the system allows a detailed specification of the conducted performance tests, data analysis as well as the tracking of all the events connected with the tests. The system has been successfully installed at Domel d.o.o. For another of Domel's production units PE ECS an end-quality control system for blowers was also developed. The system allows the acquisition and analysis of vibrations, sound emissions, pressure as well as electrical parameters such as voltage, current and power. Unlike the standard end-quality control systems that have a fixed testing profile, the developed system offers a fully customizable definition of the test profile and the order of the data acquisition. Such a property allows the testing of different types of electrical blowers.

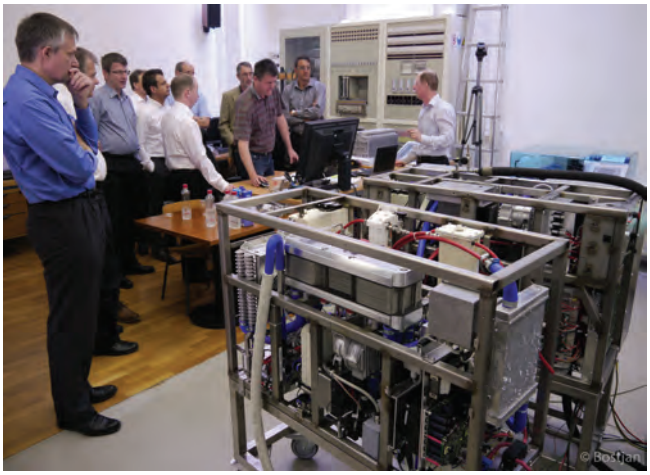

Figure 2: Presentation of a fuel-cells-based power system with diesel reforming during the closing meeting of the project FCGEN

Control of wastewater-treatment plants is our next traditional research area. We participated in the implementation of the physico-chemical model of the pH variation and ion speciation in a wastewater-treatment process. A special solving routine was developed in order to handle simultaneously ordinary differential equations and differential algebraic equations with multiple interdependencies. The strategy combines a multi-dimensional Newton Raphson method with the Simulated Annealing algorithm. The first method ensures a fast convergence, while the second one, which requires a larger number of iterations, is only used when the solution becomes unstable.

International and national R&D projects

In the final year of the 3-year international project Eurostar *ProDisMon-Probabilistic Distributed Industrial System Monitor* we have validated the algorithms for the threshold selection in the diagnosis and prognosis of rotational machines with a stress on the bearing faults. The methodology has been successfully implemented on a sanding machine. An online assessment of the system condition and a prognosis for the remaining useful life are made by processing signals from a vibration sensor mounted on the bearing supporting the rotor shaft.

In 2015 the FP7 project *FCGEN-Development and on-truck demonstration of a diesel-powered FC-based power unit* has been in its final stages and its goal was successfully achieved with an operating demonstration during the final project meeting in May 2015 (Figure 2). During this time the APU was located at the JSI, where initially the damaged reactor was replaced and the quality of the produced reformate was validated. Afterwards, the reformer part was merged with the fuel cell and the JSI-developed ECU and DC/DC converter was installed. The first integrated APU operations were targeted to control the fine-tuning and system troubleshooting, while later runs tested the real conditions and autonomous operation. The reformer completed over 50 operating days, during which numerous design modifications required for operating improvements have been identified.

This year also marks a successful end to the EU FP7-funded project FluMaBack-*Fluid Management component improvement for back up fuel cell systems*. The goal of the project was the development of advanced components for fluid management in systems with fuel cells. The final project results include the novel concept of a hydrogen recirculation pump, a more efficient air-blower unit, a new concept for a humidifier and the customization of the fuel-cell stack. The application of these components has a positive impact on the overall system durability. The team from our department was in charge of the development and the implementation of the end-quality control line for the hydrogen pump and the air blower.

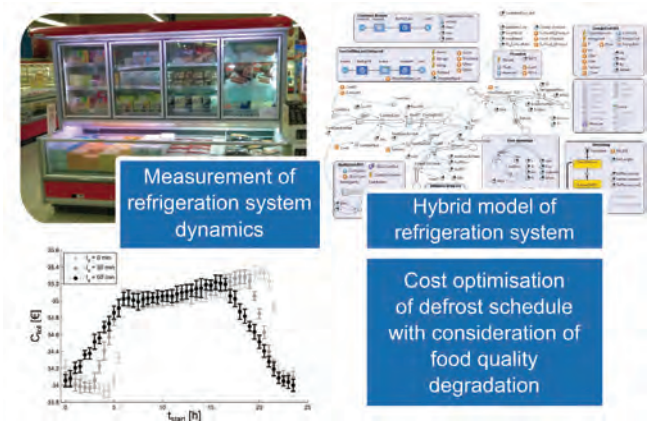

Figure 3: Optimisation of refrigerators' defrost schedule in a supermarket

From April 2014 we also participated in the third EU FP7 project *Diamond-Diagnosis-aided control for SOFC power systems*. The feedforward-feedback controllers that ensure fast load tracking of the solid-oxide fuel cell (SOFC) power system were designed during 2015 and verified via simulations. The feedforward part reacts to the electrical current demand in compliance with the stoichiometry of the electro-oxidation. The feedback part performs the corrections of the controlled system output by an additional manipulation of the system inputs. Crucial system variables, such as stack temperatures and fuel composition, were estimated from data as well as from

the stoichiometry. The designed feedforward-feedback controllers and soft sensors can be easily implemented in practice.

In collaboration with the consortium ENEA/CREATE from Naples, Italy, we also began activities within the project *Fast Model Predictive Control for Magnetic Plasma Control - FMPCFMPC.* The aim of the project is to apply novel fast MPC approaches to plasma magnetic control, where MPC is currently not applicable due to the large-scale multivariable nature of the problem and sub-second sampling rates.

Within the scope of the Slovenian Research Agency's applicative project *Optimisation of the refrigeration energy costs in shopping centres* in 2015 a hybrid model of a refrigeration system was developed. The model was applied to validate different measures for the minimisation of operating costs. Moreover, an innovative control scheme was designed that reduces the power peaks while dynamically adjusting the refrigerator's temperature reference (Figure 3).

Figure 4: Diagnostic system for the total quality control of eco-motors on the new production line ML-13 in Domel d.o.o.

For another on-going Slovenian Research Agency project *Development and implementation of a method for on-line modelling and forecasting of air pollution* a procedure for on-line Gaussian-Process modelling for ozone-concentration forecasting was developed. Moreover, a procedure for improved local-ozone forecasting using the integrated models was also developed. The integrated models also include data from meteorological and air-quality prediction models. The procedures were validated above the selected locations in Slovenia. The results were sent to be published in journals from the field of atmospheric phenomena.

In 2015 a new diagnostic system for the end-quality control of vacuum-cleaner motors on a new production line ML-13 has been installed in Domel d.o.o. The system is based upon already-installed diagnostic systems on the production lines ML-7, ML-8 and ML-10. Nevertheless, many innovations were introduced during the implementation on the electro-mechanical part as well as on the software part. The new system supports both AC and DC motors across a broad range of supply voltages, which is a significant improvement over previous systems. Next, on the software side, new diagnostic features were introduced that can detect bearing slip during motor start-up. Also, vibrations can now be measured over the whole motor housing. Finally, the most important improvement is the new connection to a central database, which improves the product traceability.

Figure 5. The TARAS award

For the company Danfoss Trata d.o.o. (project *iFlow*) we are developing (i) a method for calculating the current liquid flow on the basis of the feedback filtering of flow sensor signals and (ii) models for hydraulic components in the system based on the commercial datasheets of individual components. Among the most important results of this project is a new concept of HVAC system control that linearizes the operation of the entire system at various working points (e.g., summer–winter).

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. They also act as supervisors of Ph.D. students.

Some outstanding publications in the past year

1. Debenjak, Andrej, Petrovčič, Janko, Boškoski, Pavle, Musizza, Bojan, Juričić, Đani. Fuel cell condition monitoring system based on interconnected DC-DC converter and voltage monitor. *IEEE transactions on industrial electronics*, ISSN 0278-0046. [Print ed.], 2015, 62, no. 8, str. 5293 – 5305
2. Pregelj, Boštjan, Vrečko, Darko, Petrovčič, Janko, Jovan, Vladimir, Dolanc, Gregor. A model-based approach to battery selection for truck onboard fuel cell-based APU in an anti-idling application. *Applied energy*, ISSN 0306-2619, 2015, vol. 137, str. 64-76
3. Mileva-Boshkoska, Biljana, Boškoski, Pavle, Debenjak, Andrej, Juričić, Đani. Dependence among complex random variables as a fuel cell condition indicator. *Journal of power sources*, ISSN 0378-7753, jun. 2015, vol. 284, str. 566-573

4. Godena, Giovanni, Lukman, Tomaž, Steiner, Igor, Bergant, Franc, Strmčnik, Stanko. A new object model of batch equipment and procedural control for better recipe reuse. *Computers in industry*, ISSN 0166-3615, jun. 2015, vol. 70, 46-55
5. Boškoski, Pavle, Gašperin, Matej, Petelin, Dejan, Juričić, Đani. Bearing fault prognostics using Rényi entropy based features and Gaussian process models. *Mechanical systems and signal processing*, ISSN 0888-3270, feb. 2015, vol. 52/53, str. 327-337

Some outstanding achievements in the past year

1. Development and implementation of a new (the ninth) diagnostic system for final-quality control of electric motors on production line ML-13 in Domel d.o.o. (Figure 4)
2. At the 7th Industrial Forum of Innovation, R&D and Technology - IRT 2015, the TARAS statuette award for the most successful cooperation between research teams and industry was granted to the Danfoss Trata company and the Systems and Control research group at the Jožef Stefan Institute (Figure 5).
3. The book entitled Modelling and Control of Dynamic Systems Using Gaussian Process Models, authored by our department member Prof. Dr. Juš Kocijan, has appeared in the Springer series Advances in Industrial Control.
4. IEEE Spectrum, the leading magazine of the IEEE, the world's largest professional organization devoted to engineering and the applied sciences, reports on clean-energy production from diesel with fuel cells - a demonstrated technological solution developed in the FP7 FCGEN project finished in 2015 under the leadership of our department.

Awards and appointments

1. Boštjan Dolenc, Pavle Boškoski, Đani Juričić: the article "Distributed bearing fault diagnosis based on vibration analysis" has been ranked as the 11th most downloaded article in the journal Mechanical Systems and Signal Processing for the last quarter of 2015
2. Đani Juričić, Pavle Boškoski, Bojan Musizza, Janko Petrovčič, Boštjan Dolenc, Stanislav Černe: the first prize for the innovation with the greatest economic potential that was created in PRO's (public research organizations) in 2015 at the 8th International Conference on Technology Transfer and Innovation Day 2015
3. Danfoss Trata d. o. o. and the Systems and Control research group: the TARAS award for the most successful cooperation between research teams and organisations on one side and development teams in industry on the other side for the year 2015 at the 7th Industrial forum of Innovation, R&D and Technology - IRT 2015 held in Portorož
4. Andrej Debenjak: "Golden award" for his doctoral thesis "Condition monitoring of PEM fuel cells" in 2015 at the 25th Slovenian Trade Fair and Conference on Technical Maintenance, Otočec

Patents granted

1. Jože Vižintin, Jose Miguel Marques Querido Salgueiro, Boris Kržan, Gabrijel Peršin, Đani Juričić, Pavle Boškoski, Gregor Dolanc, Apparatus and method for on-line monitoring of oil condition and debris concentration, SI24579 (A), Slovenian Intellectual Property Office, 30. 06. 2015.
2. Damir Vrančić, Marko Nerat, Samo Krančan, Procedure of rapid signal filtering of rotational speed with automatic elimination of periodic deviation, SI 24580 (A), Slovenian Intellectual Property Office, 30. 06. 2015.

INTERNATIONAL PROJECTS

1. 7FP - FLUMABACK; Fluid Management Component Improvement for Back up Fuel Cell Systems
   Dr. Pavle Boškoski
   European Commission
2. 7FP - DIAMOND; Diagnosis-aided Control for SOFC Power System
   Prof. Đani Juričić
   European Commission
3. COST ES1202; Water_2020: Conceiving Wastewater Treatment in 2020 - Energetic, Environmental and Economic Challenges
   Dr. Darko Vrečko
   Cost Office
4. ER-3-FU; Enabling Research; EUROFUSION
   Dr. Samo Gerkšič
   European Commission

RESEARCH PROGRAM

1. Program systems and control
   Prof. Đani Juričić

R & D GRANTS AND CONTRACTS

1. Development and implementation of a method for on-line modelling and forecasting of air pollution
   Prof. Juš Kocijan
2. Optimisation of energy cost for refrigeration systems in shopping malls
   Asst. Prof. Damir Vrančić

NEW CONTRACTS

1. Optimisation of energy cost for refrigeration systems in shopping malls
   Asst. Prof. Damir Vrančić
   Danfoss Trata, d. o. o.
2. Development of advanced control strategies to increase the reliability of medical accelerators
   Dr. Matej Gašperin
   Cosylab, Laboratorij za kontrolne sisteme, d. d.

VISITOR FROM ABROAD

1. Serena Invitto, University of Salerno, Salerno, Italy, 19 January to 25 July 2015
2. Vincenzo Apicella, University of Salerno, Salerno, Italy, 5 March to 7 July 2015
3. Erik Aberg, Modelon AB, Lund, Sweden, 18–19 May 2015
4. Jonas Eborn, Modelon AB, Lund, Sweden, 18–19 May 2015
5. Per Ekdunge, PowerCell Sweden AB, Gothenburg, Sweden, 18–19 May 2015
6. Gunther Kolb, Faunhofer ICT-IMM, Mainz, Germany, 18–19 May 2015
7. Johannes Kögler, VOLVO Gropup, Gothenburg, Sweden, 18–19 May 2015
8. Carlos Navas, FCH JU, Brussels, Belgium, 18–19 May 2015
9. Joachim Pasel, Forschungszentrum Jülich, Jülich, Germany, 18–19 May 2015
10. Ralf Peters, Forschungszentrum Jülich, Jülich, Germany, 18–19 May 2015
11. Behrooz Razaznejad, VOLVO Group, Gothenburg, Sweden, 18–19 May 2015
12. Jochen Surrer, Faunhofer ICT-IMM, Mainz, Germany, 18–19 May 2015
13. David Wails, Johnson Matthey PLC, London, Great Britain, 18–19 May 2015
14. prof. dr. Cesare Pianese, University of Salerno, Salerno, Italy, 27–31 July 2015
15. dr. Fernando Aller, University of Leon, Leon, Spain, 1–4 August 2015

STAFF

Researchers
1. Dr. Pavle Boškoski
2. Dr. Gregor Dolanc
3. *Dr. Matej Gašperin, left 01.09.15*
4. Dr. Samo Gerkšič
5. Giovanni Godena, M. Sc.
6. Dr. Dejan Gradišar
7. Dr. Nadja Hvala
8. **Dr. Vladimir Jovan, Head**
9. Prof. Đani Juričić
10. Prof. Juš Kocijan
11. Dr. Bojan Musizza
12. Dr. Janko Petrovčič
13. Dr. Boštjan Pregelj
14. Prof. Stanislav Strmčnik
15. Asst. Prof. Damir Vrančić
16. Dr. Darko Vrečko

Postdoctoral associates
17. Dr. Andrej Debenjak
18. Dr. Miha Glavan
19. Dr. Marko Nerat
20. Dr. Matija Perne

Postgraduates
21. Boštjan Dolenc, B. Sc.
22. Martin Stepančič, B. Sc.

Technical officers
23. Stanislav Černe, B. Sc.
24. Primož Fajdiga, B. Sc.

Technical and administrative staff
25. Maja Janežič, B. Sc.
26. Miroslav Štrubelj

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Original Article

1. Darko Aleksovski, Juš Kocijan, Sašo Džeroski, "Model-tree ensembles for noise-tolerant system identification", *Advanced engineering informatics*, vol. 29, no. 1, pp. 1-15, 2015.
2. Darko Belavič, Marko Hrovat, Kostja Makarovič, Gregor Dolanc, Andrej Pohar, Stanko Hočevar, Barbara Malič, "3D LTCC structure for a large-volume cavity-type chemical microreactor", In: *Special issue IMAPS Poland 2014, 38th International IMAPS - CPMT Poland Conference & Exhibiton, September 21-24, 2014, Rzeszów-Czarna, Poland*, (Microelectronics international, Vol. 32, no. 2, 2015), Port Erin, Wela Publications, 2015, vol. 32, no. 3, pp. 133-137, 2015.
3. Pavle Boškoski, Matej Gašperin, Dejan Petelin, Đani Juričić, "Bearing fault prognostics using Rényi entropy based features and Gaussian process models", *Mech. syst. signal process.*, vol. 52/53, pp. 327-337, feb. 2015.
4. Andrej Debenjak, Janko Petrovčič, Pavle Boškoski, Bojan Musizza, Đani Juričić, "Fuel cell condition monitoring system based on interconnected DC-DC converter and voltage monitor", *IEEE trans. ind. electron.*, 62, no. 8, pp. 5293 - 5305, 2015.
5. Andrej Fabjan, Fajko Bajrović, Bojan Musizza, Jernej Vidmar, Martin Štrucl, Marjan Zaletel, "Study of neurovascular coupling during cold pressor test in patients with migraine", *Cephalalgia*, vol. 35, no. 8, pp. 692-701, 2015.
6. Xavier Flores-Alsina, Christian Kazadi Mbamba, Kimberly Solon, Darko Vrečko, Stephan Tait, Damien J. Batstone, Ulf Jeppsson, Krist V. Gernaey, "A plant-wide aqueous phase chemistry module describing pH variations and ion speciation/pairing in wastewater treatment process models", *Water res. (Oxford)*, vol. 85, pp. 255-265, nov. 2015.
7. Giovanni Godena, Tomaž Lukman, Marjan Heričko, Stanko Strmčnik, "The experience of implementing model-driven engineering tools in the process control domain", *Inf. technol. valdyn.*, pp. 135-147.
8. Giovanni Godena, Tomaž Lukman, Igor Steiner, Franc Bergant, Stanko Strmčnik, "A new object model of batch equipment and procedural control for better recipe reuse", *Comput. ind.*, vol. 70, 46-55, jun. 2015.
9. Dejan Gradišar, Miha Glavan, Stanko Strmčnik, Gašper Mušič, "ProOpter: an advanced platform for production analysis and optimization", *Comput. ind.*, vol. 70, pp. 102-115, jun. 2015.
10. Rok Juhant, Darko Vrečko, Jure Knez, Sašo Blažič, "Improved pose estimation for vehicle navigation using frame alignment and forward smoothing", *Automatika (Zagreb)*, vol. 56, no. 2, pp. 120-131, 2015.
11. D. A. Kenwright *et al.* (16 authors), "The discriminatory value of cardiorespiratory interactions in distinguishing awake from anaesthetised states: a randomised observational study", *Anaesthesia*, vol. 70, iss. 12, pp. 1356-1368, 2015.
12. Juš Kocijan, Marko Hančič, Dejan Petelin, Marija Božnar, Primož Mlakar, "Regressor selection for ozone prediction", *Simulation modelling practice and theory*, vol. 54, pp. 101-115, maj 2015.
13. A. J. Luhmann, Matt Covington, Joseph M. Myre, Matija Perne, Sydney W. Jones, E. Calvin Alexander, M. O. Saar, "Thermal damping and retardation in karst conduits", *Hydrol. earth syst. sci.*, vol. 19, pp. 137-157, 2015.
14. Montse Meneses, Henry Rafael Concepcion, Darko Vrečko, Ramon Vilanova, "Life Cycle Assessment as an environmental evaluation tool for control strategies in wastewater treatment plants", *J. clean. prod.*, vol. 107, pp. 653-661, 2015.
15. Biljana Mileva-Boshkoska, Marko Bohanec, Pavle Boškoski, Đani Juričić, "Copula-based decision support system for quality ranking in the manufacturing of electronically commutated motors", *J. intell. manuf.*, vol. 26, no. 2, pp. 281-293, 2015.
16. Biljana Mileva-Boshkoska, Pavle Boškoski, Andrej Debenjak, Đani Juričić, "Dependence among complex random variables as a fuel cell condition indicator", *J. power sources*, vol. 284, pp. 566-573, jun. 2015.

17. Dejan Petelin, Primož Mlakar, Marija Božnar, Boštjan Grašič, Juš Kocijan, "Ozone forecasting using an online updating Gaussian-process model", *Int. j. environ. pollut.*, vol. 57, no. 3/4, pp. 111-122, 2015.
18. Boštjan Pregelj, Darko Vrečko, Janko Petrovčič, Vladimir Jovan, Gregor Dolanc, "A model-based approach to battery selection for truck onboard fuel cell-based APU in an anti-idling application", *Appl. energy*, vol. 137, pp. 64-76, 2015.
19. Jan Přikryl, Juš Kocijan, "Modelling occupancy-queue relation using Gaussian process", *Neural Netw. World*, vol. 25, no. 1, pp. 35-52, 2015.
20. José Salgueiro, Gabrijel Peršin, Jasna Hrovatin, Đani Juričić, Jože Vižintin, "On-line detection of incipient trend changes in lubricant parameters", *Ind. Lubr. Tribol.*, vol. 67, no. 6, pp. 509-519, 2015.
21. Martin Stepančič, Alexandra Grancharova, Juš Kocijan, "Adaptive mpc based on probabilistic black-box input-output model", *Dokl. B''lg. akad. nauk.*, vol. 68, no. 6, pp. 767-774, 2015.
22. Jože Vižintin, José Salgueiro, Gabrijel Peršin, Đani Juričić, "System for automated online oil analysis", *Cond. monit.*, iss. 336, pp. 5-10, Mar. 2015.

Review Article

1. Matt Covington, Matija Perne, "Consider a cylindrical cave: a physicist's view of cave and karst science: pogled fizika na znanost o jamah in krasu", *Acta carsol.*, vol. 44, no. 3, pp. 363-380, 2015.

Published Conference Contribution (invited lecture)

1. Pavle Boškoski, Andrej Debenjak, Đani Juričić, "Spremljanje stanja gorivnih celic PEM", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 10 pp.

Published Conference Contribution

1. Erik Åberg, Jens Pålsson, Karin Fröjd, Karin Axelsson, Gregor Dolanc, Vladimir Jovan, "HIL simulations of a real-time fuel processor model", In: *5th European PEFC & H2 Forum 2015, 30 June - 3 July 2015, Lucerne, Switzerland: proceedings*, (European fuel cell forum, 19), Frano Barbir, ed., Luzern, European Fuel Cell Forum AG, 2015, pp. 44-53.
2. Andrej Debenjak, Gregor Papa, Janko Petrovčič, "Modularni sistem za upravljanje Li-Ion baterije", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 8 pp.
3. Boštjan Dolenc, Pavle Boškoski, Đani Juričić, "Change detection based on entropy indices with application to bearing faults", In: *9th SafeProcess 2015*, 9th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes, September 2-4, 2015, Paris, France, [S. l.], IFAC = International Federation of Automatic Control, pp. 1438-1443.
4. Boštjan Dolenc, Pavle Boškoski, Đani Juričić, "Condition monitoring of mechanical drives based on entropy indices", In: *Zbornik: 2. del: part 2*, 7. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 7th Jožef Stefan International Postgraduate School Students' Conference, 20.-22. 5. 2015, Ljubljana, Andraž Rešetič, ed., et al, Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2015, zv. 1, pp. 92-103.
5. Boštjan Dolenc, Pavle Boškoski, Đani Juričić, "Optimal threshold selection in fault diagnosis of mechanical drives based on information indices", In: *Surveillance 8: International Conference - October 20-21, 2015, Roanne, France*, [S. l., s. n.], 2015, 9 pp.
6. Boštjan Dolenc, Đani Juričić, Pavle Boškoski, Matej Gašperin, Jurij Pfajfar, "Sprotno napovedovanje preostale življenjske dobe elektromehanskih pogonov", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 8 pp.
7. Boštjan Dolenc, Darko Vrečko, Đani Juričić, Antti Pohjoranta, Jari Kiviaho, Cesare Pianese, "Soft sensor design for estimation of SOFC stack temperatures and oxygen-to-carbon ratio", In: *Papers presented at 14th International Symposium on Solid Oxide Fuel Cells, SOFC-XIV, July 26-31, 2015, Glasgow, Scotland, UK*, (ECS transactions, Vol. 68, no. 1, 2015), Subhash C. Singhal, ed., K. Eguchi, ed., Pennington, Electrochemical Society, 2015, vol. 68, no. 1, pp. 2625-2636, 2015.
8. Xavier Flores-Alsina, Christian Kazadi Mbamba, Kimberly Solon, Darko Vrečko, Stephan Tait, D. J. Batstone, Ulf Jeppsson, Krist V. Gernaey, "A plant-wide aqueous phase module describing pH variations and ion speciation/pairing in wastewater treatment process models", In: *9th IWA Symposium on Systems Analysis and Integrated Assessment, 14-17 June 2015, Queensland, Australia*, [S. l.], International Water Association, 2015, 3 pp..
9. Samo Gerkšič, "Regulacija toka in oblike preseka plazme v fuzijskem tokamak rektorju Iter", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 8 pp.
10. Miha Glavan, Dejan Gradišar, Đani Juričić, Damir Vrančić, Serena Invitto, Cesare Pianese, "Operation optimisation of supermarket refrigerated display case", In: *Applied mathematics and materials: proceedings of the 8th Internationa Conference on Materials Science (MATERIALS '15), proceedings of the 8th International Conference on Finite Differences, Finite Elements, Finite Volumes, Boundary Elements (F-and-B '15), proceedings of the 3rd International Conference on Optimization Techniques in Engineering (OTENG '15), Rome Italy, November 7-9, 2015*, (Mathematics and computers in science and engineering series, 54), Imre J. Rudas, ed., [S. l.], WSEAS = World Scientific and Engineering Academy and Society, 2015, pp. 92-98.
11. Miha Glavan, Dejan Gradišar, Damir Vrančić, "Modeliranje hladilnih elementov v nakupovalnih središčih za namene optimizacje energijskih stroškov", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 8 pp.
12. Matic Golob, David Jure Jovan, Damir Vrančić, "Napredni PID programski modul", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 6 pp.
13. Dejan Gradišar, Martin Stepančič, Marija Božnar, Primož Mlakar, Boštjan Grašič, Juš Kocijan, "Napovedovanje koncentracije ozona s samorazvijajočim se modelom na podlagi Gaussovih procesov", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 8 pp.
14. Nadja Hvala, Darko Vrečko, Meta Levstek, Cirila Bordon, "Dynamic mathematical modelling supporting wastewater treatment plants upgrading", In: *Digital proceedings*, 10th Conference on Sustainable Development of Energy, Water and Environmental Systems, 10th SDEWES, September 27 - October 2, 2015, Dubrovnik, Croatia, Marko Ban, ed., Zagreb, Faculty of Mechanical Engineering and Naval Architecture, 2015, pp. 0052-1-0052-12.
15. Serena Invitto, Dejan Gradišar, Miha Glavan, Đani Juričić, Damir Vrančić, "Hybrid optimisation model of the supermarket refrigeration system using AnyLogic", In: *Zbornik štiriindvajsete mednarodne Elektrotehniške in računalniške konference ERK 2015, 21. - 23. september 2015, Portorož, Slovenija*, (Zbornik ... Elektrotehniške in računalniške konference ERK ..., 24), Baldomir Zajc, ed., Andrej Trost, ed., Ljubljana, IEEE Region 8, Slovenska sekcija IEEE, 2015, zv. A, pp. 207-210.
16. Primož Mlakar, Marija Božnar, Boštjan Grašič, Amauri Pereira de Oliveira, Jacyra Ramos Soares, Dejan Gradišar, Juš Kocijan, "Modeliranje difuznega sončnega obseva", In: *Raziskave s področja geodezije in geofizike 2014: zbornik del*, 20. srečanje Slovenskega združenja za geodezijo in geofiziko, Ljubljana, 29. januar 2015, Miran Kuhar, ed., et al, Ljubljana, Fakulteta za gradbeništvo in geodezijo, 2015, pp. 45.
17. Marko Nerat, Janko Petrovčič, Samo Krančan, Damir Vrančić, "Robusten elektromotorni pogon za hidravlične ventile", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 8 pp.
18. Stefan Nikolovski, Gregor Klančar, Damir Vrančić, "Sistem za vodenje temperature ob izpadu senzorja na osnovi razmerja odprtosti izvršnih členov", In: *Zbornik štiriindvajsete mednarodne Elektrotehniške in računalniške konference ERK 2015, 21. - 23. september 2015, Portorož, Slovenija*, (Zbornik ... Elektrotehniške in računalniške konference ERK ..., 24), Baldomir Zajc, ed., Andrej Trost, ed., Ljubljana, IEEE Region 8, Slovenska sekcija IEEE, 2015, zv. A, pp. 149-152.
19. Paulo Moura Oliveira, Damir Vrančić, Hélio F. Freire, "Dual mode feedforward-feedback control system", In: *CONTROLO' 2014 - poceedings of the 11th Portuguese Conference on Automatic Control [July 21th - 23th, 2014, Porto, Portugal]*, (Lecture notes in electrical engineering, volume 321), António Paulo Moreira, ed., Aníbal Matos, ed., Germano Veiga, ed., Cham [etc.], Springer, 2015, pp. 241-250.

20. Boštjan Pregelj, Gregor Dolanc, Janko Petrovčič, "FCGEN - razvoj in izvedba sistema vodenja za pomožni agregat z gorivnimi celicami na dizelsko gorivo", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 8 pp.
21. Boštjan Pregelj, Daniel T. Mcguniness, Janko Petrovčič, Gregor Dolanc, Vladimir Jovan, "Optimization of diesel powered FC-based APU size and battery capacity for specified load demand", In: *5th European PEFC & H2 Forum 2015, 30 June - 3 July 2015, Lucerne, Switzerland: proceedings*, (European fuel cell forum, 19), Frano Barbir, ed., Luzern, European Fuel Cell Forum AG, 2015, pp. 112-118.
22. Darko Vrečko, Gregor Dolanc, Boštjan Dolenc, Damir Vrančić, Boštjan Pregelj, Dario Marra, Marco Sorrentino, Cesare Pianese, Antti Pohjoranta, Đani Juričić, "Feedforwardf- feedback control of a SOFC power system: a simulation study", In: *Papers presented at 14th International Symposium on Solid Oxide Fuel Cells, SOFC-XIV, July 26-31, 2015, Glasgow, Scotland, UK*, (ECS transactions, Vol. 68, no. 1, 2015), Subhash C. Singhal, ed., K. Eguchi, ed., Pennington, Electrochemical Society, 2015, vol. 68, no. 1, pp. 3151-3163, 2015.
23. Darko Vrečko, Nadja Hvala, Marko Krošel, Albin Lorenci, Samo Ceferin, "Napredno vodenje doziranja anaerobnega fermentorja za razgradnjo organskih odpadkov in proizvodnjo bioplina", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 7 pp.

Scientific Monograph

1. Franci Gabrovšek, Martin Knez, Janja Kogovšek, Andrej Mihevc, Janez Mulec, Bojan Otoničar, Matija Perne, Metka Petrič, Tanja Pipan, Mitja Prelovšek, Tadej Slabe, Stanka Šebela, Janez Turk, Nadja Zupan Hajna, *The Beka-Ocizla cave system: karstological railway planning in Slovenia*, (Cave and karst systems of the world), Cham [etc.], Springer, cop. 2015.

University, Higher Education or Higher Vocational Education Textbook

1. Juš Kocijan, *Modeliranje dinamičnih sistemov z umetnimi nevronskimi mrežami in sorodnimi metodami*, 2. izd., V Novi Gorici, Založba Univerze, 2015.

Encyclopaedia, Dictionary, Lexicon, Manual, Atlas, Map

1. Rihard Karba, Gorazd Karer, Juš Kocijan, Tadej Bajd, Mojca Žagar Karer, Tanja Fajfar (urednik), *Terminološki slovar avtomatike*, (Zbirka Terminologišče), Ljubljana, Založba ZRC, 2015.

Patent

1. Jože Vižintin, Jose Miguel Marques Querido Salgueiro, Boris Kržan, Gabrijel Peršin, Đani Juričić, Pavle Boškoski, Gregor Dolanc, *Apparatus and method for on-line monitoring of oil condition and debris concentration*, SI24579 (A), Urad RS za intelektualno lastnino, 30. 06. 2015.
2. Damir Vrančić, Marko Nerat, Samo Krančan, *Procedure of rapid signal filtering of rotational speed with automatic elimination of periodic deviation*, SI24580 (A), Urad RS za intelektualno lastnino, 30. 06. 2015.

Mentoring

1. Andrej Debenjak, *Condition monitoring of PEM fuel cells:* doctoral dissertation, Ljubljana, 2015 (mentor Janko Petrovčič; co-mentor Đani Juričić).
2. Nada Kocare, *Optimal threshold selection in systems condition monitoring based on probability of false alarm:* master's thesis, Ljubljana, 2015 (mentor Đani Juričić).
3. Filip Nikolovski, *Seeking for optimal maintenance strategies via Monte Carlo simulation:* master's thesis, Ljubljana, 2015 (mentor Đani Juričić).

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 several 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; iDiversiNews (http://aidemo.ijs.si/diversinews/), a system for the processing and visualization of news; Event Registry (http://eventregistry.org/), a system for identifying world events in news media; Twitter Observatory (http://twitterobservatory.net/), a system for the analysis of selected tweets; Wikifier (http://wikifier.org), a system for annotating documents with links to relevant Wikipedia pages; 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; DataScienceExplorer, a dashboard for visualizations of data science based on academic papers. The laboratory's strategy is to combine scientific excellence and strong industrial collaboration and to transfer the research results into real-world business environments.

In the past 13 years, members of the Artificial Intelligence Laboratory have successfully completed 40 EU projects, of which 4 were concluded in 2015 and 11 are still ongoing. In 2015, we were also involved in 9 national projects. Together with the Department for Communication Systems (E6) in collaboration with Adria Mobil, we have developed sensor technologies and artificial intelligence methods for the user-friendly and energy-efficient functioning of auto-homes that are being tested in real-world environments.

In the area of statistical data modelling and machine learning we have contributed an invited talk at the Financial Data Science Summit 2015 (http://fdsaglobal.org) and an invited presentation at a Panel on Big Data & Media at the Statistical Day 2015 - National Statistical Offices Conference (Marko Grobelnik). In 2015, the EU FP7 project ***TOPOSYS*** (*Topological Complex Systems*), coordinated by our department, was successfully completed. The project concluded with 65 published papers, 10 plenary talks, 9 workshops, 3 tutorials and 3 organized summer schools. The project greatly advanced our understanding of the underlying mathematical foundations of multi-scale dynamic systems, in particular using topological tools. More efficient algorithms have been developed for understanding the dynamics of complex systems along with a more thorough understanding of the statistical behaviour of computed invariants as well as generalizing the invariants themselves beyond functions. In particular, we developed tight bounds on the maximal statistics of noise as well as established central limit theorems for these algebraic objects, both of which are the first results of their kind. In the EU FP7 project ***Symphony*** (*Orchestrating Information Technologies and Global Systems Science for Policy Design and Regulation of a Resilient and Sustainable Global Economy*) our work is focused mainly on developing tools and approaches

Marko Grobelnik had an invited presentation at the Panel on Big Data & Media at the Statistical Day 2015 - National Statistical Offices Conference (http://goo.gl/tcFlDp)

for nowcasting based on media monitoring. Within the project, we have established a social media monitoring data infrastructure, connecting social media data from Twitter with news events from our EventRegistry system. Social media sentiment analysis and mainstream media geographical opinion diffusion measurements have been successfully implemented along with a scalable large-scale system of correlation analysis and basic nowcasting functionalities. The EU FP7 project ***FI-IMPACT*** (*Future Internet Impact Assurance*) is focused on measuring and projecting the potential take-up and impact of Phase III Accelerator Projects co-funded under the Future Internet PPP, by collecting and assessing qualitative and quantitative evidence of their potential socio-economic impact to 2020. Together with the Centre for Knowledge Transfer in Information Technologies (CT3), we have developed a web-based self-assessment tool to support Accelerator Projects to position their product, verify the market potential and check complementarity with other FI-PPP participants' offerings.

Dunja Mladenić had an invited lecture on Cross-Lingual Global Media Monitoring at Carnegie Mellon University (http://goo.gl/gvv6lA)

In the areas of **text and network analysis** and **language technologies**, we contributed an invited talk on Cross-Lingual & Cross Media Monitoring at the ELRA 20th Anniversary 2015 (Marko Grobelnik), an invited lecture on Cross-lingual Global Media Monitoring at Carnegie Mellon University (http://videolectures.net/cmuseminars_mladenic_media_monitoring/) (Dunja Mladenić) and two poster sessions at the European Data Forum 2015 (http://www.data-forum.eu/) (Gregor Leban, Blaz Novak). In 2015, together with the Department of Knowledge Technologies (E8), we continued to lead the Slovenenian research infrastructure ***CLARIN.SI***, which provides easy publication and sustainable access to digital language data for scholars in the humanities and social sciences. In 2015, the CLARIN.SI consortium grew to twelve partners: four Slovenian universities, three research institutes as well as societies and companies dealing with language technologies and resources in Slovenia. CLARIN.SI also became a member of the European CLARIN ERIC, while its repository for language resources and tools was awarded the Data Seal of Approval, certifying it as a stable and trusted repository. We have successfully concluded the EU FP7 project ***Sophocles*** (*Self-Organised information PrOcessing, CriticaLity and Emergence in multilevel Systems*) focused on processing social media data (Twitter, newspaper archive, event streams) with the goal of validating the theoretical models developed in the project. We have studied how to apply and interpret novel information with the theoretical measures developed during the project on the data. The new measures and techniques are especially suitable for detecting critical phenomena, such as historical events with a high global impact.

Figure 1: StreamStory: the visualization of GPS coordinates collected over a period of two years for a particular individual.

In the area of **semantic technologies**, we contributed a keynote talk at the ESWC 2015 Summer School (http://videolectures.net/eswc2015_grobelnik_global_media/) (Marko Grobelnik) and an invited talk on Global Media Monitoring at Data Science Summit 2015 (Marko Grobelnik). The EU FP7 project ***ProaSense*** (*The Proactive Sensing Enterprise*) is one of the early adopters of a shift from reactive to proactive computing in the enterprise environment. Within the project, we have developed tools for multivariate data-stream exploration, prediction and anomaly detection. Within the EU FP7 project ***XLime*** (*Cross-Lingual, Cross-Media Knowledge Extraction*) we have been working on the real-time fusion of knowledge from multiple modalities – text, social media, audio, video and user behaviour data. We have improved the state of the art in the annotation of complex concepts found in media streams, and the use of extracted annotations to visualize the monitored domain. We have been also working on methods to model the diffusion of knowledge through actors across locales, time periods, languages and social groups.

The **Knowledge management** contribution of our group includes research and development using methods and tools from a broader Artificial Intelligence area in real business settings. The aim of the FP7 EU project ***NRG4Cast*** (*Energy Forecasting*), coordinated by our department, was the development of real-time management, analytics and forecasting services for energy networks in urban/rural communities. Our work was focused on analysing multimodal data streams from the energy domain. The project was successfully completed in November 2015. The results in the form of a modular solution, which combines various analytical techniques (from data mining to reasoning) are to be transferred to industry, mainly to assist with the energy efficiency of buildings. Together with the Centre for Knowledge Transfer in Information Technologies (CT3), we have successfully concluded the FP7 EU project, ***MobiS*** (*Personalized Mobility Services for energy efficiency and security through advanced Artificial Intelligence techniques*). As part of the project results, we have developed services for traffic data collection, cleaning and fusion that are used by the traffic-prediction services and personalized traffic-assistance services. The personalized services can learn

Together with the Centre for Knowledge Transfer in Information Technologies (CT3), we organized ESWC-2015, an international conference on semantic technologies http://2015.eswc-conferences.org/

about user movements and travelling style and then predict the locations, modalities and routes the user will take. The results of the project are being used by the AMZS company to drive their new traffic information application. We are also getting interest from various traffic- and AI-related companies from the EU and the US with regard to the developed application. In collaboration with the Department for Communication Systems (E6), we have continued work on the EU FP7 project ***SunSeed*** (*Sustainable and robust networking for smart electricity distribution*), where our contribution is focused on short-term load forecasting for smart electricity distribution. In the past year, we have performed extensive analyses of the acquired data sources from real-world pilot scenarios. The analysis covers four different topics relevant for the project's objectives: (1) short-term load forecasting for a Distributed System Operator, (2) Renewable Sources Generation Forecasting, (3) Consumption Profile Estimation in NAN Incorporating the Effect of Scheduling and (4) Fault Detection in Energy and Telecom Grid. The obtained knowledge from exploratory data analysis was then used within a feature engineering and modelling process. In the H2020 EU project, ***OPTIMUM*** (*Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility*) that started in May 2015, we are building an analytical traffic data engine and infrastructure that can support various intelligent traffic systems. This covers aspects, from simple data collection and traffic information, to prediction services, user patterns, probabilities of traffic accidents, bus-arrival predictions as well as the joint analytic that can analyse the behaviour of entire fleets or groups of users and even influence the behaviour of traffic participants to be more environmentally friendly and assist in reducing traffic congestions. The aim of the H2020 EU project ***AquaSmart***, (*Aquaculture Smart and Open Data Analytics as a Service*) is to lower production costs and improve the profitability and operational efficiency of fish farms. We are working on analysing the data from fish farms, which include environmental parameters, feed types, feed composition, feeding rates and practices, mortality rate, production time, health, etc. With the use of machine-learning methods, we plan to evaluate the performance of fish farms' production, identify patterns and trends, optimize feeding and growth models and estimate the fish population. In addition to analytics, we will also support the multi-language aspect of the project in the form of a translation service based on the Moses machine translation tool.

Figure 2: DataScience Explorer: the visualization of data science academic papers for a particular individual

The **promotion of science** is continually present in the efforts of the Artificial Intelligence Laboratory. Marko Grobelnik had an interview about Big Data Technology in "STAznanost" (http://znanost.sta.si/2197573/grobelnik-tehnologija-masivnih-podatkov-ni-nic-drugega-kot-ocala-ki-nam-pomagajo-videti-bolje). Dunja Mladenić had an interview regarding the system EventRegistry on national television (RTV-SLO) (http://4d.rtvslo.si/arhiv/prispevki-in-izjave-prvi-dnevnik/174313291). She also participated in a debate on Computer vs. Human – memory, creativity, emotions, consciousness, artificial intelligence – at the Poligon center in Ljubljana (https://krog.sta.si/2125501/ali-bo-racunalnik-po-sposobnosti-prehitel-cloveske-mozgane-video). Within the H2020 EU project ***EDSA*** (*European Data Science Academy*), the Artificial Intelligence Laboratory contributed to the training delivery and learning analytics activities. We have participated in the EDSA curriculum development, collecting and providing materials on the curriculum topic "Foundations of Big Data". We also developed a data-acquisition pipeline for the EDSA demand analysis dashboard. Finally, we have begun the design and development of the learning analytics application based on videolectures.NET logs. The application is intended to monitor study behaviour and provide insights into the actual learning experience. 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 2015, more than 150 students participated in the competition. We have 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/).

We have successfully concluded the coordination of two EU FP7 projects TOPOSYS - Topological Complex Systems (http://toposys.org/) and NRG4Cast - Energy Forecasting (http://www.nrg4cast.org/)

In 2015, we were very actively involved in submitting new project proposals, particularly within the H2020 Programme. Once again, we were very successful, obtaining funding for three new projects in H2020: BigDataFinance, RENOIR and GlobalDNA. We continue with our successful efforts to include Slovenian industry in the European research area, where over the past 10 years we have produced a list of 18 companies participating in EU projects.

Some outstanding publications in the past year

1. Evgenia Belyaevaa, Aljaž Košmerlja, Andrej Muhič, Jan Rupnika, Flavio Fuart, Using Semantic Data to Improve Linking of cross–lingual Clusters, Journal of Web Semantics: Science, Services and Agents on the World Wide Web, pp 64-70, volume 32:2, Elsevier, 2015

2. Mario Karlovčec, Dunja Mladenić, Interdisciplinarity of scientific fields and its evolution based on graph of project collaboration and co-authoring, *Scientometrics*, ISSN 0138-9130, v102:1, 2015.
3. Škraba, Primož, Wang, Bei, Chen, Guoning, Rosen, Paul. Robustness-based simplification of 2D steady and unsteady vector fields. *IEEE transactions on visualization and computer graphics*, ISSN 1077-2626, 2015
4. Michiel E. Hochstenbach, Andrej Muhič, Bor Plestenjak, "Jacobi-Davidson methods for polynomial two-parameter eigenvalue problems", J. comput. appl. math., vol. 288, str. 251-263, 2015
5. Dejan Govc, "On the definition of the homological critical value", J. Homotopy Relat. Struct., 9 str., 2015
6. Alison Callahan, Igor Pernek, Gregor Štiglic, Jurij Leskovec, Howard R. Strasberg, Nigam Haresh Shah, "Analyzing information seeking and drug-safety alert response by health care professionals as new methods for surveillance", JMIR, J. med. internet res., vol. 17, no. 8, str. [1-22], 2015
7. Mikael Vejdemo-Johansson, Florian T. Pokorny, Primož Škraba, Danica Kragič, "Cohomological learning of periodic motion", Appl. algebra eng. commun. comput., vol. 26, no. 1/2, str. 5-26, 2015

Organization of Conferences, Congresses and Meetings

1. FP 7 NRG4Cast meeting, Brussels, Belgium, 16–17 April 2015

Awards and Appointments

1. Prof. dr. Dunja Mladenić, FOI Varaždin, Croatia; Friend of the faculty of organization and informatics charter recognizing the outstanding long-term contribution to the international affirmation of the faculty in the higher education and scientific area

INTERNATIONAL PROJECTS

1. 7FP - Sophocles; Self-Organised information PrOcessing, CriticaLity and Emergence in multilevel Systems
   Marko Grobelnik
   European Commission
2. 7FP - MobiS: Personalized Mobility Services for Energy Efficiency and Security through Advanced Artificial Intelligence Techniques
   Marko Grobelnik
   European Commission
3. 7FP - ProaSense; The Proactive Sensing Enterprise
   Marko Grobelnik
   European Commission
4. 7FP - SYMPHONY; Orchestrating Information Technologies and Global Systems Science for Policy Design and Regulation of a Resilient and Sustainable Global Economy
   Prof. Dunja Mladenić
   European Commission
5. 7FP - xLiMe; CrossLingual CrossMedia Knowledge Extraction
   Marko Grobelnik
   European Commission
6. 7FP - SUNSEED; Sustainable and Robust Networking for Smart Electricity Distribution
   Prof. Dunja Mladenić
   European Commission
7. 7FP - FI-IMPACT; Future Internet Impact Assurance
   Marko Grobelnik
   European Commission
8. 7FP - TOPOSYS; Topological Complex System
   Asst. Prof. Primož Škraba
   European Commission
9. 7FP - NRG4CAST; Energy Forecasting
   Maja Škrjanc, B. Sc.
10. European Commission
11. H2020 - AquaSmart; Aquaculture Smart and Open Data Analytics as a Service
    Prof. Dunja Mladenić
    European Commission
12. H2020 - EDSA; European Data Science Academy
    Marko Grobelnik
    European Commission
13. H2020 - OPTIMUM; Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility
    Marko Grobelnik
    European Commission
14. H2020 - BigDataFinance; Training for Big Data in Financial Research and Risk Management
    Marko Grobelnik
    European Commission
15. Dynamic Network Analysis of Global News Events
    Prof. Dunja Mladenić
    Slovenian Research Agency
16. PARSEME: PARSing and Multi-Word Expressions. Towards Linguistic Precision and Computational Efficiency in Natural Language Processing
    Dr. Simon Krek
    Cost Office
17. IS1305, European Network of E-Lexicography (ENeL)
    Dr. Simon Krek
    Cost Office

RESEARCH PROGRAM

1. Knowledge Technologies
   Prof. Dunja Mladenić

R&D GRANTS AND CONTRACTS

1. Model for Domain-Specific Trend Prediction based on Semantic Enrichment of Unstructured Patterns
   Prof. Dunja Mladenić
2. Development and evaluation automation of survey questionnaire
   Marko Grobelnik

NEW CONTRACTS

1. Agreement on cooperation on the software components development
   Marko Grobelnik
   Quintelligence d. o. o.
2. Technologies for next-generation intelligent motorhome
   Marko Grobelnik
   Adria Mobil, d.o.o. Novo mesto

VISITORS FROM ABROAD

1. Wray Buntine, Nicta, Melbourne, Australia, 14–15 January 2015
2. Pat Moore, Bloomberg LP, New York, USA, 8–11 February 2015
3. Stefano Pacifico, Bloomberg LP, New York, USA, 9–13 March 2015
4. Yogeshwaran Dhandapani, Indian Statistical Institute, Bangalore, India, 17–23 March 2015
5. Boris Černi, Bloomberg LP, New York, USA, 11 March 2015
6. Phillip Meerkamp, Bloomberg LP, New York, USA, 20–24 April 2015
7. Fabien Gandon, Inria, Sophia Antipolis, France, 30 May–5 June 2015
8. Marta Sabou, Vienna University of Technology, Vienna, Austria, 30 May–5 June 2015
9. Harald Sack, Hasso-Plattner-Institut, Potsdam, Germany, 30 May–5 June 2015
10. Elena Simperl, University of Southampton, Southampton, United Kingdom, 30 May–5 June 2015
11. John Davies, British Telecom, London, United Kingdom, 1–4 June 2015
12. Lisbeth Fajstrup, Aalborg University, Aalborg, Denmark, 7–11 June 2015
13. Konstantin Mischaikow, Rutgers University, New Brunswick, USA, 19–26 June 2015
14. Chris Pick, Bloomberg LP, New York, USA, 14–17 June 2015
15. Steffen Staab, Universität Koblenz-Landau, Mainz, Germany, 20–22 August 2015

16. Rok Sosič, Univerza Stanford, Palo Alto, USA, 24 August 2015
17. Miha Troha, Imperial College London, London, United Kingdom, 17 September 2015
18. Alex Božič, Bloomberg LP, New York, USA, 14–18 September 2015
19. Prhilipp Meerkamp , Bloomberg LP, New York, USA, 14–18 September 2015
20. Michael Witbrock, Cycorp USA, Austin, USA, 18–23 September 2015
21. Adam Sand, Lucid USA, Austin, USA, 18–23 September 2015
22. Paul Rector, Lucid USA, Austin, USA, 18–23 September 2015
23. Barry Norton, British Museum, London, United Kingdom, 18–23 September 2015
24. Dr. Jasminka Dobša, Fakultet Organizacije i Informatike, Univerza Zagreb, Varaždin, Croatia, 30 November 2015
25. Stefano Pacifico, Bloomberg LP, New York, USA, 14–17 December 2015

STAFF

Researchers
1. Dr. Damjan Bojadžiev
2. Asst. Prof. Branko Kavšek*
3. Dr. Simon Krek
4. Dr. Gregor Leban
5. **Prof. Dunja Mladenić, Head**
6. *Asst. Prof. Iztok Savnik*, left 01.10.15*
7. John Stewart Shawe-Taylor, B. Sc.
8. Asst. Prof. Primož Škraba

Postdoctoral associates
9. Dr. Janez Brank
10. Dr. Blaž Fortuna
11. Dr. Aljaž Košmerlj
12. Dr. Jurij Leskovec
13. Dr. Andrej Muhič*
14. Dr. Inna Novalija
15. Dr. Joao Paulo Pita Da Costa
16. Dr. Polona Škraba Stanič

Postgraduates
17. Luka Bradeško, B. Sc.
18. Rayid Ghani, M. Sc.
19. Dejan Govc*
20. Mitja Jermol, M. Sc.
21. Blaž Kažič, B. Sc.
22. *Alexandra Moraru, B. Sc., left 01.10.15*
23. Blaž Novak, B. Sc.
24. Jan Rupnik, B. Sc.
25. Janez Starc, B. Sc.
26. Luka Stopar, B. Sc.

Technical officers
27. Flavio Fuart, B. Sc.
28. Darja Grošelj, B. Sc.
29. Zala Herga, B. Sc.
30. Dr. Ganna Kudryavtseva*
31. *Dr. Ganna Kudryavtseva, left 01.10.15*
32. *Mojca Mikac*, B. Sc., left 15.10.15*
33. Matjaž Rihtar, B. Sc.
34. Maja Škrjanc*, B. Sc.

Technical and administrative staff
35. Marko Grobelnik
36. Klemen Kenda
37. Mojca Kregar Zavrl, B. Sc.
38. *Miha Papler, left 01.07.15*
39. Mateja Škraba, B. Sc.

Note:
* part-time JSI member

BIBLIOGRAPHY

Original Article

1. Evgenia Belyaeva, Aljaž Košmerlj, Andrej Muhič, Jan Rupnik, Flavio Fuart, "Using semantic data to improve cross-lingual linking of article clusters : editorial", *Journal of web semantics*, vol. 35, part 2, pp. 64-70, 2015.
2. Alison Callahan, Igor Pernek, Gregor Štiglic, Jurij Leskovec, Howard R. Strasberg, Nigam Haresh Shah, "Analyzing information seeking and drug-safety alert response by health care professionals as ew methods for surveillance", *JMIR, J. med. internet res.*, vol. 17, no. 8, pp. [1-22], 2015.
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6. Michael Kinyon, Jonathan Leech, João Pita Costa, "Distributivity in skew lattices", *Semigroup forum*, vol. 91, no. 2, pp. 378-400, 2015.
7. Sašo Moškon, Janez Žibert, Branko Kavšek, "Kartiranje morskih travnikov s podatki mnogosnopnega sonarja", *Geogr. vestn. (Tisk. izd.)*, 87, [št.] 1, pp. 103-116, 2015.
8. Primož Škraba, Bei Wang, Guoning Chen, Paul Rosen, "Robustness-based simplification of 2D steady and unsteady vector fields", *IEEE trans. vis. comput. graph.*, vol. 21, iss. 8, pp. 930-944, 2015.
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Published Conference Contribution

1. Evgenia Belyaeva, Jan Berčič, Katja Berčič, Flavio Fuart, Aljaž Košmerlj, Andrej Muhič, Aljoša Rehar, Jan Rupnik, Mitja Trampuš, "3XL news: a cross-lingual news aggregator and reader", In: *The semantic web: latest advances and new domainas: 12th European Semantic Web Conference, ESWC 2015 Portorož, Slovenia, May 31 - June 4, 2015: proceedings*, (Lecture notes in computer science, vol.9088), Cham [etc.], Springer, 2015, 5 pp..
2. Evgenia Belyaeva, Aljaž Košmerlj, Dunja Mladenić, "The pursuit of journalistic news values through text mining technique", In: *Izkopavanje znanja in podatkovna skladišča (SiKDD 2015): zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 5. oktober 2015, [Ljubljana, Slovenia]: zvezek E: proceedings of the 18th International Multiconference Information Society - IS 2015, October 5th, 2015, Ljubljana, Slovenia: volume E*, Dunja Mladenić, ed., Marko Grobelnik, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 5-8.
3. Luka Bradeško, Janez Starc, Stefano Pacifico, "Isaac Bloomberg meets Michael Bloomberg: better entity disambiguation for the news", In: *WWW 2015*, 24th World Wide Web Conference, 18-22 MAy 2015, Florence, New York, ACM = Association for Computing Machinery, 2015, pp. 631-635.
4. Thierry Declerck, Eveline Wandl-Vogt, Simon Krek, Carole Tiberius, "Towards multilingual eLexicography by means of linked (open) data", In: *Proceedings of the Fourth Workshop on the Multilingual Semantic Web (MSW4) co-located with 12th Extended Semantic Web Conference (ESWC 2015), Portorož, Slovenia, June 1, 2015*, (CEUR workshop proceedings, vol. 1532), Jorge Gracia, ed., John P. McCrae, ed., Gabriela Vulcu, ed., [S. l.], CEUR-WS, 2015, 8 pp..
5. Blaž Kažič, Dunja Mladenić, Aljaž Košmerlj, "Traffic flow prediction from loop counter sensor data using machine learning methods", In: *VEHITS 2015: proceedings of the 1st International Conference on Vehicle Technology and Intelligent Transport Systems, 20 - 22 May, 2015, Lisbon, Portugal*, pp. 119-127.
6. Blaž Kažič, Maja Škrjanc, Primož Škraba, Dunja Mladenić, Urban Kuhar, Anže Medved, Kemal Alič, Roman Novak, Aleš Švigelj, Jurij Jurše, "Pseudo-measurements based on the forecasted smart meter consumption for state-estimation : testbed deployment case study", In: *EMENDER 2015 - energy managemENT Data ElaboRation*, Ljubljana, Institut Jožef Stefan, 2015, 6 pp.
7. Klemen Kenda, Maja Škrjanc, Andrej Borštnik, "Modelling of the complex data space: architecture and use cases from NRG4CAST project", In: *IISA 2015 IEEE proceedings*, 6th International Conference on Information, Intelligence, Systems and Applications, July 6-8, 2015, Corfu, Greece, Danvers, IEEE = Institute of Electrical and Electronics Engineers, 2015, 4 pp.
8. Klemen Kenda, Maja Škrjanc, Andrej Borštnik, "Modelling in energy related scenarios", In: *Izkopavanje znanja in podatkovna skladišča (SiKDD 2015): zbornik 18. mednarodne multikonference Informacijska*

družba - IS 2015, 5. oktober 2015, [Ljubljana, Slovenia]: zvezek E: proceedings of the 18th International Multiconference Information Society - IS 2015, October 5th, 2015, Ljubljana, Slovenia: volume E*, Dunja Mladenić, ed., Marko Grobelnik, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 21-24.

9. Michael Kerber, Donald R. Sheehy, Primož Škraba, "Persistent homology and nested dissection", In: *Proceedings of the Twenty-Second Annaul ACM-SIAM Symposium on Discrete Algorithms, SODA 2015, January 4-6, 2015, San Diego, California, USA*, Robert Krauthgamer, ed., [S. l.], SIAM = Society for Industrial and Applied Mathematics, 2015, pp. 1234-1245.
10. Matjaž Kljun, Jernej Vičič, Klen Čopič Pucihar, Branko Kavšek, ""I agree": the effects of embedding terms of service key points in online user registration form", In: *Human-Computer Interaction - INTERACT 2015. Part II: proceedings: 15th IFIP TC 13 International Conference, Bamberg, Germany, September 14-18, 2015,* (Lecture notes in computer science, 9297), Julio Abascal, ed., Berlin, New York, Springer, cop. 2015, pp. 420-427.
11. Irene Koronaki, Maja Škrjanc, Tatsiana Hubina, Klemen Kenda, Kostas Kalaboukas, Simon Mokorel, George Markogiannakis, Steffen Nienke, Hamodrakas Giannis, Caterina Calefato, "Energy Forecasting and modelling in rural areas", In: *IISA 2015 IEEE proceedings*, 6th International Conference on Information, Intelligence, Systems and Applications, July 6-8, 2015, Corfu, Greece, Danvers, IEEE = Institute of Electrical and Electronics Engineers, 2015, 6 pp.
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Secondary and Primary School Textbook or Other Textbook

1. Gregor Anželj, Janez Brank, Andrej Brodnik, Patricio Bulić, Mojca Ciglarič, Mirko Đukić, Luka Fürst, Marko Kikelj, Alenka Krapež, Helena Medvešek, Nataša Mori, Matjaž Pančur, Peter Sterle*, Računalništvo in informatika 1: e-učbenik za informatiko v gimnaziji*, Koper, Založba Univerze na Primorskem, Ljubljana, Založba Fakulete za računalništvo in informatiko, Maribor, Fakuleta za elektrotehniko, računalništvo in informatiko, 2015.

Encyclopaedia, Dictionary, Lexicon, Manual, Atlas, Map

1. Peter Holozan, Simon Krek, Kaja Dobrovoljc, Tomaž Erjavec, Miro Romih*, Sloleks: slovenski oblikoslovni leksikon*, [Ljubljana], Trojina, Zavod za uporabno slovenistiko], 2015.

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1. Mario Karlovčec, *Network analysis using structural, textual and temporal data modality:* doctoral dissertation, Ljubljana, 2015 (mentor Dunja Mladenić).
2. Sašo Moškon, *Acoustic seabed classification:* doctoral dissertation, Koper, 2015 (mentor Janez Žibert; co-mentor Branko Kavšek).
3. Andrej Panjan, *Methods for automatic processing of electromyography signals of human trunk muscles:* doctoral dissertation, Koper, 2015 (mentor Nejc Šarabon; co-mentor Branko Kavšek).
4. Mitja Trampuš, *Semantic approaches to domain template construction and opinion mining from natural language:* doctoral dissertation, Ljubljana, 2015 (mentor Dunja Mladenić; co-mentor Janez Demšar).
5. Zala Herga, *Arbitraža na omrežjih:* master's thesis, Ljubljana, 2015 (mentor Tomaž Košir; co-mentor Primož Škraba).

LABORATORY FOR OPEN SYSTEMS AND NETWORKS E-5

The main activities of the laboratory are the R&D of next-generation networks, telecommunications technologies, components and integrated systems, and information-society services and applications, especially those that ensure an efficient and pervasive life-long learning concept.

Head:
Prof. Borka Jerman Blažič

In 2015 the research group implemented the research program "Future Internet Technologies: concepts, architectures, services and socio-economic issues". Research was also carried out in the EU Horizon 2020 project "Flex4Grid", the 7FP projects "COURAGE", "EmployID" and "REDIRNET", the "STORK 2.0" and "eSENS" projects from the CIP (Competitiveness and innovation) programme, the "DFET" project from the EU ISEC (Prevention of and Fight Against Crime) programme, and a national basic research project. The main fields of work were technologies and services in advanced next-generation networks, security and privacy in information systems, and technology-enhanced learning. Members of the laboratory are also teaching at the undergraduate and postgraduate levels at the University of Ljubljana, the Jožef Stefan International Postgraduate School, and the DOBA Faculty. In 2015 they were mentors for two diploma theses. One of the main achievements in 2015 was also the organisation of the Researchers' Night in the frame of the "WeForYou" project as part of Horizon 2020.

Concepts, architectures, technologies and services in the future internet

The first area of research and development was focused on security infrastructures and trusted services. The Laboratory for Open Systems and Networks is involved in the creation of a pan-European infrastructure that is needed for secure cross-border services based on national eID credentials, such as digital identity cards. The work is being performed in collaboration with partners from two large-scale pilots from the EU Competitiveness and Innovation (CIP) programme: STORK 2.0 and eSENS.

The main goal of the "Secure identity across borders linked 2.0 **(STORK 2.0)**" project, with 58 partners from 19 European countries, was to enable secure e-identity-based services across borders in the fields of e-academia, e-banking, public services for business, and e-health. The project that finished in 2015 demonstrated interoperable services in real-life settings and validated common specifications, standards and building blocks, exploring scenarios to address challenging legal and governance issues (across borders, application domains and different sectors) decisively pushing the boundaries for the wider uptake of eID in Europe.

The STORK 2.0 infrastructure connects identity providers, service providers and business-attribute providers, e.g., universities and business registries, and represents an approach to creating an infrastructure that meets the requirements of the newest eIDAS regulation. In Slovenia, the main Slovenian infrastructure node PEPS has been established by the Ministry of Public Administration, while three cross-border academic e-services, based on electronic identities and proven sources of academic attributes, were deployed at our Laboratory for Open Systems and Networks: virtual learning environment, anonymous e-surveys, and a job-selection service. The services promise to be beneficial both for students and higher-education institutions, as well as for companies that make decisions on the basis of proven academic information, for example, when validating a job applicant's qualifications in an electronic way.

Our research and development results enable secure cross-border e-services at the EU level.

A shared virtual learning environment is based on the open-source Moodle learning management system and supports a log in with STORK 2.0 credentials. On the basis of their national eID credentials and proven academic attributes (e.g., student status, study year, average grade, academic degree, teacher role) the users are being denied or granted access to specific e-learning courses, and their roles (e.g., teacher, administrator, or learner) in the system assigned. The e-survey service allows designing and carrying out of on-line surveys in an authenticated and authorized, but anonymous, way. The service is based on the open-source software LimeSurvey and enables researchers and professors to design surveys for particular target groups. Participation in such a survey is thus subject to the provision of proven attributes, issued by national identity and attribute providers. The job selection service brings together academic institutions and companies, and aims at reducing the paper work in the validation of an academic qualification when evaluating job-seeker applications. The service allows companies to specify in their job or internship position descriptions which proofs of qualifications need to be submitted in an electronic way. Only users with valid national eID credentials who provide the required academic information (attributes) obtained from the STORK 2.0 infrastructure can apply for the position.

Finally, we enabled the integration of two attribute providers from the Ministry of Education, Science and Sport (eVŠ - national central evidence student system) and the Faculty of Computer Science and Informatics at the University of Ljubljana into the STORK 2.0 infrastructure.

The "Electronic Simple European Networked Services (**eSENS**)" project is consolidating the building blocks of several large-scale pilots, including STORK 2.0, focusing strongly on the core building blocks, such as eID, eDocuments, e-Delivery, and e-Signatures. The architecture to be developed will be part of the European Interoperability Architecture (EIA) for the efficient and effective delivery of cross-border and cross-sector electronic public services. Our laboratory is leading project activities on user-attributes provision and aggregation and role management.

Figure 1: Secure cross-border academic services

We continued with the design and development of interoperability solutions for information exchange among the rescue agencies during accidents and other natural disaster situations. Interoperability solutions address the interoperation of the communication networks of different rescue agencies (e.g., police, traffic and road service, medical aid, fire-protection agency, general rescue services, mountain-rescue services, anti-terrorism agencies) used for data exchange and the interoperability of the data. The work is being performed within the frame of the "Emergency Responder Data Interoperability Network (**REDIRNET**)" project in collaboration with partners such as BAPCO (British Association of Public Safety Officers). Based on workshops with end users we analysed the user requirements. We also prepared security recommendations and guidelines for the developers and users of the interoperable infrastructure. At the beginning of the year a validation exercise was carried out in Manchester (UK) in the presence of end users from 11 countries. In May, an interim demonstration of the emerging capacities took place in Prague.

In 2015 we started with the new "Prosumer Flexibility Services for Smart Grid management (**Flex4Grid**)" project from the Horizon 2020 EU programme. The project is part of the call for Competitive Low-Carbon Energy from the Societal Challenges pillar. Based on the innovative use of ICT technologies the project aims at improving the smart-grid operation by utilizing the prosumers' flexibility. The project has a strong Slovenian contribution, with Elektro Celje and Smart Com as partners in the project, besides the Jožef Stefan Institute. Slovenian partners are working together to realize a large-scale pilot in the Celje region. The main role of our laboratory in the project is related to cloud security and privacy and multitenant virtualization of the prosumer services. In 2015 the first services have been setup and pre-pilot prosumers involved in the trials.

We co-design a research and development agenda in the area of the fight against cybercrime and cyberterrorism.

Under the Infrastructure program in research organizations we also provided support services that enable better communication among members of the various research programs, as well as students and their mentors from geographically distributed institutions. Support services helped us to organize a joint conference with the Edinburgh Napier University that took place in Ljubljana and Scotland. Within the DFET project, the centre has also established a cloud-based environment that enabled participation and collaboration across Europe.

Security, dependability and privacy in information systems

The provision of security and privacy services is crucial for the modern information society. In 2015 our activities in this field were focused on R&D in the authentication and authorization in cloud computing, attack modelling, privacy issues in mobile networks, and digital forensics. The results have been published in the "Information Security", "Information Development and Control Engineering" and "Applied Informatics" scientific journals. A conference paper presented at ICCCS 2015 received a "best paper" award.

In the field of privacy protection in mobile networks and mobile devices, for example, smart phones, we performed an in-depth study of the data privacy and personal security risks incurred by mobile users in several selected countries, most of them with low scores regarding respect for human rights. The technical testing provided sufficient information about how security threats can be overcome with additional tools, since some smartphone systems do not contain secure technology for personal data protection. Then, the user awareness regarding data protection and privacy was studied. The influence of parameters such as the country's wealth and the availability of high technology on user attitudes were explored and discussed. The results have been published in the "Telematics and Informatics" journal.

As part of the "Dynamic Forensics Evaluation and Training (**DFET**)" project activities from the EU "Prevention of and Fight Against Crime " (ISEC) programme we have created a cloud-based platform for digital forensics education and training, named EDUFORS. The platform enables the automatic and dynamic generation, delivery and

evaluation of investigation challenges that law-enforcement officers, students and security specialists have to solve with cyber forensic analytical tools. Currently, three types of scenarios are supported: distributed denial of service, phishing, and SQL injection. We have presented in multiple articles and at several conferences this novel approach to education in the area of digital forensics based on a multi-platform cloud-computer infrastructure and an innovative computer-based tool. The tool is installed and offered over the DFET cloud-based infrastructure. Cloud computing provides an efficient mechanism for a wide range of services that offer real-life environments for teaching and training in cybersecurity and digital forensics.

We have developed the cloud-based environment EDUFORS and the serious game FOREVICA for digital forensics education and training.

The main goal of the "Cybercrime and cyberterrorism European research agenda (**COURAGE**)" project is the definition of the research and development agenda in the area of the fight against cybercrime and cyberterrorism (CC/CT). Cybercrime is described as behaviour in which computers or networks are a tool, a target, or a place of criminal activity. In 2015, the Laboratory for Open Systems and Networks had the main role in a project in research gap analysis in that field. The gap analysis has been based on the COURAGE taxonomical categorisation of CC/CT and the inventory of past and on-going research and current activities in the field. The main groups of identified research gaps include offences against the confidentiality, integrity and availability of computer systems, computer-related offences, content-related offences, and offences related to copyright infringement, as well as actors and their motivation and practices, and CC/CT prevention measures. In total, we identified 47 research gaps, for example, the inadequate definition and harmonization of terms in the CC/CT field; efficiency and effectiveness of technologies for malware detection; fraud-prevention techniques, or normative frameworks for dealing with virtual crime. The list of identified gaps has been validated against stakeholders' requirements and will be used for the preparation of the final holistic research agenda in 2016.

Also in 2015, we organized a successful Researchers' Night.

In the frame of the COURAGE project the laboratory also co-organised with the CAMINO project the first Expert Forum with the title "Innovation and cybercrime: challenges of the digital transformation in Europe". The event that took place in Montpellier in France had the goal to gather insights into cyber security in Europe and beyond, and to discuss further developments in methodology, technology, and the foundations for the design and effective implementation of cyber security that enable the realisation of recommendations towards the European Commission and European citizens.

Technology enhanced learning

The main focus of the research and development activities in the area of technology-enhanced learning was on serious games and gamification, problem-based learning, and new e-learning services and platforms for public employment services. The results are published in the "Journal of educational computing research" and "TechTrends" journals. We have also developed a serious game named FOREVICA for education and training in digital forensics.

The main goal of the "Scalable cost-effective facilitation of professional identity transformation in public employment services (**EmployID**)" project is to support and facilitate the learning process of PES (Public Employment Services) practitioners in their professional identity development. We envision developing a set of services combining and linking eCoaching, reflection, MOOCs, networking, analytical and learning support tools, leading to improved individual and organisational performance in the delivery of employment services. Privacy issues are also being tackled in the project through the development of a concept for handling privacy and ethical aspects at all different levels, ranging from organisational policies, via creating awareness, up to technical measures regarding the ownership and stewardship of data. Our activities also ensure that the tools developed are privacy aware, abide privacy principles, and are compliant with the newest EU privacy and data-protection legislation. Among the other main results of our research and development activities in 2015 we need to mention our contributions to the EmployID evaluation framework, automatic usage data logging, and development of a community of practice platform for public employment services.

Figure 2: Researchers' Night 2015

Science promotion

For the fourth time the Laboratory for Open Systems and Networks successfully organized a Researchers' Night with the goal being to promote science, scientists and their results, this year in the frame of the "Meet and Learn What Excellent Science does for You and the Society (WeForYou)" project from the Horizon 2020 programme. The event took place on September 25, 2015 at 10 locations in Lju-

bljana, Izola, Planica and Novo mesto, where more than 70 lectures, workshops and other events were organized. The main topics of the events were energy, ecology, health and ICT. The Researchers' Night was widely recognized by the broader society, which proved that there is definitely a lack of projects and events with similar contents and that scientists are keen to share their experiences with their colleagues and in this way stimulate the young who are just at the beginning of their careers. The estimated total number of visitors at all the venues was between 6000 and 7000.

Some outstanding publications in the past three years

1. Callanan, Cormac, Jerman-Blažič, Borka, Jerman Blažič, Andrej. User awareness and tolerance of privacy abuse on mobile internet: an exploratory study. Telematics and informatics, ISSN 0736-5853, 2016, vol. 33, iss. 1, str. 109-128.
2. Jerman Blažič, Andrej, Jerman-Blažič, Borka. Exploring and upgrading the educational business-game taxonomy. Journal of educational computing research, ISSN 0735-6331,] 2015, str. 38 -52.
3. Jerman-Blažič, Borka, Jerman Blažič, Andrej, Arh, Tanja. A virtual user community: cultural backgrounds in the design of an internet-based service. Journal of global information management, ISSN 1062-7375, 2015, vol. 23, no. 2, str. 24-27.

Organization of conferences, congresses and meetings

1. Organisation of the Flex4Grid project meeting, Ljubljana, 2–3 June 2015.
2. Organization of General Assembly STORK 2.0, Cankarjev dom, Ljubljana, 16–17 September 2015.
3. Researchers Night 2015, WE FOR YOU – Meet and Learn what excellent science does for you and the society, Ljubljana, September 25 2015.
4. Organization of the ReDIRNET project meeting, Bled, Slovenia, 15–16 September 2015.
5. DigSec conference, Ljubljana, 23 October 2015.

INTERNATIONAL PROJECTS

1. 7FP - EmployID; Scalable Cost-effective Facilitation of Professional Identity Transformation in Public Employment Services
   Asst. Prof. Tomaž Klobučar
   European Commission
2. 7FP - REDIRNET; Emergency Responder Data Interoperability Network
   Prof. Borka Džonova Jerman Blažič
   European Commission

7FP - COURAGE; Cybercrime and cyberterrOrism (E)Uropean Research AGEnda
Prof. Borka Džonova Jerman Blažič
European Commission

3. CIP-e-SENS; Electronic Simple European Networked Services
   Prof. Borka Džonova Jerman Blažič
   European Commission
4. D-FET; Dynamic Forensics Evaluation and Training
   Prof. Borka Džonova Jerman Blažič
   European Commission
5. STORK 2.0; Secure idenTity acrOss boRders LinKed 2.0
   Prof. Borka Džonova Jerman Blažič
   European Commission
6. H2020 - Flex4Grid; Prosumer Flexibility Services for Smart Grid Management
   Dr. Dušan Gabrijelčič
   European Commission
7. H2020 - WeForYou; Meet and Learn What Excellent Science does for You and the Society
   Asst. Prof. Tanja Arh
   European Commission

RESEARCH PROGRAM

1. Future Internet Technologies: concepts, architectures, services and socio-economic issues
   Prof. Borka Džonova Jerman Blažič

R&D GRANTS AND CONTRACTS

1. Content and data communication interoperability of first responders networks
   Prof. Borka Džonova Jerman Blažič

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10. Andrej Jerman Blažič, M. Sc.
11. Tanja Pavleska, B. Sc.
12. *Matija Pipan, M. Sc., left 02.07.15*

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13. David Djurić, B. Sc.

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14. Tatjana Martun, B. Sc.

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Original Article

1. Matej Babič, "New method for image analyze using mathematical method of graph theory and it's application in robot laser hardening", *Acta Mech. Slovaca (Košice)*, vol. 19, no. 1, pp. 28-35, mar. 2015.
2. Matej Babič, "New method of hardening and comparison with another method", *Journal of production engineering*, vol. 18, no. 2, pp. 43-46, 2015.
3. Matej Babič, "Using intelligent-system metods in mechanical engineering to predict the topographical property of materials with the topological property of visibility graphs in a 3D space", *Elektrotehniški vestnik online*, vol. 82, no. 1/2, pp. 31-36, 2015.
4. Matej Babič, "Using of genetic programming to predict hardness of hardened materials", *Journal of multidisciplinary engineering science and technology*, vol. 2, issue 1, pp. 168-171, jan. 2015.
5. Primož Cigoj, Borka Jerman-Blažič, "An authentication and authorization solution for a multiplatform cloud environment", *Inf. sec. j.*, vol.24, iss.4-6, pp. 146-156, 2015.
6. Andri Ioannou, Christina Vasiliou, Panayiotis Zaphiris, Tanja Arh, Tomaž Klobučar, Matija Pipan, "Creative multimodal learning environments and blended interaction for problem-based activity in HCI education", *TechTrends*, vol. 59, no. 2, pp. 47-56, 2015.
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10. Bojan Srdjević, Matija Pipan, Zorica Srdjević, Boško Blagojević, Tihomir Zoranović, "Virtually combining the analytical hierarchy process and voting methods in order to make group decisions", *Univers. access inf. soc.*, vol. 14, no. 2, pp. 23-245, 2015.

Published Conference Contribution

1. Rok Bojanc, "Bizbox: brezpapirno poslovanje med partnerji doma in v tujini", In: *Informatika - razvijamo danes za jutri: zbornik*, 22. konferenca Dnevi slovenske informatike - DSI, 13.-15. april 2015, Portorož, Katjuša Skukan, ed., et al, 1. izd., Ljubljana, Slovensko društvo Informatika, 2015, [7] pp.
2. Primož Cigoj, Borka Jerman-Blažič, "An innovative approach in digital forensic education and training", In: *Information security information across the curriculum: 9th IFIP WG 11.8 World Conference, WISE9, Hamburg, Germany, May 26-28, 2015*, (IFIP advances in information and communicatin technology, vol. 453), Matt Bishop, ed., Natalia Miloslavskaya, ed., Marianthi Theocharidou, ed., Cham [etc.], Springer, 2015, pp. 101-110.
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Independent Component Part or a Chapter in a Monograph

1. Andrej Jerman Blažič, Franc Novak, "Challenges of busines simulation games: a new approach of teaching business", In: *E-learning: instructional design, organizational strategy and management*, Boyka Gradinarova, ed., Rijeka, InTech, 2015, pp. 227-259.

Mentoring

1. Živa Stepančič, *Statistical methods for motif finding in DNA:* doctoral dissertation, Ljubljana, 2015 (mentor Damjana Kokol Bukovšek; co-mentor Matjaž Omladič).

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 methods and software tools for the modelling, simulation, analysis and synthesis of communication systems, 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 were carried out in the framework of 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 2015 the research activities within the **Communication Technology Laboratory** were concentrated on different challenges associated with access-segment technologies, enabling end-users to access new multimedia services and applications. As part of the research programme the emphasis was on research in the areas of: radio propagation, access architectures for heterogeneous wireless networks, management of radio and network resources and cognitive communications.

The investigation of the radio-signal propagation was focused on two main topics. The first topic concerns the research of the radio-signal propagation in special environments, such as long road and railway tunnels. The emphasis was on the radio-wave propagation characteristics in curved tunnels for designing reliable communications in subway tunnels. The extensive propagation measurements provided an insight into the large-scale fading characteristics in real curved subway tunnels at various frequencies (920 MHz, 2400 MHz, and 5705 MHz). The qualitative analyses and corresponding findings are useful for realizing wireless communication systems in subways and tunnels. The second topic concerns the development, implementation and testing of a software tool for radio-wave propagation modelling in mobile communication systems' and wireless communication systems' optimization. The tool is integrated into an open-source geographical information system (GIS) and incorporates statistical models, channel models based on ray tracing and optimization procedures. We studied computationally efficient radio ray-tracing techniques in the context of physical channel models. We adapted some concepts known from computer graphics to the radio environment, including the use of massively parallel hardware that can be found in today's graphical processors. Furthermore, we studied possibilities for reducing the excessive computation times by exploiting the spatial coherence of electromagnetic propagation. The optimizations proposed are applicable to a wider set of problems that can be solved on Single Instruction Multiple Data architectures. In addition, we focused on wireless network optimization using a multi-objective evolutionary algorithm, which for given criteria functions determines the optimal network parameters. The aim of the proposed solution is to maximize the network efficiency, reduce the needed resources and consequently reduce the operational costs. Based on the terrain-profile maps and construction locations, the tool calculates the path loss by applying state-of-the-art statistical models and determines the optimal base-station locations and parameters by maximizing defined criteria functions. The implemented solution is entirely generic and, with appropriately adjusted criteria functions, could be used for planning any heterogeneous wireless network.

Integration of the LOG-a-TEC experimental testbed into the Fed4FIRE federation.

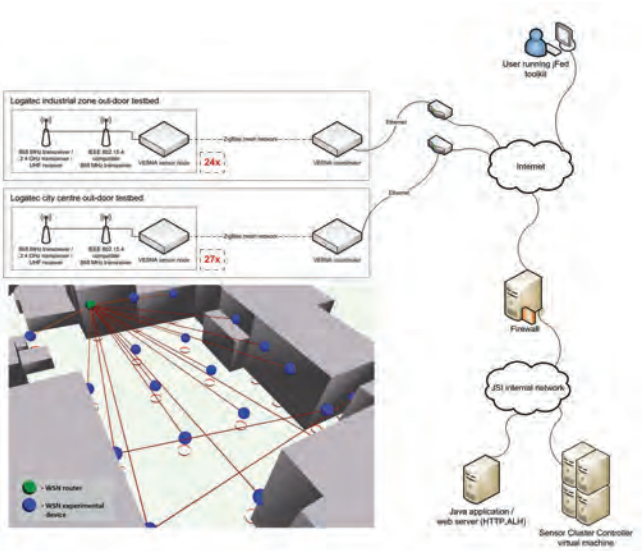

Figure 1 Integration of a LOG-a-TEC experimental testbed into the Fed4FIRE federation with a 3D representation.

We continued the investigation of advanced concepts and technologies for a capacity increase of wireless meshed networks using network-coding techniques. In particular, we focused on the development of advanced network-coding algorithms and their adapted routing procedures. We designed and built a simulation model that allows arbitrary performance evaluation

of network-coding algorithms and routing procedures on predetermined or randomly generated wireless mesh network topologies. We also developed a testbed for the evaluation of a network-coding-assisted re-transmission scheme for multimedia broadcasting in wireless networks.

In the FP7 ABSOLUTE project we participated in the design and validation of an innovative, rapidly deployable future network architecture for large coverage areas affected by large-scale disasters leading to the partial or complete unavailability of the terrestrial communication infrastructure, or for temporary events requiring very high throughput and augmented network capacity. In the past year we focused on the development of new, advanced techniques for radio-spectrum management, on the development of new network solutions and on the integration of wireless sensor networks into the emergency architecture. We have developed a simulation model to evaluate the performance of LTE networks in emergency situations, where the emergency network, besides the terrestrial base-stations, also includes low-altitude platforms (LAPS) with a large area of coverage, and portable LTE base-stations within a short range. The simulation model is based on radio environment maps from real areas, enabling an authentic analysis of the capacity also for various mobile scenarios.

A new 4-channel beacon receiver station with a tracking system has been set-up at the JSI for the European Space Agency. The station is being used for beacon signal reception from Alphasat, Europe's largest and most sophisticated telecom satellite.

In 2015 we were actively participating in several COST actions. We successfully finished the COST Action IC1101. In the final report we presented research results about the influence of weather conditions on the link performance of wireless optical communication systems, which were conducted in collaboration with TU Graz. We also evaluated the performance of the wireless optical system KORUZA, which was designed and installed at the JSI in collaboration with the IRNAS institute Rače. In the COST Action IC1104, we were developing practical network-coding procedures and evaluating them in a purpose-built simulation model. In the COST action IC1004 we mainly participated in working groups one and two, with topics related to radio-propagation aspects and problems of the physical layer.

In the scope of the SatProSi-Alpha project, carried out for the European Space Agency (ESA), a new 4-channel Alphasat beacon receiver station was set-up in August 2015 on top of the Institute's roof. It is one of the three European stations with capabilities to measure the 19.7-GHz and 39.4-GHz satellite beacons and their cross-polar components, and with capabilities to track satellites in a geosynchronous orbit. The purpose of the project is to analyse the measured data and to research the atmosphere's impacts on radio-wave propagation at high frequences. Up to now, these effects were relatively unexplored, especially for the Q-band (39.4 GHz). The results will enable engineers to develop an efficient communication technology for high-frequency bands and hence enable high satellite communication throughputs of the order of terabits/s. The results are being analysed in the scope of the international group ASAPE (Group of the AlphaSat Aldo Paraboni propagation Experimenters).

In the scope of the FP7 SUNSEED project, which aims to develop a techno-economic model to make more efficient use of the communications infrastructure in smart-grid networks of the future, we also apply our research activities in the field of the optimization and network management to the field of smart-grid networks. In 2015 we were focused on the development of software modules and algorithms for a three-phase estimator in the low-voltage network. We started the development of computationally efficient algorithms for low-voltage network phasor measurement units. Research on their optimal placement for the most efficient state estimation, as well as the supporting communication infrastructure, was one of our key activities.

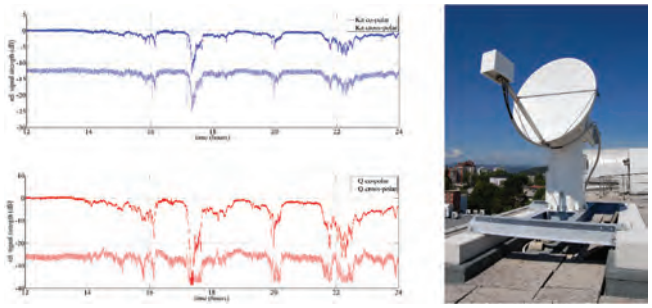

Figure 2: Right: the new Alphasat receiving station with a tracking mechanism for measuring high-frequency satellite signals. Left: example measurements of the received signal strength for the Ka-band (blue curves) and for the Q-band (red curves). The curves show a typical response of the communication channel to atmospheric influence on a rainy day.

In the **Parallel and Distributed Systems Laboratory**, we successfully continued interdisciplinary research in the framework of the research programme that also includes the Machine Vision Laboratory from the Faculty of Electrical Engineering and the Laboratory for Algorithms and Data Structures from the Faculty of Computer and Information Science, both from the University of Ljubljana. We also cooperate with researchers from industry and medicine, on research projects and with joint papers.

The basic tasks of the laboratory are the investigation of computer algorithms, efficiently implementable on parallel and distributed computers, and their testing on a 152-core computer cluster, which is also reachable within a cloud, established in cooperation with our research and industrial partners. We continued investigations in the field of wireless sensor networks' data streams with amounts that exceed the performances of personal computers and require HPC computing and communication resources.

We developed and tested, together with the Elektoinštitut Milan Vidmar and the Slovenian Environment Agency, a model of the icing on overhead electrical lines. Experimental operative forecasting and prevention of the icing on high-voltage overhead lines were designed.

We have successfully applied for a FWO project "Multi-analysis of fretting fatigue using physical and virtual experiments", with an essential work package devoted to the solution and implementation methodology based on local meshless methods. With these methods, we will simulate crack propagation in realistic circumstances. Theoretical foundations of local meshless methods were published in the book "Parallel scientific computing: theory, algorithms, and applications of mesh-based and meshless methods". These investigations are expected to enable tighter coupling between optimization and simulations, hopefully resulting in more reliable and efficient simulations of fretting-crack propagation.

We continued the development and produced improved batches of fully functional prototypes of a wearable ECG measuring device. The ECG measuring device is small and unobtrusive when worn, it transmits the measurements wirelessly to a smartphone or a tablet, and is able to work on battery power for several days. Such devices will represent the base of future telemedicine and telehealth services, which are indispensable for lowering the cost of general health services. We have connected the device into an integrated service that makes an ECG measurement and transports the data to a smartphone, where it is displayed and initially analysed, and to a PC, where it undergoes final visualization and analysis. We have registered the device as a technological improvement at the level of the Institute and successfully started the transfer of the related technology to industry, supported by private investors and the FP7 TETRACOM project.

In cooperation with the Milan Vidmar Electric Power Research Institute and the Slovenian Environment Agency we developed an icing warning system and a model for the determination of the minimum current necessary for icing prevention.

In the field of formal methods for discrete systems' development, we investigated the synthesis of complete test suites for final state machines and proposed numerous generalizations and improvements of the existing algorithms. In cooperation with the University of Podgorica, we developed and published a new algorithm for the identification of backbones in 2D percolation arrays, one that can be efficiently implemented on cellular automata.

In 2015 the **Networked Embedded Systems Laboratory** mainly focused on research and development in the areas of the Internet of Things and cognitive communications. The emphasis was on the vertical integration of different wireless-sensor and communication-network technologies in support of accesing sensors and sensor data, as well as on using various machine-learning and decision-making algorithms.

The modular and fully flexible platform VESNA for wireless-sensor networks and existing external modules, developed as the core building blocks for several research and applied projects, was upgraded with a set of new features. Contiki OS modules were adapted to enable the parallel operation of two protocol stacks. The radio-spectrum sensing module in the UHF and VHF frequency bands was applied for long-term spectrum sensing. The ProtoStack tool for remote composition, reconfiguration and reprogramming of the CRime protocol stack was developed further. The VESNA platform was applied in a spectrum war contest, a programming game where players compete for bandwidth on a limited piece of a radio spectrum, organized within the FP7 CREW project.

A testbed at the premises of the Jožef Stefan Institute has been upgraded. The large-scale outdoor wireless-sensor network LOG-a-TEC experimental testbed, setup in collaboration with the Municipality of Logatec and Komunalno podjetje Logatec was also modernized. The remote sensor nodes' firmware management, the remote execution of experiments and the remote gathering of sensor measurements' data via a web application running on one of our servers was also upgraded. The experimental testbed located in Logatec and Ljubljana was applied for a comparison of the measured and predicted DVB-T signal within the FP7 CREW project.

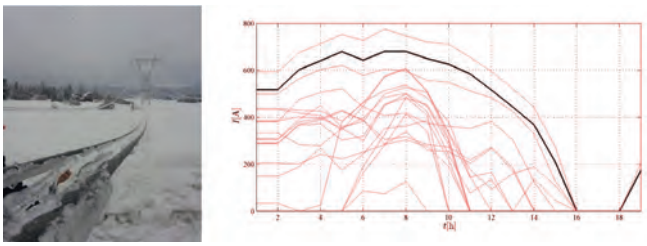

Figure 3: Glaze on Beričevo-Divača line on 1.2.2014 (source ELES) and minimum currents that could have prevented it by means of Joule losses. They have been computed from an archived meteorological forecast. Each of the curves belongs to one of 19 equidistant points on the line, the black one, for instance, to the segment nearest to Postojna.

The wireless-sensor network testbed LOG-a-TEC will be fully integrated into the existing Fed4FIRE federation of European experimental facilities. To this end we continued with the adaptation and adoption of Fed4FIRE federation interfaces and components, creating the adapters between LOG-a-TEC and the Fed4FIRE federation platform, validating the newly federated testbed and making it available to the community of experimenters through the common Fed4FIRE portal.

In the area of wireless-sensor networks we continued two FP7 projects, namely, ABSOLUTE and CITI-SENSE. In the FP7 ABSOLUTE project our role was to integrate the VESNA-based wireless-sensor network in the emergency communications network architecture. The aim was to provide an easily deployable sensor network for in-situ fixed or participatory monitoring of post-disaster parameters as well as for the spectrum sensing needed to support the ad-hoc establishment of the ABSOLUTE communication system without causing harmful interference to coexisting communication systems. In this respect, we designed, implemented and integrated the sensor network into a portable land mobile unit, which in addition to sensing the environmental parameters, includes a GPS module and a unit for the control of power consumption by the portable land mobile unit. The wireless-sensor network functionali-

ties were demonstrated at the final project demonstration. In the FP7 CITI-SENSE project, which is concerned with the establishment of sensor-based Citizens' Observatory Community for improving the quality of life in cities, our focus was mainly on providing the VESNA-based solution for air-quality monitoring. As part of this we developed a module with gas, particle matter and other ambient-related sensors, which by using Wi-Fi or Bluetooth connectivity sends measured data to a smart phone or a tablet, which is used for a graphical presentation of the measured data and as a relay for sending data to a remote data server.

In 2015, we finished two technology development projects financed by the Ministry of Economic Development and Technology SMER+, namely "Smart camper" and "Smart home". In the first one, we developed sensor and communication technologies for the intelligent remote management of motorhomes. Within the project we developed a VESNA-based controller. Six of them were integrated into a next-generation motorhome designed and produced by the company Adria Mobil. The integrated modules were connected to the central processing unit, which were collecting and processing data. Based on the measured data, intelligent algorithms discover the habits of motorhome users and predict the usage of the motorhome's resources. The system also supports connection to a smart phone and central data collection. In the second project, together with the c ompany Cosylab, we developed sensor and communication technologies for smart buildings, with an emphasis on monitoring the generation and consumption of electricity.

We have registered the wearable ECG sensor as a technological innovation and transferred the technology to industry, with private financial investment and the FP7 TETRACOM project.

Within the FP7 project SUNSEED we developed a sensor platform for measuring electricity consumption, current, voltage, frequency and distortion factor for electricity consumers. The prototype platform was demonstrated at the "Mobile World Congress" 2015 in Barcelona.

In collaboration with the company Hella, within the FP7 project ProaSense, the aim of which is to design an innovative and comprehensive approach to proactive intelligence, information management, problem solving and decision support, we are predicting the quality of headlights production from measured environmental and production parameters.

In 2015 we also concluded the project "Observe, Reason, Act (OSU)" supported by the Ministry of Education, Science and Sport. Within the project we developed a learning tool that enables the remote collection, reviewing and analysis of data, as well as simple adding of additional data sources.

The Networked Embedded Systems Laboratory members also actively contributed to the SensorLab group, which was established by the Department of Communication Systems and the Laboratory of Artificial Intelligence.

Some outstanding publications in the past year

1. Švigelj, Aleš, Sernec, Radovan, Alič, Kemal. Network traffic modeling for load prediction : a user-centric approach. IEEE network, ISSN 0890-8044, 2015, vol. 29, no. 4, str. 88-96. [COBISS.SI-ID 28767783],
2. Fortuna, Carolina, Mohorčič, Mihael. A framework for dynamic composition of communication services. ACM transactions on sensor networks, ISSN 1550-4859, 2015, vol. 11, no. 2, str. 31-1-31-10, doi: 10.1145/2678216. [COBISS.SI-ID 28254247]
3. Novak, Roman. Loop optimization for divergence reduction on GPUs with SIMT architecture. IEEE transactions on parallel and distributed systems, ISSN 1045-9219. [Print ed.], 2015, vol. 26, no. 6, str. 1633-1642, doi:10.1109/TPDS.2014.2324587. [COBISS.SI-ID 28013351].
4. Rashkovska, Aleksandra, Kocev, Dragi, Trobec, Roman. Non-invasive real-time prediction of inner knee temperatures during therapeutic cooling. Computer methods and programs in biomedicine, ISSN cid:image004.png@01D177C9.2D146C200169-2607. [Print ed.], 2015, vol. 122, no. 3, str. 136-148, doi: 10.1016/j.cmpb.2015.07.004 <http://dx.doi.org/10.1016/j.cmpb.2015.07.004>.
5. Trobec, Roman, Kosec, Gregor. Parallel scientific computing : theory, algorithms, and applications of mesh based and meshless methods, (SpringerBriefs in computer science). Cham [etc.]: Springer, cop. 2015. XI, 107 str., ilustr. ISBN 978-3-319-17072-5. ISBN 978-3-319-17073-2.

Organization of Conferences, Congresses and Meetings

1. Workshop Smart cities and communities as a development opportunity for Slovenia, Institut "Jožef Stefan", Ljubljana, 15. 10. 2015.
2. Workshop EM-Health, Institut "Jožef Stefan", Ljubljana, 9. and 12. 10. 2015.

Awards and appointments

1. Matevž Vučnik, Johana Robinson, Miha Smolnikar, David Kocman, Milena Horvat, Mihael Mohorčič: Outstanding Student Poster Award at EGU General Assembly 2015 to, "Portable air quality sensor unit for

participatory monitoring: an end-to-end VESNA-AQ based prototype", Geophysical Research Abstracts, Vol. 17, European Geosciences Union General Assembly 2015, Vienna, Austria, Aapril 2015.
2. Roman Trobec: HiPEAC Tech Transfer Award 2015, University of Gent, Gent, Belgium, Ddecember 2015.

INTERNATIONAL PROJECTS

1. 7FP - CREW; Cognitive Radio Experimentation World
   Prof. Mihael Mohorčič
   European Commission
2. 7FP - ABSOLUTE; Aerial Base Stations with Opportunistic Links for Unexpected & Temporary Events
   Prof. Mihael Mohorčič
   European Commission
3. 7FP - CITI-SENSE; Development of Sensor-based Citizens' Observatory Community for Improving Quality of Life in Cities
   Prof. Mihael Mohorčič
   European Commission
4. 7FP - ProaSense; The Proactive Sensing Enterprise
   Prof. Mihael Mohorčič
   European Commission
5. 7FP - SUNSEED; Sustainable and Robust Networking for Smart Electricity Distribution
   Prof. Mihael Mohorčič
   European Commission
6. 7FP - Fed4FIRE; Federation for FIRE - Federation for Future Internet Research and Experimentation
   Prof. Mihael Mohorčič
   European Commission
7. 7FP - TETRACOM; Technology Transfer in Computing Systems
   Prof. Roman Trobec
   European Commission
8. ESA - SatProSi-Alpha; Ka/Q-band Propagation Measurements and Modelling - Slovenian Contribution to the Alphasat TDP#5 Scientific Mission
   Dr. Andrej Vilhar
   Esa/estec.

RESEARCH PROGRAMS

1. Telecommunication Systems
   Prof. Mihael Mohorčič
2. Parallel and Distributed Systems
   Prof. Roman Trobec

R&D GRANTS AND CONTRACTS

1. Model for Domain-Specific Trend Prediction based on Semantic Enrichment of Unstructured Patterns
   Prof. Roman Trobec
2. Efficient self-configuration methods for wireless mesh networks
   Dr. Carolina Fortuna
   Ministry of Education, Science and Sport of the Republic of Slovenia
3. Observe, Infer, Act
   Prof. Mihael Mohorčič
   Ministry of Education, Science and Sport of the Republic of Slovenia

NEW CONTRACTS

1. Propagation and topology design evaluation for wireless sensor networks operating in license exempt frequency bands'
   Prof. Mihael Mohorčič
   Cosylab, Laboratorij za Kontrolne Sisteme, d. d.
2. Analysis of operational measures for prevention of ice formation on power lines
   Dr. Gregor Kosec
   Eles, d. o. o.
3. Wearable Multifunctional Body Sensor (MedSens)
   Prof. Roman Trobec
   Simed d. o. o.
4. Transfer of intellectual property rights and cooperation in the development and marketing of „Systems for mobile monitoring of vital physiological parameters and environmental context"
   Prof. Roman Trobec
   Saving Trgovina in Storitve d. o. o.

VISITOR FROM ABROAD

1. Prof. Igor Djurović, University of Montenegro, Podgorica, Montenegro, 25. 5-4. 6. 2015
2. Prof. Nikola Zarić, University of Montenegro, Podgorica, Montenegro, 12. 6.-19. 7. 2015
3. Prof. Nedjeljko Lekic, University of Montenegro , Podgorica, Montenegro, 15.- 22. 11. 2015

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Researchers
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2. Dr. Andrej Hrovat
3. Asst. Prof. Tomaž Javornik
4. Prof. Gorazd Kandus
5. Prof. Monika Kapus Kolar
6. Asst. Prof. Andrej Lipej*
7. **Prof. Mihael Mohorčič, Head**
8. Asst. Prof. Roman Novak
9. Dr. Igor Ozimek
10. Dr. Marjan Šterk
11. Prof. Aleš Švigelj
12. Prof. Roman Trobec

Postdoctoral associates
13. Dr. Matjaž Depolli
14. Dr. Carolina Fortuna
15. Dr. Gregor Kosec
16. Dr. Aleksandra Rashkovska
17. Dr. Andrej Vilhar

Postgraduates
18. Kemal Alič, M. Sc.
19. Klemen Bregar, B. Sc.
20. *Jernej Hribar, B. Sc., left 01.09.15*
21. Urban Kuhar, B. Sc.
22. Tomaž Šolc, B. Sc.
23. Matevž Vučnik, B. Sc.

Technical and administrative staff
24. Polona Anžur, B. Sc.
25. Tomaž Krištofelc
26. Vanessa Skvarča, B. Sc.
27. Miha Smolnikar, B. Sc.
28. Polonca Šega, B. Sc.

Note:
* part-time JSI member

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Original Article

1. Lars Ailo Bongo *et al.* (14 authors), "Applications for ultrascale computing", *Supercomput. front. innov.*, vol. 2015, no. 1, pp. 19-48, 2015.
2. Kemal Alič, Erik Pertovt, Aleš Švigelj, "Bearing-opportunistic network coding", *Int. J. Comput. Commun. Control*, vol. 10, no. 2, pp. 154-164, 2015.
3. Davor Davidović, Matjaž Depolli, Tomislav Lipić, Karolj Skala, Roman Trobec, "Energy efficiency of parallel multicore programs", *Scalable Comput., Pract. Exp.*, vol. 16, no. 4, pp. 437-448, 2015.
4. Carolina Fortuna, Mihael Mohorčič, "A framework for dynamic composition of communication services", *ACM transactions on sensor networks*, vol. 11, no. 2, pp. 31-1-31-10, 2015.
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6. Andrej Hrovat, Andrej Vilhar, Matjaž Depolli, Igor Ozimek, Tomaž Javornik, "Radijsko načrtovanje brezžičnih mobilnih omrežij v izrednih razmerah", *Elektrotehniški vestnik*, vol. 82, no. 4, pp. 145-152, 2015.
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10. Juš Kšela, Viktor Avbelj, Jurij-Matija Kališnik, "Multifractality in heartbeat dynamics in patients undergoing beating-heart myocardial revascularization", *Comput. biol. med.*, vol. 60, pp. 66-73, maj 2015.
11. Rok Libnik, Aleš Švigelj, "Adaptive probe-based congestion-aware handover procedure using SIP protocol", *Int. J. Comput. Commun. Control*, vol. 10, no. 4, pp. 678-693, 2015.
12. Andrej Lipej, "Numerical prediction of torque on guide vanes in a reversible pump-turbine: turbine and pump mode operation", *Journal of multidisciplinary engineering science and technology*, vol. 2, iss. 1, pp. 1616-1621, Jun. 2015.
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1. Tomaž Šolc, Carolina Fortuna, Mihael Mohorčič, "Low-cost testbed development and its applications in cognitive radio prototyping", In: *Cognitive radio and networking for heterogeneous wireless networks: recent advances in visions for the future*, (Signals and communication technology), Maria-Gabriella Di Benedetto, ed., Cham [etc.], Springer, 2015, pp. 361-405.

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1. Roman Trobec, Gregor Kosec, *Parallel scientific computing: theory, algorithms, and applications of mesh based and meshless methods*, (SpringerBriefs in computer science), Cham [etc.], Springer, cop. 2015.

Patent Application

1. Mirjan Švagelj, Štefan Fujs, Gregor Kosec, Hrvoje Petković, *Co-cultivation of propionibacterium and yeast*, EP2942397 (A1), World Intellectual Property Organization, 12. 11. 2015.

Mentoring

1. Tomaž Buh, *Efficient implementations of networking devices on multicore hardware platforms:* doctoral dissertation, Ljubljana, 2015 (mentor Roman Trobec).
2. Erik Pertovt, *Dynamic network coding-aware routing in wireless networks:* doctoral dissertation, Ljubljana, 2015 (mentor Mihael Mohorčič; co-mentor Aleš Švigelj).
3. Marko Pesko, *Radio environment map construction using dynamic spatially distributed measurements:* doctoral dissertation, Ljubljana, 2015 (mentor Mihael Mohorčič; co-mentor Tomaž Javornik).
4. Viktor Švigelj, *Občutljivost arterijskega baroreceptorskega refleksa pred in po vstavitvi kovinske opornice v področje sinusa notranje karotidne*

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6. Radivoj Fajt, *Analysis and extensions of wireless network security according to IEEE 802.11i (WPA2):* master's thesis, Ljubljana, 2015 (mentor Denis Trček; co-mentor Roman Novak).
7. Melisa Junuzović, *Network-coding-assisted retransmission scheme for video streaming applications over wireless access networks:* master's thesis, Ljubljana, 2015 (mentor Aleš Švigelj).
8. Rafael Grom, *Meritve izkoristka in določitev optimalnega razmerja odprtja vodilnika in gonilnika cevne turbine HE Vrhovo:* master's thesis, Novo Mesto, 2015 (mentor Andrej Lipej).

COMPUTER SYSTEMS DEPARTMENT E-7

The Computer Systems department is concerned primarily with the development of advanced computing structures and efficient algorithms for massive-data processing, and systems for effective human-computer interaction. Within this broad area, we are concentrating on self-reparable and self-adapting systems, modelling and optimizing of complex, dynamic and nondeterministic systems. Our research results are implemented within applications for production, transport, energy, environmental sustainability, 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:
Asst. Prof. Gregor Papa

Members of the department were actively involved in the research, design and development of various solutions while executing European projects in the Horizon 2020, ECSEL, ARTEMIS, and FP7 programs. As part of these they have designed and developed efficient algorithms for data processing, upgraded the hardware to more effectively execute the algorithms, and designed the interactive interfaces to be highly useful.

In 2015 we successfully finished our collaboration in two European projects in *FP7*. In the project ***QuaLiFY*** - *Quantify Life – Feed Yourself* (http://qualify-fp7.eu) we led the workpackage on the development of the QuaLiFY server platform, through which scientifically validated food- and nutrition-related data and knowledge rules for personalized dietary advice are available. Our contribution to the platform was the development of the Quisper taxonomy and ontology supported by a harmonization web service. In the project ***EuroDISH*** (http://www.eurodish.eu) we designed and implemented an algorithm for the semi-automated matching of food-consumption and food-composition data from various European food databases.

We continued with our actions in the European cathedra of *FP7* ***ERA Chair ISO-FOOD*** – *ERA Chair for isotope techniques in food quality, safety and traceability* (http://isofood.eu), in the field of isotope stability with the aim of ensuring food quality, safety and traceability, where we lead the horizontal area of the knowledge repository. We have developed databases and knowledge bases in the area of foodomics, tools for data handling, and methods for the extraction, management and analysis of data and knowledge. At the international conference IC3K 2015 we presented our innovative approach to solving the problem of data matching, with regards to the ingredients of recipes published on the web and food compositional data.

We made a winning science video to promote our scientific work in a popular manner.

We have started working on the *Horizon 2020* Programme. In the project **RICHFIELDS** – *Research Infrastructure on Consumer Health and Food Intake for Escience with Linked Data Sharing* (http://www.richfields.eu/) we are going to lead a workpackage on the architectural design of the RICHFIELDS platform. Its main aim is to collect research and consumer data as well as business, open and big data on food and health. In another project **REFRESH** – *Resource Efficient Food and dRink for the Entire Supply cHain* (http://eu-refresh.org/) we will contribute as a technical partner, developing a database for the compositional data of waste streams. The goal of the project is to contribute towards the objectives of reducing food waste across Europe by 30 % by 2025, reducing waste-management costs, and maximizing the value from unavoidable food waste and packaging materials.

In the project **EU Menu** – *Support to National Dietary Surveys in Complience with the EU Menu methodology*, which is supported by EFSA (European Food Safety Agency), we are upgrading the Open Platform for Clinical Nutrition (OPEN) for the aims of the national consumption survey. OPEN has been upgraded with a module for data gathering and statistical analysis. The OPEN food-composition database has also been expanded with new data as well as the FoodEx2 data classification. With the support of the Norwegian Financial Mechanism we are able to contribute to the project *Integrated innovative model for achieving a healthy lifestyle, with a focus on nutrition, exercise, prevention and treatment of obesity in children, adolescents and adults and reducing health inequalities (Let's enjoy health* - http://uzivajmovzdravju.si), where we lead a task on the development of mobile

Figure 1: Physiotherapy with a computer game.

apps and tools for tracking dietary habits and the physical activity of obese children and adults. In collaboration with the Faculty of Sport, University of Ljubljana, we are developing an app that will link OPEN with the database SloFit. The app will be wirelessly connected with a non-invasive fitness wristband.

Within the **research voucher** *Analysis of possible upgrades of the A-portal web platform* with the Abak.net company we analysed and estimated the eligibility of using open-data, meta-data structures and graphical interfaces to upgrade the existing portal into the direction of eHealth. Based on the findings it is possible to upgrade the platform and to extend the set of solutions for the mobile cloud.

Within Horizon 2020 we started with work on the project ***PD_manager*** – *mhealth platform for Parkinson's disease management* (http://www.parkinson-manager.eu/), where we have developed a mobile app for tracking the dietary habits of patients with Parkinson's disease. The app is innovative as it relies on food-image recognition. We also develop computer games for the physiotherapy of patients with Parkinson's disease. The game is controlled via the second-generation Kinect sensor, which allows tracking and capturing of the player's movements. The main idea of the game is to encourage the patients to improve their reach and motoric skills with their hands. The developed games allow doctors to monitor the patient's progress and to prescribe exercises of selected difficulty in the schedule.

Developing computer games for the physiotherapy of patients with Parkinson's disease.

Within the European ARTEMIS association we were finalizing our work in the project ***ACCUS*** – *Adaptive Cooperative Control in Urban (sub) Systems – ACCUS* (http://www.projectaccus.eu), where we developed a platform for the integration and coordination of urban systems (transportation, outdoor lighting, energy) to build applications across urban systems, to provide adaptive and cooperative control for urban subsystems, and to optimize the combined performance. We upgraded the traffic-flow simulation framework, based on the OpenDRIVE logical description of a road network. The framework includes the descriptions of a road network and traffic lights and allows the simulation of vehicle flows, according to the IDM (Intelligent driver model). It allows simple and intuitive planning of new and/or changed road segments, since their influence can be easily observed. The upgraded simulator also allows the optimization of traffic lights' switch segments, resulting in more fluid traffic flows.

Figure 2: Bioimpedance sensor developed at the department in collaboration with the Hyb company.

We started on work within the ECSEL JU association with the project ***MANTIS*** – *Cyber Physical System based Proactive Collaborative Maintenance*, where the overall goal is to provide a proactive maintenance service platform architecture based on Cyber Physical Systems that allows us to estimate future performance, to predict and prevent imminent failures and to schedule proactive maintenance in different environments (e.g., industrial machines, vehicles, renewable energy assets). We are leading the workpackage for the design and development of human-machine interfaces that will allow intuitive, adaptive and efficient maintenance processes.

In collaboration with the Hyb company we developed a contact-less bioimpedance measurement principle that can be used for measuring a patient's breathing rate and can serve as the basis for a low-power miniaturized medical device. In the frame of ***BIOMeD*** – *Low power miniaturized contact-less BIOimpedance Measurement Device* project of the *TETRACOM* we developed a working prototype for the evaluation of the developed measurement method.

On-board pilot-monitoring systems are becoming an important issue in flight safety. The **FlySentinel**, Pilot Monitoring System that monitors a pilot's psychophysical condition developed by *MedicoApps* has recently gained much attention. We participated in the development phase by creating user-requirement specifications and selecting some critical components of the system.

In the field of pattern recognition we established a low-energy Bluetooth **connection between a digital stethoscope and a smart phone** that allows the acquiring and transferring of the digital auscultation signal for further processing. Thus we produced a basic communication infrastructure for developing a personal diagnostic application that will be able to detect anomalies within the auscultation signal and alarm the user. To achieve this we developed a heart-murmur recognition method based on the classification of the distribution of a signal power over frequencies with a machine-learning approach with an achieved accuracy up to 87.5 %.

We actively collaborated in the initial and implementation activities at the Institute within *Slovenia's Smart Specialisation Strategy*. In line with our competencies we continued linking with industrial companies as well as with academic partners. Our ideas were also presented at the Slovenian workshop ***Smart cities and communities as a development opportunity for Slovenia*** that we co-organized. We are also actively involved in the domains of Factories of the Future and e/mHealth.

In cooperation with the Department of Intelligent Systems at the Jožef Stefan Institute, the Laboratory for Computer Architecture and Languages, and the Laboratory for Programming Methodologies from the Faculty of

Electrical Engineering and Computer Science, University of Maribor, we organized, for the twelfth consecutive year, the workshops on *Nature-inspired algorithms* about stochastic optimization techniques.

From the 29th of June to the 3rd of July the Gimnazija Bežigrad **high-school summer camp** *Between nature and art* was held. The staff of our department participated as co-organizers and lecturers. Our lectures covered topics on evolutionary computation, game of life, and symmetry. The purpose of the camp was to awaken the young people's interest in science and show them research as a way of thinking. The lecturers described how knowledge of mathematics, computer science, physics, and biology interact and occur at all levels of our society, while the main thread of the camp emphasizes the connection between the natural sciences and art.

We participated in the science-video competition within the project *Science on the street*, where part of our research activities was shown in the winning short, popular video contribution **We preserve health**. We presented an Open platform for clinical nutrition, mobile application, aimed at facilitating the everyday life of different patients, as well as our own developed wireless, pocket-size scale, which makes it easy to measure the intake of individual elements of nutrition in a meal.

Some outstanding publications in the past year

1. P. Gregor, R. Škrekovski, V. Vukašinović, "Rooted level-disjoint partitions of Cartesian products", Appl. math. comput., 266 (2015), 244-258
2. P. Virtič, M. Vražić, G. Papa, "Design of an axial flux permanent magnet synchronous machine using analytical method and evolutionary optimization", IEEE trans. energy convers., (2015), 1-9
3. B. Blažica, J. R. Lewis, "A Slovene translation of the system usability scale : the SUS-SI", Int. j. hum.-comput. interact., 31 (2015), no. 2, str. 112-117, 2015
4. U. Bole, A. Popovič, J. Žabkar, G. Papa, J. Jaklič, "A case analysis of embryonic data mining success", Int. j. inf. manage., 35 (2015) 2, 253-259
5. M. Santo-Zarnik, D. Belavič, F. Novak, "The impact of housing on the characteristics of ceramic pressure sensors - an issue of design for manufacturability", Sensors, 15 (2015) 12, 31453-31463

Organization of Conferences, Congresses and Meetings

1. AVN, The 26th Workshop Nature-Inspired Algorithms, Katarina nad Ljubljano, Slovenia, 19. 5. 2015
2. AVN, The 27th Workshop Nature-Inspired Algorithms, Maribor, Slovenia, 4. 12. 2015

INTERNATIONAL PROJECTS

1. 7FP - QuaLiFY; Quantify Life - Feed Yourself
   Asst. Prof. Barbara Koroušić Seljak
   European Commission
2. 7FP - TETRACOM; Technology Transfer in Computing Systems
   Prof. Franc Novak
   European Commission
3. Adaptive Cooperative Control in Urban (sub) Systems
   Asst. Prof. Gregor Papa
   Ministry of Economics of the Republic of Slovenia
4. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Asst. Prof. Barbara Koroušić Seljak
   European Commission
5. EU MENU Slovenija; LOT 1; Support to National Dietary Survey in Compliance with the EU MENU Methodology - Fourth Support
   Asst. Prof. Barbara Koroušić Seljak
   European Food Safety Authority – Efsa
6. EU MENU Slovenija; LOT 2; Support to National Dietary Survey in Compliance with the EU MENU Methodology - Fourth Support
   Asst. Prof. Barbara Koroušić Seljak
   European Food Safety Authority – Efsa
7. H2020 - MANTIS; Cyber Physical System based Proactive Collaborative Maintenance
   Asst. Prof. Gregor Papa
   European Commission
8. H2020 - REFRESH; Resource Efficient Food and Drink for the Entire Supply Chain
   Asst. Prof. Barbara Koroušić Seljak
   European Commission
9. H2020 - RICHFIELDS; Research Infrastructure on Consumer Health and Food Intake using E-science with Linked Dara Sharing
   Asst. Prof. Barbara Koroušić Seljak
   European Commission
10. H2020 - PD_manager; Mhealth Platform for Parkinson's Disease Management
    Asst. Prof. Barbara Koroušić Seljak
    European Commission

RESEARCH PROGRAM

1. Computer Structures and Systems
   Prof. Stanislav Kovačič

R & D GRANTS AND CONTRACTS

1. Norway Grants „Enjoy in Health"; An Integrated Innovative Model for the Provision of a Healthy Lifestyle, with a Focus on Nutrition, Physical Activity, Obesity Prevention and Treatment in Children, Adolescents and Adults and
   Asst. Prof. Barbara Koroušić Seljak
2. EuroDISH; EuroDISH Determinants-Intake-Status-Health; Study on the Need for Food and Health Research Infrasturcures in Europe
   Asst. Prof. Barbara Koroušić Seljak
3. Adaptive Cooperative Control in Urban (sub) Systems
   Asst. Prof. Gregor Papa
4. Upgrade of the Open Platform for Clinical Nutrition to suit the needs of the Federation of EU member National Associations of Dietitians EFAD
   Asst. Prof. Barbara Koroušić Seljak

NEW CONTRACTS

1. BT connection for Maxximum
   Asst. Prof. Gregor Papa
   BSH Hišni Aparati d. o. o.
2. Analysis of possible upgrades of the A-portal web platform
   Asst. Prof. Gregor Papa
   Abak.net d. o. o.

VISITORS FROM ABROAD

1. Dr. Stephen Webb, Daniela Fichtenbauer, RTD Services, Vienna, Austria, 29. 6.–1. 7. 2015
2. Sabri Abarkan VivSan GmbH, Witten, Germany, 29. 6.–1. 7. 2015
3. Dr. Fré Pepping, Vereniging European Nutrigenomics Organisation, Wageningen, Netherlands, 29. 6.–1. 7. 2015
4. James Lay, Food Angels, UK Limited, Newmarket, United Kingdom, 29. 6.–1. 7. 2015
5. Richard Zuber, 23ème Homme SARL, Aze, France
6. Dr. Ben van Ommen, Nederlandse Organisatie voor toegepast natuurwetenschappelijk onderzoek, Delft, Netherlands, 29. 6.–1. 7. 2015
7. Dr. André Boorsma, Nederlandse Organisatie voor toegepast natuurwetenschappelijk onderzoek, Delft, Netherlands, 29. 6.–1. 7. 2015
8. Julia Nagel, Swiss Analysis AG. Tagerwillen, Switzerland
9. Otto Knes, Swiss Analysis AG. Tagerwillen, Switzerland
10. Hille Meetsma, IP Health Solutions BV, Groningen, Netherlands
11. Ruurd Zwigt, IP Health Solutions BV, Groningen, Netherlands
12. Aggelos Androulidakis, SafeCape Software Solutions Ltd, Athens, Greece
13. Jojanneke Blaak, The Hyve B.V., Utrecht, Netherlands
14. Robert Horlings, The Hyve B.V., Utrecht, Netherlands
15. Harry van Haaften, The Hyve B.V., Utrecht, Netherlands
16. Dr. Thomas Gundersen Vitas AS, Oslo, Norway
17. Jo Goossens, shiftn, Leuven, Belgium
18. Kris Ooms, shiftn, Leuven, Belgium
19. Paul Finglas, Institute of Food Research, Norwich, United Kingdom
20. Dr. Kurt Gedrich, Technische Universität München, Munich
21. Prof. Dr. Gintaras Stauskis, Vilnius Gedimino Technical University, Vilnius, Lithuania, 4. 9. 2015
22. Dr. Richard Wheeler, eseia Graz Office, Graz, Austria, 4. 9. 2015
23. Dr. Jürgen Fabian, Technische Universität Graz, Graz, Austria, 4. 9. 2015
24. Dr. Mario Hirz, Technische Universität Graz, Graz, Austria, 4. 9. 2015
25. Prof. dr. Petr Gregor, Charles University in Prague, Faculty of Mathematics and Physics, Prague, Czech Republic, 4.–9. 11. 2015

STAFF

Researchers

1. Asst. Prof. Anton Biasizzo
2. Prof. Peter Korošec
3. Asst. Prof. Barbara Koroušić Seljak
4. Prof. Stanislav Kovačič*
5. Prof. Franc Novak
6. **Asst. Prof. Gregor Papa, Head**
7. *Dr. Marina Santo Zarnik*, left 01.11.15*
8. Asst. Prof. Jurij Šilc

Postdoctoral associates

9. Dr. Bojan Blažica
10. Dr. Marko Pavlin*
11. Dr. Drago Torkar
12. Dr. Vida Vukašinović

Technical officer

13. Špela Poklukar, B. Sc.

Technical and administrative staff

14. Jolanda Jakofčič

Note:
* part-time JSI member

BIBLIOGRAPHY

Original Article

1. Darko Belavič, Andraž Bradeško, Marina Santo-Zarnik, Tadej Rojac, "Construction of a piezoelectric-based resonance ceramic pressure sensor designed for high-temperature applications", *Metrol. Syst. Pomiarowe*, vol. XXXII, no. 3, pp. 331-340, 2015.
2. Evgen Benedik, Barbara Koroušić-Seljak, Maša Hribar, Irena Rogelj, Borut Bratanič, Rok Orel, Nataša Fidler Mis, "Comparison of a web-based dietary assessment tool with software for the evaluation of dietary records", *Zdravstveno varstvo*, vol. 54, no. 2, pp. 91-97, 2015.
3. Bojan Blažica, James R. Lewis, "A Slovene translation of the system usability scale: the SUS-SI", *Int. j. hum.-comput. interact.*, vol. 31, no. 2, pp. 112-117, 2015.
4. Uroš Bole, Aleš Popovič, Jure Žabkar, Gregor Papa, Jurij Jaklič, "A case analysis of embryonic data mining success", *Int. j. inf. manage.*, vol. 35, iss. 2, pp. 253-259, Apr. 2015.
5. Petr Gregor, Riste Škrekovski, Vida Vukašinović, "Rooted level-disjoint partitions of Cartesian products", *Appl. math. comput.*, vol. 266, pp. 244-258, 2015.
6. Uroš Jovanovič, Aleš Štimec, Daniel Vladušič, Gregor Papa, Jurij Šilc, "Big-data analytics: a critical review and some future directions", *Int. j. bus. intell. data min.*, vol. 10, no. 4, pp. 337-355, 2015.
7. Dominik Jurków, Thomas Maeder, Arkadiusz Dąbrowski, Marina Santo-Zarnik, Darko Belavič, Heike Bartsch, Jens Müller, "Overview on low temperature Co-fired ceramic sensors", *Sens. actuators, A, Phys.*, vol. 233, pp. 125-146, 2015.
8. Matej Kristan, Vildana Sulić Kenk, Stanislav Kovačič, Janez Perš, "Fast image-based obstacle detection from unmanned surface vehicles", *IEEE trans. cybern.*, vol., no., pp. 1-14, 2015.
9. Marina Santo-Zarnik, Darko Belavič, Franc Novak, "The impact of housing on the characteristics of ceramic pressure sensors - an issue of design for manufacturability", *Sensors*, vol. 15, iss. 12, pp. 31453-31463, 2015.
10. Vildana Sulić Kenk, Rok Mandeljc, Stanislav Kovačič, Matej Kristan, Melita Hajdinjak, Janez Perš, "Visual re-identification across large, distributed camera networks", *Image vis. comput.*, vol. 34, pp. 11-26, Feb. 2015.
11. Jurij Šilc, Katerina Taškova, Peter Korošec, "Data mining-assisted parameter-tuning of a search algorithm", *Informatica (Ljublj.)*, vol. 39, no. 2, pp. 169-176, June 2015.
12. Polona Tomašič, Gregor Papa, Martin Žnidaršič, "Using a genetic algorithm to produce slogans", *Informatica (Ljublj.)*, vol. 39, no. 2, pp.125-133, 2015.
13. Peter Virtič, Mario Vražić, Gregor Papa, "Design of an axial flux permanent magnet synchronous machine using analytical method and evolutionary optimization", *IEEE trans. energy convers.*, 1-9 pp., 2015.

Published Conference Contribution

1. Andrej Debenjak, Gregor Papa, Janko Petrovčič, "Modularni sistem za upravljanje Li-Ion baterije", In: *Zbornik devete konference Avtomatizacija v industriji in gospodarstvu, 9. in 10. april 2015, Maribor, Slovenija*, Nenad Muškinja, ed., Milan Rotovnik, ed., Maribor, Društvo avtomatikov Slovenije, 2015, 8 pp.
2. Petra Drevenšek, Vida Vukašinović, Gregor Papa, Peter Korošec, "Suitability of MASA algorithm for traveling thief problem", In: *SOR '15 proceedings*, 13th International Symposium on Operational Research in Slovenia, Bled, Slovenia, September 23-25, 2015, Lidija Zadnik Stirn, ed., et al, Ljubljana, Slovenian Society Informatika, Section for Operational Research, 2015, pp. 93-98.
3. Tome Eftimov, Barbara Koroušić-Seljak, "Ingredients matching in bakery products", In: *Izkopavanje znanja in podatkovna skladišča (SiKDD 2015): zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 5. oktober 2015, [Ljubljana, Slovenia]: zvezek E: proceedings of the 18th International Multiconference Information Society - IS 2015, October 5th, 2015, Ljubljana, Slovenia: volume E*, Dunja Mladenić, ed., Marko Grobelnik, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 13-16.
4. Primož Kocuvan, Drago Torkar, "Classification of the heart auscultation siganls", In: *Proceedings*, HEALTHINF 2015, 8th International Conference on Health Informatics, 12-15 January, 2015, Lisbon, Portugal, Christine Verdier, ed., [S. l.], SCITEPRESS = Science and Technology Publications, 2015, pp. 534-539.
5. Anja Kostevšek, Janez Petek, Jiri Klemeš, Petar Varbanov, Gregor Papa, "Concept of an Ecosystem model to support transformation towards

sustainable energy systems", In: *Digital proceedings*, 10th Conference on Sustainable Development of Energy, Water and Environmental Systems, 10th SDEWES, September 27 - October 2, 2015, Dubrovnik, Croatia, Marko Ban, ed., Zagreb, Faculty of Mechanical Engineering and Naval Architecture, 2015, pp. 0531-1-0531-11.

6. Matej Kristan, Janez Perš, Vildana Sulić Kenk, Stanislav Kovačič, "A graphical model for rapid obstacle image-map estimation from unmanned surface vehicles", In: *Computer vision: ACCV 2014: revised selected papers. Part 2*, (Lecture notes in computer science (Internet), 9004), Daniel Cremers, ed., et al, Cham [etc.], Springer, cop. 2015, pp. 391-406.
7. Mihael Mohorčič, Gregor Papa, "Pobuda PaMetSkup", In: *Delavnica Pametna mesta in skupnosti kot razvojna priložnost Slovenije: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 12. oktober 2015, [Ljubljana, Slovenia]: zvezek H: proceedings of the 18th International Multiconference Information Society - IS 2015, October 12th, 2015, Ljubljana, Slovenia: volume H*, Mihael Mohorčič, ed., Ana Robnik, ed., Dalibor Baškovč, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 5-7.
8. Andraž Omahen, Teo Kukuljan, Vida Vukašinović, Peter Korošec, Gregor Papa, "Upgrade of the movsim for easy traffic network modification", In: *SIMUL 2015*, The Seventh International Conference on Advances in System Simulation, November 15 - 20, 2015, Barcelona, Spain, Phillip Helle, ed., Mario Freire, ed., [Sl. l.], IARIA = International Academy, Resarch, and Indusrty Association, pp. 31-36.
9. Gregor Papa, "Napredne metode za optimizacijo izdelkov in procesov", In: *Povezujemo učinkovite tehnologije, pristope in ljudi: zbornik predavanj*, 17. Dnevi energetikov 2015, Portorož, 21. in 22. april 2015, Barbara Petelin-Visočnik, ed., Stane Merše, ed., Ljubljana, Časnik Finance, 2015, pp. 51-57.
10. Gregor Papa, Peter Korošec, Vida Vukašinović, "Pametno urejanje prometa in prostorsko načrtovanje", In: *Delavnica Pametna mesta in skupnosti kot razvojna priložnost Slovenije: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 12. oktober 2015, [Ljubljana, Slovenia]: zvezek H: proceedings of the 18th International Multiconference Information Society - IS 2015, October 12th, 2015, Ljubljana, Slovenia: volume H*, Mihael Mohorčič, ed., Ana Robnik, ed., Dalibor Baškovč, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 24-26.
11. Milivoj Piletič, Irena Sedej, Barbara Koroušić-Seljak, "Pobuda za oceno klinične uporabnosti mobilne aplikacije Nutri v povezavi z žepno tehnico Libra", In: *SPS delavnica EM-zdravje: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 9. in 12. oktober 2015, [Ljubljana, Slovenia]: zvezek G: proceedings of the 18th International Multiconference Information Society - IS 2015, October 9th and 12h, 2015, Ljubljana, Slovenia: volume G*, 18. Mednarodna multikonferenca Informacijska družba - IS 2015, Ljubljana, 6. oktober 2015, Matjaž Gams, ed., Zvezdan Pirtošek, ed., Roman Trobec, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 90-92.
12. Martin Žnidaršič, Polona Tomašič, Gregor Papa, "Case-based slogan production", In: *Workshop proceedings*, Twenty-Third International Conference on Case-Based Reasoning, ICCBR 2015, 28-30 September 2015, Frankfurt, Germany, Joseph Kendall-Morwick, ed., [S. l., s. n.], 2015, pp. 123-139.

Independent Component Part or a Chapter in a Monograph

1. Andrej Jerman Blažič, Franc Novak, "Challenges of busines simulation games: a new approach of teaching business", In: *E-learning: instructional design, organizational strategy and management*, Boyka Gradinarova, ed., Rijeka, InTech, 2015, pp. 227-259.

Mentoring

1. Marko Pavlin, *Low-power wireless biomedical signal processing:* doctoral dissertation, Ljubljana, 2015 (mentor Franc Novak).
2. Nejc Cvörnjek, *Usage of nature-inspired algorithms for stock price predictions and portfolio optimization:* master's thesis, Maribor, 2015 (mentors Miran Brezočnik, Timotej Jagrič; co-mentor Gregor Papa).
3. Rok Goljat, *Some methods for enhancement and registration of underwater images:* master's thesis, Ljubljana, 2015 (mentor Stanislav Kovačič).

DEPARTMENT OF KNOWLEDGE TECHNOLOGIES E-8

The Department of Knowledge Technologies performs research on advanced information technologies aimed at acquiring, storing and managing knowledge to be used in the development of an 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 and computational linguistics, computational creativity, decision support and knowledge management. In addition to research on knowledge technologies, we are also developing applications in environmental sciences and management, agronomy, medicine, biomedicine and bioinformatics, economics, finance and marketing. The Department is also a recognised centre for linguistic research and digital humanities.

Head:
Prof. Nada Lavrač

In 2015 we were involved in seven national projects, nine EU FP7 and two Horizon 2020 projects, one COST action, two bilateral projects, one European Science Foundation network, one infrastructure project and three industry projects. The department hosted ten young researchers working towards their PhDs.

In the area of intelligent data analysis and data mining we have developed several new methods and used them in a number of application domains. A new method for the relation extraction from texts, successfully used for incremental construction of biological networks, was published in *Current Bioinformatics*. The advantages of a new propositionalization method for relational data mining, named wordification, were investigated and the results published in *Expert Systems with Applications*. A newly developed active learning method for sentiment analysis on data streams, implemented in our web data-mining platform ClowdFlows, was published in *Information Processing & Management*. A study relating ensemble diversity and performance in class noise detection was published in *Neurocomputing*. A method for mining text-enriched heterogeneous information networks was used for the analysis of citation networks. A new multi-view clustering method was developed and used for the identification of gender-specific biomarkers for Alzheimer's disease within the FET Flagship HBP (*Human Brain Project*) project.

Our interface WHIMBOT, which uses The WHIM Machine for interacting with people through the NAO robot, attracted a lot of interest at the demonstration event *Show, tell, imagine: A day to explore computational creativity* in London and at the ICT-2015 conference in Lisbon.

We have developed new methods for the structured output prediction and modelling of dynamic systems, and have applied them to different, practically relevant problems, primarily in the areas of environmental and life sciences. We have further developed methods for learning models of dynamic systems from data and domain background knowledge, in particular methods for learning ensembles of such models and methods for taking into account domain-specific model-selection criteria. These methods were used for modelling the dynamics of aquatic ecosystems and the dynamics of endocytosis, a crucial process in the immune response.

We are coordinating the FP7 FET project MAESTRA (*Learning from Massive, Incompletely Annotated, and Structured Data*), which addresses tasks of analysing data that may be complex in several ways. It focuses on structured output prediction in the context of massive, networked and incompletely labelled data. Within MAESTRA we have developed many new methods for learning decision trees and ensembles for structured output prediction (multi-target classification, regression and (hierarchical) multi-label classification), and used them for searching and labelling images as well as various problems in the area of environmental and life sciences. The newly developed methods can address the tasks of semi-supervised multi-target regression in a batch setting, and multi-target regression and multi-label classification in a streaming setting. We describe the developed methods for mining structured data by using the OntoDM ontology of data mining. As part of OntoDM we have developed OntoDT, a generic ontology of data types, with which we can describe arbitrarily structured and complex data.

We have used methods for predictive clustering to annotate and retrieve medical and general images much more efficiently and reliably than existing approaches, as well as for the analysis of various aspects of the biology of extremophylic fungi, which can act as opportunistic human pathogens. We have also used these methods for the identification of single-output and

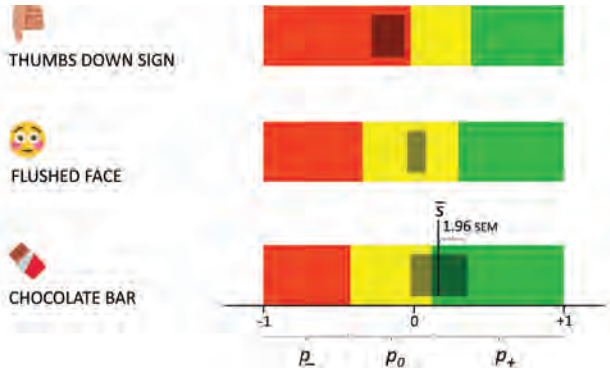

Figure 1: Three emojis and their sentiment.

Figure 2: Our WHIMBOT received a lot of media attention at the computational creativity conference Show, tell, imagine in April 2015 in London.

multi-output dynamic systems. Finally, we are using these methods in the context of the HBP project, where we have applied predictive clustering trees to relate biomarkers and clinical scores and to discover biological signatures of neurodegenerative diseases, such as Alzheimer's and Parkinson's.

We successfully completed the EVADIFF project (*Evaluation et de développement et modèles outils d'aide à la décision utilisés pour la Prevention des pollutions diffuses par les produits phytopharmaceutiques*), commissioned by ARVALIS *Institut du Vegetal*, France. Within the project we developed a decision-support system for the selection of mitigation measures to protect surface waters from pollution by phyto-pharmaceuticals. The system makes use of qualitative evaluation models based on expert knowledge and quantitative predictive models generated by data mining. After integration, customization and user training, the system will be deployed within ARVALIS during 2016.

In the area of text and web mining, and heterogeneous information network analysis we continued work on two existing FP7 projects, SIMPOL (*Financial Systems Simulation and Policy Modelling*) and MULTIPLEX (*Foundational Research on MULTIlevel comPLEX networks and systems*), and started working on a new H2020 FET project DOLFINS (*Distributed Global Financial Systems for Society*). We also concluded an application with the company Gama System in the framework of a "research voucher" project.

The CLARIN.SI infrastructure became a member of the European CLARIN ERIC and was awarded the Data Seal of Approval for its repository of language resources and tools.

The main emphasis of the research in this area is combining text mining, network analysis and sentiment analysis to reveal and highlight underlying properties in different domains. The main sources of data that we analyse are social media (Twitter, Facebook) and online news. Network analysis was applied to re-tweet networks, where we identified influential communities. Sentiment analysis, in particular, was applied to several domains: (i) to compare the sentiment learning of different network communities towards various environmental topics, (ii) to study the emotional dynamics of the Italian Facebook comments on conspiracy theories, (iii) to analyse the effects of Twitter sentiment on Dow Jones stock prices, (iv) to monitor the sentiment about political parties before and after the elections in Bulgaria, and (v) to rank the widely used emojis by sentiment. We also participated in a science festival in Genoa, where we presented infographics on re-tweet networks in the EU Parliament, the evolution of the refugee crisis in Europe as monitored on Twitter, and detection of major events in online news.

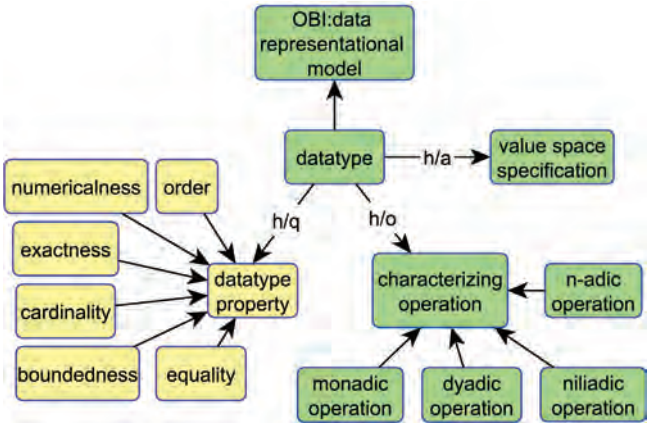

Figure 3: Part of the OntoDT ontology of data types.

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 2015 we published the results of previous applications of these methods in agronomy and the production of electric motors. We analysed the statistical properties of decision models developed with the DEX method, and investigated new approaches for the approximation of utility functions in this method. We developed two decision-support systems: SIGMO (http://decathlon.ijs.si/gmo/) for assessing the presence of genetically modified organisms in food and feed products, and OVJE for the assessment of electricity-production technologies in Slovenia until 2050. A decision model for risk assessment in ski resorts, which was developed using an innovative combination of data mining and expert modelling techniques, is also potentially useful in practice. As usual, special emphasis was put on the development of general-purpose decision-modelling software: in 2015, we developed a novel DEXx library that substantially extends the DEX methodology, and improved the existing DEXi software program and JDEXi library. An important achievement with respect to our collaboration with industry was a six-day seminar called MCDA Training, which was prepared and carried out for the customer Honda Deutschland, Offenbach, Germany.

A six-day seminar MCDA Training, prepared and carried out for Honda Deutschland, presented methods and techniques for decision modelling.

In the area of language technologies and digital humanities we work on producing language resources and methods to annotate text with linguistic information, with a focus on the Slovene language. In 2015 we published the results of our previous research on developing resources of historical Slovene and Slovene on the Web. We continued work on the national research project JANES "Resources, Tools and Methods for Research of Non-standard Internet Slovene", where we had compiled the prototype version of the JANES corpus of user-generated internet Slovene, which contains over 130 million words of tweets, web comments, forums and blogs. We developed a

method for estimating the level of technical and linguistic standardness of texts, and applied it in a comparative analysis of a large corpus of Slovene, Croatian and Serbian tweets. We cooperated with the University of Ljubljana in developing the concept of a new dictionary of Slovene language, and in advocating and enabling open access to language resources.

We 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 2015 the CLARIN.SI consortium grew to twelve partners: four Slovene universities, three research institutes as well as societies and companies dealing with language technologies and resources in Slovenia. In 2015 CLARIN.SI also became a member of the European CLARIN ERIC, while its repository for language resources and tools was awarded the Data Seal of Approval, certifying it as a stable and trusted repository.

We were active in two bilateral projects, one with Croatia and one with Serbia, and collaborated in the work of the Slovene Institute for Standardization as the Slovene representatives in ISO/TC37/SC4 (Terminology and Other Language and Content Resources / Language Resources Management) by reviewing, translating and approving Slovene standards from this field.

In the field of computational creativity we have participated in the demonstration event *Show, tell, imagine: A day to explore computational creativity together* in London, where we presented our automated slogan design tool that is based on semantic resources and genetic algorithms. At this event we also demonstrated our robotic interface WHIMBOT, which builds on our Web interface to *The WHIM Machine* and interacts with people through the NAO robot. WHIMBOT received a lot of interest, so we included it in our presentation at the ICT-2015 conference in Lisbon, where several hundreds of conference participants interacted with it. The FP7 project MUSE (*Machine Understanding for interactive StorytElling*) in the area of computer understanding of natural language was concluded in late 2015; its goal was to convert text into 3D animations. We continued to work on the FP7 project PROSECCO, the aim of which is to promote activities in the field of computational creativity, and continued to work within the framework of the FP7 projects WHIM (*The What-If Machine*) and ConCreTe (*Concept Creation Technologies*). In the scope of WHIM we conducted the first experiments on machine learning of the human evaluation models of fictional ideas; within ConCreTe we studied the processes for the generation of new concepts with concept blending methods. We continued to develop algorithms for the automatic generation of slogans. The idea of an automatic question generation system for papers presented at scientific conferences, which we named RoboCHAIR, was realized in a form of a prototype that was successfully tested in a real-world environment at the *Information Society 2015* conference in Ljubljana. The system operates on the basis of templates and natural language analysis methods, and can be used as an attractive (robotic) replacement for session chairs of scientific seminars, or as a support tool in the verification of the clarity and integrity of scientific texts.

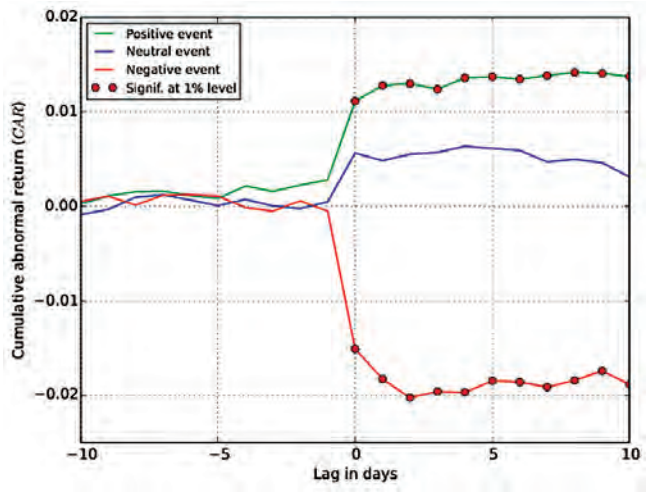

Figure 4: Correlation between the cumulative abnormal returns and Twitter sentiment for Dow Jones stocks (June 2014 - Sep. 2014).

A new method for structured output prediction on data streams, developed within the MAESTRA project, was awarded the best student paper award at the Discovery Science 2015 conference.

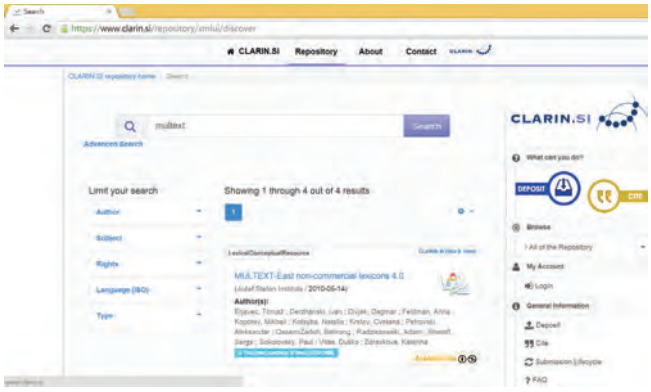

Figure 5: The language-resource repository of the research infrastructure CLARIN.SI.

Some outstanding publications in the last year

1. Aleksovski, D., Kocijan, J., Džeroski, S. Ensembles of fuzzy linear model trees for the identification of multi-output systems. IEEE transactions on fuzzy systems, ISSN 1063-6706. In press, 2015, doi: 10.1109/TFUZZ.2015.2489234.
2. Erjavec, T. The IMP historical Slovene language resources. Language resources and evaluation, 49(3) 753-775, doi: 10.1007/s10579-015-9294-7.
3. Kralj Novak, P., Smailović, J., Sluban, B., Mozetič, I.. Sentiment of emojis, PLoS ONE 10(12): e0144296, doi: 10.1371/journal.pone.0144296, 2015.
4. Kranjc, J., Smajlović, J., Podpečan, V., Grčar, M., Žnidaršič, M., Lavrač, N. Active learning for sentiment analysis on data streams: methodology and workflow implementation in the ClowdFlows platform. Information processing & management, 2015, vol. 51, no. 2, pp. 187-203, doi: 10.1016/j.ipm.2014.04.001.

5. Kuzmanovski, V., Trajanov, A., Leprince, F., Džeroski, S., Debeljak, M. Modeling water outflow from tile-drained agricultural fields. Science of the total environment, ISSN 0048-9697, 2015, vol. 505, pp. 390-401, doi: 10.1016/j.scitotenv.2014.10.009.
6. Miljković, D., Podpečan, V., Stare, T., Mozetič, I., Gruden, K., Lavrač, N. Incremental construction of biological networks by relation extraction from literature. Current bioinformatics, 2015, vol. 10, no. 2, pp. 177-190, doi: 10.2174/1574893610021505181253 21.
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8. Perovšek, M., Vavpetič, A., Kranjc, J., Cestnik, B., Lavrač, N. Wordification: propositionalization by unfolding relational data into bags of words. Expert systems with applications, 2015, vol. 42, no. 17/18, pp. 6442-6456, doi: 10.1016/j.eswa.2015.04.017.
9. Ranco, G., Aleksovski, D., Caldarelli, G., Grčar, M., Mozetič, I.. The effects of Twitter sentiment on stock price returns, PLoS ONE 10(9): e0138441, doi: 10.1371/journal.pone.0138441, 2015.
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11. Sluban, B., Smailović, J., Battiston, S., Mozetič, I. Sentiment leaning of influential communities in social networks, Computational Social Networks 2(9): 1-21, doi: 10.1186/s40649-015-0016-5, 2015.
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Awards and appointments

1. Bojan Cestnik, Marko Bohanec and Tanja Urbančič, best paper award at the 6*th International Conference on Computer Systems and Technologies* 2015, Dublin, Ireland: *QTvity: advancing students' engagement during lectures by using mobile devices*.
2. Gjorgji Madjarov, Vedrana Vidulin, Ivica Dimitrovski and Dragi Kocev, best paper award at the *16th International Conference on Intelligent Data Engineering and Automated Learning* 2015, Wroclaw, Poland: Web genre classification via hierarchical multi-label classification.
3. Aljaž Osojnik, "Carl Smith" award for the best student paper at the *18th International Conference on Discovery Science* 2015, Banff, Canada: *Multi-label Classification via Multi-target Regression on Data Streams*.
4. Dragi Kocev, best paper award at the 16th International Conference on Intelligent Data Engineering and Automated Learning (IDEAL), Wroclaw, Poland
5. Jurica Levatić: Best ICT paper on Jožef Stefan International Postgraduate School Students Conference, Ljubljana

Organization of conferences, congresses and meetings

1. Project meeting of European project PD manager, Ljubljana, Slovenia, 6-7 July 2015
2. Project meeting of European project SIMPOL, Kranjska Gora, Slovenia, 11-13 February 2015
3. The 9th International Ljubljana-Zagreb Workshop on Knowledge Technologies", Fiesa, Slovenia, 20-21 April 2015.

INTERNATIONAL PROJECTS

1. EVADIFF; Evaluation of Existing Models and Development of New Decision-making Tools to prevent Diffuse Pollution caused by Plant Protection Products
   Prof. Marko Debeljak
   Arvalis-institut Du Végétal
2. Training on Multi-Criteria Decision Analysis (MCDA)
   Prof. Marko Bohanec
   Honda R&d Europe (deutschland) Gmbh
3. 7FP - MUSE; Machine Understanding for interactive StoryElling
   Prof. Nada Lavrač
   European Commission
4. 7FP - PROSECCO; Promoting the Scientific Exploration of Computational Creativity
   Prof. Nada Lavrač
   European Commission
5. 7FP - ConCreTe; Concept Creation Technology
   Prof. Nada Lavrač
   European Commission
6. 7FP - WHIM; The What-If Machine
   Prof. Nada Lavrač
   European Commission
7. 7FP - DECATHLON; Development of Cost efficient Advanced DNA-based methods for specific Traceability issues and High Level On-site applicatioNs
   Prof. Marko Bohanec
   European Commission
8. 7FP - SIMPOL; Financial Systems Simulation and Policy Modelling
   Asst. Prof. Igor Mozetič
   European Commission
9. 7FP - MULTIPLEX; Foundational Research on Multilevel Complex Networks and Systems
   Asst. Prof. Igor Mozetič
   European Commission
10. 7FP - HBP; The Human Brain Project
    Prof. Sašo Džeroski
    European Commission
11. 7FP - MAESTRA; Learning from Massive, Incompletely Annotated, and Structured Data
    Prof. Sašo Džeroski
    European Commission
12. H2020 - DOLFINS; Distributed Global FInancial Systems for Society
    Asst. Prof. Igor Mozetič
    European Commission
13. H2020 - PD_manager; Mhealth Platform for Parkinson's Disease Management
    Dr. Dragana Miljković
    European Commission

14. Constructing a Bilingual Lexicon of Closely Related Languages From Existing Language Resources
    Prof. Tomaž Erjavec
    Slovenian Research Agency
15. The construction of corpora and lexica of nonstandard Serbian and Slovenian
    Prof. Tomaž Erjavec
    Slovenian Research Agency

RESEARCH PROGRAM

1. Knowledge Technologies
   Prof. Nada Lavrač

R & D GRANTS AND CONTRACTS

1. Integrative research of sexual dimorphism evolution
   Prof. Sašo Džeroski
2. Slovenian Literature in Unknown Early Modern Manuscripts: Information-Technology Aided Analyses and Scholarly Editions
   Prof. Tomaž Erjavec
3. Resources, Tools and Methods for the Research of Nonstandard Internet Slovene
   Prof. Tomaž Erjavec
4. Development and applications of new semantic data mining methods in life sciences
   Prof. Nada Lavrač
5. Workflows in the cloud
   Dr. Darko Cherepnalkoski
6. Sentiment analysis
   Dr. Matjaž Juršič
7. PARSEME: PARSing and Multi-Word Expressions. Towards Linguistic Precision and Computational Efficiency in Natural Language Processing
   Asst. Prof. Tomaž Erjavec
   COST Office
8. The European Network on Word Structure
   Asst. Prof. Tomaž Erjavec
   ESF - European Science Foundation

NEW CONTRACTS

1. Shallow semantic analyses for selected European languages
   Asst. Prof. Igor Mozetič
   Gama System d. o. o.
2. Development of a Prototype program solution for support of semi-automatic extraction and management of monolingual and multilingual corpora
   Dr. Senja Pollak
   Iolar d. o. o.

VISITORS FROM ABROAD

1. prof. dr. Indre Žliobaite, Department of Information and Computer Science, Aalto University School of Science, Aalto, Finland, 19-20 January 2015
2. Dr. Ivica Dimitrovski, Ss. Cyrill and Methodius, Faculty of Computer Science and Engineering, University of Skopje, Skopje, Macedonia, 11-23 January 2015
3. Dr. Gjorgji Madjarov, Ss. Cyrill and Methodius, Faculty of Computer Science and Engineering, University of Skopje, Skopje, Macedonia, 11-23 January 2015
4. Giorgi Strezovski, Ss. Cyrill and Methodius, Faculty of Computer Science and Engineering, University of Skopje, Skopje, Macedonia, 11-23 January 2015
5. Dario Stojanovski, Ss. Cyrill and Methodius, Faculty of Computer Science and Engineering, University of Skopje, Skopje, Macedonia, 11-23 January 2015
6. Andreas Karpf, UPIP - Centre d'Economie de la Sorbonne, Université Paris, Paris, France, 19-20 January 2015
7. Gabriele Ranco, Institute of advance studies Lucca, Italy, 9 Feb. - 9. May. 2015
8. Jozef Mišutka, Karlova univerza v Pragi, Prague, Czech Republic, 4-8 May 2015
9. dr. Tomislav Šmuc, Institut Ruđer Bošković, Zagreb, Croatia, 12 June 2015
10. Matej Mihelčić, Institut Ruđer Bošković, Zagreb, Croatia, 12 June 2015
11. Fran Supek, Institut Ruđer Bošković, Zagreb, Croatia, 12 June 2015
12. Maria Brbić, Institut Ruđer Bošković, Zagreb, Croatia, 12 June 2015
13. dr. Pedro Martins, University of Coimbra, Coimbra, Portugal, 6-17 July 2015
14. dr. Richard Wheeler, University of Edinburgh, Edinburgh, Scotland, 1-5 September 2015
15. Benoit Real, ARVALIS-Institut du végétal, Paris, France, 8-11 September 2015
16. Jonathan Marks-Perreau, ARVALIS-Institut du végétal, France, 8-11 September 2015
17. Francois Lauernt, ARVALIS-Institut du végétal, Paris, France, 8-11 September 2015
18. dr. Maja Miličević, University of Belgrade, Faculty of Philology, Belgrade, Serbia, 12-26 November 2015

STAFF

Researchers

1. Prof. Marko Bohanec
2. Prof. Bojan Cestnik*
3. Prof. Marko Debeljak
4. Prof. Sašo Džeroski
5. Prof. Tomaž Erjavec
6. **Prof. Nada Lavrač, Head**
7. Prof. Tanja Urbančič*
8. Asst. Prof. Martin Žnidaršič

Postdoctoral associates

9. Dr. Darko Aleksovski
10. Dr. Darko Cherepnalkoski
11. Dr. Miha Grčar
12. *Dr. Matjaž Juršič, left 01.07.15*
13. Dr. Dragi Kocev
14. Dr. Petra Kralj Novak
15. Dr. Nikola Ljubešić
16. Dr. Biljana Mileva Boshkoska*
17. Dr. Dragana Miljković
18. Dr. Panče Panov
19. Dr. Vid Podpečan
20. Dr. Senja Pollak
21. Dr. Borut Sluban
22. Dr. Jasmina Smailović
23. Dr. Aneta Trajanov
24. Asst. Prof. Bernard Ženko

Postgraduates

25. Martin Breskvar, B. Sc.
26. Jan Kralj, B. Sc.
27. Janez Kranjc, B. Sc.
28. Jurica Levatić
29. Aljaž Osojnik
30. Matic Perovšek, B. Sc.
31. Matej Petković, B. Sc.
32. Nikola Simidjievski, B. Sc.
33. *Nejc Trdin, B. Sc., left 16.11.15*
34. Anita Valmarska, B. Sc.
35. Anže Vavpetič, B. Sc.
36. Katja Zupan, B. Sc.

Technical officers

37. Tina Anžič, B. Sc.
38. Asst. Prof. Igor Mozetič

Technical and administrative staff

39. Milica Bauer, B. Sc.
40. Teja Đukić

Note:
* part-time JSI member

BIBLIOGRAPHY

Original Article

1. Darko Aleksovski, Juš Kocijan, Sašo Džeroski, "Model-tree ensembles for noise-tolerant system identification", *Advanced engineering informatics*, vol. 29, no. 1, pp. 1-15, 2015.
2. Michelangelo Ceci, Gianvito Pio, Vladimir Kuzmanovski, Sašo Džeroski, "Semi-supervised multi-view learning for gene network reconstruction", *PloS one*, vol. 10, no. 12, pp. e014403-1-e0144031-27, 2015.
3. Marko Debeljak, Andrej Ficko, Robert Brus, "The use of habitat and dispersal models in protecting European black poplar (Populus nigra L.) from genetic introgression in Slovenia", *Biol. Conserv.*, vol. 184, pp. 310-319, apr. 2015.
4. Ivica Dimitrovski, Dragi Kocev, Ivan Kitanovski, Suzana Loskovska, Sašo Džeroski, "Improved medical image modality classification using a combination of visual and textual features", *Comput. med. imaging graph.*, vol. 39, pp. 14-26, jan. 2015.
5. Young-Ho Eom, Michelangelo Puliga, Jasmina Smailović, Igor Mozetič, Guido Caldarelli, "Twitter-based analysis of the dynamics of collective attention to political parties", *PloS one*, vol. 10, no. 7, pp. e0131184-1-e0131184-17, 2015.
6. Tomaž Erjavec, "The IMP historical Slovene language resources", *Language resources and evaluation*, vol. 49, no. 3, pp. 753-775, 2015.
7. Tomaž Erjavec, Nikola Ljubešić, Nataša Logar, "The slWaC corpus of the Slovene Web", *Informatica (Ljubl.j.)*, vol. 39, no. 1, pp. 35-42, Mar. 2015.
8. Ana Herman, Kristina Gruden, Andrej Blejec, Vid Podpečan, Helena Motaln, Primož Rožman, Matjaž Hren, Klemen Zupančič, Matija Veber, Urška Verbovšek, Tamara Lah Turnšek, Andrej Porčnik, Marjan Koršič, Miomir Knežević, Matjaž Jeras, "Analysis of glioblastoma patients' plasma revealed the presence of microRNAs with a prognostic impact on survival and those of viral origin", *PloS one*, vol. 10, iss. 5, pp. 1-20, 2015.
9. Elena Ikonomovska, João Gama, Sašo Džeroski, "Online tree-based ensembles and option trees for regression on evolving data streams", *Neurocomputing (Amst.)*, vol. 150, part. 150, pp. 458-470, 2015.
10. D. A. Kenwright *et al.* (16 authors), "The discriminatory value of cardiorespiratory interactions in distinguishing awake from anaesthetised states: a randomised observational study", *Anaesthesia*, vol. 70, iss. 12, pp. 1356-1368, 2015.
11. Petra Kralj Novak, Jasmina Smailović, Borut Sluban, Igor Mozetič, "Sentiment of Emojis", *PloS one*, vol. 10, no. 12, pp. e0144296-1-e0144296-22, 2015.
12. Janez Kranjc, Jasmina Smailović, Vid Podpečan, Miha Grčar, Martin Žnidaršič, Nada Lavrač, "Active learning for sentiment analysis on data streams: methodology and workflow implementation in the ClowdFlows platform", *Inf. process. manage.*, vol. 51, no. 2, pp. 187-203, 2015.
13. Vladimir Kuzmanovski, Aneta Trajanov, Florence Leprince, Sašo Džeroski, Marko Debeljak, "Modeling water outflow from tile-drained agricultural fields", *Sci. total environ.*, vol. 505, pp. 390-401, feb. 2015.
14. Jurica Levatić, Dragi Kocev, Marko Debeljak, Sašo Džeroski, "Community structure models are improved by exploiting taxonomic rank with predictive clustering trees", *Ecol. model.*, vol. 306, pp. 294-304, jun. 2015.
15. Jurica Levatić, Dragi Kocev, Sašo Džeroski, "The importance of the label hierarchy in hierarchical multi-label classification", *Journal of intelligent information systems*, vol. 45, iss. 2, pp. 247-271, 2015.
16. Nikola Ljubešić, Kaja Dobrovoljc, Darja Fišer, "*MWELex - MWE Lexica of Croatian, Slovene and Serbian extracted from parsed corpora", *Informatica (Ljubl.j.)*, no. 3, vol. 39, pp. 293-300, 2015.
17. Biljana Mileva-Boshkoska, Marko Bohanec, Pavle Boškoski, Đani Juričić, "Copula-based decision support system for quality ranking in the manufacturing of electronically commutated motors", *J. intell. manuf.*, vol. 26, no. 2, pp. 281-293, 2015.
18. Dragana Miljković, Vid Podpečan, Tjaša Stare, Igor Mozetič, Kristina Gruden, Nada Lavrač, "Incremental construction of biological networks by relation extraction from literature", *Current bioinformatics*, vol. 10, no. 2, pp. 177-190, 2015.
19. Monika Novak, Polona Zalar, Bernard Ženko, Hans-Josef Schroers, Sašo Džeroski, Nina Gunde-Cimerman, "Candida and Fusarium species known as opportunistic human pathogens from customer-accessible parts of residential washing machines", *Fungal biology*, vol. 119, iss. 2/3, pp. 95-113, 2015.
20. Matic Perovšek, Anže Vavpetič, Janez Kranjc, Bojan Cestnik, Nada Lavrač, "Wordification: propositionalization by unfolding relational data into bags of words", *Expert syst. appl.*, vol. 42, no. 17/18, pp. 6442-6456, 2015.
21. Gabriele Ranco, Darko Aleksovski, Guido Caldarelli, Miha Grčar, Igor Mozetič, "The effects of twitter sentiment on stock price returns", *PloS one*, vol. 10, no. 9, pp. e0138441-1-e0138441-21, 2015.
22. Aleksandra Rashkovska, Dragi Kocev, Roman Trobec, "Non-invasive real-time prediction of inner knee temperatures during therapeutic cooling", *Comput. methods programs biomed.*, vol. 122, no. 3, pp. 136-148, 2015.
23. Nikola Simidjievski, Ljupčo Todorovski, Sašo Džeroski, "Learning ensembles of population dynamics models and their application to modelling aquatic ecosystems", In: Selected papers presented at the 19th ISEM Conference, 28-31 October 2013, Toulouse, France, *Ecol. Model.*, vol. 306, pp. 305-317, 2015.
24. Nikola Simidjievski, Ljupčo Todorovski, Sašo Džeroski, "Predicting long-term population dynamics with bagging and boosting of process-based models", *Expert syst. appl.*, vol. 42, no. 22, pp. 8484-8496, 2015.
25. Borut Sluban, Nada Lavrač, "Relating ensemble diversity and performance: a study in class noise detection", *Neurocomputing (Amst.)*, vol. 160, pp. 120-131, jul. 2015.
26. Borut Sluban, Jasmina Smailović, Stefano Battiston, Igor Mozetič, "Sentiment leaning of influential communities in social networks", *Comput. soc. networks*, vol. 2, pp. 9-1-9-21, jul. 2015.
27. Jovan Tanevski, Ljupčo Todorovski, Yannis Kalaidzidis, Sašo Džeroski, "Domain-specific model selection for structural identification of the Rab5-Rab7 dynamics in endocytosis", *BMC systems biology*, vol. 9, pp. 31-1-31-17, 2015.
28. Polona Tomašič, Gregor Papa, Martin Žnidaršič, "Using a genetic algorithm to produce slogans", *Informatica (Ljubl.j.)*, vol. 39, no. 2, pp.125-133, 2015.
29. Aneta Trajanov, Vladimir Kuzmanovski, Florence Leprince, Benot Réal, Alain Dutertre, Julie Maillet-Mezeray, Sašo Džeroski, Marko Debeljak, "Estimating drainage periods for agricultural fields from measured data: data-mining methodology and a case study (La JailliÈRe, France", *Irrig. drain.*, vol. 64, no. 5, pp. 703-516, 2015.
30. David Tuckett *et al.* (13 authors), "Uncertainty, decision science, and policy making: a manifesto for a research agenda", *Crit. rev. (N.Y. N.Y.)*, vol. 27, no. 2, pp. 213-242, 2015.
31. Fabiana Zollo, Petra Kralj Novak, Michela Del Vicario, Alessandro Bessi, Igor Mozetič, Antonio Scala, Guido Caldarelli, Walter Quattrociocchi, "Emotional dynamics in the age of misinformation", *PloS one*, vol. 10, no. 9, pp. e0138740-1-e0138740-22, 2015.

Published Conference Contribution (invited lecture)

1. Nada Lavrač, Anže Vavpetič, "Relational and semantic data mining", In: *Logic programming and nonmonotonic reasoning: 13th International Conference, LPNMR 2015, Lexington, Ky, USA, September 27-30, 2015*, (Lecture notes in computer science, Lecture notes in artificial intelligence, LNAI 9345), Cham [etc.], Springer, 2015, lNAI 9345, pp. 20-31, 2015.

Published Conference Contribution

1. Marko Bohanec, "Decision support systems for Parkinson's disease: state of the art and the "PD_manager" approach", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 9-12.
2. Marko Bohanec, Boris Delibašić, "Data-mining and expert models for predicting injury risk in ski resort", In: *Decision support system V - big data analitics for decision making: First International Conference, ICDSST 2015, Belgrade, Serbia, May 27-29, 2015: proceedings*, (Lecture notes in busines information processing, vol. 216), Boris Delibašić, ed., Cham [et al.], Springer, 2015, pp. 46-60.

3. Marko Bohanec, Nejc Trdin, Branko Kontić, "A qualitative multi - criteria model for the evaluation of electric energy production technologies in Slovenia", In: *SOR '15 proceedings*, 13th International Symposium on Operational Research in Slovenia, Bled, Slovenia, September 23-25, 2015, Lidija Zadnik Stirn, ed., et al, Ljubljana, Slovenian Society Informatika, Section for Operational Research, 2015, pp. 11-16.
4. Martin Breskvar, Bernard Ženko, Sašo Džeroski, "Relating biological and clinical features of Alzheimer's patients with predictive clustering trees", In: *Izkopavanje znanja in podatkovna skladišča (SiKDD 2015): zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 5. oktober 2015, [Ljubljana, Slovenia]: zvezek E: proceedings of the 18th International Multiconference Information Society - IS 2015, October 5th, 2015, Ljubljana, Slovenia: volume E*, Dunja Mladenić, ed., Marko Grobelnik, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 9-12.
5. Bojan Cestnik, Marko Bohanec, Tanja Urbančič, "QTvity: advancing students' engagement during lectures by using mobile devices", In: *CompSysTech'15: proceedings of the 16th International Conference on Computer Systems and Technologies, June 25 - 26, 2015, Dublin, Ireland*, Boris Rachev, ed., New York, ACM, 2015, pp. 334-341.
6. Darko Čerepnalkoski, Igor Mozetič, "A retweet network analysis of the European parliament", In: *SITIS 2015*, The 11th International Workshop on Signal-Image Technology & Internet-Based Systems, November 23-27, 2015, Bangkok, Thailand, Danvers, IEEE = Institute of Electrical and Electronics Engineers, pp. 350-357.
7. Jaka Čibej, Nikola Ljubešić, ""S kje pa si?": metapodatki o regionalni pripadnosti uporabnikov družbenega omrežja Twitter", In: *Zbornik konference Slovenščina na spletu in v novih medijih, Ljubljana, 25.-27. november 2015*, Darja Fišer, ed., 1. izd., Ljubljana, Znanstvena založba Filozofske fakultete, 2015, pp. 10-14.
8. Vanja Čok, Roman Žavbi, Jože Duhovnik, Martin Žnidaršič, Bernard Ženko, Nada Lavrač, "Informacijska platforma za razvoj pohištva za preventivno in rehabilitacijsko vadbo na domu", In: *SPS delavnica EM-zdravje: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 9. in 12. oktober 2015, [Ljubljana, Slovenia]: zvezek G: proceedings of the 18th International Multiconference Information Society - IS 2015, October 9th and 12h, 2015, Ljubljana, Slovenia: volume G*, 18. Mednarodna multikonferenca Informacijska družba - IS 2015, Ljubljana, 6. oktober 2015, Matjaž Gams, ed., Zvezdan Pirtošek, ed., Roman Trobec, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 22-24.
9. Tomaž Erjavec, Darja Fišer, Nikola Ljubešić, "Razvoj korpusa slovenskih spletnih uporabniških vsebin Janes", In: *Zbornik konference Slovenščina na spletu in v novih medijih, Ljubljana, 25.-27. november 2015*, Darja Fišer, ed., 1. izd., Ljubljana, Znanstvena založba Filozofske fakultete, 2015, pp. 20-26.
10. Dragan Gamberger, Bernard Ženko, Alexis Mitelpunkt, Nada Lavrač, "Identification of gender specific biomarkers for Alzheimer's disease", In: *Brain informatics and heath: 8th International Conference, BIH 2015, London, UK, August 30 - September 2, 2015: proceedings*, (Lecture notes ina artificial intelligence, LNAI 9250), Cham [et al.], Springer, 2015, lNAI 9250, pp. 57-66, 2015.
11. Dragan Gamberger, Bernard Ženko, Alexis Mitelpunkt, Nada Lavrač, "Multilayer clustering: biomarker driven segmentation of Alzheimers disease patient population", In: *Bioinformatics and biomedical engineering: proceedings, part I*, (Lecture notes in computer science, Lecture notes in bioinformatics, 9043), Third International Conference, IWBBIO 2015, [International Work-Conference on Bioinformatics and Biomedical Engineering], April 15-17, 2015, Granada, Spai, Francisco Ortuño, ed., Ignacio Rojas Ruiz, ed., Cham [etc.], Springer, 2015, pp. 134-145.
12. Donatella Gubiani, Ingrid Petrič, Elsa Fabbretti, Tanja Urbančič, "Mining scientific literature about ageing to support better understanding and treatment of degenerative diseases", In: *Izkopavanje znanja in podatkovna skladišča (SiKDD 2015): zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 5. oktober 2015, [Ljubljana, Slovenia]: zvezek E: proceedings of the 18th International Multiconference Information Society - IS 2015, October 5th, 2015, Ljubljana, Slovenia: volume E*, Dunja Mladenić, ed., Marko Grobelnik, ed., Ljubljana, Institut Jožef Stefan, 2015, 4 pp..
13. Eloy Hontoria, Darko Aleksovski, "Practical logistic applications of small scale traveling salesman problem for small and medium enterprises", In: *SOR '15 proceedings*, 13th International Symposium on Operational Research in Slovenia, Bled, Slovenia, September 23-25, 2015, Lidija Zadnik Stirn, ed., et al, Ljubljana, Slovenian Society Informatika, Section for Operational Research, 2015, pp. 439-445.
14. Dragi Kocev, Michelangelo Ceci, "Ensembles of extremely randomized trees for multi-target regression", In: *Discovery science: 18th International Conference, DS 2015 Banff, AB, Canada, October 4-6, 2015: proceedings*, (Lecture notes in computer science, Lecture notes in artificial intelligence, LNCS 9356), Nathalie Japkowicz, ed., Stan Matwin, ed., Cham [etc.], Springer, 2015, lNCS 9356, pp. 86-100, 2015.
15. Jan Kralj, Panče Panov, Sašo Džeroski, "Expanding the OntoDM ontology with network analysis tasks and algorithms", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 63-67.
16. Jan Kralj, Marko Robnik Šikonja, Nada Lavrač, "Heterogeneous networks decomposition and weighting with text mining heuristics", In: *ECML PKDD 2015 : proceedings of the 4th Workshop on New Frontiers in Mining Complex Paterns, (NFMCP 2015), September 07-11, 2015, Porto, Portugal*, Michelangelo Ceci, ur., [S. l., s. n.], 2015, 12 pp.
17. Jan Kralj, Anita Valmarska, Marko Robnik Šikonja, Nada Lavrač, "Mining text enriched heterogeneous citation networks", In: *Advances in knowledge discovery and data mining: 19th Pacific Asia Conference, PAKDD 2015, Ho Chi Minh City, Vietnam, May 19 - 22, 2015. part 2: proceedindgs*, (Lecture notes in computer science, Lecture notes in artificial intelligence, 9078), Tru Cao, ed., Cham, Springer, 2015, pp. 672-683.
18. Jurica Levatić, Michelangelo Ceci, Dragi Kocev, Sašo Džeroski, "Semi-supervised learning for multi-target regression", In: *New frontiers in mining complex patterns: third international workshop, NFMCP 2014, held in concunction with ECML-PKDD 2014, Nancy, France: selected papers*, (Lecture notes in computer science, Lecture notes in artificial intelligence, vol. 8983), Annalisa Appice, ed., Cham [etc.], Springer, 2015, pp. 3-18.
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Mentoring

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2. Miha Grčar, *Mining text-enriched heterogeneous information networks:* doctoral dissertation, Ljubljana, 2015 (mentor Nada Lavrač).
3. Tina Jaklič, *Incorporation of integrative emergy approach into agricultural production planning:* doctoral dissertation, Ljubljana, 2015 (mentor Luka Juvančič; co-mentor Marko Debeljak).
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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, and language and speech technologies. The department collaborates closely with the Faculty of Computer and Information Science at the University of Ljubljana on the joint research program "Artificial Intelligence and Intelligent Systems", led by Prof. Dr. Ivan Bratko. The department also collaborates closely with industry and contributes significantly to the introduction of intelligent systems into 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 computers to imitate human behaviour, while they also exploit raw, exponentially growing computer power. This field is rapidly developing worldwide.

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 topic of ambient intelligence tackled by the department in 2015 was e-health. As a result of our extensive earlier work on e-health, we are now attempting to translate some solutions for the elderly into practice through the H2020 project **InLife**. We prepared a smart-watch application that detects falls and similar events. To reduce the number of false alarms, the application takes into account the context of each potential fall, for example, it ignores events after which the user continues to move normally. We also studied user requirements and the best ways for the elderly to interact with technology, as well as developing an application to support their carers. Project solutions will be piloted in cooperation with the Slovenian company Doktor 24 and international partners. In the AAL project **Fit4Work**, whose goal is to help older workers do their job more easily, we worked on a method to recognize stress from the measurements of physiological sensors in a wristband. To this end, we performed extensive real-life measurements and an induced-stress experiment. In both cases intelligent stress detection was successful, but the problem proved very difficult. In the same project we also developed a method that uses ontology and sensors at the workplace to recommend actions such as changing the temperature or ventilation. In the FP7 project **COMMODITY12**, which telemonitors diabetic patients, we continued analysing the patients' lifestyle with a smartphone and a wearable ECG monitor. We improved a method that first automatically recognizes which of these devices a patient carries, then it normalizes the orientation of the phone and detects in which pocket it is carried, and finally invokes the appropriate models to recognize the patient's activity and estimates his/her energy expenditure. The method was presented at the Slovenian Innovation Forum. In addition, we analysed data from real-life patient trials. We used the trial data to develop a method that can detect too low or too high levels of blood sugar using the ECG monitor. The method for a human energy expenditure estimation from the COMMODITY12 project was adapted for the **e-Gibalec** mobile application, which monitors the physical activity of children and reports it to their parents and physical-education teachers. It also uses gamification and elements of social networks to encourage the users to be more active. Finally, we started analysing tennis using sensors in a postdoctoral research project.

In the FP7 project COMMODITY12 we developed a method to analyse human movement with a smartphone, which was accepted by the Slovenian Innovation Forum and included in a mobile application that encourages children to be physically active.

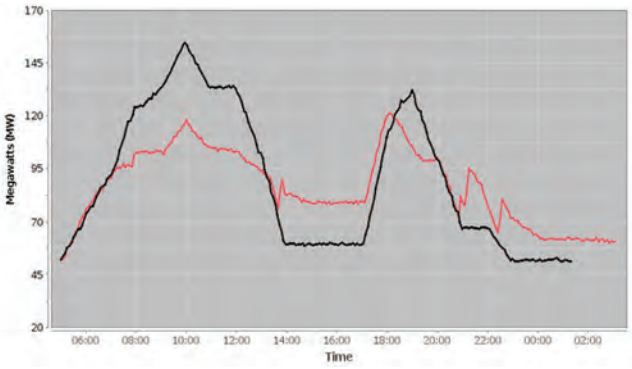

Figure 1: In the European project ACCUS we developed a platform for monitoring and controlling several key city subsystems. This figure shows energy-consumption smoothing by applying negotiations and finding the Nash equilibrium.

Computational intelligence is a study of stochastic search, optimization and learning methods, inspired by physical and biological systems. Research in this area at the Department of Intelligent Systems focuses on evolutionary computation methods. We study extensions of evolutionary algorithms for multi-objective optimization and their speedup, and apply these algorithms

The COPCAMS project results in an embedded computer system for manufacturing quality control based on computer vision, machine learning and optimization.

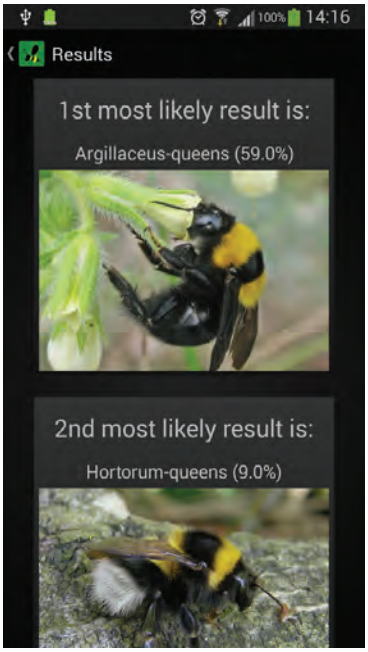

Figure 2: Mobile application for bumblebee classification, which finds the most likely bumblebee species and type based on the bumblebee's sound.

in engineering design and optimization problems. In a doctoral research project we studied the use of surrogate models in multi-objective optimization. The objective functions were approximated with Gaussian process models that, in addition to predicting the function values, estimate the confidence intervals of the predictions, while the Pareto dominance relations were generalized to take into account the confidence intervals. These extensions were incorporated into an optimization algorithm called GP-DEMO. Numerical experiments on benchmark functions and real optimization problems from metallurgical production and medical signal analysis confirmed that the new approach results in fewer incorrect comparisons of solutions and requires less-exact solution evaluations in the optimization process. The key area of testing and transferring our methods to practice is production-process optimization. We continued our work within the **COPCAMS** project, approved for funding under the Artemis call. Together with the Slovenian industrial partner Kolektor Group and international partners we are developing production quality-control procedures that are based on computer vision, machine learning and optimization. In the past year, our activities were concentrated on the optimization of computer-vision procedures to achieve the highest possible accuracy in predicting the product quality, and their implementation on the target embedded architecture to be deployed on the production line. For the Restoration Center in Ljubljana, which is part of the Institute for the Protection of Cultural Heritage of Slovenia, we previously developed the **Pedius** program for the computer-aided reassembly of wall-painting fragments, and a mobile and web application **e-Pedius** to support crowdsourcing in fragment reassembly. Equipped with these tools, the users managed to reconstruct the Roman frescoes based on thousands of fragments from an archaeological site in the region of Celje, Slovenia, last year.

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 and smart homes, and intelligent systems for improving existing educational processes and the preservation of cultural heritage. The European project **ACCUS** is aimed at developing an integration and coordination platform for urban systems to build applications across various domains, providing adaptive and cooperative control for urban subsystems, and optimizing the combined performance of the city. The platform currently balances the overall electricity consumption in the city by curbing the electricity spikes that occur during the day. In addition, the system optimizes the electricity consumption in smart houses and the production in thermal power plants, and manages the traffic flow and thus affects the external parameters, such as air quality. The smart city control continuously monitors the conditions in the city and, for example, when a warning about high air pollution is triggered, it decides to reduce the traffic flow, the energy consumption in residential areas and production in the local thermal power plant. The monitoring system, in several time steps, verifies the effects of the control actions and, if required, sends additional corrections until an adequate level of air quality is achieved. A similar system is studied within the **OPUS** project, where the focus is on the development of smart-home automation services. The aim is to apply advanced machine-learning and optimization methods in order to generate real-time control strategies that increase the users' comfort and, at the same time, decrease the operational costs of the smart home. We experimentally demonstrated that it is possible to achieve energy savings without lowering the comfort. Additional improvements were achieved when applying learning algorithms to heat pumps. The controller learns the user's behaviour 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 **Metis** project we developed an intelligent system that improves the existing educational processes and enables the early detection of pupils with learning difficulties in primary and secondary schools. This year we also started the Horizon 2020 Twinning project **eHeritage**. The Twinning partners will provide support to increase the capacity and quality of the research and innovation excellence of the Romanian partner in the area of cultural heritage preservation using intelligent methods and 3D modelling, and employing augmented and virtual reality. Another important challenge addressed in the project is to expand the recognition of the project partners through an increase in the dissemination activities by targeting publications in high-profile journals and conferences.

The ACCUS project aims at developing a coordination platform for smart cities that will enable the control of various city subsystems and provide several services for citizens.

Figure 3: Mobile application for monitoring and encouraging the movement of students for effective sports education

212 virtual assistants were developed and implemented for 212 Slovenian municipalities, providing answers to questions in natural language about municipalities and Slovenian regions.

In the field of **speech and language technologies** we work on speech synthesis, semantic analyses of text and question answering. Special attention is paid to the requirements of the elderly, handicapped and visually

impaired people, and to apply our solutions to smart devices and homes. Together with the Amebis company, we developed a new speech synthesizer for Slovene. Both the comprehensibility and naturality of the synthesized speech have been greatly improved. We also developed a free service for speech synthesis on mobile devices. For the purposes of the institute we adapted the virtual assistant, Robi, which enables employees and visitors to quickly and easily find information about the institute, and also provides a rich set of additional applications offering various functionalities (employee phone book, infrastructure malfunction reporting, etc.). We also developed virtual assistants for all 212 Slovene municipalities with a basic knowledge base that was constructed using artificial intelligence methods.

The focus points of the research and developmental potential of the department are also being expressed in successfully developed, integrated and deployed solutions, available on major digital platforms and available to a wide population of users. The methods used in typical applied projects combine the procedures of intelligent agents, statistical methods and machine learning, and serve as a basis for user interfaces on smart phones, tablets or desktop computers. The projects' services are developed for all key mobile platforms (Android, iOS and Windows) and through classic web clients.

A system for recognizing animal species from their sounds has been implemented as an open mobile and web application (http://animal-sounds.ijs.si/). It recognises Slovenian frogs, birds, bumblebees and Chinese cuckoos.

From 28 September to 14 October 2015, the **18th International Multiconference Information Society – IS 2015** (is.ijs.si) took place at the Jožef Stefan Institute and the Faculty of Computer and Information Science. It consisted of twelve independent conferences with around 600 participants that presented approximately 300 papers. Four conference awards were presented: for lifetime achievements ("Donald Michie and Alan Turing" award) to Prof. Jurij Tasič, for current achievements in the field of information society to Asst. Prof. Domen Mongus, and the information strawberry and lemon for the best and worst public information-society services.

Figure 4: In 2015, the Department of Intelligent Systems took over the coordination of the Horizon 2020 project HeartMan, which will develop an intelligent application for helping patients with congestive heart failure.

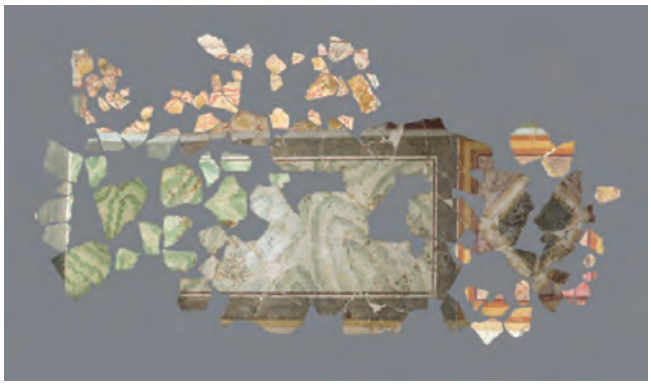

Figure 5: Using software tools Pedius and e-Pedius developed at the Department of Intelligent Systems, the Restoration Center in Ljubljana managed to reconstruct Roman frescoes from an archeological site in the region of Celje, Slovenia.

Some outstanding publications in the past year

1. Gjoreski, H., Kaluža, B., Gams, M., Milić, R., Luštrek, M. Context-based ensemble method for human energy expenditure estimation. Applied Soft Computing, 37 (2015), 960–970
2. Luštrek, M., Gjoreski, H., Gonzáles Vega, N., Kozina, S., Cvetković, B., Mirchevska, V., Gams, M. Fall detection using location sensors and accelerometers. IEEE Pervasive Computing, 14 (2015) 4, 72–79
3. Mlakar, M., Petelin, D., Tušar, T., Filipič, B. GP-DEMO: Differential evolution for multiobjective optimization based on Gaussian process models. European Journal of Operational Research, 243 (2015) 2, 347–361
4. Tušar, T., Filipič, B. Visualization of Pareto front approximations in evolutionary multiobjective optimization: A critical review and the prosection method. IEEE Transactions on Evolutionary Computation, 19 (2015) 2, 225–245

Organization of Conferences, Congresses and Meetings

1. Workshop on High Performance Predictable Embedded Systems for Cognitive Applications, HiPPES4CogApp, 10th International Conference on High Performance and Embedded Architectures and Compilers, HiPEAC 2015, Amsterdam, The Netherlands, 20. 1. 2015
2. 26th Slovene Workshop on Nature-Inspired Algorithms, AVN, Katarina nad Ljubljano, 19. 5. 2015
3. Student Workshop at the Genetic and Evolutionary Computation Conference, GECCO 2015, Madrid, Spain, 11. 7. 2015
4. 1st International KEYSTONE Conference, IKC 2015, Coimbra, Portugal, 8.–9. 9. 2015
5. Special section on Metaheuristic Optimization, 13th International Symposium on Operations Research in Slovenia, SOR 2015, Bled, 24. 9. 2015
6. 18th International Multiconference Information Society, IS 2015, Ljubljana, 28. 9.–14. 10. 2015; independent conferences:

- Intelligent Systems
- Facing Demographic Challenges
- Collaboration, Software and Services in Information Society
- Cognitive Sciences
- Data Mining and Data Warehouses
- Education in Information Society
- 2nd Student Conference for Ph.D. Students
- 2nd Student Conference for Undergraduate Students
- Cognitonics
- 8th International Conference on Informatics in Schools: Situation, Evolution, and Perspective
- SPS EM-Health Workshop
- Workshop Smart Cities and Communities as a Development Opportunity for Slovenia
- 27th Slovene Workshop on Nature-Inspired Algorithms, AVN, Maribor, 4. 12. 2015

Awards and Appointments

1. Božidara Cvetković, Vito Janko, Mitja Luštrek: Recognition for API for Motion Analysis, Slovenian Innovation Forum 2015, Šempeter pri Novi Gorici, 17.–18. 11. 2015
2. Hristijan Gjoreski, Rok Piltaver, Matjaž Gams: Best Paper Award for "Person identification by analyzing door accelerations in time and frequency domain", 12th European Conference on Ambient Intelligence, AmI 2015, Athens, Greece, 11.–13. 11. 2015
3. Anton Gradišek, Fulbright scholarship for work in USA, 27. 10. 2014–24. 6. 2015
4. Mario Konecki, Alen Lovrenčić, Matjaž Gams: Using customized reports in introductory programming courses, 3rd International Academic Conference on Development in Science and Technology, IACDST 2015, Paris, France, 11. 10. 2015

Patent granted

1. Matjaž Gams, Rok Piltaver, Hristijan Gjoreski, Method for Identification of Persons Entering a Room, SI24485 (A), Slovenian Intellectual Property Office, 31. 03. 2015.

INTERNATIONAL PROJECTS

1. 7FP - Xperience; Robots Bootstrapped through Learning from Experience
   Prof. Matjaž Gams
   European Commission
2. 7FP - Commodity12; Continuous Multi-parametric and Multi-layered Analysis of Diabetes Type 1&2
   Dr. Mitja Luštrek
   European Commission
3. Adaptive Cooperative Control in Urban (sub) Systems
   Prof. Matjaž Gams
   Ministry of Economic of the Republic of Slovenia
4. COgnitive & Perceptive CAMeraS: COPCAMS
   Prof. Bogdan Filipič
   Ministry of Economic of the Republic of Slovenia
5. CIP Programme; EcoDots
   Dr. Mitja Luštrek
   European Commission
6. H2020 - IN LIFE; INdependent Living support Functions for the Elderly
   Prof. Matjaž Gams
   European Commission
7. H2020 - eHERITAGE; Expanding the Research and Innovation Capacity in Cultural Heritage Virtual Reality Applications
   Prof. Matjaž Gams
   European Commission

RESEARCH PROGRAM

1. Artificial Intelligence and Intelligent Systems
   Prof. Matjaž Gams

R & D GRANTS AND CONTRACTS

1. Research on adaptive predictive domain models
   Dr. Boštjan Kaluža
2. DysLex: Universal voice e-reader for the Slovenian language as a personal learning tool for people with dyslexia and different types of visual disturbances
   Dr. Tomaž Šef
3. Metis: E-service for the early detection of learning issues
   Dr. Erik Dovgan
4. e-Xercise: Mobile application to monitor and promote exercise in schoolchildren for more effective physical education
   Dr. Mitja Luštrek
5. ASPO
   Prof. Matjaž Gams
   Slovene Human Resources and Scholarship Fund, Ljubljana
6. Adaptive Cooperative Control in Urban (sub) Systems
   Prof. Matjaž Gams
   Ministry of Economic of the Republic of Slovenia
7. COgnitive & Perceptive CAMeraS: COPCAMS
   Prof. Bogdan Filipič
   Ministry of Economic of the Republic of Slovenia
8. Optimizing the Management of Energy Efficient Smart Buildings
   Dr. Tomaž Šef
   Ministry of Education, Science and Sport of the Republic of Slovenia
9. Self-management of physical and mental fitness of older workers
   Dr. Mitja Luštrek
   Ministry of Education, Science and Sport of the Republic of Slovenia

NEW CONTRACTS

1. The development of text-to-speech system for Slovenian language
   Dr. Tomaž Šef
   Alpineon d. o. o.

VISITORS FROM ABROAD

1. Julien Thepot, University of Paris Sud XI, Paris, France, 13. 4.–18. 7. 2015
2. Chauraud Quentin, University of Paris Sud XI, Paris, France, 18. 4.–18. 7. 2015
3. Defendini David, University of Paris Sud XI, Paris, France, 18. 4.–18. 7. 2015
4. Lienard Loïciz, University of Paris Sud XI, Paris, France, 18. 4.–18. 7. 2015
5. Ahmed Atia, University of Paris Sud XI, Paris, France, 22. 5.–30. 7. 2015
6. He Hui, College of Communication and Information Engineering, Shanghai University, Shanghai, China, 5. 6.–14. 8. 2015
7. Scholz Stephan, University of Technology, Computer Cybenetics and Systems Theory, Ilmenau, Germany, 24. 8.–31. 12. 2015
8. Mario Konecki, Faculty of Organization and Informatics, Department of Theoretical and Applied Foundations of Information Sciences, Varaždin, Croatia, 28. 9.–14. 10. 2015
9. Mladen Konecki, Faculty of Organization and Informatics, Department of Theoretical and Applied Foundations of Information Sciences, Varaždin, Croatia, 28. 9.–14. 10. 2015

STAFF

Researchers
1. Prof. Ivan Bratko*
2. Asst. Prof. Aleš Dobnikar*
3. Prof. Bogdan Filipič
4. **Prof. Matjaž Gams, Head**
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6. Dr. Domen Marinčič*
7. Dr. Tomaž Šef

Postdoctoral associates
8. Dr. Erik Dovgan
9. Dr. Hristijan Gjoreski
10. Dr. Anton Gradišek
11. Dr. Matej Guid*
12. Dr. Miha Mlakar
13. Dr. Aleksander Pivk*
14. Dr. Tea Tušar
15. *Dr. Vedrana Vidulin, on postdoctoral leave since 11. 03. 14*

Postgraduates
16. Jani Bizjak, B. Sc.
17. Robert Blatnik, M. Sc.
18. Božidara Cvetković, B. Sc.
19. Vito Janko, B. Sc.
20. Tomaž Kompara*, B. Sc.
21. Dr. Jana Krivec*
22. Damjan Kužnar, B. Sc.
23. Martin Pečar, B. Sc.
24. Rok Piltaver*, B. Sc.
25. *Rok Piltaver, B. Sc., left 01.09.15*
26. Aleš Tavčar, B. Sc.
27. Jernej Zupančič, B. Sc.

Technical officers
28. Matej Krebelj, B. Sc.
29. Blaž Mahnič, B. Sc.
30. Gašper Pintarič*, B. Sc.
31. Jure Šorn, B. Sc.

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32. Vesna Koricki Špetič, B. Sc.
33. Mitja Lasič
34. Liljana Lasič
35. Lana Zemljak

Note:
* part-time JSI member

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Original Article

1. D. Conić, Anton Gradišek, Z. Radaković, M. Iordoc, M. Mirković, M. Čebela, K. Batalović, "Influence of Ta and Nb on the hydrogen absorption kinetics in Zr-based alloys", *Int. j. hydrogen energy*, vol. 40, no. 16, pp. 5677-5682, 2015.
2. Božidara Cvetković, Boštjan Kaluža, Matjaž Gams, Mitja Luštrek, "Adapting activity recognition to a person with Multi-Classifier Adaptive Training", *Journal of ambient intelligence and smart environments*, vol. 7, no. 2, pp. 171-185, 2015.
3. Erik Čuk, Matjaž Gams, Rok Piltaver, Franc Strle, Vera Maraspin-Čarman, Jurij F. Tasič, "Intelligent system for diagnosis of erythema migrans", *Appl. artif. intell.*, vol. 29, no. 2, pp. 134-147, 2015.
4. Hristijan Gjoreski, Boštjan Kaluža, Matjaž Gams, Radoje Milić, Mitja Luštrek, "Context-based ensemble method for human energy expenditure estimation", *Applied soft computing*, vol. 37, pp. 960-970, 2015.
5. Hristijan Gjoreski, Simon Kozina, Matjaž Gams, Mitja Luštrek, Juan Antonio Álvarez-García, Jin-Hyuk Hong, Julian Ramos, Anind K. Dey, Maurizio Bocca, Neal Patwari, "Competitive live evaluations of activity-recognition systems", *IEEE pervasive computing*, vol. 14, no. 1, pp. 70-77, 2015.
6. Anton Gradišek, Tomaž Apih, "Hydrogen dynamics in partially quasicrystalline $Zr_{69.5}Cu_{12}Ni_{11}Al_{7.5}$: fast field cycling relaxometry study", *The journal of physical chemistry. C, Nanomaterials and interfaces*, vol. 119, no. 19, 10677-10681, 2015.
7. Igor Korelič, Violeta Mirchevska, Vladislav Rajkovič, Mirjana Kljajić Borštnar, Matjaž Gams, "Multiple-criteria approach to optimisation of multidimensional data models", *Informatica (Vilnius)*, vol. 26, no. 2, pp. 283-312, 2015.
8. Jana Krivec, "Analytical review of mindfulness-based educational programs - a missing linkage between humans and a modern world", *Research in social change*, no. 7, iss. 2, pp. 107-144, May 2015.
9. Mitja Luštrek, Hristijan Gjoreski, Narciso Gonzáles Vega, Simon Kozina, Božidara Cvetković, Violeta Mirchevska, Matjaž Gams, "Fall detection using location sensors and accelerometers", *IEEE pervasive computing*, vol. 14, no. 4, pp. 72-79, 2015.
10. Miha Mlakar, Dejan Petelin, Tea Tušar, Bogdan Filipič, "GP-DEMO: differential evolution for multiobjective optimization based on Gaussian process models", *Eur. J. oper. res.*, vol. 243, no. 2, pp. 347-361, 2015.
11. Rok Piltaver, Božidara Cvetković, Boštjan Kaluža, "Denoising human-motion trajectories captured with ultra-wideband real-time location system", *Informatica (Ljublj.)*, vol. 39, no. 3, pp. 311-322, 2015.
12. Tea Tušar, Bogdan Filipič, "Visualization of Pareto front approximations in evolutionary multiobjective optimization: a critical review and the prosection method", *IEEE trans. evol. comput.*, vol. 19, no. 2, pp. 225 - 245, 2015.
13. Domen Zupančič, Mitja Luštrek, Matjaž Gams, "Multi-agent architecture for control of heating and cooling in a residential space", *Comput. j.*, vol. 58, no. 6, pp. 1314-1329, 2015.
14. Domen Zupančič, Mitja Luštrek, Matjaž Gams, "Trade-off between energy consumption and comfort experience in smart buildings", *Inf. technol. valdyn.*, vol. 44, no. 4, pp. 420-432, 2015.

Short Article

1. Hristijan Gjoreski, "An approach for context-based reasoning in ambient intelligence", *Informatica (Ljublj.)*, vol. 39, no. 1, pp. 99-100, 2015.

Published Conference Contribution

1. Božidara Cvetković, Vito Janko, Mitja Luštrek, "Demo abstract: activity recognition and human energy expenditure estimation with a smartphone", In: *Percom workshops*, IEEE International Conference on Pervasive Computing and Communication Workshops, March 23-27, 2015, St. Louis, Missouri, USA, Danvers, IEEE = Institute of Electrical and Electronics Engineers, pp. 193-195.

2. Božidara Cvetković, Violeta Mirchevska, Vito Janko, Mitja Luštrek, "Recognition of high-level activities with a smartphone", In: *UbiComp'15: proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing, September 7-11, 2015, Osaka, Japan*, New York, ACM, cop. 2015, pp. 1453-1461.
3. Božidara Cvetković, Urška Pangerc, Mitja Luštrek, "Prepoznavanje in napovedovanje hiperglikemij in hipoglikemij na neinvaziven način", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 13-16.
4. Božidara Cvetković, Rok Piltaver, Matjaž Gams, Mitja Luštrek, "Evolution of activity monitoring through various projects", In: *ICT Innovations 2015: web proceedings*, (ICT Innovations Conference Web Proceedings (Skopje)), Suzana Loshkovska, ed., Saso Koceski, ed., Skopje, ICT ACT, cop. 2015, pp. 313-322.
5. Kristina Drusany Starič, Božidara Cvetković, Alenka-Uršula Levičnik, Jože Starič, "One health concept of measuring and monitoring wellbeing", In: *ICT Innovations 2015: web proceedings*, (ICT Innovations Conference Web Proceedings (Skopje)), Suzana Loshkovska, ed., Saso Koceski, ed., Skopje, ICT ACT, cop. 2015, pp. 303-312.
6. Gašper Fele-Žorž, Karolina Počivavšek, Jaka Konda, Ana Marija Peterlin, Alen Ajanovič, Ana Prodan, Saša Rink, Anton Gradišek, Matjaž Gams, Mojca Matičič, "Application for sexually transmitted infection risk assessment", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 24-28.
7. Bogdan Filipič, Miha Mlakar, Tea Tušar, "Multiobjective optimization of process parameters in steel production", In: *SOR '15 proceedings*, 13th International Symposium on Operational Research in Slovenia, Bled, Slovenia, September 23-25, 2015, Lidija Zadnik Stirn, ed., et al, Ljubljana, Slovenian Society Informatika, Section for Operational Research, 2015, pp. 99-104.
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9. Matjaž Gams, "Begunci 2015 - vrh evropske demografske ledene gore", In: *Soočanje z demografskimi izzivi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 5. oktober 2015, [Ljubljana, Slovenia]: zvezek B: proceedings of the 18th International Multiconference Information Society - IS 2015, October 5th, 2015, Ljubljana, Slovenia: volume B*, 18. Mednarodna multikonferenca Informacijska družba - IS 2015, Ljubljana, 6. oktober 2015, Janez Malačič, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 12-14.
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12. Matjaž Gams, Martin Pečar, "Platforma za sodelovanje", In: *SPS delavnica EM-zdravje: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 9. in 12. oktober 2015, [Ljubljana, Slovenia]: zvezek G: proceedings of the 18th International Multiconference Information Society - IS 2015, October 9th and 12h, 2015, Ljubljana, Slovenia: volume G*, 18. Mednarodna multikonferenca Informacijska družba - IS 2015, Ljubljana, 6. oktober 2015, Matjaž Gams, ed., Zvezdan Pirtošek, ed., Roman Trobec, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 44-45.
13. Matjaž Gams, Aleš Tavčar, Jernej Zupančič, "Resnično inteligentna mesta", In: *Delavnica Pametna mesta in skupnosti kot razvojna priložnost Slovenije: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 12. oktober 2015, [Ljubljana, Slovenia]: zvezek H: proceedings of the 18th International Multiconference Information Society - IS 2015, October 12th, 2015, Ljubljana, Slovenia: volume H*, Mihael Mohorčič, ed., Ana Robnik, ed., Dalibor Baškovč, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 90-93.
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15. Matjaž Gams, Lana Zemljak, Vesna Koricki-Spetič, Blaž Mahnič, "Prelisičenja in pravi pomen Turingovega testa", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 29-33.
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19. Martin Gjoreski, Hristijan Gjoreski, Mitja Luštrek, Matjaž Gams, "Recognizing atomic activities with wrist-worn accelerometer using machine learning", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 42-46.
20. Martin Gjoreski, Hristijan Gjoreski, Mitja Luštrek, Matjaž Gams, "Towards unobtrusive stress detection", In: *Zbornik: 2. del: part 2*, 7. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 7th Jožef Stefan International Postgraduate School Students' Conference, 20.-22. 5. 2015, Ljubljana, Andraž Rešetič, ed., et al, Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2015, zv. 1, pp. 104-113.
21. Anton Gradišek, Gašper Slapničar, Jure Šorn, Boštjan Kaluža, Mitja Luštrek, Matjaž Gams, He Hui, Tomi Trilar, Janez Grad, "How to recognize animal species based on sound - a case study on bumblebees, birds, and frogs", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 38-41.
22. Vito Janko, Matej Guid, "Development of a program for playing progressive chess", In: *Advances in computer games: 14th International Conference, ACG 2015, Leiden, the Netherlands, July 1-3, 2015: revised selected papers*, (Lecture notes in computer science (Internet), 9525), Aske Plaat, ed., H. Jaap van den Herik, ed., Walter Kosters, ed., [Cham], Springer, cop. 2015, pp. 122-134.
23. Leon Noe Jovan, Damjan Kužnar, Matjaž Kukar, Matjaž Gams, "Data preparation for municipal virtual assistant", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 47-50.
24. Valentin Koblar, Martin Pečar, Klemen Gantar, Tea Tušar, Bogdan Filipič, "Determining surface roughness of semifinished products using

computer vision and machine learning", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 51-54.
25. Tomaž Kompara, Miomir Todorović, "Nosljive naprave za izboljšanje kakovosti življenja", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 55-57.
26. Mario Konecki, Alen Lovrenčić, Matjaž Gams, "Using customized reports in introductory programming courses", In: *3rd International Academic Conference on Development in Science and Technology, (IACDST-2015), Paris, France, October 11, 2015*, [S. l.], Academics World, 2015, pp. . 24-28.
27. Matej Krebelj, Matjaž Gams, Aleš Tavčar, "Power negotiations in smart cities", In: *Inteligentni sistemi: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 7. oktober 2015, [Ljubljana, Slovenia]: zvezek A: proceedings of the 18th International Multiconference Information Society - IS 2015, October 7th, 2015, Ljubljana, Slovenia: volume A*, Rok Piltaver, ed., Matjaž Gams, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 68-71.
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1. Vida Groznik, Martin Možina, Jure Žabkar, Dejan Georgiev, Ivan Bratko, Aleksander Sadikov, "Development, debugging, and assessment of ParkinsonCheck attributes through visualisation", In: *Health monitoring and personalized feedback using multimedia data*, Alexia Briassouli, ed., Jenny Benois-Pineau, ed., Alexander Hauptmann, ed., Cham [etc.], Springer, cop. 2015, pp. 47-71.

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Patent Application

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Mentoring

1. Miha Mlakar, *Evolutionary multiobjective optimization based on Gaussian process modeling:* doctoral dissertation, Ljubljana, 2015 (mentor Bogdan Filipič).
2. Domen Zupančič, *Comfort and energy management:* doctoral dissertation, Ljubljana, 2015 (mentor Matjaž Gams; co-mentor Mitja Luštrek).
3. Igor Avbelj, *Real-time updating of a recommender for personalized TV program:* master's thesis, Ljubljana, 2015 (mentor Ivan Bratko).
4. Vito Janko, *Razvoj programa za igranje 1-2-3 šaha:* master's thesis, Ljubljana, 2015 (mentor Matej Guid).
5. Urša Krevs, *Computer analysis and comparison of chess players' game-playing styles:* master's thesis, Ljubljana, 2015 (mentor Matej Guid).
6. Matevž Pavlič, *Estimating the quality of arguments in argument-based machine learning:* master's thesis, Ljubljana, 2015 (mentor Matej Guid).
7. Peter Šaponja, *Clustering with argument-based machine learning:* master's thesis, Ljubljana, 2015 (mentor Matej Guid).

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 the modelling of basic thermal-hydrodynamic phenomena, thermal-hydraulic safety analyses of design-basis and severe accidents, structural safety analyses and probabilistic safety assessments. Most research activities are part of international cooperation programs. The research results are incorporated into projects for industry and for regulatory authorities, as well as in under-graduate and doctoral studies programmes.

Head:
Prof. Leon Cizelj

Modelling of basic thermal-hydrodynamic phenomena

The spectral element method was used as a new tool for Direct Numerical Simulations of turbulent heat transfer. It is an accurate method that is known to be applicable for more complex geometries than standard spectral schemes that were used for similar simulations in the past. We use the spectral element method within the new European Commission (EC) Horizon 2020 project SESAME, dedicated to the thermal hydraulics of liquid metals. The first simulations of conjugate heat transfer in channel flow were performed in order to compare the performance of the spectral element method with that of the standard spectral scheme. The computer code nek5000 was used on several hundred computing nodes of our computer cluster.

The transient development of the turbulent-flow and heat-transfer characteristics in multiple impinging jets was investigated numerically by means of a Large Eddy Simulation (LES). Unstable and irregular flow dynamics near the heated surface, which are reflected in a highly heterogeneous pattern of the instantaneous heat-transfer coefficient, were successfully simulated. LES was also used to simulate the turbulent flow in a horizontal fuel bundle with an open-source computer code. The simulations were focused on the performance of various turbulent models in a rod-bundle flow. The WALE implementation of the LES model was found to be a suitable option for accurate simulations. The results were verified with the MATiS-H experiment (Measurement and analysis of turbulent mixing in sub-channels – horizontal) performed at the Korea Atomic Energy Research Institute.

The development of numerical methods in fluid mechanics was continued as well. In the frame of the 7th EC Framework programme (EC FP) project NURESAFE, new theoretical models for interface capturing and sharpening within two-fluid models of two-phase gas-liquid flow were examined. Similar methods were successfully implemented for the simulation of separated air-water flow in a vertical pipe, which is related to the so-called flooding phenomenon relevant to loss-of-coolant accidents in nuclear reactors. Within the same project, the uncertainty assessment of Computational Fluid Dynamics (CFD) codes was performed. We used our own Optimal Statistical Estimator (OSE) method to assess the uncertainty of the simulation of mixing two turbulent flows.

Figure 1: Test facility for fluid-mechanics and heat-transfer research under construction.

Basic phenomena that might occur during a hypothetical severe accident in a nuclear power plant were also investigated. A vapour explosion is an energetic fuel-coolant interaction phenomenon that might occur if, during an accident, the hot reactor-core melt comes into contact with the coolant. Vapour explosions are an important nuclear safety issue as they could jeopardize the primary system and the containment integrity. We continued with studies of vapour explosions in stratified melt-coolant configurations. The recently performed experiments in the PULiMS/SES facilities (Royal Institute of Technology, Sweden) have revealed that strong stratified explosions may develop spontaneously. The explosion potential of the PULiMS/SES material ZrO_2/WO_3 in the KROTOS facility (Commissariat à l'Energie Atomique - CEA, France) was analysed using the MC3D code (Institut de Radioprotection et de Sûreté Nucléaire, France). The results of the study are potentially useful for future KROTOS tests. Apart from that, the potential of strong vapour explosions during the melt-sodium interaction was investigated. The MC3D code was used to perform sensitivity simulations in the geometry and with the parameters of THINA experiments (Karlsruhe Institute of Technology - KIT, Germany). Also, the general relevance of sodium's physical properties and those of the melt solidification for the potential of vapour explosion were analysed. The analyses of the simulation and experimental results indicated that the explosion strength is affected by the melt solidification and the sodium-saturated vapour pressure.

In the field of hydrogen combustion in the containment of a nuclear power plant, we have, in cooperation with Nuclear Research and Consultancy Group (NRG, Netherlands), simulated an experiment that we performed in 2012 at KIT in the HYKA A2 vessel, with a volume of 220 m^3. We have also successfully submitted, again with NRG, within the ALISA project, a proposal for an experiment on hydrogen combustion that should be performed in the second half of 2016 in the HYMIT vessel, with a volume of 12 m^3, at Shanghai Jiao Tong University (China).

In order to launch our own experimental activities, we continued the building of a laboratory that will be active in the fields of reactor thermal-hydraulics, renewable energy, fluid mechanics and heat transfer on different scales and in different systems. In this respect, construction works on two secondary loops were completed and we focused on closing the primary loop. Within our current experimental activities, temperature distributions inside the cooling pool of the TRIGA research reactor were measured and compared with CFD simulations. A simplified CFD model is being used for the coupled neutronic and thermal hydraulic simulations of the reactor.

Thermal-hydraulic safety analyses

A set of measures has been proposed in response to the accident at the Fukushima Daiichi nuclear power plant (Japan) in 2011. These measures include various and flexible mitigation strategies that increase the defence-in-depth for beyond-design-basis scenarios. After the accident, new mitigation strategies have been proposed for extended station blackout (SBO), which are based on the utilization of fixed and portable equipment to maintain or restore key safety functions. The purpose of the study was to investigate the applicability of the deterministic safety analysis for proposing a mitigation strategy of SBO. The RELAP5/MOD3.3 thermalhydraulic computer code was used with the input model of the Krško nuclear power plant. A methodology for the assessment of the flowrates for steam generator makeup using a portable pump was proposed. Six different types of scenarios were investigated, considering various reactor coolant system (RCS) coolant-loss pathways during the extended SBO: maximum allowable normal system leakage, reactor coolant pump seal leakage and loss of RCS coolant through the letdown relief valve. For each type of scenario, different time delays between the extended SBO start and the start of the pump injections to steam generators were considered.

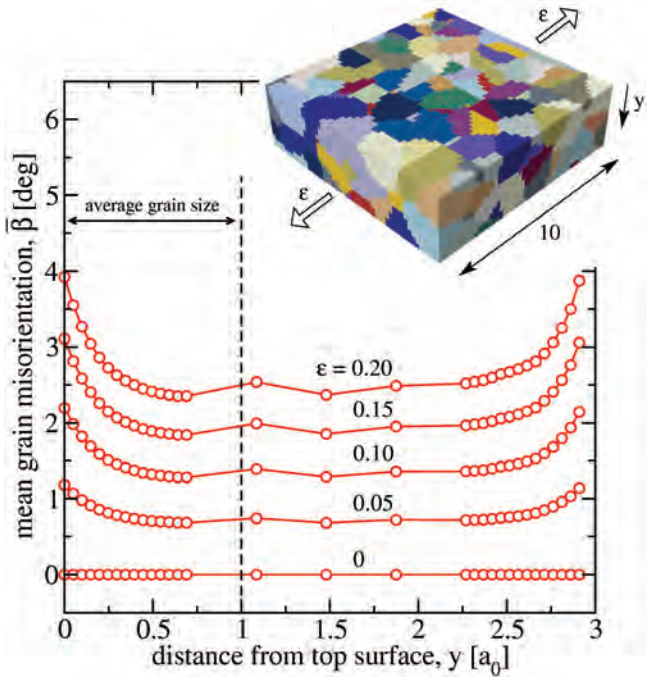

Figure 2: Mean grain misorientation calculated at various planes below the top free surface of a polycrystalline model. Different curves correspond to different tensile strains.

A global thermal radiation model for the projected DEMO demonstration fusion reactor was further developed within the frame of the EUROfusion programme. The upgraded model was based on significant design changes and the inclusion of additional passive thermal radiation shields. The effect of passive insulation on the total refrigeration power for the actively cooled thermal shields and magnets was evaluated. The results of numerical simulations on simplified models were confirmed with theoretical calculations. An accurate prediction of the radiative heat loads is of paramount importance for the design of the tokamak and refrigeration systems.

We used the system code ASTEC to simulate 15 additional experiments of hydrogen combustion in a homogeneous atmosphere with upward and downward flame propagation, performed in the THAI experimental facility (Becker Technologies, Germany). Although the system codes use a volume-averaged description of the containment, they are suitable for the safety analyses of real plants.

Structural safety analyses

The research remained concentrated on the development of multiscale computational simulation tools for polycrystalline metallic materials. The focus was on the improvement of advanced constitutive models for crystal grains.

In collaboration with CEA, a micromechanical crystal plasticity model was implemented in the ABAQUS computational tool to calculate normal stress distributions at grain boundaries for (un)-irradiated austenitic stainless steel based on finite-element simulations performed on a realistic aggregate of steel wire. Once rescaled by the macroscopic stress, the obtained distributions were found to be well approximated by a master curve. The upper tail of this master curve, relevant for intergranular corrosion crack initiation modelling, was found to be sensitive to grain shapes.

The evolution of grain misorientations close to the free surface of a polycrystalline aggregate under tensile straining was analysed within the crystal plasticity finite-element model for the Voronoi partitioning of the grains. A sharp 40% decrease in the grain misorientations was predicted when half or more of the average grain size of the material (a few tens of μm for stainless steel) was removed from the free surface, highlighting the possibly

important influence of sample-surface preparation on the interpretation of misorientation measurements obtained from surface-sensitive techniques.

We proposed an improved thermal fatigue assessment of pipes subjected to turbulent-fluid mixing using an improved spectral loading approach. The fluid temperature histories, generated synthetically from experimental or computational data, were used in a novel and rather straightforward analysis of the uncertainties involved in the calculated fatigue-life times. The fatigue lives were predicted for diverse variations in fluid temperatures. The results of the proposed method were less conservative than the results of similar methods described in the literature.

We participated in two fusion EC projects. Within the PMI-PPPT-FU (plant-level system engineering) project, thermal expansion and thermal radiation analyses of the DEMO tokamak were performed. The results provided essential information on the thermal expansion of different components and estimated the heat exchange between the tokamak systems. Within the WPDC project (design and control), initial Computer Aided Design studies and two thermal analyses were carried out on magnetic and neutron-gamma diagnostics for DEMO. A few geometrical issues were identified in the current tokamak model.

Probabilistic safety assessment

A new dynamic method for a probabilistic assessment of generation unavailability was developed. The method considers the unavailability implications of the generating unit states, being committed or decommitted as well as their start-up characteristics. The new methodology allows more comprehensive hour-to-hour scheduling analyses from the perspective of a probabilistic unavailability assessment. The obtained results indicate the need for, and benefits of, more detailed modelling of the power-generation availability

Combined loss of off-site power (LOOP) and station blackout (SBO) events were analysed with deterministic and probabilistic safety-analyses codes.

The combined loss of off-site power (LOOP) and station blackout (SBO) events were analysed with a deterministic and probabilistic safety-analysis code. The analysis was made for different time delays between the LOOP and SBO events. The results show that the time delay of the SBO after the LOOP leads to a decrease in the core damage frequency (CDF) from the SBO event tree. The reduction in the CDF depends on the time delay of the SBO after the LOOP event. The results show the importance of safety systems continuing to operate after a plant shutdown, when the decay heat is high.

Part of the work was related to international projects. Within the 7th EC FP project ASAMPSA_E, the state of the art in the link between the Defence-in-Depth Concept and Extended PSA was analysed and summarized. The impact of SAM strategies in Level 2 PSA and the potential impact of internal and external hazards on those strategies were analysed.

Technical cooperation, consulting services and education

Reactor Engineering Department researchers also cooperated in projects for industry. As an authorized institution for radiation and nuclear safety, we prepared a report with proposals for safety improvements for the Krško NPP, based on inspection activities for safety structures, systems and components during the plant's 2015 outage. We also prepared an expert opinion on the revised safety-upgrade program and accompanying technical reports, which was based on JSI expertise and experience, including deterministic analyses, as well as on international practice.

The design bases of the low- and intermediate-level radioactive waste repository were reviewed for the Slovenian Radwaste Agency.

Members of the department participated in the organization and running of two training and tutoring courses for experts of the national regulatory authorities of non-EU countries and their technical support organisations, with the purpose of developing and strengthening their regulatory and technical capabilities. The objective of the first course was to discuss the requirements and safety evaluation for a nuclear power plant safety-analysis report. The second training dealt with the nuclear fuel cycle and uranium mining from a regulatory perspective.

Members of the department are also actively involved in nuclear engineering under-graduate, masters and doctoral studies at the Faculty of Mathematics and Physics, University of Ljubljana. The programmes are associated with the European Nuclear Education Network (ENEN).

Organization of conferences, congresses and meetings

1. NUGENIA Forum 2015: Hotel Union, Ljubljana (13.-15.04.2015)
2. BRIDGE Meeting: JSI, Reactor Centre, Ljubljana (15.-16.10.2015)
3. EAES Working Group Meeting: JSI, Reactor Centre, Ljubljana (19.-20.11.2015)

Awards and appointments

1. Blaž Mikuž: Young author awards (International Conference Nuclear Energy for New Europe: Portorož, Slovenia, 14.-17.09.2015) - Nuclear Society of Slovenia ... Accurate wall-resolved Large Eddy Simulation of a turbulent flow in 5×5 fuel rod bundle

Patent granted

1. Marko Matkovič, Iztok Tiselj, Ivo Kljenak, Andrej Prošek, Matjaž Leskovar, Ljubo Fabjan, Leon Cizelj, Method and apparatus for assessing the state of a spent-fuel facility, SI24756 (A), Slovenian Intellectual Property Office, 31. 12. 2015.

INTERNATIONAL PROJECTS

1. 7FP - EURATOM - THINS; Thermal-hydraulics of Innovative Nuclear Systems
   Prof. Iztok Tiselj
   European Commission
2. 7FP - EURATOM; MULTIMETAL; Structural Peformance of Multi-metal Component
   Prof. Leon Cizelj
   European Commission
3. 7FP - NURESAFE; Nuclear Reactor Safety Simulation Platform
   Dr. Boštjan Končar
   European Commission
4. 7FP - CESAM; Code for European Severe Accident Management
   Asst. Prof. Ivo Kljenak
   European Commission
5. 7FP - ASAMPSA_E; Advanced Safety Assesment: Extended PSA
   Dr. Andrej Prošek
   European Commission
6. 7FP - ARCADIA; Assessment of Regional Capabilities for New Reactors Development through an Integrated Approach
   Prof. Leon Cizelj
   European Commission
7. 7 FP - NUGENIAS-PLUS (AIR-SFP); Spent Fuel Pool Behaviour in Loss of Cooling of Loss of Coolant Accidents
   Asst. Prof. Marko Matkovič
   European Commission
8. Better understanding and recognition of nuclear skills and qualifications
   Prof. Leon Cizelj
   University Politehnica of Bucharest
9. 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
10. Projekti H2020
    H2020 - SESAME; thermal hydraulics Simulations and Experiments for the Safety Assessment of MEtal cooled reactors
    Prof. Iztok Tiselj
    European Commission
11. 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
12. RU-FU, EUROFUSION; Research Unit - Administration and Services
    Dr. Boštjan Končar
    European Commission
13. Diagnostic and Control-WPDC-PPPT-FU, EUROFUSION
    Dr. Samir El Shawish
    European Commission
14. Investigation of Coolant Flow and Heat Transfer Characteristics in a High Temperature Gas-cooled Reactor
    Prof. Leon Cizelj
    Slovenian Research Agency
15. SNETP - Sustainable Nuclear Energy Technology Platform; SNETP General Assembly; Brussels, 29.9.2015
    Prof. Leon Cizelj
    Slovenian Research Agency
16. SNETP - Sustainable Nuclear Energy Technology Platform; SNETP General Assembly; Brussels, 16.-18.3.2015
    Prof. Leon Cizelj
    Slovenian Research Agency
17. Investigation of stratified steam explosions
    Dr. Matjaž Leskovar
    Slovenian Research Agency
18. Towards quantitative prediction of stress corrosion cracking initiation stress threshold for PWR's internals
    Dr. Samir El Shawish
    Slovenian Research Agency

RESEARCH PROGRAM

1. Reactor engineering
   Prof. Leon Cizelj

NEW CONTRACTS

1. Review of the document „The project design basis for low and intermediate level radioactive waste repository Vrbina, Krško – phase Assessment of the Environmental Impact"
   Ljubo Fabjan, M. Sc.
   ARAO-Slovenian Agency for Radioactive Waste Management, Ljubljana
2. Cooperation in an international CAMP program
   Dr. Andrej Prošek
   Krško Nuclear Power Plant, Krško
3. Expert opinion of overhaul, interventions and performed tests during the Krško nuclear power plant 2015 outage
   Dr. Mitja Uršič
   Milan Vidmar Electric Power Research Institute, Ljubljana
4. Independent Evaluation of Modified Krško 16x16 VANTAGE+Fuel design fully in accordance with NEK Technical Specification SP-ES1250 Rev.0
   Dr. Matjaž Leskovar
   Krško Nuclear Power Plant, Krško

VISITORS FROM ABROAD

1. Dr. Nikola Popov: ELEM - JSC Macedonian Power Plants Department of development and investments (Skopje, Macedonia), 20.01.2015
2. Prof. Anthony Donne: EUROFUSION (Garching, Germany), 03.02.2015
3. Dr. Milan Konstantinović: SCK-CEN Belgian Nuclear Research Centre (Mol, Belgium), 16.04.2015
4. Prof. Ivan Catton: UCLA – Mechanical and Aerospace Engineering Dept. (Los Angeles, United States), 28.05.2015
5. Ms. Kat Lennox: National Nuclear Laboratory (Warrington, United Kingdom), 18.06.2015
6. Dr. Matthew Randall: National Nuclear Laboratory (Warrington, United Kingdom), 18.06.2015
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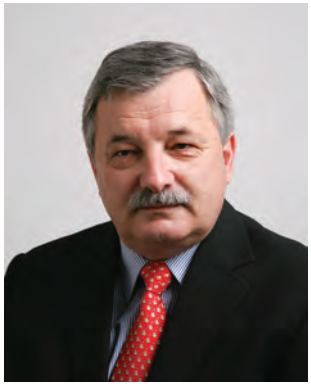
REACTOR INFRASTRUCTURE CENTRE RIC

The Reactor Infrastructure Centre (RIC) incorporates a TRIGA Mark II Reactor research reactor and a Hot Cells Facility. The reactor, operating since 1966, is used for neutron research, training and for producing radioactive isotopes. 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 within research and applicative projects. In addition, it is used for performing measurements within the regular radiological monitoring of the reactor.

Besides operating and maintaining the reactor, the members of the reactor staff participate in other activities requiring specialists skilled in the work with sources of radiation and in reactor technology, such as the servicing of industrial radioactive sources and surveillance of the fuel management in NPP Krško.



Head:
Prof. Borut Smodiš

The reactor operated in accordance with a program approved by Head of the RIC and the Radiation Protection Unit – RPU (SVPIS in Slovene) for each week. In 2015 the reactor operated for 141 days and produced 109.8 MWh of heat. Altogether, 42 pulses were carried out and 869 samples were irradiated in the rotary specimen rack and 31 in the pneumatic transfer system.

The reactor operators supported the researchers by performing the operations and services for which the researchers are not qualified and authorized, such as operating the reactor, performing irradiations and manipulating radioactive samples.

In 2015 the reactor was mainly used as a neutron source for neutron-activation analysis, the irradiation of electronic components and education. For educational purposes it was mostly used for the needs of the JSI'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 the experiments of reactor physics, and the Reactor Engineering Department (R4) used the reactor for thermal-hydraulic experiments.

Several samples were sterilised in the reactor for the Department of 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 needs.

The reactor was used for the following research:

- Reactor physics and neutronics
- Activation analysis
- Research on radiation damage to semiconductors
- Neutron dosimetry and spectrometry
- Neutron radiography
- Activation of materials, nuclear waste and decommissioning
- 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.

Preparation for a new experimental campaign at the TRIGA reactor in collaboration with researchers from Alternative Energies and Atomic Energy Commission (CEA), Cadarache, was initiated. Fission chambers with neptunium and plutonium serving as the active materials will be studied during this campaign, scheduled for 2016. Preliminary calculations were made to investigate the fission chambers' responses with respect to their location in the reactor core, to control the rod positioning, the type of active material and the use of transmission filters (e.g., cadmium, gadolinium, boron). In collaboration with researchers from CEA, Bruyers Les Chateles, we have designed and implemented a device for irradiation with thermal neutrons from our TRIGA reactor.

Figure 1: A photograph of the TRIGA Mark II Reactor was published in the magazine National Geographic Slovenia in April 2015, in the article (Un)Known Ljubljana, which reveals the lesser-known attractions of Ljubljana. The photograph was taken in the early morning, about half an hour before sunrise, when the daylight is like the blue Čerenkov radiation in the reactor.
Authors of photo: Domen Pal, Jože Maček and Branko Čeak.

A series of experiments involving the irradiation of piezo ceramic materials was conducted in the framework of a collaboration between F8 and CEA Cadarache.

Two projects in the framework of the International Atomic Energy Agency (IAEA) were completed: *"Installation DT neutron converter in the TRIGA reactor" and "Automation of a Pneumatic Transportation System for Neutron Activation Analysis".*

In collaboration with the Reactor Engineering Department (R4) measurements of the coolant temperature at different locations inside the reactor pool in the various operating modes of the reactor were made.

Before the reactor start-up at the NPP Krško, preparations and tests to conduct physical tests took place at the TRIGA reactor.

Since 2011, the TRIGA reactor participates in the FP7 AIDA (Advanced Infrastructures for Detectors and Accelerators) project that brings together advanced European infrastructures for future particle-physics experiments. Together with the Department of Reactor Physics (F8) we signed a contract in the framework of the international project *"Horizon 2020 - the AIDA-2020 GA No. 654168, Task 15.5 - Irradiation Facilities"* for the period from 1 May 2015 until 31 October 2016.

We had a one-month visit (in November and December) from a scientific researcher from the National Nuclear Research Centre in Baku, Azerbaijan within the framework of the project *"Irradiation and Analysis of Nano SiC Samples"*. We have performed the irradiation of the samples and the analysis of samples irradiated in collaboration with several departments of the Jožef Stefan Institute.

From 25 to 27 November 2015 there was a follow-up mission to the IAEA comprehensive assessment of the safety of nuclear reactors (INSARR) according to the standards of the IAEA. The mission found a substantial improvement since the first visit. Following-up the mission's recommendations, the Institute continues implementing its recommendations.

In the field of training, different lectures and practical exercises were conducted at the reactor. The participants were students from Slovenian universities: Faculty of Mathematics and Physics, Faculty of Electrical Engineering (University of Ljubljana) and Faculty of Energy Technology (University of Maribor). The experiments were conducted 15 times. The average number of participants per experiment is 10. All the exercises were conducted by our personnel in collaboration with the Reactor Physics Department (F8).

The reactor was also used for practical exercises within the training program of the NPP Krško reactor operators (practical training in the area of secure and efficient operation of nuclear reactors), lasting from 6 October 2014 to 3 March 2015, and which was attended by 21 participants.

In 2015, there were more than 50 short group visits to the reactor. The visitors were mainly foreign scientists, students and 30 groups of school children. Their total number was more than 1700.

INTERNATIONAL PROJECTS

1. Irradiations in TRIGA Nuclear Reactor
   Prof. Borut Smodiš
2. Automation of a Pneumatic Transport System for Neutron Activation Analysis
   Prof. Borut Smodiš
   IAEA - International Atomic Energy Agency
3. H2020 - AIDA-2020; Advanced European Infrastructures for Detectors at Accelerators
   Prof. Borut Smodiš
   European Commission
   Anže Jazbec, B. Sc.
   Institute of Radiation Problems of AzNAS, Azerbaijan
3. Irradiation of Piezoelectric Transducers
   Anže Jazbec, B. Sc.
   Commissariat à l'énergie atomique et aux énergies alternatives (CEA)
4. Irradiation and Analysis of Nano SiC Samples
   Anže Jazbec, B. Sc.
   National Nuclear Research Center

R & D GRANTS AND CONTRACTS

1. Irradiation for FT-TIMS Method at the JSI TRIGA Mark II Reactor
   Asst. Prof. Luka Snoj
2. Irradiation and Analysis of Nano Si Samples

NEW CONTRACT

1. Treatment and conditioning of radioactive waste for storage
   Prof. Borut Smodiš
   ARAO

VISITORS FROM ABROAD

1. 23. – 27 March 2015 / Ms. Randa Mahmound / Researcher from IAEA, working visit, Egypt
2. 23. November – 24. December 2015 / Mr. Elchin Huseynov, PhD, Senior Scientist, Head of Department of Nanotechnology and Radiation Material Science, "National Nuclear Research Center", G. Javid ave. 33, AZ1073, Baku, Azerbaijan
3. 25. – 27. November 2015 / *Follow-up INSARR Mission, IAEA* / Mr. Amgad Shokr and Mr. Alan D'Arcy, working visit, Austria

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5. Darko Kavšek, B. Sc.
6. Marko Rosman
7. Sebastjan Rupnik, B. Sc.
8. Nina Udir, B. Sc.

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1. P. Filliatre, C. Jammes, L. Barbot, D. Fourmentel, B. Geslot, Igor Lengar, Anže Jazbec, Luka Snoj, Gašper Žerovnik, "Experimental assessment of the kinetic parameters of the JSI TRIGA reactor", *Ann. nucl. energy*, vol. 83, pp. 236-245, 2015.
2. Tanja Kaiba, Gašper Žerovnik, Anže Jazbec, Žiga Štancar, L. Barbot, D. Fourmentel, Luka Snoj, "Validation of neutron fl ux redistribution factors in JSI TRIGA reactor due to control rod movements", *Appl. radiat. isotopes*, vol. 104, pp. 34-42, 2015.
3. Borut Smodiš, Marko Černe, Radojko Jaćimović, Ljudmila Benedik, "Transfer of uranium and radium to Chinese cabbage from soil containing elevated levels of natural radionuclides", *J. radioanal. nucl. chem.*, vol. 306, iss. 3, pp. 685-694, 2015.
4. Gašper Žerovnik, Tanja Kaiba, Vladimir Radulović, Anže Jazbec, Sebastjan Rupnik, L. Barbot, D. Fourmentel, Luka Snoj, "Validation of the neutron and gamma fields in the JSI TRIGA reactor using in-core fission and ionization chambers", *Appl. radiat. isotopes*, vol. 96, pp. 27-35, 2015.
5. Gašper Žerovnik, Ivan Aleksander Kodeli, Andrej Trkov, Anže Jazbec, "Re-evaluation of the EURACOS integral shielding experiment series", *Ann. nucl. energy*, vol. 77, pp. 318-325, 2015.

NETWORKING INFRASTRUCTURE CENTRE NIC

The Networking Infrastructure Centre (NIC) is responsible for the administration, development, management and expansion of the core network and ICT services and infrastructure for the Jožef Stefan Institute. It also provides the development of computing, communication, data and security infrastructure for the research departments, centres and services of the Institute.

Head:
Vladimir Alkalaj, M. Sc.*

The NIC's main mission is to maintain the computing networks, services and hardware necessary for the work of the research departments, programmes, groups and projects at the Jožef Stefan Institute. We provide a high level of connectivity and integration to the local and international communication networks and infrastructures to provide ICT support for the research activities at the Jožef Stefan Institute, including the development, management and administration of the ICT and computing infrastructure, technology, facilities and services at the Institute. We work in four main domains: networking infrastructure, network security, network services and distributed network computing.

Networking infrastructure

The Networking Infrastructure Centre provides development, management, administration and support to the physical networking infrastructure for the Institute and support to local networks so as to enable internal and internet connectivity to the users and services at the Institute. This task includes the management of wireless networks at the Institute locations and 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, etc.).

Physical network: In 2015 we continued our on-going extension and optimisation of the physical network, cabling installation, active equipment and wireless access points and we also had two new locations added to the network backbone, namely, the new building for the Department of Environmental Sciences at the Reactor Centre Podgorica campus and the new Jožef Stefan Institute Computing Centre Teslova. Additional equipment upgrades, especially core backbone routing and switching upgrades, enabled us to optimize for higher throughput and lower latency as well as expanding the network and its support for virtual network links and the IPv6 protocol. We installed a number of new routers with 10 Gbit/s bandwidth that will enable us to upgrade the backbone bandwidth in the future.

In the course of ongoing physical network infrastructure upgrades at the Reactor Infrastructure Centre Podgorica campus a number of active components and routers were upgraded, wireless coverage has been improved and the use of secure remote VLAN access to the campus network in addition to the Institute's VPN has increased considerably.

A modern, up-to-date 10 Gbit/s network backbone, IPv6 protocol and dedicated external links are the basis of a flexible modern network at the Jožef Stefan Institute that has to support high availability and advanced services with many fixed and wireless clients.

The load on our additional 0 Gbit/s connection via the ARNES and GÉANT networks to the dedicated LHCONE network (LHC Open Network Environment) used for high network throughput for the ATLAS project inside the WLCG (Worldwide Large Hadron Collider Computing Grid) and the distributed Nordic computing T1 cloud has required close support and a number of optimizations.

We have joined a project run by Arnes to provide optical connectivity to the Hard Coatings Center in Domžale. In this way, the dislocated centre is now fully integrated with the Institute's network.

Monitoring: New components and services have been integrated with existing traffic, event and status-monitoring infrastructure, which is implemented on the basis of the software packages Nagios, Ganglia, Cacati, Observium and a dynamic analytical visualisation package built with Kibana and ElasticSearch as a backend. In combination with internally developed solutions, this system enables us to react to usage changes and events in the domain of web services, security policies, firewalls, authentication and authorization, network time systems e-mail delivery, analysis, processing and security systems, etc. Our in-house developed system for environmental monitoring that allowed us to achieve much denser deployment in our existing centre has been extended with the integration of built-in sensory and monitoring systems of the new computing facility at the Jožef Stefan Computing Centre Teslova.

Wireless network: Due to a increasing use of the wireless network due to new users and due to the fact that users use multiple devices simultaneously, we have to continue with the deployment of new wireless access points in order to improve coverage and ensure a useful signal density at the critical points by the deployment of additional smaller access points.

**Photo by Sašo Radelj*

IPv6 support: Continuous upgrading and improvements in the network router protocol stack provide flexible support for new protocols. Support for the IPv6 protocol stack across the whole network segment is crucial in our long-term strategy for alleviating the load on the already mostly spent IPv4 address pool.

Network Security

The NIC is responsible for implementing security measures and policies in three domains: external network connectivity security, security of the network itself and security of the services and software deployments. External network security is provided with the dynamic management and configuration of an active deep packet inspection firewall system and routing configuration, with the exception of dedicated links where passive measures (configuration, filtering and supervision) are used. Constant dynamic supervision, traffic monitoring and event analysis are necessary to ensure suitable security in the complex constraints and requirements of an open academic network that collide with current security considerations due to the increased detection of threats from the outside network. Therefore, ensuring the secure and open environment requires disproportionate increases in equipment capabilities and efforts in the dynamic security policy configuration.

Since the NIC is responsible for the security of the ICT infrastructure of the institute, we are active members of the relevant institutions and groups, notably the national security response centre SICERT, FIRST (Forum of Incident Response and Security Teams), EGI CSIRT (European Grid Initiative distributed computing security incident response team), we are part of the response team of the national distributed computing network SLING (Slovenian Initiative for National Grid). 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 participated in the work of the Slovenian network technology and security association SINOG (Slovenian Network Operators Group) and supported the organization by hosting one of the technical workshops at the Institute.

Internal development of e-mail security and dynamic network firewalling, virtual networks, and advanced analysis and monitoring ensure the security of an open academic network in the age of a hostile Internet.

E-Mail: In the field of e-mail security and protection against undesired or malignant messages we have continued with in-house software development, notably in the SpamAssassin package, and with improving the support for international character sets in domain-name handling and e-mail message protocol stacks.

Cryptography and certification: We have continued with a gradual DNSSEC signed internet domain integration using automated mechanisms for the verification of signatures and with preparation for 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 issued digital certificates based on the SiGNET CA scientific certificate PKI system has increased, but also many free COMODO server certificates, courtesy of Arnes support, have been issued for services that are offered to the general public, since COMODO certificates are recognised by the major operating systems and browsers. The number or users of our VPN infrastructure has been steadily increasing, in particular for connections to the user network at the Reactor Infrastructure Centre Podgorica. The system is not used only by researchers at foreign conferences and exchanges who have to deal with foreign networks that block certain types of connections, it is also more frequently used by users who are working from their homes. To alleviate another common use case, we have supported the Science Information Centre in its on-going effort to ensure accessibility of scientific publications using the eduGAIN single-sign-on federation.

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 (central 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 has 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, Google Play and Microsoft Store). The software development repository has stood out by attracting a large number or new users in the past year. In addition, we 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.

In 2015 we established a new, dedicated computing centre in the Technology Park building at Teslova under the direction of the Technical Services and in the framework of the project Procurement and adaptation of facilities for Jožef Stefan Institute's Computing Centre Teslova. The new facilities have modern cooling, electrical and security systems and ample room for future growth. In the past year, we have started moving computationally intensive systems from the NIC computing centre and other rooms at Jadranska campus, which has enabled us to provide hosting for computing systems in the NIC computing centre where we can provide modern cooling and network facilities and uninterrupted power supply for critical services. A new common computing cluster has been established in the new facilities. We have expanded our web hosting activity (over 75 distinct virtual servers) and started offering virtualised hosting. A number of new physical servers have been installed and the physical network has been improved, which has allowed us to maintain and extend the range of existing services. The increased load on our personnel due to demands for hosting and services is forcing us to continue our automated provisioning efforts, which are planned to culminate in fully automated virtual and physical services on demand.

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 the European eduGAIN federation is gaining popularity since it gives our users easier access to numerous national and international services using their institute credentials. At the same time, the new feature is meant to simplify user and authentication management to software developers who work on internal projects and services.

Network computing

In the field of network computing technology and infrastructure, including high throughput computing, high-performance computing, grids and clouds (ICT as a service), the NIC is collaborating with individual computing clusters at the institute and contributing directly to the Slovenian National Grid Initiative SLING as a founding member and core partner. 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 grid network services and coordinates work with international infrastructure projects and collaborations.

The most important achievement in 2015 has been the establishment of the New System Cluster (NSC), a common computing cluster in the new facilities of the Jožef Stefan Institute's Computing Centre Teslova. The new cluster with 1728 64-bit computing cores, 16 vecor coprocessors NVidia Kepler 40, almost 9 TB RAM and 90 TB disk storage is far from being the biggest cluster at the Institute, but it is an important step in the evolving traditions of supercomputing at the Jožef Stefan Institute, since it is available to all researchers at the Institute and is thus providing and 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, we have continued with support for users of JSI clusters and supported the integration of the clusters with the national network SLING using the NorduGrid ARC Grid Middleware to enable users to use all the resources in the network with the same interfaces and in the same way.

Constant growth of network services and network computing provides better support for collaboration and teamwork, software development, data protection and access to large computing and data resources for scientific research. A new common facility is an important step further for collaboration in the field of high-performance and network computing at the JSI.

In the domain of network computing we have been most involved with the Slovenian National Grid Initiative (SLING), but we also worked with in the European Grid Initiative EGI (with development of the EGI Federated Cloud pilot – federated infrastructure as a service), the NorduGrid ARC collaboration and a number of international projects (ATLAS – dedicated link, Belle2 – computing grid network support planning, CLARIN – support for different services of Slovenian national node, ELIXIR – collaboration with the national node and the European collaboration). SLING has supported a number or research projects and applications in 2015, among others in high-energy physics, medical sensor and image analysis, theoretical physics, astrophysics, biochemistry, protein-folding simulations, crystal analysis, knowledge technologies, 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 the administration of the required run-time environments.

NEW CONTRACT

1. Acquisition of premises and their reconstruction for the relocation of the Jožef Stefan Institute Computing Centre
   Vladimir Alkalaj, M. Sc.
   Ministry of Education, Science and Sport of the Republic of Slovenia

STAFF

Technical officers
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3. Mark Martinec, B. Sc.

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5. Janez Jezeršek
6. Matjaž Levstek
7. Janez Srakar
8. Matej Wedam

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Professional Monograph

1. Mišo Alkalaj, Borut Bohanec, *Kaj je res o GSO*, 1. izd., Ljubljana, Biotehniška fakulteta, Oddelek za agronomijo, Katedra za genetiko, biotehnologijo, statistiko in žlahtnjenje rastlin, 2015.

SCIENCE INFORMATION CENTRE SIC

The Jožef Stefan Institute's 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, as well as the input, update and control of bibliographic data for 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 4,000 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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5. Katarina Modic, B. Sc.
6. Alenka Ana Stante, B. Sc.
7. Jože Škulj
8. Branka Štrancar
9. Nada Tratnik
10. Saša Žnidar

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 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 its cooperation with state institutions in the preparation of strategic documents and legislation in the field of efficient energy use, energy planning, distributed electricity production, 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 being more and more involved in European research projects.

Head:
Stane Merše, M. Sc.

Energy and the environment

In 2015 the Energy Efficiency Centre, with its professional work, ensured high-quality support to ministries in the preparation of strategic development documents and the transfer of EU legislation in the field of energy planning, energy efficiency, use of renewables and greenhouse-gases emissions, and the reduction of other pollutants.

Slovenia has ambitious goals in the framework of climate energy policy regarding an increase of energy efficiency, the exploitation of renewable energy sources (RES) and a reduction of greenhouse-gases emissions. Energy efficiency is a priority field to achieve these goals, in accordance with the demands of the European Commission and the new directive on energy efficiency (2012/27/EU). In accordance with this directive a new elaborated Action Plan for Energy Efficiency in the period 2014–2020 was accepted by the government as well as a report on the carrying out of the previous plan. The EEC also cooperated in the updating of the Action Plan for Renewable Energy Sources for the period 2010–2020 and inclusion in the procedure for the integrated assessment of impacts on the environment. The EEC was also included in the preparation of the national Long-Term Strategy for Promotion of Investments in Energy Renovation of Buildings.

The EEC cooperates with the Statistical Office of the Republic of Slovenia, where it prepares a model calculation for fuels and energy use in households for the national energy statistics.

Also in 2015, the EEC continued with activities of the state referential centre for energy by preparing an expanded set of indicators for energy and the environment.

In the field of greenhouse-gases emissions reduction, the Centre elaborated for the Ministry of Agriculture and Environment the first annual report on the carrying out of the Operational programme of GHG emissions reduction measures in the period 2013–2020, it carried out projections for GHG emissions until 2035 and carried on the professional support regarding the design of goals and national policy concerning pollutants from the NEC directive up to the year 2030.

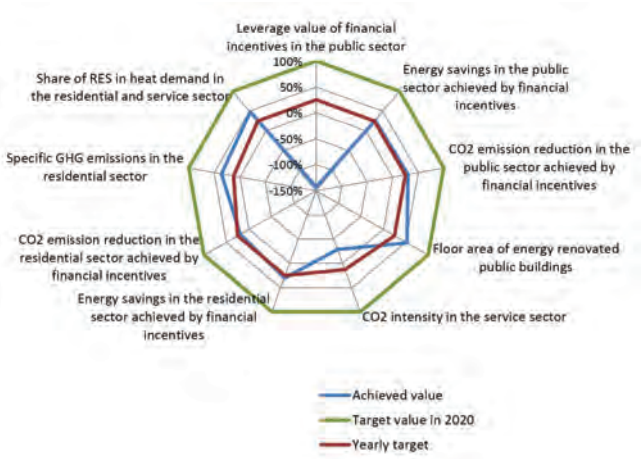

Figure 1: Strategic studies for the preparation of the first annual report on carrying out the Operation programme for greenhouse-gases emissions reduction measures up to 2020 – achieved values of the indicators in the field of buildings. Values of the selected indicators regarding annual target values in 2013 or 2014 and as regards target values in 2020.

Promotion of efficient energy use and energy consulting

The Energy Efficiency Centre in 2015 continued with its training activities where the eighth cycle of energy managers' training was successfully concluded within the European programme EUREM. Due to a very positive reaction from the participants and their interest (in Slovenia, there are already more than 175 energy managers with the EUREM licence), it is clear that there is a great need for such training. High-quality knowledge in this field is of key importance for the execution of efficient solutions in practice.

In 2015 the Center of Energy Efficiency carried out several consulting tasks in industry and the public sector, where cooperation with Luka Koper

The 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 low-carbon society. With training activities and support to industry it significantly contributes to the increase of competitiveness and development restructuring.

Figure 2: Ivana Kacafura from the agency GOLEA at the Annual Conference of European Energy Managers in Prague as the first woman to receive the EUREM award in the category of small enterprises.

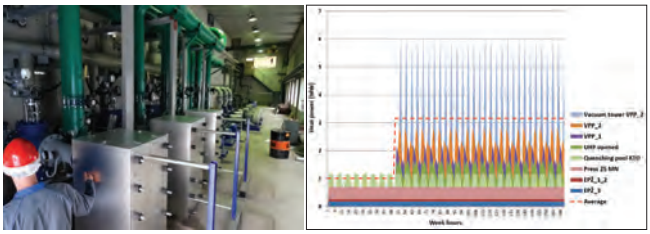

Figure 3: Analysis of available low-temperature waste heat in the company Metal Ravne

Figure 4: European code of conduct for energy contracting

was particularly strengthened. Great economic effects with a reduction of energy-use costs were achieved by the execution of deepened energy audits of individual terminals and by an analysis of the possibilities for the introduction of advanced technologies of transloading. Professional cooperation with Termoelektrarna toplarna Ljubljana, BTC, General Hospital Brežice, etc. has been continued. A prefeasibility concept of the heating plant after 2017 with the introduction of the exploitation of waste heat and cogeneration was elaborated for the company Petrol Energetika Ravne.

The Center continued professional cooperation with the company Petrol d.d. in carrying out the largest programme for large consumers to ensure the energy savings of end users. The Center prepared the programme for the seventeenth 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 2015 the EEC carried out as many as 11 international projects, financed from the European Union resources in the framework of HORIZON 2020, the 7th Framework Programme and European Commission programme "Intelligent Energy for Europe" as well as the regional programmes MEDITERAN and Central and South East Europe.

Projects cover activities in the fields of:

- development of innovative systems of energy-use monitoring and management in industry (Life Saver, 7th FP),
- increase of transparency for markets with energy services (Transparense)
- compiling and elaboration of current data on renewable energy sources use (EurObserv'ER Barometer),
- carrying out the EU directive on energy efficiency (CA – EED),
- carrying out the EU directive on renewable energy sources (CA – RES),
- monitoring the indicators of energy use and energy efficiency in the EU (ODYSSEE MURE EU-27).
- development and carrying out of integrated energy concepts in technological centres (Go ECO)
- advanced financial platform for the promotion of green growth and eco-innovations (Eco-funding)
- strengthening of the policies for urban sustainability (UrbanEmpathy)
- strengthening of Mediterranean incentives which direct small and medium enterprises towards innovations concerning the development of energy-efficient technologies (EMILIE)
- Energy contracting Plus (EPC Plus)

Projects include cooperation 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 EEC staff took part in numerous foreign professional meetings and visits.

The EEC cooperated in the carrying out of integrated energy renovation of the four largest buildings and a system for heating at the JSI Reactor Centre in Podgorica, which took place in 2014.

Some outstanding achievements in the past year

1. **Preparation of several key support documents for the government of the Republic of Slovenia** in the field of energy policy (Green paper and strategic studies for the National Energy Programme), 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, 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 of third-party financing. The Code was very successfully accepted at the European level and currently already has 171 signatories, among them also the European Association of Companies for Energy Services (eu.ESCO) and the European Federation for Intelligent Services of Energy Efficiency (EFIEES), also supported by the European Commission. In Slovenia the code was already tested in practice in the project for integrated energy renovation of the municipal building in the municipality Brda.

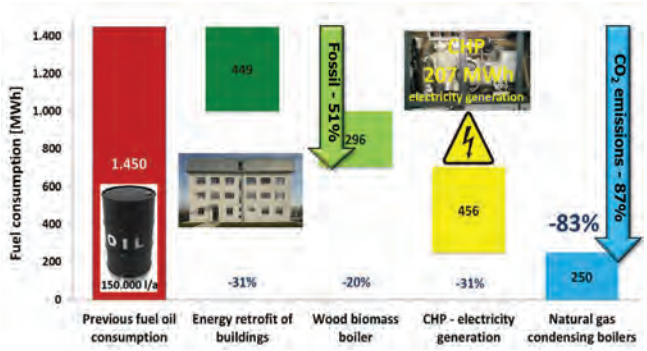

Figure 5: Reduction of fossil-fuel use and CO_2 emissions after carrying out the energy renovation at the IJS RCP in 2015

Organization of conferences, congresses and meetings

1. Energy managers' days 2015 – 17th Meeting of Energy Managers of Slovenia, Portorož, 21. – 22. 4. 2015
2. Trends of energy efficiency and renewable energy sources, Ljubljana, 7. 5. 2015

INTERNATIONAL PROJECTS

1. 7FP - LifeSaver; Context Sensitive Monitoring of Energy Consumption to Support Energy Savings and Emission Trading in Industry
   Boris Sučić, M. Sc.
   European Commission
2. Go ECO; Development and Implementation of Integrated Energy Concepts in Business Parks
   Peter Bevk, B. Sc.
   European Commission
3. EIE pr. - TRANSPARENSE; Increasing Transparency of Energy Services Markets
   Damir Staničić, M. Sc.
   European Commission
4. EIE - ODYSSEE MURE 2012; Monitoring of Energy Efficiency in the EU
   Dr. Fouad Al-mansour
   European Commission
5. IEE; EurObservER, The EurObserv'ER Barometer (2013-2016)
   Matjaž Česen, B. Sc.
   European Commission
6. MED - EMILIE; Enhancing Mediterranean Initiatives Leading SMEs to Innovation in Building Energy Efficiency Technologies
   Stane Merše, M. Sc.
   Stc Programme Med
7. MED pr.; ECOFUNDING; Innovative Funding Scheme for Energy and Eco Innovation Projects
   Polona Lah, B. Sc.
   Provence-alpes-côte D'azur Region
8. H2020 - EPC_PLUS; Energy Performance Contracting Plus
   Damir Staničić, M. Sc.
   European Commission

RESEARCH PROGRAM

1. Modelling and environmental impact assessment of processes and energy technologies
   Dr. Fouad Al-mansour

R&D GRANTS AND CONTRACTS

1. Isolated power plant exploiting renewable energy sources
   Dr. Fouad Al-mansour
   Slovene Human Resources and Scholarship Fund, Ljubljana

NEW CONTRACTS

1. Concerted Actions in the Field of the Directive on End Energy Efficiency (CA EEDII)
   Damir Staničić, M. Sc.
   Ministry of Infrastructure and Spatial Planning of the Republic of Slovenia, Ljubljana
2. Allocation of financial means and cooperation in the European project Concerted action in the field of the RES II directive
   Damir Staničić, M. Sc.
   Ministry of Infrastructure and Spatial Planning of the Republic of Slovenia, Ljubljana
3. Strategic studies for the revision of the NEC directive
   Matjaž Česen, B. Sc.
   Ministry of Agriculture and Environmnet of the Republic of Slovenia, Ljubljana
4. Action plan for energy efficiency and reporting on its carrying out
   Damir Staničić, M. Sc.
   Ministry of Infrastructure and Spatial Planning of the Republic of Slovenia, Ljubljana
5. Framework agreement on the professional advising in the field of cogeneration
   Stane Merše, M. Sc.
   Energetika Ljubljana, d. o. o.
6. Elaboration of a report on achieving of national framework goals in the field of RES and CHP for the period 2012 – 2014
   Andreja Urbančič, M. Sc.
   Slovenian Energy Agency, Maribor
7. Strategic studies for longterm strategy of buildings renovation investments promotion
   Andreja Urbančič, M. Sc.
   Gradbeni inštitut ZRMK, d. o. o., Ljubljana
8. Model calculation of energy and fuel consumption in households for 2014
   Matjaž Česen, B. Sc.
   Statistical Office of the Republic of Slovenia, Ljubljana
9. Professional Support in the Carrying Out of a Pilot regarding Monitoring of Energy Carriers Consumption in Luka Koper within EU Greenberth
   Boris Sučić, M. Sc.
   Port of Koper, Koper
10. Updating, Upgrading and Publishing on the Web of Energy and Environment Indicators 2015 and preparation of a framework proposal for the publication Environment and energy in Slovenia
    Matjaž Česen, B. Sc.
    Ministry of Infrastructure and Spatial Planning of the Republic of Slovenia, Ljubljana
11. Professional help for the preparation of the first annual report on carrying out of OP GHG 2020
    Andreja Urbančič, M. Sc.
    Ministry of Infrastructure and Spatial Planning of the Republic of Slovenia, Ljubljana
12. Preinvestment concepts of "The Heating Plant Ravne na Koroškem after 2017"
    Damir Staničić, M. Sc.
    Petrol Energetika, d.o.o., Ljubljana
13. Strategic Studies for the Preparation of the Report on Projections of Greenhouse Gases Emissions
    Matjaž Česen, B. Sc.
    Ministry of Infrastructure and Spatial Planning of the Republic of Slovenia, Ljubljana
14. Strategic Studies for the Revision of the NEC Directive, Questionnaires CLRTAP and Improvement of Emission Inventory
    Matjaž Česen, B. Sc.
    Ministry of Infrastructure and Spatial Planning of the Republic of Slovenia, Ljubljana
15. Inclusion in the procedure of integrated assessment of impacts on the environment for an updated Action plan for RES for the period 2010 - 2020
    Andreja Urbančič, M. Sc.
    Ministry of Infrastructure of the Republic of Slovenia, Ljubljana

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7. Matevž Pušnik, Fouad Al-Mansour, Boris Sučić, Matjaž Česen, "Trends and challenges of energy efficiency development in Slovenian industry", In: *State of the art on environmental protection: proceedings of the 8th International conference on sustainable energy & environmental protection - Part 2*, 8th International Conference on Sustainable Energy & Environmental Protection, SEEP 2015, 11-14 August 2015, Paisley, Abdul Ghani Olabi, ed., Paisley, University of the West of Scotland, 2015, pp. 108-113.
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CENTRE FOR ELECTRON MICROSCOPY AND MICROANALYSIS CEMM

The Centre for Electron Microscopy and Microanalysis (CEMM) is a JSI instrumental centre that comprises the research equipment for electron microscopy and microanalysis that is necessary for the research work of the JSI departments. Other research institutes, universities and industry also have access to the equipment. The users of the CEMM's equipment are the researchers in the field of materials science that are involved in chemical and structural analyses of materials on the micro and atomic scales. The major pieces of equipment of the CEMM are three scanning electron microscopes (JSM-5800, JSM-840A, JSM-7600F), two transmission electron microscopes (JEM-2100 (CO NiN) and JEM-2010F) and SEM and TEM sample-preparation facilities. Additionally, CO NAMASTE upgraded the equipment of the CEMM with a CCD camera for the JEM-2010F, an ADF detector for the JEM-2010F and an EBSD system for the JSM-7600F.

Head:
Prof. Miran Čeh

Scanning electron microscopy (SEM) is used for morphological studies of either fractured or polished surfaces. Since all scanning electron microscopes are equipped with X-ray spectroscopy (EDXS and/or WDXS), qualitative and quantitative chemical analyses on the micro scale are also possible. Since only a few μm^3 of the material are non-destructively analysed, the term electron-probe microanalysis (EPMA) is used for such analytical work. Apart from EDXS and WDXS, the FEG-SEM JSM-7600F is also equipped with electron back-scatter diffraction (EBSD) and electron lithography.

Various techniques of transmission electron microscopy (TEM) are used when structural features on the nano-scale are investigated. The JEM-2010F with a FEG (field-emission gun) is equipped with a STEM unit, EDXS, EELS and a CCD camera, while the JEM-2100 is equipped with EDXS and a CCD camera. The CEMM also comprises the equipment for SEM and TEM specimen preparation, which is the starting step for all the electron microscopy observation procedures. Especially important are the high- and low-energy ion-mills (Bal-Tec RES010, PIPS 691 and Linda IV), which enable the preparation of thin foils that are transparent to high-energy electrons, and a tripod polisher (Allied MultiPrep) for the mechanical thinning of the samples.

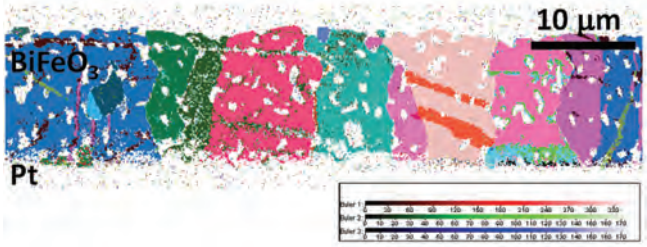

Figure 1: EBSD orientation map of $BiFeO_3$ thick film on Pt electrode sintered at 820°C with the corresponding all Eulers legend. The film possesses columnar, randomly orientated grains with clearly visible domains. (Evgeniya Khomyakova, K5, Jeol JSM-7600F)

The analytical work that is performed on the CEMM equipment varies, concerning both the investigated materials and/or the used electron microscopy techniques. While the scanning electron microscopy is used mainly for microstructural characterizations and chemical analyses of polycrystalline ceramic materials (functional ceramics, engineering ceramics, bio-ceramics, and composites), magnetic materials, glasses, metals, alloys, etc., the transmission electron microscopy is used for structural and chemical investigations of grain boundaries, planar faults, dislocations and precipitates within the same materials. The structural and chemical analyses of grain boundaries are especially important since it is known that the final physical properties to a great extent depend on the structure and chemistry of the grain boundaries.

One of the main tasks of the CEMM employees is to maintain the equipment in optimal working condition. Other activities of the CEMM include the training of new operators, the organization of workshops and electron-microscopy-related conferences, service work for industrial partners and the implementation of new electron microscopy analytical methods. Another important activity of the CEMM is the dissemination of information on electron microscopy to the public. In 2015, the CEMM received over 25 groups of visitors, mostly from elementary schools, explaining to them the basic concepts of electron microscopy and its usefulness in basic and applied research. The CEMM maintains a web page in English and Slovene, where it presents our analytical techniques and the CEMM's equipment. We are also active in the business-oriented social networks (LinkedIn) and social networks (Twitter and Facebook), where we regularly report on interesting achievements in the field of electron microscopy. Facebook is also used as a bulletin board for instant notifications about the condition of the CEMM's equipment and lectures.

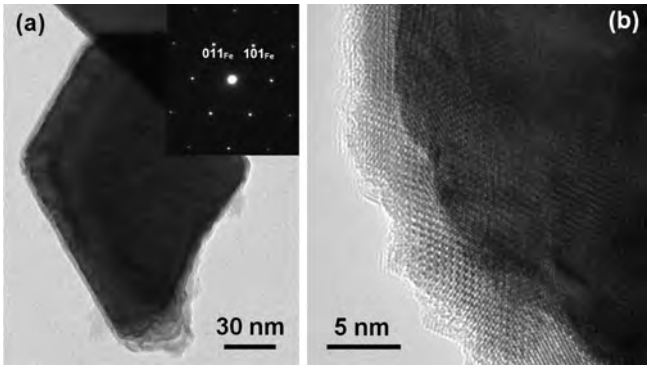

Figure 2: Transmission electron microscopy (TEM) image with the corresponding electron-diffraction pattern (a) and high-resolution image (b) of an iron nanoparticle protected against oxidation with a crystalline carbide layer. (Darko Makovec, K8, Jeol 2010F)

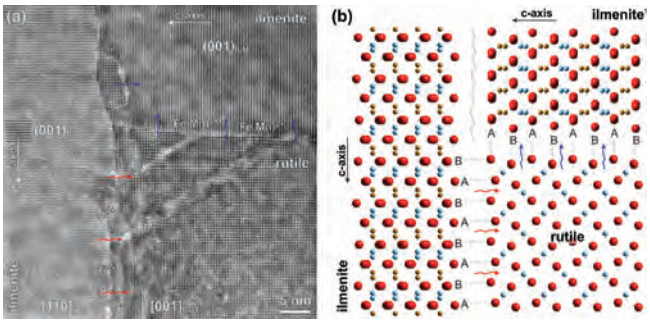

Figure 3: The mechanism of exsolution processes during the oxidation of an ilmenite single crystal: The process of ilmenite-rutile transformation during the oxidation of a natural ilmenite crystal was studied at elevated temperatures in air. The surface oxidation and out-diffusion of Fe^{2+} and Mn^{2+} ions from the parent ilmenite triggers the intrinsic exsolution of rutile within the pseudo-hexagonal oxygen sublattice, following a simple topotaxial orientation relationship: $\langle 001\rangle_{RUT}\{010\}_{RUT} \,||\, \langle 210\rangle_{ILM}\{001\}_{ILM}$. (a) HRTEM image showing parent ilmenite (left), exsolved rutile (centre) and secondary ilmenite' (above). (b) Structural relations between the exsolved phases. First, rutile is exsolved from the parent ilmenite, forming a coherent $(110)_{ILM} \mid (100)_{RUT}$ interface. On cooling, the Fe^{2+} and Mn^{2+} cations that diffused through the rutile are exsolved and form ilmenite with a secondary coherent $(010)_{RUT} \mid (110)_{ILM}$ interface. With this operation the two generations of ilmenite are brought into a non-crystallographic $(110)_{ILM} \mid (003)_{ILM}$ orientation.
(Nadežda Stanković, K7; reference: N. Stanković, A. Rečnik, N. Daneu, Topotaxial reactions during the oxidation of an ilmenite single crystal, Journal of Materials Science 51/2 (2016) 958-968, .Jeol 2010F)

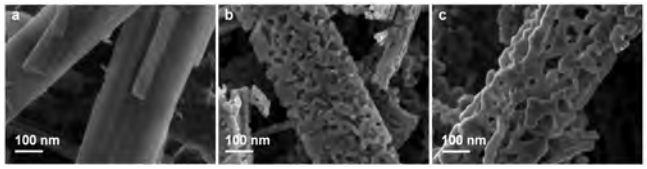

Figure 4: SEM images represent protonated titanate nanoribbons (a) that were transformed to titanium oxynitride (Ti(O,N)) nanoribbons with calcination in a NH_3(g) atmosphere at 800 °C for 4 h (b) and 30 h (c). During the transformation porosity emerges, which even increases with a prolonged calcination time (4h (b) and 30 h (c)). This is a consequence of the Kirkendall effect. The research was carried out by Melita Sluban, Polona Umek and Denis Arčon from the Condensed Matter Physics department, Aleš Mrzel and Jože Buh from the Complex Matter department of the Jožef Stefan Institute in collaboration with researchers from the universities of Ljubljana (Petra Šmitek, Zvonko Jagličić), Mons (Carla Bittencourt), Bordeaux (Marie-Helene Delville), and the Helmholtz centre in Berlin (Peter Guttmann). The results were published in ACS Nano 2015, 9 (10), 10133–10141. (Melita Sluban, F5, Jeol JSM-7600F)

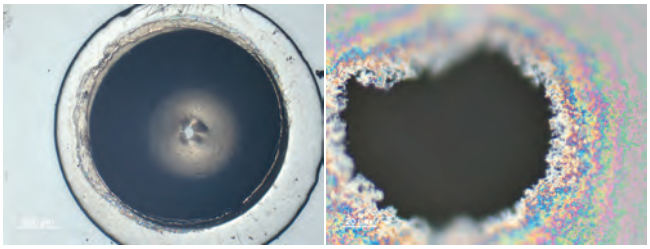

Figure 5: Optical micrographs of a TEM sample that was prepared by ion-milling. The homogeneity of the Fresnel rings confirms the even thickness of the sample region that is transparent to high-energy electrons.
(Andreja Šestan, CEMM, Gatan PiPS Mod. 691 and OM Zeiss Imager.Z1m).

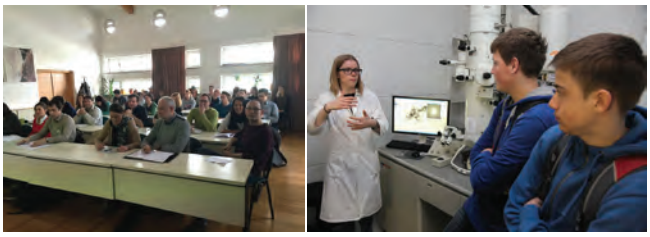

Figure 6: Images from the CEMM workshop on JSM 7600F and Maja Koblar from CEMM with pupils from the Lila elementary school visiting the CEMM.

Figure 7: In 2015 the CEMM co-organized two electron-microscopy-related international conferences: the Modern Developments and Applications in Microbeam Analysis workshop with EMAS (European Microbeam Analysis Society) and the 1st Slovenian Microscopy Congress with SSM (Slovene Society for Microscopy).

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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.

Head:
Mitja Jermol, M. Sc.

By partnering and active engagement in different European research projects the Centre successfully extends its activities to research and development. Most of the research is performed in the area of knowledge management for traditional and emerging forms of organizations, like networked and virtual organizations. In 2015 the centre was active in several European projects from FP7: *MOBIS (Personalized Mobility Service for energy Efficiency and Security through Advanced), NRG4CAST (Energy Forecasting), SOPHOCLES (Self-Organised information Processing, Criticality and Emergence in multile), CENTRAL COMMUNITY (Emerging communities for collective innovation in Central Europe), SYMPHONY (Orchestrating Information Technologies and Global Systems Science for Policy Design and Regulation of a Resilient and Sustainable Global Economy), X-LIME (crossLingual crossMedia knowledge extraction), PROASENSE (The Proactive Sensing Enterprise), SUNSEED (Sustainable and Robust Networking), FI-IMPACT (Future Internet Impact), and some projects from the H2020 program: EDSA (European Data Science Academ), AQUASMART (Aquaculture Smart and Open Data Analytics as a Service) OPTIMUM (Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility)*

In 2015 the centre was active in 12 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, marketing, automatization and process control. Special consideration is put on the managers and decision makers who are aware of the strengths and benefits to the success of their business.

In 2015 the Centre for Knowledge Transfer in Information Technologies was actively involved in 12 European projects.

All 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/. It now offers 21,496 recorded tutorials from different scientific events and is visited monthly by an average of 75,000 visitors from around the world. 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 provides a learning opportunity to audiences of all social levels.

We have successfully collaborated within the Videolectures.net portal with some of the top ten American Universities MIT (Massachusetts Institute of Technology), University of California, Berkeley, Yale University, Johns Hopkins University, University of California, Irvine, and Carnegie Ethics Studio, as well as with the European CERN and ETH from Zurich. VideoLectures.Net has strong connections in the Open Cast Foundation, Open Course Ware Consortium and Knowledge 4 All Foundation Ltd.

Figure 1: In June 2015 we finished with Cycle 1 of My Dream Machine project

In 2015 we organized the 10th Student Competition in Computer Science, attended by 159 students from Slovenian secondary schools. We also organized project meetings for different EU projects (NRG4CAST, Xlime, EDSA, Optimum, Aquasmart), an international conference ESWC - European Semantic Web Conference, which was attended by 300 experts and ELRC - European Language Resource Coordination workshop with 50 experts.

In 2015 the Institute "Jožef Stefan" was granted UNESCO's patronage to the International Conference "Internet of Education 2015", since the theme and goals of the event were very well articulated with UNESCO's vision and action to support Member States in building inclusive, participatory and

CT3 is operating the web portal http://videolectures.net/, which is now the largest world reference portal presenting high-quality scientific lectures.

Figure 2: Joy at the final exhibition of the My Dream machine project

In 2015 we held a number of activities within the framework of the UNESCO Chair in open technology, educational resources and learning http://unesco.ijs.si/, which attracted the attention of the wider domestic and global public.

robust 21st Century knowledge societies. With that event the Jožef Stefan Institute has aligned with UNESCO's increasingly active advocacy role, spearheading global initiatives to harness the power of the internet and other information and communication technologies (ICTs) in order to help developing and least-developed countries reach their internationally agreed development targets by and beyond 2015.

It ran the first year of the UNESCO Chair http://unesco.ijs.si/ and the Chair is creating a portfolio of tools, services and projects with a long-term scope, large impact and practical results. Here are a selection of exemplar projects that were launched with the participation of the Chair and are part of its long-term vision for sustainability in open education and OER through the use of smart technologies: Opening Up Slovenia, ExplorEdu, MyMachine Slovenia and traMOOC.

The Slovenian 1st cycle of MyMachine Slovenia http://www.mymachine.si/ in 2015 included 150 children, pupils and students, 13 teachers and professors, which created 120 ideas and drawings of dream machines. The pilot year was successful and it resulted in 4 working prototypes, which sparked a lot of interest for participation at all levels of education all over Slovenia. In autumn 2015 we also successfully implemented a first international collaboration on the realization of a prototype, involving all levels of education from Slovenia and Belgium.

In January 2015 we are organized the 1st OpeningupSlovenia workshop in Bosnia-Hercegovina, together with the Ministry of Education and Science, Canton Sarajevo, Bosnia-Hercegovina. This is the first attempt at presenting and directly influencing a new Openingup*MemberState* initiative, which is one of the goals of OpeningupSlovenia. There were 130 experts participating.

The results of the ExplorEdu project - a system of open web services for the intelligent use of OER are evident from the portal http://exploredu.org. The web service idea is to establish a uniform system for easy and open access to Open Educational Resources and data with the aim of centralizing materials and promoting new ideas, cooperation between educators, institutions and industry, the promotion of educational content and achievement, establishing creative environments in the field of innovative and intensive use of ICT in educational processes.

The main expected outcome of the traMOOC project is a high-quality machine translation service for all types of educational textual data available on a MOOC platform http://tramooc.eu/. Open source will turn the MOOC translation service into a platform that will enable the integration of any machine translation (MT) solution in the educational domain, for any language.

Organization of conferences, congresses and meetings

1. Project meeting of the EU project Xlime, Bled, 9.-10. 2. 20154
2. 10th Student competition in computer science, Ljubljana, 21. 3. 2015
3. Organization of the international conference "ESWC-European Semantic web conference" Portorož, 31.5.-4.6. 2015
4. Final My Machine exhibition, Ljubljana, 11.6. 2015
5. Project meeting of the EU project Xlime, Dubrovnik, Croatia, 10. - 12.6. 2015
6. Project meeting of the EU project EDSA, Dubrovnik, Croatia, 15. - 16.6. 2015
7. Project meeting of the EU project Optimum, Bled, 5.-6.10.2015
8. Project meeting of the EU project NRG4CAST, Ljubljana, 7. – 8.10. 2015
9. Workshop for project partners in the EU project NRG4CAST, Ljubljana, 6.10. 2015
10. Project meeting of the EU project Aquasmart, Ljubljana, 15. – 16.9. 2015
11. International My Machine BEL-SLO meeting, Ljubljana, Nova Gorica, 9. – 15.11. 2015
12. Workshop ELRC- European Language Resource Coordination, Ljubljana, 8.12. 2015

INTERNATIONAL PROJECTS

1. Videorecording and Post-Processing
   Mitja Jermol, M. Sc.
2. European Language Resource Coordination (ELRC) 2015, 08.12.2015, JSI, Ljubljana
   Mitja Jermol, M. Sc.
   Dfki Gmbh - Deutsches Forschungszentrum Fuer
3. 7FP - Sophocles; Self-Organised information PrOcessing, CriticaLity and Emergence in multilevel Systems
   Marjana Plukavec, B. Sc.
   European Commission
4. 7FP - MobiS: Personalized Mobility Services for Energy Efficiency and Security through Advanced Artificial Intelligence Techniques
   Mitja Jermol, M. Sc.
   European Commission
5. 7FP - ProaSense; The Proactive Sensing Enterprise
   Mitja Jermol, M. Sc.
   European Commission
6. 7FP - SYMPHONY; Orchestrating Information Technologies and Global Systems Science for Policy Design and Regulation of a Resilient and Sustainable Global Economy
   Mitja Jermol, M. Sc.
   European Commission
7. 7FP - xLiMe; CrossLingual CrossMedia Knowledge Extraction
   Mitja Jermol, M. Sc.
   European Commission
8. 7FP - SUNSEED; Sustainable and Robust Networking for Smart Electricity Distribution
   Mitja Jermol, M. Sc.
   European Commission
9. 7FP - FI-IMPACT; Future Internet Impact Assurance
   Mitja Jermol, M. Sc.
   European Commission
10. 7FP - NRG4CAST; Energy Forecasting
    Mitja Jermol, M. Sc.
    European Commission
11. H2020 - AquaSmart; Aquaculture Smart and Open Data Analytics as a Service
    Anja Polajnar, M. Sc.
    European Commission
12. H2020 - EDSA; European Data Science Academy
    Mitja Jermol, M. Sc.
    European Commission
13. H2020 - OPTIMUM; Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility
    Dr. Matej Kovačič
    European Commission

R&D GRANTS AND CONTRACTS

1. ExplorEdu - a system of open and available web services and mobile applications for automatic identification of OER
   Mitja Jermol, M. Sc.
   Ministry of Education, Science and Sport of the Republic of Slovenia

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13. Tanja Zdolšek Draksler, B. Sc.

Note:
* part-time JSI member

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, ICJT is actively informing the public about those technologies.

Head:
Dr. Igor Jenčič

Training in the area of nuclear technologies is our primary mission. In spring of 2015, the 15th edition of the course *Nuclear Technology* was concluded. This course is the initial theoretical training for future nuclear-power-plant control-room operators and is normally organized every second year. In the autumn there was also a course *Basics of Nuclear Technology,* which is intended for the non-control-room personnel of NPP and participants from other organizations.

There were 31 radiological protection training courses for the medical, industrial and research use of radioactive sources.

In collaboration with divisions for environmental sciences, reactor physics and reactor engineering, we have organized 3 international courses. The topics of these courses were research reactors and the regulatory control of nuclear facilities. We have also concluded the preparation of training materials (23 modules) for the IAEA course "Basic Professional Training Course" (BPTC).

Public information remains an important part of our activities. Groups of visitors (mainly schoolchildren, students and various societies) were regularly attending lectures on electricity from nuclear energy, on radioactive waste, and on fusion. They have also visited the permanent exhibition on nuclear energy. Altogether there were 148 groups or 6355 visitors this year. Since 1993 our information centre has been visited by 161819 pupils, teachers and other visitors. We have continued monitoring and analysing media reports on nuclear energy.

In 2015, the 15th generation of future nuclear-power-plant control-room operators concluded their initial training. Since the establishment of ICJT in 1989, a total of 254 participants have been trained by our most versatile course: Nuclear Technology.

Figure 1: Workshop on heat engines for elementary-school pupils

Figure 2: Demonstration of Slovenia's electricity supply on a simulator

Figure 3: Introductory lectures on the Basics of Nuclear Technology course 2015

Figure 4: Participants on the 15th Nuclear Technology course

Table of training activities at the Nuclear Training Centre in 2015

Date	Title of the course	Partici-pants	Lecturers	Weeks	Participants × weeks
(6.10.2014)-3.3.	Nuclear Technology, Theory	14,136	24	21.5	451.5
26.-30.1.	Radiation protection for RP department staff - Refresher course	9	6	1	9
16.2.-6.3.	10th IAEA Group Fellowship Training Programme on Research Reactors	9	9	3	27
9. -13.3.	Radiation protection for medical and veterinary workers - Nuclear medicine workers	7	10	1	7
9. -11.3.	Radiation protection for industrial and other practices (unsealed sources)	4	5	0.6	2.4
9. -11.3.	Radiation protection for industrial and other practices (sealed sources)	9	4	0.6	5.4
12. -13.3.	Radiation protection for Dental Radiography	1	5	0.4	0.4
17.3.	Radiation protection for industrial and other practices (sealed sources) - Refresher Course	9	4	0.2	1.8
17.3.	Radiation protection for industrial and other practices (unsealed sources) - Refresher Course	8	5	0.2	1.6
17.3.	Radiation protection for industrial and other practices (measurement of roadway density and humidity) - Refresher Course	3	4	0.2	0.6
19.3.	Training Extension for RP Officers	12	2	0.2	2.4
9.4.	Radiation protection for industrial and other practices (sealed sources) - Refresher Course	4	2	0.2	0.8
22.4.	Radiation protection for Instrumentation Technologies Workers	17	2	0.2	3.4
24.4.	Training Extension for RP Officers	1	1	0.2	0.2
28.5.	Training Extension for RP Officers	1	2	0.2	0.2
10.6.	Radiation protection for industrial and other practices (min. exposed workers)	21	3	0.2	4.2
6. -11.7.	Training Course on "Requirements and safety evaluation of NPP SAR"	12	12	1	12
5.10.-4.11.	Basics of nuclear technology, theory	6	12	4.6	27.6
14.10.	Radiation protection for industrial and other practices (Ministry of Defence)	34	2	0.2	6.8
19.-21.10.	Radiation protection for industrial and other practices (sealed sources)	21	4	0.6	12.6
19. -21.10.	Radiation protection for industrial and other practices (unsealed sources)	1	4	0.6	0.6
19. -23.10.	Radiation protection for medical and veterinary workers - Nuclear medicine workers	2	9	1	2
22. -23.10.	Radiation protection for Dental Radiography	4	5	0.4	1.6
27.10.	Radiation protection for industrial and other practices (sealed sources) - Refresher Course	4	4	0.2	0.8
27.10.	Radiation protection for industrial and other practices - Refresher Course	9	5	0.2	1.8
27.-29.10.	Radiation protection for industrial and other practices (radiography) - Refresher Course	5	4	0.4	2
27.10.	Radiation protection for industrial and other practices (unsealed sources) - Refresher Course	15	5	0.2	3
29.10.	Training Extension for RP Officers	13	2	0.2	2.6
30.10.	Radiation protection for exposed workers in medicine and veterinary - Refresher Course	1	3	0.2	0.2
30.10.	Radiation protection for Dental Radiography - Refresher Course	9	3	0.2	1.8
30.10.	Radiation protection for exposed workers in medicine and veterinary - Refresher Course	3	3	0.2	0.6
5.-27.11.	Basics of nuclear technology, systems	8	10	3.4	27.2

Table of training activities at the Nuclear Training Centre in 2015

Date	Title of the course	Partici-pants	Lecturers	Weeks	Participants × weeks
09.11.	Radiation protection for industrial and other practices	12	2	0.2	2.4
16.-20.11.	EU Dedicated Training Course "Nuclear Fuel Cycle and Uranium Mining From a Regulatory Perspective"	10	18	0.8	8
4.12.	Radiation protection for exposed workers in nuclear medicine - Refresher Course	49	5	0.2	9.8
21.12.	Radiation protection for exposed workers in medicine and veterinary - Refresher Course	4	4	0.2	0.8
21.12.	Radiation protection for minimally exposed workers in medicine and veterinary	6	4	0.2	1.2
TOTAL		364	208	45.1	643.3

INTERNATIONAL PROJECTS

1. Registration Fees for the OTJE-Theory
   Dr. Igor Jenčič
2. 7FP - EAGLE; Enhancing Education, Training and Communication Processes for Informed Behaviors and Decision-making related to Ionizing Radiation Risks
   Rado Istenič, B. Sc.
   European Commission
3. Realization of the International Workshop: „10th IAEA Group Fellowship Training Programme on Research Reactors" (IAEERRI15), ICJT, 16.02.2015-06.03.2015
   Vesna Slapar Borišek, B. Sc.
   IAEA - International Atomic Energy Agency
4. 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
   Saša Bobič
   Iter-consult Srl – Independent
5. Design, Development and Delivery of Training Material for the Train-the-Trainer"s Package on Nuclear Safety
   Dr. Igor Jenčič
   IAEA - International Atomic Energy Agency

R & D GRANTS AND CONTRACTS

1. Trainings of the RZ for Foreign Market
   Matejka Južnik, M. Sc.

NEW CONTRACTS

1. Public information and monitoring of media regarding nuclear energy and activities of GEN-energija
   Dr. Igor Jenčič
   Gen Energija, d. o. o.
2. Implementation of Training program „Technology of Nuclear Power Plants - Theory"
   Dr. Igor Jenčič
   Gen Energija, d. o. o.
3. Operation of the Nuclear Information Centre in 2015
   Dr. Igor Jenčič
   Arao, Ljubljana
4. Inplementation of 2015 Training Program for Krško NPP
   Dr. Igor Jenčič
   Krško Nuclear Power Plant, Krško

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1. Matjaž Koželj, Bruno Cvikl, "The inverted distorted parabola-like shape of the bias-dependent electric field at an electron-injecting metal/organic interface deduced using the current-voltage method", *Journal of energy technology*, iss. 2, vol. 8, pp. 17-30, 2015.

Published Conference Contribution

1. Radko Istenič, Igor Jenčič, "Public opinion about nuclear energy: year 2015 poll", In: *Proceedings*, 24th International Conference Nuclear Energy for New Europe - NENE 2015, Portorož, Slovenia, September 14-17, Igor Jenčič, ed., Ljubljana, Nuclear Society of Slovenia, 2015, 8 pp.
2. Matjaž Koželj, Igor Jenčič, "Radiation protection training needs in Slovenia", In: *Proceedings*, 24th International Conference Nuclear Energy for New Europe - NENE 2015, Portorož, Slovenia, September 14-17, Igor Jenčič, ed., Ljubljana, Nuclear Society of Slovenia, 2015, 8 pp.

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 the reactor and the 17 laboratories that use sources of ionising radiation in their research work. More than 100 different sources are used, such as sealed sources, open sources, X-ray units and the TANDETRON accelerator, which need regulatory control.

SVPIS is authorized by the Slovenian radiation-protection administration to perform control in industrial and research institutions dealing with open or sealed radioactive sources and X-ray units. Furthermore, we are involved in radioactive-waste management.

The measurements of dose rate, contamination and gamma spectrometry are performed using an accredited method (EN ISO/IEC 17025).

Personal dosimetry

The personal doses of 121 workers that regularly or occasionally deal with ionizing radiation were monitored with Thermo Luminescent Dosimeters. The maximum individual yearly dose was 0.24 mSv. This is only 1.2 % of the regulatory limit for occupational exposure (20 mSv per year) and 24 % of the limit for the general public (1 mSv per year). The collective dose at the JSI in 2015 was 1.5 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 were 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 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 in the controlled areas.

In 2015, a total of 18 inspections in other JSI laboratories were performed. An independent inspection by an 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.

At present, 100 sources of radiation are used, which require regulatory control. Additionally, 421 low-activity sources are also used in different laboratories.

Environmental measurements

The environmental monitoring of the Reactor Center was performed in accordance with the existing program. The monitoring program consists of effluent measurements and measurements of samples in the environment. The activity concentrations of gamma emitters in water samples, filters, noble gases, soil samples and sediment samples were measured periodically. About 350 different samples have been measured with gamma spectrometry. Environmental passive dosimeters have been used to monitor 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. **The public exposure in 2015 due to activities at the Reactor Center was insignificant.**

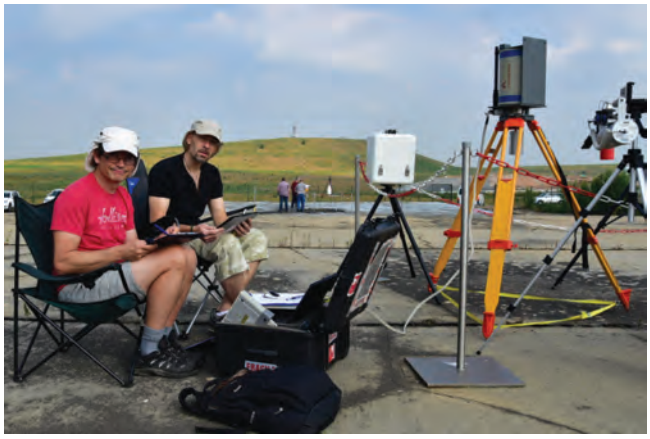

Figure 1: In-situ gamma spectrometry measurements and dose-rate measurements at a former uranium mine near Ronneburg.

Expert assessments and measurements for outside customers

The Radiation Protection Unit is authorized for 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. Our group has participated in the evaluation of radiological monitoring of Krško NPP, the TRIGA Research Reactor and storage for low- and intermediate-level waste in Brinje.

In the field of international cooperation our team has participated in intercomparison measurements at Ronneburg (Figure 1) and measurements of ionising radiation at several locations in Croatia.

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Independent Component Part or a Chapter in a Monograph

1. Matjaž Stepišnik, "Reka Sava", In: *Značilnosti in ocena vplivov radioaktivnosti na prebivalstvo ob normalnem delovanju NEK*, Matjaž Korun, et al, 1. izd., Ljubljana, Institut Jožef Stefan, 2015, pp. 7-26.

CENTER FOR TECHNOLOGY TRANSFER AND INNOVATION CTT

The Center for Technology Transfer and Innovation (CTT) has existed at the Jožef Stefan Institute since January 2011. The center's primary task is to enable and facilitate the transfer of technologies and knowledge from the JSI to the economy (contract and collaborative research, licensing, spin-out creation and associated procedures for the protection of intellectual property). We also transfer knowledge from science to the school system. The financing of the CTT is based on research work in the field of innovation and innovation management – mainly through EU projects.

Head:
Dr. Špela Stres, MBA, LLM

In the OECD's opinion (October 2014), the CTT is the largest and most successful technology-transfer unit in this part of the EU. The center's success originates in the work of 12 professionals, 8 of which are educated in natural sciences and engineering, 5 in economics, 2 in law and 2 in social sciences, while one of the experts is also qualified as a patent attorney. We are members of the ASTP (Association of Science and Technology Professionals), the LES (Licensing Executives Professionals), and in 2014/2015 we acquired the US certificate "Certified Licensing Professional". Additionally, in 2015 we were invited to present our concepts in Manchester, Trieste, Brussels, Prague, Bratislava, among others.

We are active in the field of technology and knowledge transfer, while our key tool is an exceptional network of contacts with enterprises and other organisations in Slovenia and abroad. Our services, fine-tuned towards individual needs, are offered to the JSI's researchers and external organisations and include first meeting, needs analysis, IL marketing, negotiations and the preparation of suitable agreements.

In 2015 the Center for Technology Transfer and Innovation funded its activities through seven larger and more smaller EU and national projects. These projects belonged to various funding programmes and schemes: Openismes (CIP scheme), Firemed (MED programme), Evlia (SouthEast Evropa programme), Enterprise Europe Network Slovenia (CIP scheme), Fidias (Alps programme), We4SMESLO (Horison 2020) and in 2015 a new project, SciChallenge (Horison 2020). The project activities were connecting and completing our core TT activities. Part of our funding also came from the JSI through the clearly defined and approved activities of research departments. Our direct clients were also Slovenian universities and larger Slovenian companies.

Internally, the CTT is divided into four groups whose activities mutually interact and complement each other.

Group for the protection and marketing of intellectual property deals with cases that were applied through the single entry point (27 cases), gives first advice to researchers (10), prepares assessments of patentability – reviews state of the art (6), evaluates market potential (6), helps prepare the invention for disclosure within the research organisation (5), helps draft the patent application, prepares agreements on the ownership of intellectual property (2), chooses the patent attorney and prepares and files the patent application and takes care of the international (7) and national (2) expansion of the patent protection. The group also takes care of the active marketing of technologies from the JSI (21 technologies promoted to 644 enterprises and other organisations). It manages received interests and starts the negotiations (15). Moreover, group members arrange for the signing of non-disclosure agreements (19), take part in negotiations (15), prepare license agreements and arrange for their signing. Experts that belong to this group provide individual consulting regarding all the phases of spin-out company formation, help with the preparation of business plans, manage discussions on the arrangement of the relationship between the JSI and the researcher and

1400 visitors during the Open Day at the JSI, 79 school visits, and the 8th International Technology Transfer Conference

Figure 1: Impressions from the very successful JSI Open Day event 2015

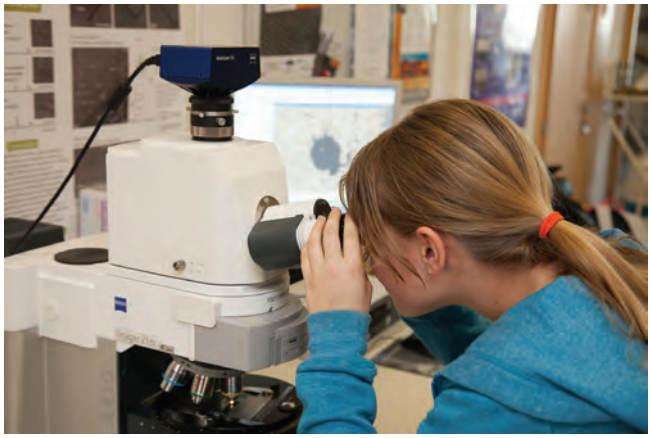

Figure 2: Pupils could in the context of regular visits throughout the year learn about the research departments of the Institute.

Marketing of 21 JSI technologies, procedures for the creation of 3 spin-out companies, and 66 identified RR topics

prepare license agreements for the use of the technology within the company (2). To encourage the researchers in their entrepreneurial aspirations, this group's experts organize a contest for the selection of innovations with the highest commercial potential and various workshops for young researchers. In 2015 one spin-out company was created, two cases are in the final stages.

The above-mentioned group cooperates closely with the **Group for contractual collaboration with the economy**, which visits both large (30 since 2012) and small companies (57 in 2015), organises their return visits to the JSI, organises sector and regional visits of companies to the JSI and collaborates with other support environment entities. This group's members are trying to find new topics for cooperation within the development projects among companies and researches (66), prepare technology offers, arrange for the signing of non-disclosure agreements and acquire written consent for further cooperation (15). The group also takes part in various events; in the course of the 8th International Technology Transfer Conference it organised individual meetings between companies and researchers (64) and enabled attendance at trade fairs (40 attendees having 109 individual meetings).

Figure 3: In September 2015 we organized the 8th International Technology Transfer Conference

The **Group for promotion, education and project management** has prepared and disseminated lists of Slovenian and EU tenders (12) and foreign partner searches, helped prepare project applications, especially in the Exploitation and Dissemination part, weekly disseminated other information to TT coordinators, which has efficiently contributed to the application of new projects with foreign partners (39). The group has successfully spread a variety of information through the CTT e-newsletter and the CTT's Facebook profile, organised an Open Day at the JSI (1400 visitors), organised 79 school visits at the JSI (with an additional 3160 visitors), provided entrepreneurial education to young researchers in compliance with the Slovenian Research Agency's requirements (35 participants), organised expert excursions to companies for young researchers to Union and Revoz and organised the 8th International Technology Transfer Conference.

The **Group for research in the field of technology transfer and innovation** has prepared studies on the work of four different European consortiums in the area of ICT and NMP (Factories of the Future) and as special invitation workshops "Exploitation Strategy Seminar" for eminent foreign institutions such as Manchester University and Charles University in Prague. It analysed the potential of including children in the STEM programme in South-Eastern Europe. Through evaluation workshops it cooperated by creating systems for TT in Estonia, Malta and Slovakia.

Organization of Conferences, Congresses and Meetings.

1. 8th International Technology Transfer Conference, Brdo, Kranj, Slovenia, 16. 9. 2016
2. Workshop for young researchers – Young hopes 2016, Ljubljana, 16. 6. 2016

Figure 4: Together with the Chamber of Commerce and Industry of Slovenia, we organized 109 meetings between JSI researchers and industry representatives.

Figure 5: Award ceremony for the innovation with highest commercial potential at the 8th International Technology Transfer Conference

INTERNATIONAL PROJECTS

1. Evaluation of Industrial Projects for Italian Partner
   Dr. Špela Stres
   Veneto Innovazione Spa
2. 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
3. FIDIAS - Innovative Financial Instruments for Sustainable Development in Alpine Space
   Dr. Špela Stres
   European Commission
4. MED - FireMed; Innovative Financial Instruments to support Energy Sector SMEs in Med Area
   Dr. Špela Stres
   Stc Programme Med
5. OPENiSME; Open Platform for Innovative SMEs; EACI, CIP Programme
   Dr. Špela Stres
   European Commission
6. COSME - EEN Slovenia; EEN Slovenia Services in Support of Business and Innovation in Slovenia
   Dr. Špela Stres
   European Commission
7. H2020 - SCICHALLENGE; Next Generation Science Challenges using Participatory Techniques and Digital Media
   Dr. Špela Stres
   European Commission
8. H2020 - We4SMESLO; Enhancing the Innovation Management Capacity fo SMEs (by EEN), Slovenia
   Dr. Špela Stres
   European Commission

VISITORS FROM ABROAD

1. Ms. Triin Udris, 16.9.2015, Oxford Innovation
2. Mr. Marko Derča, 16.9.2015, AT Kearney
3. Mr. Luigi Amati, 16.9.2015, META Group and Business Angels Europe

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1. Klemen Burja, Urban Šegedin, Saša Skale, Peter Berce, Primož Šket, Polona Prosen, Dolores Kukanja, "Improved anticorrosion properties of polyurethane coatings based on high-solids acrylics synthesized in a high pressure reactor", *Prog. org. coat.*, vol. 78, pp. 275-286, Jan. 2015.
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2. Špela Stres, Robert Blatnik, Luka Virag, "Sodelovanje pisarn za prenos tehnologij v projektih pametne specializacije za Pametna mesta in skupnosti", In: *Delavnica Pametna mesta in skupnosti kot razvojna priložnost Slovenije: zbornik 18. mednarodne multikonference Informacijska družba - IS 2015, 12. oktober 2015, [Ljubljana, Slovenia]: zvezek H: proceedings of the 18th International Multiconference Information Society - IS 2015, October 12th, 2015, Ljubljana, Slovenia: volume H*, Mihael Mohorčič, ed., Ana Robnik, ed., Dalibor Baškovč, ed., Ljubljana, Institut Jožef Stefan, 2015, pp. 110-112.

Professional Monograph

1. Anton Habjanič, Špela Stres, Aleš Zorc, Peter Alešnik, Luka Virag, *Prenos tehnologij na javnih raziskovalnih organizacijah v Sloveniji*, Ljubljana, Združenje profesionalcev za prenos tehnologij Slovenije, 2015.