Annual Report

2008

Jožef Stefan Institute, Ljubljana, Slovenia

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INTRODUCTION

When preparing the Annual Report of the Jožef Stefan Institute, writing the introduction is always the most difficult part. As the Institute operates in such a wide area, it is not possible to mention all the achievements for a particular year. After selecting some of them, I soon realise that there are several other, equally excellent and important, achievements.

Each year I am pleased to read the annual report, but this time I have also read it with a view to the approaching 60th anniversary of the Institute’s establishment, which we will celebrate on Jožef Stefan’s birthday, 24 March 2009. The extent and the quality of our research results have had an international impact, so it is not surprising that the funds that the Institute obtained with projects included in the EU 6FP and EU 7FP are increasing at an annual rate of 50%, currently amounting to 15% of the Institute’s total income. Additionally, the efforts of our researchers aimed at contributing their knowledge and innovations for the common good are not in vain, as the Institute annually carries out more than two hundred projects for industry and other direct users.

In its development resolutions Slovenia set itself some ambitious objectives; however, these objectives are not being achieved, the conditions for research activities and technological development are not being improved, and our investments lag behind the investments in other developed countries. Consequently, Slovenian researchers do not focus enough on achievements at the highest level, cooperation and exchange with the colleagues around the world, and the transfer of knowledge to industry. Instead, we spend a lot of time solving everyday difficulties. Sometimes we hear that the reason for this situation is the fact that not enough research results are transferred to industry. In reply to such claims, we should point out that the funds for cooperation between science and industry in Slovenia are almost non-existent, while more successful countries make most of their investments in this area.

Where can our researchers and those researchers active in industry find the means to work on joint projects? We also have to understand that creativity in science, as well as creativity in other areas, cannot be assessed only in terms of an immediate profit. Creativity is a long-term and sensitive process, fostering the development of both the individual and society; however, in order to succeed, scientists sometimes have to take actions that do not have an immediate practical value. Science has to develop on the basis of both creative freedom and the developmental needs of society. Without this freedom and without the responsibility to society, no progress is possible in science or in other areas. I am worried when I see that in Slovenia people wish to have better results, but they are not prepared to change the old ways of doing things. However, it seems that this is not only a Slovenian disease, as it is also to be found in many other parts of Europe.

In 2008 we celebrated the hundredth anniversary of the birth of the academician Anton Peterlin, the founder and first director of the Institute. The celebration took place on 25 September, and on the same day the book Anton Peterlin 1908-1993,
his life and work was published jointly by the Slovenian Academy of Sciences and Arts and our Institute. The book brings together facts about Anton Peterlin, physics and other sciences in Slovenia, the political events of the period concerned, and the setting up of the Jožef Stefan Institute. It is an important document that deserves our attention.

Following the vision of Anton Peterlin, I wish to point out that the Jožef Stefan Institute is not only a scientific establishment; it is also an important cultural centre that extends beyond the Slovenian ethnic borders. In particular, I would like to remind you that in the past year we presented Boris Pahor, when visiting the Institute, with the Institute’s award, celebrating his 95th birthday. Together with Drago Jančar and Boštjan Žekš, Boris Pahor took part in the Discussion about Creativity, which we organised at the end of September. Let me, for this reason, conclude with the words of this great humanist, esteemed writer, a man to whom the most influential authorities pay their respect: “May freedom finally come, the freedom that I have never experienced in my life. A freedom that is not mine, and so a feeling I do not know.”

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

1962
~ One of the first compounds of a noble gas, XeF₂, 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

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

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 Copic 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 EBDARBS beamline installed at the TANDETRON accelerator at the Microanalytical center

1985
- The beginnings of robotics at the JSI, in 1985

FORMER DIRECTORS

Prof. Anton Peterlin, Founder and first Director of the Jožef Stefan Institute, 1949–1955
Karol Kajfež, 1955–1958
Lucijan Šinkovec, B. Sc., 1959–1963
Prof. Milan Osredkar, 1963–1975
Prof. Boris Frlec, 1975–1984
Prof. Tomaz Kalin, 1984–1992
Prof. Danilo Zavrtanik, 1992–1996
Prof. Vito Turk, 1996–2005

Prof. Anton Peterlin, first Director of the Jožef Stefan Institute
ORGANISATION OF THE JOŽEF STEFAN INSTITUTE

BOARD OF GOVERNORS

DIRECTOR

SCIENTIFIC COUNCIL

RESEARCH DEPARTMENTS

Physics

Theoretical Physics (F-1)
  Prof. Stejščina Fajfer
Low and Medium Energy Physics (F-2)
  Asst. Prof. Matjaž Lipoglavšek
Thin Films and Surfaces (F-3)
  Dr. Peter Panjšen
Surface Engineering and Optoelectronics (F-4)
  Prof. Anton Zalar
Solid State Physics (F-5)
  Prof. Igor Muševič
Complex Matter (F-7)
  Prof. Dragan Dragojub Milhailović
Reactor Physics (F-8)
  Prof. Bogdan Glumac
Experimental Particle Physics (F-9)
  Prof. Marko Mikusić

Biochemistry, Molecular and Structural Biology (B-1)
  Prof. Boris Turk
Molecular and Biomedical Sciences (B-2)
  Prof. Igor Križaj
Biotechnology (B-3)
  Prof. Janko Kiso
Environmental Sciences (O-2)
  Prof. Milena Horvat

Electronics and Information Technology

Automation, Biocybernetics and Robotics (E-1)
  Asst. Prof. Leon Žlajpah
Systems and Control (E-2)
  Prof. Stanislav Šmrčnik
Open Systems and Networks (E-5)
  Prof. Borka Jerman Blazič
Communication Systems (E-6)
  Prof. Gorazd Kandus
Computer Systems (E-7)
  Prof. Franc Novak
Knowledge Technologies (E-8)
  Prof. Nada Lavec
Intelligent Systems (E-9)
  Prof. Matjaž Gams

Chemistry and Biochemistry

Inorganic Chemistry and Technology (K-1)
  Asst. Prof. Tomaž Štaplin
Physical and Organic Chemistry (K-3)
  Dr. Ingrid Milošev
Electronic Ceramics (K-5)
  Prof. Marija Kosec
Engineering Ceramics (K-6)
  Prof. Tomaž Kosmac
Nanostructured Materials (K-7)
  Prof. Spomenka Kobe
Synthesis of Materials (K-8)
  Prof. Darko Makovec
Advanced Materials (K-9)
  Prof. Danilo Suvorov

Reactor Techniques and Energetics

Reactor Engineering (R-4)
  Prof. Borut Mavko
Centre for Networking Infrastructure (CNI)
Vladimir Alkalaj, M. Sc.

Science Information Centre (SIC)
Dr. Luka Sutnerič

Energy Efficiency Centre (EEC)
Izvan Mersic, M. Sc.

Centre for Knowledge Transfer in Information Technologies (CT-3)
Mitja Jermol, M. Sc.

Milan Čopič Nuclear Training Centre (ICJT)
Prof. Igor Jenčič

Helium Liquifier with Superconducting Magnet and Helium Regeneration System
Milan Rožmarin, B. Sc.

Mass Spectrometry Centre
Dr. Bogdan Kralj

National Centre for Microstructure and Surface Analysis
Prof. Marija Kosec

Centre for Electron Microscopy (CEM)
Asst. Prof. Miran Ceb

Microanalytical Instrumental Centre (MIC)
Dr. Primoz Pelicon

National High Resolution NMR Spectroscopy
Prof. Janez Dolinsek

Centre for Protein Structure
Prof. Dušan Turk

PARTICIPATION IN REGIONAL DEVELOPMENT OF RESEARCH

University of Nova Gorica

Founders:
Jožef Stefan Institute
Nova Gorica Municipality

Ajdovščina Municipality

Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Ljubljana

Jožef Stefan International Postgraduate School

Founders:
Jožef Stefan Institute
Gorenje, Velenje

Kolektor Group, Idrija

Salonit, Anhovo

Slovenian Insurance Association, Ljubljana

Technology Centres

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

Security Technology Competence Centre (SETCCE)

Technology Centre for Circuits, Components, Materials, Technologies and Equipment for Electrotechnic (TC SEMTO)

Nanotesla Institute Ljubljana

Development Centre for Hydrogen Technologies
MANAGEMENT

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Director JSI
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Prof. Jurij Franc Tasić

Advisers
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Marta Slokan Butina, LL. B.

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Dr. Andreja Umeck Venturina, Ministry of Higher Education, Science and Technology
Prof. Boris Žemva, JSI

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Prof. Matjaž Gams
Prof. Milena Horvat, Deputy President
Prof. Nada Lavrač
Prof. Jadran Lenarčič
Prof. Andrej Likar, Deputy President
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Prof. Stanislav Strmčnik
Prof. Danilo Savorov
Prof. Vito Turk
RECIPIENTS OF THE JSI AWARDS AND TITLES

HONORARY MEMBERS

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Prof. Boris Frlec, Director of the Jožef Stefan Institute from 1975 to 1984
Prof. Robert Huber, Nobel Prize Winner, Max-Planck-Institut für Biochemie, Munich, Germany
Prof. Milan Ostreikar*, Director of the Jožef Stefan Institute from 1963 to 1975 (1939–2003)
Prof. Anton Peterlin*, Founder and First Director of the Jožef Stefan Institute from 1949 to 1955 (1908 - 1995)

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Zdravko Gabrovšek, B. Sc., Slovenia
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Milan Slokan*, M. Sc., Ljubljana, Slovenia
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Prof. Andrej Župančič, Slovenian Academy of Sciences and Arts, Ljubljana, Slovenia
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Prof. Dietrich Munz, Universität Karlsruhe, Karlsruhe, Germany
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Prof. Bernard Roth, Stanford University, Stanford, California, USA
Prof. John Ryan, University of Oxford, Oxford, United Kingdom
Prof. Volker Sörgel, Ruprecht-Karls-Universität, Heidelberg, Germany
Prof. H. Eugene Stanley, Boston University, Boston, Massachusetts, USA
Prof. Thomas Walcher, Universität Mainz, Mainz, Germany

INTERNATIONAL COOPERATION AGREEMENTS

In 2008, cooperation agreements were signed between the Jožef Stefan Institute and:

1. European Food Safety Authority (EFSA), Parma, Italy
2. Institute of Mathematics, Physics and Mechanics (IMPM), Ljubljana, Slovenia
3. Forschungszentrum Jülich GmbH, Jülich, Germany
4. The European Organization for Nuclear Research (CERN), Geneva, Switzerland
5. Argonne National Laboratory, Argonne, Illinois, USA
6. Korea Institute of Material Science (KIMS), Changwon, Korea
7. The Walter and Eliza Hall Institute of Medical Research, Parkville, Victoria, Australia
8. University Health Network, The Microarray Centre, Toronto, Ontario, Canada
9. University of Wollongong, Thermal Physiology Laboratory, Wollongong, Australia
10. Université Louis Pasteur, Laboratoire d’Imagerie et de Neurosciences Cognitives, Strasbourg, France
11. Kobe University, Faculty of Human Development, Laboratory for Applied Human Physiology, Kobe, Japan
12. University of Portsmouth, Human and Applied Physiology Laboratory, Portsmouth, Hampshire, Great Britain
13. National and Kapodistrian University of Athens, Faculty of Physical Education and Sport Science, Department of Sport Medicine and Biology of Exercise, Athens, Greece
14. Japan Advanced Institute of Science and Technology, Ishikawa, Japan
15. Cycorp, Inc., Austin, Texas, USA
16. The Korea Atomic Energy Research Institute (KAERI), Yuseong, Daejeon, Korea
17. Veneto Innovazione Spa, Venezia Marghera, Italy; Veneto Nanotech Scpa, Padova, Italy
# INTERNATIONAL COOPERATION

## Multilateral international cooperation

<table>
<thead>
<tr>
<th>No. of projects</th>
<th>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)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. FP - EURATOM</td>
<td>31</td>
</tr>
<tr>
<td>6. FP (LIFESCIHEALTH, IST, NMP, AERO, TREN, SPACE, FOOD, ENERGY, TRANSPORT, GLOBAL CITIZENS, SSP, NEST, SME, INCO, ERA-NET, MOBILITY, INFRASTRUCTURES, SCIENCE AND SOCIETY, RESEARCH/INNOVATION POLICIES)</td>
<td>68</td>
</tr>
<tr>
<td>IEE</td>
<td>1</td>
</tr>
<tr>
<td>CENTRAL EUROPE</td>
<td>1</td>
</tr>
<tr>
<td>LEONARDO DA VINCI</td>
<td>3</td>
</tr>
<tr>
<td>ECONTENTPLUS (PHEA)</td>
<td>3</td>
</tr>
<tr>
<td>Socrates / Minerva, Erasmus</td>
<td>1</td>
</tr>
<tr>
<td>Eureka</td>
<td>4</td>
</tr>
<tr>
<td>Cost</td>
<td>11</td>
</tr>
<tr>
<td>NATO (SIP, CLG, RIG)</td>
<td>4</td>
</tr>
<tr>
<td>IAEA</td>
<td>15</td>
</tr>
<tr>
<td>ESF (EMAR)</td>
<td>1</td>
</tr>
<tr>
<td>UNESCO-ROSTE</td>
<td>1</td>
</tr>
<tr>
<td>INTERREG</td>
<td>1</td>
</tr>
<tr>
<td>INTAS</td>
<td>1</td>
</tr>
<tr>
<td>ERA-NET (MATERA, MNT, SEE)</td>
<td>7</td>
</tr>
<tr>
<td>IFPPO</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>198</strong></td>
</tr>
</tbody>
</table>

## Bilateral cooperation

<table>
<thead>
<tr>
<th>No. of projects</th>
<th>Albania</th>
<th>Argentine</th>
<th>Austria</th>
<th>Belgium</th>
<th>Bulgaria</th>
<th>Bosnia and Herzegovina</th>
<th>Cyprus</th>
<th>Czech Republic</th>
<th>Montenegro</th>
<th>Denmark</th>
<th>Finland</th>
<th>France (PROTEUS - 11)</th>
<th>Croatia</th>
<th>Italy</th>
<th>Japan</th>
<th>China</th>
<th>Hungary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Albania</strong></td>
<td>1</td>
<td>2</td>
<td></td>
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DELEGATIONS AND VISITORS


Prof. Rado Bohinc, Rector University of Primorska, February 1 2008

Prof. Stane Pejovnik, Dean, Faculty of Chemistry and Chemical Technology 12 February 2008

Dr. Franc Gider, Director, Public Agency for Technology of the Republic of Slovenia, 26 February 2008

Dr. Andrej Stritar, Director, The Slovenian Nuclear Safety Administration, 7 March 2008

Delegation of the European Commission, 10 March 2008:
Dr. Janez Potočnik, Commissioner for Science & Research
Dr. Zoran Stančič, Deputy Director General of Research Directorate
Dr. Lino Barašao, Argentinean Minister for Science, 21 April 2008

Delegation of the Embassy of the United States of America, 8 May 2008:
H. E. Ms. Maryruth Coleman, Chargé d’Affaires a.i.
Ms. Susan M. Shultz

Prof. Bai He with delegation, Liaoning Cancer hospital, Shenyang, China, 12 May 2008

Ms. Katarina Kresal, president of Liberal democracy of Slovenia, 16 May 2008

Dr. Franci Demšar, Director Slovenian Research Agency, 19 May 2008

Korean delegation, 3 June 2008:
Dr. Lee, G. Brian Kim

Visit of participants of ministerial conference EUREKA 5 June 2008

Delegation of Government Office for Growth and Elaphe, d. o. o., 15 July 2008:
Dr. Žiga Turk, minister and representatives of Elaphe, d. o. o.

Dr. Chris Hull, 20 August 2008

Discussion about Creativity, 30 September 2008:
Mr. Boris Pahor
Prof. Boštjan Žekš
Mr. Drago Jančar

H. E. Ms. Ivana Hlavsova, Ambassador of the Czech Republic, 7 October 2008

Delegation of NATO, Research and Technology Agency, IST Panel, 16 October 2008

Visit of the Executive board of the Association of Europe’s specialised research and technology organisations (EARTO), 23 October 2008:
Prof. Erkki KM Leppávuori, president VTT, Finland, president of EARTO
G. Dirk-Meints Polter, vice-president, Fraunhofer, Germany, vice-president EARTO and others

Korean delegation, 30 October 2008:
Sang Sup Han, Korea Institute of Energy Research, Daejeon
Seong Hyeon Hong, Korea Institute of Materials Science, Daejeon
Hae Jin Kim, Korea Basic Science Institute, Daejeon

Delegation ETA Cerkno, d. d., 6 November 2008:
Mr. Zorko Golob, chairman of executive board with co-workers

Delegation of Korea Institute of Materials Science (KIMS), 20 November 2008:
Dr. Kim Byoung-Kee, president, Dr. Jeon Jae-Ho

Mr. Gregor Golobič, Minister for Higher Education, Science and Technology, 27 November 2008

ART EXHIBITIONS AT THE JSI

Martin Avsenik, 21 January–14 February 2008
Stefan Plancic, 25 March–17 April 2008
Stojan Kerbler, 21 April–12 May 2008
Rajko Čuber, 26 May–16 June 2008
Arjan Pregl, 16 June–14 July 2008
Beti Bricelj, 14 July–4 August 2008
Mateja Sever, 4 August–11 September 2008
Katja Rojaj, 15 October–9 October 2008
Lado Jakša, 13 October–6 November 2008
Silvester Plotajs-Sicoe, 10 November–4 December 2008
Stefan Marflak, 8 December–8 January 2009

Stefan Plancic at the opening of the exhibition of his work

Annual Report 2008
COOPERATION WITH UNIVERSITIES

FULL-TIME FACULTY MEMBERS

Professors
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2. Prof. Iztok Arčon, University of Nova Gorica
3. Asst. Prof. Irena Ban, University of Maribor, Faculty of Chemistry and Chemical Engineering
4. Prof. Janez Bonča, University of Ljubljana, Faculty of Mathematics and Physics
5. Prof. Ivan Bratko, Academican, University of Ljubljana, Faculty of Computer and Information Science
6. Prof. Milan Brumen, University of Maribor, Faculty of Education
7. Dean Cvetko, University of Ljubljana, Faculty of Mathematics and Physics
8. Prof. Bruno Cvikl, University of Maribor, Faculty of Civil Engineering
9. Prof. Mojca Čepič, University of Ljubljana, Faculty of Education
10. Prof. Martin Čepič, University of Ljubljana, Faculty of Mathematics and Physics
11. Prof. Janez Dolinšek, University of Ljubljana, Faculty of Mathematics and Physics
12. Prof. Irena Drevenšek Olenik, University of Ljubljana, Faculty of Mathematics and Physics
13. Prof. Mihael Drofenik, University of Maribor, Faculty of Chemistry and Chemical Engineering, Faculty of Medicine and Jožef Stefan International Postgraduate School, Ljubljana
14. Prof. Svjetlana Fajfer, University of Ljubljana, Faculty of Mathematics and Physics
15. Prof. Boštjan Golob, University of Ljubljana, Faculty of Mathematics and Physics
16. Prof. Bojan Golli, University of Ljubljana, Faculty of Mathematics and Physics
17. Asst. Prof. Tomaz Geyer, University of Ljubljana, Faculty of Electrical Engineering
18. Asst. Prof. Branko Kavšek, University of Primorska, Koper, ENSAIA, Nancy, France
19. Asst. Prof. Borut Paul Kersičevan, University of Ljubljana, Faculty of Mathematics and Physics
20. Prof. Juš Kocijan, University of Nova Gorica
21. Prof. Aleš Franc Kodre, University of Ljubljana, Faculty of Mathematics and Physics
22. Asst. Prof. Samo Korpar, University of Maribor, Faculty of Chemistry and Chemical Engineering
23. Prof. Janko Kos, University of Ljubljana, Faculty of Pharmacy
24. Prof. Samo Kralj, University of Maribor, Faculty of Education
25. Asst. Prof. Matjaž Kristl, University of Maribor, Faculty of Chemistry and Chemical Engineering
26. Prof. Peter Križan, University of Ljubljana, Faculty of Mathematics and Physics
27. Prof. Brígida Lenzarrič, University of Ljubljana, Faculty of Chemistry and Chemical Technology
28. Prof. Andrej Likar, University of Ljubljana, Faculty of Mathematics and Physics
29. Prof. Marko Mikuz, University of Ljubljana, Faculty of Mathematics and Physics
30. Prof. Igor Muševec, University of Ljubljana, Faculty of Mathematics and Physics
31. Prof. Slavko Pečar, University of Ljubljana, Faculty of Pharmacy
32. Prof. Rudolf Podgornik, University of Ljubljana, Faculty of Mathematics and Physics
33. Asst. Prof. Tomaz Podobnik, University of Ljubljana, Faculty of Mathematics and Physics
34. Asst. Prof. Dušan Ponikvar, University of Ljubljana, Faculty of Mathematics and Physics
35. Prof. Peter Prelovšek, University of Ljubljana, Faculty of Mathematics and Physics
36. Asst. Prof. Saša Prelovšek Komelj, University of Ljubljana, Faculty of Mathematics and Physics
37. Prof. Vladimir Ošlag, University of Maribor, Faculty of Organisational Sciences
38. Prof. Anton Ramšak, University of Ljubljana, Faculty of Mathematics and Physics
39. Prof. Metka Renko, University of Ljubljana, Faculty of Chemistry and Chemical Technology
40. Prof. Janez Seliger, University of Ljubljana, Faculty of Mathematics and Physics
41. Asst. Prof. Lea Spindler, University of Maribor, Faculty of Mechanical Engineering
42. Prof. Aleš Stanovnik, University of Ljubljana, Faculty of Electrical Engineering
43. Prof. Janez Štepnič, University of Ljubljana, Faculty of Mathematics and Physics
44. Prof. Saša Svetina, Academican, University of Ljubljana, Faculty of Medicine
45. Asst. Prof. Simon Širca, University of Ljubljana, Faculty of Mathematics and Physics
46. Prof. Žiga Šmit, University of Ljubljana, Faculty of Mathematics and Physics
47. Prof. Borut Štrukelj, University of Ljubljana, Faculty of Pharmacy
48. Prof. Jurij Franc Tasić, University of Ljubljana, Faculty of Electrical Engineering, University of Primorska, Koper
49. Asst. Prof. Tanja Urbanič, University of Nova Gorica
50. Asst. Prof. Nataša Vaupotič, University of Maribor, Faculty of Education
51. Asst. Prof. Darko Veberič, University of Nova Gorica
52. Prof. Danilo Zavrtanik, University of Nova Gorica
53. Prof. Marko Zgonik, University of Ljubljana, Faculty of Mathematics and Physics
54. Asst. Prof. Primož Žibernl, University of Ljubljana, Faculty of Mathematics and Physics
55. Prof. Marko Andrej Zupan, University of Ljubljana, Faculty of Chemistry and Chemical Technology
56. Prof. Boštjan Žekš, Academican, University of Ljubljana, Faculty of Medicine
57. Prof. Slobodan Žumer, University of Ljubljana, Faculty of Mathematics and Physics

Assistants and researchers
1. Dr. Marko Bračko, University of Maribor, Faculty of Chemistry and Chemical Engineering
2. Dr. Marijan Maček, University of Ljubljana, Faculty of Electrical Engineering
3. Dr. Tomaz Bejek, University of Ljubljana, Faculty of Mathematics and Physics
PART-TIME FACULTY MEMBERS

Professors
1. Asst. Prof. Milan Ambrožič, University of Ljubljana, Faculty of Computer and Information Science, University of Maribor, Faculty of Natural Sciences and Mathematics
2. Asst. Prof. Ljudmila Benedik, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Faculty of Mathematics and Physics and Jožef Stefan International Postgraduate School, Ljubljana
3. Asst. Prof. Anton Biasizzo, Jožef Stefan International Postgraduate School, Ljubljana
4. Prof. Robert Blinc, Academician, Jožef Stefan International Postgraduate School
5. Asst. Prof. Vid Bobnar, Jožef Stefan International Postgraduate School, Ljubljana
6. Prof. Marko Bohanec, University of Ljubljana, Faculty of Public Administration, University of Maribor, Faculty of Organisational Sciences, University of Nova Gorica and Jožef Stefan International Postgraduate School, Ljubljana
7. Prof. Vladimir Cindro, University of Ljubljana, Faculty of Natural Sciences and Technology
8. Prof. Leon Cizej, University of Ljubljana, Faculty of Mathematics and Physics
9. Asst. Prof. Uroš Cvelbar, Jožef Stefan International Postgraduate School, Ljubljana
10. Asst. Prof. Miran Ceh, University of Ljubljana, Faculty of Chemistry and Chemical Technology and Jožef Stefan International Postgraduate School, Ljubljana
11. Asst. Prof. Marko Čepin, University of Ljubljana, Faculty of Electrical Engineering
12. Prof. Milan Čerček, University of Ljubljana, Faculty of Mathematics and Physics and University of Maribor, Faculty of Civil Engineering
13. Prof. Marko Debeljak, University of Nova Gorica, ENSAIA, Nancy, France
14. Asst. Prof. Jure Demšar, University of Konstanz, Germany, Jožef Stefan International Postgraduate School, Ljubljana
15. Asst. Prof. Goran Dražič, Jožef Stefan International Postgraduate School, Ljubljana
16. Prof. Sašo Dizeroski, University of Nova Gorica and Jožef Stefan International Postgraduate School, Ljubljana
17. Prof. Borka Đonona Jerman Blažič, University of Ljubljana, Faculty of Economics, University of Maribor, Faculty of Criminal Justice and Security and Jožef Stefan International Postgraduate School, Ljubljana
18. Asst. Prof. Tomaz Erjavec, University of Nova Gorica, Jožef Stefan International Postgraduate School, Ljubljana
19. Asst. Prof. Andrej Filipčič, University of Nova Gorica
20. Asst. Prof. Bogdan Filipčič, University of Ljubljana, Faculty of Mechanical Engineering, Faculty of Computer and Information Science, University of Nova Gorica, Faculty of Engineering and Management, Jožef Stefan International Postgraduate School, Ljubljana
21. Prof. Matija Gams, University of Ljubljana, Faculty of Economics, Faculty of Computer and Information Science, Faculty of Arts, Jožef Stefan International Postgraduate School, Ljubljana
22. Asst. Prof. Marko Gerbec, Jožef Stefan International Postgraduate School, Ljubljana
23. Prof. Bogdan Glumac, University of Maribor, Faculty of Civil Engineering, University of Ljubljana, Faculty of Mathematics and Physics and University of Nova Gorica
25. Prof. Milena Horvat, Jožef Stefan International Postgraduate School, Ljubljana
26. Asst. Prof. Tomaz Javornik, Jožef Stefan International Postgraduate School, Ljubljana
27. Prof. Igor Jenčič, University of Maribor, Faculty of Civil Engineering, University of Ljubljana, Faculty of Mathematics and Physics
28. Asst. Prof. Robert Jeraj, University of Ljubljana, Faculty of Mathematics and Physics, University of Wisconsin, School of Medical Physics, Madison
29. Prof. Danijuričič, University of Nova Gorica, University of Maribor, Faculty of Logistics and Jožef Stefan International Postgraduate School, Ljubljana
30. Asst. Prof. Viktor Kabanov, Jožef Stefan International Postgraduate School, Ljubljana
31. Prof. Gorazd Kandus, University of Maribor, Faculty of Electrical Engineering and Computer Science and Jožef Stefan International Postgraduate School, Ljubljana
32. Prof. Monika Kapus Kolar, University of Maribor, Faculty of Electrical Engineering and Computer Science
33. Dr. Tomaz Kloubucar, University of Maribor, Faculty of Criminal Justice and Security
34. Prof. Spomenka Kobe, University of Ljubljana, Faculty of Natural Sciences and Technology, Jožef Stefan International Postgraduate School, Ljubljana
35. Asst. Prof. Robert Kocjančič, Jožef Stefan International Postgraduate School, Ljubljana
36. Prof. Branko Konitić, University of Nova Gorica
37. Asst. Prof. Dušan Kordić, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Jožef Stefan International Postgraduate School, Ljubljana
38. Asst. Prof. Peter Korosec, University of Primorska, Koper, Faculty of Mathematics, Sciences and Information Technologies; Faculty of Education Koper
39. Dr. Barbara Koroušič Seljak, Jožef Stefan International Postgraduate School
40. Prof. Marija Kosec, University of Ljubljana, Faculty of Natural Sciences and Technology and Jožef Stefan International Postgraduate School, Ljubljana
41. Prof. Tomaz Kosmac, University of Ljubljana, Faculty of Natural Sciences and Technology, Jožef Stefan International Postgraduate School, Ljubljana
42. Asst. Prof. Janez Kovač, Jožef Stefan International Postgraduate School, Ljubljana
43. Prof. Igor Krizaj, University of Ljubljana, Faculty of Chemistry and Chemical Technology, Biotechnical Faculty, Medical Faculty, Jožef Stefan International Postgraduate School, Ljubljana
44. Prof. Zdravko Kutnjak, University of Ljubljana, Faculty of Mathematics and Physics and Faculty of Mechanical Engineering, Jožef Stefan International Postgraduate School, Ljubljana
45. Prof. Gojmir Lahajnar, University of Ljubljana, Biotechnical Faculty
46. Prof. Nada Lavrač, University of Ljubljana, Faculty of Social Sciences, University of Nova Gorica, Jožef Stefan International Postgraduate School, Ljubljana
47. Prof. Jadrar Lenarčič, University of Ljubljana, Faculty of Electrical Engineering, University of Nova Gorica, Università degli studi di Bologna
48. Asst. Prof. Igor Lengar, University of Maribor, Faculty of Energy Technology
49. Asst. Prof. Matej Lipoglavšek, University of Ljubljana, Faculty of Mathematics and Physics
50. Asst. Prof. Darja Lisjak, Jožef Stefan International Postgraduate School, Ljubljana
51. Asst. Prof. Sonja Lojen, University of Ljubljana, Faculty of Natural Sciences and Engineering, University of Nova Gorica, School of Environmental Sciences and Jožef Stefan International Postgraduate School, Ljubljana
52. Prof. Darko Makovec, University of Maribor, Faculty of Chemistry and Chemical Engineering and Faculty of Medicine, Jožef Stefan International Postgraduate School, Ljubljana
9. Matej Gašperin, B. Sc., University of Nova Gorica
10. Dr. Andrej Goršek, University of Ljubljana, Faculty of Natural Sciences and Technology and Faculty of Mathematics and Physics
11. Dr. Dejan Gradisar, University of Ljubljana, Faculty of Electrical Engineering
12. Dr. Boštjan Jančar, Jožef Stefan International Postgraduate School, Ljubljana
13. Dr. Peter Jeglič, University of Ljubljana, Faculty of Chemistry and Chemical Technology and Faculty of Mathematics and Physics
14. Dr. Zvonka Jeran, University of Ljubljana, Biotechnical Faculty
15. Dr. Martin Klamšek, University of Ljubljana, Faculty of Mathematics and Physics
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22. Dr. Ingrid Milošev, University of Ljubljana, Faculty of Chemistry and Chemical Technology and University of Zagreb, Croatia, Faculty of Chemical Engineering and Technology
23. Dr. Rok Pestotnik, University of Ljubljana, Faculty of Mathematics and Physics
24. Dr. Boris Pukl, Faculty of Civil Engineering and Goodyear
25. Dr. Aleksander Rečnik, University of Ljubljana, Faculty of Natural Sciences and Technology, Jožef Stefan International Postgraduate School, Ljubljana
26. Petra Rogan, B. Sc., University of Maribor, Faculty of Civil Engineering
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32. Dr. Matjaž Vencelj, University of Ljubljana, Faculty of Mathematics and Physics
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34. Dr. Darko Vrečko, University of Nova Gorica
35. Dr. Andrej Zorko, University of Ljubljana, Faculty of Natural Sciences and Technology and Faculty of Chemistry and Chemical Technology
36. Anže Zupanc, B. Sc., University of Ljubljana, Faculty of Mathematics and Physics
37. Dr. Dušan Žigon, Jožef Stefan International Postgraduate School, Ljubljana
INSTITUTE COLLOQUIA

4 January 2008: Prof. Bruno Siciliano
PRISMA Lab, Università degli Studi di Napoli Federico II, Napoli, Italy
*Force and Visual Control for Physical Human-Robot Interaction*

9 January 2008: Dr. Alexei Y. Smirnov
Abdus Salam ICTP, Trieste, Italy
*Neutrinos: Discovering a New Physics World*

30 January 2008: Dr. Bojan O. Bosković
University of Cambridge, Cambridge in Meggitt Aircraft Braking Systems, Coventry, Great Britain
*Carbon Nanotubes: Synthesis and Applications*

13 February 2008: Prof. Philippe Mendels
University Paris-Sud 11 Orsay, France
*Novel States in Frustrated Antiferromagnets*

12 March 2008: Dr. Mark Pleško
Cosylab d. o. o., Ljubljana, Slovenia
*Cosylab: IJS spin-off that transformed into an international high-tech company*

25 March 2008: Prof. Ivan Bratko
University of Ljubljana, Faculty of Computer and Information Science and Jožef Stefan Institute, Ljubljana, Slovenia
*Computer analysis of chess champions*

26 March 2008: Prof. Igor Gregorič
Texas Heart Institute at St. Luke's Episcopal Hospital, Houston, USA
*Left ventricular assist devices in treatment of heart failure*

27 March 2008: Prof. Svjetlana Fajfer
University of Ljubljana, Faculty of Mathematics and Physics and Jožef Stefan Institute, Ljubljana, Slovenia
*Success and limitations of quantum chromodynamics*

28 March 2008: Dr. João da Silva
Directorate Converged Networks and Services, DG-INFSO European Commission, Belgium
*The Future of the Internet, Perspectives emerging from R&D in Europe*

9 April 2008: Miha Pavšek
Anton Melik Geographical institute, Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Ljubljana, Slovenia
*Snow avalanches in Slovenia*

7 May 2008: Dr. Viktor Kabanov
Jožef Stefan Institute, Ljubljana, Slovenia
*Magnetic quantum oscillations in 2D metals and metallic nanowires*

14 May 2008: Dr. Bojan Costnik
Temida d. o. o., Ljubljana, Slovenia and Jožef Stefan Institute, Ljubljana, Slovenia
*Bridge between science and practical applications: examples of modern technologies in computer applications*

11 June 2008: Dr. Alexandre Gloter
CNRS - University of Orsay, France
*Transmission electron microscopy for nanomaterial characterization, how far can we go?*

18 June 2008: Prof. Martin Frenz
Institute of Applied Physics, University of Bern, Switzerland
*Optoacoustic imaging, a promising technique for non-invasive diagnosis of cancer*

22 August 2008: Prof. Susan Trolier-McKinstry
Pennsylvania State University, USA
*Piezoelectric Thin Films for Sensors, Actuators, and Energy Harvesting*

3 September 2008: Prof. S. Fred Singe
Science & Environmental Policy Project, USA
*Nature, not human activity, rules the climate*

1 October 2008: Prof. Jean-Marie Dubois
Institut Jean Lamour, Ecole des Mines, Nancy, France
*Complex Metallic Alloys: Concept, Properties, and Perspective*

22 October 2008: Prof. Gregor Cevc
Idea AG., München, Germany
*The first approved nanotechnological therapeutic product: Direactin(R)*

12 November 2008: Andrej Detela
Jožef Stefan Institute, Ljubljana, Slovenia
*About the creativity on the way to innovation*

19 November 2008: Prof. Florentin Wörgötter
Bernstein Center for Computational Neuroscience, Göttingen, Germany
*Robots under Adaptive Neural Control*

11 December 2008: Asst. Prof. Primož Žiherl
University of Ljubljana, Faculty of Mathematics and Physics and Jožef Stefan Institute, Ljubljana, Slovenia
*A simple insight into the structure of cellular clusters*
FINANCING

REVENUES JSI* (€) AND NUMBER OF PROJECTS

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* Without financial revenues

POSTGRADUATES FINANCED BY ARRS**

1985-2008

**ARRS - Slovenian Research Agency
## JSI UNDERGRADUATE SCHOLARSHIPS 1977-2008

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**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  
**FPA** Faculty of Pharmacy, University of Ljubljana  
**FDV** Faculty of Social Sciences, 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  
**FS** Faculty of Mechanical Engineering, University of Ljubljana  
**EF** Faculty of Economics, University of Ljubljana  
**MF** Faculty of Medicine, 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
### COMPLETED THESIS UNTIL 2008

#### PhD Theses

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#### M. Sc. Theses

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**TOTAL** 791 829 1620
PUBLICATIONS

1995-2008

Original Articles indexed on the Web of Science

M. Sc. and Ph. D. Theses
AWARDS AND APPOINTMENTS

AWARDS MADE TO JSI RESEARCHERS BY THE REPUBLIC OF SLOVENIA

Zois Recognitions and Award of the Republic of Slovenia

Prof. Robert Blinc
Presented with the Zois Award for his lifetime achievements

Prof. Peter Križan
Presented with the Zois Award for his outstanding achievements in experimental particle physics

Asst. Prof. Denis Arčon
Presented with the Zois Recognition for his achievements in the field of solid-state physics

Dr. Gregor Dolanc
Presented with the Puh Recognition for automatic control of a steel-strip slitting line

INTERNATIONAL AWARDS TO JSI RESEARCHERS

Dr. Zrinka Abramović
L’Oréal-UNESCO fellowship, ‘For Women in Science’ award for 2008

Wu Aying, Paula M. Vilarinho, Andrei Kholkin, Dr. Janez Hole, Prof. Marija Kosec
Excellent Paper Award for contribution at the International Materials Research Conference (MRS), 9 Jun. 2008

Prof. Sašo Džeroski
ECCAI fellow – ECCAI award. Awarded by European Coordination Committee for Artificial Intelligence

Saša Kovačič
L’Oréal-UNESCO fellowship, ‘For Women in Science’ award for 2008

Prof. Igor Križaj
Elected to the post of Secretary of the European Section of the International Society on Toxicology (EIST) and a member of the Council of the IST

Prof. Igor Mekjavič
BORELLI medal for his Original Contribution to Space Medicine, granted by 2nd University of Napoli, Italy

Prof. Igor Muševič
Samsung-Mid-Career Award, Južna Koreja, International Liquid Crystal Society

The winners of the Jožef Stefan Golden Emblem Prize and their mentors

The Jožef Stefan Golden Emblem Prize presented to the following for doctoral theses with high impact:

Dr. Urh Černigoj, University of Nova Gorica,
Photodegradation of organic pollutants in aqueous solutions catalyzed by immobilized titanium dioxide: Novel routes towards higher efficiency

Asst. Prof. Peter Korosčec, Jožef Stefan International Postgraduate School and Jožef Stefan Institute
Stigmergy as an Approach to Metaheuristic Optimization

Dr. Rok Žitko, Faculty of Mathematics and Physics University of Ljubljana and Jožef Stefan Institute
Many-particle effects in resonant tunneling of electrons through nanostructures

The recipients of Zois awards and recognitions
Prof. Danilo Suvorov

Inauguration: Fellow of the American Ceramic Society, Board of Directors of the American Ceramic Society

Hana Ursič
Certificate of Award for Encouragement of Research in Materials Science for the contribution “Effect of Processing for CSD-derived LNO Seeding Layer on Electrical Properties of PZT Thin Film”, The IUMRS International Conference in Asia 2008

Asja Veber
Award for the best poster on conference YUCOMAT 2008, Herceg Novi, Montenegro, Awarding Committee of the YUCOMAT 2008 Conference
The Thickness, Morphology and Structure of Sol-Gel Bi$_{2}$SiO$_{5}$ thin films.

Asst. Prof. Primož Žiherl
Outstanding Referee (American Physical Society, 2008)

The award “European Regional Environment Champion 2008” was awarded to the Environmental Technologies Excellence Centre by the European Regional Champions Award Expert Panel.

AWARDS TO JSI RESEARCHERS BY SLOVENIAN INSTITUTIONS

Kristina Eleršič
Best poster award, 3rd European School in Materials Science of Complex Metallic Alloys, Surface and Coatings, “Damages and surface modification on bacteria Escherichia coli caused by plasma treatment” Ljubljana, Slovenia

Ita Junkar
Best poster award, Conference MIDEM, 44th International Conference on Microelectronics, Devices and Materials with the workshop on Advanced Plasma Technologies
Improvement of polymer properties by plasma treatment

Boštjan Kaluža
Faculty Prešeren award, Faculty of Computer and Information Science, Ljubljana, Bachelor thesis: Analysis of pathological models of minimax and Pearl’s game.

Katja Koenig
3rd Best Poster Award, HOT NANO TOPICS 2008, Workshop “Functional nanostructures and particles”
Influence of the suspension stability on the electrophoretic deposition of nanosized alumina and silica

Prof. Marija Kosec
Acknowledgement from Chamber of Craft and Small Business of Slovenia for extraordnary effort in the integration of science and business

Dr. Tadeja Kosec
Trimo research award for Ph.D. thesis 2008

Alja Kupec
Students Prešeren Award, B. Sc. thesis
Insulation of electrically conductive fibres

Aljoša Maglica
Award for the best lecture presentation among fellow researchers in the group for inorganic materials, 1st International Conference on Materials and Technology, sponsored by IUVSTA and FEMS

Prof. Slavko Pečar
Minarikovo acknowledgment, Slovenian Pharmacy Association

Asst. Prof. Uroš Petrovič
Lapanje prize of the Slovenian Biochemical Society for outstanding achievements in biochemical sciences

Katarina Rade
3rd Best nanoArt Contribution at the HOT NANO TOPICS 2008, for the nanoArt photo of the Hydroxyapatite precipitated from simulated body fluid on bio-glass substrate.Hungry Bacteria Was Here

Dr. Jerica Sabotič
Krka Award for Ph. D. thesis
Characterisation of mycocypins from selected basidiomycete species using genetic and protein engineering

Dr. Srečo D. Škapin
Award for the poster presentation, Hot Nano Topics 08, Portorož Slovenia, Photocatalytic undoped and doped nanotitania for building applications

Janja Zupančič
Student Prešeren Award for B. Sc. Thesis
Development and usage of gene construct for expression of heterolous proteins by using lactic bacteria

Prof. Natasa Vaupotič
The Silver Sign of the University of Maribor, University of Maribor, for the successful leadership of the Department of Physics, for innovative and successful work in the field of physics education and for top achievements in scientific research at the Faculty of Natural Science and Mathematics at the University of Maribor.

Mojca Zanidarič
Award for the best contribution of young researchers, 1st International Conference on Materials and Technologies, Portorož, Awarding Committee of the Conference The structural and electrical properties of a solid solution based on Na$_{x}$Bi$_{y}$TiO$_{3}$–K$_{x}$Bi$_{y}$TiO$_{3}$

Jožef Stefan Institute and Špica International d. o. o.
Award for placement among 30 selected innovations in 2008, Ljubljana, 3rd Slovenian Forum of Innovations, Public Agency of the Republic of Slovenia for Entrepreneurship and Foreign Investments
Device for intelligent entry control
# REVIEW OF PUBLICATIONS

## FOR 2008

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* Articles in Journals and Conference proceedings, and Chapters in books
PATENTS GRANTED

1. Processing of dense ceramics based on alkaline niobates and tantalates
   Janez Holc, Janez Bernard, Barbara Malič, Marija Kosec
   SI Patent No. 22380

2. Lead-perovskite-based thick-film structures on reactive ceramics and methods of production
   Janez Holc, Silvo Drnovšek, Marija Kosec
   SI Patent No. 22401

3. Scanning projection field emission microscope designed to study flat broad-area field emission cathodes
   Vincenc Nemanič, Marko Žumer, Bojan Zajec, Mihael Kocmur
   Patent No. 22425

4. Procedure for the synthesis of threadlike tungsten oxide \( \text{W}_4\text{O}_{11} \)
   Maja Remškar, Marko Viršek, Miha Kocmur, Adolf Jesih
   SI Patent No. 22445

5. Polarization-enhanced double-channel NQR/NMR detection of solid and liquid explosives with multi pulse sequences
   Robert Blinc, Zvonko Trontelj, Janko Lužnik, Tomaž Aplh, Janez Seliger, Gojmir Lahajnar
   SI Patent No. 22459

6. Polyester material with surface having antithrombogenic properties and a method for preparation
   Simona Strnad, Tea Indest, Janne Laine, Karin Stana-Kleinschek, Alenka Vesel, Renate Dworczak
   SI Patent No. 22467

7. A process for the synthesis of nanotubes and fullerene-like nanostructures of dichalcogenides transition metals
   Aleš Mrzel, Maja Remškar, Adolf Jesih, Marko Viršek
   SI Patent No. 22485

8. Procedure of synthesis of amidines and their derivatives
   Kristina Nadrah, Marija Sollner Dolenc, Slavko Pečar
   SI Patent No. 22487

9. Metamaterials and resonant materials based on liquid crystal dispersions of colloidal particles and nanoparticles
   Igor Muševič, Miha Škarabot, Slobodan Žumer, Miha Ravnik
   SI Patent No. 22508

10. Process for Applying Adhesion Coating to a Substrate
    Tomaz Kosmač, Kristoffer Krnel, Andraž Kocjan, Peter Jevnikar
    SI Patent No. 22527

11. Procedure of preparation of magnetic nanocomposites with high content of nanoparticles dispensed in polymer matrix
    Darko Mavovec, Sašo Gergcek, Miroslav Huscic, Mila Drofenik
    SI Patent No. 22539

12. Processing of alumina porcelain for electrotechnics
    Martina Oberzan, Janez Holc, Marjan Buh, Vlasta Imperl
    SI Patent No. 22541

13. High Contrast, Wide Viewing Angle LCD Light-Switching Element
    Janez Pirš, Matej Bažec, Sivija Pirši, Bojan Marin, Andrej Vrečko

14. Tool for measuring magnetic properties at high temperatures
    Paul J. McGuiness, Gregor Geršak, Spomenka Kobe
    Patent US7368906 B2

_Nanoparticles in air form nuclei for liquid condensation in a previous process. The droplets enter a dielectric field of a capacitor changing its capacitance and forming an electric signal. The method is suitable for detection of aerosols in a wide range of their concentration in air and is not specific for a shape or a chemical composition of nanoparticles._

_Title of patent application: Method and capacitance apparatus for aerosol nanoparticle counting
Inventors: Maja Remškar, Ivan Iskra, Marko Viršek (JSI), Mark Pleško, Damjan Golob (Cosylab, d. d.)
(published with permission of the authors)
CENTRES OF EXCELLENCE

Research Centres of Excellence, a concept developed by the Ministry of Higher Education, Science and Technology and co-financed by the European Regional Development Fund, are a new form of cooperation between research institutes, academic institutions, and industry. Their main goal is the development of an innovative environment to facilitate the transfer, management, and development of new technologies in various priority areas of research and technology. For the period 2004-2006, the Jožef Stefan Institute has been chosen as the coordinator of four Centres of Excellence, with twenty R&D projects.

Nanoscience and Nanotechnology

Head: Prof. Dragan Mihailović

Project Activity Group: (projects are cofunded by European Union):

1. Project for encouraging innovation, Measure 1.1.
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: LPKF, d.o.o., Žgornje Jezersko; Belinka Belles, d.o.o., Ljubljana; Iskra Feriti, d.o.o., Ljubljana; Keko Oprema, d.o.o., Žužemberk; MS Production, Bled; Iskra Mehanizmi, d.d., Kropa; Tek, d.d., Ljubljana; Acroni, d.o.o., Jesenice; Iskra Kondenzatorji, d.d., Semič; Vela Cerkno, d.o.o., Cerkno; Steklarna Hrašnik, d.d., Hrašnik; Steklarna Rogaška, d.d., Rogaška Slatina; HYB, d.o.o., Šentjernej; Balder, d.o.o., Ljubljana; Ginkarna Celje, d.o., Celje; AET, d.o., Tolmin; Kolektor Pro, d.o., Idrija; AtoTech, d.d., Podnart; Iskra Tela, d.d., Ljubljana; Predlnica Litiţa, d.o.o., Litiţa; Termo, d.d., Škofja Loka; Mo6, d.o.o.; National Institute of Chemistry, Ljubljana
   - Project leader: Slobodan Žumer

2. Synthesis of 1D Inorganic Nanostructures, Bionanostructures and Preparation of Composites
   - Project leader: Aleš Mrasel
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: Termo, d.d., Škofja Loka; Mo6, d.o.o., Ljubljana

3. Nanomaterials in Electrochemical Systems
   - Project leader: Janez Jamnik
   - Leading institution: National Institute of Chemistry, Ljubljana
   - Cooperating partners: AtoTech, d.d., Podnart; Iskra Tela, d.d., Ljubljana; Predlínca Litiţa, d.o.o., Litiţa; Jožef Stefan, Ljubljana; University of Ljubljana, Faculty of chemistry, Ljubljana; University of Maribor, Faculty of mechanical engineering, Maribor

4. Nanostructured Surfaces and Interfaces
   - Project leader: Igor Mušević
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: HYB, d.o.o., Šentjernej; Balder, d.o.o., Ljubljana; Ginkarna Celje, d.d., Celje; AET, d.o.o., Tolmin; Kolektor Pro, d.o.o., Idrija; HIPOT-RR, d.o.o., Šentjernej; University of Nova Gorica, Nova Gorica

5. Characterisation on a Nanometric Scale
   - Project leader: Miran Čeh
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: Tek, d.d., Ljubljana; Acroni, d.o.o., Jesenice; Iskra Kondenzatorji, d.d., Semič; Vela Cerkno, d.o.o., Cerkno; Steklarna Hrašnik, d.d., Hrašnik; Steklarna Rogaška, d.d., Rogaška Slatina; Institute of Metals Technology, Ljubljana; National Institute of Chemistry, Ljubljana

6. Synthesis of Nanoparticles and Nanocomposites
   - Project leader: Darko Makovec
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: Belinka Belles, d.o.o., Ljubljana; Institute of Metals and Technology, Ljubljana; National Institute of Chemistry, Ljubljana; Keko Oprema, d.o.o., Žužemberk; MS Production, Bled; Iskra Mehanizmi, d.d., Kropa; KOLEKTOR MAGMA, d.o.o., Ljubljana

7. Nanoelectronics and Nanotechnology Facilities
   - Project leader: Dragan Mihailović
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: LPKF Laser & Elektronika, d.o.o., Žgornje Jezersko; University of Nova Gorica

8. The Development of the Research Infrastructure of The Center of Excellence and Nanotechnology (CE NS and NT), Measure 1.4.
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: LPKF Laser & Elektronika, d.o.o., Žgornje Jezersko; National Institute of Chemistry, Ljubljana

Materials for Electronics of Next Generation and Other Emerging Technologies

Head: Prof. Marija Kovec

Project Activity Group:

1. Magnetic Materials and Intermetallic Alloys
   - Project leader: Spomenka Kobe
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: Institute of Metals and Technology, Ljubljana; Magneti, d. d., Ljubljana; Kolektor Magna, d. o. o., Ljubljana; Kolektor, d.o.o., Idrija.

2. Microstructures and Microsystems
   - Project leader: Janez Trontelj
   - Leading institution: University of Ljubljana, Faculty of Electrical Engineering, Ljubljana
   - Cooperating partners: Iskra Tela, d. d., Ljubljana; Iskra Avtoelektrika, d. d., Nova Gorica

3. New generation of Elements and Devices for Protection Against Transient Surges
   - Project leader: Slavko Bernik
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: Milan Vidmar Electric Power Research Institute, Ljubljana; Zavod TC SEMTO, Ljubljana; VARSI, d. o. o., Ljubljana; Iskra Zaščite, d. o. o., Ljubljana; University of Ljubljana, Faculty of Electrical Engineering, Ljubljana; Iskra Tela, d. d., Ljubljana

4. Hybrid Materials and Structures
   - Project leader: Janez Holc
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: HIPOT-RR, d. o. o., Šentjernej; HYB, d. o. o., Šentjernej

   - Project leader: Shubodan Žumer
   - Leading institution: Jožef Stefan Institute, Ljubljana
   - Cooperating partners: Gorčen, d. d., Velenje; Balder, d. o. o., Ljubljana; University of Ljubljana, Faculty of Mathematics and Physics, Ljubljana; Institute for Mathematics, Physics and Mechanics in Ljubljana, Laboratory for NQR and weak magnetic fields, Ljubljana

Annual Report 2008

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Environmental Technologies
Head: Prof. Milena Horvat

Project Activity Group:
1. Biological Methods of Wastewater Treatment
   **Leading institution:** University of Ljubljana, Faculty of Civil Engineering and Geodesy, Ljubljana
   **Cooperating partners:** University of Ljubljana, Biotechnical Faculty; University of Ljubljana, Faculty of Medicine; University of Nova Gorica; National Institute of Biology, Ljubljana; Institut za vodarstvo, d.o.o., Ljubljana; National Institute of Chemistry, Ljubljana; Komunalno podjetje Velenje, d.o.o., Velenje; Esotech, d.d., Velenje; RACI d.o.o., Ljubljana; LIMNOS – Company for Applied Ecology; d.o.o., Ljubljana; Lek farmacevtska družba d.d., Ljubljana; Fructal živilska industrija d.d., Ajdovščina; Javno podjetje Okolje Piran, d.o.o., Piran; Helios Domžale d.d., Domžale; Euroinvest, d.o.o., Nova Gorica; Saloni Anhovo gradbeni materiali, d.d., Anhovo; Cinkarna Celje, d.d., Celje.

2. Ecoremediation Technologies
   **Leading institution:** University of Ljubljana, Biotechnical faculty, Ljubljana
   **Cooperating partners:** Institute of Physical Biology, Grosuplje; University of Ljubljana; Slovenian Forestry Institute, Ljubljana; GSF - National Research Center for Environment and Health, Institut for Soil Ecology, Neuherberg, Germany; Community of Celje, Celje; EROIco, Environmental Research & Industrial Co-operation Institute, Velenje; Limnos – Company for Applied Ecology, d.o.o., Ljubljana; Nuclear Power Plant Krško, d.o.o., Krško; PV Invest, d.o.o., Velenje; Javno komunalno podjetje Canikova, d.o.o., Canikova; Komunalno podjetje Velenje, d.o.o., Velenje; Javno podjetje Centralna čistilna naprava Domžale-Kamnik, d.o.o., Domžale.

3. Recycling and Use of Waste
   **Leading institution:** Jožef Stefan Institute, Ljubljana
   **Cooperating partners:** University of Maribor, Faculty of Chemistry, Maribor; Esotech, d.d., Velenje; National Institute of Biology, Ljubljana; Domžale – Kamnik Wastewater Treatment Plant, d.o.o., Domžale; National Institute of Chemistry, Ljubljana; TKI Hranstnik, d.d., Hranstnik; TANIN Sevnica, Industry of Chemistry, d.d., Sevnica; Radenska d.d., Radenci.

Advanced Control Technologies
Head: Prof. Stanko Strmčnik

Project Activity Group:
1. Advanced Control Methods
   **Leading institution:** University of Ljubljana, Faculty of Electrical Engineering, Ljubljana
   **Cooperating Partners:** Jožef Stefan Institute, Ljubljana; Robotina d.o.o., Koper; Metronik, d.o.o., Ljubljana; Liko Pris, d.o.o., Vrhnika; Lek, d.d., Ljubljana; Domžale – Kamnik Wastewater Treatment Plant, d.o.o., Domžale

2. Automatic On-line Supervision of Processes and Product Quality Control
   **Leading institution:** Jožef Stefan Institute, Ljubljana
   **Cooperating partners:** Domel, d.d., Železniki; Telem, d.o.o., Maribor; FIS Research, d.o.o., Trzin;

3. Technologies of Distant and Distributed Control
   **Leading institution:** University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor
   **Cooperating partners:** Jožef Stefan Institute, Ljubljana; University of Ljubljana, Faculty of Electrical Engineering, Ljubljana; Inea, d.o.o., Ljubljana; Špica International, d.o.o., Ljubljana; Telem, d.o.o., Maribor

4. Decision Support for Control in Production
   **Leading institution:** Jožef Stefan Institute, Ljubljana
   **Cooperating partners:** University of Ljubljana, Faculty of Electrical Engineering, Ljubljana; University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor; Inea, d.o.o., Ljubljana; Domžale – Kamnik Wastewater Treatment Plant, d.o.o., Domžale; National Institute of Chemistry, Ljubljana; Syntace, d.o.o., Idrija.

5. Product Information Management through Complete Lifecycle
   **Leading institution:** University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana
   **Cooperating partners:** Domel, d.d., Železniki; Alpina, d.d., Žiri

6. Project Control in System of Orders
   **Leading institution:** University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana
   **Cooperating partners:** Eti Elektroelement, d.d., Izlake; Liv Plastika, d.o.o., Postojna
KNOWLEDGE TRANSFER

The JSI pay 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. Agenda, d. o. o., Maribor
2. Alpinoon, d.o.o., Ljubljana
3. Amebio, d. o. o., Kamnik
4. ARKO, Ljubljana
5. ATR, Computational Neuroscience Laboratories, Hikaridai, Seika-cho, Japan
6. Balder, d. o. o., Ljubljana
7. Biskis, d.o.o., Ljubljana
8. CEA - Commissariat à l’Énergie Atomique, Gif-sur-Yvette, France
9. CEMEON AG, Würselen, Germany
10. Cinkarna Celje, d. d., Celje
11. Dartmouth College, Hanover, USA
12. DESY - Deutsches Elektronen-Synchrotron, Hamburg, Germany
13. Druja Kolinska, d. d., Ljubljana
14. Elgo - line, d. o. o., Cerklje
15. EPICS OHR Ceramic Components Division, Deutschlandsberg, Austria
16. ESF - European Science Foundation, Strasbourg, France
17. ESOTECH, d. o. o., Velenje
18. European Commission, Brussels, Belgium
19. European Commission-Directorate General JRC, Brussels, Belgium
20. Gamma Meccanica S. p. A., Bibbiano, Reggio Emilia, Italy
21. Gen, d. o. o., Krško
22. Health Insurance Institute of Slovenia, Ljubljana
23. Heraklith Consulting & Engineering GmbH, Ferndorf, Austria
24. HFSPO-International Human Frontier Science Program Organization, Strasbourg, France
25. Hyb Proizvodnja hibridnih vezij, d. o. o., Šentjernej
26. IAEA - International Atomic Energy Agency, Vienna, Austria
27. Indukto, d. o. o., Ljubljana
28. INEA, d. o. o., Ljubljana
29. Institute of Oncology, Ljubljana
30. Instrumentation Technologies, d. d., Solkan
31. INTAS - International Association for the promotion of co-operation in science and technology from the New Independent States of the former Soviet Union, Brussels, Belgium
32. Intertent, d. o. o., Celje
33. IRMM - Institute for Reference Materials and Measurements, Geel, Belgium
34. Iskra Kondenzatorji Industrija kondenzatorjev in opreme, d. d., Semič
35. Iskra Začiščje, d. o. o., Ljubljana
36. JAPTI-Public Agency of the Republic of Slovenia for Entrepreneurship and Foreign Investments, Ljubljana
37. ARRS-Slovenian Research Agency, Ljubljana
38. Joanneum Research Forschungsgesellschaft mbH, Graz, Austria
39. Kolektor group, d. o. o., Idrija
40. Korea Basic Science Institute, Daejeon, South Korea
41. Kovimos, d. o. o., Horjul
42. Laboratory for Protection and Physiology, Empa, Materials Science and Technology, St. Gallen, Switzerland
43. LEK farmacevtska družba, d. d., Ljubljana
44. Lenisko, bvba, Antwerp, Belgium
45. L’OREAL – Moyens Communs Comptabilité Antenne G
46. Ministry of the Economy, Ljubljana
47. Ministry of Defence, Administration for Civil Protection and Disaster Relief, Ljubljana
49. Ministry of Environment and Spatial Planning, Slovenian Nuclear Safety Administration, Ljubljana
50. Ministry of Environment and Spatial Planning, Ljubljana
51. Ministry of Education and Sport, Ljubljana
52. Ministry of Higher Education, Science and Technology, Ljubljana
53. Ministry of Higher Education, Science and Technology, Metrology Institute of the Republic of Slovenia, Ljubljana
54. Ministry of Health, Ljubljana
55. Ministry of Health, Chemicals Office of the Republic of Slovenia, Ljubljana
56. Ministry of Health, Slovenian Radiation Protection, Ljubljana
57. Municipality of Ljubljana, Ljubljana
58. National Institute of Biology, Ljubljana
59. Nanotesa Institut Ljubljana, Ljubljana
60. NATO Public Diplomacy Division, Brussels, Belgium
61. Nederlands Normalisatie-instituut, Delft, Netherlands
62. Nevron, d. o. o., Ljubljana
63. Nuklearna elektrarna Krško, Krško
64. Österreichische Energieagentur - Austrian Energy Agency, Vienna, Austria
65. PAROC group oy AB, Vantaa, Finland
66. Phos, d. o. o., Sečovlje
67. PHOTONIS Netherlands B.V., Roden, Netherlands
68. PlasmaBull Engineering GmbH, Lebring, Austria
69. Prof. Dr. Erich Prunč, Graz, Austria
70. Royce & Bach, d. o. o., Celje
71. Rudnik živega srebra v zapiranju, d. o. o., Idrija
72. RZV, d. o. o., Gorenja vas
73. SCRI - The Scottish Crop Research Institute, Living Technology, Dundee, United Kingdom
74. Sint, d. o. o., Grosuplje
75. Sincrotrone Trieste S.C.p.A., Bazovica, Italy
76. SRC.si, d. o. o., Ljubljana
77. Steiklarna Hrastnik - Opal, d. o. o., Hrastnik
78. TELECOM & Management SudParis, Évry, France
79. Telekom Slovenije, d. d., Ljubljana
80. Telsima, d. o. o., Trzin
81. Termoelektrarna Toplarna Ljubljana, d. o. o., Ljubljana
82. The United Nations Environment Programme, Nairobi, Kenya
83. Trimo, d. d., Trebnje
84. TÜV Rheinland Immissionsschutz und Energiesysteme GmbH (TIE), Ljubljana
85. Urban Planning Institute RS, Ljubljana
86. University of Ljubljana, Faculty of Electrical Engineering, Ljubljana
87. University of Ljubljana, Faculty of Electrical Engineering, Ljubljana
88. University of Ljubljana, Faculty of Electrical Engineering, Ljubljana
89. USNRC - United States Nuclear Regulatory Commission, Washington, USA
90. VARSI, d. o. o., Ljubljana
91. WSL - Swiss Federal Research Institute, Birmensdorf, Switzerland
INSTITUTE IN NUMBERS
2004–2008

COMPARISON OF REVENUES (€M)

REVENUES FROM MARKET-BASED ACTIVITIES (€M)

REVENUES FROM PUBLIC SERVICES - PROJECTS ONLY (€M)

EMPLOYEES (FTE)

NUMBER OF PUBLICATIONS IN THE WEB OF SCIENCE

NUMBER OF CITATIONS
RESEARCH DEPARTMENTS
The research program of the Department of Theoretical Physics is focused on the theory of condensed-matter physics, statistical physics, the physics of nuclei, particles and fields, as well as biophysics and soft condensed-matter physics. The department also maintains its own high-performance computing facility, for which it develops the necessary software. These studies are carried out in close collaboration with several experimental groups at the Jožef Stefan Institute as well as with local and foreign universities and institutes. The department is also involved in various international projects.

The group of Theoretical Physics of Nuclei, Particles and Fields has investigated the structure of hadrons, the effective theories of weak and electromagnetic mesonic decays, the unified theory of elementary interactions, the relativistic theory of membranes and precise calculations of the properties of three-body systems in atomic physics.

We have derived a method for calculating the multi-channel K matrix applicable to a broad class of models in which mesons linearly couple to the quark core. A good agreement with experiment has been achieved for pion scattering in the energy region of the low-lying P11 and P33 resonances, assuming that the two-pion decay proceeds through the intermediate pion-Delta and sigma-nucleon channels.

The only hadronic states that have been confirmed beyond doubt are barions, composed of three quarks, and mesons, composed of a quark and an antiquark. There are several strong indications that the observed light scalar resonances might be non-conventional tetraquark states, composed of two valence quarks and two antiquarks. However, our lattice QCD simulations at $m_{\pi} > 40$ MeV give no indication of the existence of light scalar tetraquark states.

We have analyzed models of “beyond the Standard Model” physics, respecting the minimal flavour violation hypothesis in the effective theory approach. We have explored possible signals at the B and K meson factories, derived bounds on new physics contributions from existing measurements and gave suggestions for future experiments. In addition we have analyzed and emphasized the rare semileptonic decay $B \rightarrow \tau \nu$, which is sensitive to possible new-physics contributions and can be put under theoretical control with the combined application of heavy-quark effective theories, chiral theories and lattice QCD simulations. Therefore, it is suitable for precise studies at the LHCb experiment.

Recently, B-factories have published new results on the $B \rightarrow K \eta \gamma$ decays, being inspired by the theoretical suggestion to search for new physics in B meson decays to two pseudoscalar mesons and a photon. Using heavy-meson chiral perturbation theory we found a mechanism that governs the amplitude in parts of the Dalitz plot where either K or $\eta$ mesons are soft. The dominant contributions in these cases come from the nonresonant decay modes. We also discuss the $B \rightarrow K \eta \gamma$ Dalitz plot. Our partially integrated rates are in agreement with the experimental findings.

Together with our collaborators we have written a review article for Rev. Mod. Phys. on the searches for new physics at the future Super Flavor Factory. We have shown that even in two-body hadronic decays one can arrive at precise predictions for the interesting observables — we have shown this for the case of time-dependent asymmetries in the decays of neutral B mesons into a neutral kaon and a neutral pion. We have shown that the ratio of the Higgs production cross-section with a cut on the Higgs particles transverse momentum and the inclusive cross-section can be precisely predicted in the Standard Model. This is an interesting observable for light-resonance searches. We have also shown that with a two-component dark-matter model we can explain the large annihilation cross-sections indicated by the results of PAMELA and ATIC experiments.
We have constructed a supersymmetric model without gauge singlets that spontaneously breaks both supersymmetry and gauge symmetry. We have shown that the minimal supersymmetric unified SO(10) model can describe all fermion masses and mixings, if the sfermions are much heavier than the gauginos. The solution found implies a fast d=6 proton decay and a 13-neutrino mixing angle of 5 degrees.

We have investigated the unification of fundamental interactions and particles within the framework of a 16-dimensional space whose tangent space is the Clifford algebra Cl(1,3). The latter space is a vector space, whose elements can be rotated into each other by the action of the group SO(8,8), and over which we can generate a higher dimensional Clifford algebra Cl(8,8). A subspace of Cl(8,8) is the Lie algebra of the exceptional group E8, a possible unification group.

Using the quasilinearization method (QLM) for differential equations we calculated the energies of the harmonic oscillator with a power-type singular term (spiked oscillator) for small and large values of the spike coefficient. In this case even perturbation theory works with, at most, limited precision and only for certain values of the coefficient, while QLM yielded 20 significant digits with a few iterations.

The group for Solid-State Theory and Statistical Physics has been investigating the properties of relaxor ferroelectrics, complex networks and self-organised structures, thermodynamic and transport properties of spin systems, nanosystems and quantum dots as well as models of strongly correlated electrons that are relevant to novel materials.

Two types of relaxation processes occurring in dipolar glasses and relaxor ferroelectrics have been discussed. The first of these is based on the analogy with supercooled glass-forming liquids and involves cooperative reorientation of the dipolar degrees of freedom. The relaxation time diverges at the Kauzmann temperature, where the extrapolated entropy tends to zero. This process is applicable to dipolar glasses. The second process is due to the growth and percolation of polar nanoregions in relaxor ferroelectrics. In both cases the relaxation time diverges according to the Vogel-Fulcher law.

We have continued with our study of the statistical physics of complex systems and networks, and have applied the theory of networks to study the structure of nanoparticle films and its influence on the single-electron conductivity. We have also studied the collective dynamical behaviour and stability of complex networks using the coupled chaotic maps and have developed appropriate algorithms for the detection of “weighted” subgraphs in modular (computer-generated and real-data) networks.

We have continued our investigation of the dynamical properties of 1D spin systems, in particular of the spin and thermal transport in such systems. With the application of numerical methods it was shown for the anisotropic Heisenberg model with random local fields that interaction does not destroy localization and the absence of transport within the ground state. On the other hand, at finite temperatures all the systems reveal normal dissipative transport. The effects of localization were also observed using the tDMRG method. Prior to any realization is the development of the novel DMRG method for the dynamical properties of correlated systems at finite T. We studied the consequences of Dzyaloshinsky-Moriya interactions on the spin-spin correlations in the S=1/2 Heisenberg model on the Kagome lattice. We found that the out-of-plane DzJ>0.1 component spontaneously breaks the U(1) symmetry and stabilizes the coplanar configurations of the spins. The application to the ZnCu(OH)Cl3 compound was discussed. We also examined in simulations the ground-state configurations of dimeric and trimeric systems, which are realized on square and triangular lattices, when either two or three macro-ions are trapped in each external potential minimum. The bipartite orders of the checkerboard or stripe types were reported together with more complex quadripartite orderings.

Solutions of the models with correlated electrons coupled to lattice degrees of freedom represent one of the fundamental unsolved problems of modern solid-state physics. We have developed a new numerical method for calculating the physical properties of spin-lattice polaron in the t-J-Holstein model. Using this model in the strong electron-phonon coupling limit we were able to describe spectral properties of oxide superconductors in the low-doping regime. We have also analysed recent experimental data on inelastic neutron scattering in these compounds at low doping. In this regime the resonant peak is absent but another phenomenon, the E/T-scaling, is observed in a wide energy (E) and temperature (T) region. We explained why in nanostructures, e.g., oscillating molecules, the conductance can be drastically reduced simultaneously, by a drastic increase of the Kondo temperature.
have shown that the E/T-scaling is a direct consequence of the overdamped nature of excitations, accompanied by the freezing of the spin dynamic, which is manifested in the saturation of spin-spin correlations at low T. We continued the study of the Luttinger sum rule in correlated systems. On a convenient example of 1D spinless fermions it was shown that the sum rule is broken within the Mott-Hubbard insulator, whereby the deviation is diminishing in the vicinity of the metal-insulator transition.

Quantum-dot cellular automaton (QCA) is a processing platform based on interacting quantum dots. We presented a study that introduces adiabatic switching into the ternary QCA and employs the adiabatic approach to successfully solve the issues of elementary ternary QCAs. This opens up the possibility for a realistic design of logical gates. In this way we were able to identify different contributions to the binding energy. The results were compared to the properties of nanowires, measured in the Department of Complex Matter of the JSI.

The group of Theoretical Biophysics and Soft Matter Physics focused on polyelectrolytes, liquid crystals, colloids, and phospholipid and biological membranes

Our efforts in the field of the physics of intermolecular interaction in biological systems are focused on studies of electrostatic and van der Waals forces. We investigated the effects of screening in dilute Na-DNA solutions. We showed that due to the electrostatic interactions, DNA molecules may collapse and form clusters. We analyzed the electrostatic interactions in the strong coupling limit in the presence of dielectric inhomogeneities, the weak and strong limits of electrostatic interaction between asymmetrically charged planar surfaces, ionic-cloud distribution close to a charged surface in the presence of salt, and the disorder and collapse of like-charged macroions. We also studied the van der Waals forces between carbon nanotubes and the packing of RNA in viral capsids.

We explored the phase diagram of colloidal molecular crystals and identified macroscopic structures stabilised by the internal molecular degrees of freedom. We studied the phonon spectra of 2D colloidal crystals and evaluated the wave-vector dependence of friction, which is caused by hydrodynamic interactions. We studied the bilayer structure in bent-core liquid crystals using both theoretical and experimental methods. We showed that the bilayer structure may result either from an asymmetric structure of the constituent molecules or from the general tilt structure.

We studied the structure of aggregates of simple cells and we showed that cell elasticity strongly affects the aggregate topology, simplifying it considerably in the moderate adhesion regime. We investigated the effect of the shape of a cell doublet on the formation of multicellular aggregates of red blood cells. We found that the rouleaux formation is expected whenever the outer doublet surfaces are either concave or flat, whereas in the strong-adhesion regime where the outer doublet surfaces are convex the cells should form rounded clump-like aggregates. We also explored the structure of layered tissues such as epithelia. We developed the equilibrium model of single-layer epithelia, whose three distinct solutions - disordered, hexatic, and hexagonal phase - are all observed experimentally. In a chapter in the monograph The Golgi Apparatus - State of the art 110 years after Camillo Golgi’s discovery we discussed the geometry of organelles of the secretory pathway.

We used the model of airway smooth-muscle contraction to study the enzyme Rho kinase’s action on calcium-dependent force development. In the model, explicit consideration of the mutual interaction between enzymes Rho kinase and myosin light-chain phosphatase was taken into account. We simulated the effect of the Rho kinase blockade and we showed

We proposed a theory of packing of DNA in bacteriophages and a theory of the self-assembly of RNA viruses.
that the enzyme blocker acts as a phosphatase activator, which leads to the relaxation of muscles during a cholinergic stimulation. This important conclusion was verified experimentally by our collaborators from Bordeaux.

Our work included experimental and theoretical studies of physical phenomena that may improve the teaching practice in elementary and high schools. In particular, we explored two examples of everyday phenomena that can make school children more interested in science: the three-dimensional caustic networks, which can easily be observed in water, and the lensless sharpening of sight.

Some outstanding publications in the past three years

**Theoretical Physics of Nuclei, Particles and Fields**

**Solid-State Theory and Statistical Physics**

**Theoretical Biophysics and Soft Matter Physics:**

**Awards and appointments**
1. Prof. Dr. Nataša Vaupotič, The Silver Sign of the University of Maribor, University of Maribor, for the successful leadership of the Department of Physics, for innovative and successful work in the field of physics education and for top achievements in scientific research at the Faculty of Natural Science and Mathematics at the University of Maribor.

**Organization of conferences, congresses and meetings**
1. Few-Quark States and the Continuum, Bled, Slovenia 15–22 Sept. 2008

**INTERNATIONAL PROJECTS**

1. Minimal Grand Unified Theory
   - Must
   - Marie Curie
   - 6. FP, MIF1-CT-2006-049017
   - EC
   - Asst. Prof. Borut Bajc
   - NoMag
   - 6. FP, 035980
   - Prof. Peter Prelovšek
3. Multifunctional-Ceramic Layers with High Electromagnetoelastic Coupling in Complex Geometries
   - Multiceral
   - 6. FP, NMP3-CT-2006-052616
   - EC, Prof. Andrei Kholkin, University of Aveiro, Department of Ceramics & Glass Engineering, Aveiro, Portugal
   - Prof. Raša Pirc, Prof. Robert Blinc, Prof. Marjia Kosec, Dr. Janez Holč
4. Fundamentals of Nanoelectronics
   - RtnNano
   - 6. FP, MRTN-CT-2003-504574
   - EC, Lancaster University, Lancaster, Great Britain
   - Prof. Anton Ramišek
5. Unifying Principles in Non-equilibrium Pattern Formation
   - Patterns
   - 6. FP, MRTN-CT-2004-005728
   - EC, The University of Nottingham, Nottingham, Great Britain
   - Prof. Bosiljka Tadić
6. Emergent Behaviour in Correlated Matter
   - Cost P16
   - EC
   - Prof. Peter Prelovšek
7. Colloidal Molecular Crystals
   - Cristaux colloidaux moleculaires
   - Proteus 2008 – 2009
   - Br-FR/08-09-PROTEUS-012
   - Prof. Emmanuel Trizac, Laboratoire de Physique Théorique et Modèles Statistiques, Université Paris Sud, Orsay Cedex, France
   - Dr. Jure Dobnikar
VISITORS FROM ABROAD

1. Dr. George Giavasis, Department of Physics, Lancaster University, Lancaster, Great Britain, 7 Jan. to 26 Apr. 2008
4. Dr. Jure Zupan*, Asst. Prof. Simon Širca
5. Dr. Alejandra Lucero Melfo Prada, left 16 Jan. 2008
6. Prof. Svjetlana Fajfer*
7. Prof. Nataša Vaupotič*
8. Dr. Igor Vilfan
9. Dr. Tomaz Rejec*
10. Dr. Maja Pavičič

STAFF

Researchers

1. Asst. Prof. Biorat Rijč
2. Dr. Oktor Slaven Baršič
3. Prof. Janez Bočna*
4. Prof. Milan Brunner*
5. Prof. Mojca Čepič*
6. Dr. Jure Dohlerš

8. Prof. Svjetlana Fajfer*, Head

9. Prof. Alois Fajnut*
10. Prof. Bojan Golli*
11. Prof. Mojca Čepič*
12. Dr. Aleksandar Mulev Mijoč Prade, left 16 Jan. 2008
13. Dr. Matej Pavičič

RESEARCH PROGRAMS

1. Theoretical physics of nuclei, particles and fields
2. Theory of condensed matter and statistical physics
3. Biophysics of polymers, membranes, gels, colloids and cells

R&D GRANTS AND CONTRACTS

The annual report of the Department of Theoretical Physics from 2008 contains information about visiting researchers from abroad and the staff members of the department. The report also includes details about research programs and grants and contracts related to various fields of theoretical physics.
BIBLIOGRAPHY

ORIGINAL ARTICLES


30. Dr. Jernej Fesl Kamenik

31. Dr. Kristjan Haule

32. Dr. Anita Prelovšek

33. Dr. Michael-Atzal Zemljic


35. Ana Hočovar, E. Sc.

36. Matej Kačuk, B. Sc.

37. Jure Kokalj, B. Sc.

38. Miha Nemevšek, B. Sc.

39. Lev Vlvid, B. Sc.

40. Nejc Košnik, B. Sc.

41. Zoran Levnajić, M. Sc., left 1 Sept. 2008

42. Jernej Mravlji, B. Sc.

43. Borut Bajc, "Supersymmetry breaking", In: Jožef Stefan Institute


TEXTBOOKS AND LECTURE NOTES


THESIS

Ph. D. Theses


B. Sc. Theses


The F-2 department conducts basic and applied research in low- and medium-energy physics. The low-energy physics relates to our atomic physics research, while the nuclear physics studied at the department can be classified as intermediate-energy physics. The third research field of the department is radiological environmental protection, which includes monitoring nuclear objects and environmental radioactivity. The department also operates the Ecological Laboratory with a mobile unit as a specialized civil protection unit.

In the A1 collaboration at MAMI, Mainz, Germany, we have performed the second part of the measurements of the electric form-factor of the neutron during large momentum transfers. A polarized 3He target was used and a double-polarization asymmetry was measured. The asymmetry is proportional to the interference of the poorly known electric, and the relatively better known magnetic, form-factor. A part of the experimental program has been devoted to the measurement of charged-pion electro-production in the vicinity of the threshold. The purpose of these experiments is a precise extraction of the axial form-factor of the proton. We have been developing a prototype Cherenkov counter for the K4OS spectrometer, based on an aerogel radiator. In the initial test measurements the absorption and scattering length were examined, as well as the various options for the internal geometries of the detector.

At the Jefferson Laboratory, in the framework of the Hall A Collaboration, we have performed a first set of experiments on neutral-pion electro-production at the threshold. The measurement is expected to deliver vital information in the E0+ and L0+ electro-production s-wave amplitudes and the corresponding partial cross-sections, which at low energies and low momentum transfers represent an important testing ground for the effective theory of quantum chromodynamics, the chiral perturbation theory. In the Hall C Collaboration, the measurements of the ratio of electric-to-magnetic proton form-factor have been extended to momentum transfers of up to 10 GeV². The focal-plane polarimetry technique has been used to determine the ratio of the elastic recoil proton polarization components. We have performed a measurement of the transverse polarized (quark) structure functions in the neutron by using a transversely polarized 3He target (polarization perpendicular to the scattering plane). Numerous data analyses from previous years have been completed. Selected results are given in the papers R. Subedi et al. (Hall A Collaboration), *Science* 320 (2008) 1476; E. Geis et al. (BLAST Collaboration), *Phys. Rev. Lett.* 101 (2008) 042501; P. Janssens et al. (A1 Collaboration), *Eur. Phys. J. A* 37 (2008) 1.

Work in the low-energy physics part of the F-2 department was mainly driven by the research programme “Study of atoms, molecules and structures with photons and particles” (P1-0112) and two projects which are running within the frame of the Slovenian Fusion Association (EUROTOM-MHEST). Basic and applied research was performed at home, mainly at the Microanalytical Infrastructure Center (MIC), and abroad, most frequently at different synchrotron labs in Europe, where we have conducted research on our own projects and done some work in collaborations, too.

In collaboration with the group of prof. P. Lambropoulos from IESL, Heraklion, Crete, we have modelled the two-photon inner-shell ionization of noble gases. We have also calculated the electron spectra that are emitted upon the photoexcitation of the metastable He states 1s2s 1S in the region of doubly excited states below the N=2 ionization threshold. With the group of prof. P. Paripas from the Physics Department at University of Miskolc and the Institut Atomki in Debrecen, Hungary, we have measured interference effects in the (e,2e) reaction close to the Ar 2p threshold.

At the XAFS beamline (Elettra) we have measured the absorption spectra of some simple molecules and performed high-resolution x-ray spectrometry to determine the Coster-Kronig coefficients for the decay of the Xe 2p1/2 and 2p3/2 holes. At ID26, the ESRF beamline, we measured high-resolution x-ray spectra in April 2008 for three weeks. We have employed our own high-resolution spectrometer, optimized for the study of low-density targets to record the

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**DEPARTMENT OF LOW AND MEDIUM ENERGY PHYSICS F-2**

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**Figure 1:** Calculated (solid lines, M.G. Makris, P. Lambropoulos and A. Mihelíc) and measured (points, Sorokin et al., *Phys. Rev. Lett.* 99, 23002, 2007) averaged ionisation signal produced by exciting ground-state xenon atoms with a 10 fs free-electron laser pulse with photon energy of 93 eV. The signal pertaining to different ionic species Xe⁺ᵢ, is labelled with i. The unaveraged single-atom signal is plotted with dashed lines.
high-resolution x-ray resonant Raman spectra in the vicinity of S and Cl K-thresholds for simple molecules (HCl, H2S), liquids (CuSO4·5 H2O) and solid targets (S-containing minerals, BaS, crystals).

With its successful projects, the Laboratory for X-Ray Absorption Spectroscopy gained collaboration beamtime at three synchrotron facilities: Elettra, Trieste (beamline XAFS, 18–22 March), ESRF in Grenoble (beamline BM29, 30 Sept. to 10 Oct.) and Hasylab, DESY Hamburg (beamline C, 13–20 Oct.). Within the allotted beamtime we provided access to advanced analytic technologies with synchrotron light to a number of collaborating laboratories in Slovenia and abroad. In the 3-year project ‘XAS analysis of transition metals in lead-free piezoelectric thin films and in catalysts based on porous silicates’ (II-20080058 EC) at Hasylab we performed structural analyses of new, mesoporous catalysts, doped with the transition metal Mn, and Ti, and of the ferroelectric materials K(Ta0.6Nb0.4)O3, Pb(Mg0.33 Nb0.67)O3 and thin films CaCu3Ti4O12, together with their precursors, in collaboration with groups from the Institute of Chemistry, Ljubljana, and from the K-5 department of the JSI, respectively. In another multilateral collaboration with the Faculty of Biotechnology of the University of Ljubljana, the Universidad Autonoma de Barcelona, Spain, and Université de Louvain, Belgium, the binding of the metals Cd, Zn and Pb in the hyperaccumulating plant Thlaspi praecox was studied at ESRF. A similar bioavailability study of As and Pb in the contaminated soil from the region of Mežica was carried out in a collaboration with the Jožef Stefan Institute.

In 2008, several studies were completed with publications, among them most notably the absolute determination of the K-edge atomic absorption in monatomic iodine vapour, with the analysis of the thermal dissociation of I2 at Institute of Chemistry. At Elettra, an in-situ x-ray absorption study of the structural and valence changes during the charging and discharging of new, nanostructured cathode materials, Li1+xFe1−xMn1−yTiO4, and of the ferroelectric materials Li1+xFe1−xMn1−yTiO4, for Li-ion batteries was implemented, to elucidate the electrochemistry of batteries and to optimize their capacity. The cathode materials were also studied in-situ using Moessbauer spectroscopy.

In surface physics we have studied the ultrafast charge-carrier dynamics and excited charge delocalisation at hybrid organic interfaces – PTCDA/Au, Ca-phtalocyanine/Au and hybrid PTCDA/CaPc sandwiched layers – relevant for photovoltaics and molecular electronics. This has been studied with X-ray absorption and resonant photoemission at the ALOISA beamline (Elettra synchrotron, D.Cvetko, Elettra beamtime proj. ID. 2008401). The identity of the occupied wavefunctions at the Fermi level of the hybrid PTCDA/Au interface has been determined, which evidenced the metallic nature of the monolayer PTCDA/Au film. Also, the spontaneous self-assembly process of L-methionine aminoacid molecules on weakly interacting substrates like Ag and Au(111) has been studied and observed to proceed via the zwitterionic coupling into dimers with lateral H-bonding to form extended linear chains, capable of mesoscopic 2D organisation into tunable biomolecular nanogratings. The deprotonation of carboxylic and the protonation of amino functional groups represent the key molecular-recognition mechanism in the case of a negligible functional interaction with the substrate. The detailed chemical, long-range order and orientational geometry properties have been examined on Ag, Au and Cu(111) substrates.

We continued our work on the development of the spectrometer of vibrationally excited hydrogen molecules, with an emphasis on the extraction system of negative ions and published a paper about its operation. With the ERDA ion method we measured the depth profile of hydrogen in tungsten, tantalum and copper during controlled exposure of the samples to hydrogen atoms at different sample temperatures. The vibrational temperature of the excited molecules H2 and D2 produced in the extraction system of negative ions and published a paper about its operation. With the ERDA ion method we measured the depth profile of hydrogen in tungsten, tantalum and copper during controlled exposure of the samples to hydrogen atoms at different sample temperatures. The vibrational temperature of the excited molecules H2 and D2 produced in the recombination of H and D atoms on a cold tungsten surface was determined and new data about the dissociative electron attachment to H2 and D2 in the ground state were obtained.

A measuring station with a high-energy focused ion beam has been reconstructed and long measuring cycles were performed with micro-
PIXE and STIM for the analysis of the elemental distributions in plant and animal tissues. In collaboration with the Laboratory for Plant Physiology of the Biotechnical Faculty, University of Ljubljana (UL) and prof. Herrman Bothe from the University of Cologne, the elemental distribution in roots of Viola Calaminaria and Viola Westfalica were measured and the results were accepted for publication in the book *Symbiotic Fungus: Principles and Practice* by Springer-Verlag. Research on wound recovery in tree tissue has been completed in collaboration with the Dept. of Wood Science and Technology, UL. The intake of nanoparticles in animal tissue and the uptake of heavy metals in cereals were studied together with the Biotechnical Faculty, UL. A study of the uranium uptake in plant tissues was initiated and started together with the Belgian Nuclear Research Centre, Mol. In the frame of a bilateral collaboration with Tohoku University, Sendai, Japan, micro-PIXE was used to study the aerodynamic separation of atmospheric nanoparticles and the studied aerosol samplers were tested in a working environment with an increased concentration of nanoparticles. We have published our results about the 3D imaging of an aerosol sample with the confocal micro-PIXE method. In collaboration with an industrial partner, micro-ERDA with a focused `Li beam was used to measure the hydrogen concentration in titanium alloys.

**Some outstanding publications in the 2008**


**Organization of conferences, congresses and meetings**

1. Dr. Mark Pleško, Cosylab d.d., Ljubljana, Slovenia: Cosylab Co.: spin-off of IJs, international Co., Seminar on IJS, 13 Mar. 2008

2. Prof. Zdeněk Herman, J. Heyrovský Institute of Physical Chemistry, Prague, Czech Republic: Interaction of slow ions with surfaces, 3 Apr. 2008


4. Dr. Marc Simon, Université Pierre et Marie Curie, Paris, France:RIXS on Chlorinated Molecules in the Tender X-ray Region, 9 Oct. 2008

**INTERNATIONAL PROJECTS**


4. GammaGuru – Efficiency and True Coincidence Summing Corrections Calculation in Gamma Ray Spectrometry of Environmental Samples Benchmarking Calibration for Low-Level Gamma Spectrometric Measurements of Environmental Samples 14894 IAEA, Vienna, Austria Dr. Tim Vidmar 5. Holder for Annular Source, including Pure Sn Collimator, to fit a Si(Li) Detector RAF0023-9283OL IAEA, Vienna, Austria Dr. Peter Kump 6. Improvement of the XRF Quantification and Enhancement of the Combined Applications by EXIF and Micro-PIXE 13858/RBF, RO, R1 IAEA, Vienna, Austria Dr. Peter Kump 7. Optimization of Portable X-ray Fluorescence Analyzer (XRF) System and Procedures for In situ Analysis of Environmental Samples and Archaeological Objects BI-AL/06-09-003 Asst. Prof. Cosci Nikola, Institute of Nuclear Physics, Tirana, Albania Dr. Peter Kump 8. Material Analysis of the Objects of Cultural Heritage from the Slovenian and Albanian Area BI-AL/06-08-001 Prof. Aferdita Vevecka-Priftaj, Polytechnic University Tirana, Tirana, Albania Prof. Ziga Smit
9. Novel Detection Techniques in pulsed Coincidence Experiments
   BI-FRO-PROTEUS-010
   PROTEUS
   Dr. Francis Penent, Lab de chimie physique matiere et rayonnement CNRS, Unite UMR, Paris Cedex, France
   Asst. Prof. Marjál Zitnik

10. Convention de mise à disposition
    Contract between CNRS and JSI, dated 27.5.2004
    Dr. Paul Indelicato, Laboratoire Kastler-Brossel (LKB - UMR 8552), Ecole normale superieure, Paris Cedex, France
    Dr. Istok Cadžek

11. XAS Studies of Ti, V, Mn and Fe Local Environment in Hierarchical Porous Catalysts
    ELETRA Project Number 2007:556
    Luca Olivi, Sincrotrone ELETTA, Trieste, Italy
    Prof. Istok Arčon

12. Applications of Ion Beam Technology to Environmental Research
    BN/JPN-07-09-02
    Dr. Inhi Keizo, Department of Quantum Science and Energy Engineering, Tohoku University, Sendai, Japan
    Asst. Prof. Primož Pelicon

13. Calculation of Efficiencies and True Coincidence Summing Corrections for Environmental Gamma-ray Spectrometry
    BR/07-08-085
    Dr. Sándor Sudár, University of Debrecen, Institut za eksperimentalno fiziko, Debrecen, Hungary
    Prof. Andrej Lukar

14. Development and support of Java applications for use in DESY accelerator control
    Attachment #7
    Dr. M. Claussen, DESY (Deutsches Elektronen Synchrtron), Hamburg, Germany
    Dr. Mark Pleisk, Asst. Prof. Matej Lipoglavšek

15. Optimalna digitalna analiza spektroskoških sunkov
    Hi-Light Agreement
    Hi-Light, Opto Electronics BV, Tolbert, The Netherlands
    Dr. Matjaž Venclo

16. Quark Models for Meson Electroproduction
    Models of quarks for eleetroproduco de meses
    BI-PET/08-09-012
    Prof. Maxuel Fiolhais, Physics Department, University of Coimbra, Coimbra, Portugal
    Asst. Prof. Simón Siča, Prof. Rejan Golli

17. Nucleon Resonances in Chiral Models
    BI-PET/06-07-005
    Prof. Maxuel Fiolhais, Physics Department, University of Coimbra, Coimbra, Portugal
    Asst. Prof. Simón Siča, Prof. Rejan Golli

18. Quantum Mechanics of Nuclear Radiative Capture Models based on Optical Potential
    BI-SK/05-07-003
    Asst. Prof. Emil Betak, Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia
    Prof. Andrej Lukar

19. Electron induced Fragmentation of Organic Molecules and Small Hydrocarbons
    Fragmentacjan organicznych molekul i mal³ u¿ytozku u¿runku elektronow uzdaru
    BR-BS/08-09-028
    Prof. Aleksandar Milosavljevic, Institut za fiziku, Zemun, Serbia
    Dr. Istok Cadžek

20. Studies of Parity Violation in H/He and Electromagnetic Structure of the Deuteron
    BI-UUS/06-07-048
    Gidal Shalev, Massachusetts Institute of Technology (MIT), Cambridge, MA, USA
    Asst. Prof. Simón Siča

R &D GRANTS AND CONTRACTS

1. Electron screening in metals and alloys
   Asst. Prof. Matej Lipoglavšek

2. Fusion relevant research of plasma interactions with surfaces
   Prof. Milan Čerček, Asst. Prof. Primož Pelicon

3. Development of the diagnostics for certain parameters of the edge plasma in fusion devices
   Prof. Milan Čerček, Dr. Istok Cadžek

4. Novel, environmentally friendly, high energy density materials for use in Li-ion batteries
   Dr. Robert Dominiko, Dr. Darko Hanel

5. Mapping in tomakamaks and inside biological cells
   Asst. Prof. Primož Pelicon

6. Natural and man-made gamma- and beta-ray emitters in underground waters in Slovenia
   Dr. Matjaž Aškori

7. Natural hydrochemical backgrounds and dynamics of Slovenian groundwaters.
   Dr. Jasmina Kolzar Logar

8. Inventory of Securité saltan flora and optimisation of growth of autochthonous Salicornia species
   Dr. Marjan Nečemer

9. Dating of Waters by H-3 and Pb-210: groundwater dynamics and vulnerability of deep aquifers
   Dr. Jasmina Kolzar Logar

10. Application of x-ray analytical techniques
    Dr. Peter Kump

11. Synthesis of magnetic nanoparticles for the microwave absorbers and magnetic fluids
    Prof. Darko Makovec, Dr. Darko Hanel

12. Age, origin and dynamics of deep aquifer's groundwaters of Ljubljiensko barje
    Dr. Jasmina Kolzar Logar

13. Tracing of tritium in the in the environment around the Krsko NPP
    Dr. Matjaž Aškori

14. Determination of geographical and botanical origin of honey
    Dr. Marjan Nečemer

15. Quality and authenticity of honey on Slovenian market
    Dr. Marjan Nečemer

RESEARCH PROGRAMS

1. Structure of hadronic systems
   Asst. Prof. Simon Širca

2. Studies of atoms, molecules and structures with photons and particles
   Asst. Prof. Matjaž Zitnik

3. Parallel and distributed systems
   Asst. Prof. Roman Trobec

4. Mobile archaeological heritage: archaeological and archaeometric investigations
   Prof. Ziga Smit

NEW CONTRACTS

1. Monitoring of central LILW storage facility at Brniče 2008
   Agency of Badwaste Management
   Dr. Marjan Nečemer

2. Radionuclide content in building material for high constructions in Slovenia
   Ministry for Environment and Spatial Planning
   Dr. Tim Vidmar

3. Ecology Laboratory with mobile unit 2008
   Ministry of Defence
   Asst. Prof. Matej Lipoglavšek

4. Digital Pulse Processor
   Instrumentation Technologies, d. d., Solkan
   Asst. Prof. Primož Pelicon

5. Dosimetrical service
   Oncological Institute Ljubljana
   Boštjan Crnčič, B. Sc.

6. Monitoring of radioactivity in the living environment
   Ministry for Environment and Spatial Planning
   Dr. Benjamin Zorko

7. Radiological monitoring in Slovenia 2008-2010
   Krško Nuclear Power Plant
   Asst. Prof. Matej Lipoglavšek

8. Monitoring of radioactivity of drinking water 2008
   Ministry of Health
   Asst. Prof. Matej Lipoglavšek

9. Maintainance of measurement traceability of reference standards
   Ministry of Higher Education, Science and Technology
   Matjaž Mihelič, M. Sc.

10. Monitoring of radioactivity in RŽV 2008
    Rživ, d. o. o., Gorrena Vas
    Asst. Prof. Matej Lipoglavšek

VISITORS FROM ABROAD


2. Prof. Shigoe Matsuyama, Department of Quantum Science and Energy Engineering, Tohoku University, Sendai, Japan, 8–12 Jan. 2008

3. Prof. Zdeněk Herman, J. Heyrovský Institute of Physical Chemistry, Prague, Czech Republic, 1–4 Apr. 2008

4. Prof. Miodrag Gulić, VMA, Belgrade, Serbia, 7 May 2008

5. Prof. Ilir Vullkaj, Polytechnical University Tirana in Edlira Duka, doctor student, University in Draci, Albania, 9–12 Jun. 2008

6. Dr. Aleksandar Milosavljevic, Institute of Physics, Belgrade, Serbia, 1–30 Sept. 2008

7. Dr. Marc Simon, Université Pierre et Marie Curie, Paris, France, 7–10 Oct. 2008

8. Prof. Shigoe Matsuyama, Department of Quantum Science and Energy Engineering, Tohoku University, Sendai, Japan, 5–11 Nov. 2008


10. Dr. Sile Bolsmann, SCK-CEN, Burex Impact Studies, Boortang, Belgium, 26–27 Nov. 2008
BIBLIOGRAPHY

ORIGINIAL ARTICLES


2. Gregor Bavdek, Albano Cossaro, Dean Cvetko, Cristina Africh, Cecilia Dr. Klemen Bučar24.


4. Denis Glavič cindro, m. sc.4.

5. Dr. Darko Hanžel5.


7. Mihael Drofenik, Matjaž Kristl, Darko Makovec, Zvonko Jagličić, Darko Hanžel, Denis Glavič cindro, m. sc.4.


TEXTBOOKS AND LECTURE NOTES

1. Iztok Arčon, Introduction to XANES and EXAFS analysis, Nova Gorica, [I. Arčon], 2008.
The main field of research of the Department of Thin Films and Surfaces is the development, deposition and characterization of hard protective PVD coatings, while research is done also on 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 well as the study of processes during heat treatment. In the applied research different coatings are developed for the protection of tools for various production processes in industry.

The main event of the past year was the purchase of new equipment for hard-coating deposition: the CemeCon CC800/9 sinOx. It is the most modern apparatus of its type, and enables magnetron sputtering in three different regimes: (i) classical DC deposition, (ii) pulsed deposition at medium frequencies and (iii) pulsed deposition at high power. By applying a suitable combination of process parameters we can deposit various so-called supernitride coatings, which have a fine-grained microstructure, excellent adhesion on the substrate and low internal stresses. Using pulsed deposition we can also deposit non-conductive thin films (e.g., Al2O3), or classical films at low substrate temperatures. New possibilities are available with the high-power pulsed magnetron sputtering (HPPMS). Its main feature is a pulsed power supply, which generates pulses with a peak power of around one megawatt, but with a duration of only a few tens of microseconds. At such a high power density, the target material is almost completely ionized, which enables the formation of a nanocrystalline microstructure and superb adhesion. A millisecond-long pause follows the pulse, and therefore the substrate temperature remains relatively low.

The first major achievement with the new system is the deposition of blue-coloured coatings. These are based on TiAlN, and as with many similar, well-established coatings they do not provide any advantage from the wear-resistance point of view. However, the major colour difference substantially improves the ability to detect tool wear, which is not the case with classical coatings that tend to be a metallic-grey colour.

We continued work on other topics related to hard coating development, where an important emphasis was given to the study of defects. Micrometer-sized defects increase friction, and cause pitting corrosion and material build-up on the tool’s surface. Based on measurements with a large series of depositions we determined the dependence of the defect density on the deposition parameters: deposition rate, bias voltage, substrate-surface orientation, location in the vacuum chamber, rotation geometry, substrate type and cleaning procedures. A novel method of defect study was the application of 3D-profilometry and scanning electron microscopy in combination with a focused ion beam (FIB). Using this knowledge we are now ensuring better film purity on those substrates where a low defect density is a key property. We also continued with the development of corrosion-resistant coatings based on Al-W for the protection of aluminium alloys, where we concentrated on tungsten’s influence on the microstructural properties.

To better understand the sputtering rates of composite targets, we constructed an experiment equivalent to the camera obscura used in optics. We succeeded to record a “picture” of the target through a small pinhole. By measuring the transparency of the coating deposited on glass and by measuring the film thickness we calculated the deposition rates of various target components.

The department intensively collaborates with Slovenian industry. In addition to the protection of tools with hard coatings, we performed several advanced analyses of tool protection, chose the appropriate technology and solved specific problems. In 2008 we made analyses for the companies PHOS, d. o. o., Kovicov, d. o. o., and Kolektor, d. d.

We actively collaborate in three European projects. Within the Network of Excellence “Complex metallic alloys” (CMA) we analysed the diffusion processes in the thin-film structures Al/Cr, Al/Fe and Cr/Fe, where we revealed the decisive mechanisms for diffusion. In the same network we are leading the preparation of a subproject for the combinatorial analysis of thin films with a lateral compositional gradient. The recently started EU 7FP project “Development of wear resistant coatings based on complex metallic alloys for functional applications” (AppliCMA) is to an extent a continuation of the existing Network of Excellence. In this project we will develop applications for these alloys over the next three years. There are 17 partners from eight countries.
We developed TiAlN-based supernitride coatings that ensure the better wear resistance of tools, enhanced adhesion and lower internal stresses compared to classical nitride coatings. These coatings have been successfully tested in industrial production.

Among the other international projects, ITER takes first place, where our task is the synthesis of various deposits of hydrogenated carbon, which should be as similar as possible to the impurities in the fusion reactor. We have long-established bilateral collaborations with the Institute for Nuclear Sciences Vinča, Serbia, on the laser treatment of surfaces and subsequent analysis, the University of Zagreb, Croatia, on the depth profile analysis of multilayer structures, and Joanneum Research, Laser Center Leoben, Austria, on the deposition of diamond-like carbon films by anode layer source. In addition, we are developing coatings for architectural structures for the Australian company Bluescope Steel. In order to study the influence of ion etching on depth profiling we deposited several bi- and multilayer structures (Cr/Si, Ni/C, W/Nb). This research was done in collaboration with the Department of Surface Engineering and Optoelectronics, and the Research Institute for Technical Physics and Materials, Budapest, Hungary.

Some outstanding publications in the past three years

INTERNATIONAL PROJECTS

1. Development of Wear Resistant Coatings based on Complex Metallic Alloys for Functional Applications
   APPROCOMA
   7. FP, 214407
   RE: Susanne Puch, Austrian Research Centers GmbH - ARC, Functional Materials, Seibersdorf, Austria
   Dr. Miha Čekada, Prof. Janez Dolinšek, Dr. Kristoffer Kromel, Dr. Srečko D. Škapin
   EURATOM - MHEST
   7. FP, EURATOM, Slovenian Fusion Association - SPA 3211-08-000102, FU07-CT-2007-00065
   RE: RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   Dr. Peter Panjan
3. Complex Metallic Alloys
   CMA
   6. FP, NMP5-CT-2005-500140
   RE, Centre National de la Recherche Scientifique, Paris, France
   Dr. Peter Panjan, Prof. Janez Dolinšek, Prof. Spomenka Kobe
4. Hydrogen Impermeable Nano-material Coatings for Steels
   Hy - Nano – IM
   MNT ERA NET
   Dr. Miha Čekada, Dr. Paul McGuiness, Dr. Vincenc Nemanič
5. Improvement of Resurfacing Hip Implants with DLG, TiO2 and DGL/pb Nanocomposite Coatings
   RISH-DLC-NanoComp
   MATERA ERA NET
   ORTON Research Institute, Helsinki, Finland
   Dr. Darinka Kek Merl, Dr. Ingrid Milošev
6. Characterization of Composition and Mechanical Properties of PVD Ceramic Coatings
   BHR-07-09-001
   Dr. Lidija Ćurković, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, Croatia
   Dr. Peter Panjan
7. Characterization of the Selected Coatings
   Dr. Rainer Cremer, CemeCon AG, Coatings, Technology & Processes, Würselen, Germany
   Dr. Peter Panjan

R &D GRANTS AND CONTRACTS

1. Development of measuring platform PowerQ4
   Dr. Peter Panjan
2. Study of plasma parameters for conditioning of the inner surfaces of a fusion reactor
   Asst. Prof. Miran Mozetič, Dr. Peter Panjan
3. PVD hard coatings as an alternative for corrosion protection of Fe- and Al-alloys
   Dr. Darinka Kek Merl
4. Smart functional coatings for improvement of structures and components used in defensive purpose
   Dr. Peter Panjan

RESEARCH PROGRAM

1. Thin film structures and plasma surface engineering
   Prof. Anton Zalar, Dr. Peter Panjan

NEW CONTRACTS

1. PVD hard coatings as an alternative for corrosion protection of Fe- and Al-alloys
   PHON d. o. o., Sečovlje
   Dr. Peter Panjan
2. Development of nanolayered PVD hard coatings
   Kovinos d. o. o., Horjul
   Dr. Peter Panjan

VISITORS FROM ABROAD

1. dr. Rainer Cremer, dr. Christoph Schaeffers, CemeCon AG, Würselen, Germany, 10–11 Jan. 2008
3. Dr. David Nolan, Blauscope Steel, Port Kembla, Australia, 29–30 Sept. 2008

STAFF

Researchers
1. Dr. Miha Čekada
2. Dr. Darinka Kek Merl
3. Dr. Peter Panjan, Head

Postgraduates
1. Matjaž Panjan, B. Sc.
2. Srečko Paskvale, B. Sc.

Technical officers
6. Dr. Marijan Malek*, left 1 Apr. 2008

Technical and administrative staff
7. Jožko Fiter
8. Damjan Matelič
9. Andrej Mohar
10. Tomáš Struik

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLES

4. Julien Malherbe, Beatriz Fernandez, Hervé Martinez, Patrick Chapon, Peter Panjan, Olivier F.X. Donard, "In-depth profile analysis of oxide films by radiofrequency glow discharge optical emission spectrometry
Published Conference Papers

Invited Papers


Regular Papers


The main activities of the Department of Surface Engineering and Optoelectronics are oriented towards surface engineering, surface, interface and thin film characterization, plasma applications, the synthesis of nano- and biomedical materials, vacuum optoelectronics, ultra-high-vacuum techniques and technologies. The department collaborates with other groups at the Institute as well as with other Slovenian and foreign institutes, universities and industry. The group is also active in the field of the education of students at two Slovenian universities and at the Jožef Stefan International Postgraduate School.

Surface analytical techniques are indispensable for the characterization of the surfaces and interfaces of bulk materials, layered structures and nanomaterials. In the department Auger electron spectroscopy (AES), X-ray photoelectron spectroscopy (XPS) and atomic force microscopy (AFM) have been used successfully, all for basic research and for the characterization of technological samples. Our research group is recognized worldwide for the depth profiling of thin films and multilayers at a high depth resolution.

To study the ion sputtering rates of W, Ti- and Cr-carbides, trilayer structures comprising C/WC/W, C/TiC/Ti and C/Cr,Cr were sputter deposited onto smooth silicon substrates. Their precise structural and compositional characterization by transmission electron microscopy (TEM), AES and XPS revealed that the WC and Cr,C layers were amorphous, while the TiC layer had a polycrystalline structure. The ion sputtering rates of all three carbides, amorphous carbon and polycrystalline Cr, Ti and W layers were determined by means of Auger electron spectroscopy depth profiling as a function of the angle of incidence of two symmetrically inclined 1 keV Ar⁺ ion beams in the range between 22° and 82°. The sputtering rates were calculated from the known thicknesses of the layers and the sputtering times necessary to remove the individual layers. We found that the sputtering rates of the carbides, C-graphite and metals were strongly angle dependent. For the carbides in the range between 36° and 62° the highest ion sputtering rate was found for Cr,C, and the lowest for TiC, while the values of the sputtering rates for WC were intermediate. The normalized sputtering yields calculated from the experimentally obtained data for all three carbides followed the trend of the theoretical results obtained from calculations of the transport of ions in solids by the SRIM code. The sputtering yields we also presented in terms of atoms/ions (Figure 1). The influence of the ion-induced surface topography on the measured sputtering yields was estimated from atomic force microscopy (AFM) measurements at the intermediate points of the corresponding layers on the crater walls formed during depth profiling.

In order to introduce our work and methods to the wider community, we built a new teaching model of the atomic force microscope (AFM) in collaboration with prof. Planinšič from the Faculty of Physics and Mathematics at the University of Ljubljana. The AFM model is intended as an introduction to nanoscience for high-school students. The AFM model was presented in a very well received article in the journal Physics Education, as shown in Figure 2. The teaching model of the AFM can be assembled by students themselves in a very simple way from components that are easily found. The model can demonstrate the contact and oscillating modes of operation of the AFM microscope, how the AFM image is created as well as some basics principles that limit the resolution of the method.

Using X-ray photoelectron spectroscopy (XPS) we investigated the reasons for the weak adhesion of electrical contacts in solar cells. We analyzed the multilayer structure Ag/Ni/TiC on a Si substrate, prepared at the Faculty of Electrical Engineering, University of Ljubljana. After a thermal treatment at 400 °C the multilayer structures have a weak adhesion to the silicon substrate. We found that a very thin amorphous Ti-Si phase was grown at the Ti/Si interface, which failed at the required mechanical loads. Our research is helping to optimize the technological process to improve the adhesion.

Using XPS and AFM methods we investigated thin organic coatings, prepared from hybrid, polyhedral oligomeric silane-based precursors (POSS) by the sol-gel process at the National Institute of Chemistry, Ljubljana.
coatings were intended for the corrosion inhibition of aluminium alloys. Our measurements show the formation of very thin, self-assembled and compact coatings with thicknesses of only 40 nm, which provide very good corrosion protection of aluminium alloys.

Systematic research on the interaction of neutral oxygen atoms in the ground state with bacteria has been performed. Bacteria Staphylococcus aureus have been investigated in detail in order to obtain valuable data on the efficiency of the removal of different segments. Experiments were performed in an afterglow chamber made from borosilicate glass. The source of the oxygen atoms was a remote, inductively coupled RF oxygen plasma. The density of atoms at the samples was $8 \times 10^{23}$ atom/m$^2$. The treatment was performed at room temperature. The first effect was the removal of the dried capsule. The dose on exposed parts of bacteria was removed after receiving a dose of $6 \times 10^{23}$ atom/m$^2$, while the parts of the capsule filling the gaps between the bacteria were removed after receiving a dose of $2.4 \times 10^{24}$ atom/m$^2$. After removing the capsule the etching continued as etching of the bacterial cell wall. The etching was rather non-uniform as holes with a diameter of several 10 nm were observed (Figure 3). The cell wall was removed after receiving a dose of about $7 \times 10^{24}$ atom/m$^2$. The results were explained by the different compositions of the capsule and the cell wall.

The interaction of gaseous plasma with ITER-relevant materials has been investigated in close collaboration with partners from the European Fusion Development Agreement (EFDA) association. Experiments on the behaviour of materials treated with plasma under different conditions have been performed at our laboratories as well as at the National Fusion Laboratory, Madrid, Spain (Figure 4), the National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania, the PROMES Laboratory, Font Romeu, France, and the Laplace Laboratory, University Paul Sabatier, Toulouse, France. Reduction of thin oxide films on the surface of stainless-steel samples was performed at PROMES with a highly reactive hydrogen plasma and the results showed that the removal of the passive oxide film causes the sublimation of manganese from the samples even at a temperature of about 500 °C. The technique is therefore suitable for the removal of oxide thin films, but causes a weak depletion of manganese. The removal of hydrogenated carbon films, on the other hand, was performed using a highly reactive oxygen plasma at laboratories in Bucharest and Toulouse. The results of systematic research on the treatment of deposits with an oxygen plasma showed that the removal rate was below 1 nm/s at room temperature, reached about 10 nm/s at a temperature of 300 °C and increased to over 100 nm/s for temperatures above 500 °C. Similar results were obtained with an atmospheric nitrogen plasma torch, except that this technique is more suitable for the removal of deposits from small samples.

Systematic research on the functionalization of organic materials revealed the strong influence of plasma parameters on the type and concentration of specific functional groups on the surface of different polymers. The modification of the surface properties of the following polymers was studied: polyethylene terephthalate (PET), polyethersulphone (PES), polyphenylenesulphone (PPS), nylon 6 polyamide (PA6), polytetrafluoroethylene (PTFE), polystyrene (PS), polypropylene (PP) and cellulose (ink-jet paper and textile). The polymer samples were treated in an oxygen plasma (the glow region as well as early afterglow) at a pressure of 75 Pa, where the O-atom density is the highest. The appearance of the functional groups on the surface of the samples was monitored by high-energy-resolution X-ray photoelectron spectroscopy (XPS). The results showed that oxygen-plasma treatment was an effective tool for surface modification. On all the polymer surfaces an increased concentration of oxygen was detected. The high resolution C 1s peaks indicated the formation of several new oxygen-containing functional groups. On all the polymers groups like C–O, C=O and O–C=O are observed. However, in some cases, more complex groups were found as well. The concentration of these functional groups depended on the type of polymer and the time of the plasma treatment. The highest increase of oxygen by the polymer was found for cellulose, and the lowest was found for polypropylene. The only exception was the PTFE polymer, where practically no chemical changes were observed after the plasma treatment.

The safe operation of future fusion reactors and their decommissioning after their operational lifetime sets some questions that are not completely answered. For the ITER project, the main source of radioactivity is caused by high-energy neutron capturing as well as by tritium retention, since not all the applied fuel is spent in fusion. The most affected area is the first wall (i.e., tungsten, beryllium), but there is a large surface area of stainless-steel vacuum chamber exposed to gaseous tritium after the plasma ignition. The prediction of tritium retention is today mainly calculated from data taken in a small system using similar parameters as expected for
Deuterium provides valuable and complementary data on its retention in metals, as usually taken by tritium. We investigated the kinetics of deuterium absorption and desorption in selected ITER-grade metals, such as tungsten, beryllium and stainless steel, at the prescribed low pressures and high temperatures (Figure 5). Working at a very low concentration of deuterium required us to improve and refine the existing setup, which was a time-consuming task. As a result, we obtained some new data on the kinetics of evolution and absorption as well as the amount of retained deuterium. Isotope exchange with residual hydrogen in the bulk represents the reaction channel, which decreases the accuracy of the measured data.

The field-emission (FE) characterization of nanowires, together with two-terminal current-voltage measurements, was conducted inside a transmission electron microscope (TEM) equipped with a scanning-tunnelling microscope (STM) sample holder. The nanowires were manipulated by the electron-beam-induced deposition (EBID) of amorphous carbon (a-C) fixed to a W tip inside the TEM. Preliminary field-emission characterization and two-terminal current–voltage measurements followed. In order to get an additional insight into the characteristics of the nanowires, a second experimental setup, a classical field-emission microscope with a diode configuration designed for a point-to-plane geometry, was applied. Current-voltage relations, current field-emission microscopy imaging, and the FE current stability and reduced angular current density distribution were obtained. We found that the investigated inorganic nanowires represent a very bright point electron source comparable to carbon nanotubes.

It has been reported that relatively smooth nanocrystalline diamond films exhibit an intense electron emission at low-to-moderate applied electric fields, which was in the past attributed exclusively to nanotips and nanotubes. The spatial distribution of the emission sites that originate from the surface of nanocrystalline diamond films was determined. To characterize the relation of the emission sites over the whole surface, a triode concept has been developed, which employs a pulsed voltage to the mesh and a DC potential applied to the luminescent screen to display the emission site distribution across the 20-mm-diameter substrates. Besides this method, a novel, scanning field-emission microscope was constructed, where the applied field at the surface of the sample is uniform, and the electron emission from individual emission sites is projected onto the phosphor screen. In this way, the emission current versus the voltage for individual emitting sites was observed and characterized. This provided a fundamental insight into the relation of the materials’ properties and the emission characteristics.

One of our group members spent nine months at Uppsala University in Sweden as a postdoctoral fellow. A major part of his research work consisted of measurements of heavy-ion-induced desorption yields. A rotational sample holder with various samples (flat and tubular) is shown in Figure 6. The investigated samples were made from metals such as stainless steel, copper, tantalum, etc., which are the most promising candidates for the beam pipe elements of the SIS 100/300 heavy-ion accelerator at GSI, Germany. The grazing incidence of ions exhibited a significant increase in the measured desorption yield. The experiments were conducted at the beam line of the heavy ion accelerator at The Svedberg Laboratory in Uppsala.

Some outstanding publications in the past three years

2. S. Hofmann, J. Y. Wang, A. Zalar, Backscattering effect in quantitative AES sputter depth profiling of multilayers, Surface and Interface Analysis, 39 (2007), 787-797
6. V. Nemanič, M. Žumer, B. Zajec, Deuterium retention in ITER-grade austenitic stainless steel, Nuclear Fusion, 48 (2008), 11509-1-11509-8

Patents granted
1. Polyester material with surface having antithrombogenic properties and a method for preparation
   Simona Strnad, Tea Indest, Janne Laine, Karin Stana-Kleinschek, Alenka Vesel, Renate Dworczak
   SI Patent No. 22467
2. Scanning projection field emission microscope designed to study flat broad-area field emission cathodes
   Vincenc Nemanič, Marko Žumer, Bojan Zajec, Mihael Kocmur
   SI Patent No. 22425

Awards and Appointments
   Ljubljana, Slovenia
   Fiesa, Slovenia.

Organization of conferences, congresses and meetings
1. 15. International meeting on vacuum science and techniques, Varazdin, Croatia 4 Jun. 2008

INTERNATIONAL PROJECTS
1. Atmospheric Plasmas for Nanoscale Industrial Surface Processing
   PlasmaNice
   Dr. Johanna Lahit, Tampere University of Technology, Department of Energy and Process Engineering, Paper Converting and Packaging Technology, Tampere, Finland
   EURATOM – MHEST
   7. FP, EURATOM, Slovenian Fusion Association – SFA
   TW6-1.3R3-TWS-695, 3211-08-000102, FU07-CT-2007-00065
   EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   Dr. Vincenc Nemanič
3. Removal of Deposits by Neutral Oxygen and Nitrogen Atoms - 1.4.2.-FU
   EURATOM – MHEST
   Dr. Jonez Kovač
2. Deuterium Retention and Release from Metal Surfaces - 1.4.4. – FU
   EURATOM – MHEST
   Dr. Vincenc Nemanič
4. Sensitive and Differential Blood and Cerebrospinal Fluid Test for Neurodegenerative Dementia Diagnosis
   Innovation Projects Under the Sixth Framework Programme of the European Community NeuroScreen
   Dr. Vincenc Nemanič
5. Vascular Graft Interfaces
   VafGrm
   MNT ERA NET
   3211-07-000024
   University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
   Asst. Prof. Miran Mozetič
6. Hydrogen Impermeable Nano-material Coatings for Steels
   Hy - Nano – IM
   MNT ERA NET
   Dr. Vincenc Nemanič, Dr. Paul McGuiness, Dr. Miha Gakada
7. Determination of the Density of Nitrogen and Hydrogen Atoms in Plasma created in mixture of both gases
   Détermination des densités locales d'atoms d'azote et d'hidrogène dans deux types de décharges plasmas
   PROTEUS 2008 – 2009
   BI-FR/08-09-PROTEUS-001
   Dr. Marianne Balat – Pichelin, PROMES-CNRS, Laboratory for Processes, Materials and Solar Energy (PROMES)-French National Centre for Scientific research (CNRS), Odillo-Font Romeu, France
   Dr. Alenka Vesel
11. Planar Cold Cathodes Composed of Inorganic Nanowires
   Bi-CN/07-09-008
   Dr. Lian-Mao Peng, Institute of Physical Electronics, Peking University, Department of Electronics, China

12. Research of Bacterial Damages after Plasma Radical Interaction
   Bi-SC/06-07-001
   Asst. Prof. Dragana Lašević, Institut za zdravje Crave Gore, Podgorica, Montenegro
   Asst. Prof. Miran Možetič

13. Simulations and Analysis of Complex Networks in Planetary Dynamics, Algorithms and Applications
   Sinteza, modifikacija jonskim zračenjem i karakterizacija višeslojnih struktura na nanometarskoj skali
   BH-RS/08-09-041
   Prof. Momir Milošavljević, Institute for Nuclear Sciences “Vinča”, Belgrade, Serbia
   Prof. Anton Zalar

Metal Oxide Nanowire/Nanotube Arrays for Electrochemical Energy Conversion

Metal Oxide Nanowires/Nanotube Arrays for Electrochemical Energy Conversion Applications
   Bi-US/08-10-030
   Prof. K. Mahendra Sunkara, University of Louisville, Department of Chemical Engineering, Louisville, KY, USA
   Asst. Prof. Uroš Cvelbar

Large Scale Synthesis and Dispersions of Metal Oxide Nanowires
   Bi-US/06-07-002
   Prof. K. Mahendra Sunkara, University of Louisville, Department of Chemical Engineering, Louisville, KY, USA
   Asst. Prof. Miran Možetič

14. Microscopic Characterization of Field Emission Sites on Nanostructured Carbon Films
   Bi-US/06-07-023
   Prof. Robert Nemanich, North Carolina State University (NCSU), Department of Physics, Raleigh, NC, USA
   Dr. Vincenc Nemanič

R &D GRANTS AND CONTRACTS

1. Fusion relevant research and plasma surface interaction
   Prof. Milan Gerček, Asst. Prof. Miran Možetič

2. Development of diagnostics for some edge plasma parameters in fusion
   Prof. Milan Gerček, Asst. Prof. Miran Možetič

3. Electron field emission from flat nanostructured cathodes
   Dr. Vincenc Nemanič

4. Polymer nanocomposites for chemical sensors
   Asst. Prof. Miran Možetič

5. Development of treatments and procedures for improvement of hemocompatibility of polyethylene terephthalate surfaces
   Asst. Prof. Miran Možetič

6. Study of the plasma parameters for conditioning of the inner surfaces of a fusion reactor
   Asst. Prof. Miran Možetič

7. Printed passive electronic components for smart packaging
   Asst. Prof. Alenka Vesel

8. Investigation of gaseous discharges for introduction of a new environmentally friendly technology for semimanufactures functionalization at capacitors production
   Asst. Prof. Miran Možetič

9. Plasma sterilization and functionalization of biocompatible materials
   Asst. Prof. Miran Možetič

10. Electron beam writer with nanometric resolution
    Dr. Vincenc Nemanič

11. Research of the integrated surge protective system
    Dr. Vincenc Nemanič

12. Oxidation of metals by reactive oxygen plasma
    Asst. Prof. Miran Možetič

13. Field emission cathode from nanomaterials for THz miniature klystron
    Asst. Prof. Miran Možetič

14. Self cleaning photocatalytic paints and coatings
    Asst. Prof. Miran Možetič

15. Smart functional coatings for improvement of structures and components used in defensive purpose
    Dr. Peter Panjan, Asst. Prof. Janez Kovač

16. Industrial intelectual rights as an instrument for economy development
    Asst. Prof. Uroš Cvelbar

NEW CONTRACTS

1. Oxidation of metals by reactive oxygen plasma
   Kolektor Group d. o. o., Idrija
   Asst. Prof. Miran Možetič

2. Plasma sterilization and functionalization of biocompatible materials
   Indukti d.o.o., Ljubljana
   Asst. Prof. Miran Možetič

3. Development of treatments and procedures for improvement of hemocompatibility of polyethylene terephthalate surfaces
   Bioski d.o.o., Ljubljana
   Asst. Prof. Miran Možetič

4. Study of the plasma parameters for conditioning of the inner surfaces of a fusion reactor
   Indukti d.o.o., Ljubljana
   Asst. Prof. Miran Možetič

5. Investigation of gaseous discharges for introduction of a new environmentally friendly technology for semimanufactures functionalization at capacitors production
   Ioka Konsenzatorji Industrija Konsenzatorjev in Opreme d. d., Semič
   Asst. Prof. Miran Možetič

VISITORS FROM ABROAD

1. Dr. Sljodan Milošević, Nico Čutić, Nikša Kristolović, Institute of Physics, Zagreb, Croatia, several times in the year

2. Dr. Primož Eiselt, Plasmabull, Lebring, Austria, several times in the year

3. Zoran Vratnica in Danijela Vujošević, Institute for Health of Montenegro, Podgorica, Montenegro, several times in the year

4. Dr. Jiang Yong Wang, Max-Planck-Institute for Metals Research, Stuttgart, Germany, 15 – 19 May 2008

5. Prof. dr. Kosta Drtnik, University of Sydney, Australia, 5 Jun. to 20 Sept. 2008


STAFF

Researchers

1. Asst. Prof. Janez Kovač
2. Asst. Prof. Miran Možetič
3. Dr. Vincenc Nemanič
4. Asst. Prof. Alenka Vesel
5. Dr. Bojan Zajec
6. Prof. Anton Zalar, Head

Postdoctoral associates

7. Asst. Prof. Uroš Cvelbar

Postgraduates

8. Aleksander Drenik, B. Sc.
10. Ida Juncar, B. Sc.
12. TJaka Velčnik, B. Sc.

Technical and administrative staff

14. Rudiča Bolhe
15. Tatjana Filipčič, B. Sc.
16. Mihael Kocmur
17. Janez Trtnik

Annual Report 2008
PUBLISHED CONFERENCE PAPERS

Invited Papers


Regular papers


PATENT APPLICATIONS

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 the 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 microscopy, scanning-tunnelling, electronic and atomic force microscopy, as well as dielectric relaxation spectroscopy and dynamic specific-heat measurements.

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 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, the Institute of Mathematics, Physics and Mechanics and the Jožef Stefan International Postgraduate School. In 2008, the research was performed within three research programs:

- NMR and Dielectric Spectroscopy of Condensed Matter: Smart New Materials and Translational Symmetry Breaking,
- Physics of Soft Matter, Surfaces and Nanostructures,
- Experimental Biophysics of Complex Systems.

**Research programme “Magnetic Resonance and Dielectric Spectroscopy of Condensed Matter: Smart New Materials and Translational Symmetry Breaking”**

The program group was 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 the investigations was to discover the basic laws of physics governing the behaviour of these systems, which represent a link between perfectly ordered crystals, on the one hand, and amorphous matter, soft condensed matter and living systems, on the other. This knowledge provides the key to the understanding of the macroscopic

The group has investigated important open questions in the physics of spin liquids, and it has discovered the principal reason for the giant electromechanical response of ferroelectric relaxors in the vicinity of the critical point. It has determined the physical and chemical properties of selected nanomaterials and discovered the thermal memory effect in quasicrystalline intermetallic compounds.
properties of these systems and is an important condition for the discovery and development of new, multifunctional materials and nanomaterials for new applications. In 2008, the members of the program group published their research in 51 original publications in international scientific journals. The investigations were directed to:

**Giant electromechanical response of relaxor ferroelectrics.** The electric field-temperature phase diagram was calculated for perovskite ferroelectric relaxors in the vicinity of the critical point where the giant electromechanical response is observed. It was shown that the PMN single crystal exhibits remarkable anisotropy, in contrast to previous views that this system is an isotropic relaxor glass. We also confirmed the existence of the critical point in the [111] axis in PMN and its absence in the [001] axis. These findings are important for understanding the giant electromechanical response and for the future engineering and production of sensors and actuators on the basis of these materials. Relevant publications: M. Iwata, Z. Kutnjak, Y. Ishibashi, R. Blinc, J. Phys. Soc. Jpn. 77, 034703-1 (2008); Z. Kutnjak, B. Vodopivec, R. Blinc, Phys. Rev. B 77, 054102-1 (2008); M. Iwata, Z. Kutnjak, Y. Ishibashi, R. Blinc, J. Phys. Soc. Jpn. 77, 065003-1 (2008); Z. Kutnjak, Ferroelectrics 369, 198 (2008); Z. Kutnjak, Ferroelectrics 369, 133 (2008).

**Synthesis and characterization of newly developed all-ceramic percolative composites.** In a collaboration between researchers from the Condensed Matter Physics Department and the Electronic Ceramics Department of the JSI, the first all-ceramic percolative composites (comprising a conductive filler in a dielectric matrix) have been developed. Until now only organic percolative composites and inorganic systems, comprising metal particles within an insulator, have been developed. The structural analysis revealed an almost ideal structure – conductive ceramic grains uniformly distributed in a dielectric ceramic matrix. Thus, in the lead-based PZT-PbRuO3 and in the lead-free KNN-RuO3 systems, the dielectric response follows the predictions of the percolation theory. The dielectric constant actually diverges on approaching the percolation threshold (values as high as 40,000 were detected) and the critical exponents and percolation points agree reasonably well with the theoretically predicted values. The electromechanical properties further demonstrated the potential for use as high-dielectric-constant materials in various applications. Published in: V. Bobnar, M. Hrovat, J. Holc, M. Kosec, Appl. Phys. Lett. 92, 182911 (2008).

**Polarons in magnetoelectric K3Fe5F15.** In the past decade, the number of investigations of magnetoelectrics has grown rapidly, as they are promising materials for new types of memory elements. We discovered a new magnetoelectric, i.e., K3Fe5F15. We showed from the measured electric conductivity that the charge transport is governed by a thermally activated process at high temperatures, while at low temperatures the tunnelling of small polarons prevails. We were the first to show that polarons play an important role as a charge-transport mechanism in K3Fe5F15, which could provide a clue for understanding the magnetoelectric effect in this system. Published in: R. Blinc et al., J. Appl. Phys. 103, 074114 (2008); A. Levstik, C. Filipič, V. Bobnar, G. Tavčar, and B. Zemva, Europhys. Lett. 83, 27001 (2008).

**Synthesis and characterization of titanate and MnO2 nanostructures.** An important achievement was the synthesis of Cu2+-doped titanate nanoribbons by in situ and ex situ methods and the determination of the accumulation sites for Cu2+ ions with electron microscopy and electron paramagnetic resonance. The results represent joint work with the group from Université Paris Sud, France. The results were published in Journal of Physical Chemistry C. The accumulation sites for the Cu2+ ions in the sample of titanate nanoribbons doped ex situ with Cu2+ are shown in figure 4. The Cu2+ ions accumulate on the surface of the nanoribbons in the form of CuO nanoparticles (figure 4A) and between the titanate layers, where they exchange the Na+ ions (the bright contrast in figure 4B).

**Nonexistence of a nematic phase for the 12CB.** The first homologues of the n-acyl cyanobipheyl family of liquid crystals (n-CB) were synthesised more than 30 years ago. Their stability and electro-optical properties at room temperature have made them attractive materials for display technology. Higher homologues (n = 8–14) of the same family were studied extensively using various techniques, such as differential...
scanning calorimetry (DSC), high-resolution calorimetry, light scattering, dielectric spectroscopy and X-rays, and phase diagrams have been constructed. In spite of this intensive research, several important questions have remained unresolved, among them being the possibility of the existence of a nematic phase for 12CB. We have employed high-resolution calorimetric techniques to investigate the unresolved issue of the existence of a nematic phase for the 12CB. Various heating and cooling runs were performed on 12CB samples of different origin; these revealed no signature of a nematic phase, which was further supported by optical polarising microscopy. The research was also focused on the preparation of mixtures of ferroelectric liquid crystals (FLCs) and anisotropic magnetic nanoparticles (NPs), as well as the study of phase ordering due to FLC-NP coupling. By measuring the magnetic response, a finite FLC-NP coupling effect was observed for a mixture of weakly anisotropic magnetic NPs and the FLC phase, suggesting that such systems could be used as soft magnetoelectrics.

**Liquid crystalline elastomers and emulsions.** Studies of liquid crystalline elastomers (LCEs) are of interest because of their potential applicability as biologically active actuators or artificial muscles. They exhibit exceptional mechanical properties, such as an elastic modulus comparable to that of human skeletal muscles and a giant anisotropic deformation (up to 400%) at the phase transition between the ordered and the disordered liquid crystalline phase. We demonstrated, using ac-calorimetry and nuclear magnetic resonance of deuterium, that by increasing the crosslinking density in a LCE the thermodynamic response of the system changes from below-critical to supercritical. Accordingly, the thermomechanical response at the phase transition becomes more gradual, and can thus be tuned by selecting an appropriate crosslinking density. This result was obtained for the side-chain and the main-chain LCEs and is an indication that the link between the crosslinking density and the criticality of the phase transition is universal. We investigated the applicability of photoactive LCEs for their use in photonics. We found that information could be stored in these systems by "optical writing", thus creating tunable optical gratings. We employed spectroscopic NMR imaging in our investigations of the solubility of nanoscopic micelles in a nematic liquid crystal. The expulsion of micelles from the nematic phase was visualized at the onset of the isotropic-to-nematic phase transition, which results in the phase separation of the nematic-poor nematic phase and the micelle-rich isotropic phase. This process is driven by the elastic forces of the nematic director field caused by the incompatible spherical shape of the micelles. Our investigation ruled out the assumptions of other groups about the formation of a thermodynamically stable "transparent nematic phase". Published in Phys. Rev. E 78, 031707 (2008).

**Strongly correlated electron systems.** We focused on certain fulleride salts as a model system. In particular, we were interested in systems with a greatly expanded unit cell as we expected that in these systems electronic correlations will gain in importance. We demonstrated in our magnetic resonance experiments that (CuI,NH):k(Cu1) has an insulating antiferromagnetic ground state with a Neel temperature TN ≈ 46 K. The work was published in J. Am. Chem. Soc. and Phys. Rev. B. We were the first to find the antiferromagnetic resonance in this model system and simulations of H and H NMR spectra enabled us to determine the exact antiferromagnetic structure. In our studies of Li4C60 we focused on the phase diagram and demonstrated that Li4C60 is a metallic cubic system with a very small unit cell at high temperature.

**Nanomaterials.** We focused on titane nanostructures and their possible applications. A very important study was published in Adv. Funct. Mat., where we reported on a pulsed EPR study of sol-gel titane structures and their charge excitation upon UV-light illumination. These results are relevant for the development of novel solar cells and we propose an alternative structure to Gdtzeles. Considerable effort was devoted to the doping of semiconducting titanate nanostructures with transition-metal elements. The basic idea of these activities was to prepare semiconducting ferromagnetic structures, which are potentially interesting for future spintronic devices. We demonstrated that in copper-doped titane nanotubes, Cu2+ intercalates into the structure as anticipated. However, we also found that a large amount of copper forms CuO nanoparticles (typical dimensions of 5 nm) that grow on the outer surface of the titane nanotubes.

**Magnetic systems.** We studied the magnetic properties of low-dimensional antiferromagnetic systems and discovered an antiferromagnetic resonance in layered Ni,TeO2,Br, and explained this resonance with a microscopic spin model. We have also studied the magnetic properties of hollandite structures with a typical frustrated antiferromagnetic triangular lattice. We found that some vanadium ions change their valence because of electron doping (a non-stoichiometry that appears during the synthesis) and that this may be responsible for a three-dimensional antiferromagnetic ordering at low temperatures.
Geometrically frustrated spin lattices. We studied two novel realizations of a kagomé spin lattice as part of our investigations of geometrically frustrated spin lattices, in which all pairwise exchange interactions cannot be simultaneously minimized. Both spin lattices are lacking any signs of magnetic instabilities, at least down to 20 mK. In the case of the classical-spin compound Nd₄Ga₅SiO₁₄, we demonstrated the existence of a spin-liquid state, in which an applied magnetic field strongly affects the spin fluctuations (A. Zorko et al., Phys. Rev. Lett. 100, 147201 (2008)). In the quantum-spin system ZnCu₄(OH)₆Cl₂, on the other hand, we determined the symmetry and magnitude of the magnetic anisotropy – the Dzyaloshinsky-Moriya interaction – which can crucially affect the spin-particle ground state and explain the absence of a spin gap in this system (A. Zorko et al., Phys. Rev. Lett. 101, 026405 (2008)).

Luttinger spin liquids. In collaboration with the NMR group from the Grenoble High Magnetic Field Laboratory we have studied CuBr₄(C₅H₁₂N)₂, a system of magnetic Cu²⁺ atoms arranged to form parallel ladders. We have shown that its magnetic behaviour at low temperatures can be perfectly described by the general “Luttinger liquid” theory, which is assumed to describe any 1D microscopic system, including the magnetic ladder. Our work represents the first quantitative demonstration of this powerful theory. Published in Klancnik et al., Phys. Rev. Lett. 101, 137207 (2008).

New methods for the detection of solid explosives. Despite its relatively low sensitivity, the ¹⁴N NQR detection of solid explosives is still promising among the many technologies used for the detection of buried antipersonnel landmines and improvised explosive devices. The reason is its characteristic response, which results in a very small false-alarm rate. In 2008 we obtained two major results:

- we determined some important TNT NQR properties,
- we developed a new detection technique, without polarization enhancement, which is able to detect a small amount of the explosive TNT, ~70 g in less than 1 min.

Hydrogen-storage materials. The transition of our society towards a “hydrogen economy” will require that we find a way to store hydrogen. Intermetallic alloys of rare earths and transitional metals represent a promising class of hydrogen-storage materials. In particular, alloys with a quasicrystalline structure have been shown to exhibit a high density of hydrogen interstitial sites. We used fast field cycling relaxometry to study the hydrogen dynamics in partially quasicrystalline alloy Zr₆₉.₅Cu₁₂Ni₇.₅. We have demonstrated that this method is superior to classical NMR and allows us to distinguish various models of hydrogen binding. We were able to determine the distribution of hydrogen activation energies, and, in combination with our previous diffusion measurement, the hopping distance between the interstitial sites.

Setting of dental cements. The dynamics of the setting of dental cements is important information for both designing new cements and for a comparison of different cements. Also, the cement paste is very sensitive to the fluids in the mouth during the early stages of the setting reaction. NMR relaxation is a well-established method for following the setting reaction of ordinary Portland cements, where the hydration lasts for as long as 28 days. We have successfully applied this technique to follow the setting reaction of dental glass-ionomer cements, which set in the course of several minutes. The method allows us to qualitatively and quantitatively compare the setting dynamics of various dental cements.

Quasicrystals and complex metallic alloys. One of our important achievements was the synthesis, structure determination and thermoelctric properties of boron-doped Ba₄Al₁₄Si₃₃ clathrate phases. The structure of boron-doped Ba₄Al₁₄Si₃₃ is shown in figure 10. Using the solid-state MAS and MQMAS NMR techniques we proved the incorporation of boron into the framework structure. This work is an important step towards an efficient thermoelctric material, containing light elements, which are advantageous for transportation applications. The results represent joint work with the Max-Planck Institute for Chemical Physics of Solids in Dresden and the Department of Chemistry from the University of California. Published in Inorganic Chemistry 47, 8204 (2008) (P. Jeglšč et al.).

As part of our research on complex metallic alloys we have investigated the Y-Al-Ni-Co approximant phase to the decagonal quasicrystal. We determined the spatially anisotropic physical properties (magnetic, electrical and thermal conductivity, thermoelctric power, Hall coefficient) along three orthogonal crystalline directions. The transport coefficients were theoretically simulated by an ab-initio calculation, showing that the origin of the anisotropy is the anisotropic Fermi surface, as a consequence of the stacked-layer structure of the crystalline lattice. The anisotropic Fermi surface of the Y-Al-Ni-Co phase is shown in figure 11. The investigation was published in: A. Smontara, I. Smiljanči, J. Ivkov, D. Stanič, O. Baršič, Z. Jagličič, P. Gille, M. Komelj, P. Jeglšč, M. Bobnar, J. Dolinšek, Phys.Rev. B 78, 104204(2008).
**Memory effect in complex metallic alloys.** A new type of complex metallic alloys, known as the Taylor phases, exhibit a memory effect, where the thermal history of the crystal can be stored by pure temperature manipulation. The crystal “knows” the temperature where the cooling was temporarily stopped and for how long it was stopped. The information is stored in the local magnetic order of magnetically frustrated electronic spins. The stored information can be read by measuring the electronic magnetization in a small magnetic field. We have successfully thermally written one byte of eight bits of digital information, so that the Taylor-phase crystal represents a thermal memory cell. This discovery represents the introduction of a new kind of memory element, where the digital information is stored by pure temperature manipulation in the absence of any external static electrical or magnetic field or electromagnetic radiation (J. Dolinšek et al., Phys. Rev. B 77, 064430(2008)).

**Development of novel double-resonance methods; study of phase transition in organic ferroelectric; analysis of NQR parameters \(^{17}\text{O}\) in P=O and P-O-H bonds**

The \(^{1}\text{H}-^{17}\text{O}\) nuclear quadrupole double resonance using magnetic field cycling between high and low magnetic fields and the solid effect in a low magnetic field was analyzed in detail. The transition probabilities per unit time for the solid-effect transitions were calculated. The double resonance spectra were calculated in the limiting cases of fast and slow nitrogen spin–lattice relaxation. The double resonance spectra were measured in histamine and quinolinic acid. The experimental spectra were analyzed and the \(^{17}\text{O}\) NQR frequencies were, for the first time, determined in both substances. The sensitivity of Slusher and Hahn’s nuclear quadrupole double resonance technique was calculated in general for an arbitrary nuclear spin \(S\) of the quadrupole nuclei and for an arbitrary transition between the quadrupole energy levels. The nuclear spin \(S = 5/2\) \((^{17}\text{O}, \text{Mg})\) was treated in detail. The influence of the cross-relaxation rate between the quadrupole nuclei and the protons on the sensitivity of the double resonance was discussed. The results of the theoretical analysis were applied in the analysis of the \(^{1}\text{H}-^{17}\text{O}\) nuclear quadrupole double resonance spectra in p-toluenesulfonamide and 2-nitrobenzoic acid. The \(^{17}\text{O}\) nuclear quadrupole resonance frequencies from a sulphonamide group were determined for the first time. The proton–oxygen cross-relaxation rates were experimentally determined from the nuclear quadrupole double resonance spectra.

**European projects in 2008.** The above research was partially supported by the EU FP6 project MULTICERAL (principal Slovenian investigator, R. Blinc), and by the EU FP6 Network of Excellence project “Complex Metallic Alloys” (principal Slovenian investigator, J. Dolinšek), which is the cover project for the annual European School in Materials Science, conducted in Ljubljana, Slovenia. Since 1 December 2008 we have been involved in the EU FP7 project ‘AppliCMA’ (principal Slovenian investigator, J. Dolinšek). The research was also supported by numerous bilateral, industrial and national defence projects.

**Guest Editorial in the journal Ferroelectrics.** Four volumes of the journal Ferroelectrics were published in 2008, which include the proceedings of the 11th European Meeting on Ferroelectricity (EMF-2007, Bled, Slovenia). The guest editors of these volumes were dr. Vid Bobnar and dr. Boštjan Zalar.

**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 dynamic 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. A special emphasis is given to possible electro-optic and medical applications.

A substantial part of our research in 2008 was devoted to the field of nematic colloids. We demonstrated that the symmetry of the elastic interaction between the dipolar and quadrupolar colloidal particles in the nematic liquid crystal leads to a novel variety of 2D nematic “binary” colloidal crystals, which have so far not been observed in any colloidal system. The dipolar-quadrupolar interaction is highly anisotropic and shows a power-law dependence when the particles approach each other along the director field. This work was published in the paper “2D Interactions and...”
Department for Complex Matter. (Maja Remškar)

Topics 08, organized in collaboration with the frame of the international conference Hot Nano

Figure 15: Scanning electron micrograph of MoS2 cubes, surrounded by coaxial MoS2 nanotubes. Awarded the first prize in the NanoArt competition in the frame of the international conference Hot Nano Topics 08, organized in collaboration with the Department for Complex Matter (Maja Remškar)

Nych and M. Ravnik)

simulation using the Landau-de-Gennes theory. (A. Nych and M. Ravnik)

Figure 13: Smaller colloidal particles are trapped into the topological defect loop, twisting around a larger colloidal pair. (M. Škarabot)

Figure 14: Myosin motors acting on an actin filament with a right-handed structure induce a left-handed helical motion. (A. Vilfan)

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are promising for tribology, solar-energy conversion, and for smart polymer composites. In the field of the home-made instrumentation and its application, which includes, in particular, the surface manipulation of single adatoms and molecules, an investigation of phenomena like surface electronic standing waves, and single-atom spectroscopy. After a series of successful manipulation experiments with surface copper adatoms on different single-crystal substrates, we succeeded in 2008 for the first time to clearly demonstrate our ability to measure completely reproducible spectroscopy spectra on individual Cu adatoms and even the Kondo effect, i.e., the interaction of an individual magnetic atom, in our case Co, with the free electrons of a non-magnetic substrate (Fig. 5). We also continued to study experimentally and theoretically the structure and related

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using a simple lebwohl-lasher semimicroscopic approach. A phenomenon of particular interest is the stochastic resonance in ferroelectric liquid crystals. We were the first to analyse systematically the combined influence of static and dynamic disorder in stochastic resonance for short- and long-range interactions in these systems.

In the field of molecular motors we have investigated the collective properties of motors (myosin molecules) interacting with helical filaments (actin). We have shown that motors can induce a left-handed twirling motion of actin, even though the latter has a right-handed helical structure. The period of rotation depends on the sliding velocity and increases for high, as well as for very low, velocities. Furthermore, we have started to investigate more complex structures involving bundles of microtubules, maintained by motor proteins that play an important role in cell division. In collaboration with the group of Professor Igor Poberaj we have used the findings of our past research to design biomimetic concepts of biomimetic microfluidic pumps and mixers driven by a magnetic field.

In the Laboratory for inorganic nanotube synthesis we optimized the synthesis of hybrid nanostructures based on MoS2 nanotubes. Besides “mama-tubes”, i.e., nanotubes with in-situ grown encapsulated MoS2 nanospheres, we succeeded in growing coaxial nanotubes with tube walls split into several cylinders, and also MoS2, cubes (Fig. 4). In cooperation with the Faculty for Mechanical Engineering, University of Ljubljana, we have performed the first testing of our hybrid nanotubes mixed with synthetic oils. We also started the mixing of the materials with polymers (in collaboration with the Universities in Madrid and Lisbon). We applied for PCT protection of the method for the synthesis of these unique nanostructures. Such hybrid materials are promising for tribology, solar-energy conversion, and for smart polymer composites. In the field of the detection of nanoparticles in air we applied for a patent for a new detection method and built – in collaboration with the company CosyLab d.d – a new generation of a prototype for a cheap, portable detector.

In 2008, the Laboratory for low-temperature ultra-high vacuum scanning-tunnelling microscopy, spectroscopy and single-atom manipulation focused on improvements to the home-made instrumentation and its application, which includes, in particular, the surface manipulation of single adatoms and molecules, an investigation of phenomena like surface electronic standing waves, and single-atom spectroscopy. After a series of successful manipulation experiments with surface copper adatoms on different single-crystal substrates, we succeeded in 2008 for the first time to clearly demonstrate our ability to measure completely reproducible spectroscopy spectra on individual Cu adatoms and even the Kondo effect, i.e., the interaction of an individual magnetic atom, in our case Co, with the free electrons of a non-magnetic substrate (Fig. 5). We also continued to study experimentally and theoretically the structure and related

Figure 12: Microscopic images of mixed dipolar-quadrupolar 2D lattice micron-sized particles in a nematic liquid crystal (left) together with computer simulation using the Landau-de-Gennes theory. (A. Nych and M. Ravnik)

Figure 14: Myosin motors acting on an actin filament with a right-handed structure induce a left-handed helical motion. (A. Vilfan)

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properties of certain low-dimensional compounds like intercalated NbTe₅ single crystals, and the charge density waves, stabilized by different intercalants. Apart from the low-temperature scanning-tunnelling microscopy and spectroscopy, we also used low-energy electron diffraction, Auger spectroscopy, and transmission electron microscopy.

Applications of liquid crystals. The applied research in the field of light modulation by means of a fast LC light shutter was focused on an analysis of light transition through thin layers of ordered nematic. The computer-modelling software, on the basis of the Berreman method, was upgraded to also allow for a Poincaré sphere analysis. A number of high-tech processes for soft as well as for rigid substrates were developed in order to allow for the small-series production of novel LC light-protective filters. The research results were published in *Appl. Optics* 47, 12(2008), and two international patents were granted (EP 1625445, US 7,420,631) as well as transferred to the small-series production in the spin-off company of IJS Balder Ltd. The new method as well as the prototype equipment for measuring the light sensitivity of the optical protective filters for the new international ISO standard was accepted by the Task Groups ISO/TC94/SC6/WG2 and WG4 on the occasion of the conference ISO/TC94/SC6 group for Eye Protection in Sydney, Australia.

The results of our research programme in 2008 appeared in 22 articles in peer-reviewed journals (including Physical Review Letters and Nano Letters), one monograph contribution, 10 papers in conference proceedings, and led to two patent applications. Members of the program group have given 11 invited talks at international conferences (San Jose, Odessa, Philadelphia, New London, Manchester, Jeju (2x), Boulder (2x), Ljubljana) and organized 3 scientific meetings (in Portorož, Podčetrtek, and Erice). It is worth mentioning that our group was the only one in Slovenia to obtain, in 2008, an award from the Human Frontiers Science Program organization, which was founded years ago by the G7 and the EU to speed up the basic research on complex processes in living organisms. The head of our program group, Professor Slobodan Žumer, was elected as President of the International Liquid Crystal Society (ILCS) for the next four-year term of office. ILCS is the main society worldwide in the field of liquid crystals and has over 900 members that elect the president. Professor Igor Muševič is the first recipient of the new, mid-career ILCS award for outstanding achievements in the field of liquid crystals. He was awarded at the ILCS conference at Jeju in Korea in July this year.

**Research programme “Experimental Biophysics of Complex Systems”**

Within the program “Experimental Biophysics of Complex Systems” we explore the processes and structures of various complex systems (from model systems to the structures in living cells, tissues and even small animals) including the effects of various bioactive molecules on these systems. One of the aims is to investigate the structural properties of different membrane structures, such as membrane domains, membrane proteins and the glycosaccharide matrix as well as their interactions with other cell parts at different pathogenic states. These activities will improve our understanding of cell signalling and signal transduction in biomembranes, which in turn will enable a better insight into complex cell responses. In addition, research in different fields is conducted, for example, in vivo oxymetry studies on live animals for the optimization of medical treatment in tumor therapies, magnetic resonance imaging techniques and mathematical modelling of thrombolysis, magnetic resonance microscopy for application in forestry and wood science, studies of constrained diffusion as well as food processing by magnetic resonance imaging. Another important part of our activities is the development of spectroscopic methods of electron paramagnetic resonance, magnetic resonance imaging and combined fluorescence microspectroscopy. The latter will broaden the range of the molecular spectroscopies used in the group within the nanometre spatial and nanosecond time scale and the coupling of the molecular spectroscopies with the microscopic analysis, with the aim being to detect the interdomain interactions in living cells.

Within the **biomembrane characterization** we focus on solving the **membrane domain paradox**, a consequence of the characterization mismatch of different microscopies and spectroscopies of these supramolecular structures mediating the activities of membrane receptors, channels and pump. To solve this problem, we started to develop a combined experimental approach based on electron paramagnetic resonance (EPR) and fluorescence microscopy. The main connection between these three techniques is the so-called double probes, possessing a nitroxide group and fluorophore at the same time. In such a way we couple the microscopic image describing the partitioning of the probes among cell structures with a resolution of 150 nm on a millisecond time-scale and a molecular image derived by EPR and fluorescence spectroscopy with nanometre resolution on a nanosecond time-scale. The properties of membrane domains have been modified by

Using our scanning-tunnelling microscope at low temperatures we have manipulated individual atoms and assembled artificial nanostructures. The spectra of the electron tunnelling current through individual atoms have been studied.
various chemical substances, including alkyl-phospholipids, representing a strong potential in cancer treatment. The electron spin resonance (EPR) method was therefore used to investigate the interaction between liposomes composed of alkylphospholipid (OPP) and cholesterol, the potential anticancer drugs, with breast cancer cells. We found that the interaction depends strongly on the liposome membrane domain structure, which is determined by the cholesterol content in the liposomes. The rapid release of the liposome entrapped hydrophobic substance into the cell, which is supposed to be the consequence of membrane fusion, coincides with the presence of domains with a highly disordered alkyl-chain motion that disappears at 50 mol% of cholesterol. We proposed that these highly fluid domains are responsible for membrane fusion. These results suggest that the micelles are not the only reason for the cytotoxic effect of OPP formulations, but the liposomes with less than 45 mol% cholesterol also contribute to the cytotoxicity of these formulations. EPR was also used to investigate the formation of vesicles from the most simple amphiphilic system—decanoic acid-sodium decanoate—which is important for understanding the processes, which led to the formation of membranes and protocells during early evolution. We have found that the vesicles are formed from micelles in a well-defined pH region between pH 6.5 and pH 7.8. In this interval the micelles remain in coexistence with vesicles.

Within the activities dedicated to protein structure characterization, where classical high-resolution techniques are not so successful, we determined the structure of the major coat protein as well as its conformational dependence on membrane biochemical composition. In addition we characterized the temperature-induced structural degradation of a protein complex of the N-terminal end of a measles virus nucleoprotein and its biological partner phosphoprotein. This represents the first characterization ever determined dedicated to structures stable for not more than a few nanoseconds and still being physiologically active. Finally, we also characterized the structure of one terminal end of the photosystem protein CP29 and compared the differences with better-known photosystem proteins.

We have optimized the deposition of titanate nanomaterials for application in the maintenance of clean surfaces, to increase their photocatalytic antimicrobial activities on predefined surfaces, chosen according to applications in the food-processing industry. Special care was taken to increase the efficiency of the method to prevent bacterial growth of those bacteria that are adapted to grow at lower temperatures. At the same time we continued to work in the field of oxymetry. The sensitivity of the L-band EPR spectrometer was increased by an order of magnitude. In this way the measurements of radicals in tooth enamel, which are formed during ionizing radiation in hydroxypatite of tooth enamel at the doses of about 2 Gy. In this way the possibility of applying the EPR method for biodosimetry in in-vivo conditions on the human population is greatly increased.

The moisture content of wood can also be determined by NMR. In the past year our group for MRI discovered a method for moisture determination by NMR, which has, in comparison to other presently known methods for moisture-content determination, the advantage of greater accuracy and instantaneous response. The method is currently in the process of a patent registration and a scientific paper, where the method presented is already accepted in Holzforschung, a well-renowned scientific journal in the field of wood science. The paper got very positive critiques from all the reviewers.

The MRI group at the JSI was also scientifically active in the field of thrombolysis. Experiences with diffusion imaging gained over the years were combined with those in the field of thrombolysis. This resulted in a new protocol that could help improve thrombolytic treatment. Namely, we discovered that the apparent diffusion coefficient (ADC) images are more accurate in the prediction of clot regions that are susceptible to thrombolysis than the currently used T2 mapping method. We determined a relation between the NMR parameters ADC and T2 and the success rate of the thrombolysis. The group was also active in studies of diffusion in porous materials. The group discovered a new method for the measurement of diffusion spectra. The method excels in its high accuracy and wide frequency range. The method was used in the discovery of the anomalous diffusion behaviour of water at low frequencies in comparison to other liquids. The measured diffusion spectra indicate that water forms clusters of molecules that slow down diffusion in the low-frequency range. Another discovery of the group is an improved RARE method that enables auxiliary phase encoding. The method was demonstrated with electric current density imaging. Namely, the original RARE method cannot be used with auxiliary phase encoding and the discovered modification of the method has overcome this problem and can be used whenever auxiliary phase encoding and imaging speed are needed.

The above research has been supported by a number of international projects financed by the European Union within the 5FP and 6FP, as well as by NATO. It was also supported within the bilateral Slovenia–USA, Slovenia–German and Slovenia–Greece projects and other scientific cooperations.
We also have international cooperations with:
- The high magnetic field centers in Grenoble, France, and Nijmegen, The Netherlands,
- The high magnetic field center 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 Saarbrücken 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 Delbrück Center for Molecular Medicine in Berlin, Germany,
- The Dartmouth Medical School, Hanover, NH, USA,
- The Mayo Clinic, Rochester, USA.

Some outstanding publications in 2008


Some outstanding publications in 2007


Some outstanding publications in 2006


Some outstanding publications in 2005


Patents granted

1. Procedure for the synthesis of thread-like tungsten oxide W$_2$O$_5$
   Maja Remškar, Marko Viršek, Miha Kocmur, Adolf Jesih
   SI Patent no. 22445
2. Polarization-enhanced double-channel NQR/NMR detection of solid and liquid explosives with multi pulse sequences
   Robert Blinc, Zvonko Trontelj, Janko Lužnik, Tomaž Apil, Janez Seliger, Gojmir Lahajnar
   SI Patent no.22459
3. A process for the synthesis of nanotubes and fullerene-like nanostructures of dichalcogenides transition metals
   Aleš Mrzel, Maja Remškar, Adolf Jesih, Marko Viršek
   SI Patent no. 22485

4. Procedure of synthesis of amidines and their derivatives
   Kristina Nadrah, Marija Sollner Dolenc, Slavko Pečar
   SI Patent no. 22487

5. Metamaterials and resonant materials based on liquid crystal dispersions of colloidal particles and nanoparticles
   Igor Muševič, Miha Skarabot, Slobodan Žumer, Miha Ravnik
   SI Patent no. 22508

6. High Contrast, Wide Viewing Angle LCD Light-Switching Element
   Janez Piriš, Matej Bažec, Sivija Piriš, Bojan Marin, Andrej Vrečko

Awards and appointments
5. Slavko Pečar: Minarikovo acknowledgment, Ljubljana, Slovenian Pharmacy Association

Organization of conferences, congress and meetings
1. 6th Physics Conference in Basic Research, Podčetrtek, Slovenia, 7 Nov. 2008
2. 15th Workshop Liquid Crystal Phases and Nano-Structures, Erice, Italy, Co-organiser, 27 Oct. to 1 Nov. 2008
6. 3rd European School in Materials Science, Mons, Ljubljana, Slovenia, 26–31 May 2008
7. F5 Department Brainstorming Day, Bistra, Slovenia, 17 Sept. 2008

INTERNATIONAL PROJECTS
1. Development of Wear Resistant Coatings based on Complex Metallic Alloys for Functional Applications
   applicMA
   7. FP 214407
   EC, Susanne Fuchs, Austrian Research Centers GmbH - ARC, Functional Materials, Seibersdorf, Austria
   Prof. Janez Dolinshek, Dr. Miha Čakada, Dr. Kristoffer Kruzel, Dr. Srečo D. Škapin
   2. Hierarchical Assembly in Controllable Matrices
   HIERARCHY
   7. FP 215851, PITN-GA-2008-215851
   EC, Harry Ballmann, Radboud University Nijmegen, Faculty of Science, Finance and Economic Affairs, Nijmegen, The Netherlands
   Prof. Igor Muševič
   3. Multifunctional Ceramic Layers with High Electromagnetostatic Coupling in Complex Geometries
   MULTICERAL
   6. FP NMP3-CT-2006-032606
   EC, Prof. Andrei Khlokin, University of Aveiro, Department of Ceramics & Glass Engineering, Aveiro, Portugal
   Prof. Robert Blinc, Prof. Marija Kosec, Dr. Janez Holc, Prof. Raša Pirc
   4. Reliable, Tuneable and Inexpensive Antennas by collective fabrication processes
   RETINA
   6. FP AST4-CT-2005-561251
   EC, Dr. Volker Ziegler, EADS Deutschland GmbH, Corporate Research Centre, Dept. LG-ME, München, Germany
   Dr. Vid Bobnar, Prof. Marija Kosec, Ass. Prof. Barbara Malić
   5. Complex Metallic Alloys
   CMA
   6. FP NMP3-CT-2005-500140
   EC, Centre National de la Recherche Scientifique, Paris, France
   Prof. Janez Dolinshek, Dr. Peter Panjun, Prof. Spomenka Kobe
   6. Safe Production and Use of Nanomaterials
   NANOSAFE2
   6. FP NMP2-CT-2005-515843
   EC, Frederic Schuster, Commissariat a l’Energie Atomique, Grenoble, France
   Ass. Prof. Maja Remškar
   7. Fulleren-based Opportunities for Robust Engineering: Making Optimised Surfaces for Tribology
   FOREMOST
   6. FP 515840-2
   EC, Alberto Alberdi, Fundacion Tekesiker, Elbar, Spain
   Ass. Prof. Maja Remškar, Dr. Marko Žumer, B. Sc.
   8. Improving the Understanding of the Impact of Nanoparticles on Human Health and the Environment
   IMPART
   6. FP 015968
   EC, Mark Pullinger, Chalex Research Ltd., Torquay, Great Britain
   Ass. Prof. Maja Remškar
   9. Optical Micro-manipulation by Nonlinear Photonics
   OIST-MP0604
   EC, Prof. Igor Muševič
   10. Advanced Paramagnetic Resonance Methods in Molecular Biophysics
   COST P15
   EC
   Ass. Prof. Janez Strancar
R&D GRANTS AND CONTRACTS

1. Patterning, structural self-assembly and multifunctional states in mixtures of nanoparticles and liquid crystals
   Prof. Samo Kraš

2. Physico-chemical processes involved in formation of radioactive nano aerosols
   Prof. Janja Vaupotič, Ass. Prof. Maja Remškar

3. Carbon nanotube based spin qubits
   Prof. Anton Ramsak, Dr. Bolko Žeklo

4. Active devices - dispersion force based nanosensors
   Ass. Prof. Andrej Vilfan

5. MRI research of wood as a material and as a live tissue
   Dr. Moja Ušika Mikše

6. Selforganization of molecular nanomagnets in nanotubes
   Dr. Polona Umeš

7. Novel nanostructured materials with giant electromechnaical response, soft elasticity and unusual physical properties: thermal, dielectric, transport and selforganization studies
   Prof. Zdravko Kutnjak

8. Elaboration and evaluation of a toxicity test for engineered nanoparticles with terrestrial isopods
   Ass. Prof. Maja Remškar

9. Organic and inorganic percolative composites with giant dielectric constant
   Ass. Prof. Vid Bohnar

10. Self-assembly of nanoparticles in 2D nematic colloidal crystals: photonic crystals and metamaterials
    Prof. Igor Mulevič

11. Ecotechnological 1D nanomaterials: Synthesis and characterization of 1D titane nanorods doped with transition metal ions
    Dr. Polona Umeš

12. Study of the structure and the dynamics of blood clot dissolution: mathematical modeling supported by magnetic resonance experiments
    Ass. Prof. Igor Serša

13. Formulation and characterization of nanogenic nanoparticles for efficient drug delivery
    Dr. Marija Sentjark

14. NQR - nondestructive method for study of polymorphism in pharmacy
    Dr. Tomáš Apil

15. Applications of nanoparticle-macromolecule complexes for the formulation of biological drugs
    Prof. Igor Mulevič

16. Wire-less Network of Networks with Radio over Fiber
    Prof. Jurij Franc Tasič

17. Numerical detection of nanoparticles in air
    Ass. Prof. Maja Remškar

18. Analysis, computer modeling and optimization of the storage of explosives
    Ass. Prof. Janje Pirić

19. Selfcleaning materials for antimicrobial protection of surface of vehicles and equipment
    Ass. Prof. Janez Strančar

20. Biosimmetry by magnetic resonance methods
    Dr. Marija Sentjark

21. Rapid two-channel NQR/NMR detection of solid and liquid explosives
    Dr. Tomáš Apil

22. Development of superhard PA composites
    Ass. Prof. Denis Avčin

23. Smart functional hard coatings for increased durability of defence-related equipment
    Dr. Peter Panjan, Prof. Janez Dolinšek

24. Thermally stable antioxidants and food stability
    Dr. Marija Sentjark
25. Antimicrobial surfaces for safety production of food
   Asst. Prof. Janez Strancar

   Dr. Peter Jeglič

27. Preparation of Supported Lipid Membranes with Enzymes for Development of Biosensors
   Dr. Zoran Arsov

28. Magnetism in Geometrically Frustrated Two-Dimensional Spin Systems
   Dr. Andrej Zorko

RESEARCH PROGRAMS

1. Experimental biophysics of complex systems
   Asst. Prof. Janez Strancar

VISITORS FROM ABROAD

1. Aleh Kavalenka, Belarusian State University Work, Systems Analysis Department, Mirak, Belarus, 1 Jan. to 31 Dec. 2008
3. Prof. Dr. Danielle Finotello, Kent State University, Kent, Ohio, USA, 31 Mar. to 5 Apr. 2008
5. Dr. Roland Roth, Max-Planck Institut fuer Metallforschung, Stuttgart, Germany, 12–15 May 2008
8. Prof. Dr. Erwin Frey, Ludwig Maximilian University, Munich, Germany, 12–15 May 2008
10. Prof. Dr. Valentin Laguta, Ukrainian Academy of Science, Institute for Problems of Materiał Science, Department of Oxides Materials, Kiev, Ukraine, 20 Aug. 2008
11. Prof. Dr. Uichiro Mizutani, University of Nagoya, Nagoya, Japan, 29 May 2008
12. Prof. Dr. Michael V. Romalis, Princeton University, New Jersey, USA, 13 June 2008
13. Dr. Azerbaijani Woscura, Polish Academy of Sciences, Institute of Molecular Physics, Poznan, Poland, 1–7 June 2008 and 27 Sept. to 24 Dec. 2008
14. Dr. Lise Lyngsnes Randeberg, Norwegian University of Science and Technology, Department of Electronics and Telecommunications, Trondheim, Norway, 21 May 2008
15. Prof. Dr. Pedro Sebastiao and Prof. Dr. Maria Helena Godinho, Instituto Superior Tecnico, Departamento de Fisica, Lisbon, Portugal, 10–18 Jul. 2008
16. Dr. Janez Pirš, Balder, optoelectronic elements and measuring systems, ltd. 75th Annual Report 2008

STAFF

Researchers
1. Asst. Prof. Tomaž Apšič
2. Asst. Prof. Denis Arčon
3. Prof. Robert Blinc
4. Asst. Prof. Vid Bohnar
5. Asst. Prof. Pavel Gove
6. Prof. Janez Dolinšek
7. Dr. Gine Filipič
8. Prof. Marija Jamšek Vilfan
9. Dr. Peter Jeglič
10. Dr. Martin Klajdšek
11. Prof. Samo Kral
12. Prof. Zdravko Kutnjak
13. Prof. Gojmir Lahajnar
14. Prof. Adrian Levstik
15. Dr. Mojca Uska Melčak

16. Prof. Igor Misievič*, Head
17. Prof. Slavko Pečar
18. Dr. Janez Pirš
19. Asst. Prof. Dušan Ponikvar
20. Prof. Albert Prodan
21. Asst. Prof. Maja Remškar
22. Prof. Janez Seliger
23. Asst. Prof. Igor Serša
24. Prof. Janez Stepišnik
25. Dr. Marija Sentež, retrained 31 Dec. 2008
26. Dr. Miha Skarabot
27. Asst. Prof. Janez Strancar
28. Prof. Jurij Franc Tašku

29. Prof. Slobodan Zumer

NEW CONTRACT
1. Export analysis of the state-of-the-art LCD active light filters
   Balder, optoelectronic elements and measuring systems, Ltd. Dr. Janez Pirš
**BIBLIOGRAPHY**

**ORIGINAL ARTICLES**


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Department of Solid State Physics
Primož Oven, Maks Merela, Igor Serša, Urška Mikac, "Raziskava...


1. Stanislav Gobec, Andreja Kovač, Alja Brajić, Slavko Pečar, Julieanne M. Kočevar, Slovenko Polanc

TEXTBOOKS AND LECTURE NOTES


THESIS

Ph. D. Theses


PATENT APPLICATIONS

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 and biomolecules to superconductors and nanowires. The experimental methods used are suitably diverse, from synthetic chemistry to biomedicine and femtosecond laser spectroscopy and magnetometry. Last year’s research achievements are thus quite diverse, but we are able to report on breakthroughs in a number of areas.

The activities in the department can be grouped together into a number of thematically inter-related research areas:

**Ultrafast studies of electron dynamics in correlated systems.**

The field of the research of relaxation processes of photo-excited electrons in strongly correlated electron systems remains one of our main research topics. Several experimental studies of carrier-relaxation phenomena in strongly correlated electron systems have been performed using femtosecond time-resolved techniques. The aim of the ongoing research is to gain additional information about the nature of the low-lying excitations in these materials, and to explore the nature and strength of the interactions of electrons with other low-lying excitations. Femtosecond spectroscopy has been instrumental in elucidating the nature of the electronic excitations in superconductors, since it allows us to distinguish the different components by their lifetimes. Moreover, the relaxation kinetics can yield valuable information on the mechanism for superconductivity.

As an important contribution to the understanding of the nature of high-temperature superconductivity we should mention our study of the relaxation processes in the cuprate superconductor $\text{La}_2\text{Sr}_2\text{CuO}_4$. We studied the photo-induced phase transition from the superconducting to the normal state. The absorbed energy density required to suppress the superconductivity was found to be an order of magnitude higher than the thermodynamically measured condensation energy. The implication of this result is that in cuprates charge carriers have by far the strongest interaction with phonons. This work has been published in *Physical Review Letters* 101, 227001 (2008).

The recent discovery of high-temperature superconductivity in iron-based pnictides has attracted a great deal of attention, partly because of their high critical temperatures, but more fundamentally because they appear to have some similarities and important differences compared to cuprate superconductors, which raises the question of the superconductivity mechanism. Particularly pertinent are the questions regarding the existence of a pseudogap precursor state, which is believed by many to be essential for high-temperature superconductivity and is attributable to pre-formed pair formation above the $T_c$.

We are the first group in the world to investigate the quasiparticle relaxation and low-energy electronic structure in a near-optimally doped pnictide superconductor, $\text{SmFeAsO}_0.8\text{F}_{0.2}$, with $T_c \sim 49.5$ K. Multiple relaxation processes are evident, with distinct superconducting state quasiparticle recombination dynamics exhibiting a $T$-dependent superconducting (SC) gap, and a clear “pseudogap” (PG)-like feature with an onset around 200K, indicating the existence of a temperature-independent gap of magnitude $\Delta_{PG} \approx 61 \pm 9$ meV above the $T_c$. Both the SC and PG components show saturation as a function of fluence. This work has been submitted to *Physical Review Letters*.

The first systematic studies of photo-induced charge density wave (CDW) – metal phase transition have been performed on the prototype quasi one-dimensional CDW system $\text{K}_{\text{x}}\text{MoO}_3$. The photo-induced phase transition is found to be non-thermal and takes place on the 100 fs timescale. The recovery of the electronic subsystem is found to be extremely fast, on the sub-ps timescale. The fact that several folded phonons, characteristic for the modulated ground state, are observed at fluences far above the phase transition threshold implies that on a timescale of several 100 fs after the photo-excitation the lattice remains in its unperturbed state. We believe that this could be the reason for an extremely fast order-parameter recovery in this class of systems. The paper is currently under review in *Physical Review Letters*.

The coupling of phonons with collective modes and single-particle gap excitations associated with one (1D) and two-directional (2D) electronically driven CDW ordering in metallic RTe₅ is investigated as a function of rare-

**Laboratory experiments investigating the evolution of the universe rely on investigating the evolution of single-particle and collective excitations in analogue systems, such as liquid helium $^3\text{He}$. In a new type of cosmic-quench experiment we have proposed investigating the mechanisms for domain-wall anti-wall recombination processes on the ultra-fast timescale in a model electronically ordered system.**
Nano-bio-sensors are currently a very hot topic in nanotechnology, with potential applications in medicine, the environment and for the detection of explosives. MoSI molecular wires have been found to be unique in providing a substrate for the attachment of antibodies and aptamers for the ultra-sensitive specific electrochemical detection of proteins. The sensor was found to have universal application for the detection of femtomolar concentrations of proteins.

Ultrafast studies of electron dynamics in low-dimensional systems.

We studied the equilibrium and non-equilibrium optical properties of $\text{Mo}_6\text{S}_3\text{I}_6$ nanowires using a range of different laser wavelengths from 0.5 to 2.8 µm. The absorption of oriented thin films of MoSI nanowires shows good qualitative agreement with density functional theory calculations (in collaboration with the department F-1). The broad features indicate the large density of the interpenetrating electron sub-bands as well as the damping of transitions and disorder in the bulk. The electron relaxation from a non-equilibrium situation was explored with femtosecond pump-probe spectroscopy. We found a cascade relaxation involving three distinct states determined from the $T$ dependence of the cDW gap and the amplitude of excited states and hence their lifetime can be modulated by an electric field ($\text{Phiz. Rev. B}$ 78, 045207 (2008)). A further consequence of this effect is the non-linear bimolecular relaxation properties and has been published in $\text{Phys. Rev. Lett.}$ 100, 057401 (2008). A new method of three-pulse ultrafast optical spectroscopy was introduced and used for the investigation of the phase-transition dynamics from the disordered state to the ordered CDW state in $\text{FeTe}_2$. We found that the local CDW gap develops on a significantly faster timescale than the long-range coherent order. The paper reporting these results is currently in the final stage of preparation.

We also continued with measurements and analyses of the magneto-optical Kerr effect in (Pr,Ca)MnO$_3$ thin films. Some of the results were published in $\text{Applied Physics Letters}$ 93, 042512 (2008). Another part of the results was submitted to $\text{Europhysics Letters}$.

The temperature and fluence dependence of the time-resolved photo-induced optical reflectivity in a decagonal $\text{Al}_{71.9}\text{Ni}_{11.1}\text{Co}_{17.0}$ quasicrystal was also measured. We found no evidence for the relaxation of a hot thermalized electron gas, as observed in metals. Instead, a quick diffusion of the hot, non-thermal carriers ~40 nm into the bulk is detected, enhanced by the presence of a broad pseudogap. From the relaxation dynamics we found evidence for the suppression of the electronic DOS at the Fermi energy, with respect to the electronic DOS at ~13 meV away from the Fermi energy, which is consistent with recent theoretical calculations. The manuscript is currently under review in $\text{Physical Review Letters}$.

In conjugated polymers, in particular polyfluorenes, which are the preferred polymer family for blue polymer LEDs or the blue component of organic displays, we used femtosecond spectroscopy in combination with a modulated electric field, which yields additional information on the electronic structure of photo-excited states. We showed that the Stark effect, and the nonlinear optics related to it, is not only seen in transitions involving the ground state, but also in transitions between two excited states. This opens up broad opportunities for switchable, nonlinear, optical properties and has been published in $\text{Phys. Rev. Lett.}$ 100, 057401 (2008). A further consequence of this effect is the non-linear bimolecular relaxation of excited states and hence their lifetime can be modulated by an electric field ($\text{Phys. Rev. B}$ 78, 045207 (2008)).
Theoretical studies on the nanoscale.

We developed the theory of the proximity effect for a clean superconductor-to-metal interface. We have shown that contrary to the dirty limit the order parameter decreases in normal metal as a power low of the distance from the interface. We also predicted that there exists a characteristic temperature, which is dependent on the size of the sample, at which the decay of the order parameter becomes exponential. (Physical Review B, 78, 132510 (2008)).

After the reports of observations of the de Haas–van Alphen oscillations in underdoped high-Tc superconductors we have developed the theory of quantum oscillations in doped antiferromagnetic semiconductors. We have shown that the presence of magnetization axes leads to the strong anisotropy of the amplitude of oscillations, which allows the detection of the antiferromagnetic order on the basis of quantum-oscillation measurements. We also investigated the appearance of mixed frequencies in the Shubnikov-de Haas effect in the case of quasi-2D materials with complex Fermi surfaces. (Physical Review B, 77, 075434 (2008), ibid 77, 132403 (2008)).

We have developed the analytical kinetic theory of the relaxation of hot electrons photo-exited by the laser pulse in metals. In the regime of weak perturbation we were able to linearize the kinetic equations and reduce them to differential form. As a result the problem was reduced to the so-called Calogero-Sutherland equations, which have exact analytical solutions. An analysis of the solution shows that the two temperature model, commonly used for the analysis of the relaxation in metals, is qualitatively incorrect and predicts shorter relaxation times than exact theory (Physical Review B, 78, 174514 (2008)).

Nanotubes and nanomaterials.

Two major breakthroughs were reported in the area of nano-biosensors using MoS$_{2−}x$I nanowires. In the first report, which appeared in Chem. Materials, MoS$_{2−}x$I nanowire networks of interest are found to change their resistance in response to the presence of analyte vapors. This vapour-sensing behaviour is quantitatively described very well phenomenologically in terms of the concentration of adsorbed analyte molecules in the contact tunneling junctions, and an expression is derived for the dynamics and sensor resistance in terms of the analyte vapour pressure. The time response of the sensor is observed to follow simple adsorption–desorption kinetics. The network sensor shows a very clear selectivity, whereby the response is related to the dipole moment of the analyte. The response function favours rapid detection of small analyte concentrations. The work has opened the way to an entirely new type of olfactory sensor, which can be tailored to have recognition detection of small molecules and is sensitive over a wide range, and has a linear response. Intensive efforts are now continuing in this direction to produce a prototype e-nose sensor.

In the second report, this time in collaboration within the DESIGN-IT project, “Bioassembled Nanocircuits of MoS$_{2−}x$I Nanowires for Electrochemical Immunodetection of Estrone Hapten” are reported. We demonstrated a novel and highly sensitive electrochemical detection of estrone based on an immunosensor platform, composed of bio-assembled nanocircuits of MoS$_{2−}x$I nanowires (MoSi NWs) covalently connected to anti-estrone antibodies. The one-step, label-free, and quantitative detection of estrone is realized by employing the [Ru(NH)$_3$Cl$_2$]$_3$/2+ redox ions to sense anti-estrone antibody and estrone interactions. The MoSi NWs/antiestrogen nanocircuit architectures provide an amplification and conductive pathway for the specific electrochemical sensing of estrone hapten. A detection limit of 1.4 pg mL$^{-1}$ was achieved, in contrast to previous electrochemical techniques in which the sensitivity was limited to the nanomolar range. The report was published in Analytical Chemistry.

MoS$_{2−}x$I are semi-metallic nanowires that have already been tested with others as molecular-scale connectors, bio- and chemosensors, electrodes for Li-ion batteries, and field emission tips. Due to their particularly low interaction with each other and their environment (hence their application also in lubricants), they are currently the “most one-dimensional” material we know. One of their key advantages is solubility in a number of common solvents, like acetone, ethanol or water, without the need for surfactants or chemical functionalisation (which was one of the big show stoppers for carbon nanotubes). In such solutions they are usually present as bundles of diameters, varying from 1 nm to 1 micron, depending on the procedure and concentration. We showed how we can rapidly centrifugate such a dispersion into fractions with different diameters and find a clear correlation between the bundle size and the optical absorption spectrum. Therefore, we can easily determine the diameter distribution by a simple optical measurement, which enormously speeds up the preparation and characterization of such dispersions.
Iron-based pnictide high-temperature superconductors discovered in 2008 have generated a lot of interest, both from the fundamental point of view and applications for potentially reducing energy-transport losses. We have performed the first measurements investigating the electronic structure, and particularly the band extrema, using femtosecond pump-probe experiments, which indicate the existence of a low-energy pseudogap in the electronic spectrum. This observation has important fundamental consequences for the mechanism of high-temperature superconductivity in the pnictides.

We discovered a method for growing vertically aligned bundles of Mo$_{6}$S$_{9-x}$I$_{x}$ (4.5 < x < 6) nanowires, perpendicular with respect to the substrate. In this efficient method, a one-step synthesis direct from molybdenum, sulphur and iodine in temperature-gradient conditions is used. The bundles with similar lengths and diameters could be grown on quartz or conductive materials like molybdenum foil at a temperature of around 1040 K. X ray diffraction (XRD), scanning electron spectroscopy (SEM) and transmission electron microscopy (TEM) were used to characterize the obtained bundles of nanowires. Due to the similar lengths of the aligned bundles and the ease of dispersion in some polar solvents, this material could also be potentially used for some applications, for example, as the building blocks in nanodevices.

Electron dynamics in biological macromolecules.

In 2008 we have continued our study of the electronic transitions in M-DNA, a new form of DNA where divalent metal cations are incorporated into the DNA structure by replacing one of the hydrogens from the hydrogen bonds in the interior of the double helix. Our intention was to complement previous results, which we have obtained with optical spectroscopy methods, with electron spin resonance (ESR) measurements. For this purpose we needed dry samples of M-DNA, which would be extracted from a buffered solution. Because M-DNA complexes are very sensitive to pH, temperature and salt concentration, the only suitable method for sample drying was lyophilisation (freeze drying). In the lyophilisation process we first freeze a buffered solution of M-DNA with liquid nitrogen and then we connect it to a vacuum system. During lyophilisation the solution always stays in the frozen state and the vacuum system pumps out water molecules directly from the ice. After approximately 24 hours the process is completed. The result is a white, waterless powder consisting mostly of dried Tris buffer and metal chloride (ZnCl$_2$). The percentage of M-DNA complex in a dry sample is approximately 5%, which is still much greater than in solution with a DNA concentration of 100 µg/ml. For the ESR measurements we used from 20 to 40 mg of sample. At room temperature the M-DNA ESR signal is wide (∼1000 G) and inhomogeneously broadened – the ESR signal’s line shape deviates significantly from the Lorentz curve, which is characteristic for homogeneously broadened ESR line shapes. When we cool the system we observe two features: i) the ESR line gets narrower and ii) the resonant field strongly decreases (from 3400 G to 2400 G). The sole detection of a strong ESR signal has led us to an important discovery: Zn$^{2+}$ ions, if trapped in a dry DNA, reduce to their monovalent state Zn$^{+}$, which is paramagnetic and produces a strong ESR signal. This is only the second known example of a stable zinc monocation in the solid state. The other known example, Zn$^{+}$ trapped in zeolit changes, was discovered five years ago. From the width and the position of the ESR line we can conclude that the unpaired electrons are mobile at room temperature and localized at low temperatures. The electron dynamics at room temperature is faster than the ESR time-scale 100 ps (10 GHz). This suggests that dry M-DNA could be an effective electron conductor. If so, it would be a major step forward in the development of molecular electronics, where a poor DNA conductance is still a major obstacle.

In the Light and Matter research group we continued our interdisciplinary studies of the interaction of light and matter and its use in research and applications in different fields.

Soft Matter.

Magneto-optical tweezers were used to study nematic colloids. In such systems, the interactions between colloidal particles are long ranged, due to the elastic deformations in the liquid crystal’s director field. We measured this interaction between two spherical particles under the influence of the confining surfaces. Our results show that there is a significant cross-over in the force versus particle separation dependence: the power law, which is expected due to the symmetry of the elastic deformations, holds only for separations up to approximately the thickness of the cell. At larger separations, the interparticle force decays exponentially, with the characteristic decay length being proportional to the sample thickness. We found an excellent agreement with a theoretical model made at the University of Ljubljana, Department of Physics, and corroborated the results by an analogy from classical electrostatics. The results are presented in a paper that was published in Physical Review Letters, 101, 257801 (2008).
In cooperation with the Faculty of Physics at the University of Vienna we continued investigations of the diffraction properties of holographic polymer-dispersed liquid crystals (HPDLCs). The effect of the phase and amplitude modulation on the angular dependence of the diffraction efficiency of 1D transmission gratings was analyzed. The results were published in Optics Express, 16, 6528-6536 (2008). We studied the effects of ageing, which occur after photopolymerization of the HPDLC gratings, on their structural and diffractive properties. The results show that most of the so-called “dark modifications” of the structure, which take place several days after the termination of the illumination, are associated with the phase-separation process. This investigation was reported in a paper published in Applied Physics B Laser Opt., 91, 11-15 (2008). A new series of optical gratings with different grating periodicities was fabricated and a comparative study of their diffraction properties for cold neutrons was performed. The results show that the amplitude of the modulation of coherent scattering length density for cold neutrons strongly decreases with a decreasing grating periodicity. The results are reported in a manuscript accepted for publication in Journal of Optics A, (2009).

We continued with investigations of 2D composite photonic structures from polymers and liquid crystals. With the use of an interference pattern of four coherent laser beams that were mixed on the sample with the help of a glass pyramid, we fabricated 2D photonic lattices with four-fold rotational symmetry. The role of the nematic-isotropic phase transition and the effect of an external electric field on the structural and diffraction properties of the lattices were investigated. The results of this work are reported in a manuscript accepted for publication in Journal of Optics A, (2009). In cooperation with TEDA College, Nankai University, P.R. China, we investigated the phenomenon of coherent back-scattering in polymer-dispersed liquid crystals (PDLCs).

In cooperation with the Department for Condensed Matter Physics at the Jožef Stefan Institute and the National institute for Chemistry in Ljubljana we started to investigate the process of optical holographic patterning in light-sensitive liquid crystal elastomers (LCEs). We demonstrated a large range of reversible tunability for the grating period of 1D transmission gratings made from this material by modification of the strain and the temperature of the medium. These features have a large potential for applications in optical sensors and various optical diffractive devices.

We continued to upgrade our experimental setup for the optical spectroscopy of surfaces and interfaces based on the nonlinear frequency mixing of IR and visible radiation (IR-Vis SFG). The technique was used to investigate the surface properties of Langmuir and Langmuir-Blodgett (LB) films of various organic molecules: heptadecanoic acid, guanosine 5 monophosphate (GMP), different lipophilic guanosine derivatives, etc. Structural data on surface adsorbates deduced from the SFG measurements were evaluated in comparison to the structural information attained by the use of atomic force microscopy (AFM). We found that on the mica surface the ammonium salt of GMP makes much more homogeneous and ordered films than sodium GMP. The results of the comparative SFG/AFM study are reported in a paper that is accepted for publication in Chemical Physics Letters, (2008).

Our cooperation with the laser company Fotona d.d. was focused on the further development of computer-simulation methods for determining the optical field in unstable laser resonators. The main part of the work was devoted to resonators with Gaussian mirrors and to investigations of the self-Q-switching effect in ruby lasers.

Using dynamic light scattering we have studied suspensions of ferrimagnetic maghemite ($\gamma-Fe_2O_3$) nanoparticles in n-decane. The measurements in the suspensions of different concentrations ranging from 0.21 to 25.8 wt % have been compared in zero external field and in a magnetic field of 270 mT. In all samples a well-defined relaxation process was observed. In the absence of an external field the suspensions were homogeneous, while in the magnetic field more concentrated suspensions undergo a phase separation in needle-like islands of a very dense suspension surrounded by a dilute suspension. The dynamical behaviour in the phase-separated samples is found to be anisotropic. In the direction parallel to the external field it keeps the free diffusion behaviour, but it is enhanced. In the perpendicular direction the diffusion is anomalous. The mean squared displacement grows faster than linearly with time and the dependence of the relaxation rate on the scattering vector $q$ is not quadratic. In this direction the system behaves like a repulsive glass close to dynamic arrest.

**Nonlinear optics.**

In the Nonlinear Optics Laboratory we study new materials and their interaction with laser light. We study new concepts of compact laser sources on the basis of the nonlinear optical conversion of Nd:YAG lasers.
We are interested in compact laser sources in the eye-safe wavelength region of 1550 nm and the challenging THz region. We cooperated with Fotona from Ljubljana and with the National Institute for Materials Science in Tsukuba, Japan, studying the optical properties of domain-engineered LiTaO$_3$ crystals with Mg doping and various degrees of stoichiometry. In addition, we studied the nonlinear conversion in KTP (Potassium Titanyl Phosphate) monolithic crystals. In cooperation with ETH, Zurich, a new topic is THz generation with difference frequency mixing. In an optical parametric oscillator we produce pulses with two frequency components with a prescribed frequency difference. These pulses are then sent to a nonlinear optical crystal where they generate a pulse of THz waves.

Biomedical optics.
We have developed a laboratory system for non-contact measurements of laser-induced temperature profiles in strongly scattering tissues using pulsed photo-thermal radiometry (PPTR), and investigated its potential for the characterization of vascular lesions in human skin. We have developed an original approach to the computation of the optimal effective absorption coefficient from the spectral properties of the tissue and the IR radiation detector. Using systematic measurements in agar models of soft tissue and detailed numerical simulations, we have determined the optimal IR spectral band for radiometric signal acquisition. A comparison of the results with magnetic resonance imaging demonstrated the unprecedented accuracy and spatial resolution of our PPTR system. (Performed in part in collaboration with the Beckman Laser Institute, University of California at Irvine).

We have collaborated with the Clinical Center Ljubljana (Department for Plastic Surgery and Burns) and Fotona d.d., Ljubljana, in clinical trials of dermatologic laser therapy, primarily of port-wine-stain birthmarks and keloid scars, using various laser systems and dynamic cryogen cooling. A quick and objective evaluation of the therapeutic efficacy in these trials was provided by measurements of skin colour with a tri-stimulus colorimeter, supported with a custom PC application.

Biological systems.
We continued our research on biomimetic systems. We are now able to generate the directed motion of two particles in thin cells with an isotropic liquid by applying an external magnetic field. We expanded our research to similar systems and discovered a large variety of so-called artificial swimmers. A paper is in preparation.

We also studied the hydrodynamics around a regular array of artificial cilia. They are composed of individual superparamagnetic spheres, held together by an external magnetic field. An additional component of the magnetic field is used to rotate them and due to the asymmetry in the rotation, there exists a net flow above the ciliated surface. We measured the velocity profile as a function of distance from the sample surface and studied the influence of the rotation parameters (tilt angle, frequency) on the flow. A paper is in preparation.

Some outstanding publications in 2008

Visitors from abroad

1. Prof. Dr. András Kis, Laboratory of Nanoscale Electronics and Structures, School of Engineering, Lausanne, Switzerland, 03 Jan. 2008.


7. Dr. Damir Dominko, Institute of Physics, Zagreb, Croatia, 19–21 May 2008.

8. Prof. Dr. Ivan Jurić, Department of Physics, University of Split, Croatia, 26–30 May 2008.


R&D GRANTS AND CONTRACTS

1. Dynamics of Complex Functional States
   Prof. Dragan Dragoljub Mihailović

2. Synthesis and characterization of novel nanostructures on the basis of transition metal nanostructures: applications to implantology (Prof. dr. Mihăilescu), Nanostructured metal oxides thin films for optical gas sensing (Dr. Ristocu).

3. Theory of condensed matter and statistical physics
   Prof. Janič R. Božič, Božič R. Božič

4. Light and Matter
   Prof. Martin Cupić

RESEARCH PROGRAMS

1. Dynamics of Complex Systems
   Prof. Dragan Dragoljub Mihailović, Prof. Dragan Dragoljub Mihailović

2. Theory of condensed matter and statistical physics
   Prof. Janič R. Božič, Božič R. Božič

3. Light and Matter
   Prof. Martin Cupić

4. Department for Complex Matter
   F-7

5. Annual Report 2008

Patent granted

1. A process for the synthesis of nanotubes and fullerene-like nanostructures of dichalcogenides transition metals
   Ales Mrzel, Maja Remškar, Adolf Jesih, Marko Viršek
   SI Patent no. 22485

Organization of Conferences, Congresses and Meetings


INTERNATIONAL PROJECTS

1. Electronic Response of Single Inorganic Nanowires
   IEEE
   7. FP 230975, PERG05-GA-2008-230975
   IE
   Prof. Dragan Mihailović

2. Electronic Response of Molybdenum-based Nanowires
   EUREMON
   6. FP MEIR-CT-2006-049058
   IE
   Prof. Dragan Mihailović

3. Controlling Mesoscopic Phase Separation
   COMEPHIS
   6. FP NMP4-CT-2005-570059
   IE, Prof. E. Liarokapis, National Technical University of Athens, Zografou, Athens, Greece
   Prof. Dragan Mihailović

4. Design, Synthesis and Growth of Nanotubes for Industrial Technology
   DESIGN-IT
   6. FP NMP4-CT-2004-595626
   IE: Grace Dempsey, The Provost Fellow and Scholars of the College of the Holy and Undivided Trinity of Queen Elizabeth near Dublin, Dublin, Ireland
   Prof. Dragan Mihailović

5. Ultrafast Processes in Low-Dimensional Nanomaterials
   NATO Reintegration Grant
   PDD (CD)-EAP-981429
   Dr. P. Pedrazzini, NATO, Public Diplomacy Division, Collaborative Programmes Section, Brussels, Belgium
   Asst. Prof. Jure Demšar

6. Processes in Biophysical Matter Studied with Optical Tweezers
   NATO Reintegration Grant
   PDD (CD)-EAP-981429
   Dr. P. Pedrazzini, NATO, Public Diplomacy Division, Collaborative Programmes Section, Brussels, Belgium
   Dr. Moja Villan

7. Self-assembled Guanosine Structures for Molecular Electronic Devices
   COST-Workshop-MP0802-01830
   Dr. Caroline Whelan, Milena Stoyanova, COST Office, Brussels, Belgium
   Asst. Prof. Lea Spindler

8. Photonic Structures from Polymer-Liquid Crystal Composites
   BI-AT/07-08-004
   Asst. Prof. Martin Fally, Faculty of Physics, University of Vienna, Vienna, Austria
   Prof. Irena Drevenšek Olenik

9. Guanosine-based Nanodevices on Polymeric Templates
   PROTEUS
   BI-FR07-PROTEUS-015
   Dr. Günter Reiter, CNRS, Institut de Chimie des Surfaces et Interfaces, Mulhouse, France
   Dr. Martin Cupić

10. Surface Structure of Guanosine Derivatives on Solid Substrates
    BI-AT/05-08-008
    Prof. Paolo Mariani, Facolta di Scienze, Università Politecnica delle Marche, Ancona, Italy
    Irena Drevenšek Olenik

11. Fabrication and Characterization of New Ultraviolet Nonlinear Optic Materials
    BI-CN/07-09-024
    Guoquan Zhang, College of Physics Science, Nankai University, Tianjin, China
    Prof. Marko Žigon

12. Organic Materials for Newly Emerging Photonic Technologies
    BI-CN/07-09-024
    Jingjin Xu, Key Laboratory of Weak-Light Nonlinear Photonics, Ministry of Education of China, Nankai University, Tianjin, China
    Prof. Irena Drevenšek Olenik

    BI-CN/07-09-003
    Prof. Xin Yao, Department of Physics, Shanghai Jiao Tong University, Shanghai, China
    Asst. Prof. Viktor Kabanov

14. Ultrafast Electronic and Structural Dynamics in thin Films of Charge Density Wave Compounds
    BI-RO/08-09-007
    Dr. Mihăilescu Ion, National Institute for Lasers, Plasma and Radiation Physics, NILPRP, Magurele, Ilfov, Romania
    Asst. Prof. Jure Demšar

15. Structure and Dynamics of Confined Bent-core Liquid Crystals
    BI-UK/08-10-029
    Neil A. Clark, Department of Physics, University of Colorado, Boulder, CO, USA
    Prof. Martin Cupić
9. Prof. dr. Gregory Gutman, Moscow State Pedagogical, University of Moscow, Moscow, Russia, 9–11 Jun. Department seminar: Terahertz range hot-electron bolometers, mixers, and infrared photon counters based on non-equilibrium phenomena in ultrathin superconducting films.

BIBLIOGRAPHY

ORIGINAL ARTICLES

14. Joaquín Gabriel Miranda Mena, Viktor V. Kabanov, “Coulomb frustrated first order phase transition and stripes”, In: Proceedings of...


During the past year we have focused mainly on:
- theoretical, experimental and applied reactor physics
- plasma physics
- neutron-transport calculations
- semiconductor physics
- medical physics

Our research in reactor physics has been oriented mostly to new methods for power and research-reactor calculations, where special attention has been given to the calibration and benchmarking of nuclear data and to computational methods. We have linked theoretical and practical reactor physics by participating in a project to evaluate older, critically safety experiments, which is hosted by the Idaho National Laboratory. With the use of advanced Monte Carlo techniques, we evaluated the criticality and uncertainties of the nuclear-powered ship Otto Hahn propulsion reactor, which has all the characteristics of a pressurized water-reactor. We have focused attention on Monte Carlo neutron, photon and electron-transport and nuclear-data processing for transport calculations, and on advanced nodal methods aimed at a detailed power-distribution reconstruction. The results of this basic research have been published in a number of papers, both in scientific journals and conference proceedings. We have developed detailed physical models of the TRIGA research reactor, aimed at the characterization of important operating parameters, mainly the neutron flux and spectrum distribution. The power peaking in mixed TRIGA cores was also studied. The results were applied to two research projects aimed at the irradiation of SiC and organic specimens. The SiC specimens were studied together with the Department for Nanostructured Materials in order to characterize first-wall fusion-reactor materials. Our target is to identify materials with as low as possible activation. The materials were irradiated and then analysed using gamma spectrometry. A second experiment dealt with the irradiation of teeth in order to explore the use of biological specimens for the received-dose determination.

In the field of plasma physics the research was directed into several areas. We continued the study of the potential formation in front of a negative electron-emitting electrode immersed in a two-electron temperature plasma. We used a fluid and a kinetic model of the bounded plasma system. For the kinetic model we have shown that the regular numerical solutions of the Poisson equation correspond to physically possible potential states in the diode and that the shooting method for the determination of the second boundary condition of the Poisson equation can be used as a criterion for which states are possible and which are not. This is particularly useful when one wishes to determine whether the Bohm potential drop in front of the electrode is determined by the hot or by the cool electrons. A similar result is also found in the fluid model. A kinetic model of a plasma diode and a PIC simulation using the XPDP1 code were also used for the analysis of the potential formation in a plasma with two positive ion species. Our interest was focused on the boundary-ion concentrations, where the Bohm criterion becomes determined by the lighter or the heavier ion species. We have started to develop a method for the measurements of the electron temperature with an elongated emissive probe. The longer wire of the emissive probes means a larger voltage drop across the wire, and this makes possible the measurement of the electron temperature. Modelling of the entire current-voltage characteristics of the emissive probe, also taking into account space-charge effects, is also progressing very well. We have initiated the computer simulations of the current-voltage characteristics of various types of probes using a two-dimensional XOOTIC code. At present we are still dealing with the bugs of the code itself. Using a fluid model we studied the formation of a pre-sheath in front of a negative electrode immersed in a plasma with an oblique magnetic field. The results of the model were compared to the computer simulations using the BIT1 code. We have developed a simple and original method for normalizing the length of the simulated system to the system length predicted by the model. This enabled us to make quantitative

![Figure 1: Radial thermal flux distribution in the Krško nuclear power plant reactor core, calculated with the MCNP Monte Carlo code.](image)
comparisons of the model with the simulations. The agreement was relatively satisfactory. Within the Slovenian Fusion Association we have successfully continued with the work in the field of fusion-energy development. The research was carried out in the frame of 14 projects, with more than 50 collaborators from 6 departments of the Institute. Most of the projects are from the field of plasma-wall interactions, and besides 5 projects of several years we have won this year two additional preferentially supported EFDA projects. This year collaborators from the Department for Reactor Engineering have joined the Association. In collaboration with Forschungs Zentrum Karlsruhe they work on the development of a helium-cooled divertor for the demonstration fusion reactor. The researchers from our department who are dealing with nuclear data research have acquired a grant from the Joint Undertaking for ITER in Barcelona. Within two projects in a consortia consisting of several institutions from the EU they are developing the breeding-blanket module for the fusion reactor. The collaborators from the Institute who are dealing within the association with public information activities have acquired an EFDA project, within which they have to organize, in 18 months, 16 FUSION EXPOS in EU countries. They have already successfully set up an exposition as part of the European City of Science fair in Paris on the occasion of the French presidency of the EU.

The collaboration with JET (the Joint European Torus), the largest fusion reactor in the world, was intensified, especially in the field of neutron-transport calculations. Co-workers of the reactor physics division collaborated on the beryllium-wall upgrade project and predicted future changes in the neutron and γ fields during longer visits at the institute, which is situated in the UK. The response of the neutron detectors was modelled with the Monte Carlo method and the sensitivity of the response with regards to the changes of some components in the torus was estimated. It was found that the diagnostics is relatively insensitive to changes in the torus configuration.

Another topic was the modelling of an irradiation probe response and the experimental results were successfully interpreted using transport calculations. Besides this, the differential distribution of the γ rays was calculated, as was their influence on the profile monitors response. In the frame of the Gamma-Ray Cameras Upgrade Project the neutron attenuation in the shielded flanks for the γ cameras and the neutron field around the cameras were calculated. Activation of the SiC/SiC composite, a material developed for the first wall of future fusion reactors by the Department for Nanostructured materials, was calculated. The activation is dependent mainly on impurities, which are needed for the sintering process. Neutron transport and activation calculations were coupled and the results show that in the case of a deuterium-deuterium plasma the activation in the first wall is dominated by thermal neutrons and irradiations in the TRIGA reactor fairly well resemble the conditions in a fusion reactor. In the case of a deuterium-tritium plasma, the conditions change and predictions on-hand of fission reactor irradiations, become difficult. It has also been established that the activation of a compound is the sum of the activations of the individually irradiated elements. Additional modelling of the activation detectors used within JET and the possibility of their use in ion-energy-loss measurements within the torus was also performed.

In the domain of semiconductor physics we performed an investigation of the metal/organic semiconductor/metal/organic structures for radiation sensors the investigators have determined, based upon the published measurements of the electric current through the ITO/PPV(200 nm)/Al organic structure, an archetype for (shallow) trap-controlled space-charge-limited conduction characteristics, that the theoretical basis of the Mott-Gurney derivation of the spatial distribution of the internal electric characteristics, like the internal electric field, the (free and trapped) charge density, and the electric potential within the organic semiconductor is based on an erroneous assumption. In contrast to the expectations governed by the usual space-charge-limited current results, it was determined that these quantities are all linearly distributed throughout the above structure, instead. The breakdown of the Mott-Gurney approach was assigned to the usual, but an inappropriate, assumption of the boundary condition at the hole-injecting metal/organic junction. It was explicitly shown that for the above-stated structure the electric field at the ITO/PPV boundary is non-zero and linearly increases with the forward bias voltage. The organic bulk differential capacitance is small in magnitude and exhibits a nonlinear decrease with the increasing value of the applied voltage.

Our research in the field of medical physics has been focused on three main areas: cancer-treatment assessment with biomedical imaging, radio-biological studies on zebrafish, and computer simulations of cancer growth and the response to therapy. In the cancer-treatment assessment we are using biomedical imaging, particularly positron-emission tomography (PET) using novel tracers of cellular proliferation (FLT) and hypoxia (CuATSM) to assess the biological substructure of tumors prior to and during antineoplastic therapies. We are performing experiments on...
small animals (mice) and large animals (dogs with spontaneous tumors). In addition, we are involved in several human clinical trials in patients with brain, head and neck, lung, oesophagus, and prostate tumors, as well as patients with leukaemia and lymphomas. In the previous year we have completed a preclinical study on dogs with lymphomas, investigating the treatment efficacy of a novel drug, which provided the basis for the accelerated start of a human clinical trial. In patients receiving radiotherapy, chemo-radiotherapy and molecular targeted therapies we have observed large heterogeneity and variability of the pre-treatment biological substructures as well as the complex dynamics of the response. For radio-biological studies on zebrafish we have developed a new image-guided micro-irradiator, which is capable of the localized irradiation of zebrafish embryos with photon fields of less than 1 mm in diameter. This will enable radio-biological studies of localized irradiation, similar to the conditions met in external beam radiotherapy. In preliminary studies, comparing total and partial body irradiation, following up the apoptosis and inflammatory response, we observed that while apoptosis is high in both cases, the inflammatory response is significant only during partial irradiation. In computer simulations of cancer growth and the response to therapy we have developed a stochastic multi-layer model that feeds from biomedical images. In parallel we have developed a vasculature growth model.

We have been able to apply the models to experimental datasets of in-vitro and in-vivo dynamics of the response. For radio-biological studies on zebrafish we have developed a new image-guided micro-irradiator, which is capable of the localized irradiation of zebrafish embryos with photon fields of less than 1 mm in diameter. This will enable radio-biological studies of localized irradiation, similar to the conditions met in external beam radiotherapy. In preliminary studies, comparing total and partial body irradiation, following up the apoptosis and inflammatory response, we observed that while apoptosis is high in both cases, the inflammatory response is significant only during partial irradiation. In computer simulations of cancer growth and the response to therapy we have developed a stochastic multi-layer model that feeds from biomedical images. In parallel we have developed a vasculature growth model. We have been able to apply the models to experimental datasets of in-vitro and in-vivo experiments. This provides a foundation for the future development of biological cancer-treatment planning.

**Some outstanding publications in 2008**


**Organization of conferences, congress and meetings**

1. 36th Meeting of the EFDA Steering Committee, Nuclear Training Centre Milan Copic, Joze Stefan Institute, Brinje, Dol near Ljubljana, 10–11 Mar. 2008 (45 participants)

**INTERNATIONAL PROJECTS**

   - EURLATOM – MHEST
   - 7. FP, EURATOM, Slovenian Fusion Association – SFA
   - R07-CT-2007-00865
   - EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   - Dr. Matjaz Ravnik, Ass. Prof. Goran Drazić
2. Ceramic Processing of Si/SiC Composites for Functional Application - 4.1.1.
   - EURLATOM – MHEST
   - 7. FP, EURATOM, Slovenian Fusion Association – SFA
   - R07-CT-2007-000102
   - EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   - Dr. Matjaz Ravnik, Ass. Prof. Goran Drazić
3. Nuclear Data: Benchmark Experiments to Validate EFF/EAF Data (TW6-TTMN-002B)
   - T1.002B-FU
   - EURLATOM – MHEST
   - 7. FP, EURATOM, Slovenian Fusion Association – SFA
   - R07-CT-2007-000102
   - EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   - Dr. Matjaz Ravnik, Ass. Prof. Goran Drazić

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**Nuclear Data**

1. Nuclear Data: Benchmark Experiments to validate EFF/EAF Data (TW6-TTMN-002B)
   - T1.002B-FU
   - EURLATOM – MHEST
   - 7. FP, EURATOM, Slovenian Fusion Association – SFA
   - R07-CT-2007-000102
   - EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   - Asst. Prof. Andrej Trkov
2. Nuclear Data: EFF/EAF Data File Upgrade, Processing and Benchmark Analyses (TW6-TTMN-001B) - T1.001B-FU
   - EURLATOM – MHEST
   - 7. FP, EURATOM, Slovenian Fusion Association – SFA
   - R07-CT-2007-00016 (EFDA 07-1708)
   - EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   - Asst. Prof. Andrej Trkov
3. Nuclear Data: EFF/EAF Data File Upgrade, Processing and Benchmark Analyses (TW6-TTMN-001B) - T1.001B-FU
   - EURLATOM – MHEST
   - 7. FP, EURATOM, Slovenian Fusion Association – SFA
   - R07-CT-2007-00016 (EFDA 07-1708)
   - EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   - Asst. Prof. Andrej Trkov
4. Nuclear Data: EFF/EAF Data File Upgrade, Processing and Benchmark Analyses (TW6-TTMN-001B) - T1.001B-FU
   - EURLATOM – MHEST
   - 7. FP, EURATOM, Slovenian Fusion Association – SFA
   - R07-CT-2007-00016 (EFDA 07-1708)
   - EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   - Asst. Prof. Andrej Trkov

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**Upgrade of Gamma-Ray Cameras: Neutron Attenuators**


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**Dr. Igor Lengar**

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**Dr. Igor Lengar**

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**Dr. Igor Lengar**

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**Dr. Igor Lengar**
R & D GRANTS AND CONTRACTS

1. PET with a novel photon detector
   Prof. Peter Križan, Asst. Prof. Robert Jeraj
2. A development of low-activation material for the first wall in fusion reactor
   Asst. Prof. Saša Novak Krmotič, Luka Snoj
3. Fusion relevant research of plasma interaction with surfaces
   Prof. Milan Čerček
4. Development of the diagnostics for certain parameters of the edge plasma in fusion devices
   Prof. Milan Čerček
5. A study of the plasma parameters for conditioning of the inner surfaces of a fusion reactor
   Asst. Prof. Miran Montuš, Prof. Miloš Brežnik
6. Radiation field characterization for diagnostic and therapeutic use of radioactive isotopes
   Dr. Marijeta Šentjurc, Asst. Prof. Robert Jeraj
7. On the use of benchmark experiments for improved utilization of nuclear facilities
   Asst. Prof. Andrej Trkov
8. Concrete construction properties and water seeping through concrete structures
   Asst. Prof. Igor Lengar
9. Prevention and reduction of the consequences of the terrorist attack on TriGa research reactor
   Prof. Matjaž Ravnik
10. Development of procedures for neutron spectrum characterization with covariance matrices for irradiation experiments
    Asst. Prof. Andrej Trkov

RESEARCH PROGRAM

1. Reactor Physics
   Prof. Bogdan Glumac

NEW CONTRACT

1. NEK spent fuel container loading scheme optimization regarding maximum permissible power
   Agency for Radioactive Waste, Ljubljana
   Prof. Matjaž Ravnik

VISITORS FROM ABROAD

1. Dr. Jørgen Kjems, director DTU Electro, Technical University of Denmark, Lyngby, Denmark, 7 March 2008
2. Francesca Sinischalchi, Steven Booth, scientific coordinator, J4-energy and Douglas Bartlett, European Commission, Brussels, Belgium, 30 June 2008
5. Rustam Khan, MAE fellow, Atominstitut Vienna, Austria, 10–12 Dec. 2008
6. Prof. Petro Gorley and Dr. Sergii Bilichuk, University Chernivci, Ukraine, 9 Dec. 2008

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Note:
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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, at DESY in Hamburg and at KEK in Tsukuba. The department is also engaged in developing and applying technologically advanced particle detectors, which 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 the measurements of ultra-high-energy cosmic rays with the Pierre Auger observatory, spread over a surface of 3000 km² near Malargue in Argentina.

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, the German centre DESY in Hamburg and the Japanese centre KEK in Tsukuba. We are taking part in three experiments, each conducted as an international collaboration:

- ATLAS at the Large Hadron Collider (LHC) at CERN (2000 researchers, 167 institutions),
- Belle at the asymmetric electron-positron collider (KEK-B) at KEK (380 researchers, 55 institutions),
- HERA-B at the HERA electron-proton collider at DESY (310 researchers, 33 institutions).

In the field of astroparticle physics we are part of the Pierre Auger collaboration (200 researchers, 55 institutions), 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 detailed report on the 2008 activities follows, focused on the contributions of our researchers:

**ATLAS**

The ATLAS detector will from 2009 onwards measure proton collisions at the LHC, which briefly began its operation in September 2008 (Fig. 1). Once restarted in 2009, we expect that the luminosity will increase gradually and reach the design value of $10^{34}$ cm⁻² s⁻¹ in the years 2011–2012. CERN has already approved two upgrades of the beam optics system in front of the ATLAS and CMS detectors as well as the proton injectors, which each by itself can increase the luminosity by a factor of two, above the design value. In accordance with this, the development of new detector components is taking place, which will be able to function at the increased luminosity. Until 2015 the LHC luminosity should have gradually increased to $10^{35}$ cm⁻² s⁻¹ (super LHC - sLHC) and subsequently at least the inner part of the ATLAS detector will need replacing. Also, an upgrade of the radiation protection of external components, especially the muon chambers, will be required.

On 10 September the Large Hadron Collider at CERN was successfully turned on in front of an audience of several hundred million people. Unluckily enough, a faulty connection between the superconducting magnets brought the collider to a temporary halt after only nine days of operation, postponing the start-up of physics measurements by nearly a year.

**Figure 1:** On 10 September the ATLAS detector recorded this first event, provoked by a 450-GeV proton bunch from the Large Hadron Collider. The protons hit a foil at a collimator 100 m upstream of the detector. The detected spray of particles consists of muons, the only particles from proton-induced interactions that penetrate the material to the detector.
We expect a very rich and relevant yield of fundamental physics results. Already the first collisions should extend our knowledge of Quantum Chromodynamics in the description of peripheral (soft) collisions at presently unattainable energies. With the growing integrated luminosity the number of observed and measured processes at higher effective energies of parton collisions (hard scattering) will increase and with it the possibility of the production of new, heavy particles, which were impossible to observe at the up-to-date colliders.

Already in the initial phase, the ATLAS detector will be able to perform much more accurate measurements of the heavy top-quark masses with respect to the present precision. It will also significantly contribute to the precision of the Standard Model parameter measurements, such as, for example, the properties of the W and Z weak bosons.

The expected discovery of the Higgs boson is highly dependent on its actual mass; in the most favourable realisation with its mass around 150 GeV it is estimated that only somewhat more than 800 pb⁻¹ is required, which could be accumulated in 2009–2010. Harder to discover are lower masses, of around 120 GeV. About 10 fb⁻¹ of integrated luminosity will be needed, which might be achievable by 2011. The discovery of the lightest supersymmetric particles also depends on their actual mass, which is only weakly bracketed by the present measurements. A total of 100 pb⁻¹ of integrated luminosity, feasible in 2009, makes it possible to unveil such particles with masses up to 750 GeV; 10 fb⁻¹ expands the discovery potential up to masses of 1.8 TeV. These measurements also require a precise understanding of the detector’s response; this can, however, be calibrated only on the data itself. Nevertheless, we will be able to quickly detect any exotic particles at the TeV scale, decaying into leptons as well as possible micro-black-holes with a mass of a few TeV, which would evaporate in the detector.

To further increase the physics reach of the collider two directions are foreseen: increasing the luminosity by an order of magnitude, and doubling or even tripling the collision energy. The increased luminosity places very stringent demands to the detector’s performance, and only marginally increases the predictive power (e.g., about 30% in new particle masses), but is achievable with a small investment and continuous increase of the maximum luminosity maintains the operational stability of the collider. An increase of the collision energy would be much more desirable from the perspective of physics reach and detector performance; however, the increase of energy by more than 10% requires replacing all the magnets, which practically means building a completely new collider.

The Slovenian group is actively participating in the R&D phase of the tracking-detector upgrade, particularly in radiation hardness studies of position-sensitive detectors, suitable for operation in the extreme radiation conditions of the LHC. Measuring the charge collection in heavily irradiated silicon micro-strip detectors, anomalously high values were obtained at high detector biases, matching the non-irradiated values (Fig. 2). This is in contradiction with the previously established data on irradiation-induced charge trapping at lower fluences. The background of this phenomenon is yet to be understood, although there are some indications for avalanche multiplication in the strong electric field close to the read-out electrodes.

The ATLAS experiment will produce about a PB of data per year, corresponding to a quantity of data that can be written on 1.5 million CDs. In the full life cycle of the experiment the data quantity is expected to get 30 times larger. Thus it becomes evident that it will be impossible to store and process it within a single computing centre. The network infrastructure is thereby an additional bottleneck. We cannot expect such a quantity of data in its entirety to be sent over the internet more than once: from CERN, where the experiment will take place, into one of the computing centres, where the data will actually be stored and where particular data processing procedures and physics analyses will take place according to the needs of ATLAS collaboration.

The use of Grid technology is the only solution facilitating the fast data transfer from the collider to remote centres where such quantities of data can be stored at a sufficient rate. Due to the quantity of data and the complexity of processing it is mandatory to also use Grid technologies for data processing, since none of the research centres has enough storage and computing capacity. It is due to such huge storage and processing demands with the forthcoming experiments that the Experimental Particle Physics community exerts such a strong initiative for the development and application of Grid technologies. Subsequently, a large portion of software and standards, which are being developed in the framework of the LHC Computing Grid (LCG) project, became the basis of the EGEE (Enabling Grids for E-sciencE) infrastructure.

As ATLAS Collaboration members, our Department took part in the LHC Computing Grid and from 2003 participated in the preparation of the EGEE project. Since autumn 2003 we have been maintaining our own infrastructure and have put into production a grid cluster named SIGNET (Slovenian Grid Network). SIGNET became the Slovenian grid infrastructure centre and is working as a part of the European grid network.

![Figure 2: Measured collected charge as a function of bias voltage for un-irradiated and irradiated silicon micro-strip detectors of 300 µm thickness. The expected irradiation fluences are in the SLHC range, depending on the distance from the interaction point, between 5x10^14 and 10^16 n/cm².](image-url)
and EGEE. We are participating as a fully-flagged Tier-2 computing research centre in the production and analysis part of the ATLAS experiment. From the start we have been taking part in the development of the newest technologies to make the ATLAS experiment possible and open the door to new fundamental research results in the field of particle physics. In 2008 SiGNET was upgraded to a total capacity above 500 processors and 170 TB of disk space. Due to the exemplary reliability of the system, we managed to considerably exceed our predicted share in Monte Carlo sample production for the ATLAS experiment.

The development of new computational methods in combination with distributed data processing is expected to stimulate the development in other branches of science where large computing capacities and/or computing simulations are needed (computing, informatics, meteorology, statistics), and in the final instance also significantly contribute to the development of the informatics infrastructure. As a showcase example, the world wide web (WWW) was developed at the European Laboratory for Particle Physics (CERN) for the early needs of the LHC collaborations; to the present day it has become a totally new branch of information technology. Similar expectations are also being raised for the development of the distributed computing (Grid), which is being pushed for the exploitation of the LHC project.

**Belle**

The Belle experiment records data of electron-positron collisions at a centre-of-mass energy corresponding to the bound state of a beauty or b quark and an anti-b quark, Y(4S). This resonance instantaneously decays into a pair of B mesons, and up to now decays of around 900 million B-meson pairs have been recorded. Furthermore, in electron-positron collisions other processes take place as well, giving rise to an abundant production of heavy particles composed of charm – c – and lighter quarks. The experimental facility thus represents a perfect environment for various studies of particles composed of heavy quarks b and c. A huge sample of recorded decays enables measurements of extremely rare processes, where we might observe unexpected effects, not included in the Standard Model (SM) of strong and electroweak interaction among elementary particles. Generally speaking, the measurements performed by the Belle collaboration represent a complementary approach (the so-called precision frontier) to the future experiments at the LHC (the so-called energy frontier). While the latter may discover the so far unknown - but long searched for - particles due to the high available energy, measurements at Belle and its successor SuperBelle, to start operation by 2013, may provide insight into various theories beyond the SM that predict such particles (for example, string theories).

The largest success of the Belle collaboration, encompassing around 370 scientists from 60 institutions worldwide, came at the end of 2008. The 2008 Nobel Prize for physics was awarded to Makoto Kobayashi and Toshihide Maskawa for their theory of the so-called CP symmetry-breaking, which was precisely confirmed and verified by the Belle experiment in numerous measurements (Fig. 3). CP violation in the B-meson system was one of the primary goals of the experiment since its start-up in 1999. CP symmetry violation reflects in the slightly different properties of particles and their anti-particles, and is one of the conditions for an almost complete domination of matter over anti-matter in the Universe.

The CP symmetry violation nevertheless hides some puzzles, which are so far not completely understood. In 2008 members of the Belle collaboration discovered a significant difference in CP symmetry violation between the decays of neutral and charged B-meson decays. The results were presented in a paper published in the prestigious journal Nature. The explanation of the observed phenomena in the framework of the SM proves to be difficult. While there are less anti-B mesons (with b quark) decaying to Kπ than B mesons (with anti-b quark) decaying to Kπ, the situation is reversed for the charged B mesons: there are more B mesons (with b quark) decaying to Kπ than B mesons (with anti-b quark) decaying to Kπ (see Fig. 4).

In the search of processes beyond the Standard Model, the Belle experiment in 2008 broke another precision frontier by the measurement of decays where the beauty quark decays into a strange quark and a photon. Since this process is extremely rare within the SM, it is sensitive to possible contributions of new, yet undiscovered particles. Measurements of the decay rate and of the photon energy spectrum with an unprecedented precision impose stringent constraints on values of parameters used in the theories that predict new particles.

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**Precise verifications of CP symmetry-breaking in the neutral B meson system, accomplished in a major part by the Belle collaboration, led to the 2008 Nobel Prize in physics for the Japanese theoretical physicists Makoto Kobayashi and Toshihide Maskawa.**

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**KEKBとBelleに携わった全ての人に感謝。アップグレード計画の成功を祈念しません。**

Figure 3: Makoto Kobayashi (2008 Nobel Prize laureate for physics) thanks members of the Belle collaboration and wishes all the best for their future work.
Using sophisticated experimental methods that consider subtle interferences among decay products of B mesons, the Belle experiment obtained evidence for several, so far unobserved particles. The large interest triggered by these results lies in the fact that the observed bound states are electrically charged. Hence, while their properties are similar to the properties of well-known, but electrically neutral bound states of a charm quark and its anti-particle, they cannot be placed into the existing scheme of heavy particles composed of a quark and an anti-quark.

The preparation of the upgrades of the Belle spectrometer and the KEK-B collider in Tsukuba has reached an important new phase. A major reconstruction of the collider that will allow running at luminosities exceeding, by 10–50, the present best values has become one of the priorities of the Japanese KEK laboratory. To carry out such a long-term project, a new research group was formed with scientists from US, Germany, Japan, Austria, Poland, Australia, Russia, China, Korea and Slovenia; in this group, our collaborators coordinate some essential activities. The aim of the project is to use a considerably larger data sample to investigate with high precision processes where deviations from the Standard Model predictions could be observed. These measurements will represent an important complement to the searches for physics beyond the Standard Model planned at the LHC collider.

For the upgraded Belle spectrometer, we have developed a new method for charged-particle identification. The method uses a measurement of the time of propagation (TOP) of charged particles and Čerenkov photons, emitted in a quartz bar; the method was examined under various conditions and by varying the parameters of the counter. We have continued the investigation of a proximity focusing Čerenkov counter with aerogel as a radiator, for which a new single-photon detector was developed. This detector is based on a novel type of sensor, known as a silicon photomultiplier or Geiger mode APD, and is based on the photoelectric effect in a suitably doped semiconductor. With this new detector type we have successfully carried out first tests in a test beam. We have also investigated another type of single-photon detector, a hybrid photodiode; in such a light sensor, photoelectrons gain kinetic energy in a high electric field, and are subsequently detected in a silicon counter, enclosed in the same vacuum container.

**HERA-B**

We have continued with the analysis of data collected with the HERA-B spectrometer at DESY in Hamburg. The following analyses were finalized and prepared for publication: cross-section measurements for the production of excited charmonium states, the production of strange baryons and the polarisation of the J/ψ mesons.

**PIERRE AUGER**

The Pierre Auger collaboration has constructed a huge high-energy cosmic-ray observatory in Argentina, sensitive to cosmic rays with energies above \(10^{19}\) eV. The Auger Observatory is a “hybrid detector”, employing two independent methods to detect and study high-energy cosmic rays. One technique detects high energy particles through their interaction with water placed in surface detector tanks. The other technique tracks the development of air showers by observing ultraviolet light emitted high in the Earth’s atmosphere. An upgrade with HEAT (High Elevation Auger Telescope) is underway to extend the sensitivity to lower energies.

The main physics results in 2008 are the discovery of the correlation of the highest-energy cosmic rays with nearby active galactic nuclei and the observation of the suppression of the flux of cosmic rays above \(10^{19}\) eV. Our group is involved in data analysis, the the LI DAR system operation, the development of an offline data-analysis package and detector simulation, and calibration.

**Detector development**

In collaboration with CERN, University of Valencia, University of Michigan, Ann Arbor and Ohio State University we have continued with the development of the Compton camera and a novel PET apparatus, based on position-sensitive silicon detectors. Work on a high-resolution PET probe utilizing the same technology has started in the framework of MADEIRA, a EU FP7 project. A dual-head prototype detector for a brachytherapy source locator was assembled and tested in real time at the Oncology Institute in Ljubljana.

Encouraged by successful measurements with silicon photomultipliers, we have designed, constructed and tested a novel type of detector module for position emission tomography (PET), and investigated the two important parameters, its energy and timing resolution. Such a counter seems to be an extremely interesting candidate for the dual modality medical imaging, where a PET apparatus is embedded in an MRI imager, and the light sensors have to operate in magnetic fields exceeding 2 T. This research is a part of the FP7 research project aimed at the development of novel detection methods for particle physics and medical imaging.
Some outstanding publications in the past three years


3. The ATLAS Collaboration, G Aad et al., The ATLAS Experiment at the CERN Large Hadron Collider, 2008 JINST 3 S08003.

Awards and appointments

1. Prof. Peter Križan, Zois award, Ministry of Higher Education, Science and Technology, Ljubljana, Research field of experimental particle physics

Organization of conferences, congresses and meetings


INTERNATIONAL PROJECTS

1. Conceptual Modelling of Networking of Centres for High-Quality Research in Slavic Lexicography and Their Digital Resources
   MINDLEX
   7. FP, 219398
   EC, Institute of Mathematics and Informatics of the Bulgarian Academy of Science, Sofia, Bulgaria
   Jan Jona Javoršek, B. Sc., Ass. Prof. Tomaz Erjavec

2. Marie Curie Training Network on Particle Detectors
   MC-PAD
   7. FP, 214560, PITN-GA-2008-214560
   EC, Seamas Hegarty, CERN, Geneva, Switzerland
   Prof. Peter Križan

3. Joint Research on Various Types of Radiation Dosimeters
   RADDOSS
   7. FP, 207122
   EC, University College Cork, National University of Ireland, Tyndall National Institute, Cork, Ireland
   Dr. Gregor Kramberger

4. Enabling Grids for E-sciencE III
   EGEE-III
   EGEE-SA1, EGEE-NA2, EGEE-NA4
   7. FP, 222667
   EC, Dr. Body Jones, Anna Cook, CERN IT-EGE, Geneva, Switzerland
   Prof. Marko Mikulčič

5. Minimizing Activity and Dose with Enhanced Image Quality by Radiopharmaceutical Administrations
   MADEIRA
   7. FP, EURATOM, 212100
   EC, GSF- Forschungszentrum für Umwelt und Gesundheit GmbH, München Neuherberg, Germany
   Prof. Marko Mikulčič

6. Image-based Navigation in Multimedia Archives
   IMAGINATION
   6. FP, 034626
   EC, Clemens van Dintner, Forschungszentrum Informatik an der Universität Karlsruhe, Karlsruhe, Germany
   Asst. Prof. Dunja Mladenčič, Mitja Jermol, M. Sc., Prof. Marko Mikulčič

7. Semantic Web Services Interoperability for Geospatial Decision Making
   SWING
   6. FP, 0250514
   EC, Arne J. Biere, SINTEF - Stiftelsen for Industriell Og Teknisk Forskning Ved Norges Tekniske Hoegskole, Trondheim, SINTEF ICT, Oslo, Norway
   Prof. Marko Mikulčič, Ass. Prof. Dunja Mladenčič, Marko Grobelnik, Mitja Jermol, M. Sc.

8. Enabling Grids for E-sciencE II
   EGEE-II
   EGEE-NA1, EGEE-NA2, EGEE-NA3, EGEE-NA4
   6. FP, 034668
   EC, Dr. Body Jones, CERN IT-EGE, Geneva, Switzerland
   Prof. Marko Mikulčič

9. Safe Production and Use of Nanomaterials
   NANOSAFE2
   6. FP, NMP2-CT-2005-515845
   EC, Commissariat a l’ Energie Atomique, Grenoble, France
   Andrzej Detela, B. Sc., Ass. Prof. Maja Remškar, Marko Žumer, B. Sc., Prof. Boris Turk

10. Collaboration DELPHI
    Dr. Jan Timmermans, CERN, Geneva, Switzerland
    Asst. Prof. Borut Paul Kerševan

11. Collaboration HERA-B
    Dr. Mike Medinnis, Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany
    Prof. Peter Križan

12. Collaboration ATLAS
    Prof. Peter Jenni, CERN, Geneva, Switzerland
    Prof. Marko Mikulčič

13. Collaboration CERN RD-39
    Dr. Jaido Haarkon, HIT, Finland
    Dr. Zsuzsa I., BNL, USA
    Prof. Marko Mikulčič

14. Collaboration CERN RD-42
    Prof. Peter Weilhammer, CERN, Geneva, Switzerland
    Prof. Marko Mikulčič

15. Collaboration CERN RD-50
    Prof. Mara Bruzzi, University of Florence, Florence, Italy
    Dr. Michael Moll, CERN, Geneva, Switzerland
    Prof. Marko Mikulčič

16. Collaboration Belle
    Prof. Masanori Yamauchi, KEK, Tsukuba, Japan
    Prof. Peter Križan

17. Collaboration CDA
    Cameras for Imaging in Medical Applications
    Prof. Peter Weilhammer, CERN, Geneva, Switzerland
    Prof. Marko Mikulčič

18. Study of Top Events produced at the LHC for the Commissioning of the ATLAS Detector
    BHT/05-08-003
    Dr. Marina Gobal, Università di Udine, Udine, Italy
    Asst. Prof. Borut Paul Kerševan

19. Measurement of Properties of Charged Hadrons
    SLO-JPN
    BHP-07-09-C-002
    Prof. Fumihiko Takasaki, High Energy Accelerator Research Organization, Ibaraki ken, Japan
    Asst. Prof. Tomio Živko

R & D GRANTS AND CONTRACTS

1. Construction of test beam telescope
   Dr. Andrej Goršvieš

2. Positron-emission tomography with a novel photo-detector
   Prof. Peter Križan
VISITORS FROM ABROAD

1. Dr. Olav Villard, CERN, Geneva, Switzerland, 8-10 Jan. 2008

STAFF

Researchers
1. Prof. Vladimir Cindro
2. Assist. Prof. Andrej Filipčič
3. Prof. Boštjan Golob*
4. Dr. Andrej Gorišek
5. Prof. Dr. Goran Ristić, Electrofaculty, Niš, Serbia, 3-4 Nov. 2008
6. Dr. Maharz Ali, Universiti Teknologi Malaysia, Malaysia, 1-6 Mar. 2008
7. Dr. Fabrizio Stigliano, Università di Napoli Federico II, Naples, Italy, 22-26 July 2008
8. Prof. Dr. Milan Šušteršič, University of Maribor, Maribor, Slovenia, 1-5 Sep. 2008
9. Prof. Dr. Tomaz Podobnik*, Asst. Prof. Trunde Ščepič
10. Prof. Dr. Andrej Stupar, University of Ljubljana, Ljubljana, Slovenia, 1-5 Sep. 2008
11. Prof. Dr. Črtomir Zupančič, University of Ludwig Maximilian, Munich, Germany, 1-6 Jun. 2008
12. Prof. Dr. William Tischuk, University of Toronto, Toronto, Canada, 17-19 Sept. 2008
13. Prof. Dr. Aleksandar Jakšić, Tyndall National Institute, Ireland, 5-6 Nov. 2008
14. Prof. Dr. Goran Barić, Electotechnology, Niš, Serbia, 3-4 Nov. 2008

Postdoctoral associates
1. Dr. Urban Bitenc
2. Dr. Ilija Bizjak
3. Dr. Marko Bračko*
4. Dr. Gregor Kramberger
5. Dr. Dejan Žontar
6. Prof. Peter Križan*
7. Prof. Marko Starič
8. Prof. Alessandro Della Morte
9. Prof. Danilo Zavrtanik
10. Dr. Vladimir Cindro

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1. Dr. Andrej Studen
2. Prof. Dr. Matej Talek
3. Asst. Prof. Borut Grosičar, B. Sc.
5. Asst. Prof. Tomaž Erjavec, Jan Jona Javoršek, B. Sc.
6. Asst. Prof. Tomaž Erjavec, Jan Jona Javoršek, B. Sc.
7. Prof. Dr. Črtomir Zupančič, University of Ludwig Maximilian, Munich, Germany, 1-6 Jun. 2008
8. Prof. Dr. William Tischuk, University of Toronto, Toronto, Canada, 17-19 Sept. 2008
9. Dr. Aleksandar Jakšić, Tyndall National Institute, Ireland, 5-6 Nov. 2008
10. Prof. Dr. Goran Barić, Electotechnology, Niš, Serbia, 3-4 Nov. 2008

Technical and administrative staff
1. Dr. Andrej Stupar
3. Asst. Prof. Tomaž Erjavec, Jan Jona Javoršek, B. Sc.
5. Asst. Prof. Tomaž Erjavec, Jan Jona Javoršek, B. Sc.
6. Asst. Prof. Borut Grosičar, B. Sc.
7. Asst. Prof. Borut Grosičar, B. Sc.
8. Erik Margan

New Contract
1. Verification of radioactive sources positioning during brachytherapy
Ego - Line d. o. o., Ljubljana, 2008
2. New electric direct drive systems
Dr. Erjan Detela, B. Sc.
3. Verification of radioactive sources positioning during brachytherapy
Dr. Erjan Detela, B. Sc.
4. New electric direct drive systems
Dr. Andrej Gorišek
5. Detector in the Grid environment
Jan Jona Javoršek, B. Sc.
6. Detector in the Grid environment
Jan Jona Javoršek, B. Sc.
7. Verification of radioactive sources positioning during brachytherapy
Dr. Andrej Gorišek
8. New electric direct drive systems
Asst. Prof. Borut Grosičar
9. New electric direct drive systems
Asst. Prof. Borut Grosičar
10. New electric direct drive systems
Asst. Prof. Borut Grosičar
11. Hadron collider physics
Dr. Ilija Bizjak

RESEARCH PROGRAMS

1. Astroparticle Physics
2. Experimental Particle Physics
3. Hadron Physics

BIBLIOGRAPHY


Belle Collaboration: Galina Pakhlova, et al. (140 authors), "Observation of a near-threshold enhancement in the $e^-\to \Lambda^*_c\bar{c}$ cross section using initial-state radiation", Phys. Rev. lett. vol. 101, no. 17, pp. 172001-1-172001-6, 2008.


Belle Collaboration: Galina Pakhlova, et al. (140 authors), "Observation of a near-threshold enhancement in the $e^-\to \Lambda^*_c\bar{c}$ cross section using initial-state radiation", Phys. Rev. lett. vol. 101, no. 17, pp. 172001-1-172001-6, 2008.


Belle Collaboration: C. Schwanda, et al. (136 authors), "Measurement of the moments of the photon energy spectrum in $B^-\to X\gamma$ decays and determination of $W_{\gamma\gamma}$ and $\Gamma_{\gamma\gamma}$ at Belle", Phys. Rev. D, Part. fields gravit. cosmol., vol. 78, no. 3, pp. 031201-6-031201-13, 2008.


Belle Collaboration: C. Schwanda, et al. (136 authors), "Measurement of the moments of the photon energy spectrum in $B^-\to X\gamma$ decays and determination of $W_{\gamma\gamma}$ and $\Gamma_{\gamma\gamma}$ at Belle", Phys. Rev. D, Part. fields gravit. cosmol., vol. 78, no. 3, pp. 031201-6-031201-13, 2008.


The Department of Inorganic Chemistry and Technology is one of the leading groups in the world in the field of synthesising new inorganic compounds containing fluorine. The main research fields of the department are reactions in superacids, 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 and ecological problems in Slovenia. The group has already been cooperating closely with Slovenian industry for more than thirty years. The group is also active in the field of educating teachers of chemistry and in the field of the promotion of natural sciences among students of colleges and elementary schools.

In the field of the research of new inorganic compounds containing fluorine, new coordination compounds of the type \([M^x(L)](A_{f6}^-)^x\) have been synthesized (\(M\) is a metal; \(A\) is P, Sb, Nb, or Ru; \(L\) is a ligand, e.g., Xef\(_2\), Xef\(_3\), PF\(_6\), HF, and \(x\) is the oxidation number of the central atom).

In connection with this the synthesis and characterization of the compound \([Ba(Xef_2)](PF_6)^2\) should be mentioned. The molecules of Xef\(_2\) are bonded directly to the central Ba\(^{2+}\) cation with electrostatic forces between the negatively charged F ligands of the Xef\(_2\) molecules and the positively charged Ba\(^2+\) centres. The structure consists of two crystallographically independent barium atoms with the coordination numbers 10 and 12. The barium atoms and the bridging Xef\(_2\) molecules form double layers, which are further interconnected into the 3D network by the weak Xe—F(PF\(_6\))− interactions. With Ba as the central atom, two interesting new compounds \([Ba(Xef_2)](AF_6)^2\) (\(A = \) Ru, Nb) were isolated and compared with analogous, already-known compounds with \(A = \) Sb and As. We found that the influence of the anion on the structure diversity of these coordination compounds is small although the Lewis basicity of AF\(_x^-\) anions is different. The compounds with \(A = \) Nb and Ru are the first known coordination compounds with Xef\(_2\), as a ligand and RuF\(_6^-\) and NbF\(_6^-\) as anions. In 2008, besides the already known compound \([Cu(Xef_2)](SbF_6)^2\) two new coordination compounds in the system Cu(SbF\(_6\))\(_x\)-Xef\(_2\) have been isolated. These two compounds are \([Cu(Xef_2)](SbF_6)^2\) (\(n = 2, 4\)).

The research of the possibility of using Xef\(_2\), as a ligand to the metal ion was continued. The first compound of this type, \([Mg(Xef_2)(Xef_4)](AsF_6)^2\) was prepared and its structure was determined. In this compound two molecules of xenon fluorides in different oxidation states (Xef\(_2\), Xef\(_4\)) are acting as ligands. The magnesium atom is surrounded by six fluorine atoms from four AsF\(_6^-\) units, one Xef\(_2\), and one Xef\(_4\) molecule. Both xenon fluorides are non-bridging ligands, while the surrounding AsF\(_6^-\) units connect magnesium atoms (by cis and trans F bridges) forming the layers along the b axis. Our efforts to synthesize the coordination compound with only Xef\(_2\), as a ligand have not been successful up to now.

The compounds where HF is acting as a ligand or where HF forms with an \(F^-\) anion (poly-)hydrogen-fluoride anions of the type \(H_2F\_x\) should be mentioned here. In 2008 two new compounds with HF acting as a ligand were isolated and characterized: \([Sr(HF)](TaF_6)^2\) and \([Sr(HF)](BF_4)^2\). In addition to the compound Ba(H\(_2F\))\(_4\), which was isolated and its structure determined in our laboratory in previous years, the compound Ca(HF)\(_3\) represents the second known compound in which the central atom has a homoleptic environment of HF molecules. Furthermore, ribbon-like polymeric compounds of the type \((MF)\_x^-\) were synthesized. These ribbons could be further connected with the HF\(_2^-\) anions in the double ribbons, e.g., Ba\(_2\)(HF)\(_2\) (PF\(_6\))^2 or in the infinite layers, e.g., Pb\(_2\)(HF)\(_2\) (PF\(_6\))^2.

This year, the first known compounds with mixed anions (BF\(_3^{-}\), PF\(_6^-\), and AsF\(_6^-\)) were synthesized and their structures were determined: Ba(BF\(_3\))(PF\(_6\)) and Ba\(_2\)(AsF\(_3\))(BF\(_4\))(PF\(_6\)). These types of compounds are interesting because a whole series of different AF\(_x^-\) anions (\(A = \) Sb, Bi, Nb, Ta, Ru, Au etc.) could be applied.

The crystal structures of AMF\(_x\) (\(A = \) In, Tl; \(M = \) P, As) were determined on single crystals. Together with the crystal structure of InBF\(_3\), the crystal structures of InPF\(_6\), and InAsF\(_3\), represent unique examples of ternary In(I) compounds with In(I) in a solely fluorine environment.

Until now, only the coordination compounds with the Xef\(_2\) molecule acting as a ligand to the metal ion were known. However, in 2008 we succeeded in synthesising the first compound in which the molecule Xef\(_2\) is connected to the Mg\(^{2+}\) ion as a ligand. We also determined the structure of this compound.

Figure 1: The coordination of ligands around the Mg\(^{2+}\) ion in the crystal structure of Mg(Xef\(_2\))(Xef\(_2\)) (AsF\(_3\))
With the Aichi Institute of Technology, Nagoya, Japan, we studied the electrochemical behaviour of natural graphite (fluorinated by ClF\(_3\) and NF\(_3\)) in propylene-carbonate-containing solvents. Additionally, surface fluorination of the graphitized vapour grown carbon fibre (VGCF) has been performed with F\(_2\), F\(_2\) + O\(_2\), NF\(_3\), and ClF\(_3\) under mild conditions and the charge/discharge characteristics were investigated.

Together with researchers from Colorado State University, USA, and Moscow State University, Russia, we have continued our study of the selective fluorination of fullerenes and investigations of the vapour composition obtained by the thermal decompositions of different fluorides. The application of Fourier transform mid- and far-IR spectroscopy for studies of the oxo-derivatives of Ag(II) was made in cooperation with Warsaw University, Poland. With the same partner we also studied the reactivity of the potent AgF\(_2\) oxidizer to a whole range of organic and inorganic compounds.

In cooperation with the Department of Solid State Physics (F-5) we continued our research on ferroelectric and ferromagnetic metal fluorides. Most of our research was made on K\(_3\)Fe\(_5\)F\(_{15}\), which exhibited both properties. The contribution of our department was mainly in the preparation of these compounds. This research is very promising and will be continued.

In the frame of the Centre of Excellence for Environmental Technologies we merged expertise in the fields of mercury’s environmental impact (Department O-2) and technological expertise in the field of flue-gas cleaning from high-temperature industrial processes (Department K-1), which enables a quantitative evaluation of the mercury emissions and also technological interventions needed for emission abatement.

The BF\(_4\)\(^-\) and SiF\(_6\)\(^-\) derivatives of protonated 3,5-diamino-1,2,4-triazole have been obtained and structurally investigated with X-rays. A complex system of strong hydrogen bonds was found in both compounds, the same as in the \([\text{Cu}(\text{C}_2\text{N}_5\text{H}_6\text{)}_2\text{]}\text{SiF}_6\) derivative. In collaboration with the Ivan Franko National University, Lviv, Ukraine, five new copper(I) \(\pi\)-complexes with fluoride-containing anions have been obtained: CuBF\(_4\) with 2-allylbenzotriazole and diallylcyanamide, Cu(CF\(_3\)COO) with 1-allylbenzotriazole, and Cu\(_2\)SiF\(_6\) with N-allylmorpholinium and diallylcyanamide.

The influence of different reaction conditions on the plasma polymerization was evaluated. In plasma of the gases CF\(_4\), C\(_6\)F\(_{12}\), C\(_2\)F\(_6\) and hydrogen, the polymerization rate depends strongly on the gas pressure in the reactor; by increasing the pressure in the range of 1 mbar the polymerization rate increases strongly. By increasing the pressure to a few mbar the precipitation of polymer in the form of a powder takes place. 4-amino arylsulfur pentafluoride is a product used in the syntheses and transformation of arylsulfur pentafluorides into different products. Single-crystal X-ray diffraction revealed that the torsion angles F-S-C-C differ considerably from the corresponding angles in a 4-acetamidoarylsulfur pentafluoride.

The B(\(\text{BF}_4\))\(_2\) and \(\text{SiF}_6\)\(^2-\) anions of the first compound containing simultaneously tetrahedral BF\(_4\)\(^-\) and octahedral PF\(_6\)\(^-\) anions.
consultation services related to the implementation and performance of the safety management system (in the context of the EU directive 96/82/EC, or Seveso II). In addition, we were engaged by the Ministry of Environment and Spatial Planning of the Republic of Slovenia in updating the expert review of process-safety aspects for the project documentation for two planned LNG terminals in the Gulf of Trieste, Italy. In cooperation with another research group we finished a quantitative analysis of operational and process safety aspects of PEMFC-type fuel cells. With the company Esotech d.d. we continued work in terms of the remaining uncertainties related to comparative analyses of alternative technological processes for a wet flue-gas desulphurization process. For Geoplin plinovodi d.o.o. we started with the reliability analysis of a part of a natural gas distribution system.

The final report of the Centre of Excellence Environmental Technologies (CEET) activities for the first period has been submitted to the authorities as well as the draft program for the next period. In the framework of CEET we merged international expertise in the fields of mercury environmental impacts (Department O-2) and technological expertise in the field of flue-gas cleaning from high-temperature industrial processes (Department K-1), with the aim of understanding the processes that influence the amount of emission and emitted species. The gained knowledge enables a quantitative evaluation of the emissions and also the technological interventions needed for the abatement of these emissions.

In cooperation with the technological firm Esotech d.d. and in the frame of the development of volatile organic compounds (VOCs) removal technology from the secondary lead processing we performed technological measurements. We studied the problem of arsenic and antimony removal from the industrial waste waters of a glass factory. It was established that the classical methods of co-precipitation are not successful because As and Sb are in the form of chemically very stable ions AsF$_6^-$ and SbF$_6^-$, respectively. We participated in the technological design of a flue-gas desulphurisation plant for the planned block VI (600-MW power) of the Soštanj thermal power plant. In the same project we also cooperated during the design of a pilot plant for the preparation of boiler water based on membrane techniques.

In cooperation with S&T Slovenija and the Slovenian Army and in the frame of the Targeted Development Project for Peace, financed by the Slovenian Ministry of Defence, we developed an ammunition-categorisation system and prepared a model for the inclusion of ammunition categorisation into the overall quality-assurance information system.

In cooperation with three Belgian companies – Leniko, IRE and Tecnubel – a contract financed by the European Union with the title “Improvement of the management of institutional radioactive waste in Slovenia” was obtained. The project was managed with the help of the Radiation Protection Group at the JSI in the JSI Hot Cell Facility. With this project a foundation for future cooperation in the field of radioactive-waste management was laid.

Two European projects were finished in 2008 – Form-it and PROBASE – which involved a collaboration between the JSI, the University of Ljubljana and various secondary schools. In 2008 the School of Experimental Chemistry provided 54 one-week courses of physical and chemical experiments for the students of elementary and secondary schools. The number includes attractive experiments that were performed for some special visits to our laboratories and for performances at schools all over Slovenia. We participated at the 14th Science Festival in Ljubljana, organized by the Slovenian Scientific Foundation, and in the 1st HOKUS-POKUS natural sciences festival, organised by the Youth Culture Centre Ljubljana. We were again invited to the 2008 International Science Festival in Genova, Italy.

**Awards and appointments**

1. The award “European Regional Environment Champion 2008” was awarded to the Environmental Technologies Excellence Centre by the European Regional Champions Award Expert Panel.
Some outstanding publications in 2008


Patents granted

1. Procedure for the synthesis of threadlike tungsten oxide W₁₅O₁₄
Maja Remškar, Marko Viršek, Miha Kocmur, Adolf Jesih
SI Patent no. 22445

Awards and appointments


Organization of conferences, congress and meetings

1. PROBASE partners meeting, Celje, 31 Mar to 4 Apr. 2008
11. Molybdenum and Tungsten Carbides, Titanium and Zirconium Diborides: Obtained from Fluoride Melts, Structure and Properties
   BI-UA/07-08-003
   Dr. Viktor Malyshev, Faculty of Chemistry and Technology, National Technical University of Ukraine, "Kyiv Polytechnical Institute", Kyiv, Ukraine
   Dr. Melita Tramišek

12. Study of Polymerization Process in RF Plasmas
   BB-CS/06-07-622
   Prof. Zoran Petrović, Institut za fiziku Beograda, Zemun, Belgrade, Serbia
   Dr. Adolf Jesih

13. Advanced Nanocaged Fluorocarbon Materials and Their Chemical Modifications
   BI-US/08-10-018
   Prof. Steven Strauss, Department of Chemistry, Colorado State University, Fort Collins, CO, USA
   Dr. Zoran Mazej

R & D GRANTS AND CONTRACTS

1. Control of Hg and some other toxic elements emissions from TPP, cement works and other high-temperature industrial processes
   Prof. Mladen Horvat, Dr. Andrej Stergaršek

2. Development of an ammunition categorisation system with implementation into the Quality Manager and Warehouse Management system
   Asst. Prof. Robert Kocjančič

3. Smart functional coatings for improvement of structures and components used in defensive purpose
   Dr. Peter Panjan, Dr. Adolf Jesih

VISITORS FROM ABROAD

1. Prof. dr. Joel F. Liebman, University of Baltimore, USA, 4–6 Feb 2008

2. Prof. dr. Mews Rüdiger, Universität Bremen, Germany, 30 Apr. to 5 May 2008

3. Dr. angelina Gab and dr. Dmytro shakhnin, faculty of chemistry and technology, Moscow, Russia, 22 Nov. to 6 Dec. 2008

4. Igor M. Shlyapnikov, "Chemical Department, Lomonosov Moscow State University", Moscow, Russia, 18 Jun. to 17 Sept. 2008

5. Dr. Norbert Chilingarov, "Chemical Department, Lomonosov Moscow State University", Moscow, Russia, 22 Nov. to 6 Dec. 2008

6. Dr. Angelina Gab and Dr. Dmytro Shakhnin, Faculty of Chemistry and Technology, National Technical University of Ukraine, "Kyiv Polytechnical Institute", Kyiv, Ukraine, 27 Nov. to 4 Dec. 2008

STAFF

Researchers

1. Asst. Prof. Marko Gerbec
2. Dr. Veseljko Hurešnik
3. Dr. Adolf Jesih
4. Asst. Prof. Robert Kocjančič
5. Dr. Zoran Mazej
6. Asst. Prof. Maja Ponikvar
7. Assst. Prof. Tomaz Skapin, Head
8. Dr. Andrej Stergaršek
9. Dr. Melita Tramišek
10. Prof. Boris Žemva

Postdoctoral associates

11. Dr. Gašper Tavčar

BIBLIOGRAPHY

ORIGINAL ARTICLES


4. Tina Bunič, Melita Tramišek, Evgeny A. Goreshnik, Boris Žemva, "Synthesis and structural investigation of the compounds containing F2 and C(F2)2 anions, Ca(HF2)2, BaH2(F2), BaF2(HF2)2, and Pb2F2(HF2)(F2)2”, J. solid state chem, vol. 181, no. 9, pp. 2318-2324, 2008.


The basic research of the department is focused on the experimental and theoretical study 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.

Experimental research in the field of electrochemistry looks at the materials that are important in biomedical and technological applications. We have studied the passive film formed on a Ti-6Al-7Nb alloy in a simulated physiological solution. It is characterized as a dual oxide layer comprising an inner barrier layer and an outer porous layer. The resistance of the barrier layer TiO₂ is high throughout the potential range investigated, whereas that of the outer layer is low in the lower potential range but increases at higher potentials. The greater corrosion resistance and stability of the Ti-6Al-7Nb alloy compared to the Ti-6Al-4V alloy investigated in our previous study is ascribed to the incorporation of niobium oxides – NbO, NbO₂, and primarily Nb₂O₅ – into the passive layer. This result is important for the safe long-term in-vivo application of the Ti-6Al-7Nb alloy, since niobium has the characteristics of an immunologically inert metal.

Our experimental studies of biomedical materials were focused on total hip replacements and were carried out in collaboration with the Orthopaedic Hospital Valdoltra and the Faculty of Medicine. We have developed a procedure for the isolation of nanometre-sized metal particles formed by the wear of a bearing surface made of the Co-28Cr-6Mo alloy. The composition and size of these particles were analysed using high-resolution transmission electron microscopy. Two types of particles were recognized: needle-shaped particles, ranging from 40 to 120 nm and containing both cobalt and chromium; and globular particles, ranging up to 90 nm and containing high levels of chromium and no cobalt. The composition of the isolated particles was related to the composition of the layer formed in vivo at the surface of the Co-28Cr-6Mo alloy.

In the field of corrosion protection we are interested in various ways of protecting materials – from corrosion inhibitors to surface layers. Electrochemical and electrochemical quartz microbalance measurements of BT₅H and BT₅OH inhibition efficiency for copper corrosion in 3%NaCl solution were analyzed. The experimental results were supplemented by molecular modeling to gain a better insight into the structural differences, electronic effects, reactivity parameters and adsorption properties of inhibitor molecules in relation to their inhibiting effectiveness. The superior inhibition effectiveness of BT₅H was attributed to the interplay of the planar molecular structure, physisorption and intermolecular H-bonding, resulting in the formation of a thin and protective film on the surface (Fig. 1).

Our theoretical investigations based on quantum chemical methods were focused on the examination of the structural, spectroscopic and stability features of the halogenated methyl nitrates, which have a great atmospheric relevance (Fig. 2). The computational results demonstrate the significant structural changes of CXONO₂, CX,Y₃ONO₂ (X,Y=F, Cl) caused by the halogen electron withdrawing effect, compared with the plain methyl analogue. A high stabilization of nitrates is achieved upon halogenation. The distinguishing spectroscopic features of the FC(O)ONO and FC(O)NO₃ isomers have been determined, which should allow these species to be identified experimentally. A comparison of the relative energetic stabilities of these isomers with those of chlorine analogues clearly demonstrates that the chlorine isomers are unstable relative to the fluorine analogues.

In the context of chemistry at silver surfaces, we investigated – by means of quantum mechanical computer simulations – the ethylene epoxidation reaction, which is one of the most important selective oxidation processes occurring on metal catalysts. We found that the catalyst’s selectivity in this reaction is determined in part by the differential bonding affinity of the catalyst toward the oxygen and carbon atoms of the reaction intermediate. We believe that the concept of the differential bonding affinity of a catalyst toward the various atoms of the molecule to which it binds may also be important in determining the selectivity in other surface reactions.
In the field of organic and bio-organic chemistry we continued our investigation on the application of green reaction conditions to the selective halogenation of organic compounds. We developed a method for the iodination of organic compounds with elemental iodine in the presence of 30% aqueous H₂O₂ under organic solvent-free reaction conditions. We applied the method for the selective and efficient iodination of methoxy-substituted benzene derivatives and aryl alky ketones. We used the same reagent system also for the iodination performed in ionic liquids and proved that this reaction media could also be used for the efficient and selective iodofunctionalisation of activated aromatics and aryl alkyl ketones. On the basis of our preliminary research performed last year we developed the aerobic oxidative iodination of organic compounds with iodide catalysed by sodium nitrite under acidic conditions. Using the reagent system KI/Na₂NO₂(cat.)/H₂SO₄ in polar aprotic (MeCN) or protic (EtOH) solvent we iodinated activated and moderately deactivated aromatic compounds, ketones and 1,3-ketones, alkenes and alkynes. We also established that the regioselectivity of the iodination of aryl alkyl ketones bearing a strongly activated aromatic ring could be directed with the solvent used. In acetonitrile the aromatic ring was selectively iodinated, while in ethanol α-iodo the derivatives were selectively obtained. On the basis of an editorial invitation we prepared and published a review article dealing with the electrophilic iodination of organic compounds using iodine or iodide. The method of aerobic oxidative halogenation catalysed by NaN₃ was also applied for the bromination of alkenes and we established that in this way the dibromination of the alkene double bond resulting in vicinal dibromides could be performed using 48% aqueous HBr. By developing these methods of oxidative halogenation using H₂O₂ or oxygen as the oxidants the mimicking of related natural processes was performed, thus proving that these processes could also be successful in the case of non-encimatics or non-metallic catalysis (Fig. 3). We developed a method for the direct fluorination of ketones with Selectfluor™ F-TEDA-BF₄® in aqueous reaction media by using anionic amphiphile sodium dodecylsulfate in concentrations higher than its critical micelle concentration. In a collaboration we experimentally determined the solubility of halogens in fluorous solvents as a function of the temperature, and the data obtained complemented the theoretical calculations.

Some outstanding publications in 2008

2. A. Lesar and T. Sajevic, Structures, vibrational spectra, and relative energetics of FC(O)ONO and FC(O)NO₂ isomers at DFT and ab initio levels, Mol. Phys. 106 (2008), 2301-2308
5. S. Stavber, M. Jereb, M. Zupan, Electrophilic iodination of organic compounds using elemental iodine or iodide, Synthesis 2008, 1487-1513

Awards and appointments

2. Tadeja Kosec Trimo research award for Ph.D. thesis 2008
INTERNATIONAL PROJECTS

1. Core Laboratories for the Improvement of Medical Devices in Clinical Practice from the Failure of the Explanted Prostheses Analysis (FEPA) COST Action 537 (WG 1) EC
   Dr. Ingrid Milošev
2. A Swedish-Slovenian Nanobattery Network SVEN-SLO-BATT Micro-Nano-Technology MNT ERA NET Uppsala University, Uppsala, Sweden Dr. Anton Kokalj
3. Improvement of Resurfacing Hip Implants with DLC, TiO2 and DLC-p-h Nanocomposite Coatings RHIS-DLC-NanOmp MATERA ERA NET ORTON Research Institute, Helsinki, Finland Dr. Ingrid Milošev
4. Investigation of Elemental Steps of Competing Radical Reactions important for Atmospheric Chemistry, especially Chlorine and Bromine Containing Compounds BAT-07-08-017 Prof. Max Muehlhaeuser, Management Center Innsbruck, Innsbruck, Austria Dr. Antonija Lesar
5. Fluorous Phases as Substitutes to Organic Solvents. Study of Solvation and Molecular Transport PROTEUS III-BRO-TQOTEUS-005 Dr. Margarida Costa Gomes, Laboratorie de Thermodynamique des solutions et des polymères UMR 6693 CNRS/Université Blaise Pascal, Clermont-Ferrand, Aubière, France Dr. Jernej Iskra
6. Chemistry at Silver Surfaces: Understanding Ethylene Epoxidation and Other Popular Reactions on Silver based Catalysts BHT/05-08-004 Dr. Mario Bocca, Department of Physics, University of Genova, Genova, Italy Dr. Anton Kokalj

R & D GRANTS AND CONTRACTS

1. The influence of electronic structure of corrosion inhibitors on their efficiency Dr. Anton Kokalj
2. Survivorship of total hip replacements as a function of type of bearing surfaces Dr. Ingrid Milošev
3. PVD hard coatings as an alternative for corrosion protection of Fe and Al-alloys Dr. Drininka Rek Merl, Dr. Ingrid Milošev
4. Smart functional coatings for improvement of structures and components used in defensive purposes Dr. Peter Panjan, Dr. Ingrid Milošev

RESEARCH PROGRAMS

1. Bioorganic and biorganic chemistry Dr. Stojan Stavber
2. Micro- and nanostructured functional materials: development, physical and chemical characterization and simulation of processes Dr. Ingrid Milošev

STAFF

Researchers
1. Dr. Jernej Iskra
2. Dr. Anton Kokalj
3. Dr. Antonija Lesar
4. Dr. Ingrid Milošev, Head
5. Dr. Stojan Stavber
6. Prof. Marko-Andrej Zupan*

Postdoctoral associates
7. Dr. Tadeja Kosec, left 1 Sept. 2008
8. Dr. Mattjaž Finšgar, B. Sc.
9. Dr. Saša Kovačič, left 1 Jul. 2008

Postgraduates
10. Saša Kovačič, Jože Koller, Janez Cerkovnik, Tell Tuttle, Božo Plesničar, Barbara Kapun, B. Sc.
14. Chemistry at Silver Surfaces: Understanding Ethylene Epoxidation and Other Popular Reactions on Silver based Catalysts, BHT/05-08-004, Dr. Mario Bocca, Department of Physics, University of Genova, Genova, Italy, Dr. Anton Kokalj
15. R & D GRANTS AND CONTRACTS, 1. The influence of electronic structure of corrosion inhibitors on their efficiency, Dr. Anton Kokalj
16. Survivorship of total hip replacements as a function of type of bearing surfaces, Dr. Ingrid Milošev
17. PVD hard coatings as an alternative for corrosion protection of Fe and Al-alloys, Dr. Drininka Rek Merl, Dr. Ingrid Milošev
18. Smart functional coatings for improvement of structures and components used in defensive purposes, Dr. Peter Panjan, Dr. Ingrid Milošev

RESEARCH PROGRAMS, 1. Bioorganic and biorganic chemistry, Dr. Stojan Stavber
2. Micro- and nanostructured functional materials: development, physical and chemical characterization and simulation of processes, Dr. Ingrid Milošev

BIBLIOGRAPHY

ORIGINAL ARTICLES

5. Anton Kokalj, Paola Gava, Stefano de Gironcoli, Stefano Barnini, “Activated adsorption of ethylene on atomic-oxygen-covered Ag(100) and Ag(210): formation of an oxometallacycle”, The journal of physical chemistry, C, Nanomaterials and interfaces, vol. 112, no. 4, pp. 1019-1027, 2008.
10. Antonija Lesar, Tamara Sajevic, “Structures, vibrational spectra, and relative energetics of FC(O)NO and FC(O)NO,omers at DFT and ab initio levels”, Mol. phys., vol. 106, no. 19, pp. 2301-2308, 2008.


15. Jasminka Pavlinac, Marko Zupan, Stojan Stavber, "Iodination of organic compounds using the reagent system $\text{Ag}_3\text{O}_2\cdot\text{aq}, \text{HIO}_3$ under organic solvent-free reaction conditions", Acta chim. slov., vol. 55, no. 4, pp. 841-849, 2008.


**Review Articles and Chapters in Books**


**Published Conference Papers**

**Invited Papers**


**Regular Papers**


**Theses**

**Ph. D. Theses**


**ELECTRONIC CERAMICS DEPARTMENT**

**K-5**

The Electronic Ceramics Department is active in the research of the synthesis, properties and applications of materials for electronics, mainly complex multifunctional materials and structures. The materials of interest include ceramic piezoelectrics, ferroelectrics, relaxors, ‘conductive’ oxides and materials for solid-oxide fuel cells (SOFCs). The emphasis is on the creation of properties by the synthesis and the structure on the nano-, micro- and macro-levels.

Lead-free piezoceramics based on the $K_xNa_{1-x}NbO_3$ solid solution represent an environment-friendly alternative to lead-based piezoelectrics; however, not much data is available on its basic properties. X-ray diffraction measurements were used to follow the change of the unit-cell parameters of $K_xNa_{1-x}NbO_3$ ($0.4 \leq x \leq 0.6$) in the temperature range 100–800 K. At room temperature all the compositions exhibited a monoclinic metric of the unit cell with a small monoclinic distortion ($90.32^\circ \leq \beta \leq 90.34^\circ$) and not an orthorhombic structure, as found in the literature. With increasing temperature, the samples underwent first-order monoclinic–tetragonal and tetragonal–cubic transitions. No major change of the symmetry was evidenced in the investigated compositional range, which should be characteristic of the morphotropic phase-boundary region at $x \approx 0.5$, as reported in earlier papers.

We continued research on the processing of alkaline niobate-based ceramics. Our objective was to lower the sintering temperature of $K_{0.5}Na_{0.5}NbO_3$ (KNN) without diminishing its piezoelectric properties by using a novel sintering aid based on (K,Na)-germanate. (Figure 1) The KNN ceramics modified with 1 mass% of alkaline-germanate reached 96% of theoretical density after sintering at temperatures as low as 1000 K, which is approximately 100°C lower than the sintering temperature of KNN without additives. The relative dielectric permittivity and losses measured at 10 kHz are 397 and 0.02, respectively, and the piezoelectric coefficient is 120 pC/N, and the electromechanical coupling and mechanical quality factors ($k_p$, $k_t$, $Q_m$) are 0.40, 0.44, and 77, respectively. These values are comparable to the best values obtained for KNN ceramics sintered at 1115°C.

We continued research of the properties of $K_{0.5}Na_{0.5}NbO_3$ single crystals prepared by solid-state crystal growth (SSCG). We performed a detailed study of the chemical homogeneity and the domain structure by X-ray powder diffraction, as well as optical, scanning, and transmission electron microscopy. No compositional inhomogeneities were encountered in the crystals with monoclinic symmetry. The domain pattern consists of 90°-domains that are about 100 µm across, and which contain smaller, 180° domains of up to a few hundred nm.

Lead-free percolative all-ceramic composites based on $K_{0.5}Na_{0.5}NbO_3$ and $RuO_2$ were synthesized and a dielectric permittivity of over 20,000 at 10 kHz was obtained for compositions close to the percolation threshold. Percolative composites of $Pb(Zr_{0.53}Ti_{0.47})O_3$ and conductive $PbRuO_3$ with permittivities over 40,000 were also fabricated.

We systematically studied the synthesis of nanoparticles with the aim of controlling the morphology and attaining a high chemical homogeneity. The research of the solution synthesis of nanoparticles of multicomponent oxides was focused on $La_2Zr_2O_7$. The nanometre-sized powder was prepared from dehydrated lanthanum nitrate and zirconium n-butoxide in 2-methoxyethanol and heating at 800°C. We followed the structural evolution from the sol to the amorphous powder by X-ray absorption spectroscopy (EXAFS). The La environment in both the La-nitrate solution and the La$_2Zr_2$O$_7$ sol is similar to that of the lanthanum nitrate hydrate. The Zr environment is populated by six Zr–O–Zr links and it remains almost unchanged in the transition from the sol to the dried and amorphous powder, heated at 500°C. The La–O–Zr links have not been established. We concluded that the reaction between individual metallic-oxide species proceeds in the solid state. The solution-synthesis route ensures a very good mixing of the species at the nanometre level, which is also confirmed by the nanometre-sized powder.

**Figure 1:** Shrinkage versus temperature for $K_{0.5}Na_{0.5}NbO_3$ (KNN), (K,Na)-germanate, and KNN modified with 0.5, 1, 2, and 4 mass% of alkaline germanate (KNN+0.5G, KNN+1G, KNN+2G, KNN+4G). Insets: photos of a (K,Na)-germanate pellet on top of a KNN pellet on a ZrO$_2$ substrate in a heating-stage microscope (a) at room temperature and (b) at 800°C, when the melted (K,Na)-germanate completely wets the surface of the KNN.
By mechanochemical activation of the mixture of constituent powders we prepared dense, chemically homogeneous (K_{0.485}Na_{0.485}Li_{0.03}) (Nb_{0.8}Ta_{0.2})O_3 piezoelectric ceramics. Using this approach we could avoid a number of processing steps typical for classical solid-state synthesis.

During conventional synthesis to be avoided, such as multiple calcinations with intermediate milling steps, has been patented. We found that during the activation an amorphous carbonato complex is formed, which plays a crucial role in obtaining homogeneous KNLNT ceramics.

We prepared the 0.3 Pb(Fe_{0.5}Nb_{0.5})O_3–0.7 Pb(Mg_{0.5}W_{0.5})O_3 and 0.8 Pb(Fe_{0.5}Nb_{0.5})O_3–0.2 Pb(Mg_{0.5}W_{0.5})O_3 multiferroic powders by mechanochemical synthesis, and by sintering we prepared dense ceramics. Colleagues at the Condensed Matter Physics Department confirmed for the first time that the materials are magnetoelectric relaxors.

The research of the chemical solution deposition of ferroelectric thin films was focused mainly on alkaline earth titanates and alkaline tantalates/niobates.

In cooperation with the partners HyB d.o.o., Sentjernej, Slovenia; EPFL, Switzerland; and Thales, France; several demonstration antennas for aeronautics (10 to 14 GHz) were fabricated in the frame of the EU 6FP project retina. Planar capacitors from (Ba,Sr)TiO_3 thin films on alumina substrates, processed in our laboratory, were integrated into the phase shifters of a reflect-array, which makes possible electronic steering towards a telecommunications satellite.

K(Ta,Nb)O_3 is a structural analogue of (Ba,Sr)TiO_3 with an expected higher capacitance tunability and therefore possible applications in microwave phase shifters; however, due to a difficulty synthesis there are only a few reports on its functional properties in both bulk and thin-film forms. KTa_{0.83}Nb_{0.17}O_3 thin films on polycrystalline alumina were prepared from potassium acetate and transition-metal alkoxides in 2-methoxyethanol. The films, prepared at 900°C have a dielectric permittivity value of 1690, a dielectric loss value of 0.04 and a tunability (C_{0V}/C_{30V}) value of 2.6 at 1 MHz.

In the frame of the EU 6FP project CAMELLIA we studied thin films with a high permittivity for microelectronics. CaCu_3Ti_4O_{12} single crystals and ceramics have been reported to possess extremely high values of permittivity, but there are almost no data on thin films prepared by chemical solution deposition. We prepared the CaCu_3Ti_4O_{12} films on platinumized silicon from nitrate-alkoxide based sols and after heating at 750°C we obtained a permittivity of about 1000 at 1 kHz.

The R&D of transparent materials and their integration onto an organic substrate enable the manufacturing of flexible, large-area displays. Within the EU 6FP project MULTIFLEXIOXIDES we developed the materials and procedures for the fabrication of thin-film transistors (TFTs) on polymer substrates. We prepared 2-inch ZnO–In_{2}O_{3}–Ga_{2}O_{3}–GaAs-based ceramic targets with a dense and homogeneous microstructure. These have been further used for RF-magnetron sputtering or the pulsed laser ablation of amorphous thin films, acting as the electrode, and semiconductor components in TFT. Project partners from the University Nova, Lisbon, Portugal, processed the semiconductor elements of TFTs at a remarkably low temperature of 150°C, which exhibited a field-effect mobility of 55 cm²/Vs and an on/off ratio of 10⁸. (Figure 2)

In_{2}O_{3}–ZnO-based liquid precursors have been developed for the chemical solution deposition of thin films or, after optimizing the viscosity, surface tension and solids content, as the inks for the shaping of different structures by ink-jet printing. Spin-coating of the precursors on polymeric substrates and heating at as low as 150°C resulted in transparent amorphous films without any organic residues.

We studied the processing of ferroelectric thick film structures based on complex lead-based perovskites such as 0.65 Pb(Mg_{0.33}Nb_{0.67})O_3–0.35 PbTiO_3 (PMN–PT) and PbZr_{0.2}Ti_{0.8}O_3 (PZT) by screen-printing and electrophoretic deposition (EPD). Chemically homogeneous, nanosized powders were synthesized by high-energy milling. With a careful control of the amount and type of additives, the pastes for screen printing and suspensions with a high absolute value of the zeta-potential in organic solvents for EPD have been prepared.

We prepared homogeneous and dense ceramics from mechanochemically activated ZnO–In_{2}O_{3}–Ga_{2}O_{3}–GaAs-based powder. The ceramics, used as targets for the sputtering of source-drain electrodes and semiconductor layers, enabled the fabrication of thin-film transistors on transparent, flexible substrates at as low as 150°C.

enables a strongly reduced temperature of the reaction when compared to classical solid-state synthesis.

In the past year we broadened our research of the mechanochemical synthesis to complex systems. We prepared the (K_{0.485}Na_{0.485}Li_{0.03}) (Nb_{0.8}Ta_{0.2})O_3 (KNLNT) solid solution by introducing mechanochemical activation of the mixture of the initial compounds. Dense and homogeneous KNLNT ceramics have been obtained, which is quite difficult with the conventional solid-state synthesis route. The procedure, which allows numerous processing steps encountered during conventional synthesis to be avoided, such as multiple calcinations with intermediate milling steps, has been patented. We found that during the activation an amorphous carbonato complex is formed, which plays a crucial role in obtaining homogeneous KNLNT ceramics.
Using EPD we prepared homogeneous PZT films of about 50 µm thickness with a high green density. The films, sintered at 850°C, exhibited a room-temperature dielectric permittivity of 1050, dielectric losses of 0.038, a remnant polarization of 29 µC/cm², a coercive field of 21 kV/cm, and a piezoelectric d₃₃ coefficient of 97 pC/N.

About 50-µm-thick PMN–PT films were prepared by screen-printing. By using a suitable amount of packing powder when sintering the films, which prevented the sublimation of PbO, we obtained a room-temperature dielectric permittivity of 3600, dielectric losses of 0.036, and a d₃₃ of 140 pC/N.

The structural, dielectric, ferroelectric and electrostrictive characteristics of PMN–PT thick films screen printed and sintered on different substrates, i.e., alumina, bulk PMN–PT, and platinum were investigated. The results indicated that the microstructure of the films, the phase composition, i.e., the ratio between the tetragonal and monoclinic phases, and the electrical characteristics, depended on the substrates. The highest density, dielectric permittivity and piezoelectric d₃₃ coefficient were obtained when using alumina substrates.

We continued work on LTCC (Low Temperature Co-fired Ceramic) materials that are used for multilayer hybrid circuits and 3D structures with buried channels and cavities. A number of LTCC materials have been investigated; both those containing a few percent of PbO in the glassy phase as well as lead-free formulations. Thick-film resistors on LTCC substrates, which will be used as piezoelectric pressure sensors, were realized. The sheet resistivity and temperature coefficient of resistivity of the structures increased due to interactions between the glassy phase from the LTCC substrate and the material resistors. However, the gauge factors, which are important for the sensing characteristics, remained unchanged.

Sacrificial layers are often used to realize buried channels or cavities within 3D LTCC structures without de-lamination and/or sagging during the lamination and firing processes. We evaluated sacrificial materials based on graphite. Thermogravimetric analysis was used to optimize the filler burn-out profiles. We found that we could prepare 3D structures without cracks and deformations by heating at 850°C, with a hold at 700–720°C to allow the complete burn-out of carbon.

Based on the studies of LTCC and sacrificial materials the ceramic micro-reactor for the reforming of fuel for fuel cells was designed and realized in collaboration with HIPOT-RR. The reactor is composed of two evaporators, a mixing chamber and a part where the reaction takes place. This 3D structure of 50 x 30 mm³ in size is assembled from eight LTCC layers. It contains buried channels in several layers. The width, thickness and length of the channels are 400 µm, 30 µm and nearly 2 m, respectively. Thick-film Pt-based heaters are printed and fired on the surface. The inlets for the reactants are on the left-hand side and the outlet for the reaction products is on the right-hand side. The microstructure of the cross-section of the channels (line A–A) and the cross-section of the cavity (line B–B) are shown on the right. The schematic cross-section of the micro-reactor is presented below. Collaboration JSI and HIPOT-RR.

In collaboration with ETI d.d. Izlake, we developed a new alumina porcelain with the addition of lithium minerals for the fabrication of fuse bases with a lower thermal expansion coefficient, better resistance to thermal shocks and improved flexural strength than the standard formulation. We exhibited the new material and products at the Slovenian Innovation Forum 2008 in Ljubljana, where JSI and ETI won recognition for their innovation.

Figure 3: The ceramic micro-reactor with the dimensions 70 x 30 x 1.5 mm³ is assembled from eight LTCC layers. It contains buried channels in several layers. The width, thickness and length of the channels are 400 µm, 30 µm and nearly 2 m, respectively. Thick-film Pt-based heaters are printed and fired on the surface. The inlets for the reactants are on the left-hand side and the outlet for the reaction products is on the right-hand side. The microstructure of the cross-section of the channels (line A–A) and the cross-section of the cavity (line B–B) are shown on the right. The schematic cross-section of the micro-reactor is presented below. Collaboration JSI and HIPOT-RR.

Our postgraduate student Hana Uršič won the Young Scientist Award for Encouragement of Research in Materials Science at the IUMRS-ICA 2008 conference in Nagoya, Japan, 9–11 December 2008 for the contribution Effect of Processing for CSD-derived LNO Seeding Layer on Electrical Properties of PZT Thin Film.
ETI (Figure 4). The developed materials and products were presented at the Slovenian Innovation Forum 2008 in Ljubljana, where the JSI and ETI obtained recognition for their innovation.

The department’s research was conducted in the frame of the research programme “Electronic Ceramics, Nano, 2D and 3D Structures”, two fundamental ARRS projects, four ARRS projects, co-financed by Slovenian industry, one post-doc project, one CRP-MIR project, one project financed by Slovenian industry and eight EU FP6 and FP7 projects.

Some outstanding publications in 2008

5. Hana Uršič, Marko Irovat, Janez Holc, Marina Sante-Zarnik, Silvo Drnovšek, Srečo Maček, Marija Kosec, A large-displacement \( \frac{1}{2} \)Pb(Mg_{0.33}Nb_{0.67})O_3−\( \frac{1}{2} \)PtBiO_3/ Pt bimorph actuator prepared by screen printing. Sens. Actuators, B, Chem., 2008, 133 [2], 699-704.

Patents granted

1. Processing of dense ceramics based on alkaline niobates and tantalates
   Janez Holc, Janez Bernard, Barbara Malič, Marija Kosec
   SI Patent No. 22380
2. Lead-perovskite-based thick-film structures on reactive ceramics and methods of production
   Janez Holc, Silvo Drnovšek, Marija Kosec
   SI Patent No. 22401
3. Processing of alumina porcelain for electrotechnics
   Martina Oberžan, Janez Holc, Marjan Buh, Vlasta Imperl
   SI Patent No. 22541

Awards and Appointments

1. Kupec Alja: Students Prešeren Award, B. Sc. thesis entitled Insulation of electrically conductive fibres
2. Wu Aiying, Vilarinho Paula M., Kholkin Andrei, Holc Janez, Kosec Marija: Excellent Paper Award for contribution at the International Materials Research Conference (MRS)
3. Kosec Marija: Acknowledgement from Chamber of Craft and Small Business of Slovenia for extraordinary effort in the integration of science and business
4. Hana Uršič: Certificate of Award for Encouragement of Research in Materials Science for the contribution "Effect of Processing for CSD-derived LNO Seeding Layer on Electrical Properties of PZT Thin Film"

Organization of conferences, congresses and meetings

2. AMF-6, 6th Asian Meeting on Ferroelectrics, Taipei, Taiwan, 2–6 Aug., 2008
5. 3rd International IMAPS-IEEE CPMT Poland Conference, Warsaw, Pułtusk, Poland, 21–24 Sep., 2008
7. IWA03, 3rd International Workshop on Advanced Ceramics, Limoges, France, 5–8 Nov., 2008
INTERNATIONAL PROJECTS

1. Micro Fabrication Production Technology for MEMS on New Emerging Smart Textiles/Flexibles  
   MICROFLEX  
   7. FP. NMP-2-LA-2008-213155  
   EC. Dr. Steve Beeby, University of Southampton, School of Electronics and Computer  
   Science, Hampshire, Southampton, Great Britain  
   Dr. Janez Holc, Prof. Marija Kosec

2. Novel Technology for High-PERformance pieoelectric Actuators  
   HIPER-Act  
   CFIR  
   FP7-NMP-2007-LARGE-1  
   7. FP. EC. Anders Bjerrum, Claus Bo Andersen, Noliac A/S, Kvistgaard, Denmark  
   Prof. Marija Kosec, Dr. Andreja Benčan Golob

3. MEMS/snfc above IC Ultra High Value Capacitors for Mobile and Wireless  
   Communication Systems  
   CAMELIA  
   6. FP. NMP-CT-2006-053103  
   EC. Gidonna Boran, Tyndall National Institute, Lee Maltings, Cork, University College  
   Cork, National University of Ireland, College Road, Cork, Ireland  
   Asst. Prof. Barbara Malič

4. Multifunctional Ceramic Layers with High Electromagnetoelectric Coupling in Complex Geometries  
   MULTICERAL  
   6. FP. NMP-CT-2006-052306  
   EC. Prof. Andrei Kholkin, University of Aveiro, Dept. of Ceramics & Glass Engineering,  
   Aveiro, Portugal  
   Prof. Marija Kosec, Dr. Janez Holc, Prof. Robert Blinc, Prof. Raša Pirc

5. Multicomponent Oxides for Flexible and Transparent Electronics  
   MULTIFLEXIDES  
   6. FP. NMP-CT-2006-053231  
   EC. Prof. Rodrigo Ferras de Patra Martins, UNINOVA – Instituto de Desenvolvimento de  
   Novas Tecnologias. Campus da FCT/UNI, Monte de Caparica, Portugal  
   Dr. Danjela Kuščer Hrovatin

6. RELiable, Tuneable and Destructible Antennas by collective fabrication processes  
   BETINA  
   6. FP. AST-CT-2005-516213  
   EC. Dr. Volker Ziegler, EADS Deutschland gmbh, Corporate Research Centre, Dept.  
   LG-ME, München, Germany  
   Prof. Marija Kosec, Asst. Prof. Barbara Malič

7. Multifunctional & Integrated Piezoelectric Devices  
   MIND  
   6. FP. NMP-CT-2005-515757  
   EC. Wanda Wolny, Ferroperm Piezoceramics A/S, Kväsvärd, Denmark  
   Prof. Marija Kosec, Asst. Prof. Barbara Malič

8. Fuel Cell Application in a New Configurated Aircraft  
   CELINA  
   6. FP. AST-CT-2005-516236  
   EC. Wolfgang Dressel, Airbus Deutschland gmbh, Hamburg, Germany  
   Prof. Marija Kosec, Dr. Danjela Kuščer Hrovatin

9. Electroceramics from Nanopowders produced by Innovative Methods  
   ELENA  
   COST 559  
   EC. Asst. Prof. Barbara Malič

10. Invisible  
    Sincronotrière S.C.p.A di interesse nazionale, Basovizza, Trieste, Italy  
    Dr. Danjela Kuščer Hrovatin

R & D GRANTS AND CONTRACTS

1. Functional properties of thin films based on environment friendly complex perovskite  
   materials: dependence on microstructure and chemical homogeneity  
   Asst. Prof. Barbara Malič

2. Materials and processes for shaping miniature thick film ceramic 2D and 3D structures  
   Dr. Marko Hrovat

3. Energy-saving ceramic pressure sensors with digital output  
   Dr. Marko Hrovat

4. Processing of ceramic microelectromechanical systems (MEMS) by novel technologies  
   Dr. Janez Holc

5. Capacitive ceramics: pressure sensors  
   Dr. Marko Hrovat

6. Miniaturised Ceramic Low Pressure Sensors  
   Dr. Marko Hrovat

7. Fuel cell systems as an auxiliary energy sources for autonomous military vehicles;  
   Auxiliary power supply based on fuel cells  
   Dr. Janko Petrović, Dr. Danjela Kuščer Hrovatin

8. Mechanocchemical synthesis of complex ceramic oxides  
   Dr. Tadej Bujac

RESEARCH PROGRAM

1. Electronic Ceramics, Nano-, 2D and 3D Structures  
   Prof. Marija Kosec

NEW CONTRACTS

1. Processing of ceramic microelectromechanical systems (MEMS) by novel technologies  
   Hydro-BiHybrid Circuits and Sensors d.o.o., Sentjernej  
   Dr. Janez Holc

2. KeraPro – Ceramic Processor for Fuel Reforming and Cleaning of Obtained Gasses  
   Ministry of Defence  
   Dr. Marko Hrovat

VISITORS FROM ABROAD

1. Prof. Marc Lethecio, University of Tours, Tours, France, 9 Jan. 2008

2. Dr. Miguel Alguero, Instituto de Ciencia de Materiales de Madrid, Madrid, Spain,  

3. Prof. Susan Trolier-McKinstry, Pennsylvania State University, Pennsylvania, USA,  

4. Dr. Elena Daniela Ion, National Institute for Materials Physics, Magurele, Romania,  
   5–7 Jun. 2008

5. Dr. Atavay Popov, University of Oulu, Oulu, Finland, 22 Sept. 2008

6. Dr. Sophie D’Astorg, Cranfield University, Cranfield, Great Britain, 23 Sept. to 4  
   Oct. 2008

7. Mr. Kozma Gabor, University of Szeged, Szeged, Hungary, 13–26 Oct. 2008

8. Dr. Dmitry Kiselev, University of Aveiro, Aveiro, Portugal, 1–15 Nov. 2008

9. Dr. Tadej Bujac

10. Dr. Jenny Julie Angeline Tellier

11. Prof. Andrej Babić, University of Zagreb, Zagreb, Croatia, 7–19 Apr. 2008


STAFF

Researchers

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15. Jurij Koruža, B. Sc.

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19. Hana Urista, B. Sc.
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23. Brigita Kužnik, B. Sc.
24. Tina Ručigaj, B. Sc.
25. Miha Skalar, B. Sc.

Technical and administrative staff
27. Srečko Maček
Note:
* part-time JSI member

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2. Harvey Amorín, Jesús Ricote, R. Jiménez, Janez Holc, Marija Kosec,
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3. Darko Belavič, Marko Hrovat, Janez Holc, Marina Santo‐Zarnik, Marija
Kosec, Marko Pavlin, "The application of thick‐film technology in C‐
4. Janez Bernard, Andreja Benčan, Tadej Rojac, Janez Holc, Barbara Malič,
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5. Vid Bobnar, Marko Hrovat, Janez Holc, Marija Kosec, "Giant dielectric
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by solid‐state crystal growth using �� ����� ��� as a sintering aid", J.
9. John Gerard Fisher, Andreja Benčan, Marija Kosec, Sophie Vernay,
Daniel Rytz, "Growth of dense single crystals of potassium sodium
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10. Elena‐Daniela Ion, Barbara Malič, Iztok Arčon, Alojz Kodre, Marija
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11. R. Jiménez, Marija Kosec, Janez Holc, (9 authors), "Effect of grain size
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18. Barbara Malič, Darja Jenko, Janez Holc, Marko Hrovat, Marija Kosec,
"Synthesis of sodium potassium niobate: a diffusion couples study", J.
19. Barbara Malič, Mira Mandeljc, Goran Dražić, Miha Škarabot, Igor
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titanium‐rich PZT thin films by chemical solution deposition", Integr.
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26. Marina Santo‐Zarnik, Darko Belavič, Srečo Maček, "Experimental and
numerical analysis of thick‐film piezoceramics structures for
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Regular papers


THESSES

M. Sc. Theses

1. Jerneja Godnjavec, Influence of synthesis conditions on phase composition, microstructure and electrical properties of (K\textsubscript{0.5}Na\textsubscript{0.5})NbO\textsubscript{3} ceramics, Ljubljana, [J. Godnjavec], 2008.

B. Sc. Theses


PATENT APPLICATIONS

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 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.

We continued the application of the reactivity of aluminium nitride (AlN) powder with water at elevated temperatures in the synthesis of thin coatings of aluminium hydroxide with large specific areas on ceramic substrates. We studied the kinetics of the hydrolysis and determined the aluminium species in aqueous suspensions of AlN powder, which are responsible for the formation of the hard crystalline phase. We investigated the influence of the temperature and the reaction time on the nucleation and growth of crystalline products, with the focus on the growth of nanostructured boehmite (AlOOH). By using stereometric analyses we characterized quantitatively the morphology of the boehmite nanocoatings and the geometry of individual boehmite particles on the substrate. We also determined the crystal structure and the morphology of the oxide coating after thermal treatment.

In the frame of bioceramics research, tetragonal ZrO₂, partially stabilized with Y₂O₃ (Y-TZP), was used as the basic material that possesses the best mechanical properties from among all bio-compatible ceramic materials. However, it is bio-inert because of its chemical stability. Bio-inertness is desirable for the friction surfaces of artificial joints, but it imposes great problems for the fixation of an implant since the tissue does not grow on the implant’s inert surface. The bio-inertness problem was first tackled by inserting bioactive particles of Ca₅(PO₄)₂ and Ca₁₀(PO₄)₆ into the Y-TZP matrix. However, since these composites could not be sintered to a high density and with the desirable strength by the usual procedures because of the reactivity of the secondary-phase particles with the matrix at elevated temperatures, we paid, in the following, greater attention to the synthesis of bioactive coatings on a Y-TZP substrate. We used the biomimetic method of precipitation of hydroxyapatite (HA) from a super-saturated solution of calcium and phosphate ions. Polycrystalline particles of octacalcium phosphate (OCP) in the form of large, semicircular agglomerates or thin homogeneous coatings were formed on the substrate, depending on the concentration of calcium, phosphate and hydroxide ions. The formation of OCP was proved by electron diffraction (SAED), energy-dispersive spectroscopy (EDS) and electron energy-loss spectroscopy (EELS). The different morphologies of the coatings were explained by the influence of the supersaturation degree of the solution on the critical size and the corresponding number of nuclei, together with the influence of temperature on the saturation speed and the final coating thickness. With these results, we set up a model to describe the mechanism and the kinetics of the saturation of calcium phosphate from the Ca/P solution on the surface of sintered Y-TZP ceramics.

In the frame of the R&D of dental ceramics based on tetragonal (Y-TZP) ZrO₂ we also studied the influence of mechanical surface treatments, e.g., grinding and sand-blasting, on the kinetics of the accelerated ageing of this material in artificial saliva, as well as fatigue under simulated clinical conditions. We showed that untreated specimens are subjected to the most accelerated ageing, while the sand blasted and ground surfaces are more resistant. The better stability of mechanically surface treated Y-TZP ceramics is attributed to twinning and the partial deformation of the crystal lattice of re-transformed tetragonal grains, although it is also influenced by surface compressive stresses. The survival level after mechanical fatigue in artificial saliva is significantly lowered in comparison with the fatigue in air, which indicates a strong influence of stress corrosion that is additionally influenced by the mechanical damage due to grinding. We continued the clinical study of restoring teeth with ceramic posts, which were developed in cooperation with stomatologists from the Medical Faculty, University of Ljubljana. The results so far indicate a high percentage of success in restoring endodontically cured teeth with zirconia ceramic posts, and they confirm the hypothesis that this material is appropriate for the fabrication of dental posts in the intercanine region of dental arcs. Since the Young’s modulus of Y-TZP ceramics is significantly higher than the modulus of dentine the large elastic stresses appear at the connection of the dental restoration framework with tooth preparation, which in turn increases the...
probability of the malfunction of the marginal seal and consequently the secondary caries and periodontal disease. In the frame of a young researcher fellowship we started the development of porous ceramics with a lower elastic modulus, while retaining a satisfactory bending strength. We tried to achieve this by coating ZrO₂ microparticles with nanoparticles of the same material. This combination should ensure intermediate porosity (80%) with pore sizes in the nanometre range. We made use of the help of the homo-aggregation of nano- and microparticles. SEM/FESEM analyses revealed pores of nanometre dimensions and their uniform distribution across the fracture surface. In addition, we worked a lot on the adhesion of dental cements to the surface of sintered Y-TZP ceramics as a structural material for full ceramic dental restorations. We found that coating the structural ceramic surface with a thin adhesion layer made of alumina may lead to values of the contact shear strength that are even five times higher. The fact that the contact strength with the use of adhesion coating does not decrease even after long-term thermocycling is even more important for clinical practice.

We began research on the rheological properties of paraffin suspensions with a high solids loading. We found that the yield stress of these suspensions after cooling below the melting temperature of the dispersion medium (paraffin) and heating again above this temperature increases by at least an order of magnitude. The magnitude of this change increases with the volume fraction of powder in the suspension and decreases with the size of the powder particles used. The reason for this is attributed to the strengthening of attractive inter-particle forces, because the distances between the suspension particles are decreased due to the significant contraction of the medium (approximately 20 vol.%) in the liquid-solid phase transition.

We have run preliminary Monte Carlo simulations of critical-crack propagation in uniaxial tests of the bending strength of flat ceramic monoliths or multilayered composites. In the first step of the simulation development we focused on narrow edge cracks with commonly known weight functions for the calculation of the intensity factor of the mechanical stress. We searched for parameters in the Weibull distribution of the breaking forces or the corresponding tensile stresses. We also simulated Gaussian measurement uncertainty and the possible arrestment of the crack in the layers with compressive stresses and studied this influence on the Weibull distribution. The measurement uncertainty apparently decreases the Weibull modulus due to a widening of the standard deviation of the measurements. An analytical approach cannot deal with all these complications. Further developments of this method including other types of faults in the material will enable the forecast and crude recognition of fault types just on the basis of a sufficient number of strength measurements, rather than the time-consuming fractographic analysis method that is used at present.

We investigated theoretically the effective uniaxial bending strength of full or hollow cylindrical multilayered composites. We also considered the residual stresses that can arise in individual layers for different reasons, such as the different temperature expansion coefficient in different layers. The findings will be applied to 4-point measurements of the uniaxial bending strength of sintered cylindrical Al₂O₃ composites and hollow monolithic cylindrical green bodies, from which all the binder or just a part of it was expelled during different drying times.

In 2008 our cooperation with other research organizations and industrial partners continued to be very extensive. Work continued in the field of new composites on the basis of the compound B/C infiltrated with Al₄, in cooperation with the K-9 department and the private researcher V. Kevorkjan. The possibilities of the fabrication of these materials without increased pressure, with the use of reaction infiltration of melted metal into the ceramic preform were investigated. Our results revealed the possibility of the preparation of such composites and also their good mechanical properties, which indicates their potential use in anti-ballistic protection.

We continued our work on the preparation of ceramic composites with a double matrix and carbon fibres. Composites of this kind are used in the production of brake pads in the company MS Production from Bled, Slovenia. We investigated predominantly the influence of the preparation process and the conditions of thermal treatment on the microstructure, mechanical and friction properties. We studied the wear mechanisms of sintered metal brake pads, which are used in combination with composite ceramic brake discs. We found that a thin friction layer made of a mixture of metal oxides is formed on the surface of brake pads during braking, which in turn influences the coefficient of friction as well as the wear of the pad. We made tests on some other commercial products of the companies MS Production and Sinter with the aim of improving and optimizing the serial production. The investigations included the phase analysis of materials, microstructure analyses and measurements of the mechanical properties.

In the frame of the project “Ageing of dental zirconia (Y-TZP) ceramics under simulated clinical conditions” we cooperate with the company Interdent d.o.o. from Celje. In choosing materials we consider two criteria: sensitivity to mechanical damage in standard machining procedures of fixed-prosthetic constructions, i.e., grinding with diamond drills and sand-blasting, and the durability of sintered Y-TZP ceramics in an aqueous environment. We used two commercial powders of ZrO₂ with equal compositions, but different specific areas, to make green bodies, followed by pre-sintering at various temperatures. In this way, we influenced the strength and machining ability of semi-products.

In the frame of the applicative project “The influence of fillers on the mechanical properties of fibre-cement composites”, we continued to study the possibility of substituting amorphous silica by meta-kaolinite. We applied...
various methods for the preparation of fibre-cement (FC) composites as well as various conditions. We confirmed our finding from previous research year that the substitution described does not degrade the mechanical properties. Next, we investigated the influence of different additives, such as polyacrylates, polyacrylates modified with silanes, colloidal SiO₂, boron silicate and PRIMAL E-330 EF, between the layers in the fabrication of FC composites, on their mechanical properties, in particular the bending strength. We found that the additives do not influence significantly the mechanical properties. This is an important conclusion since we subsequently began with a study of the rheological properties of cement pastes, in order to determine the conditions that make possible the evaluation of the rheological properties of the composite that still allow plastic shaping of the flat FC sheet into a corrugated one. In 2008 an industrial test was performed in Esal where polyacrylate additives were injected between the layers of the FC composite during fabrication, with the aim of improving the mechanical and other properties. We found that the additives did not improve significantly the mechanical properties; however, they strongly decrease the leakage of water, and this is an important parameter for composites used for roofing sheets.

In the frame of the development of a ceramic glow plug for diesel engines, in cooperation with the company Hidria AET d.o.o. from Tolmin, Slovenia, in 2008 we studied the preparation and properties of ceramic composites on the basis of silicon nitride with dispersed particles of the conducting phase. Conducting TiO₂ or ZrN particles were synthesized by the gel-precipitation of hydroxides and a subsequent thermal treatment. After calcination at 600°C in air TiO₂ and ZrO₂ are formed, which react with Si₃N₄ at elevated temperatures in nitrogen to form TiN (at 1250°C) and ZrN (at 1600°C). In the fabrication process of electrically conducting Si₃N₄/TiN and Si₃N₄/ZrN composites we added an appropriate amount of oxide additives (Y₂O₃, Al₂O₃) to coated Si₃N₄ powder and then we sintered such mixtures at 1850°C, 2h in N₂. In both cases we achieved a high density and a high strength of the composites. However, we could not obtain the appropriate electrical conductivity, because of the intense growth of TiN and ZrN particles during sintering.

In cooperation with the same partner, within the project “Two-component low pressure injection moulding (LPIM) of ceramic heaters” we focused on the development of the two-component injection of paraffin suspensions prepared from mixtures of silicon nitride (Si₃N₄) and molybdenum disilicide (MoSi₂). For this purpose we optimized the rheological properties of paraffin suspensions, with the aim of preparing suspensions with the highest possible fraction of ceramic powders, while keeping the appropriate viscosity. We studied the influence of the suspension’s composition on the contraction of the bodies after the thermal removal of the binder, as well as the conditions which still allow for the successful preparation of two-component green bodies. We found that both suspensions must have a similar contraction, which depends on the solids loading and the size of the particles used for the preparation of the suspension. The appropriate rheological properties were achieved by optimising the quantity of the surface agent octadecyl amine. We chose appropriate conditions for shaping the green bodies, which were subsequently thermally treated to remove the binder and finally sintered to a high density. The final result was the fabrication of a working heater for the glow plug by LPIM method.

In the frame of our cooperation with the University of Maribor in the project “Patterns, structural self-organization and magnetoelectrics in mixtures of nano-particles and liquid crystals” we performed preliminary theoretical investigations of the interaction between nematic molecules and ferromagnetic particles in a mixture of liquid crystal and ferromagnetic powder. To help in the understanding of this complex system we first studied in detail the three-dimensional Heisenberg spin model as the basis for investigating the behaviour of a nematic liquid crystal with impurities in a flat cell. We were interested mostly in the influence of impurity concentration, ordering of the external field and the preparation history (i.e., the memory effect) on system ordering, e.g., whether there is long-range order or not. This question is still unresolved in basic science. After the successful testing of the Heisenberg model on the liquid crystal it was generalized to the system of liquid crystal and magnetic particles.

Within our bilateral cooperation with the University Chubu, near Nagoya in Japan, we investigated the possibility of improving the wear resistance of titanium alloys for bone implants by the method of direct nitriding in ammonium. Preliminary results indicate that it is possible to increase the surface hardness significantly in this way, while the adhesion of the layer with the substrate still has to be improved.
Some outstanding publications in the past three years


Patents granted

1. Process for Applying Adhesion Coating to a Substrate
Tomaz Kosmač, Kristoffer Krnel, Andrež Kocjan, Peter Jevnikar
SI Patent No. 22527

Awards and appointments


INTERNATIONAL PROJECTS

1. Novel Technology for High-PERformance pieoelectric Actuators
HIPER-Act
CP-IP 212394, FP7-NMP-2007-LARGE-1
7. FP
EC, Anders Bjerrum, Claus Bo Andersen, Noliac A/S, Kristgaard, Denmark
Prof. Tomaz Kosmač, Prof. Marija Kosec
2. Monolithic above IC Ultra High Value Capacitors for Mobile and Wireless Communication Systems
CAMELIA
6. FP, NMP-3-CT-2006-033303
EC, Cindhira Horm, Tyndall National Institute, Lee Maltings, Cork; University College Cork, National University of Ireland, College Road, Cork, Ireland
Prof. Tomaz Kosmač, Asst. Prof. Barbara Malic
3. Development of Wear Resistant Coatings based on Complex Metallic Alloys for Functional Applications
applicoMA
7. FP, 214407
EC, Susanne Fuchs, Austrian Research Centers GmbH - ABC, Functional Materials, Seibersdorf, Austria
Dr. Kristoffer Krnel, Dr. Miha Čekada, Prof. Janez Dolinšek, Dr. Srečo D. Škapin
4. Formation of Modified Oxide Layers to Improve the Wear Resistance of Titanium-based Alloys for Artificial Joint Prostheses
Bi-JP/08-10-003
Prof. Tadashi Kokubo, Chubu University, Department of Biomedical Sciences, College of Life and Health Sciences, Aichi, Japan
Prof. Tomaz Kosmač

R & D GRANTS AND CONTRACTS

1. Patterns, structural self-assembling and magnetoelectrics in mixtures of nano-particles and liquid crystals
Prof. Samo Krah, Asst. Prof. Milan Ambrožič
2. Ageing of dental zirconia (Y-TZP) ceramics under simulated clinical conditions
Prof. Tomaz Kosmač
3. Development of multifunctional B4C-Al and B4CMg composite materials for new products
Prof. Tomaz Kosmač
4. Synthesis of magnetic nanoparticles for the microwave absorbers and magnetic fluids
Prof. Darko Makovec
5. Influence of the fillers on mechanical properties of fibre-cement composites
Dr. Kristoffer Krnel

RESEARCH PROGRAMS

1. Engineering and bio-ceramics
Prof. Tomaz Kosmač
2. Advanced inorganic magnetic and semiconducting materials
Prof. Mihael Drofenik, Natalija Petkovic Habe
NEW CONTRACTS

1. Ageing of dental zirconia (YTZP) ceramics under simulated clinical conditions
   INTERIDENT, d.o.o., Celje
   Prof. Tomaz Kosmač

2. Research & development work in the frame of the project "CarCIM"
   HIDRIA JET, d.o.o., Tolmin
   Prof. Tomaz Kosmač

3. Co-financing of the project "Influence of the fillers on mechanical properties of fibre-
   cement composites"
   ESLK, d.o.o., Anthovo
   Dr. Kristoffer Krol

VISITORS FROM ABROAD

1. Dr. Shen Zhijian, Stockholm University, Stockholm, Sweden, 19 Mar. 2008
2. Dr. Ferhat Kara, Anadolu University, Faculty of Engineering and Architecture,
   Division of Materials Science and Engineering, Eskisehir, Turkey, 28 Apr. 2008
3. Prof. Hiroshi Takatama, Dr. Takashi Kizuki, Chubu University, College of Life and Health Sciences, Department of Biomedical Sciences, Kasugai, Japan, 20–25 Aug. 2008
4. Dr. Robert Danzer, Dr. Peter Sapančič, Dr. Raul Bermejo, Dr. Tanja Lube, Leoben University, Leoben, Austria, 18–19 Sept. 2008

STAFF

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2. Dr. Kristoffer Krol

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4. Dr. Aleš Dakskobler
5. Dr. Irena Pribošič
6. Dr. Žiga Završek
7. Dr. Jernej Šuper

Technical officers
8. Dr. Sabina Beranič, B. Sc.
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BIBLIOGRAPHY

ORIGINAL ARTICLES


PUBLISHED CONFERENCE PAPERS

Invited Papers
1. Tomaz Kosmač, Aleš Dakskobler, “Tetragonal zirconia (Y–TZP) ceramics for dental applications: criteria for materials selection”, In:

Regular papers

Textbooks and Lecture Notes

Theses
Ph. D. Theses
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 includes the experimental and theoretical investigations of structures, the 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.

One-dimensional Co-Pt-based nanostructures were prepared via template-assisted electro-deposition into high-aspect-ratio track-etched polycarbonate membranes. Tubular nanostructures with a diameter of 200 nm and lengths of 1000–8000 nm were obtained directly, without any pore-wall functionalization, as was previously reported to be necessary in the literature. The mechanism of direct tube formation was attributed to the appropriate relative rates of the deposition and the diffusion of the Co<sup>2+</sup> and Pt<sup>2+</sup> ions into partially Au-covered pores. We found that diffusion is the rate-determining step of the electro-deposition process; therefore, the stoichiometry and the related properties can be controlled via the electrolyte composition. The highest obtained coercivity was $H_C \approx 670$ kA/m, which makes these materials interesting for advanced electronic and magnetic devices, as media for high-density magnetic recording or as a potential drug delivery agent. Furthermore, their large surface-to-volume ratio and Pt content would make them interesting for catalytically driven processes. Another ferromagnetic system, Fe-Pd, was successfully synthesized via the electro-deposition method and thin films as well as one-dimensional nanostructures were obtained. The reaction regime was found to be kinetically controlled; therefore, the stoichiometry and the related properties can be influenced via the applied voltage. This knowledge is extremely important since the Fe<sub>70</sub>Pd<sub>30</sub> composition gives high coercivities, while the Fe<sub>50</sub>Pd<sub>50</sub> composition is a magnetic shape-memory alloy capable of producing strains of 6-10 % in moderate magnetic fields.

The combination of scanning electron microscopy (SEM, FEGSEM) and atomic force microscopy (AFM) was used to analyze the grain size, the distribution and the morphology of the nanoparticles in submicrometre thin films that were obtained by the electro-deposition and laser-ablation methods. An improved method of quantitative electron-probe microanalysis with wavelength-dispersive x-ray spectroscopy (WDXS) was applied for the analysis of the chemical composition of thin nanostructured ferromagnetic Co-Pt films. The results of the microanalysis allowed us to study and define the influence of the process parameters of electro-deposition on the thickness and the composition of Co-Pt films as well as to correlate the composition with the magnetic properties of the material.

One-dimensional Co-Pt-based fibril or tubular nanostructures were prepared via template-assisted electro-deposition with the highest coercivity $H_C = 670$ kA/m. These materials can be used in advanced electronic and magnetic devices, and as media for high-density magnetic recording.

Figure 1: Co-Pt-based tubular structures synthesized with direct electroplating (left). Magnetic properties of the as-deposited Co-Pt-based nanotubes and the heat treated Co-Pt-based nanotubes (right).
We continued our work on quasicrystals as a promising material for hydrogen storage by performing melt-spinning experiments on Ti-Zr-Ni-Cu alloys with various compositions: Ti50Zr40Ni10, Ti50Zr40Ni10Cu5 (x=3.5), Ti50Zr40Ni10Cu5 (x=3.5) and Ti50Zr40Ni10Cu5 (x=3.5). We were mainly interested in the formation of the icosahedral quasicrystalline phase (the i-phase). From previous studies we know that the optimal cooling rate for i-phase formation is at a wheel speed of 22 m/s. Using this technique we prepared a series of samples under identical conditions, varying only the composition. XRD results showed that the i-phase is formed across a relatively wide range of compositions. Also, with increasing content of titanium from the ideal value (40 at.%) the content of crystalline phases increases (the hexagonal C14 Laves phase and the FCC cubic (Ti, Zr) solid solution). Doping with copper, in general, does not contribute to a higher i-phase content. With a higher titanium-to-zirconium ratio the quasicrystalline lattice constant $a_0$ is linearly decreasing. A new composition of i-phase was found, i.e., Ti55Zr24Ni18, which to the best of our knowledge has not been reported previously. This material absorbed the largest amount of hydrogen of all our samples, up to 2.4 mass percent. Using XPS analysis we determined that the thickness of the oxide layer containing TiO2 and ZrO2 in the surface of melt-spun ribbons was 5 nm. Using mass spectrometry we analysed the desorbed hydrogen and discovered that the bonding energy of the hydrogen depends only on the structure of the material, and not on the composition, nor on the content of bonded hydrogen.

In the frame of the EU MNT-ERA.Net project “Hydrogen-impermeable nano-material coatings for steels” (Hy-nano-IM) we investigated the possibility of producing hydrogen-impermeable coatings for steels for the long-term storage and transport of gaseous and liquid hydrogen. Initial efforts have been focused on depositing diamond-like carbon (DLC) layers, either directly onto a steel substrate, or in combination with a chromium layer, to improve the adhesive properties. High-resolution transmission electron microscopy has been employed to investigate the layer thickness and the state of the boundaries between the steel, chromium and DLC.

The technologically interesting properties of materials were studied within the framework of the density-functional theory. We focused on calculations of the transport properties in the approximants of quasicrystals and the alloys which exhibit magnetocaloric effect by applying the semi-classical Boltzmann theory and the relaxation-time approximation.

In the field of intermetallic alloys with magnetocaloric properties we continued our research by studying iron substitutions in the matrix phase. We observed very significant differences in terms of the macrostructures, microstructures and magnetic properties. The matrix phase with the Gd(Si,Ge) composition and no iron addition is gradually replaced by the new matrix phase Gd(Si,Ge) when substituted with iron. The iron contributes mainly to the grain-boundary phases that are formed and to a change in the relative amounts of Si and Ge in the matrix phases. The final properties are strongly dependent on the element that is substituted. This also affects the transition temperature of the alloy. The low losses and the broad $\Delta S$ peak suggest that the first-order transition is suppressed when substituting germanium. However, this is not the case when substituting silicon. Here, a sharp peak and large hysteresis losses are present. The TEM study suggest the presence of twins in the Gd,Si,Ge sample and revealed the presence of features not seen previously in the iron-containing sample, such as amorphous regions, dislocations, planar faults and crystallographically related grains.

Nanostructured magnetic-based materials, such as in-situ-nitrogenated Sm-Fe-based magnetic nanospheres prepared by pulsed laser deposition (PLD), were investigated by employing state-of-the-art techniques of TEM. The magnetic response of individual nanospheres was detected and quantified for the first time in this system by applying electron holography. The development and implementation of electron holography is part of the EU project ESTEEM. The electron energy-loss spectroscopy (EELS) technique was implemented to study multilayer coatings based on the Ti/Al/Cr/V-N system. By using spatially resolved EELS we were able to simultaneously detect and quantify the amount of N and the related electronic structure in the investigated phases, enabling us to trace the compositional and structural differences across the interfaces localized over only a few nanometres. In the Zn-Mn-O system the thermal evolution of spinel phases was found to be induced by the Mn(I) to Mn(III) reduction during the long-term storage and transport of gaseous and liquid hydrogen. Initial efforts have been focused on depositing diamond-like carbon (DLC) layers, either directly onto a steel substrate, or in combination with a chromium layer, to improve the adhesive properties. High-resolution transmission electron microscopy has been employed to investigate the layer thickness and the state of the boundaries between the steel, chromium and DLC.

We found a new composition of quasicrystal phase (i-phase), Ti55Zr24Ni18, which has not been reported previously. This material absorbed the largest amount of hydrogen of all our samples, up to 2.4 mass percent.

*Figure 2: Picture of the Fermi surface (visualized with the program Xcrysden) for the majority spin states in the magnetocaloric alloy LaFe13.***

*Figure 3: Above: TEM image of two representative in-situ nitrogenated Sm-Fe-based nanospheres prepared by PLD: one amorphous and the other with a core-shell structure, where the amorphous rim and the crystalline core can be differentiated. Below: EEL spectra confirming that the nitrogen is associated only with the core-shell type of nanospheres.*
process. This phenomenon was successfully experimentally verified by tracing the Mn$^{4+}$/Mn$^{3+}$ ratio of the spinel phases sintered at different temperatures by a detailed fine-structure analysis of the EELS Mn$\text{L}_{2,3}$ ionization edges. We also studied doped anatase nanowires using HRTEM and EDXS. By combining electrical measurements with TEM studies a potential use of nanostructured anatase for Li-based batteries was successfully demonstrated.

Our research work also involves colloidal processing, which enables us to prepare composite materials with improved properties as well as to develop new forming techniques. Based on a comprehensive study of the electrokinetic behaviour of the fine particles and fibres we developed an efficient electric field-assisted technique for the infiltration of thick ceramic fibre-fabrics with ceramic particles and hence to prepare composites SiC$_{f}$/SiC and C$_{f}$/SiC, which are being developed as part of a collaboration within the European Fusion Research Programme and with the French Atomic Energy Agency, CEA. The electrophoretic deposition technique has also been employed for the deposition of a thin bioglass coatings on metallic body implants and, in collaboration with National Institute of Chemistry, Ljubljana, for the assembly of monodispersed SiO$_2$ nanospheres as well as for the separation of the inclusion bodies used as therapeutic agents from the bacteria matrix.

A part of the research within the EU 6FP project MEDDELCOAT has been focused on the synthesis and study of bioactive titania coatings on Ti6Al4V body implants that should, in particular, prevent the diffusion of toxic elements (Al, V) from the alloy into the body. A layer of anatase, up to 1 µm thick, has been successfully synthesized by hydrothermal treatment and proved to beneficially affect the wetting behaviour as well as a the cells' response.

We continued the research and development of new fusion-relevant materials within the European fusion programme Euratom. The first batch of fibre-reinforced composite samples for neutron irradiation has been prepared and in collaboration with the Department for Reactor Physics irradiated in the TRIGA reactor and analyzed for their activation. It has been proved that the activations were lower than those for the other available fusion-relevant materials. Lately, the most attention has been paid to the required increase in thermal conductivity, which we have tried to increase by the incorporation of tungsten or carbon nanotubes.

The nucleation and crystallization of various nanomaterials were investigated using analytical electron microscopy. In collaboration with different research groups from Slovenia, Croatia, Greece and Portugal we studied the evolution of particles in NiO, SiO$_2$, InN, CeO$_2$, and TiO$_2$. Using high-resolution electron microscopy and Z-contrast imaging we determined the quantity, morphology and the position of the nanoparticles of Pt and Au on matrix CeO$_2$-TiO$_2$, used as a material for catalysis. We also studied the development and the structure of ZnO nanoparticles and the formation of mesoporosity in SiO$_2$ gels. Together with our industrial partner Cinkarna Celje we investigated the chemical composition and the structure of nanometre-sized Al$_2$O$_3$-SiO$_2$ coatings on the top of TiO$_2$ rutile particles, which improve the optical and chemical properties of the pigment. We found that at the coating–rutile particle interface there is a very thin layer (a few atomic layers thick) of alumina. Based on these results the technological procedure during the fabrication of the rutile pigment was optimized.

In the field of the nanostructural engineering of semiconducting materials we have shown in several polycrystalline materials that special boundaries are responsible for anisotropic and exaggerated grain growth. The most common types of special boundaries in semiconducting materials are the so-called inversion boundaries (IBs), which form with the addition of

The magnetic response of individual nanospheres of Sm-Fe-Ta-N was detected and quantified for the first time by applying electron holography. The development and implementation of electron holography is part of the EU project ESTEEM.
Composite materials with improved properties were prepared by using colloidal processing. In the frame of the European fusion research programme we developed an efficient electric-field-assisted technique for the infiltration of thick ceramic fibre-fabrics with ceramic particles and hence to prepare composites of SiC/SiC and C/SiC.

Parameters for the reproducible synthesis of either ZnO tetrapods or arrays of ZnO nanorods were determined. Also, the synthesis of ZnO nanopowder from water solutions with different concentrations of Zn-acetate using a combination of spray-drying and the decomposition of Zn-acetate powder to ZnO, either by conventional or microwave calcinations, was studied. The advantages of microwave calcinations resulted in the preparation of uniform ZnO powder with the size of the spherical particles being about 80 nm and the crystallite size being about 20 nm. Based on studies of ZnO ceramics doped with only up to several 1000 ppm of Bi$_2$O$_3$ and Sb$_2$O$_3$ we determined the conditions for tailoring the microstructure using the IB-induced grain-growth mechanism. We prepared a fine-grained and, like the first one, also a coarse-grained ZnO ceramic doped with Bi$_2$O$_3$ and Sb$_2$O$_3$, with an average grain size much larger than in pure ZnO, sintered under the same conditions. Consequently, we were able to prepare low-doped varistor ceramics with the addition of only about 3 wt.% of varistor dopants (typical additions are about 10 wt.%) with the grain size in the range from 22 µm to 7 µm, the breakdown voltage from 100 V/mm to 330 V/mm and the nonlinearity between 30 and 50. The synthesis of conductive polymer composites was also studied. Using thermal curing of the mixtures from a polyethylene powder (matrix) and varistor powder (filler), varistor-type polymer composites with current-voltage nonlinearity expressed in the nonlinear coefficient ranging from 9 to 17, depending on the amount of filler and the curing temperature, were prepared. Also, hollow varistors with lengths from 30 to 60 mm, outer diameter 10 to 25 mm and wall thickness from 2 to 4 mm, were successfully prepared using slip-casting technology of a varistor water suspension into a gypsum mould.

Perovskite BaTiO$_3$, nanorods and SrTiO$_3$, nanotubes were synthesized by sol-gel electrophoretic deposition into track-etched hydrophilic polycarbonate (PC) membranes and/or anodic aluminium oxide (AAO) membranes. The stability of the sols and the optimization of the parameters for the electro-deposition was a prerequisite for successful synthesis. The obtained nanorods and nanotubes were polycrystalline in nature with diameters ranging from 100 to 250 nm and grain sizes from 25 to 50 nm. Electron diffraction studies and high-resolution TEM revealed that the BaTiO$_3$ nanorods consist of all three polymorph structures (cubic, tetragonal and hexagonal), while the SrTiO$_3$ nanotubes possess a cubic structure. Hydrothermal synthesis was used to synthesize BiFeO$_3$, goethite and hematite in various nanosized morphologies. Multiferroic BiFeO$_3$, and hematite were obtained in the shape of isotropic nanocubic crystals, while goethite was prepared as nanorods. The aspect ratio of the goethite nanorods was controlled by varying the concentration of Bi$^{3+}$ ions in the reaction. The observed stacking faults in the hematite may indicate potential sites for additional Bi$^{3+}$ incorporation, suggesting a possible mechanism for the synthesis of nanosized BiFeO$_3$ in anisotropic morphologies.

One of the important research areas of the group is the implementation and development of various electron microscopy analytical techniques within the existing EU project ESTEEM, such as electron energy-loss spectroscopy (EELS), high-resolution scanning transmission electron microscopy (STEM, HAADF-STEM), electron holography and the mechanical preparation of TEM samples. In atomically resolved HAADF-STEM images we were among the first to show, on the model ceramic materials CaTiO$_3$, SrTiO$_3$, and BaTiO$_3$, that the local lattice distortions, apart from chemical composition,
significantly influence experimentally determined intensities of single-atom columns. Furthermore, we showed that realistic values of the Debye-Waller factor for atoms comprising the investigated structure (interface, planar fault, etc.) are needed for an exact quantitative interpretation of the experimental HAADF-STEM intensities. Only then can the intensities of atom columns in the simulated images correspond to true values and can they be successfully compared with the intensities in simulated images. The research group is additionally heavily involved in managing the Center for Electron Microscopy within the frame of the national infrastructure Center for Microstructural and Surface Analysis.

The implementation of various electron microscopy analytical techniques and the possibility for researchers to access a research infrastructure for electron microscopy is of utmost importance for numerous research institutions, industrial partners, as well as for graduate and post-graduate education.

**The most important technological achievements in the past year**


**Patent granted**

1. Tool for measuring magnetic properties at high temperatures

   Paul J. McGuiness, Gregor Geršak, Spomenka Kobe
   Patent US7368906 B2

**Awards and Appointments**

Organization of conferences, congresses and meetings

2. Hot Nano Topics 2008 incorporating SLONANO2007; 3 overlapping workshops on current hot subjects in nanoscience, Portorož, Slovenia, 23–30 May 2008 (co-organisation)
3. 1st International Conference on Materials and Technology sponsored by FEMS and IUVSTA, Portorož, Slovenia, 13–15 Oct. 2008 (co-organisation)
4. European School in Materials Science: Properties and Application of Complex Metallic Alloys, Ljubljana, Slovenia, 26–31 May 2007 (co-organisation)
5. 20th Workshop on rare Earth Permanent Magnets and Applications, REPM ’08, Heraklion, Crete, Greece, 8–10 Sept. 2008 (member of International Scientific Board)

INTERNATIONAL PROJECTS

1. Development of Composites with Advanced Alternative Manufacturing Concepts: Vacuum slip infiltration of SiC/SiC – 4.1.2. FU
2. Development of functional material for insulating flow channel inserts: Ceramic Processing of SiC Composites for Functional Application – 4.1.1. FU
3. fUseX: Fusion Expo Support Action – EU-FU
4. Multifunctional Bioresorbable Biocompatible coatings with Biofilm inhibition and optimal implant fixation – Medical FUECC
5. Zno-nanostructures for novel applications – ENSTIM
6. CMA
7. Complex Metallic Alloys
8. Hydrogen Impermeable Nano-material Coatings for Steels
9. WomenINNANO
10. Low-doped ZnO-based ceramics for energy varistors
11. Development of Ceramic Matrix Composite for Advanced Nuclear Applications, with an SiC Continuous Fiber Reinforcement and a Nanostructured Carbide Matrix, Processes by the Electrophoretic Infiltration
12. Influence of Quantum Effects on Vibrational Properties of Nano-crystalline Silicon
13. Environmental Hydrogen-based Recycling of Nd-Fr-B magnets
14. Structural and Chemical Characterization of Titanate-based Nanorods and Nanotubes
15. Synthesis and characterization of Nanostructured Catalytic Materials
17. Texturing and Characterisation of ZrO-based Ceramics
18. ZnO/Nanostructures for Novel Applications
19. Development of fusion relevant ceramic matrix composites
20. R & D GRANTS AND CONTRACTS

1. Fabrication of novel thin films by pulser-laser ablation with in situ ICP-MS analysis of target plumes for deposition control
2. Nanostructural engineering of semiconducting materials
3. A development of low-activation material for the first wall in fusion reactor
4. The influence of magnetic structure of the materials on the magnetocaloric effect
5. Ecotechnological 1D nanomaterials: synthesis and characterisation
6. Texturing and characterisation of Zno-based ceramics
7. Complex Metallic Alloys
8. Hydrogen Impermeable Nano-material Coatings for Steels
9. WomenINNANO
10. Low-doped ZnO-based ceramics for energy varistors
VISITORS FROM ABROAD

2. Dr. Davide Gracina, Instituto Radijs Bošković, Zagreb, Croatia, 30 Jan. 2008
5. Prof. Aldo Boccaccini, Imperial College London, London, United Kingdom, 24 May 2008
10. Dr Dan Gazit, Nogev Nuclear Research Center, Haifa, Israel, 10 Oct. 2008
11. Dr. Davide Gracina, Dr Andreja Gajovic, Institut Radijs Bošković, Zagreb, Croatia, 20 Oct. 2008
12. Dr Helder Gomes, Faculdade de Engenharia da Universidade do Porto, Departamento de Engenharia Química, Porto, Portugal, 12-19 Oct 2008
14. Dr Adam Silva, Faculdade de Engenharia da Universidade do Porto, Departamento de Engenharia Química, Porto, Portugal, 12-19 Oct 2008
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18. Dr Helder Gomes, Faculdade de Engenharia da Universidade do Porto, Departamento de Engenharia Química, Porto, Portugal, 12-19 Oct 2008
19. Decheng Meng, Imperial College London, United Kingdom, 5–14 Dec. 2008
20. Dr. Andreja Gajovic, Institut Radijs Bošković, Zagreb, Croatia, 1–3 Dec. 2008
21. Iomai Özgr oxid Anadolu University, Engineering, Eskihel, Turkey, 27 Nov. to 16 Dec. 2008

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BIBLIOGRAPHY

ORIGINAL ARTICLES


The research of the Department for Materials Synthesis is mainly related to the synthesis of different advanced materials, especially magnetic and semiconducting oxides. Special attention is given to nanostructured materials, such as ferrofluids, functionalized nanoparticles for use in biomedicine, multifunctional nanocomposites, and magnetic coatings for use in the microwave frequency range.

In 2008 our investigations were directed to three important materials, i.e., materials containing magnetic nanoparticles, microwave magnetic ceramics and ceramic coatings for use in the area of telecommunications, and ferroelectric materials with a high Curie temperature for the preparation of high-temperature thermistors.

The research on magnetic nanoparticles mainly focused on their functionalization. For biomedical applications, the magnetic nanoparticles should be functionalized with a surface layer of organic molecules, which enables the selective bonding of different bioactive molecules to their surfaces. At the same time, the functionalization layer allows the nanoparticles to be compatible with physiological fluids and prevents their agglomeration. The bonding of different organosilane molecules directly onto the nanoparticles’ surfaces or through a surface layer of silica was systematically studied. The functionalization layer was then used to further bind different molecules that are needed in biomedical applications. In cooperation with the National Institute of Chemistry, University of Ljubljana, we have studied the coordination binding of histidine-rich protein and its controlled release from nanoparticles. In cooperation with the Faculty of Pharmacy, University of Ljubljana, we studied the targeting of nanoparticles into cancer cells using the bonding of monoclonal antibodies.

A significant part of our research has been devoted to the synthesis of nanoparticles. In cooperation with the Faculty of Chemistry and Chemical Engineering, University of Maribor and with the support of the co-founder Nanotesla Institute we were the first in the world to synthesize superparamagnetic nanoparticles of Ba-hexaferrite (BaFe$_{12}$O$_{19}$) using the hydrothermal method. Normally, high temperatures are needed to form hexaferrite, resulting in relatively large particles. By understanding the involved mechanisms, especially the formation of iron hydroxo complexes at increased pH, we managed to decrease the temperature of hexaferrite formation during hydrothermal synthesis, and consequently to decrease the nanoparticle size to the superparamagnetic range. The structural and magnetic properties of Ba-hexaferrite nanoparticles have been extensively studied. We also prepared stable colloidal suspensions – ferrofluids, based on Ba-hexaferrite.

In cooperation with the Faculty of Electrical Engineering and Computer Science, University of Maribor, we developed a system for measurements of ferrofluid energy dissipation under high-frequency magnetic fields. The apparatus will be used in the testing of the ferrofluids for magnetic hyperthermia.

A new method for the synthesis of particles of cubic magnetite spinel with an anisotropic plate-like shape and of spinel-hexaferrite intergrowth nanocomposite particles has been developed. The method is based on the hydrothermal decomposition of pre-synthesized Ba-hexaferrite (BaFe$_{12}$O$_{19}$) particles in the presence of NaHCO$_3$ and a hydrazine reducing agent. By the preferential reaction of Ba from the layered, hexagonal structure of BaFe$_{12}$O$_{19}$ with CO$_3^{2-}$, the hexaferrite crystals disintegrate to thin platelets containing only the cubic spinel magnetite. When the disintegration is only partial, nanocomposite particles containing an intergrowth of spinel and hexaferrite are obtained.

Synthesized superparamagnetic nanoparticles were dispersed in different matrices and thus superparamagnetic nanocomposites were prepared. Here, it is of crucial importance to disperse a high content of nanoparticles to ensure high magnetizations, without their agglomeration, which would influence their superparamagnetic properties. The functionalization of magnetic nanoparticles by binding different silane molecules to their surfaces, directly or through a thin silica layer, was studied.

Hard-magnetic particles were successfully stabilized in polar media and hard-magnetic ceramic films were prepared by electrophoretic deposition.

Figure 1: High-resolution electron micrograph of a superparamagnetic Ba-hexaferrite nanoparticle synthesized using the hydrothermal method.
The most important technological achievements in the past year


A method for the synthesis of superparamagnetic photocatalytic nanocomposite nanoparticles for the decomposition of organic pollutants in water was developed.

We were the first to successfully stabilize hard-magnetic nanoparticles in water and we prepared hard-magnetic ceramic films by electrophoretic deposition.
Patent granted

1. Procedure of preparation of magnetic nanocomposites with high content of nanoparticles dispersed in polymer matrix
   Darko Makovec, Sašo Gyergyek, Miroslav Huskić, Miha Drofenik
   SI Patent No. 22539.

INTERNATIONAL PROJECTS

1. New Generation Microwave Ferrite Thick Films for Absorbers
   ABSOFILM
   MATERA ERA-NET_5211-07-000176
   Technical Research Centre of Finland, Finland
   Asst. Prof. Darja Lajšak
2. Integrated Miniature Circulators for Microwave Modules
   IMICIMO
   EU/REKA
   Chelton Telecom & Microwave FRANCE, France
   Asst. Prof. Darja Lajšak
3. Non Conductive Magnetic Materials for Microwave Absorbers
   II/FT/05-08-007
   Dr. Ezio Ferrara, Instituto Elettrotecnico Nazionale Galileo Ferraris Torino, Torino, Italy
   Asst. Prof. Darja Lajšak
4. Co-fired Ferrite-ceramic Systems for Integrated Miniature Circulators applied in Microwave Modules
   Egységtekert férter-kéramia rendszerek mikrohullámú modulokban használt korszerű, integrált miniatúr cirkulátorokhoz
   BH/EU/08-09-0988
   Prof. Anna Satanišvili, Tüti Ferrit Development and Manufacturing Ltd., Budapest, Hungary
   Asst. Prof. Darja Lajšak

R & D GRANTS AND CONTRACTS

1. Patterns, structural self-organization and magneto-electrics in mixtures of nanoparticles and liquid crystals
   Prof. Samo Kralj, Prof. Mihael Drofenik

VISITORS FROM ABROAD

3. Marion Begard, RWTH, Aachen University, Aachen, Germany, 26–27 Jun. 2008

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Note:
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BIBLIOGRAPHY

ORIGINAL ARTICLES


PUBLISHED CONFERENCE PAPERS

Invited Papers


Regular papers


Research in the Department for Advanced Materials is focused mainly on synthesizing and characterizing new inorganic materials. The emphasis is on investigations of high-temperature phase equilibria, the identification of new compounds, and determining their crystal structures and properties. Investigations relating to ceramics with special electrical and magnetic properties and super-hard materials and glasses are of primary importance. In recent years, nanomaterials and nanotechnologies have become an important part of the department’s activities.

In 2008 the investigations of the Department for Advanced Materials were directed to two main important fields, i.e., the research and investigation of materials exhibiting special electrical properties and the research of nanostructured materials and the processes for their preparation.

In the scope of the investigations of materials exhibiting special electrical properties we investigated tunable materials, microwave dielectrics and materials compatible with low-temperature co-fired ceramic (LTCC) technology.

The investigations of voltage-tunable materials by the scientific community have focused mainly on paraelectric modifications near ferroelectric transitions of the displacive type, in particular on (Ba_{1-x}Sr_{x})TiO_3-based compounds. However, their high losses, dielectric constant and the temperature dependence of the dielectric constant limit their widespread use, leading us to search for novel materials. We focused our investigations of tunable materials on ferroelectrics of the relaxor type, in particular on Na_{0.5}Bi_{0.5}TiO_3. The temperatures of the Na_{0.5}Bi_{0.5}TiO_3 phase transitions and thus the intensities of the dielectric relaxations were modified by the addition of various incipient ferroelectrics, such as SrTiO_3, KTaO_3 and NaTaO_3. We observed that samples with the highest tunability also exhibit the highest dielectric relaxations as well as having a morphotropic phase composition. However, these samples also show increased dielectric losses. Improved figures of merit were obtained for samples with increased additive concentrations and paraelectric polar order. We determined that this improvement relates to the low-temperature dielectric relaxations and to the dynamics of nanosized polar regions. In addition, it might be expressed by the exceptionally high nonlinear coefficients β.

In the scope of tunable materials we investigated the mechanical-stress tunability of Na_{0.5}Bi_{0.5}TiO_3–KTaO_3 and Na_{0.5}Bi_{0.5}TiO_3–K_{0.5}Bi_{0.5}TiO_3 solid solutions. These solid solutions have potential applications in pressure sensing, due to their stress-dependent dielectric properties. Therefore, the effect of axial pressure on the permittivity of these materials was investigated. The responses of the different compositions were very different, which is connected with the materials’ structural and electrical properties. According to the obtained results, the most interesting materials are:

- Investigations of voltage-tunable and mechanical-stress-tunable materials based on Na_{0.5}Bi_{0.5}TiO_3 and Na_{0.5}Bi_{0.5}TiO_3–KTaO_3, Na_{0.5}Bi_{0.5}TiO_3–K_{0.5}Bi_{0.5}TiO_3, respectively.
- Investigations of microwave dielectrics based on complex perovskites (Ba_{3}CoNb_{2}O_{8}), hexagonal perovskites (Ba_{3}Nb_{2}O_{8}), CaLa_{4}Ti_{5}O_{17}, SrLa_{4}Ti_{5}O_{17}, Mg_{3}B_{2}O_{6}, scheelites (BaWO_{4}, CaWO_{4}, NaLa_{2}WO_{4}) and feldspars (KxBa_{2}Ga_{4}Ge_{2+x}O_{8}).
- Synthesis and characterization of CaTiO_{3} and Na_{0.5}Bi_{0.5}TiO_{3} low-dimensional nanostructures.
- In-situ synthesis of ZnS and Mn^{2+}-doped ZnS nanocrystallites in a polymer matrix.
- Investigations of hard materials based on Ti_{3}Al, TiAl and TiAl_{3} with additions of TiB_{2}, TiC and B_{4}C.

![Figure 1: The coherent intergrowth of hexagonal-perovskite polytypes and the cubic perovskite Ba_{3}CoNb_{2}O_{8} triggered by Co-deficiency.](image-url)
are those which exhibit relaxor properties. In these materials, a high stress dependence of the permittivity and reversibility with changing stress were observed.

Special emphasis was also given to the solid-state synthesis of the Na,Bi,TiO,

KTaO,

and Na,Bi,TiO,

K,Bi,TiO,

solid solutions. Our investigations showed that during the synthesis of K,Bi,TiO,

ceramics the potassium and bismuth components volatize, resulting in the formation of secondary phases, which were identified using X-ray powder diffraction. The sinterability of the material is low and at elevated temperatures a thermal decomposition of the matrix phase occurs. Scanning electron microscopy with wavelength-dispersive spectroscopy revealed that the matrix phase is non-stoichiometric; it is potassium deficient and contains an excess of bismuth. The secondary phase, i.e., potassium polyanitate, also forms during the synthesis of other compounds that contain potassium and bismuth oxides, e.g., the Na,Bi,TiO,

KTaO,

and Na,Bi,TiO,

K,Bi,TiO,

solid solutions. Therefore, the choice of the firing temperatures is important if we wish to obtain dense ceramics with a low fraction of secondary phases.

We investigated the piezoelectric properties of (Na,K)0.5Bi0.5TiO solid solutions. These materials are good candidates to replace lead-based piezoelectric materials, which are toxic for humans and the environment. As we know from previous studies, some solid solutions with the complex perovskite structure reach a morphotropic phase boundary (MPB) at a certain ratio of different a-site cations. This boundary region is important because of the higher remanent polarization, and therefore enhanced electromechanical properties for a material are possible at room temperature. As an example of such a ceramic material with more than one phase we chose the (Na,K)0.5Bi,TiO solid solution. It is known that pure Na,Bi,TiO is rhombohedral, whereas pure K,Bi,TiO is tetragonal. We found that there is a morphotropic phase, with the coexistence of the rhombohedral and tetragonal structures, in the region between 17 and 25 mol percent of potassium. The dielectric, ferroelectric, and piezoelectric properties were measured for different compositions at and near the MPB. The investigated piezoceramic material has a high dielectric constant and a high transition temperature (near 300°C), a relatively high remanent polarization, and a relatively high piezoelectric constant (up to 134 C/N).

In the field of microwave dielectrics we investigated several materials, such as complex perovskites (Ba,Co,Nb,O), hexagonal perovskites (Ba,Nb,O), CaLa,Ti,O, and SrLa,Ti,O. Within the scope of the research of microwave dielectrics we found that Co-deficiency leads to an increase in the Q-value of Ba,Co,Nb,O complex perovskite ceramics. Apart from exhibiting faster B-site cation ordering kinetics the Co off-stoichiometry causes the formation of hexagonal-perovskite polytypes that are coherently intergrown with a 1:2 ordered cubic-perovskite matrix. Such coherent intergrowth can also be understood as a sequence of two succeeding BaO layers arranged in the ABA hexagonal close-packing arrangement in a matrix of an ABC cubic close-packed crystal structure, where the B-site vacancies are ordered between the hexagonally packed layers. The experimental results indicate that an increase in Qxf can be mainly attributed to such a superstructure of ordered cation vacancies. The highest Q-value, Qxf >10000 GHz, was measured in the case of ceramics with the nominal composition Ba,Co,Nb,O, which was found to consist mainly of the intergrown cubic Ba,Co,Nb,O and hexagonal Ba,Nb,O perovskites.

The investigations of Ba,Nb,O were focused on the study of high-temperature polymorphic phase transitions in Ba,Nb,O and on the crystal-structure determination of individual polymorphs with the help of transmission electron microscopy (TEM) and a tilting experiment. We have isolated two stable polymorphs — the low-temperature α-modification and the high-temperature γ-modification — with a phase-transition temperature at 1160°C. The rate of cooling applied to the γ-Ba,Nb,O sample strongly affects the nature of the phase transitions. The rapid cooling (quenching) of the γ-phase sample down to room temperature results in the γ-modification, while slow cooling (1-2°C/min) leads to the formation of a pure α-modification. Cooling the γ-phase at a rate of ~3°C/min results in the formation of the β-modification, which was also observed between 360-585°C after reheating the γ-modification and on the surface of the quenched γ-Ba,Nb,O sample. Using HRFTEM experiments the orthorhombic B-Ba,Nb,O has been proved to be a distorted γ-modification (γ'). All the polymorphs of Ba,Nb,O are structurally closely related, implying that only minor structural perturbations are involved in the polymorphic phase-transformation processes in this system. Collected high-resolution electron images and electron-diffraction patterns along different low-index zone axes allowed us to propose the crystal-structural model of the α-modification. Regarding the stoichiometry of the Ba,Nb,O compound and the discrepancy in the distance between the Ba-O layers along the hexagonal c axis with respect to this distance in the conventional perovskite structures, we proposed a crystal-structural model that is closely related to the 2H-type perovskite structure. The proposed structure comprises alternating Ba,O and oxygen-deficient Ba,O close-packed layers along the c axis. Such a stacking of the close-packed layers creates the infinite chains of octahedrally and trigonally primitively coordinated B-sites cations. Based on the data collected by SAED and HRFTEM we confirmed the validity of the chosen structural model. In addition, based on the tilting experiment we reconstructed the orthorhombic unit...
cell for $\alpha$-Ba$_4$Nb$_2$O$_9$ and measured the unit-cell parameters ($a = 17.81$ Å, $b = 10.25$ Å in $c = 8.5$ Å). We observed that the $\gamma$-Ba$_4$Nb$_2$O$_9$ in air partially decomposes to Ba$_3$Nb$_2$O$_8$ and BaO, which instantly reacts with CO$_2$ to form BaCO$_3$, whereas heating the Ba$_4$Nb$_2$O$_9$ sample in vacuum results the formation of Ba$_3$Nb$_2$O$_8$ due to the increased loss of BaO from the system.

A major part of our investigations of microwave dielectrics was focused on low-permittivity materials ($\varepsilon < 10$), which, in comparison to high-permittivity materials, are more appropriate for high-frequency applications (>10 GHz). During a study of magnesium borates (Mg$_3$B$_2$O$_6$ and MgB$_2$O$_4$) we focused on the synthesis conditions and correlations between the microstructural characteristics and the dielectric properties. We found that the synthesis of single-phase Mg$_3$B$_2$O$_6$ and MgB$_2$O$_4$ required 11 and 14 wt.% excess of B$_2$O$_3$. The highest Qxf values of over 200,000 GHz were measured for Mg$_3$B$_2$O$_6$ ceramics with a grain size of around 1000 microns. In the scope of our study of low-temperature-sinterable, low-permittivity and low-loss materials we investigated materials based on K$_{1-x}$Ba$_x$Ga$_{2-x}$Ge$_x$O$_8$ solid solutions with the paracelsian crystal structure and materials with the scheelite structure. In our study of K$_{1-x}$Ba$_x$Ga$_{2-x}$Ge$_x$O$_8$ the focus was on determining the crystal structure with a Rietveld structural refinement and on determining the structural changes that occurred during the $P_{2_1}/a \rightarrow C2/m$ phase transition. On the basis of the difference in the fundamental features of the topology between the $P2_1/a$ and $C2/m$ phase, we found that the tetrahedral T-O bonds in the crystal structure have to be partially disassociated and reconnected to form the new phase, which led to an extensive thermal effect during the phase transition.

A comparative microstructural and dielectric study of BaWO$_4$, SrWO$_4$, and CaWO$_4$ scheelite ceramics revealed some important differences between these materials in terms of the grain size, their growth and their sensitivity to humid air. Compared to BaWO$_4$, SrWO$_4$, and CaWO$_4$ ceramics were found to be hygroscopic and more incoherently soluble in water. These properties mean SrWO$_4$ ceramics are inappropriate as materials for electronic components. In contrast to SrWO$_4$, BaWO$_4$, and CaWO$_4$ ceramics were found to be resistant to water and humidity. Scheelite LiLaW$_{10}$O$_{32}$, NaLaW$_{10}$O$_{32}$, and KLaW$_{10}$O$_{32}$ ceramics could be densely sintered at temperatures as low as 700–800°C. Only NaLaW$_{10}$O$_{32}$ exhibits promising microwave dielectric properties, i.e., $\varepsilon = 11.7$, Qxf = 27900 GHz and $\tau_f = -20$ ppm/°C.

In the scope of low-permittivity LTCC materials we investigated materials from the MgO-B$_2$O$_3$-SiO$_2$ system, which were in contrast to K$_{1-x}$Ba$_x$Ga$_{2-x}$Ge$_x$O$_8$ and scheelites, prepared by recrystallization.

In the field of investigating LTCC ceramics with higher permittivity ($\varepsilon = 80$) we studied the influence of Nb substitution in the compound Bi$_3$NbO$_7$ by Ta and the sintering conditions on the microwave dielectric properties of the resulting ceramics. We confirmed that the properties of the formed solid solution Bi$_3$Nb$_{1-x}$Ta$_x$O$_7$, depended on the Ta content: the permittivity of the ceramics decreased with Ta content, while the quality factor (Qxf) increased; however, the temperature coefficient of resonant frequency decreased and reached the value $\tau_f = -12$ ppm/K at $x = 0.6$. Based on these properties our ceramics can be classified as commercially interesting materials.

The research on nanostructured materials was mainly focused on the synthesis of low-dimensional nanostructures, inorganic-organic composites and the preparation of thin films. The synthesis of low-dimensional nanostructures of CaTiO$_3$ and Na$_2$Bi$_4$TiO$_9$ was carried out under hydrothermal conditions. The synthesis of CaTiO$_3$ started from nanostructured, layered alkali metal titanates with tubular morphology. The layered structure of the titanate...
precursor enables the ion exchange of an alkali metal cation with calcium under hydrothermal conditions. Hydrothermal treatment (100-150°C) of the tubular precursor with Ca(OH)₂ leads to the ion-exchange reaction of interlayer Na⁺ cations with Ca²⁺ cations. The morphology is preserved but the chemical composition is changed. According to the EDS analysis, nanotubes prepared under these conditions contained about 10 at. % of calcium after the hydrothermal ion-exchange reaction. Increasing the temperature to 200°C led to the formation of well crystallised, anisotropic single crystals of CaTiO₃ with a length of 800 nm and a width of 100–200 nm. The hydrothermal synthesis of NaₓBi₁₋ₓTiO₃ was optimized by changing the concentrations of the reactants, the temperature and the duration of the synthesis. NaₓBi₁₋ₓTiO₃ with a crystallite size of 20–75 nm was successfully synthesized.

Nanocomposite inorganic/organic thin films were fabricated by the in-situ synthesis of ZnS and Mn²⁺-doped ZnS nano-crystallites in a polymer matrix. The polymer network acts as a nanoreactor, where the morphology, size and volume density of the synthesized crystallites are controlled by the pH value of the polymer solution and the number of reaction cycles. By controlling the size of the semiconducting nanocrystallites a control over the optical properties is obtained, resulting in an efficient fluorescence of the composite films.

Thin Bi₁₂SiO₂₀ films were prepared by the pechini and sol-gel methods. In the pechini route the metallic precursors were prepared and then esterified with the addition of ethylene glycol. The prepared precursor solution was deposited on Si/SiO₂/TiO₂/Pt substrates. We studied the influence of the precursor concentration, the number of deposited layers and the thermal treatment on the microstructure and thickness of BSO thin films. The thin films were thermally treated in three stages: drying, pyrolyzing and annealing. The results showed that for both precursor concentrations, 0.3 M and 0.2 M, we obtained dense, homogeneous BSO thin films. The difference between the precursor solutions was shown in the thickness and the grain size. Therefore, we obtained, in the case of a 0.3 M solution, a thickness of 200 nm and an average grain size of 450 nm, and for a 0.2 M solution, a thickness of 100 nm and average grain size of 300 nm.

For the preparation of thin Bi₁₂SiO₂₀ films by the sol-gel route two synthesis procedures using different solvents, 2-ethoxyethanol and acetic acid, were compared. The solvents actually behave as true chemical reagents: they are able to react with the precursors and change them at the molecular level, therefore changing the whole process, i.e., the stability and ageointime of the sols, the morphology and the thickness of thin films. We found that in sols prepared with the help of acetic acid, acetic groups bidentately bonded to bismuth ions. This shortened the gelation time (τₜ) (τₜ ≈ 192 h) compared to sols prepared with 2-ethoxyethanol (τₜ ≈ 24 h). The microstructure development of Bi₁₂SiO₂₀ thin films, prepared from sols using 2-ethoxyethanol, showed homogeneous and dense thin films. A porous microstructure was observed for Bi₁₂SiO₂₀ thin films deposited from a sol using acetic acid as the co-solvent.

In the field of hard materials we studied the influence of the additives Ti₂O₅, TiC and B₄C on the compounds Ti₃Al, TiAl and TiAl₂. We determined the phase composition and the mechanical properties of samples fired at 800 to 1300°C.

In the research area of glass and mineral fibres our investigations were made for the industrial partners Gamma Meccanica, Knauf Insulation and Paroc. The investigations included the analysis of mineral rocks, glassy materials and fibres. The basic aim of the investigations was to determine the correlations between the composition and the glass-forming conditions in order to obtain the optimal melt properties of the glass for the production of fibres. We performed numerous melting tests on the samples to analyse the melting behaviour of various basalts and their compositions with dolomites. In the scope of the investigations with TRIMO Trebnje we developed new product, termoinsulation plate, which is made entirely from recycled waste mineral fibres.

In the scope of industrial research projects we developed several middle-permittivity LTCC materials that are compatible with other already-commercialized LTCC materials. The compatibility includes, in addition to chemical compatibility, a matching of the thermal expansion coefficient and the kinetics of sintering.

Some outstanding publications in 2008


3. Marjeta Maček Kržmanc, Boštjan Jančar, Danilo Suvorov. The influence of tetrahedral ordering on the microwave dielectric properties of Sr_{0.95}Ba_{0.05}Al_{2}Si_{2}O_{8} and BaM_{2}O_{3} (M = Al, Ga, M = Si, Ge) ceramics. J. Eur. Ceram. Soc., 28 (2008) 16, 3141-3148.


Awards and Appointments


4. Moja Žnadišič: Award for the best contribution of young researchers, 1. International Conference on Materials and Technologies, Portorož, Awarding Committee of the Conference, contribution entitled The structural and electrical properties of a solid solution based on Na_{x}Bi_{2}TiO_{3}-K_{x}Bi_{2}TiO_{3}.

5. Srečo D. Škapin: Award for the poster presentation, Hot Nano Topics 08, 23-30 May, 2008, Portorož Slovenia, “Photocatalytic undoped and doped nanotitania for building applications”

Organization of conferences, congresses and meetings

1. Meeting of the EU 6FP project: Safe, integrated and controlled production of high tech multifunctional products and their recycling (SAPHIR), Ljubljana, 17–19 Mar. 2008.


6. 5th International Conference on Microwave Materials and Their Applications (MMA-2008), Hangzhou, China, 1–4 Nov. 2008 (co-organizers).

INTERNATIONAL PROJECTS

1. Controlled Production of High Tech Multifunctional Products and their Recycling SAPHIR
   6. FP, NMP2-CT-2006-026666
   EC: Laurent Demeur, Christophe Gompert, Compagnie Industrielle des Lasers Gilas SA, Orleans, France
   Prof. Danilo Suvorov

2. Tantalum Free Microwave Dielectric Resonators with Enhanced Quality Factor NATO SIP 980883
   NATO Public Diplomacy Division, North Atlantic Treaty Organisation, Brussels, Belgium;
   Prof. Peter Mascher, McMaster University, Department of Engineering Physics,
   Faculty of Engineering, Hamilton, Ontario, Canada
   Dr. Boštjan Jančar

3. Relax-based Tunable Materials T090038
   Dr. Christian Hoffmann, Dr. Andrea Testino, EPCOS OHG Ceramic Components Division,
   Deutschlandberg, Austria
   Prof. Danilo Suvorov, Dr. Boštjan Jančar

4. ITCMC Materials for High Frequency Applications T090033
   Pavol Budaysek, EPCOS OHG Ceramic Components Division, Deutschlandberg, Austria
   Prof. Danilo Suvorov, Dr. Boštjan Jančar

5. Characterisation of Bio Soluble Mineral Fibres T070031
   Markus Mente, B. Sc., Heraklith GmbH, Furtitz, Austria
   Prof. Danilo Suvorov

6. ITCMC Materials for High Frequency Applications T070033
   Dr. Justinus Slachhorst, Christian Block, B. Sc., EPCOS OHG, Ceramic Components Division,
   Deutschlandberg, Austria
   Prof. Danilo Suvorov

7. Characterization of Bio Soluble Mineral Fibres T070031
   Niklas Bergman, B. Sc., Paroc Group OY Ab/R&D, Pargas; Vantaa, Finland
   Prof. Danilo Suvorov

8. Characterization of the Materials for Mineral Fibres Production T070001
   Giovanni Burini, B. Sc., Gamma Meccanica, Bibbiano, Reggio Emilia, Italy
   Prof. Danilo Suvorov

   Prof. Dragan Uskoković, Institut tehničkih nauka Srpske akademije nauka i umetnosti,
   Belgrade, Serbia
   Prof. Danilo Suvorov

10. Materials World Network: Improved Lanthanide-based Filters for Mobile Telecommunications B4/R/08/10-005
    Prof. Rick Ubc, Boise State University, Boise, Idaho, USA
    Prof. Danilo Suvorov

11. Development of Wear Resistant Coatings based on Complex Metallic Alloys for Functional Applications applicMCMA
    7. FP, 214407
    EC, Susanne Fuchs, Austrian Research Centers GmbH - ARC, Functional Materials,
    Seibersdorf, Austria

Dr. Srečo D. Škapin, Dr. Miha Čekada, Prof. Janez Dolinšek, Dr. Kristoffer Krikel
R & D GRANTS AND CONTRACTS

1. Development of multifunctional B,C,Al and B,C,Mg composites for emerging applications
   Prof. Tomaz Kosmač, Dr. Srečo Davor Škapin
2. Multifunctional composites based on Al-Mg-Ti intermetallic compounds reinforced with ceramic particles
   Dr. Srečo Davor Škapin
3. Self-cleaning photocatalytic coatings
   Asst. Prof. Miran Mozetič, Dr. Srečo Davor Škapin
4. Smart functional coatings for increasing sustainability of structures and components for defense purposes
   Dr. Peter Parpij, Dr. Srečo Davor Škapin

VISITORS FROM ABROAD

1. Dr. Christian Hoffmann, Pavol Dudesek, B. Sc., EPCOS OHG, Deutschesland, Austria, 1 Apr. 2008
4. Dr. Philippe Thomas, University of Limoges, France, 26-29 Jun. 2008
5. Dr. Jason JAE-BO, Korea Institute of Materials Science, Changwon, Korea, 4-6 Sept. 2008

STAFF

Researchers

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1. Silvo Zupančič

Note: * part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLES

8. Marjeta Maček, Boštjan Jančar, Danilo Suvorov, “The influence of tetrahedral ordering on the microwave dielectric properties of Sr0.5Ba0.5Al2Si2O11 and Ba0.5Mg0.5O2 (M = Al, Ga, M’ = Si, Ge) ceramics”, J. Eur. Ceram. Soc., vol. 28, no. 16, pp. 3141-3148, 2008.
11. Ivan Sondi, Srečo D. Škapin, Branka Salopek-Sondi, “Biomimetic precipitation of nanostructured colloidal calcite particles by enzyme-


PUBLISHED CONFERENCE PAPERS

Regular papers


THESIS

Ph. D. Theses

1. Matjaž Spretizer, Influence of synthesis and structural characteristics in electrical properties of Na0.5Bi0.5TiO3, Ljubljana, (Prof. Danilo Suvorov), 2008.

B. Sc. Theses

1. Tina Šetinc, Electrical conductivity of porous LSM ceramic, Ljubljana, [T. Šetinc], 2008. (Asst. Prof. Marjan Marinšek)

The research activities of the members of the Department of Biochemistry, Molecular and Structural Biology 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.

Proteases, which were long considered as primarily protein-degrading enzymes, are extremely important signalling molecules involved in numerous vital processes, such as cell-cycle regulation, proliferation, cell death and immune response. 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 autoimmune, neurological and cardiovascular disorders, cancer and osteoporosis.

Monitoring protease activities in vivo is one of the major challenges of the postgenomic era in biomedical research. In collaboration with partners from Sanofi-Aventis we developed selective cell-permeable activity-based probes for the detection of cysteine cathepsins in cellular systems. The probes were developed by so-called reverse-design from existing optimized compounds in preclinical development, rather than starting from the substrates. This offers an enormous advantage over existing probes, as such compounds have been already optimized for in vivo use. It also provides an excellent basis for future work in drug discovery, focusing on the in vivo imaging of proteases in various diseases, such as cancer, osteoporosis and inflammatory diseases, with a further goal to identify new targets and/or to monitor disease treatment.

Proteases, in particular caspases and recently also cysteine cathepsins, have a major role in various cell-death processes. We have characterized the action of the lysosomotropic agent LeuLeuOMe using distinct cellular models as a model for defining the role of lysosomal cathepsins in apoptosis. LeuLeuOMe was found to induce lysosomal membrane permeabilization, resulting in the release of lysosomal cathepsins that cleave the proapoptotic Bcl-2 family member Bid and degrade the antiapoptotic member Bcl-xL. On the basis of inhibitor studies, we demonstrated that lysosomal disruption triggered by LeuLeuOMe occurred before mitochondrial damage. The degradation of antiapoptotic Bcl-2 family members by lysosomal cathepsins was found to synergize with the cathepsin-mediated activation of Bid to trigger a mitochondrial pathway to apoptosis. Moreover, XIAP (X-chromosome-linked inhibitor of apoptosis) was also found to be a target of cysteine cathepsins, suggesting that cathepsins can also mediate caspase-dependent apoptosis downstream of the mitochondria. Since the antiapoptotic Bcl-2 family members and IAPs are often upregulated in cancer, it is possible that lysosomal destabilization has a major potential in cancer treatment.

On the other hand, the expression levels of various cysteine cathepsins, including cathepsin B, have been positively correlated with mammary-tumour progression and metastasis, although their roles in the hallmark processes of malignant growth remain poorly defined. In collaboration with a group from Freiburg we investigated tumour-cell differentiation, proliferation and apoptosis in the Tg(MMTV-PyMT) mouse mammary cancer model using cathepsin B-deficient mice. The absence of cathepsin B significantly impaired the development of high-grade invasive ductal carcinomas and reduced the metastatic burden in the lungs. Mice lacking cathepsin B exhibited reduced cell proliferation in mammary carcinomas and their lung metastases. However, no cathepsin-B-dependent difference in tumour-cell death was observed in vivo or by the treatment of isolated PyMT cancer cells with tumour necrosis factor-alpha. However, cancer cells lacking cathepsin B exhibited a significantly higher resistance to apoptosis induction by the lysosomotropic agent Leu-Leu-Ome.

We have also investigated the role of proteases in autophagy, which is the major mechanism used by eukaryotic cells to degrade and recycle proteins and organelles. Using a bioinformatics analysis of the genome of the protozoan parasite Trypanosoma cruzi we identified the presence of all the components of the Atg8 conjugation system, whereas several components of the Atg12 pathway could not be identified. The two TcATG4 (cysteine protease autophagin) homologs present in the genome were
found to correctly process the two ATG8 homologs after the conserved Gly residue. During starvation of the parasite, TcAtg8.3 was found to be located in autophagosome-like vesicles, which confirms its function as an Atg8/LC3 homolog and its potential to be used as an autophagosomal marker. Most importantly, autophagy was found to be involved in the differentiation between the developmental stages of T. cruzi, a process that is essential for parasite maintenance and survival. These findings suggest that the autophagy pathway could represent a target for a novel chemotherapeutic strategy against Chagas disease. The paper was also highlighted in the Faculty of 1000 Biology.

Cysteine cathepsins also play an indispensable role in the proteolytic processing of the major histocompatibility complex class-II-associated invariant chain (Ii) and the foreign antigens in a number of antigen-presenting cells. A comparison of 3D structures indicated that the selectivity of the interactions between cysteine cathepsins and the p41 fragment is far from being understood. The p41 fragment was thus shown to inhibit the human cathepsins V, K, and F and the mouse cathepsin L with Ki values in the low nanomolar range. These values are sufficiently low to ensure the complex formation at physiological concentrations. In addition, the p41 fragment was found to inhibit both mouse and human cathepsin S. These findings suggest that the regulation of the proteolytic activity of most of the cysteine cathepsins by the p41 fragment is an important and widespread control mechanism of antigen presentation.

We have also continued our work on other inhibitors and successfully expressed and characterized several of the thyropins. Similarly, our studies on the stefin formation of amyloid fibers extended our knowledge on their structure and cellular toxicity.

In the Group of Structural Biology they have, in addition solved, the structures of several new proteins and/or protein complexes and developed the PURY database of geometric parameters of chemical compounds, together with a server that accesses it. The PURY database is suitable for use in macromolecular crystal-structure refinement and should be of value to the crystallographic community. The database can be accessed through the web server http://pury.ijs.si/, which creates topology and parameter files from deposited coordinates in suitable forms for the refinement programs MAIN, CNS and REFMAC.

Most recently, we entered into the field of proteomics, with the ultimate goal of analyzing the functional regulation of investigated proteins with a major focus on potential physiological protease substrates. We established a complete Proteomics Laboratory and the first experiments were performed.

We participate in two projects within the EU FP6 and one FP7 project. We also participate in the prestigious project within the Human Science Frontiers Program (HSFFP) jointly with the groups from the University of Tokyo, Stanford University and the Burnham Institute for Medical Research, San Diego. In addition, there are many other international collaborations with many high-quality research teams from different countries, including Germany, USA, Australia and Japan, which resulted in joint publications. Several members of the group were invited to give lectures at international symposia and foreign universities.

Some outstanding publications in 2008


Organization of conferences, congresses and meetings

1. 25th Winter School on Proteinases and their Inhibitors, Recent Developments, Tiers, Italy, 27 Feb. to 2 Mar. 2008 (coorganisers)
2. 11th International Symposium on Proteinase inhibitors and Biological control, Portorož, Slovenia, 30 Aug. to 3 Sept. 2008
INTERNATIONAL PROJECTS

1. Understanding and Fighting Metastasis by Modulating the Tumour Microenvironment through Interference with the Protease Network  
   MICROENVIRONMENT  
   7. PF, 2012/79  
   EC, Universite de Liege, Liege, Belgium
   Dr. Olga Vasileva

2. Chemical Genomics by Activity Monitoring of Proteases  
   6. PF, CAMP  
   ESMR-FCT-2005-018830  
   EC, Manuel Morellas, Universitat Autonoma de Barcelona, Institut de Biotechnologia i de Biomedicina (UAB), Bellaterra (Cerdanyola del Vallés), Spain
   Prof. Boris Turk

3. High Throughput Development of Drugs for Immunotherapy of (Auto)immune Diseases and Drugs for Therapy  
   6. FP  
   MRTW-CT-2004-512385  
   EC, Prof. Fruta Koning, Leiden University Medical Center, Leiden, The Netherlands
   Prof. Dušan Turk

4. Safe Production and Use of Nanomaterials  
   NANOFASE  
   6. PF  
   NMP2-FCT-2005-515843  
   EC, Commissariat a l’Energie Atomique, Grenoble, France
   Prof. Boris Turk, Asst. Prof. Maja Rentnikar, Marko Zamer, B. S., Andrej Detela, B. S.

5. Intracellular Protease Signaling induced by Homopolymeric Amino Acid (HPAA) Tracts  
   RB105, 0024/2006-C  
   IBFSPO: International Human Frontier Science Program Organisation, Strasbourg, France
   Prof. Boris Turk

6. FEBS Fellowship for Dr. Zorana Štefanić  
   FEBS Fellowship for 15  
   FEBS - Federation of European Biochemical Societies, Prof. Maciej Nalecz, UNESCO, SU, BES, Paris, France
   Prof. Dušan Turk

7. Proteolytic Activities in Trypanosoma Cruzi: Cruzipain, Metacaspase, Serine Carboxypeptidases  
   BA-6R/06-08-03  
   Prof. Juan Jose Cazzulo, Instituto de Investigaciones Biotechnologicas, Instituto Tecnologico de Chascomus, Universidad Nacional de General San Martin-CONICET, San Martin, Provincia de Buenos Aires, Argentina
   Prof. Vito Turk

8. Chosen Site-mutations of Aromatic Amino Acids in Human Stefins A and B: Influence on Dimerization, Folding and Aggregation  
   Izabrane tačkaste mutacije aromata u čovječijim stefinima A i B. Uticaj na stabilnost, dimerizaciju i svijanje protein  
   RB-BIH 05-456-003  
   Prof. Selma Berbić, Farmacevtska fakulteta, Univerza v Tuši, Tužla, Bosnia i Hercegovina
   Asst. Prof. Eva Zerovnik

9. Izabrane tačkaste mutacije aromata u čovječijim stefinima A i B. Uticaj na stabilnost, dimerizaciju i svijanje protein  
   BB-BIH 06-08/001
   prof. dr. Selma Berbić, Medicinski fakultet, Univerza v Tuši, Tužla, Bosnia i Hercegovina
   Asst. Prof. Eva Zerovnik

10. Bayesian Decision Making to support Charge Detection in Complex Manufacturing Systems  
    BA-CZ/07-08-0120  
    Prof. Libor Grubhoffer, Faculty of Biological Sciences, University of South Bohemia, České Budějovice, Czech Republic
    Dr. Tina Zavašnik Bergant

11. Interactions between Tuberculosis causing Mycobacteria and Dendritic Cells  
    Interakcije među bakterijama koje uzrokuju tuberkulozu i dendritičkima  
    Dr. Tina Zavašnik Bergant

12. Export of the Cathespins B  
    Gábala G Pazmany, Dynx Corp., Cambridge, MA, USA
    Prof. Boris Turk

R & D GRANTS AND CONTRACTS

1. Proteomic identification of extracellular substrates of cysteine proteases  
   Dr. Marko Fonović

2. Role of cysteine cathespin in regulation of proliferation and cell death  
   Prof. Boris Turk

3. Differences Between Mouse And Human Endosomal Immune Response Pathway: Crystal Structures of Protein Complexes and their Analysis  
   Prof. Dušan Turk

4. The effect of citrullination of extracellular matrix proteins to degradation by cysteine and metalloproteases in arthritis joints  
   Prof. Boris Turk

5. Cathespin F, new cysteine protease involved in neuronal ceroid lipofuscinosis  
   Asst. Prof. Veronika Stoka

6. The role of nuclear cystatins in the regulation of interleukin-10 synthesis during endotoxin tolerance  
   Asst. Prof. Nataša Kopitar Jerala

7. The role of cysteine proteinases and their inhibitors in endotoxin tolerance  
   Asst. Prof. Nataša Kopitar Jerala

8. Using phage display for new medicinal substances of biotechnological source  
   Prof. Borut Strukelj, Polocnà Priko Kovačić

RESEARCH PROGRAMS

1. Structural biology  
   Prof. Dušan Turk

2. Proteolysis and its regulation  
   Prof. Vito Turk

VISITORS FROM ABROAD

1. Dušana Majera, Raški Petrovac, Serbia, 1 Jan. to 31 Dec. 2008 (Scholarship Marie Curie Actions: Research Training Network)

2. Zoran Štefanić, Ruder Bošković Institute, Physical Chemistry - Laboratory for Chemical and Biological Crystallization, Zagreb, Croatia, 1 Jan. to 31 Dec. 2008 (scholarship Ruder Bošković Institute, Zagreb)

3. Georgy Mikhaylov, Siberian State Medical University, Tomsk, Siberia, Russia, 1 Jan to 31 Dec. 2008

4. dr. Maria Luisa Jordao, Centro de Patogenese Molecular-UCP, faculty of Pharmacy, University of Lisbon, Lisbon, Portugal, 2–31 May 2008


6. prof. Boštjan Kobe, ARC Federation, Fellow Professor of Structural Biology School of Molecular and Microbial Sciences and Institute for Molecular Bioscience, University of Queensland, Brisbane, Australia, 24 Jun. 2008


8. prof. dr. Francese Xavier Aulètes, Universitat Autonoma de Barcelona, Institut de Biotechnologia i de Biomedicina Campus UAB, Barcelona, Spain, 27 Aug. to 5 Sept. 2008


10. Prof. Salvador Ventura, Department of Biochemistry and Molecular Biology and the Institute of Biotechnology and Medicine of the Autonomous University of Barcelona (UAB), Spain, 29 Nov. 2008

11. Prof. Boštjan Kobe, ARC Federation, Fellow Professor of Structural Biology School of Molecular and Microbial Sciences and Institute for Molecular Bioscience, University of Queensland, Brisbane, Australia, 24 Jun. 2008

12. Prof. Boris Turk, Department of Biochemistry and Molecular Biology and the Institute of Biotechnology and Medicine of the Autonomous University of Barcelona (UAB), Spain, 29 Nov. 2008

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Researchers

1. Dr. Iztok Dolenc
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6. Asst. Prof. Veronika Stoka
7. Prof. Boris Turk, Head
8. Prof. Dušan Turk

9. Prof. Vito Turk
10. Prof. Tina Zavašnik Bergant
11. Asst. Prof. Eva Zerovnik

Postdoctoral associates

12. Dr. Lea Bojić, left 15 Oct. 2008
13. Dr. Dejan Ćagić
14. Dr. Marko Fonović
15. Dr. Saška Ivanova
16. Dr. Saša Jenko Kokalj, left 1 Jun. 2008
BIBLIOGRAPHY

ORIGINAL ARTICLES


8. Marko Mihelč, Andreja Božič, Gregor Gunčar, Dušan Turk, "Inhibitory fragment from the p41 form of invariant chain can regulate activity of cysteine


14. Marko Mihelč, Andreja Božič, Gregor Gunčar, Dušan Turk, "Inhibitory fragment from the p41 form of invariant chain can regulate activity of cysteine


**REVIEW ARTICLES AND CHAPTERS IN BOOKS**


**PUBLISHED CONFERENCE PAPERS**

**Invited Papers**


**Theses**

Ph. D. Theses


**Patent Application**

1. Matthew Bogoy, Steven H. L. Verhelst, Marko Fonovič, "A mild chemically cleavable linker system: patent application no. 3815.33-1 PCT, Stanford, National Technology Center for Networks and Pathways, 2008."
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 to acquire a new understanding of mammalian pathophysiology, with the aim of improving human and animal health.

Secreted phospholipases A₂ (sPLA₂)

The major research topic of the department is secreted phospholipases A₂ (sPLA₂) originating from animal toxins as well as those found in humans. We are studying the molecular mechanisms of the action of the toxic sPLA₂, particularly those endowed with presynaptic neurotoxicity, and the role of endogenous sPLA₂ in pathological and physiological processes in mammals.

In 2008 we studied the molecular mechanism of the action of ammodytoxin (Atx), a presynaptically neurotoxic sPLA₂ from the long-nosed viper’s (Vipera a. ammodytes) venom, on murine cell lines and on murine and rat neuromuscular (NM) preparations. Our results, obtained by fluorescent and electron microscopy (EM) analysis of the cell culture, have demonstrated the uptake of Atx into motoneuron-like cells, as well as its translocation into the cytosol (Figure 1). The results from the microscopy studies were confirmed by the detection of the formation of the complex between the toxin and cytosolic proteins, calmodulin (CaM) and 14-3-3, in living cells, Z. Jenko Pražnikar et al., Biochim. Biophys. Acta – Mol. Cell Res. 1783 (2008) 1129–1139. In this way we also confirmed in vivo the results obtained in vitro, that the cytosolic concentrations of Ca²⁺ allow the interaction between Atx and CaM U. Logonder et al., Acta Chimica Slovenica 55 (2008) 541-546. We were the first to demonstrate that an sPLA₂ can translocate into the cytosol of a nerve cell from the extracellular space. The exposure of the cells in a culture to the toxic sPLA₂ in vitro resulted in the apoptotic death of cells, Z. Jenko Pražnikar et al., in International Meeting Mechanisms(s) of Exocytosis and 15th Young Neuroscientists Meeting, Ljubljana, Slovenia, Book of Abstracts, 2008, p. 65. As the recent results show, one of the main factors of apoptotic cell death is a particular product of the enzymatic degradation of cellular membranes by the toxic sPLA₂. The photoreactive derivative of AtxC, sulfo-SBED-AtxC, was used to develop a new method for the targeted therapy of cancer. We synthesized the conjugate of sulfo-SBED-AtxC and “targeting” antibodies, which specifically recognized the CaCo-2 cancer cells. Following the specific binding on the cancer cells, the conjugate was internalized into the cells. In the reducing conditions of the cytosol the toxin molecule was released, A. Premzl et al., Toxicon 51 (2008), 754–764.

Mitochondria are one of the main targets of Atx following its internalization into nerve cells. The consequence of the enzymatic action of Atx on mitochondria in the nerve ending is also the reduced production of ATP, which is likely to be one of the main reasons for the interruption of the cycling of synaptic vesicles filled with neurotransmitter. The data gathered on the NM preparations were published in the distinguished medical pathophysiology journal, U. Logonder et al., Journal of Neuropathology and Experimental Neurology 67 (2008), 1011-1019. The high relevance of our report is reflected in its announcement on the cover page of the journal, presenting a collage of figures from the paper (Figure 2). Atx was labelled with a nanogold particle and used to block in vivo mouse NM junctions. Labelled junctions were isolated and in collaboration with colleagues from Newcastle University, UK, analysed by EM. We demonstrated the localization of the nanogold toxin derivative inside the nerve ending, which was done for the first time in the case of the nerve ending of a motoneuron, not only for a neurotoxic but for any sPLA₂. These results are in preparation for publication.

The study of the topology of the interaction of Atx with CaM, which is ready for submission, revealed two very interesting facts: the stability and the phospholipase activity of Atx increased substantially in the complex with CaM, both in reducing (cytosol-like) and non-reducing conditions. We performed a detailed kinetic study of the activation of the enzymatic activity of Atx and some other sPLA₂ with CaM. The most accurate description of the activation is by the non-essential activation model and the Atx-CaM system...
is the first practical example discovered. The results are in preparation for publication. Following the demonstration of the interaction of Atx with CaM in the cytosol of motoneuron-like cells, Z. Jenko Pražnikar et al., Biochim. Biophys. Acta – Mol. Cell Res. 1783 (2008) 1129–1139, and the internalization of the toxin into the nerve ending of a motoneuron, this finding indicates the enzymatic activity of sPLA$_2$ also in the cytosol and nucleus of mammalian cells, its role in the process of β-neurotoxicity and in some other processes connected to endogenous sPLA$_2$s (e.g., during nuclear signalling, mRNA transport and apoptosis). With the obtained results we further strengthened our hypothesis about the molecular mechanism of action of presynaptically neurotoxic sPLA$_2$s, which claims that for the full expression of the toxic action of these sPLA$_2$s their internalization into the nerve cell is crucial. In order to exactly describe what happens at the nerve ending on the molecular level, e.g., molecular details of the internalization of the Atx into the cytosol of the nerve cell and its translocation into the mitochondria, we continued this year with efforts to identify some known Atx-receptors: R25, R45 and R47. However, we have not made any final conclusions yet. We were also looking for novel Atx-binding molecules (proteins, lipids and glycolipids).

In the past year we published an extensive study on the structural features of presynaptically neurotoxic snake sPLA$_2$s that are responsible for their potent and specific action, P. Prijatelj et al., Toxicon 51 (2008) 1520-1529. To identify the residues that distinguish a highly neurotoxic ammodytoxin A from a structurally similar but more than two-orders-of-magnitude less toxic Russell’s viper (Daboia r. russelli) sPLA$_2$, VIIIa, we prepared a range of mutants and compared their properties. The results showed that the structural features that confer high neurotoxicity to AtxA extend from its C-terminal part, with a central role of the residues Y115, I116, R118, N119 (the YIRN cluster) and F124, across the interfacial binding surface (IBS) in the vicinity of F24, to the N-terminal helix, whose residues M7 and G11 are located on the edges of the IBS. Binding studies indicated that the surface of interaction with the neuronal M-type sPLA$_2$ receptor extends over a similar region of the molecule. In addition, the YIRN cluster of AtxA is crucial for the high-affinity interaction with two intracellular binding proteins, cytosolic CaM and mitochondrial R25. The concept of a single “presynaptic neurotoxic site” on the surface of snake venom sPLA$_2$s is not consistent with these results, which suggest that different parts of the toxin molecule are involved in distinct steps of the presynaptic neurotoxicity (Figure 3).

We participated in the development of the chromatographic method for the rapid and accurate determination of Atx content in venoms of Vipera a. ammodytes specimens. B. Halassy et al., Journal of Liquid Chromatography & Related Technologies, 31 (2008), 38-53. Namely, we found a high correlation between the content of Atx in the venom and the suitability of the venom for the preparation of high-quality antiserum by animal immunization, B. Halassy et al., Comparative Biochemistry and Physiology, 148 (2008), 178-183. These findings will substantially lower the price of high-quality antiserum production and reduce the work on animals in the process of its preparation.

At the beginning of this year we published a review article on the pathophysiological role of sPLA$_2$s where, among others, their involvement in various cancer and neurodegenerative disorders was presented, B. Jerman et al., Farmacevtski vestnik, 59 (2008), 9-15. In 2008 we started a new project aimed at exploring the role of sPLA$_2$s in the development and progression of breast cancer (Research project: The role of secretory phospholipases A$_2$ in breast cancer). Currently, ten structurally distinct sPLA$_2$s enzymes are known in humans, which differ in enzymatic activity, membrane-binding and receptor-binding affinities. These enzymes show diverse tissue expression patterns, suggesting tissue-specific pathophysiological roles and mechanisms of action. Our hypothesis is that certain sPLA$_2$s enzymes are involved in cellular processes that have an impact on breast-cancer development and progression. In the first year of the project we focused our attention on identifying members of the sPLA$_2$ family that display differential levels of expression in the cell models of breast cancer. We used several human breast-cancer cell lines, which differ in their invasiveness in vitro, tumourigenicity in vivo and steroid hormone receptor status, as well as two nontumourigenic cell lines, which retain the characteristics of normal breast epithelial cells. We determined the differences in mRNA expression levels of the whole set of human sPLA$_2$s in the selected cell models using real-time quantitative PCR (qPCR). Our results indicate that breast-cancer cell lines with different tumourigenic characteristics, reflecting the progression of the disease from less aggressive and hormone-dependent to the more invasive and hormone-independent forms, display different levels of expression of particular sPLA$_2$s.

An investigation has also been focused on the presence and role of endogenous sPLA$_2$s in the (peripheral) nervous system, which is also an important target site of action for snake venom neurotoxic sPLA$_2$s. In collaboration with the Institute of Pathophysiology, Medical Faculty, University of Ljubljana, we analyzed a co-culture of rat embryonal spinal cord explants and human skeletal muscle cells (Figure 4) by immunocytochemistry for the presence of five groups of endogenous sPLA$_2$s, Ib, IIA, IIE, V and X. This heterologous co-culture could also serve as a model for the study of the action of endogenous and snake sPLA$_2$s in the region of neuromuscular junction. Preliminary results showed the
presence of group IIa, V and X sPLA\(_5\) in different cell types in the co-culture (neurons, their support cells, muscle cells). The demonstration of different sPLA\(_5\)s in the co-culture, able to form functional neuromuscular junctions, has provided a good basis for the investigation of sPLA\(_5\) in less-complex systems of neuronal cells. We confirmed the presence of group X sPLA\(_5\) in a mouse motoneuronal cell line, and groups V and X in a rat neuron-like cell line. Aiming to investigate the specificity of immunodetection of different groups of sPLA\(_5\), we are currently occupied with the production of certain recombinant mammalian sPLA\(_5\). The latter will be used to test the potential cross-reactivity of particular antibodies and to observe the effect of different sPLA\(_5\) on the neuronal cells and functional heterologous co-culture.

Other pharmacologically active components from natural toxins

We studied Vipera a. ammodytes venom components that affect haemostasis, particularly different proteases, and published the work describing the isolation and characterization of two novel coagulation factor X activators with the potential to treat patients with dysfunctional factors IXa or Vila, A. Leonardi et al., *Toxicon*, 52 (2008), 628-637. In this year we also started with a new project dedicated to the development of the potential of fibrinogenolytic and non-haemorrhagic ammodytase to serve in the therapy of thrombosis (Research project: Proteins of the long-nosed viper venom acting on haemostasis – development of innovative biomedical antithrombotic).

In 2008 we continued work on the EU 6FP Integrated Project Conco. As one of the 20 partners we have been involved in the analysis of the genome, transcriptome and venom proteome of the marine snail *Conus consors*. We investigated the toxicity of the C001 conopeptide from the venom of this snail possessing a potent inhibitory activity on Na\(^+\) voltage-gated channels. No cytotoxicity on neuroblastoma cells was observed, even at a 100 mM concentration, whereas a transient cytotoxicity was detected in myoblasts and motoneuron-like cells. Currently, we are analyzing different HPLC fractions of the *C. consors* venom for the presence of phospholipase activity. Venoms of two species of cone snails, piscivorous *C. consors* (whose prey is mainly fish) and vermivorous *C. quercinus* (whose prey are marine worms), have been successfully separated by 2D electrophoresis into individual protein components.

The methodology of the preparation of the photoreactive derivative of AtxA was successfully used to prepare photoreactive derivatives of human SMOC (“secreted modular Ca\(^{2+}\) binding”) proteins to study interactions with proteins in human serum, M. Novinec et al., *Protein Expression and Purification*, 62 (2008), 75-82. In collaboration with a group from the New York University Langone School of Medicine from New York we investigated the perturbation of transforming growth factor (TGF)-β1 association with latent TGF-β binding protein and found positive effects on inflammation and tumourigenesis, K. Yoshinaga et al., *Proceedings of the National Academy of Sciences of the United States of America*, 48 (2008), 18758-18763.

High-throughput genetics and functional genomics in yeast Saccharomyces cerevisiae

In 2008 we have made some important steps toward measuring yeast-colony volumes on agar plates, which is an important advancement in high-throughput genetics (Figure 5). We have demonstrated that by the application of this development into our experimental platform, the quality of the generated data is significantly improved.

Based on the interpretation of our high-throughput genetics data, we have elucidated the first contours of the core genetic network of membrane biology: we discovered a functional interaction between peroxisome proliferation and endocytosis and some of the genes/proteins involved in this pathway.

In close collaboration with the Faculty of Computer and Information Sciences of the University of Ljubljana we have started to analyze the not-yet-published 3\(^{rd}\) generation data on the genetic interactome of yeast *Saccharomyces cerevisiae*, generated at the University of Toronto. This project is making a huge contribution towards the understanding and treatment of polygenetic diseases.

In collaboration with the University of Nova Gorica we have identified some novel targets of the action of pesticides, which could explain some of their side effects and enable the development of safer new compounds.

In the past year we have also initiated work on a new applicative project. With our partners, the Lek-Novartis pharmaceutical company and the Faculty of Computer and Information Sciences of the University of Ljubljana, we have started to develop novel knowledge-technology.
approaches in drug discovery that are based on analyses and experiment planning in high-throughput genetics (Research project: Knowledge technology approaches in drug discovery: analysis and experiment planning in high-throughput genetics)

**Evolutionary genomics of transposable elements and functional studies of retrotransposons**

The origin of the novel mammalian genes (neogenes) from retro-element remains (e.g., gag and integrase) and their evolution has until now been only partially elucidated, due to the absence of the genome data or the limited analysis of a single family of neogenes. By using phylogenomic analysis (combining phylogenetic tree construction, integration of the experimental data and differentiation of orthologs and paralogs) we obtained and characterized retro-element-derived neogenes from all the currently available mammalian genomes (more than 50 different species available at NCBI and ENSEMBL) and their progenitors from the genomes of the key tetrapod genomes (amphibians and reptiles). Phylogenomic analysis provided a very large amount of information for each novel neogene, such as the genome sequence, the gene structure, the genome locus, the chromosomal location, the protein sequence, the coding and the non-coding regions as well as the regulatory regions. With the analysis of numerous mammalian genomes (from monotremes, marsupials and four placental superorders) and by the analysis of novel neogene families, an in-depth insight into the origins, evolution, regulatory and functional diversification of diverse retro-element-derived neogenes in mammals has been obtained. We explained where and when the domestication of retro-elements occurred and how similar to the modern neogenes the first mammalian retro-element-derived neogenes were. Until now the evolutionary relationships of currently known retro-element-derived neogenes were not well resolved due to the poor taxonomic sampling. Novel data that we obtained from the genomes of monotremes, marsupials and basal placental superorders has greatly improved and finally resolved the evolutionary relationships of diverse neogenes. The well resolved evolutionary relationships of mammalian retro-element-derived neogenes are crucial for the elucidation of their unusual dynamics of chromosomal mobility as well as for the timing of domestication.

Several APOBEC3 proteins (A3F and A3G), a group of cytidine deaminases, restrict the human immunodeficiency virus (HIV) replication in the absence of the viral infectivity factor (Vif) protein. However, Vif leads to their degradation and counteracts their effects. Another member, A3A, restricts some retrotransposons and another virus, but not HIV. We reasoned that this failure was due to the lack of appropriate targeting. Thus, we fused A3A to another viral protein, Vpr, which binds p6 in Gag and is incorporated into viral cores. Indeed, the Vpr.A3A chimera but not A3A was found abundantly in the viral core. It also potently restricted the replication of HIV and the simian immunodeficiency virus (SIV) in the presence and absence of Vif. Since a high frequency of G to A mutations in viral cDNAs was identified, we assumed this antiviral activity was mediated by DNA editing. Interestingly, our fusion protein did not restrict the murine leukemia virus, which does not incorporate Vpr. Thus, by appropriately targeting a potent single-domain cytidine deaminase, we rendered HIV and SIV restriction resistant to Vif. Because the Vpr.A3A chimera inhibited SIV, such therapeutic strategies could be tried first in the monkey model of AIDS in rhesus macaques, R. S. Aguiar et al., *The Journal of Biological Chemistry*, 283 (2008), 2518-2525.

**Outstanding publications in 2008**

Awards and appointments

1. Uroš Petrovič: Lapanje prize of the Slovenian Biochemical Society for outstanding achievements in biochemical sciences
2. Igor Križaj: Elected to the post of Secretary of the European Section of the International Society on Toxinology (EIST) and a member of the Council of the IST
3. Franc Gubenšek (retired member of the department): Slovenian Biochemical Society Honorary membership

INTERNATIONAL PROJECTS

1. Applied venomics of the cone snail species conus consors for the accelerated, cheaper, safer and more ethical production of innovative biomedical drugs
   CONCO
   6. FP, IP
   037592, LSBB-CT-2007-03792
   BC: Dr. Beto Stichlön, Athiris Laboratories, Plan-les-Quates - Geneve, Switzerland
   Prof. Igor Križaj
2. Phospholipases A₁ and PEX11 in fatty acid signalling in yeast
   BB-AF-07-08174
   Prof. Sepp D. Kohlwein, University of Graz, Institute of Molecular Biosciences, Graz, Austria
   Asst. Prof. Uroš Petrovič
3. Biochemical and structural characterization of phospholipases A₁ from vipers in complexes with their binding proteins
   Études biochimiques et structurales des phospholipases A₁ des venins de Viperidae en complexes avec leurs cibles protéiques
   PROTEUS 2008 – 2009
   BB-FR/08-09-PROTEUS-007
   Dr. Grazyna Faure, Institut Pasteur, Unite d’Immunologie Structurale, Paris, France
   Prof. Igor Križaj
4. The role of secreted phospholipases A₁ in mitochondrial function and dysfunction
   BI-IT/05-08-021
   Prof. Gianfrancesco Goracci, Department of Internal Medicine, Division of Biochemistry, University of Perugia, Perugia, Italy
   Prof. Igor Križaj

R &D GRANTS AND CONTRACTS

1. Use of yeast for determination of toxicity of selected neonicotinoids on the genome level
   Asst. Prof. Uroš Petrovič
2. Computational phenomics
   Asst. Prof. Uroš Petrovič
3. The role of secretory phospholipases A₁ in breast cancer
   Prof. Jože Pungerčar
4. Proteins of the long-cored viper venom acting on haemostasis – development of innovative biomedical antitrombotics
   Prof. Igor Križaj
5. Knowledge technology approaches in drug discovery: analysis and experiment planning in high-throughput genetic
   Asst. Prof. Uroš Petrovič

RESEARCH PROGRAM

1. Toxins and biomembranes
   Prof. Igor Križaj

NEW CONTRACT

1. Knowledge technology approaches in drug discovery: analysis and experiment planning in high-throughput genetics
   Lek d. d., Ljubljana
   Asst. Prof. Uroš Petrovič

VISITORS FROM ABROAD

1. Kristina Radošević, dipl. ing., Faculty of Food Technology and Biotechnology, Laboratory for Cell Technology, Application and Biotransformations, Zagreb, Croatia, 6 Feb. to 26 May, and 11 Nov. 2008
2. Dr. Matej Orešič, Quantitative Biology and Bioinformatics Group, VTT, Espoo, Finland, 30 Sept. 2008
3. Dr. Grazyna Faure Kuzmirskia, Dr. Frederick Saul, Institut Pasteur, Paris, France, 7–10 Dec. 2008
4. Dr. Klaus Natter, Dr. Jürgen Zanghellini, University of Graz, Austria, 9–10 Dec. 2008
5. Dr. Antonio Baici, Department of Biochemistry, University of Zürich, Switzerland, 10 Dec. 2008

STAFF

Researchers
1. Asst. Prof. Dušan Kordiš
2. Prof. Igor Križaj, Head
3. Asst. Prof. Uroš Petrovič
4. Prof. Jože Pungerčar
Postdoctoral associates
5. Dr. Toni Petan
6. Dr. Jernej Šribar
Postgraduates
7. Zala Jenko Pražnikar, B. Sc.
8. Borut Jerman, B. Sc.
10. Lidija Kovačič, B. Sc.
12. Dr. Uroš Logonder
15. Tamara Sajevic, B. Sc.

Technical officers
16. Petra Katerle, B. Sc.

Technical and administrative staff
17. Igor Koprivec
18. Darja Žanič Kotar
BIBLIOGRAPHY

ORIGINAL ARTICLES

REVIEW ARTICLES AND CHAPTERS IN BOOKS

PUBLISHED CONFERENCE PAPER
Invited Paper

THESIS
Ph. D. Thesis

B. Sc. Theses
3. Anja Pucar, Vpliv amoditoksina, fosfolipase \(A_2\) iz strupa modrsana, na mitohondrije modelne celične linije PC12, diplomsko delo, Ljubljana, [A. Pucar], 2008.
At the Department of Biotechnology we generate new knowledge and participate in education in the fields of biochemistry, pharmacy, molecular and cell biology, immunology for health prevention, and the protection of the environment. The main interests of our research are biological molecules that can be used for diagnostic and therapeutic applications in human and veterinary medicine, for the protection of plants and for the production of safe food.

In 2008 we continued with the characterization of mycocypins, cysteine protease inhibitors from mushrooms. We focused our research on the new representative of mycocypins, i.e., macrocypin from the parasol mushroom (*Macrolepiota procera*). Macrocypin is encoded by a family of genes that we put into five groups based on the sequence identity. From among the five macrocypin groups it is 75–86%, while sequences within the groups share more than 90% of the identity. Three macrocypin clones, belonging to three different groups, were heterologously expressed in the bacterial expression system and homogenous material for biochemical characterization was obtained. These proteins are exceptionally stable at high temperatures and extreme pH. The sequence variability is reflected in the pattern and the strength of the inhibition of selected cysteine proteases. In collaboration with the Department of Biochemistry and Molecular and Structural Biology (B1) three-dimensional structures of the clitocypin and macrocypin were determined. The three-dimensional structure of clitocypin in a complex with cathepsin V was also determined, which revealed the active site of the mycocypins responsible for the inhibition of cysteine proteases belonging to the papain family. On the basis of the determined N-terminal amino acid sequence and some internal sequences of the native protein we expressed in *E. coli* also the recombinant inhibitor of serine proteases CnSPI (Cnsipin). This mushroom inhibitor was studied with regard to the physiological role, its anti-tumour activity and potential impact on the growth of bacteria, fungi and plant pathogens.

From the mushroom *Clitocybe nebularis* we investigated lactozil-specific lectin (CNL), which exhibited an anti-proliferative effect on leukemic T lymphocytes. We identified the complete genome with the promoter region (available GenBank code EU682006) and cDNA. The deduced amino acid sequence was analyzed, providing a ricin-like β-trefoil terciar structure. Recombinant CNL, expressed in *E. coli* was also prepared. Hemagglutination tests showed that CNL specifically agglutinates the group A erythrocytes, whereas hemagglutination tests provided specific binding to asialofetuin, lactose and galactose. The specific binding of biotynilated lectin to sugars was assessed by using glycan microarrays. The CNL was determined to be specific for carbohydrate chains with determinants for the blood group A (GalNacα1-3(Fucα1-2)Galβ), as already determined by the hemagglutination test. Additionally, the glycan microarray test showed the specificity of the CNL to also bind N,N’-diacetylactosediamine (GalNAcβ1-4GlcNAc). This glycan is present predominantly in tumour cells and tissues, suggesting that it might be a target for CNL in leukemic T lymphocytes, providing an anti-proliferative effect.

**Figure 1:** Determination of glycans bound to lectin using a glycan micro-array
Within the study of the response of plants to drought we developed and optimised the quantitative zymography using fluorogenic substrates, enabling the detection of substrate specificity, pH optimum and the quantity of active enzymes. An important advantage of the method is the simultaneous detection of the protease activity in leaves of stress and control plants. In this way we determined in the plants *Phaseolus vulgaris* and *Ramonda serbica* various aminopeptidases, which are involved in the response to drought. The response of a bean (*Phaseolus spp.*) to drought was also followed at the gene level, and for three genes the changes in expression were confirmed.

In 2008 we continued our studies of the role of cysteine proteases and their endogenous inhibitors in cell signalling and the regulation of the immune response. For cystatin F, which is predominantly present in immune cells, we determined the mechanism of transition of the inactive dimeric form to an active monomer. In dendritic cells we investigated its changes in sub-cellular localisation during the cell maturation and found that it is significantly different compared to the related cystatin C. In collaboration with the Faculty of Pharmacy of the University of Ljubljana we studied the role of cathepsin X in cell signalling, adhesion and migration. We found that the expression and localisation of this enzyme in macrophages correlates with the step of eradication of the disease with antibiotic therapy after infection with the bacteria *Helicobacter pylori*. The method could serve for the prediction of the aggressiveness of *Helicobacter pylori* strains and the selection of the most appropriate therapy for an individual patient.

We optimized the expression of the sweet protein brazzein in *Lactococcus lactis* and *Escherichia coli*. In *Lactococcus lactis* we detected an 800-times-higher expression of brazzein if the combination of the NZ9000 strain and the plasmid pNZ8148 was used instead of the IL1403 strain and the plasmid pMSP3545. With the RT-qPCR method we determined that the larger number of pNZ8148 plasmid copies was the reason for the higher expression. In *Escherichia coli* we prepared gene constructs for nine point mutations, resulting in changes to the encoded amino acids, which should affect the sweet taste and profile. Wild-type brazzein was fused with the protein SUMO, which was cleaved after expression with the SUMO protease enabling the easier purification and characterisation of brazzein. The expression of brazzein as a fusion protein with SUMO will be subsequently used for the preparation of its mutants.

We also started the preparation of a system that will enable the expression of heterologous proteins on the surface of *Lactococcus lactis*. We intend to use these bacteria as a vector for the delivery of heterologous proteins with various biological functions to the gut. For now we have a gene construct that enables the expression of the binding domain of streptococcus protein A in *Lactococcus lactis*, its secretion to the medium and the binding to peptidoglycan on the cell membrane via autolysin AcmA, as was also determined by the antibody to protein A.

The results of the research work at the Department of Biotechnology in 2008 were published in 34 scientific papers in journals with an impact factor, in three chapters in books and presented at scientific conferences as lectures and posters. Two national and one international patent applications have been filed. The members of the department were also very active in pedagogical work as lecturers and mentors to students preparing diploma, master’s and doctoral theses at the University of Ljubljana, University of Maribor and the Jožef Stefan Postgraduate School. A member of the department was awarded the Krka prize for research work.
The most important publications in the past three years:


Awards and appointments

1. Jerica Sabotič, Krka Award for Ph. D. thesis: Characterisation of mycocypins from selected basidiomycete species using genetic and protein engineering (Borut Štrukelj, Jože Brzin)
2. Zupančič Janja: Student Prešeren Award for B. Sc. thesis: Development and usage of gene construct for expression of heterologous proteins by using lactic bacteria (Borut Štrukelj)

Organization of conferences, congresses and meetings


R & D GRANTS AND CONTRACTS

1. Lectins as modulators of anti-tumor immune response
   Prof. Janko Kos
2. Evaluation of genotypes of bean (Phaseolus vulgaris L.) with the help of candidate genes for drought resistance
   Prof. Janko Kos
3. Food supplements for optimal diet in extreme conditions
   Prof. Borut Štrukelj

RESEARCH PROGRAM

1. Pharmaceutical biotechnology: Man and environment
   Prof. Janko Kos

VISITOR FROM ABROAD

1. Goran Hellekant, Medical School Duluth, Department of Physiology and Pharmacology, Duluth, Great Britain, 7–9 Sept. 2008

STAFF

Researchers
1. Dr. Jože Brzin, retired 7 Dec. 2008
2. Asst. Prof. Kristina Gruden*
3. Prof. Janko Kos*, Head
4. Dr. Tanja Popovič, retired 1 Dec. 2008
5. Dr. Boris Rogelj
6. Prof. Borut Štrukelj*

Postdoctoral associates
7. Dr. Aleš Berlec
8. Dr. Tomaž Langerholc, left 1 Jul. 2008
9. Dr. Jerica Sabotič

Postgraduates
10. Petra Avanzo, B. Sc.
11. Špela Magister, B. Sc.

Technical and administrative staff
12. Darja Žunič Kotar

Note:
* part-time JSI member
BIBLIOGRAPHY

ORIGINAL ARTICLES


PUBLISHED CONFERENCE PAPERS

Invited Papers

Regular papers
The basic characteristic of the Department of Environmental Sciences is multidisciplinarity: our research covers a variety of fields in natural and sociological sciences, especially physical, chemical, geological and biological processes that create our environment, society and human activity. Above all, we wish to explain the connections between natural processes and human activity, and the influences of those activities on human and environmental health. We are combining the scientific excellence of our research work with solving concrete technological problems in industry, education and development that are interplayed with research in the fields of analytical chemistry, radiochemistry and radioecology, biological and the geochemical cycles of elements, nutrition and health of humans, animals and plants, waste management, mathematical and GIS modelling of environmental processes and risk and environmental impact assessment.

Environmental analytical chemistry

In 2008, new analytical procedures for the determination of separate species, complexes and the isotopic composition of elements in the environment were developed, as state-of-the-art analytics is the basic prerequisite for researching the pathways and mechanisms of the transport and transformations of different natural and anthropogenic compounds in the environment. Some new analytical procedures were developed and applied on different sample matrices to study the speciation of elements (Al, As, Cr, Hg, Sn) and processes governing their distribution. A new analytical procedure using anion-exchange separation support based on convective-interaction media (CIM) was developed for the speciation of Al in unspiked human serum. The Al species in the serum were separated on a weak anion-exchange CIM diethylamine (DEAE) fast-monolithic column and detected online using ICP-MS. The results confirmed that 90 ± 5% of the Al in human serum is eluted under the transferring peak. The main advantage of the developed procedure is in its ability to quantitatively determine the Al species in human serum at very low concentration levels (around 1 ng mL⁻¹). We continued our collaboration with the University of Padova, Italy, in investigations of the potential pathogenic role of the β-amyloid(1-42)-aluminium complex in Alzheimer’s disease.

The parameters influencing the detection of organotin compounds by a pulsed-flame photometric detector were investigated in collaboration with the University of Pau, France, in order to develop a reliable analytical procedure for the determination of these toxic compounds in sewage sludge. To estimate the pollution with organotin compounds in the Slovenian marine environment, a survey based on measurements of butyl-, phenyl- and octyltin species by gas chromatography—mass-spectrometry was performed in the period from 2000 to 2006 in water, sediment and mussel samples from the Northern Adriatic Sea. The results indicated a decrease in the organotin pollution in the investigated period. The extraction of chromium species from yeast biomass (Candida intermedia) was optimized to determine the proportion of biologically active chromium bound to organic molecules. An amount of 0.05 mol L⁻¹ EDTA was found to be the optimal extracting agent.

For the determination of arsenic compounds, a method of arsenic speciation is used that allows the separation and quantitative determination of the twelve ecologically and/or toxicologically most important arsenic compounds by chromatographic separation in combination with atomic fluorescence spectrometry (AFS). In 2008, an alternative method with the coprecipitation of dibenzil ditiocarbaminate and AFS or ICP-MS detection was developed. The method uses ICP-MS detection.

The development and validation of the method for determining methylation and the reduction potentials of mercury using the radioisotope Hg¹⁹⁷ in environmental samples was continued. The method was validated on sediment samples from the Idrijca River. The sensitivity of the method was improved, so it is possible to perform experiments with additions of very small amounts of tracer. It was pointed out that when reporting the results of methylation of inorganic mercury, it is important to present the results, not only as the percentage of methylation (as in most publications up to now), but also in absolute amounts of produced methylmercury.

- The concentration and size distribution of nano-aerosols in different environments have been measured for the first time
- A new, analytical procedure for Al speciation in human serum at very low concentration levels was developed and applied in clinical studies
- Large-scale human biomonitoring in Slovenia was launched for the first time as part of the Environment and Health strategy.
- Waste materials from steel production were investigated for their effective re-use in construction.
This year we studied the extraction of Se compounds with enzymes from biological samples. In the literature, the most frequently used enzymes for Se speciation are proteases. The aim of our work was to check if commercially available enzymes are pure enough to be used for selenium speciation analysis and the contribution of impurities to Se determination on a real-sample basis. For this purpose, twelve commercially available enzymes of different origin and classification — protease, amylase, cellulase, lipase — were analysed. After the dissolution of the enzyme in water, the separation of the Se species was made by ion-exchange chromatography, with inductively coupled plasma mass spectrometry used as the detection system. The results showed that the Se content was found to be relevant in several cases. The highest value was obtained for β-amylase from barley, 3100 ng Se per g of enzyme. Speciation analysis showed that Se-methionine, selenite, selenate and some unknown compounds were present in several enzymes. In general, the identified Se species represented a low fraction of the total Se. For instance, only 17% of the total Se was determined for β-amylase from barley. On the other hand, about 100% of the total Se was identified in protease from Streptomyces griseus. The results from different lots of the same enzyme were not always comparable. Therefore, the presence of selenium species in commercially available enzymes could be due to the preparation procedure used for the enzyme, or as a degradation product. Therefore, attention should be paid to enzyme purity regarding selenium compounds when an enzyme is used for hydrolysis in determining the selenium species in samples with a low Se content. This work is very important on the field of Se speciation.

In the field of organic analytical chemistry our main achievement was the identification of numerous degradation products of selected pharmaceutical residues that persist in the environment. We also evaluated their toxicity and highlighted the importance of studying the fate of emerging contaminants, since many of the transformation products that we identified were found to be more toxic than the parent compounds.

In 2008 we continued with the development of methods based on instrumental neutron activation analysis (INAA) for the determination of macro, micro and trace elements in environmental samples. Among the INAA methods, the greatest attention is paid to the development of the k0-method, for which two programs are available: Kayzero for Windows and k0_IAEA. The former is validated at our department and has been used routinely for many years. We participated in the validation of the k0_IAEA software in the framework of the IAEA SLO-13279/1B project “Measurements and calculations of the neutron spectrum in different irradiation channels of the TRIGA Mark II reactor, Slovenia” and in cooperation with the Centre of Nuclear Technology from Belo Horizonte, Brazil (CDTN/CNEN). In addition, the k0-method has been optimized to work with samples that have Fe as a matrix element. The accuracy and reliability of the method we checked by analysing reference materials from Japan (ISS). Together with colleagues from SS. Cyril and Methodius University from Skopje, Macedonia, we analyzed iron minerals from Macedonia and discovered that the introduced technique k0 RNA is also an appropriate tool for such very complicated matrices. We participated in the certification processes of three new reference materials — Polymers EC590 and EC591 and Rye Grass ERM-GD281 — organized by the Institute for Reference Materials and Measurements (IRM, Geel, Belgium). We also collaborated with Slovenian industry, especially with thermal power plants and pharmaceutical factories.

The cooperation with EC/JRC/IRM was in the field of impurities in Pu-239 solutions and gamma spectrometry as well as the organisation of a laboratory intercomparison within the framework of preparing a new EU directive for drinking water. In the field of RNA, a method for the simultaneous determination of vanadium, uranium and manganese in biological samples through their short-lived radionuclides was developed as well as a method for cobalt determination through its short-lived nuclide Co-60m.

The Centre for Mass Spectrometry (CMS) services researchers from various scientific areas, such as chemistry, biochemistry, pharmacy, medicinal chemistry and biology. Currently, the CMS supports the research of about 30 national and international research programs, projects and some technological applications of the pharmaceutical industry and produces about 4500 analyses a year.

Recently, a new, hybrid orthogonal acceleration time-of-flight mass spectrometer (oaToF) Q-Tof Premier™ equipped with an atmospheric pressure ionization (ESI) source and coupled with an ultra-performance liquid chromatograph (Aqutix UPLC, Waters) has been applied in the following projects: a) identification of drug biodegraded products, and b) analyses of target endogenous opioid peptides in urine samples as potential biomarkers of autistic disorders, and c) ESI studies of proteins and the inclusion of complexes of cyclodextrins and isomeric coumaric acids.

We collaborated with the Metrology Institute of the Republic of Slovenia in ensuring measurement traceability at the international level as a carrier of reference etalon for soil. For the purpose of ensuring traceability we bought the certified reference material BCR-320R (Channel Sediment). We cooperated during the certification of new reference materials, and we were included into various interlaboratory comparison tests.

Our task within the EU project PHIME is to supervise all aspects of quality control and quality assurance. Therefore, four interlaboratory comparisons were organised to assess laboratory performance in determining trace elements and their species in blood. Special attention was paid to three elements, mercury, lead and cadmium, which are crucial for the realisation of the project.
Biological and geochemical cycles

We introduced the measurement of forest-soil respiration and flux measurements of CO₂ between vegetation and the atmosphere with the Eddy Covariance technique at different selected forest platforms. In addition, these conventional measurements were combined with measurements of the carbon isotopic composition. The obtained data were used as the input data for the model GOTILWA+ and Castanea, with which we have accurately studied the structure of the transport processes of carbon (plants-soil-water; layout design) in selected beech stands. Using ¹⁵N-labelled fertilizer, nitrogen cycling in the system soil-plant-soil water was studied on an experimental field near Ljubljana. Different agricultural practices for the production of white cabbage and endive were studied and optimized with respect to the biomass growth and the nitrate leaching from the soil.

The first results of the measurements of the carbon isotopic composition in tree rings in Slovenia show the possibility of using stable isotopes in the determination of anthropogenic emissions of CO₂ to the atmosphere. The potential of riverine tufas as palaeoclimate archives on the Dinaric carbonate platform was studied. Standard uncertainties attached to the input parameters used in isotope (δ¹⁸O) and geochemical (Mg/Ca) thermometers were estimated; it was shown that the complicated hydrological situation and uncertain trends in the temporal variation of input parameters increase the uncertainties to a level that makes tufas unsuitable for palaeotemperature estimation.

The importance of iodine for humans, especially in the early stages of life, is well recognized. The chemical forms of iodine in food supplements, infant formulae and iodated salt are either iodide (KI) or iodate (KIO₃). Because there are no or only few data on iodine uptake by yeasts, we investigated the influence of different sources of iodine, i.e., KI, KIO₃ and periodate (KIO₄), on its uptake in, and growth of, the model yeast Saccharomyces cerevisiae. KIO₃ inhibited the growth of the yeast the most. Even at a 400-µM initial concentration in the growth medium, the optical density was reduced by 23% in comparison to the control, where no KIO₃ was added. The uptake of different iodine sources by the yeast S. cerevisiae was minimal; in total less than 1%. We investigated the specificity of iodine uptake added as KIO₃ in the presence of Na₂SeO₄ or ZnCl₂ or K₂CrO₄ in the growth medium; the chromate had the most influence on the reduction of KIO₃ uptake.

A detailed investigation of the biogeochemical cycling of members of the uranium-radium decay series was carried out under the specific conditions within the area of the former uranium mine at Žirovski vrh. Special emphasis was given to the speciation of the particular radionuclides in the soil–water system, and their transfer and mobility within the studied area.

Our investigations in the Radon Centre have mainly been devoted to radon’s short-lived decay products (RnDP). Initially, they appear in the air as positively charged metal ions, which after recombination form clusters of nano RnDP aerosols of 10 nm size; a great part of them are then attached to particulates in air and are eventually present as radioactive RnDP aerosols in the size range 200–600 nm. The dependence of the fraction of the nanosize RnDP on the ventilation rate and the indoor air movement was studied under controlled conditions, both in a radon chamber and in the living environment. This research was recently extended to non-radioactive nano-aerosols. Thus, the concentration of the aerosols and their size distribution in the range from 10 to 1100 nm were carried out at some selected places, such as in a clean room, an office, a laboratory, a mechanical workshop and at a parking lot close to a street with heavy traffic. In addition, our study of the dependence of radon transport on the seismic and tectonic activity was continued by continuous radon recording in thermal springs at Bled and Hotavlje, in soil gas in Friuli and Sicily in Italy, and in Sapporo in Japan, as well as in air at a fault zone in the Postojna Cave. Machine-learning programs (decision trees and neuron networks) were used successfully to identify the anomalies in the time series of the radon activity concentration, possibly caused by seismic activity, and not ascribed solely to environmental parameters. The influence of tectonic activity on the soil-gas radon concentration was also studied at the Ravne fault (north-western Slovenia), where in several profiles, both perpendicular and parallel to the fault, the radon concentration, the radon exhalation rate, the soil permeability and the gamma dose rate were measured (Slovenia-Poland bilateral collaboration). In addition, on the slopes of Mt. Etna in Sicily, the radon concentration in the outdoor air was measured (Slovenia-Italy bilateral collaboration) and the relationship with the tectonic and volcanic activity sought.

On the River Idrija, research was focused on the periphyton community, both on natural substrates and using glass plates as artificial substrates. Samplings of the periphyton community and in-situ measurements of the relevant abiotic parameters (physical and chemical) were performed seasonally. The diatom composition is analysed in the periphyton from

Figure 1. In 2008, a method for the determination of Po-210 was developed. Po-210 is one of the most radiotoxic elements. The figure shows Po-210 spectra in fish samples measured with an alpha spectrometer.
natural and artificial substrates in order to establish whether there are significant differences in the abundance and diversity between the two communities and to see the differences in these communities at sites with different mercury levels. Using the radioisotope $^{197}\text{Hg}$, we traced the processes of mercury methylation ($\text{Hg}^{2+} \rightarrow \text{CH}_{3}\text{Hg}$) and reduction ($\text{Hg}^{2+} \rightarrow \text{Hg}$).

In the area of the former mercury mine at Idrija, work from previous years was continued and focused mainly on the development of erosion models for the simulation of mercury transport into the basin of the River Idrija.

Besides the anthropogenic sources of mercury, natural sources that are very poorly understood are also of great importance. Tectonic activity with the accompanying phenomena, such as volcanoes, earthquakes, tectonic movements of the earth’s crust and others are the main natural mercury sources in the environment. At Europe’s most active volcano, Mt. Etna, on the island of Sicily, Hg concentrations were measured in the air, the soil gases and evaporation in connection with other gases such as $\text{CO}_2$, $\text{SO}_2$, Rn and others. The influence of the tectonics on Hg evaporation was also studied at some other tectonically active areas, such as Postojna Cave and thermal springs in Hotavlje and Bled.

**Environment, nutrition, health**

Recently, much attention has been given to the research of chemical forms in which Se appears in functional foods and dietary supplements, as information only about Se concentration is not enough to estimate its bioavailability, mobility and eventual toxicity. The ability of several plants to accumulate and transform inorganic forms of selenium into bioactive organic compounds has important implications for human and animal nutrition and health. We studied the selenium (Se) distribution in the potato ($\text{Solanum tuberosum}$ L.) cultivar Desiree, enriched in Se by foliar spraying with a water solution containing 10 mg Se per L in the form of sodium selenate. Four combinations of treatments were utilized: well-watered plants with and without Se foliar spraying, and drought-exposed plants with and without Se foliar spraying. We optimized a method for the isolation and determination of selenium species. Water-soluble Se compounds were extracted from potato tubers by water or by enzymatic hydrolysis with the enzyme protease XIV or amylase or a combination of protease XIV and amylase. The extraction was performed using incubation at constant temperature and stirring ($37^\circ\text{C}$, 24 h) and by ultrasound-assisted extraction (300 W), using different extraction times. The results showed that the concentration of selenate extracted was found to be independent of the technique, whereas the concentration of SeMet changed with the enzymatic extraction technique. Selenate and SeMet were the main soluble Se species (representing 51–68% of the total Se) in the potato tubers, regardless of the growth conditions.

Stable isotopes were also used as tracers of the sources, origin and authenticity of various natural and processed foodstuffs, such as honey, oil, wine, fruit juices and milk.

An assessment of the Po-210 ingestion dose due to marine-food consumption was carried out. Fish and squid samples from the Slovenian market were collected in accordance with the statistical data on their consumption. The assessed yearly effective ingestion dose is 34 $\mu\text{Sv}$/year for fish and 5.0 $\mu\text{Sv}$/year for mussels.

Cadmium and arsenic metabolism was investigated in terms of its influence on the cellular protective mechanisms in human glia: in normal human astrocytes (NHA cells) and in human tumor cells (U87 astrocytoma). So far, we confirmed the interplay between metallothioneins and cadmium or arsenic, but also the influence of this interaction on copper metabolism. The metallothioneins identification and their interactions with various metals (Hg, Se, As, Cd, Sb, Cu, and Au) was also followed in tetrahymena, a unicellular organism used as environmental pollution marker. In a clinical study of cancer patients treated with arsenic trioxide we proceeded with the investigation of individual differences in the formation of arsenic metabolites. The metabolites were followed in blood and urine samples. In all cases, we also followed the metabolism of selenium regarding its involvement in cellular antioxidative mechanisms and its interactions with arsenic.

In cooperation with University Medical Centre in Ljubljana, many investigations on the influence of mercury on the health on Idrija’s inhabitants...
and the wider Slovenian population, especially women in childbearing age and pregnancy, were continued within the project PHIME.

Within the PHIME framework, research was conducted on exposure to cadmium, lead and mercury in different areas of Slovenia on the population of children aged between 6 and 11 years. Children living in rural (Žužemberk), urban (Ljubljana) and industrial (Idrija) areas of Slovenia were sampled for blood, urine and hair. The analytical work was done at the Jožef Stefan Institute and the University Medical Centre Ljubljana. This research provided preliminary information on general exposure to cadmium, lead and mercury of the selected Slovenian population of children and therefore preliminary reference values for Slovenia, which have not been identified so far.

Another study was conducted within the PHIME framework, in which we assessed the suitability of different validated as well as potential biomarkers (indicators) of prenatal methyl mercury exposure in humans, as this is of crucial importance when conducting large-scale epidemiological studies. We have evaluated and compared the total and methyl mercury values measured in maternal and umbilical cord blood, umbilical cord tissue, maternal scalp and pubic hair, placenta, foetal membranes and meconium, collected in connection with randomly selected parturitions in the Maternity Hospital in Ljubljana.

A human biomonitoring programme was implemented in Slovenia in 2008, which involves our department as well as the National Chemical Bureau of the Republic of Slovenia, the University Medical Centre Ljubljana and the Institutes of Public Health in Slovenia. Within this research, concentrations of toxic metals (cadmium, lead, mercury) and persistent organic pollutants (dioxins, furans, pesticides, polychlorinated biphenyls, polybrominated flame retardants) in body fluids (blood, breast milk, urine) and hair are followed. The obtained results will be the basis for a determination of the reference values and an estimation of human exposure to selected environmental pollutants.

**Environmental Monitoring**

To estimate the pollution with organotin compounds in the Slovenian marine environment, a survey based on measurements of butyl-, phenyl- and octyltin species by gas chromatography, mass spectrometry was performed in the period from 2000 to 2006 in water, sediment and mussel samples from the Northern Adriatic Sea. The results indicated a decrease of organotin pollution in the period investigated.

In cooperation with the Environmental Agency of the Republic of Slovenia, the monitoring of metals and organotin compounds in marine and riverine waters was continued.

Upgrade and maintenance of the database on the isotopic composition of the rivers Sava and Danube, as well as the GNIP database of the isotopic composition of the precipitation in Slovenia and Croatia, were performed.

Researchers participated in two regional projects of the International Atomic Energy Agency (IAEA) concerned with collecting internationally comparable data on air and marine pollution within the Mediterranean area as well as in radiological monitoring surveys of the Krško nuclear power plant and the Žirovski vrh uranium mine.

Concentrations of mercury in the air at the location Iskra (southern Slovenia) were measured for the Environmental Agency of the Republic of Slovenia. At the same location, measurements of mercury concentration in precipitations and deposition were also conducted. Monthly control measurements of the Hg concentrations in the River Sava were performed.

We collaborated in radioactivity monitoring of the environment in the area of the Nuclear Power Plant Krško (contractor Nuclear Power Plant Krško) and in the monitoring of food and drinking-water radioactivity (contractor URSJV). The specific activity of the radionuclides strontium and tritium in environmental samples, food and water were measured, as well as the presence of tritium and C-14 in gas effluents from the Nuclear Power Plant Krško. In the Idrija area, the long-term monitoring of mercury in precipitations, surface waters, air, garden vegetables, game, mushrooms and wild berries, were started.

Within the framework of postgraduate studies of a student from Serbia at the Biotechnical Faculty, the biomonitoring method using epiphytic lichens has been applied to assess the air quality in South Serbia. In-situ and transplanted lichens were used to obtain insight not only into the degree of heavy-metal air pollution but also to assess and control secondary contamination with depleted uranium at selected sites (Borovac I and Borovac II) around the city of Vranje, where an extensive decontamination took place in 2005. These two sites were the most bombarded sites by NATO in the south of Serbia with depleted uranium ammunition during the Balkan conflicts.

In the framework of an international project using mosses as biomonitor, a cross-border quality of mapping metal loads in mosses in 8 European countries in three sampling campaigns (1990, 1995 and 2000) was checked.

**Figure 3.** Concentrations and size distribution of nano-aerosols at a parking place near heavy traffic.
using geostatistical methods and the confounding factors affecting the local variation in metal concentrations (metal accumulation) in mosses were investigated. It was found that after using harmonised procedures for the preparation and chemical analysis, the main factors that influence the bioaccumulation of metals in mosses could be ranked as follows: moss species, potential emission sources around the monitoring site, canopy drip and precipitation.

**Clean technologies and waste management**

Among the research for industry, the most important investigations were performed on the cycling of mercury and its compounds, and some other toxic and non-toxic elements in the combustion cycle of clinker production in the cement plant Anhovo and electricity production in the Thermal Power Plant Šoštanj.

For the industrial partners EkoplanA, d.o.o. and Štore Steel, d.o.o., the potential for using electric arc furnace (EAF) dust was investigated. From the point of view of their physical and mechanical properties, as well as from the environmental point of view, it was experimentally established that EAF dust up to 2% per mass may be used in asphalt composites. It was also demonstrated that cement composites to which a maximum of 1.5% by mass of EAF dust has been added can be used in civil engineering for all purposes, including applications in the external environment. Cement composites with the addition of EAF dust can also be used as balances in washing machines which, at the end of their service life, are disposed of in landfills. The re-use of waste materials from steel production represents an opportunity to save natural resources.

The Hot Cell Facility was fully licensed as a nuclear facility. This enabled our participation in the project entitled "Improvement of the management of institutional radioactive waste" in Slovenia that was carried out for the Agency for Radwaste Management.

**Risk and environmental impact assessment**

Projects in 2008 were primarily associated with strategic (spatial) environmental evaluation. The project “A case study integration of risk assessment into spatial development planning of the Municipality of Koper” dealt with making a risk analysis of a part of the overall spatial planning process. A schematic representation of this integration is presented in Figures 1 and 2.

The targeted research project on sustainability of the Port of Koper is aimed at clarifying the role and contribution of the Port of Koper on the development of the coastal region. The results show that the port contributes significantly to environmental qualities' improvement at the local level; however, more should be done at regional level and in terms of public health investments.

A targeted research project on TIA (Territorial Impact Assessment) explores the impacts of the energy policy of Slovenia on the goals of spatial cohesion. Preliminary results provide an insight into the whole heterogeneity of the issue and the difficulty of specifying the impacts on individual territorial cohesion components: spatial efficiency, identity, and quality.

The EU projects CIVITAS II – MOBILIS and CIVITAS – ELAN confirmed the expected environmental benefits of different measures in public transportation in Ljubljana.

Expert basis for the preparation of an argumentation document on the reduction of mercury’s negative impacts on humans and the environment on a global level were contributed within the framework of the Slovenian Presidency of the EU. The document should present the EU’s official statements due to the demands of the United Nations Environmental Programme (UNEP).

The negative consequences of mercury mobilisation in the Gulf of Trieste due to the building of gas terminals were re-estimated.

**Some outstanding publications in 2008**

International projects

1. Floating Sensorised Networked Robots for Water Monitoring
   HYDRONET
   - Dr. Monica Vignoni, Scuola Superiore di Studi Universitari e di Perfezionamento
   - Sant’Anna, Pisa, Italy
   - FP 7-ENI-2007-1
   - Floating sensorised networked robots for Water monitoring

2. Early Recognition, Monitoring and Integrated Management of Emerging, New Technology Related Risks
   iNTeQ Risk
   - European Virtual Institute for Integrated Risk Management, Stuttgart, Germany
   - Asst. Prof. Branko Korić, Asst. Prof. Marko Gerbec

3. Evaluation of Methyl-mercury Production and Decomposition by Using Hg-197 Radiotracer Produced Out of Mercury Enriched in Hg-196 Isotope
   - Hg-197 Meth.ASSess
   - Prof. Milena Horvat

4. A Future for Radioecology in Europe
   - FUTURE
   - Asst. Prof. Branko Korić

   - PHIME
   - Asst. Prof. Branko Korić

6. Network of Reference Laboratories and Related Organizations for Monitoring and Bio Monitoring of Emerging Environmental Pollutants
   - NORMAP
   - Asst. Prof. Janja Vaupotič

7. Isotope Investigation of the River Sava in Slovenia: Long-term Isotopic Monitoring of Surface Water and Precipitation at Selected Sites
   - 14345/R0, R1
   - IAEA, Vienna, Austria
   - Asst. Prof. Nives Ogrinč

8. Measurements and Calculations of the Neutron Spectrum in Different Irradiation Channels of the TRIGA Mark II Reactor, Slovenia
   - 13279/R1
   - IAEA, Vienna, Austria
   - Dr. Radoklu Jamičník

9. Nutritional Status and Exposure to Mercury and its Compounds in Pregnant Women and Women of Childbearing Age in Former Mercury Mining Site using Nuclear and other Techniques; Exposure to Toxics and Potentially Toxic Elements in Women of Childbearing Age in Developing Countries
   - 13250/R1, R2
   - IAEA, Vienna, Austria
   - Prof. Milena Horvat, Dr. Jože Kotuk

10. Fellowship for Mr Dennis Kpakpo Adotei
    - IAEA Fellow, GHA/07017
    - IAEA, Vienna, Austria
    - Prof. Vekoslava Stibilj

11. Fellowship for Ms Gulnura Beishenkulova
    - IAEA Fellow, Geo/07015
    - IAEA, Vienna, Austria
    - Asst. Prof. Maxima Ignat’ev

12. Fellowship for Ms Maxim Ignatyev
    - IAEA Fellow, KIG/07016
    - IAEA, Vienna, Austria
    - Prof. Vekoslava Stibilj

13. Fellowship for Ms Mounir El Hassani
    - IAEA Fellow, MOR/08005
    - IAEA, Vienna, Austria
    - Dr. Radoklu Jamičník

14. Fellowship for Ms Gulnura Beishenkulova
    - IAEA Fellow, KIG/07028
    - IAEA, Vienna, Austria
    - Prof. Vekoslava Stibilj

15. Fellowship for Ms Mirjana Čolović
    - IAEA Fellow, SBE/08001
    - IAEA, Vienna, Austria
    - Asst. Prof. Nives Ogrinč

16. Fellowship for Mr Dennis Kpakpo Adotei
    - IAEA Fellow, GHA/07017
    - IAEA, Vienna, Austria
    - Prof. Vekoslava Stibilj

17. Sources and Sinks of Mercury in Freshwater Ecosystems
    - BALR/06/08/01
    - Prof. Ribeiro Guevara Sergio, Centro Atómico Bariloche, Comisión Nacional de Energía Atómica, Bariloche, Argentina
    - Asst. Prof. Milena Horvat

18. Supporting Activities in Upgrading the Homepage of Climate Change in SEE for Creating a List of Researchers and Providing Relevant Publications to publish
    - RTG 2007.GF.027-01
    - Cornelia Sterner, M.Sc., Dr. F. Pretenthaler, Prof. Bernhard Peliz, Edmund Müller, M.Sc., Joanneum Research Forschungsgesellschaft mbH, Institut of Technology and Regional Policy, Graz, Austria
25. Determination of Agua Regia Soluble Content and Total Content of As, Cd, Co, Cr, Hg, Fe, Mn, Ni, Pb, and Zn in Sewage Sludge

26. Characterisation of EBM-CD281 Rye Grass: Cr, Cu, Mn, Pb, Zn, by ICP-MS, Cd, Cr, Cu, Ni, Pb by ETAAS, Mn, Zn, by FAAS, As, Cd, Cr, Cu, Hg, Mn, Mo, Sb, Se, Sn, Zn, by K0-ENAA, Hg by CIAS, Hg by DIAA, As by EUNAA, Se by K0-ENAA

27. Characterisation Study for Total Br in Polymers (EC590 and EC591)

28. LOT 7: Measurements of Cd in Polyethylene

29. Improvement of the Management of Institutional Radioactive Waste in Slovenia

30. Radiolokalna istraživanja na području Bosne i Hercegovine

31. Determination of aqua regia soluble content and total content of As, Cd, Co, Cr, Hg, Fe, Mn, Ni, Pb and Zn in sewage sludge

32. Characterisation of EBM-CD281 Rye Grass: Cr, Cu, Mn, Pb, Zn, by ICP-MS, Cd, Cr, Cu, Ni, Pb by ETAAS, Mn, Zn, by FAAS, As, Cd, Cr, Cu, Hg, Mn, Mo, Sb, Se, Sn, Zn, by K0-ENAA, Hg by CIAS, Hg by DIAA, As by EUNAA, Se by K0-ENAA

33. Determination of Uranium Radioisotopes in Environments

34. Development of Innovative Technologies for Determination and Treatment of Xenobiotic Organic Compounds in Elastomer Systems

35. The Creation of Cypriot and Slovenian Analytical Databases for Authentic Fruit Juices

36. Stationary Radon Monitoring at the Slovenian Italian Border at the Etna Volcanic Area

37. Mercury Interdisciplinary Research for Appropriate clam farming in lagoon environment

38. Monitoring of Chemical and Physical Parameters at the Seismic Active Zone at the Slovenian Italian Border at the Etna Volcanic Area

39. The Estimation of the Impact of Mercury Released in Environmental by a Human Activity The Behavior of Mercury Released from the Mining Area

40. Cycling of Mercury in Contaminated Environments

41. Modelling of Mercury and its Compounds in Polluted Freshwater Systems: Comparison between Reservoirs in the Guihuo Province and the Idrička River System

42. Harmonization of Determining the Radiation Dose of the Population Originating from Radon in Slovenia and in Hungary

43. Radon Potential on Different Geologic Basis-continuation

44. Stable Isotope Applications in Hydrologic Studies of Slovenian and Serbian River Systems

45. Monitoring of Chemical and Physical Parameters at the Seismic Active Zone at the Slovenian Italian Border at the Etna Volcanic Area

46. Radon Potential on Different Geologic Basis-continuation

47. Radon Potential on Different Geologic Basis-continuation

48. Radon Potential on Different Geologic Basis-continuation

49. Radon Potential on Different Geologic Basis-continuation

50. Radon Potential on Different Geologic Basis-continuation

R & D GRANTS AND CONTRACTS

1. Chemical and biological cycling of compounds with endocrine disrupting function in wastewater treatment

2. Assessment of the risk from metal contaminated soils and aerosols to human health through advanced in vitro gastrointestinal and respiratory bioaccessibility tests

3. The impact of microbial processes on Hg biomagnification in food webs of the Gulf of Trieste (N Adriatic Sea)

4. Development and evaluation of a toxicity test for engineered nanoparticles with terrestrial isopods

5. Study of Defects in Si and Ge Irradiated by Fast Neutrons

6. Development and evaluation of a toxicity test for engineered nanoparticles with terrestrial isopods

7. Harmonization of Determining the Radiation Dose of the Population Originating from Radon in Slovenia and in Hungary

8. Radon Potential on Different Geologic Basis-continuation

9. Stable Isotope Applications in Hydrologic Studies of Slovenian and Serbian River Systems

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11. The Estimation of the Impact of Mercury Released in Environmental by a Human Activity The Behavior of Mercury Released from the Mining Area

12. Cycling of Mercury in Contaminated Environments


14. Harmonization of Determining the Radiation Dose of the Population Originating from Radon in Slovenia and in Hungary

15. Radon Potential on Different Geologic Basis-continuation

16. Stable Isotope Applications in Hydrologic Studies of Slovenian and Serbian River Systems

17. Monitoring of Chemical and Physical Parameters at the Seismic Active Zone at the Slovenian Italian Border at the Etna Volcanic Area

18. The Estimation of the Impact of Mercury Released in Environmental by a Human Activity The Behavior of Mercury Released from the Mining Area

19. Cycling of Mercury in Contaminated Environments


21. Harmonization of Determining the Radiation Dose of the Population Originating from Radon in Slovenia and in Hungary

22. Radon Potential on Different Geologic Basis-continuation
6. CO₂ fixation in river carbonates: mass balance, hydrological, geochemical and biochemical controls
   Asst. Prof. Sonja Lojen
7. Influence of arsenic trioxide metabolites on treatment of various cancer types
   Prof. Dr. Bogdan Kralj
8. Biochemical correlates of autism spectrum disorders
   Asst. Prof. Nives Ogrinc
9. Deprosted kast grasslands and their changes in sink activities for carbon
   Asst. Prof. Nives Ogrinc
10. The response of soil organic matter and natural ecosystems (primarily forests) to climate change
    Asst. Prof. Nataša Jaecks Vidic
11. Functional foods with polyphenol's antioxidants, plant proteins and trace elements
    Prof. Vekoslava Stibilj
12. Carbon transport processes and mechanisms in forest ecosystems
    Asst. Prof. Nives Ogrinc
13. The influence of UV-B radiation to antioxidant content and distribution in cultivated plants
    Asst. Prof. Vekoslava Stibilj
14. Integrated methodology for remediation of Hg contaminated sites
    Prof. Milena Horvat
15. Natural hydrochemical backgrounds of groundwaters in Slovenia
    Asst. Prof. Sonja Lojen
16. Nitrate migration in the plant-soil-water system
    Asst. Prof. Sonja Lojen
17. Biological methods for Hg monitoring
    Prof. Milena Horvat
18. Modeling, hydrodynamics, transport of suspended matter and pollutants using SPH
    Prof. Milena Horvat
19. The use of new materials from the recycled industrial products and building rubbles in civil engineering
    Asst. Prof. Radmila Milačič
20. Emission control of mercury and other toxic elements from termopowerplants, cement kilns and other high temperature industrial processes
    Prof. Milena Horvat
21. Radiotherapy and evaluation of their therapeutic potential
    Asst. Prof. Nives Ogrinc
22. Establishment of ratio between 129I and 127I in marine and terrestrial environment in Slovenia
    Asst. Prof. Vekoslava Stibilj
23. The comparison and development of new methods for determining the authenticity of oil in foodstaff
    Asst. Prof. Nives Ogrinc
24. Determination of geographical and botanical origin of honey
    Asst. Prof. Nives Ogrinc
25. Fate and speciation of pollutants during production of sythenetical fuel and pure hydrogen from polluted biomass
    Dr. Jure Kotnik
26. Port of Koper in the framework of sustainable development of the coastal region
    Asst. Prof. Branko Korić
27. Territorial impact assessment of sectoral policies
    Asst. Prof. Branko Korić
28. Development and preparation of new radiotherapeutic agents for targeted therapy
    Dr. Urška Repinc

RESEARCH PROGRAMS

1. Modelling of structure-property relationships - Q SAR-QSPR
   Dr. Bogdan Kralj
2. Cycling of nutrients and contaminants in the environment, mass balances and modeling of environmental processes and risk analysis
   Prof. Bogdan Kralj
3. Modeling and environmental impact assessment of processes and energy technologies
   Asst. Prof. Borut Smidiš

NEW CONTRACTS

1. Radioactivity monitoring in RS 2009-2010
   Krško NPP
   Prof. Vekoslava Stibilj
2. Monitoring of radioactivity in drinking water for 2008
   Ministry of Health, Slovenian Radiation Protection Administration, Ljubljana
   Prof. Vekoslava Stibilj
3. Co-funding of measurement traceability of reference etalons and reference measurements to international level in year 2008
   Ministry of Higher Education, Science and Technology, Metrology Institute of the Republic of Slovenia, Ljubljana
   Dr. Polona Vreča
4. Control of mercury emission and other elements in termo power plants, cement production and other high temperature industrial processes
   Esotech, d. d., Velenje
   Prof. Milena Horvat
5. Lišćiana measures evaluation in CITVITAS-Mobiles
   Municipality of Ljubljana
   Prof. Branko Korić
6. Integrated methodology for remediation of contaminated sites
   Mercury Mine, Idrija
   Prof. Milena Horvat
7. Istope analyses for water tracing
   Ministry of the Environment and Spatial Planning, Environmental Agency of the Republic of Slovenia, Ljubljana
   Asst. Prof. Sonja Lojen
8. Support during the Slovenia presidency EU
   Ministry of Health, Slovenian Radiation Protection Administration, Ljubljana
   Prof. Milena Horvat
9. Emission evidences of POPs and IM with implementing the UNECE questionaries
   Ministry of the Environment and Spatial Planning, Environmental Agency of the Republic of Slovenia, Ljubljana
   Dr. Taja Karadžu
10. Analyses of selected metals, mercury and organotin compounds in water and cadmium and mercury in sediment and mussels
    Ministry of the Environment and Spatial Planning, Environmental Agency of the Republic of Slovenia, Ljubljana
    Asst. Prof. Janaš Ščančar
11. Monitoring of mercury in precipitation
    Ministry of the Environment and Spatial Planning, Environmental Agency of the Republic of Slovenia, Ljubljana
    Prof. Milena Horvat
12. Technical basis for the spatial development plan of the Ljubljana urban region
    Urban Planning Institute of the Republic of Slovenia
    Prof. Branko Korić
13. Radioactivity monitoring RŽV 2008
    Zirovski vrh Mine
    Asst. Prof. Borut Smidiš
14. Measurements of CH₄ and H₂ in gas effluents
    Krško NPP
    Prof. Vekoslava Stibilj

VISITORS FROM ABROAD

2. Ingrid Bergdahl, Staffan Skarving, University of Gothenburg, Gothenburg, Sweden, 14−18 Jan. 2008
4. Mirjana Čolović, Institute of Nuclear Sciences, Physical Chemistry Department, Vincza, Belgrade, Serbia, 2 Mar. to 3 Apr. 2008
5. Prof. Dr. Hiroki Tamura, Graduate school of Engineering, Hokkaido University, Sapporo, Japan, 15−10 Mar. 2008
7. prof. dr. takashi tomiyasu, Dr. akito matsuyama, national minamata institute Dr. ryusuke imura, Dr. hitoshi kodamatani, Kagoshima University, 23 aug. 2008 to 23 aug. 2008
8. ljudmila Antalovcic, IUSS International Center for Environmental Education and Communication, Peng Bin, Meng Bo, Yao Heng, State Key Laboratory of Environmental Geochemistry, Chinese Academy of Science, Guiyang, China, 5−10 May 2008
9. Branko Pivac, Rudjer Bošković Institut, Zagreb, Croatia, 10 Jun. 2008
10. Dr. mmkn Toumouchi, Division of Quantum science and Engineering, Graduate school of Engineering, Hokkaido University, Sapporo, Japan, 6−11 Aug. 2008
11. Dr. S. Savoie, Université de Pau, Pau, France, 24 Apr. to 3 May 2008
12. Prof. Dr. Werner Hoffmann, Division of Physics and Biophysics, Department of Materials Engineering & Physics, University of Salzburg, Austria, 5−6 June 2008
13. Dr. Polona Vreča, Division of Quantum science and Engineering, Graduate school of Engineering, Hokkaido University, Sapporo, Japan, 6−11 Aug. 2008
14. Dr. polona Vreča, Division of Quantum science and Engineering, Graduate school of Engineering, Hokkaido University, Sapporo, Japan, 6−11 Aug. 2008
15. Dr. dušan Golobočanin, Vinča institute, Belgrade, Serbia, 16 Jul. to 16 Aug. 2008
16. Prof. Dr. michel Arnaud-Airaud, Center of Studies of Environmental and Technical Sciences, CNES, Rabat, Morocco, 1−21 Aug. 2008
17. Dr. došo Goloborodchik, Vinča Institute, Belgrade, Serbia, 16 Jul. to 16 Aug. 2008
18. Dr. polona Vreča, Division of Quantum science and Engineering, Graduate school of Engineering, Hokkaido University, Sapporo, Japan, 6−11 Aug. 2008
BIBLIOGRAPHY

Staff

Researchers
1. Asst. Prof. Ilijana Benčič
2. Dr. Ing. Piluška Benič
3. Asst. Prof. Ester Heath
4. Prof. Milena Horvat, Head
5. Dr. Radojko Jaćimović
6. Dr. Zvonka Jeran
7. Prof. Branko Korić
8. Dr. Jože Kotnik
9. Dr. Bogdan Kralj
10. Dr. Andrej Osterc
11. Asst. prof. Sonja Lojen
13. Dr. Antoine Ščančar
14. Dr. Rožle Jakopič
15. Asst. prof. Borut Smodiš
16. Prof. Vekoslava Stibilj
17. Prof. Brent Peyton
18. Prof. Timothy R. Ginn
19. Asst. prof. Janja Vaupotič
20. Dr. Zdenka Šlejkovec
21. Prof. Vekoslava Stibilj
22. Prof. Peter Green
23. Dr. David Kocman
24. Dr. Tjaša Kanduč
25. Dr. Brendan Keane
26. Dr. Darja Mazej
27. Prof. Brent Peyton
28. Asst. prof. Ljudmila Benedik
29. Dr. Anna Riggio
30. Dr. Filippo Antonio Ugozzi
31. Dr. Darija Gibičar
32. Dr. Andrea Zelenik
33. Dr. Rožle Jakopič
34. Dr. Annarita Zuccato
35. Dr. Suzana Žižek
36. Dr. Drago Berneklj
37. Dr. Valentina Boscaini
38. Dr. Tadeja Milivojevič Nemanič
39. Dr. Anna Riggi
40. Dr. Itsik Shani
41. Dr. Paolo De Zorzi
42. Dr. Angela Casini
43. Dr. Mattia Guerrieri
44. Dr. Ivan Kreft
45. Dr. Andreja Fajgelj
46. Dr. Tea Zuliani
47. Dr. Paolo De Zorzi
48. Dr. Maria Angelina Di Cesare
49. Dr. Fabio Faleiro
50. Dr. Marina Giudici
51. Dr. Barbara Svetek
52. Dr. Barbara Svetek
53. Dr. Barbara Svetek
54. Dr. Barbara Svetek
55. Dr. Barbara Svetek
56. Dr. Barbara Svetek
Postdoctoral Associates

Original Articles


Jožef Stefan Institute


Annual Report 2008


TEXTBOOKS AND LECTURE NOTES


THESIS

Ph. D. Theses


Our research brings together the different fields of automatics, robotics, biocybernetics, kinesiology and environmental medicine. Most of the research topics are connected to the so-called “movement of man and machine” and its connection and interaction with the environment. The purpose of our activities is to bridge the gap between the advanced knowledge from research and systems development, in order to provide our customers in industry, medicine and sports with sophisticated applied technology.

The main directions of research in the past year focused on: a) humanoid robotics, b) learning strategies and the control of robot systems, c) studies of human physiology in extreme environments, d) the evaluation of protective equipment, e) the development of biomedical devices and methods, and f) the robotics and automation of industrial manufacturing.

In the area of humanoid robotics we continued with our research on the realization of cognition in humanoid robots. This work was initiated by our participation in the FP6 Integrated Project “Perception, Action, and Cognition through Learning of Object-Action Complexes” (PACO+). PACO+ aims at the design of a cognitive robot that is able to develop perceptual, behavioural and cognitive categories in a measurable way and to communicate and share these with humans, as well as with other artificial agents. In the past year we focused on robot action learning, without assuming the availability of models describing the physics of the task. Our basic strategies were twofold: learning by exploration, and imitation learning. Learning by exploration was used to provide basic sensorimotor knowledge, whereas imitation learning was applied to overcome problems arising from high dimensional and continuous perception-action spaces. We tested various approaches to learning, including neural networks, reinforcement learning, dynamic systems, and locally weighted regression. As particular examples we studied the learning of tasks that involve the manipulation of objects, including pushing, pouring, and reaching. Another important issue was to what extent we can use 3D vision on a humanoid robot with an active vision system. This is much more difficult than on a static vision system because various transformations need to be updated online to enable 3D computations. We showed that such systems can nevertheless be used to acquire 3D information with sufficient accuracy to implement tasks such as grasping.

We continued to collaborate with ATR Computational Neuroscience Laboratories, Kyoto, Japan. Together we completed the project “Sensorimotor primitives for nonverbal humanoid communication”. The aim of this research was to implement methods that can be used to transfer human gestures to humanoid robots. This comprised the transformation of motion-capture data acquired from people demonstrating a gesture, movement interpolation between the key postures of the observed gestures, and a suitable trajectory controller that enables the robot to follow the newly learned gestures. In this way we provided techniques that can be used by a humanoid robot to acquire a rich repertoire of gestures. Special attention was paid to the hand gestures (involving one or two hands), which are the most numerous category of gestures.

We continued with studies of the methods for controlling periodic robotic tasks. The emphasis was on a system for imitating periodic motion without specifying the input frequency and the waveform of the signal. The important improvement is that all an operator needs to do is to demonstrate a few periods of the signal and the system will extract the frequency and learn a single period. Two methods were used, i.e., the adaptive frequency oscillators for extracting the frequency and a statistical learning method for learning the waveform. The work was implemented and demonstrated on a HOAP-2 robot at EPFL in Lausanne, Switzerland.

In the field of robot control we developed an original strategy for treating the kinematic redundancy that originates from the shape of the tool or the active object. The idea is to describe the tool as a serial link mechanism and then to include this mechanism as a virtual mechanism in the control and learning by exploration was used to provide basic sensorimotor knowledge, whereas imitation learning was applied to overcome the problems arising from high-dimensional and continuous perception-action spaces.

Learning by exploration was used to provide basic sensorimotor knowledge, whereas imitation learning was applied to overcome the problems arising from high-dimensional and continuous perception-action spaces.
optoelectronic measuring system attached to the hands and legs and then the motion is captured with an optoelectronic measuring system.

Figure 3: Human-motion analysis during a fall: Twelve markers are attached to the hands and legs and then the motion is captured with an optoelectronic measuring system.

To achieve a flexible production facility for the concurrent production of different tea products, functional improvements to the supervisory and control systems were needed, together with the tight integration of the manufacturing execution and enterprise resource planning levels.

The detection and recognition of abnormal events (such as falls) or unexpected behaviour that may be related to a health problem in elderly people has been studied in the framework of the European project “Ubiquitous Care System to Support Independent Living” (CONFIDENCE). Using a motion-capture system we measured the motion of people for different everyday situations and for abnormal behaviour, like characteristic falls or motion influenced by the typical pathologies associated with elderly people. After the motion capture and the tracking of 12 markers, the trajectories of the characteristic points of the human body were used as the input for analysis, modelling and recognition.

In the context of our past research on kinematics and dynamics we continued our research of the energy-efficient motion of human and robot mechanisms. Due to the low gear-ratio between the motors and the joints of the robotic jumper that we developed in previous years we extended all mechanisms. Due to the low gear-ratio between the motors and the joints of the robotic jumper that we developed in previous years we extended all mechanisms.

We investigated the closed-loop transfer of human motion to a humanoid robot where a human subject actively controls the humanoid robot motion through an adaptive controller. Instead of the visual feedback information that we used in the past, we designed and manufactured a Stewart parallel platform that enables the information transfer from the humanoid robot to the subject, which controls the robot through the closed loop. We enhanced the adaptive controller with the Supported Vector Machines method. The research was carried out in collaboration with the Japanese institute ATR.

During the past year we continued our research on human-body movement during sports activities. We developed and built a robot-skier mechanism, capable of autonomous navigation of the ski slope. The robot uses a complex sensory system for control and navigation, which consists of robot vision, GPS, force sensors and an electronic gyroscope. We applied hierarchical control structures and developed a new decision-making stabilization control algorithm, which simultaneously tracks the desired path of a non-holonomic system and ensures the stability in the presence of external disturbances on the ski slope. We also developed a new navigation algorithm based on a human-like navigation strategy. One of the most challenging problems was the race-gate detection using a vision sensor in the presence of changeable lighting conditions in an unstructured environment. We solved the problem using the extended Kalman filter for the path prediction and reconstruction. We also accomplished a number of experiments on the ski slope and proved that our robot is capable of autonomous skiing between the gates on the ski slope.

We continued the applied research work for a large regional food production company Droga-Kolinska. Specifically, we were working on a three-year R&D project to make a major rearrangement and upgrade of a tea-production plant. The company has taken over complete tea production...
for a foreign company. In order to integrate the production of existing and new items at the same plant, major changes and updates to the present facility are required. To achieve a flexible production facility and the concurrent production of a large number of different tea products, we carried out the functional improvements of the supervisory and control-system components. Following the introduction of the company’s new manufacturing execution and enterprise resource planning levels we also designed and developed components for the integration of these with the plant’s supervisory and control system.

In the past year we started to cooperate with a large glass production company Steklarna Hrastnik. We started a feasibility study for the automation of a production cell where the operations are now predominantly manual. We are defining the specifications of the requirements and the solutions, identifying the processes that are critical for the automation and proposing the appropriate solutions. Following this phase, the intention of both partners is to carry on with the design and implementation of an automated production cell.

In cooperation with the Slovenian Olympic Committee we continued to conduct research in the area of hypoxic training, particularly in the use of a “sleep high and train low” regimen. The experiments were performed at the Olympic Nordic Centre Planica, where the subjects slept at simulated altitudes of 2800 to 3200 metres above sea level and trained at ambient conditions during the day. In addition to other aspects affecting performance, we investigated the effect of prolonged hypoxic training on the oxygenation of the brain and skeletal muscle. Additionally, within the framework of a project funded by the Ministry of Defence we studied the effect of prolonged hypoxic training on the cold-induced vasodilatation (CIVD) response in hands and feet. We showed that the response is substantially improved in the feet, suggesting that hypoxic exercise may act as a protective mechanism against cold injury. Our current research is focussed on determining the mechanism of this hypoxia-induced improvement of CIVD.

Within the framework of the “Knowledge for Security and Peace” funding initiative of the Ministry of Defence, we demonstrated the contribution of individual components of the protective clothing ensemble worn by members of the Slovenian Armed Forces in desert conditions to the overall heat stress under simulated desert conditions while wearing full battle gear. Experiments with human subjects evaluated the physiological responses during work in hot and dry conditions, whereas studies with a manikin determined the thermal and evaporative resistances of different combinations of garment ensembles for work in desert conditions. With colleagues from the Centre d’Etudes de Physiologie Appliquee at CNRS, France, we evaluated the psychomotor ability of subjects during prolonged work in a hot and dry environment simulated in the climatic chamber. Studies completed with colleagues from the University of Wollongong, Australia, revealed the regional pattern of sweating for the foot, hand, torso, and head. These regional patterns of sweating were incorporated into the control of sweating in the sweating thermal manikin. This innovation allows a more physiological evaluation of the thermal characteristics of the clothing and clothing systems. The development and manufacturing of manikins has now been transferred to a UCS d.o.o., a small-medium enterprise.

An older version of the electromechanical Gait simulator was modified to obtain a more reliable device and it is now used as a reference and testing simulator. A built-in micro PLC is used for the control and communication with other devices. The new Gait simulator enables the thorough testing and evaluation of footwear under different conditions, for different gait paces and loads.

In collaboration with the Swedish Defence Research Agency we investigated the efficacy of different pharmacological agents on motion sickness. The focus of our research was also to determine which pharmacological agents also exert an influence on temperature regulation in cold environments. This study revealed which agents would be preferred in extreme environments.

Cooperation with the Swedish Defence Research Agency also continued in the fields of space and diving medicine. During investigations of the effects of simulated weightlessness on physiological systems conducted at the Orthopaedic Hospital Valdoltra, Ankaran, Slovenia, we investigated the effect of the regular local distension of vessels of one leg on the vascular distensibility, and compared the results with the untreated leg. We also investigated the effect of 5 weeks of bed rest on the risk of decompression...
sickness. Astronauts and cosmonauts need to conduct a decompression procedure in preparation for extravehicular activities (EVAs). Namely, the atmosphere in the international space station is normobaric, whereas the pressure in the space suit is substantially lower. Thus, donning the space suit requires a carefully controlled decompression procedure to avoid the aetiology of venous gas emboli (VGE), which would enhance the risk of decompression sickness. In our study we investigated the risk of decompression sickness during EVAs in collaboration with the Eye Clinic at the Clinical Centre of Ljubljana. In this collaboration we also compared the incidence of VGE with ocular tear film bubble formation, both precursors of decompression sickness.

**The most important technological achievements in the past three years**


**Awards and appointments**

1. Igor Mekjavić: Borelli medal for his Original Contribution to Space Medicine, granted by 2nd University of Napoli, Italy.

**INTERNATIONAL PROJECTS**

1. Ubiquitous Care System to Support Independent Living CONFERENCE
   7. FP 218498
   EC, Centro de Estudios e Investigaciones Tecnicas de Guipuzcoa, San Sebastian, Spain
   Prof. Leon Žlajpah, Prof. Matej Gams
   2. Innovation Relay Centre of Slovenia S-HRC/04-08
   6. FP 510419 (IBC 6)
   Alice Wu, European Commission, DG Enterprises and Industry Innovation Policy D/2, Support for Innovation, Brussels, Belgium
   Prof. Leon Žlajpah, Prof. Peter Stegnar
   6. FP 027657
   EC, Universität Karlsruhe (TH), Karlsruhe, Germany
   Dr. Aleš Ude
   4. European Robotics Network EU-ROX
   6. FP 507728
   EC, Kungliga Tekniska Högskolan, Stockholm, Sweden
   Prof. Jadrjan Lenarčič
   5. Sensorimotor Primitives for Nonverbal Humanoid Communication 027657
   Advanced Telecommunications Research Institute International, Computational Neuroscience Laboratories, Department of Humanoid Robotics and Computational Neuroscience, Kyoto, Japan
   Dr. Aleš Ude

6. Human to Humanoid Robot Full Body Motion Transfer BI-JP/08-10/009
   Dr. Erhan Oztop, JST, IORP Computational Brain Project/Advanced
   Telecommunications Research Institute International (ATR), Computational Neuroscience Laboratories, Kyoto, Japan
   Dr. Jan Babič

**R & D GRANTS AND CONTRACTS**

1. Controlled internal combustion engine
   Dr. Jan Babič
2. System for automatic supervision and control of a production line for simultaneous production of different products
   Asst. Prof. Leon Žlajpah
3. Protective systems for warrior
   Prof. Igor Mekjavić

**RESEARCH PROGRAM**

1. Automation, robotics and biocybernetics
   Prof. Jadrjan Lenarčič

**NEW CONTRACT**

1. Production analysis and automation assessment for a class of glass components
   Steklarna Hrastnik - Opal LLC, Hrastnik
   Dr. Anton Ružič

**VISITORS FROM ABROAD**

1. Dr. Tamim Asfour, University of Karlsruhe, Germany, 30 Sept. to 7 Oct. 2008
5. Denis Herzog, University of Aalborg, Denmark, 3 Jan. to 31 Mar. 2008
7. Dr. Minija Tamošiūnaitė, Vytautas Magnus University, Kaunas, Lithuania, 11–22 Nov. 2008
STAFF

Researchers
1. Dr. Jan Bah!é
2. Dr. Ljudslav Lenart
3. Prof. Igor Mekjavić
4. Dr. Bojan Nemec
5. Dr. Anton Ružič
6. Dr. Aleš Ude
7. Asst. Prof. Leon žaižap, Head
Postdoctoral associates
8. Dr. Stylianos Kounalakis
9. Dr. Damir Omrčen
10. Dr. Martin Tomšič
Postgraduates
11. Mitja Bah!é, B. Sc.
12. Tadej Debevec, B. Sc.
13. Andrej Gams, B. Sc.

BIBLIOGRAPHY

ORIGINAL ARTICLES

TECHNICAL OFFICERS
20. Andrej Kosi, B. Sc.
22. Marija Trampuž, B. Sc.
23. Bogomir Vrhovec, B. Sc.

TECHNICAL AND ADMINISTRATIVE STAFF
24. Dušan Filipić
25. Josip Opek
26. Janez Zalar

REVIEW ARTICLES AND CHAPTERS IN BOOKS
2. José González-Alonso, Ola Eiken, Igor B. Mekjavić, "A critical core temperature and the significance of absolute work rate", In: Physiological bases of human performance during work and exercise,
PUBLISHED CONFERENCE PAPERS

Invited Papers


Regular papers


TEXTBOOKS AND LECTURE NOTES

1. Drago Matko, Peter Omeršel, Anton Ružič, Marjan Mihelin, "Regulacijsko podpro sto načrtovanje, Ljubljana, Fakulteta za elektrotehniko in računalništvo, 1988-.

PATENT APPLICATIONS

The Department of Systems and Control is engaged in research, development, applications and education across a variety of areas of control technology. Its mission is “to bridge the gap between theory and practice”. Hence, the research activities are relatively application oriented, and the content of the work is closely related to the needs of production companies. 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 and construction 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.

Basic and applied research

The basic and applied research during 2008 was devoted to four sub-areas: the analysis and control of complex systems and processes, fault detection and isolation, computer-integrated production control, and advanced implementation technology.

In the sub-area analysis and control of complex systems and processes our work was devoted to the development of some general purpose methods. The research in dynamic systems modelling of Gaussian process models was directed towards various computer-simulation methods and the propagation of prediction uncertainties. Application case studies of conventional and explicit predictive control based on Gaussian process models were also pursued. In the field of advanced control algorithms we continued R&D on parametric predictive controllers based on linear and hybrid models. In the final phase of the EU 6FP project CONNECT we have successfully completed two pilot case studies using such controllers in industrial environments: pressure control in a vacuum chamber and cooling-water temperature control in a CHP unit. The tuning of PID controllers is a traditional research area at our department. In 2008 a new, efficient tuning algorithm was developed, which does not require any additional input from the operator, except an open-loop or a closed-loop experiment.

New control methods and algorithms were developed in various specific problem domains. Within the EU 6FP project PEGASE a system for landing aircraft and helicopters automatically is being developed, which is completely autonomous and does not depend on any kind of infrastructure or equipment, located outside the aircraft. The idea is to guide the aircraft using images, acquired by a camera installed on the aircraft. In 2008 a position-based predictive control scheme that uses a set of local linear models was developed (Fig. 1). Within the EU 6FP project PRISM the control algorithms for the online dosing of process ingredients was proposed and tested on the developed mathematical model of the polymerization process. The control algorithms keep the reactor temperature in a narrower region and shorten the batch cycle by around 10%. For wastewater-treatment processes, research on the automatic generation of conceptual descriptions of classifications was performed in cooperation with foreign partners.

In the sub-area of fault detection and isolation work has been conducted along two main lines. In the area of rotational machinery the focus was on gearbox drives. In cooperation with the Faculty of Mechanical Engineering, University of Ljubljana, a laboratory test-bed has been functionally completed along with a new prototype for online oil analysis (Fig. 2). The software for the administration of the experimental runs is realized in the Labview environment. It takes care of the acquisition and archiving of 21 measurement channels, so that the content is accessible over the web. Thus, a valuable benchmark is believed to become available to the researchers and potential users. Research has been concentrated on feature extraction for several of the most common faults in mechanical drives, such as pitting, scarfing, unbalance and various misalignment faults. New algorithms have been designed by employing the vibration measurements, the noise and the current of an electrical motor. An extensive laboratory study has been performed, showing that features based on electrical current reflect the nature of mechanical faults in mechanical drives reliably enough. This result paves the way for the development of an efficient, low-cost monitoring and fault-diagnosis device, which would be widely applicable in industry.

Within the highest state awards for scientific and research achievements, issued by the Slovenian Ministry of Higher Education, Science and Technology, the “Puh” award for development achievements was this year bestowed on our colleague Dr Gregor Dolanc, for a system for the automatic control of a steel-strip slitting line.

Figure 1: A simplified scheme of the image-based aircraft-landing control system
Another area refers to the robust model-based fault diagnosis of non-linear dynamic systems. Almost all of the available techniques assume prior knowledge of the system model, which is not easy to obtain. Therefore, the emphasis in the initial phase of the research was on the identification of continuous nonlinear models from discrete process data. This includes parameter estimation, the estimation of noise statistics and, potential miss-modelling effects.

A part of the work related to this sub-area was devoted to the EU 6FP project BRACCIA, which deals with the problem of monitoring the depth of anaesthesia. A special device, Cardio&Brain Signals, which was developed at our department, was used to perform experiments on laboratory animals during anaesthesia. The gathered data was then analysed using state-of-the-art methods for causality inference. The preliminary results of the study indicate that interactions between several biological oscillations could be used to monitor the depth of anaesthesia.

Our research in the sub-area of computer-integrated production control was concentrated on the design and verification of a hierarchical production control system. In 2008 a concept for production control, based on an expert system for a case-study chemical batch production, was developed. The activities towards the development of a suitable methodology for the identification of key production indicators have also been performed using the well-known Tennessee-Eastman benchmark process.

In the area of advanced implementation technologies a part of the activities was devoted to the development of a rapid-prototyping tool for the design and implementation of control algorithms. A feed-forward compensator, multivariable controller, and PFC (Predictive Functional Controller), with appropriate tuners, have been implemented in 2008. The second part was related to methods and tools for the development of control SW. Guidelines for the systematic procurement of software tools, used for the realization of the model-driven engineering paradigm in software development, have been developed. These guidelines minimize the cost and risk during the adoption of model-driven engineering. Based on the guidelines a suitable tool was selected. To fulfil the needs for the development of new electronic devices further work on the environment, which will enable the design of embedded control and digital signal processing systems, was carried out. The ARM-microcontroller-based evaluation boards were successfully connected into the Ethernet communication network and the distant code downloading and execution supervision were prepared. With the connection to the LabView software tools a very convenient design environment was established and successfully used during the design of the ARM-based embedded control devices for various industrial customers. Also, the Cortex-M3-based ARM microprocessor was evaluated for diverse applications.

R&D projects for industry and other users

In cooperation with the Slovenian Ministry of Defence four projects in the area of fuel-cell-based system applications and the development of subsystems for fuel-cell power units are being performed. In November 2008 the project to install a 7-kilowatt fuel-cell-based auxiliary electrical power unit into a special purpose military vehicle was completed. A still ongoing project is the design of a mobile cogeneration fuel-cell-based system for military use, where during this year the complete project documentation has been elaborated. In the frame of the project with the goal to develop a reliable ceramic fuel reformer for small power fuel cells we have developed a miniature reactor for steam reforming. The last ongoing project is the development of the experimental laboratory set-up for the testing and validation of various subsystems for PEM fuel cells, where in 2008 all the necessary subsystems were defined and the majority of the installation equipment was purchased.

We were also very active in R&D projects for industry. Based on a contract with the company DOMEL an Air Delivery Control System was developed. It is intended for the control of air flow in the fuel-cell and natural-gas reformer based a co-generation heating/power supply system. The control system consists of the SmartModule control board.
and the control algorithm. The SmartModule is an ARM-based embedded control board, while the algorithm is based on the cross-coupled control automaton and PID control loops. Besides the functional requirements a low cost was also taken into consideration during the design as the final product is also intended for domestic applications. A small series of 25 SmartModules was produced and sold to the PlugPower company (Fig. 4). For the company GOAP a new version of an algorithm for calculating the optimal room-temperature set-points in buildings was developed and tested on a simulation model of a hotel building.

In cooperation with the company INEA a control system for the resin-synthesis process at the COLOR chemical works was developed. In the frame of the project the batch control tool PLCbatch was used. Based on the feedback information from the project, the tool was further improved in terms of the phase behaviour and synchronization model and the recipe system efficiency in terms of reducing the repetition of information and increasing the degree of reuse. For the company Danfoss-Trata a new, patented, innovative system for reducing the oscillations in the control loop has been developed and tested within the project “Intelligent Actuators”. For the same company a new series of electronic drives for valves, based on BLDC motors, has also been developed.

**Education and training activities**

Some members of the department are giving lectures and practical courses at 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 M.Sc. and Ph.D. students. Special care was given to post-qualification training for engineers from industry. In 2007, four one-week courses were organized. These courses were organized in close cooperation with the Information Technologies Knowledge Transfer Centre at the Jožef Stefan Institute.

**Some outstanding publications in the past three years**


**The most important technological achievements in the past three years**

1. A series of electronic drives for valves, based on BLDC motors, 2008, (Janko Petrovič, Damir Vrančič, Aleš Svetek, Stane Černe, Miroslav Strubelj)
2. PLCbatch – a tool for the control of batch processes with PLC’s, based on the S88.01 standard, 2007, (Giovanni Godena)

**Awards and appointments**

1. Dr Gregor Dolanc: within the “Zois” awards, the highest state awards for scientific and research achievements, issued by the Slovenian Ministry of Higher Education, Science and Technology, the “Puh” award for development achievements was this year bestowed for a system for the automatic control of a steel-strip slitting line.
INTERNATIONAL PROJECTS

1. Design of Advanced Controllers for Economic, Robust and Safe Manufacturing Performance
   CONNECT
   6. FP, COOP-CT-2006, 031638
   EC: Dr. Govertszinus Panteliades, Process Systems Enterprise Limited, London, Great Britain
   Dr. Samo Gerkšič, Dr. Vladimir Jovan
   2. Helicopter and aeronautic navigation Airborne System Experimentations
   PEGASE
   6. FP, AST-CT-2006-030839
   EC: Bruno Pattin, Claire Lallemend, Dassault Aviation, Paris, France
   Dr. Gregor Dolanc, Dr. Gregor Dolanc

2. Towards Knowledge - Based Processing Systems
   PRISM
   6. FP, MRTN-CT-2004-512233
   EC: Imperial College of Science Technology and Medicine, London, Great Britain
   Dr. Gregor Kandare

3. Explicit Nonlinear Model Predictive Control based on Gaussian Process Models
   Prof. Alexandra Grancharova, Institute of Control and System Research, Bulgarian Academy of Sciences, Sofia, Bulgaria
   Prof. Juš Kocijan

4. Bayesian Decision Making to support Change Detection in Complex Manufacturing Systems
   BiCZ/07-08-011
   Dr. Tatiana Valentine, Department of Adaptive Control, Institute of Information Theory and Automation, Prague, Czech Republic
   Prof. đani Juričič

5. On-line Monitoring and Fault Diagnosis of Industrial Systems
   BiMK/07-08-018
   Prof. Mile Starokovski, Faculty of Electrical Engineering, Skopje, the Republic of Macedonia
   Prof. đani Juričič

6. R & D Grants and Contracts

7. Design of PID Controllers: Interchange of Technology and Experience - Second Part
   BI-PF/06-07-005
   Prof. José Paulo de Maura Oliveira, Engineering Department, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal
   Ass. Prof. Damir Vrančič

8. Building Virtual Communities for Research and Education in Automation and Control
   BB-3R/07-09-009
   Prof. Mikišábi Huba, Slovak University of Technology in Bratislava, Bratislava, Slovakia
   Ass. Prof. Damir Vrančič

RESEARCH PROGRAM

1. An intelligent system for condition monitoring of rotating machinery
   Prof. đani Juričič

2. Optimization of HVAC systems using dynamic models
   Prof. đani Juričič

3. Rapid prototyping of advanced control algorithms in industrial environment
   Ass. Prof. Damir Vrančič

4. Early detection of lung cancer in workers with asbestos disease
   Prof. đani Juričič

5. Fuel cell based auxiliary power system for autonomous operation of military vehicles
   Dr. Janko Petrovič

VISITORS FROM ABROAD

1. Pavle Boškoski, Faculty of Electrical Engineering, , St. Cyril and Methodius University, Skopje, R. Macedonia, 1 Jan. to 31 Dec. 2008

2. Dr. Kosta Boshnakov, University of chemical technology and metallurgy, Sofia, Bulgaria, 16–17 Apr. 2008


4. Dr Pavel Etlér, Compureg Plzen, Plzen, Czech Republic, 11–14 Nov. 2008

5. Teodora Miteva, work in the frame of the project PRISM, Sofia, Bulgaria, 1 Jan. to 25 Dec. 2008

STAFF

Researchers

1. Dr. Gregor Dolanc
2. Dr. Samo Gerkšič
3. Dr. Nadja Hvala
4. Dr. Vladimir Jovan
5. Ass. Prof. đani Juričič
6. Prof. Juš Kocijan
7. Dr. Janko Petrovič
8. Prof. Stanislav Strmčnik, Head
9. Ass. Prof. Damir Vrančič
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12. Dr. Gregor Kandare
13. Dr. Alenka Žnidaršič

Postgraduates


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15. Giovanni Godena, B. Sc.
16. Tomisl Lakumen, B. Sc.
17. Jana Lupar, B. Sc.
18. Janja Macek, B. Sc.
19. Dr. Bojan Musizza
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22. Stanislav Cerne, B. Sc.
23. Vremo Fajdiga, B. Sc.
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25. Dr. Zoran Martinčič

Technical and administrative staff

26. Mirko Marušič

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLES


**PUBLISHED CONFERENCE PAPERS**

**Invited Papers**


**Regular papers**


The main activities of the Laboratory for Open Systems and Networks are the R&D of next-generation networks, telecommunications technologies, components and integrated systems and information-society services and applications, especially those which ensure an efficient and pervasive life-long learning concept.

In 2008 the research group implemented the research program “Technology, services and business in next generation networks”. Research was also carried out in the EU 7FP projects P2P-Next, Eiffel and GLOBAL, the EU 6FP projects iCamp and SERENITY, the eContentPlus iCoper project, the Merlab and eVET projects from the Leonardo da Vinci programme, the MAUSE project from the COST programme, and in a few national projects. The main fields of work were technology-enhanced learning, security and privacy in information systems, and technologies and services in advanced next-generation networks. Members of the laboratory are also teaching at the undergraduate and graduate levels at the University of Ljubljana, the University of Maribor, and the Jožef Stefan International Postgraduate School.

Concepts, architectures, technologies and services in the future internet

The group is a partner in the EU 7FP project “Evolving Future Internet for European Leadership” (EIFFEL) that aims at identifying and developing the major concepts and design architecture of the future internet. This area of research is being carried out within the “think tank” group of European and world-wide scientists and experts. In the frame of this project, in 2008 we organized a very successful conference called The Future of the Internet, which gathered everyone in Europe working in this field. At the conference The Bled Declaration on European research strategy and an approach to the future internet was adopted, which is vital for the future European economy. The Future Internet Forum was also formed.

R&D of an open-source, efficient, trusted, personalized, user-centric and participatory television and media delivery system with social and collaborative connotations using the emerging peer-to-peer (P2P) paradigm is part of the “Next Generation Peer-to-Peer Content Delivery Platform” (P2P-Next) project. The research takes into account the existing EU legal framework and is oriented towards the development of a next-generation P2P content-delivery platform by taking into account the heterogeneous and demanding environments and the demands for the low-cost delivery of professional and user-created content.

An important project in the field of research e-infrastructures is the “Global Linkage Over Broadband Links” (GLOBAL) project. This project will provide a virtual conference centre using advanced communication technologies and concepts to support the promotion of e-infrastructure topics in Europe and around the world. With the ISABEL videoconference tool we connected the infrastructures in South America, India and Africa and transferred knowledge and the research results of European researchers and projects.

Technology-enhanced learning

In the EU 6FP project “Innovative, inclusive, interactive & intercultural learning campus” (iCamp) we have created an infrastructure – the iCamp Space – for collaboration and social networking across systems, countries and disciplines. The iCamp Space builds on existing interfaces and integrates shared community features. The large number of repositories raises the problem of finding and selecting the right learning resources for particular learning goals and required competencies. As a solution to this problem we have created a framework for personalized access to educational networks that enables a learner to find the optimal resources on the basis of his or her learner personal profile and resources metadata. The results were presented in a special issue of the ACM Transactions on Internet Technology. Competencies are also the main research theme of the “Interoperable Content for Performance in a Competency-driven Society” (iCoper) project. In this project we evaluate technology-enhanced learning standards and describe good practices in learning needs and learning opportunities identification and description, instructional modeling, content development, content...
delivery, and learner assessment and content evaluation. The main research goal is to create a reference model that will integrate existing and new or improved standards, and describe competency-based learning scenarios in an interoperable way.

The main goal of the project “Towards the Maturation of IT Usability Evaluation” (MAUSE) is to bring more science to bear on Usability Evaluation Methods (UEM) development, evaluation, and comparison, aiming for results that can be transferred to industry and educators, thus leading to an increased competitiveness of European industry and benefits to the public.

The “Innovative Remote Laboratory and the E-training of Mechatronics” (MeRLab) project, founded by the Leonardo da Vinci Programme – Transfer of Innovation, tries to introduce best practices in the field of vocational training of mechatronics, and further support them with state-of-the-art information-communication technology, as well as with established methodological and didactical approaches. The goal is to improve the quality and efficiency of vocational training; this should result in a greater recognition and attractiveness of the profession and will have a positive influence on the reduction of disparities between the supply and demand of qualified mechatronic staff in the market. A concrete aim of the project is to prepare an e-course in mechatronics, which will be in our area represented in a completely new way of vocational training of this profile, because both the theoretical and practical training will be entirely conducted online. Practical work will be done through an innovative virtual laboratory for practical work, based on web technology that allows the performance of real mechanical-electrical and programming-related experiments in the physical laboratory, which is crucial in the training of mechatronics.

An important part of the laboratory's scientific research work is an empirical study that links the fields of technology-enhanced learning, organizational learning, and financial and non-financial business performance. The study focuses on the conceptualization of a research model (structural and measurement) that has been developed to test the impact of technology-enhanced organizational learning on the business performance of companies with more than 50 employees. In accordance with stakeholder theory and a balanced scorecard, both financial and non-financial aspects of the performance are considered. In the research, special attention is given to the presentation of the definitions of the four main constructs of the research model: technology-enhanced learning, organizational learning, financial and non-financial business performance, and their operationalization. The results of the study indicate the strong impact of ICT and technology-enhanced learning on organizational learning and non-financial business performance.

The purpose of the iDotik project was to develop a prototype of interactive awareness and information e-service in public places with the assistance of artificial-intelligence technologies. The key effect and, at the same time, the biggest project innovation was the development of a web-based application “Scenarist”, which allows, on the one hand, simplification of the process of building e-content, streamlining costs and raising quality, and, on the other hand, shortening the length of time of the whole process of the development of e-content. The integration of intelligent technologies allows the implementation of ‘Pametnega skladišča e-vsebin’ (Intelligent e-content repository), which forwards e-content on a multimedia touch screen, depending on the user profile, which is determined with the presence of sensors on the screen. This represents the enormous impact of information on the user, because the e-content storage forwards the e-content, which is, according to his or her profile, the most appropriate. The loss of information in this mode of information transmission is much less than with a conventional mode.

Security, dependability and privacy in information systems

Information security, dependability and privacy are some of the most important research fields of the laboratory. Besides the research of privacy aspects in the field of technology-enhanced learning we addressed security in the EU 6FP Integrated Project “System Engineering for Security & Dependability” (SERENITY) and in the VIZIPIN project financed by TIA. The main properties of modern heterogeneous communication systems, like pervasive systems, systems with ambient intelligence or the Internet of Things, are ubiquitous and complex interconnections of services and devices, the dynamic nature and adaptability of the systems and services’ awareness of the user’s context. Privacy, security and dependability issues of
such systems are being investigated in the SERENITY project. Here, research is focused on issues such as interoperability and the development of standardized security patterns for embedding in network services and applications. The results have been accepted for publication in a book that is being published by Springer. In SERENITY we have also addressed the standardization issues of dynamic security solutions and proposed some potential for standardization. Dynamic security management and control was the core of our work in the VIZIPIN project, where we have adapted the research challenges of the field to potential modern military needs.

In 2008 we continued with our research on security economics, where we analyse the assessment of the appropriate investment that is economically affordable and provides enough protection for enterprise information systems. The results, i.e., an approach for the quantification of the necessary investment and a recommendation for a standard approach to security-information investment assessment, have been published in two scientific journals with an SCI impact factor, one of them in the first half of the journals in the field of informatics and management.

**Monitoring and promoting the development of telecommunications**

Our original research contribution in this area of research is a techno-economic model that provides a tool for designing and applying an appropriate measure for fostering broadband communications and related e-services. The results were published in three journal papers with SCI or SSCI impact factors. The created knowledge was also used in the design of a wireless broadband network for the city of Ljubljana.

**Some outstanding publications in the past three years**


**Organization of conferences, congress and meetings**


**INTERNATIONAL PROJECTS**

1. Next Generation Peer-to-Peer Content Delivery Platform
   7. FP, 216217
   EC; Jari Shola, VTT - Valtion Teknillinen Tutkimuskeskus, Espoo, Finland
   Dr. Dušan Gabrijelčič
2. Global Linkage Over Broadband Links
   GLOBAL
   7. FP, 2253120
   EC; Zentrum für Soziale Innovation, Vienna, Austria
   Prof. Borka Jerman Blažič
3. Evolved Internet Future for European Leadership
   EIFFEL
   7. FP, 216068
   EC; Rheinisch-Westfälische Technische Hochschule Aachen (RWTH - Aachen), Lehrstuhl für Mobilfunknetze, Aachen, Germany
   Prof. Borka Jerman Blažič
4. Innovative, Inclusive, Interactive & Intercultural Learning Campus
   ICAMP
   6. FP, 027368
   EC; Claudia Magdalena Fabian, Zentrum für Soziale Innovation, Vienna, Austria
   Prof. Borka Jerman Blažič, Asst. Prof. Tomaz Klobučar
5. Towards the Maturation of IT Usability Evaluation – MAUSE
   COST 294
   EC
   Prof. Borka Jerman Blažič
6. Enhancing, Empowering and Emphasizing E-learning in Vocational Education and Training
   e4 YET Community Portal
   Leonardo da Vinci Programme
   Tanja Arh, M. Sc.
7. Innovative Remote Laboratory in the E-training of Mechatronics
   MeRLab
   Leonardo da Vinci Programme
   2007-5050-LAV/TOI
   Julija Lapuh Bele, B2, d.o.o., Ljubljana, Slovenia
   Matija Pipan, M. Sc.
8. Interoperable Content for Performance in a Competency-driven Society
   ICOPER
   eContentplus
   ECP-2007-EDU-417007
   EC; Dr. Bernd Simon, Wirtschaftsuniversität Wien, Institut für Wirtschaftsinformatik und Neue Medien, Vienna, Austria
   Asst. Prof. Tomaz Klobučar
   EATEL
   EC; Nuzio Santoro, Délégué à la Valorisation, Direction de la Recherche, Telecom & Management SudParis, Evry, France
   Asst. Prof. Tomaz Klobučar
R & D GRANTS AND CONTRACTS

1. Security, dependability and privacy in pervasive systems
   Prof. Borka Jerman Blažič

2. Building blocks of educational networks
   Asst.prof. Tomaž Klobučar

3. Technical and economical models of development of broadband communications and their use in rural areas in Slovenia
   Prof. Borka Jerman Blažič

4. Technical and economical models of development of broadband communications and their use in rural areas in Slovenia
   Prof. Borka Jerman Blažič

5. Knowledge centre for e-learning and convergent multimedia content
   Tanja Arh, M. Sc.

6. "Dotik - The development of an e-service prototype for interactive inquiring and informing in public places with innovative technology of artificial intelligence, e-content development and multimedia touch screens"
   Tanja Arh, M. Sc.

7. Developing integral e-learning model of the Slovene national educational system - Min.si
   Prof. Borka Jerman Blažič

RESEARCH PROGRAM

1. Technologies, services and business in the next generation networks
   Prof. Borka Jerman Blažič

NEW CONTRACTS

1. Building blocks of educational networks
   Nevron d. o. o., Ljubljana
   Asst.prof. Tomaž Klobučar

2. Study: “Challenges of Future Internet”
   Agenda d. o. o., Maribor
   Prof. Borka Džonova Jerman Blažič

VISITORS FROM ABROAD


2. Gabriela A. Tobias Cárdenas, IAESTE students interchange, Poza Rica, Mexico, 1 Jan. to 15 May 2008

3. Aleksej Jerman-Blažič*, M. Sc.


5. Prof. Borka Jerman Blažič

6. Tomaž Klobučar


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4. Dr. Arso Savanović

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8. Tomaž Klančnik, B. Sc.


Technical and administrative staff

10. Tatjana Martin

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLES


REVIEW ARTICLES AND CHAPTERS IN BOOKS

1. Tanja Arh, Vlado Dimovski, Borka Jerman-Blužič, "Model of impact of technology-enhanced organizational learning on business performance", In: Collaboration and the knowledge economy: issues,


The Department of Communication Systems is concerned mainly with the research, development and design of next-generation telecommunications networks, wireless networks and new algorithms for parallel and distributed computing in computer simulations. Other research activities include the development of methods and software tools for the modelling, simulation, analysis and synthesis of communication systems, security services in communication networks, the development of sensor networks, advanced bio-signal processing, the education of young researchers, and the transfer of knowledge and new technologies to industry.

R&D activities at the department are carried out in two groups, one specialising in telecommunications systems and the other in parallel and distributed systems. With the convergence of telecommunications and information systems, the work in both groups is becoming increasingly interconnected, bringing about synergy effects, particularly in applied projects.

**Telecommunications Systems**

Most of our research activities in 2008 related to telecommunications systems were concentrated with wireless sensor networks and with advanced terrestrial, stratospheric and satellite access networks, enabling the end-user to access new services and applications and new multimedia content. We also initiated research activities in the area of cognitive networks. The research emphasis was in the areas of: radio transmission; multiple input multiple output (MIMO) systems based on multiple antennas; access architectures for heterogeneous wireless networks; the management of radio and network resources; and mobile, personal and emergency communications. We continued the work on cross-layer design and the optimisation of communication protocols in wireless communication systems, in order to improve the utilisation efficiency of scarce radio resources and to support the provision of quality of service. We have been developing advanced and innovative concepts and technologies enabling interworking, the convergence of networks and the mobility of terminals and networks, with a special emphasis on solutions providing network robustness, security and quality of service.

We studied the radio interface and signal propagation in the radio channel, taking into account terrain configuration. The main emphasis was on the development and implementation of adaptive modulation and coding schemes, synchronization and equalization techniques, and methods to predict the status and assess the quality of the radio channel. Particular attention was given to the modulation and coding schemes specified in the DVB-S2 communication standard, which were extensively investigated in the satellite and stratospheric fixed and mobile radio channels. We developed a methodology for the optimal sub-selection of transmission modes in a DVB-S2/RCS-based satellite-communication system and proposed an enhanced LDPC-decoder-assisted switching between different modulation and coding schemes. We proposed the advanced access architecture SmartA for an efficient service delivery in heterogeneous wireless networks based on the general concept of cognitive networks.

- We developed a methodology for the optimal subselection of transmission modes in a DVB-S2/RCS-based satellite-communication system and proposed an enhanced LDPC-decoder-assisted switching between different modulation and coding schemes.
- We proposed the advanced access architecture SmartA for an efficient service delivery in heterogeneous wireless networks based on the general concept of cognitive networks.

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For the implementation of seamless vertical handover in heterogeneous wireless networks we proposed an adaptation of the existing SIP communication protocol by the inclusion of additional messages that enable collision detection in the target network.

We developed and implemented a mobile integrated device for the measurement, recording, presentation and analysis of the signal level in different mobile-radio systems for emergency communications.

We initiated research work on cognitive networks that will make use of new approaches in the telecommunications area, such as the cross-layer design and optimisation of communication protocols, and technologies for machine learning and decision making from the area of artificial intelligence. The initial research activities are following two directions. We started the investigation of machine-learning methods suitable for the recognition of the current state and the short-term prediction of the future state of a mobile radio channel, which could be used for decision support in the selection of the most suitable fade-mitigation technique, depending on the cause, duration and depth of the signal fade. As such, these methods are expected to notably improve the link availability. The other direction is concerned with the development of the advanced access architecture SmartA for an efficient service delivery in heterogeneous wireless networks based on the general concept of cognitive networks. For this architecture we investigated the multi-objective optimization problem of the optimal mapping of application requirements to a wireless interface, while minimizing the monetary costs and maximizing satisfaction with respect to QoS metrics.

On the network layer we continued our investigation of fixed–mobile convergence and hierarchical mobility. The emphasis in fixed–mobile convergence was on mobility management in convergent networks, in particular on the seamless vertical handover between networks based on different access technologies. We were focusing on the minimisation of the handover-execution time and the provision of the requested quality-of-service level in the target network. We proposed an adaptation of the existing SIP communication protocol by the inclusion of additional messages that make possible collision detection in the target network. For a more detailed performance evaluation and analysis of the proposed procedures and protocols for seamless handover we developed a simulation model of the communication system composed of WLAN and HSDPA networks using the discrete-event simulation tool OPNET modeller. In addition, we included in the simulation model measurement data from a real network in order to provide as realistic a simulation as possible. With such input parameters we verified and evaluated the proposed procedures for a seamless handover. We also continued the investigation of the optimisation procedures for hierarchical mobility management. We improved the previously built simulation model for the evaluation of the algorithms for the selection of mobility anchor points, so as to allow the evaluation of those algorithms also in realistic internet network models. Particular attention was given to the analysis of these algorithms in realistic synthetically designed networks using a previously developed model of business relationships between autonomous systems. Analytically and by simulations, we proved that the tree topologies intrinsically have an important limitation that is not present in realistic topologies. Using a method based on evolutionary algorithms we showed the relationship between the network topology characteristics and the possibility for the improvement of algorithms for the selection of mobility anchor points that are independent of the user parameters.

With our research work in the areas of stratospheric and satellite communication systems and wireless sensor networks we participated in the EU 6FP and 7FP projects “Satellite Communications Network of Excellence” (SatNeX) and “Wireless Sensor Networks and Remote Sensing - Foundation of a modern agricultural infrastructure in the region” (AgroSense). In 2008 we successfully concluded a multi-annual R&D of the pilot TETRA network for the Ministry of Defence. For the Administration for Civil Protection and Disaster Relief we developed and implemented a mobile, integrated device for the measurement, recording, presentation and analysis of the signal level in mobile radio systems for the emergency...
communications ZARE, ZARE+, DMR and TETRA. We also established a collaboration with the Department of Low and Medium Energy Physics (FZJ) in the field of communication architectures for data-acquisition systems needed in the detector systems for particle experiments. Joint research activities also took place in the field of digital signal processing, where numerically lightweight methods for a real-time pile-up correction using field-programmable arrays were investigated.

Parallel and Distributed Systems

Computer algorithms for an efficient and secure implementation on parallel and distributed computers were investigated. Software tools for cluster computing were tested on a 32-processor cluster computer, which runs at our department, and on a grid recently installed in cooperation with the Faculty of Computer and Information Science of the University of Ljubljana and a hi-tech company Xlab d.o.o. A computer simulation for medical applications was investigated and applied to several practical examples. We have developed new numerical methods which, unlike, e.g., the finite-element method, are based on meshless computing. We investigated the computational complexity of mesh-free methods and the possibilities for their parallelization. The work resulted in two papers in eminent journals: Engineering Analysis with Boundary Elements and Computers and Structures. Team members are also contributing to the book Parallel Computing: Numerics, Applications, and Trends (edited by Roman Trobec, Marian Vajtersic and Peter Zinterhof), which is to be published in May 2009 by Springer, in the Computer Communications and Networks (CCN) series.

We succeeded in joining the EU FP7 project consortium “Promote, mobilize, reinforce and integrate wireless sensor networking research and researchers: Towards pervasive networking of WBC and the EU” (ProSense). In this way we entered into a new research area, founded on the theory of parallel and distributed computing and communications.

In the field of medical research, the spatial model of a human knee with a resolution of 1 mm was finalized in cooperation with colleagues from the Ljubljana University Clinical Centre (UCC). We improved the simulation of the heat transfer in biological tissues, including the heat transfer in the surrounding fluids. In the model we also included the heat transfer over capillaries and the metabolic heat source. A parallel simulation program was finalized using advanced numerical methods (multigrid and meshless). Parallel programs for the simulation of human-knee cooling were developed and employed for comparing the results of various post-operative knee-cooling methods, which were selected by the UCC team members. A paper on the subject was published in the journal Computers in Biology and Medicine and a paper reporting results obtained with the improved methods is already in review.

It would be unethical to perform measurements on the human-heart muscle just to explain a specific phenomenon. With the help of a simulation, however, we were able to investigate the cause of the so-called U-wave, a feature of electrocardiograms (ECG), which has been waiting for an explanation since the beginnings of electrocardiography. We discovered a yet unknown possibility for the genesis of the wave and reported it in the Journal of Cardiovascular Electrophysiology. Together with colleagues from the Ljubljana UCC and the Maribor UCC, we analyzed the heart-beat dynamics of patients before and after a heart operation and obtained promising knowledge for the prediction of post-operative arrhythmias. A paper on this subject was published in the journal Heart Surgery Forum and two others are in review.

We developed a new, generic method for the segment-based synthesis of tests for deterministic finite-state machines and specialized it as a method for checking sequence construction, which facilitates the synthesis of cheaper tests also for distributed testing with no coordination between the testers.
Some outstanding publications in 2008


Organization of conferences, congress and meetings

2. Project meeting 7FP AgroSense, Ljubljana, Slovenia, 2-5 Dec. 2008
3. Project meeting 7FP ProSense, Ljubljana, Slovenia, 18-21 Dec. 2008

INTERNATIONAL PROJECTS

1. Promote, Mobilize, Reinforce and Integrate Wireless Sensor Networking Research and Researchers: Towards Pervasive Networking of WBC and the EU
   ProSense
   7. FP, 205494
   EC, Alex Ghițău, LM Ericsson Ltd., Dublin, Ireland
   Asst. Prof. Roman Trobec

2. Trans-national Cooperation among ICT NCPs
   IDEALIST2011
   7. FP, 231567
   EC, Deutsches Zentrum für Luft- und Raumfahrt E. V. (DLR), Köln, Germany
   Asst. Prof. Michael Mohorcic

3. Wireless Sensor Networks and Remote Sensing - Foundation of a Modern Agricultural Infrastructure in the Region AgroSense
   7. FP, 209472
   EC, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
   Prof. Kandus Gorazd

4. Support for Participants in ICT Priority by Network for IST under the Transition to the 7th Framework Programme
   Idealist7FP
   6. FP, 045059
   EC, Dr. Michael Chebli, Deutsches Zentrum für Luft- und Raumfahrt E. V. (DLR), Köln, Germany
   Asst. Prof. Michael Mohorcic

5. Satellite Communications Network of Excellence - Phase II SatNet-X II
   6. FP, 027381
   EC, Dr. Dörthe Gottschalk, Deutsches Zentrum für Luft- und Raumfahrt E. V. (DLR), Köln, Germany
   Asst. Prof. Gorazd Kandus

6. Precise Mobile & Ambient Wireless Communications
   COST 2100
   EC, Prof. Roberto Verdeone, DEIS- Università degli Studi di Bologna, Bologna, Italy
   Dr. Tomaz Javornik

7. Quality of Service in Future Wireless Systems
   COST 290
   EC, Prof. Yevgeni Koucheryavy, Tampere University of Technology, Tampere, Finland
   Prof. Gorazd Kandus

8. High Altitude Platforms for Communications and other Services
   COST 297, HAPOS
   EC, Prof. Tim C. Tozer, University of York, York, Great Britain
   Asst. Prof. Alen Sviželj

9. A Telecommunications Economics COST Network - Eon & Tel
   COST IS0605
   EC, Prof. Burkhard Stiller, Institut für Informatik - IFI, University of Zürich, Zürich, Switzerland
   Prof. Denis Trček

10. Teledoctorate Project
    UNESCO-ROSTIE Grant
    Silvano Pupolin, Università di Padova, Dipartimento di Ingegneria dell’Informazione, Padova; Dr. Paola Magri, Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CINT), Parma, Italy
    Prof. Gorazd Kandus

11. Interactive Visual Analysis of BIO – signals
    SEE ERA NET
    ID:9999, 1000-07-580018
    Asst. Prof. Roman Trobec

12. Third International Summer School on Applications of Wireless Sensor Networks and Wireless Sensing in the Future Internet, senzations’08
    Asst. Prof. Roman Trobec

13. Advanced Technologies for Digital Forensics
    Dr. Asmund Skomeadal, Norwegian Computing Center, Oslo, Norway
    Prof. Denis Trček

R&D GRANTS AND CONTRACTS

1. Lightweight Services for Security, Privacy and Trust Management
   Asst. Prof. Roman Novak

2. Multiple antennas system for mobile WiMAX
   Prof. Gorazd Kandus

3. Development of advanced digital mobile system TETRA for MOD
   Prof. Gorazd Kandus

4. IT development and data gathering, maintenance and management strategy
   Asst. Prof. Igor Ozimek

5. Computational Grid technologies for efficient usage of computer resources in companies
   Asst. Prof. Roman Trobec

RESEARCH PROGRAMS

1. Telecommunication systems
   Prof. Gorazd Kandus

2. Parallel and Distributed Systems
   Asst. Prof. Roman Trobec

NEW CONTRACTS

   The Health Insurance Institute of Slovenia, Ljubljana
   Asst. Prof. Roman Novak

2. Multiple antennas system for mobile WiMAX
   Telekom Slovenije, d. d., Ljubljana
   Prof. Gorazd Kandus


PUBLISHED CONFERENCE PAPERS

Regular papers


8. Tomaž Javornik, Gorazd Kandus, Erich Leitgeb, Michael Mohorčič, "Modelling of atmospheric impairments in mobile propagation


18. Miha Smolnikar, Tomaž Javornik, Michael Mohorčič, Matteo Berló, "DVB-S2 adaptive coding and modulation for HAP communication system", In: VTC2008-spring: mobile media: ubiquity and convergence,


**THESES**

M. Sc. Theses


2. Andrej Hrovat, "_ocena motenj med sosednjimi kanali v sistemu TETRA pri neposrednem načinu delovanja: magistrsko delo, Ljubljana, [A. Hrovat], 2008."
The Department for Computer Systems is concerned primarily with the design automation of computing structures and systems. Within this broad area we concentrate particularly on a metaheuristic approach to engineering design and logistics problems as well as system design and testing. As an integral part of our research activity, members of the department have close contacts and collaborations with scientists world-wide, through academic links and industrial contacts, thus enabling us to maintain our position at the forefront of this rapidly developing field.

An important part of our research activities is related to the development of metaheuristic optimization methods and their applications. We have developed efficient self-setting and self-adapting evolutionary algorithms and ant-stigmergy-based optimization algorithms. These approaches were used for solving various combinatorial and numerical optimization problems. The evolutionary algorithms were tested on constrained numerical optimization problems. The multiple ant-colonies approach can be successfully used to solve mesh-partitioning problems that arise in mechanical, civil, automobile, and aerospace engineering. The multilevel ant-stigmergy approach was applied to solving discrete numerical optimization problems. We have proposed a novel general approach to transforming a multi-parameter optimization problem into a finding-the-minimum-path problem. We have also developed a differential ant-stigmergy approach, suitable for solving discrete as well as continuous numerical optimization problems.

The multilevel and differential ant-stigmergy approaches were used in several real-world applications. In collaboration with Domel d.d., Železniki, Slovenia, we reduced the production costs of an electro-motor and optimized the aerodynamic power of a dry vacuum-cleaner impeller. Within the project "The Role of Luka Koper in the Logistic Support of the Slovenian Armed Forces and Allies" in the frame of the Target Research Programme (CRP MIR) "Science for Peace and Security 2006-2010" we developed software components for the optimization of logistic procedures for equipment and material transportation. Within the project "Secure Infrastructure for Implementing Command and Control" in the frame of the Technology Program (TP MIR) "Technology for Peace and Security 2006-2012" we optimized the structure of an absorber used in telecommunications systems.

In the research area of computer-based menu planning, collaborating with the Department of Environmental Sciences (JSI), CINDI Slovenia and the Slovenian Society for Clinical Nutrition we performed the following activities:

- We upgraded the web application Optijed with a module for planning nutrition for children, adolescents and patients with special nutritional needs. In addition, we extended the food composition database with new data and described data by using the standardized LanguaL method;
- We finished the project "Nutrition for Special Needs" (M4-0119), in which we analysed and optimized menus for people working in extreme conditions;
- In the project "Slovenian Web-based Food Composition Tables", we associated with the European Network of Excellence on Food Composition Databank Systems European Food Information Resource Network (EuroFIR FP6-CT-2005-513944).

In the project "Enhancing Elementary Mathematics Pedagogy Competencies by e-Learning" that is part of a large ESS project "Evaluation of Slovenian Education", we developed a web application for e-learning grammar-school mathematics. The decision-making system, which we formalized as a combinatorial optimization problem of graph colouring, is based upon a metaheuristic optimization method.

Within the EU 6FP project ARFLEX the work was focused on the preparation of three demonstrators that should have proven the advantages of a sensor control in industrial robotics over the classic approach and the
advantage of the embedded implementation over the non-embedded. Two of them were prepared at Gomau Sp.A. in Italy and the third one was put together in our laboratory. The first demonstrator consisted of four embedded (smart) video cameras produced within the Arflex project with infrared (IR) light sources able to process images in real time and to communicate over the network with other devices, an industrial robot equipped with passive IR markers and a calibration rig composed of a set of passive markers placed in three perpendicular spatial directions. The cameras were able to measure the 3D position of a robot’s tool center point (TCP) in real time and to control the robot performing different tasks. The second demonstrator presented the advantages of a force sensor on robot control. The application was prepared with a robot’s TCP smoothly following the contour of an unknown object. Within this demonstrator, another application simulated the behavior of a fish during a fish hunt, also using the force sensor. The third demonstrator prepared in our lab was the Arflex non-embedded experimental platform consisting of four 1Mb 75Hz cameras, IR light sources, an industrial robot, active and passive markers and a precise motorized linear guide. The platform was used to precisely establish the capabilities of a robot-vision system, like the accuracy and repeatability of 3D positioning with IR active and passive markers.

The main purpose of the EUREKA project DIPIMAM is to improve the quality of the production of ceramic parts with powder injection moulding (PIM) technology at Hidria AET, Tolmin, Slovenia. The variation of the technological process used in this particular plant is called low-pressure injection moulding (LPIM), which consists of the following stages: feedstock preparation, mould filling, debinding, sintering, machining and glazing. The project investigates the impact of a combination of different feedstock binders on the mould-filling and debinding stages. Our role in the project is to use advanced methods to model the relationship between the quality of the ceramic part before and after debinding, and the composition of the binders using the experimental data. In 2008 we investigated the relationship between the mechanical properties of the ceramic parts before debinding and the four technological parameters: tool temperature, ceramic suspension temperature, time and pressure of the injection phase.

In the frame of the Target Research Programme (CRP MIR) "Science for Peace and Security 2006-2010" we developed software components for the optimization of logistic procedures for equipment and material transportation.

SRAM-based FPGA circuits are relatively sensitive to single-event upsets (SEUs), which limits their widespread adoption in safety- or mission-critical applications. Depending on the required level of reliability and the availability of the system is tested concurrently or occasionally. Since FPGA circuit resources are normally not 100% occupied by the design, the defects located in some areas of the chip that are not used by a particular design may be tolerated. Hence, a strategy of testing the resources of an FPGA with respect to a specific design to be implemented on it has been proposed. This type of test is called an application-dependent test. Currently, we are working on application-oriented test solutions for testing processor cores. We have developed an efficient approach that combines the whole instruction-set test into a compact test sequence, which can then be repeated with different input test patterns. This considerably improves the fault coverage with no additional memory requirements. The concept is being tested on experimental case studies on selected processor cores.

In the scope of the multiconference Information Society we organized the third biennial international conference on “Bioinspired Optimization Methods and their Applications - BIOMA 2008”. The areas of interest at the conference included genetic algorithms, evolution strategies, evolutionary programming, genetic programming, ant-colony optimization, particle-swarm optimization and related bio-inspired methods, and their applications in science, engineering and business. Members of our research programme actively participated in the International Program Committee and Organizing Committee of the conference.

In collaboration with FERI, University of Maribor, we implemented a lossless compression technique for volumetric data sets in FPGAs using the Celoxica RC1000 development system. The purpose of the prototype version is to gain experience in the optimisation of hardware resources for prospective applications.
Some outstanding publications in the past three years


Awards and appointments


Organization of conferences, congresses and meetings


INTERNATIONAL PROJECTS

1. Adaptive Robots for Flexible Manufacturing Systems
   ARFLEX
   6. FP, NMP2-CT-2005-016680
   EC, Dr. Gabriella Caporalelli, EICAS Automazione S.p.A., Torino, Italy
   Dr. Drago Torkar
2. BEE-Surveyor
   225997-Cp-1-2005-1-FR-ERASMUS-TNPP
   EC, Prof. Jean-Marc Thiriet, Université Joseph Fourier Grenoble, Institut Universitaire de Technologie 1 de Grenoble, Département Réseaux et Télécommunications, Saint Martin d’Hères, France
   Prof. Franc Novak
3. European Food Information Resource Network
   EuroFIR
   6. FP, NoE
   M01, 515944
   EC, Dawns Wright, Paul Finglas, Institute of Food Research, Norwich, Great Britain
   Asst. Prof. Barbara Koroušič Seljak
   DIPFAM
   EUREKA
   Hiðra AET d.o.o., Tolmin, Slovenia
   Dr. Drago Torkar
5. New Approaches to SRAM-based FPGA Testing
   PROTEUS
   Hi-FR07-PROTEUS-016
   Dr. Michel Rouvoll, LIRMM, Montpellier, France
   Prof. Franc Novak

R & D GRANTS AND CONTRACTS

1. The role of Luka Koper in logistic support of the Slovenian Armed Forces and allies
   Asst. Prof. Jurij Šilc
2. Nutrition for special needs - POVIK
   Asst. Prof. Barbara Koroušič Seljak
3. Optimization of packaging, loading and transportation of pre-fabricated building elements
   Asst. Prof. Peter Korošec
4. Open platform for Scalable e-Service Systems: OPSESS
   Prof. Franc Novak

RESEARCH PROGRAM

1. Computing structures and systems
   Prof. Franc Novak

NEW CONTRACT

1. Slovene Web-based Food Composition Tables
   Ministry of Health, Government of the Republic of Slovenia
   Asst. Prof. Barbara Koroušič Seljak

VISITORS FROM ABROAD

1. Dr. Jan-Olaaf Gustavsson, Blekinge Institute of Technology, Karlskona, Sweden, 25 Apr. 2008

STAFF

Researchers
1. Asst. Prof. Anton Biasizzo
2. Asst. Prof. Barbara Koroušič Seljak
3. Prof. Franc Novak, Head
4. Asst. Prof. Gregor Papa
5. Asst. Prof. Jurij Šilc

Postdoctoral associates
6. Dr. Uroš Kac
7. Asst. Prof. Peter Korošec
8. Dr. Drago Torkar

Postgraduates
10. Katerina Tashkova, B. Sc.
11. Vida Vukalićović, B. Sc.

Technical and administrative staff
13. Jolanda Jakobčič

Note:
* part-time JSI member
BIBLIOGRAPHY

ORIGINAL ARTICLES


PUBLISHED CONFERENCE PAPERS

Regular papers

The Department of Knowledge Technologies performs research in advanced information technologies, aimed at acquiring, storing and managing knowledge to be used in the development of knowledge-based applications. The established areas of knowledge technologies include intelligent data analysis (machine learning, data mining, knowledge discovery in databases), text and web mining, the semantic web, social network analysis, language technologies and computational linguistics, as well as decision support and knowledge management. The research areas of the department also include Web 2.0, the management of virtual organizations, new media and e-science. In addition to knowledge technologies research, we also develop applications in environmental sciences and ecology, medicine and health care, biomedicine and genetics, as well as the economy and marketing.

In 2008 the Knowledge Technologies research programme was evaluated as the best research programme in ICT (for the period 2004–2008) by the Slovenian Research Agency (ARRS). In terms of our collaboration in EU projects, our programme group is the most successful in Slovenia. In 2004–2008 we collaborated in 28 FP6 and FP7 projects, the most important being our successful coordination of the STREP project “Inductive Queries for Mining Patterns and Models” (IQ) and our collaboration in six large Integrated Projects (IPs) and two Networks of Excellence (NoEs).

In the area of intelligent data analysis we have developed a conceptual framework of supervised descriptive rule induction and have shown that methods for subgroup discovery, contrast set mining and emerging pattern mining represent special cases of supervised descriptive rule induction methods. An algorithm for closed-sets mining was published in the prestigious Journal of Machine Learning Research. A lemmatizer for Slovene, constructed by the Ripple-Down rule learning algorithm, was published in the journal AI Communications. We have continued the development of semantic data mining, which enables the use of ontologies in machine learning. On the one hand, ontologies can be used as background knowledge of the application domain (our paper published in the Journal of Biomedical Informatics presents the analysis of gene expression based on the ontology of gene functions, processes and interactions). On the other hand, an ontology of data mining methods can be used for the automated planning of data-mining workflows in the framework of a novel service-oriented data-mining architecture (three workshop papers were published and a workshop, Service-Oriented Knowledge Discovery, was organized at the ECML/PKDD-08 conference in Antwerp in September 2008). In collaboration with the National Institute of Biology, Ljubljana, Slovenia, we have continued the development of a cost-optimization system for micro-array testing for genetically modified organisms in food and feed samples.

We have developed a model of the Slovenian Health Care network for the Ministry of Health of Slovenia in the scope of the MediNet and MediNet+ projects. In 2008, the project results were upgraded with a web portal that enables querying for analysis results and which offers numerous reporting and visualization facilities. As a result, it can be used to support decision making, monitoring and planning of the Slovenian health care network.

We successfully concluded the coordination of the FP6 project “Inductive Queries for Mining Patterns and Models” (IQ), which was concerned with developing techniques and applications for inductive databases and queries. Besides data, inductive databases contain generalizations (patterns and models) valid in the data, which are generated, accessed and manipulated by inductive queries. In its final evaluation, the IQ project received much praise, both for its outstanding scientific content and our excellent management. Among our scientific contributions to the project, we wish to highlight the proposed general framework for data mining, which has led to the development of an ontology for data mining. We have also developed many specific approaches to mining complex data, such as ensembles of decision trees for hierarchical multi-label classification, which were applied to

![Figure 1: The main window of Visual OntoBridge: the software being developed by our department in the European project SWING. The software provides facilities for annotating web resources with entities from the domain ontology with the purpose of establishing semantic descriptions based on a common vocabulary.](image-url)
problems in bioinformatics (e.g., functional genomics) and environmental sciences. In addition, the IQ project addressed the problem of using equation discovery for systems biology, which will be further studied in one national and in one FP7 research project that started this year. A national applied research project that deals with the problem of estimating the state of forest ecosystems from remote sensing data was also successfully completed. The forest-vegetation height and the canopy cover are predicted from satellite images. To this end, ensembles of predictive models are used, which are learned from a combination of 2D satellite images and 3D LiDAR data. Maps of forest-vegetation height and canopy cover can now be produced for much larger areas than with previous pilot studies.

In the area of **decision support**, our long-term goal is to develop methods and techniques for decision modelling, support them with software and integrate them with data-mining systems. In 2008 we have improved our software for qualitative multi-criteria decision making, DEXi. We have added three methods for the analysis of decision options: a comparison of options, a selective explanation and a “plus-minus-1 analysis”. DEXi 3.0 is freely available from the web page: http://kt.ijs.si/MarkoBohanec/dexi.html.

The developed decision-support methods and tools were successfully used in the EU projects SIGMEA, Co-Extra and HEALTHREATS. The first two projects are focused on the analyses of impacts of producing and using genetically modified (GM) plants in Europe: SIGMEA from the viewpoint of ecological and economic impacts, and Co-Extra from the viewpoint of co-existence and traceability in production and supply chains. We concluded our contribution to SIGMEA with a publication in the journal Ecological Modelling, where we described our model for the assessment of the ecological and economic impacts of growing GM maize. In the ongoing Co-Extra project we have developed three multi-criteria models for the assessment of analytical and sampling methods, as well as for the assessment of the likelihood of the emergence of unapproved GM organisms in food and feed products. In the EU project HEALTHREATS, which aims to develop a decision-support system for the rapid, efficient and coordinated response to threats to health (such as epidemics), we have developed models for an internal evaluation of the work and the results of the project.

In the area of **text and web mining**, our work in the FP6 project “Statistical Multilingual Analysis for Retrieval and Translation” (SMART) was focused on testing and using our automatic evaluation system (of machine translation and cross lingual information retrieval) by the project partners, coordination of a user-evaluation study (with different user groups, tasks, datasets and evaluation measures) and an extension of the KCCA method for cross-lingual data analysis in terms of scalability and performance in collaboration with the FP6 project PASCAL. The developed component was integrated into the existing system for contextual search SearchPoint and applied to the problem of cross-lingual information retrieval (demo at SIGIR-2008). As a part of our activities in the FP6 project “Image-based Navigation in Multimedia Archives” (IMAGINATION) we have developed software components to help enrich the existing textual metadata. In particular, the developed software components support three functionalities: (1) annotations of images, (2) discovery of duplicate candidates for ontology concepts and (3) proposing new concepts and relations between them. (1) The annotation of images is based on using textual information that is provided for each image in order to annotate the image with concepts of a predefined ontology. Each image has a very limited amount of text associated with it, usually just a handful of keywords. In some cases additional content is provided via a link to external web pages. Thus, in the proposed approach we handle these two cases separately. (2) The discovery of potential duplicates in an ontology is based on representing each ontology concept by text that can be associated with it, originating either from the concept name and metadata, from external web pages or from the name of an associated URL. (3) The proposing of new ontology concepts and some relations between them is based on using external web pages providing information on particular concepts.

We have successfully concluded two FP6 projects, PASCAL and KDUbiq, where our research in the past year included (1) the development of the visualization of named entities in time based on the use of Wikipedia for extracting named entities and relating them over time, (2) the development of SearchPoint – a system for interfacing an existing search engine that
organizes its results into groups or shows the search results in the context of some existing ontology or classification schema, and (3) the development of Semantic Pointer – a system for social browsing with semantic context that enables real-time identification of the visitors to semantically similar web pages and real-time interaction between them. We have obtained a new FP7 Network of Excellence “Pattern Analysis, Statistical Modelling and Computational Learning 2” (PASCAL2) for the period 2008–2013 where our work will be mainly on research in text mining and natural language processing.

In the area of the Semantic Web we have successfully concluded two National Targeted Research projects on “Statistical Semantic Web Systems” (Sistemi za statistični semantični splet) and “Metaservices – Semantic Grid Services” (MetaSoritev - Semantično sklapljanje Grid storitev, 2006–2008), where our main contributions are: the development of methods and components for (1) knowledge acquisition, (2) cross-modal data analysis, (3) handling cross-lingual data and several support components for (4) data and text mining, (5) visualization, and (6) evaluation. Our activities in the FP6 project “Lifecyle Support for Networked Ontologies” (NeOn) in the past year resulted in an extension of the NeOn Toolkit with: (1) an alignment server incorporating our pragmatic approach to using large-scale ontologies as contexts (based on a lightweight ontology model and grounding of the ontology concepts in textual documents), (2) a system for ontology visualization in the context of a predefined landscape. Work in the FP6 project “Transitioning Applications to Ontologies” (TAO) resulted in a methodology for cross-modal data analysis focused on connecting textual data and graph/network. We have also designed an evaluation of the methodology on three real-world case studies. In the FP6 project “Semantic Web Services Interoperability for Geospatial Decision Making” (SWING) we have developed the semantic annotation engine OntoBridge and designed several scenarios for real-world data. We have obtained a new large FP7 IP project “Enabling the Knowledge-Powered Enterprise” (ACTIVE) for the period 2008–2011, where our work is mainly in the direction of modeling informal knowledge processes in an organization.

We represent the Jožef Stefan Institute in the World Wide Web Consortium (W3C), which develops and recommends future web standards. We actively participate in the Rule Interchange Format (RIF) working group. The group has so far produced a working draft and last-call recommendations for a number of standards: RIF Core, Basic Logic Dialect, Framework for Logic Dialects, RDF and OWL Compatibility, Datatypes and Built-Ins, Production Rules Dialect, Use Cases and Requirements.

In the area of knowledge management we have successfully concluded three FP6 research projects: “European collaborative networked organisations leadership initiative” (ECOLEAD), “Extended Enterprise management in Enlarged Europe” (E4) and “Open Source Enterprise Resource Planning and Order Management System for Eastern European Tool and Die Making Workshops” (Tool-East). The project results have already been transferred to new projects as well as to industrial applications for KOGAST, EM0, the High-Tech cluster, the Toolmakers cluster and the Slovenian automotive cluster. We are continuing the R&D work in the areas of networked organizations, interoperability and collaboration in the FP7 integrated project “Collaboration and Interoperability for networked enterprises” (COIN). We are very successful in the development of Intelligent Cargo Transport in the FP7 project “European Inter-Disciplinary Research on Intelligent Cargo for Efficient, Safe and Environment-friendly Logistics” (EURIDICE), where we have already demonstrated some prototypes and in the FP7 project “Enabling the Knowledge-Powered Enterprise” (ACTIVE) with the tools and methods for enterprise “hidden” knowledge formalization.

In the area of language technologies we have continued work on the basic research project “Linguistic annotation of Slovene language: methods and resources” (JOS) in the scope of which we are developing automatic inductive methods for the annotation of morphology, syntax and semantics and use these methods to produce freely available linguistically annotated corpora of Slovene.

We finished work on the SEE-ERA-NET project “Building Language Resources and Translation Models for Machine Translation focused on South Slavic and Balkan Languages”, where we produced a parallel and linguistically annotated corpus of EU legal documents, which contains aligned texts in English, Slovene, Serbian, Bulgarian and Romanian.

Our knowledge transfer to industry is demonstrated by the help given to twelve Slovenian companies in becoming partners of EU projects, thus securing approximately €2 m of co-financing.

The Videolectures.net web portal, which we co-manage with the CT3 department, has started to host lectures from the MIT portal “Open Course Ware” and the Openpencast community.

The software we developed is used by the EU Commission, the New York Times, Microsoft and many other international companies.

Figure 4: Forest-vegetation height in m (a) and canopy cover in % (b) for the Slivnica region of Slovenia, as predicted from satellite images by ensembles of predictive models learned from a combination of 2D satellite images and 3D LIDAR data.
We have successfully completed work on a six-month R&D project from the area of eContent and eServices “BMT: development of a text speech reader for mobile telephones for blind and partially sighted users” under the coordination of the company alpineon R&D, where the JSI was in charge of the development of a morphosyntactic tagger and lemmatiser that improves the quality of the speech synthesis. For Alpineon we also completed the XML_FED project, where we developed the XML specifications for use with a speech synthesiser.

We started work on several new EU projects. In the scope of the project “Conceptual Modelling of Networking of Centres for High-Quality Research in Slavic Lexicography and Their Digital Resources” (MondiLex) and in cooperation with the F-9 department we are investigating the possibilities of using grid technologies for the processing and dissemination of large corpora. In the project “Fostering Language Resources Network” (FlareNet) we are working on the compilation of language resources for Slovene.

In the scope of the bilateral Japanese-Slovenian cooperation with Tokyo International University, we compiled, on the basis of the previously produced jpWaC corpus, a corpus of sentences appropriate for learners of Japanese, where the words are annotated with their difficulty level. The corpus is freely available for use via a web concordancer.

Some outstanding publications in the past three years


Awards and appointments

1. Sašo Džeroski, ECCAI fellow – ECCAI award. Awarded by European Coordination Committee for Artificial Intelligence

Organization of conferences, congress and meetings


INTERNATIONAL PROJECTS

1. Systems Biology of Phagosome Formation and Maturation, Modulation by Intracellular Pathogens
   PRAGONSIS
   7. FP, 223451, HEALTH-F4-2008-223451
   EC, Anne-Marie Fish, Imperial College of Science, Technology and Medicine, London, Great Britain
   Prof. Sašo Džeroski
2. Bisociation Networks for Creative Information Discovery
   BISON
   7. FP, 211898
   EC, Universität Konstanz, Konstanz, Germany
   Prof. Nada Lavrač
3. Conceptual Modelling of Networking of Centres for High-Quality Research in Slavic Lexicography and Their Digital Resources
   MONDILEX
   7. FP, 21938
4. Enabling the Knowledge Powered Enterprise
   ACTIVE
   7. FP, 215040
   EC, Philip Hewitt, British Telecommunications plc, London, Great Britain
   Marko Grobelnik, B. Sc., ASt. Prof. Dunja Mladenić, Mitja Jermol, M. Sc.
5. Pattern Analysis, Statistical Modelling and Computational Learning 2
   PASCAL 2
   7. FP, 216886
   EC, Eileen Simon, University of Southampton, Highfield, Southampton, Great Britain
6. European Inter-Disciplinary Research on Intelligent Cargo for Efficient, Safe and Environment-friendly Logistics
   EURIDICE
   7. FP, 216271
   EC, INSELE - Informatica per il Sistema degli Enti Locali s.p.a., Trieste, Italy
   Marko Grobelnik, B. Sc., ASt. Prof. Dunja Mladenić, Mitja Jermol, M. Sc.
7. Collaboration and Interoperability for networked enterprises 
   CON
   7. FF. 216256
   IE; Claudia Guglielmo, TXT e-Solutions Spa, Milano, Italy
   Asst. Prof. Dunja Mladenič, Marko Grobelnik, B. Sc., Mitja Jermol, M. Sc.

8. GI and nano-GM supply chains: their OX-Existence and TBEaBility 
   Co-Extra
   6. FF. 007158
   IE; Institut National de la Recherche Agronomique, Paris, France
   Prof. Marko Bohanec

9. European Embryonal Tumor Pipeline 
   E.E.T - Pipeline
   6. FF. 037269
   IE; Angelika Eggert, Universiirstadt Duisburg-Essen, Essen, Germany
   Prof. Sašo Džeroski

10. Stimulating Policy Debate on Women and Science Issues in Central Europe 
    WS-DEBAT.
    6. FF. 036651
    IE; Dr. Dora Groo, Eszter Papp, Hungarian Science and Technology Foundation;
    Tudomanyos es Technológiai Alapítvány, Budapest, Hungary
    Asst. Prof. Dunja Mladenič, Marko Grobelnik, B. Sc., Mitja Jermol, M. Sc.

11. Statistical Multilingual Analysis for Retrieval and Translation 
    SMART
    6. FF. 055947
    IE; Nicola Canotta, Xerox Research Centre Europe, Meylan, Xerox, Aulnay-Sous-Bois, France
    Asst. Prof. Dunja Mladenič, Marko Grobelnik, B. Sc., Mitja Jermol, M. Sc.

12. Image-based Navigation in Multimedia Archives 
    IMAGINATION
    6. FF. 054626
    IE; Gemeins Vom Einzelf. Forschungszentrum Informatik an der Universität Karlsruhe,
    Karlsruhe, Germany
    Asst. Prof. Dunja Mladenič, Mitja Jermol, M. Sc., Prof. Marko Mikul

13. Extended Enterprise Management in Enlarged Europe 
    E4
    6. FF. 027282
    IE; Roberto Tardini, Centro Ricerche Fiat Societa Consortile per Anon. Orbassano (TO), Italy
    Asst. Prof. Dunja Mladenič, Marko Grobelnik, B. Sc., Mitja Jermol, M. Sc.

14. Open Source Enterprise Resource Planning and Order Management System for Eastern 
    European Tools and Design Workshop 
    ToolEast
    6. FF. 027921
    IE; de ing. Volker Stich, Forschungsinstitut füor Rationalisierung (FIR) and der RWTH Aachen,
    Research Institute for Operations Management at Aachen University, Aachen, Germany
    Asst. Prof. Dunja Mladenič, Marko Grobelnik, B. Sc., Mitja Jermol, M. Sc.

15. Semantic Web Services Interoperability for Geospatial Decision Making 
    SWING
    6. FF. 026514
    IE; Arne F. Berre, SENTEF – Stiftelsen for Industriell OG teknisk Forsknin og ved Norges
    Tekniske Hoegskole, Trondheim, SENTEF ICT, Oslo, Norway
    Asst. Prof. Dunja Mladenič, Marko Grobelnik, B. Sc., Mitja Jermol, M. Sc., Prof. Marko Mikul

16. Lifecycle Support for Networked Ontologies 
    NESN
    6. FF. 027995
    IE; Prof. Enrico Motta, Kmi, The Open University, Milton Keynes, Great Britain
    Asst. Prof. Dunja Mladenič, Marko Grobelnik, B. Sc., Mitja Jermol, M. Sc.

17. Transitioning Applications to Ontologies 
    TAO
    6. FF. 026660
    IE; Dr. Kalina Bontcheva, University of Sheffield, Department of Computer Science,
    Sheffield, Great Britain
    Asst. Prof. Dunja Mladenič, Marko Grobelnik, B. Sc., Mitja Jermol, M. Sc.

18. Inductive Queries for Mining Patterns and Models 
    IQ
    6. FF. 516369
    IE; Prof. Sašo Džeroski, Institut “Jožef Stefan”, Ljubljana, Slovenia
    Prof. Sašo Džeroski

19. European Collaborative networked Organizations LEADership initiative 
    ECOLEAD
    6. FF. 506958
    IE; Martin Ollus, Technical Research Centre of Finland, Espoo, Finland
    Prof. Nada Lavrač, Mitja Jermol, M. Sc.

20. Pattern Analysis, Statistical Modelling and Computational Learning 
    PASCAL
    6. FF. 506778
    IE; Prof. John Shawe-Taylor, The University of Southampton, School of Electronics and
    Computer Science, Highfield, Southampton, Great Britain
    Asst. Prof. Dunja Mladenič, Mitja Jermol, M. Sc.

21. KD-ubiq - A Blueprint for Ubiquitous Knowledge Discovery Systems 
    KD-ubiq
    6. FF. 021321
    IE; Dr. Michael May, Stephan Kollner, Fabian Perpeet, Fraunhofer Gesellschaft zur
    Förderung der Angewandten Forschung e.V., München, Sankt Augustin, Germany
    Asst. Prof. Dunja Mladenič

22. Integrated Decision Support System for HEALTH THREATS and Crises Management 
    HEALTHTHREATS
    Prof. Marko Bohanec

23. Fostering Language Resources Network 
    FlaNet
    e-Contentplus
    6. FP. 037680
    IE; Dr. Gregor Pipan, asst. Prof. Dunja Mladenič

24. Building Language Resources and Translation Models for Machine Translation focused on 
    South Slavic and Balkan Languages 
    SEE-ERA NET
    3. FP. 200007-380024
    Radoslav Pavlov, Institute of Mathematics and Informatics, Bulgarian Academy of
    Sciences, Sofia, Bulgaria
    Asst. Prof. Tomaz Erjavec

25. The use of a Dedicated Service on the HTTP Server of IJS http://ijs.nl.is:80 to be used by 
    FP for Up-loading and Storing Texts which constitute the FP Corpus of IX Century 
    Translated Books 
    Forschungsprojekt: Deutsch-slowenische/kroatische Übersetzung 1848 bis 1918
    Agreement, dated 3.5.2007
    Prof. Erich Prunz, Graz, Austria
    Asst. Prof. Tomaz Erjavec

26. Information Fusion for Data Mining in Bioinformatics and Biomedicine 
    BI-42/08-09-007
    Prof. Olga Štefanková, Czech Technical University in Prague, Prague, Czech Republic
    Prof. Nada Lavrač

27. Inductive Databases for Genomics and Proteomics 
    BI-08-07-028
    Dr. Tomislav Smuc, Rudjer Boskovic Institute, Zagreb, Croatia
    Prof. Sašo Džeroski

    BI-4/P/08-10/006
    Prof. Yoshiko Kawamura, Tokyo International University, Saitama, Japan
    Asst. Prof. Tomaz Erjavec

29. Knowledge Discovery for Ecological Modeling of Lake Ecosystems 
    BI-8/7-008-017
    Prof. Kosta Mitreski, Faculty of Electrical Engineering, Skopje, The Republic of Macedonia
    Prof. Sašo Džeroski

30. Landscape Functioning under Different Management Regimes 
    LANDEco
    SCRI, Living Technology, Dundee, Scotland, Great Britain
    Asst. Prof. Marko Debeljak

31. Analysis of Dynamic Networks with Graph and Text Mining Methods 
    BuUES/86-07-032
    Fakultas Christos, Carnegie Mellon University, Pittsburgh, PA, USA
    Asst. Prof. Dunja Mladenič

R & D GRANTS AND CONTRACTS

1. Advanced ML methods for automated modeling of dynamic systems 
   Prof. Sašo Džeroski

2. Linguistic annotation of Slovene language: methods and resources 
   Asst. Prof. Tomaz Erjavec

3. Methodological aspects of cognitive process research-learning and decision-making 
   Prof. Andrej Ule, Prof. Marko Bohanec

4. Unknown 17th and 18th century manuscripts of Slovenian literature: information-
   technology aided register, scholarly editions and analyses 
   Dr. Matija Ogrin, Asst. Prof. Tomaz Erjavec

5. Slovene Terminology Web Portal 
   Prof. Vojko Gorjanc, Simon Krek

6. Methodology for producing a detailed digital map of the height and density of 
   vegetation cover 
   Prof. Sašo Džeroski

7. Voice/TRAN II - Multilingual mobile speech communicator for 21th century warriors 
   Dr. Jernej Čepeček, Asst. Prof. Tomaz Erjavec

8. Crisis management simulator 
   Prof. Matej Penca, Asst. Prof. Dunja Mladenič

9. Development of Knowledge Management System for SV 
   Asst. Prof. Jaroslav Berc, Marko Grobelnik

10. Statistical semantic web systems 
    Asst. Prof. Dunja Mladenič

11. Metaservices - Semantic reasoning Grid services 
    Dr. Gregor Pipan, Asst. Prof. Dunja Mladenič

12. Digital text centre with multimedia communication 
    Dr. Matija Ogrin, Asst. Prof. Tomaz Erjavec
13. Harmonisation of technologies for following genetically modified organisms in food and feed production chain and its co-existence with conventional and ecological production chains
Asst. Prof. Vladimir Mekić, Prof. Nada Lavrač

14. Guidelines for national strategy of preservation of forest trees genefond due to introduction of genetically modified organisms in agriculture
Dr. Robert Brus, Prof. Marko Debeljak

15. Harmful factors for contemporary forests: methods for monitoring and ecological modelling; the impact of exploitation, and strategies for management
Prof. Maja Jure, Prof. Šašo Džeroski

16. Analysis and scenario of development and exploration of forests in Slovenia
Dr. Andrej Bončina, Prof. Marko Debeljak

17. Influence of gene transfer, genetic diversity and cultivation technology on sustainability and tracing methods
Asst. Prof. Vladimir Mekić, Prof. Marko Debeljak

Marko Grobelnik

VISITORS FROM ABROAD

1. Prof. Luis Torgo, Faculty of Economics, University of Porto, Portugal, 5-8 Jan. 2008 and 10-14 Dec. 2008


3. Tricia Jenkins, University of Liverpool, Liverpool, United Kingdom, 22-25 Jan. 2008

4. Margaret Evans, University of Liverpool, Liverpool, United Kingdom, 22-25 Jan. 2008


6. Prof. John Shawe Taylor, School of Electronics and Computer Science, University of Southampton, Southampton, United Kingdom, 31 Jan. 2008

7. Dr. Hendrich Blockeel, Katholieke Universiteit Leuven, Belgium, 4-8 Feb. 2008

8. Prof. Suzana Laksavsky, Faculty of Electrical Engineering and Information, Skopje, Macedonia, 15-22 Feb. 2008

9. Dr. John Davies, British Telecom, Ipswich, United Kingdom, 16. Feb. 2008


15. Elena Mitreska, Faculty of Electrical Engineering and Information, Skopje, Macedonia, 16-25 Mar. 2008


17. Andreja Naumoski, Faculty of Electrical Engineering and Information, Skopje, Macedonia, 16-25 Mar. 2008

18. dr. Paul B. Lossiewicz, European Office of Aerospace Research and Development, United Kingdom, 21-22 Apr. 2008


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1. Prof. Marko Bohaneč
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34. Nina Novinc, M. Sc.

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36. Marko Grobelnik
37. Jolanda Jakočič
38. Boštjan Pajntar

Note: * parttime JSI member


PUBLISHED CONFERENCE PAPERS

Invited Papers


Regular papers


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, evolutionary computing, data mining, search algorithms, language and speech technologies, decision support, intelligent sensors, distributed supervisory systems and network services. The department collaborates closely with the Faculty of Computer and Information Science of the University of Ljubljana on the joint research programme “Artificial Intelligence and Intelligent Systems”, led by Prof. Ivan Bratko.

Intelligent systems simulate intelligence so that a typical user seemingly perceives them as truly intelligent. In reality, these systems use complex mechanisms and implement them on digital computers to imitate human behaviour as well as possible, and combine them with raw, exponentially growing computer power.

**Ambient intelligence** is a relatively new research area. It aims at introducing technology into our everyday environment in a friendly and unobtrusive way, making it usable without special knowledge. Due to the rapid aging of the population, one of the area’s main goals is care for the elderly. The department has been developing methods for posture and movement recognition with an emphasis on fall detection. We were also investigating the recognition of common patterns of behaviour in general. To do this, we first needed to tackle the problem of the representation of human motion. The purpose of this research is the recognition of unusual events, be it signs of health problems or security threats.

**Evolutionary computing** deals with theoretical research, design and applications of search and optimization algorithms inspired by biological evolution. Our work in this area included the development and analysis of evolutionary algorithms for solving two demanding problems: the construction of markers for the production of clothes and vehicle assignment in cargo transportation. In the first problem, a sequence of markers needs to be found such that the production costs are as low as possible. In real problems the developed algorithm outperforms the algorithms used in practice up until now. The algorithm and its empirical evaluation were presented in the journal *Engineering Applications of Artificial Intelligence*. In the second problem, cargo of various types and amounts has to be transported between two sites, and the task is to assign cargo, loading positions at the origin, and unloading positions at the destination to the vehicles of various capacities in such a way that the total transportation time is minimised. The current version of our evolutionary algorithm improves the results of an available greedy heuristic algorithm for several problem instances, and we plan further improvements of its vehicle-assignment strategies.

Using **data-mining** techniques we tackled two tasks: genre identification and modelling of a tablet-manufacturing process. As part of a doctoral research in automatic web-genre identification, we used style-based categorization to identify genres of web pages. The impact of various types of features on the quality of identification was explored. Results showed that complex features - concepts - can be beneficial. We continued our research on an analysis of a pharmaceutical tablet-manufacturing process. For this purpose we developed a new method for process analysis. The method was successfully implemented on the data from the tablet-manufacturing process. We also developed an application for process visualization and modelling. The application contributed to a better understanding of the manufacturing process and achieving a higher quality for the produced tablets.

We study **search algorithms** for path-finding and other applications. We explained many cases of pathological behaviour of these algorithms. We have been developing an intelligent system for the surveillance of the movement of personnel and equipment in buildings that require high security. The project is called “Commander’s Right Hand” and is financed as a Targeted Research Project by the research program “Science for Security and Peace 2006–2010”.

Figure 1: We have developed an application for the visualization and modelling of a pill-manufacturing process. It uses machine learning to achieve a high-quality product.

We have been developing an intelligent system for the surveillance of the movement of personnel and equipment in buildings that require high security. The project is called “Commander’s Right Hand” and is financed as a Targeted Research Project by the research program “Science for Security and Peace 2006–2010”.

Figure 1: We have developed an application for the visualization and modelling of a pill-manufacturing process. It uses machine learning to achieve a high-quality product.
The European project Confidence aims at helping the elderly stay independent for longer at home and providing them with a better quality of life. The system is based on new, ambient intelligence methods and tags attached to the ankles. With this unobtrusive surveillance, the system can detect falls or illnesses and call for help.

In collaboration with the companies INEA, Elektro Ljubljana and Količevo Karton we carried out the project “Development of an e-service for power flow optimization in the distribution network by adaptable power consumption and power generation” (OPEDiOm). The service supports coordinated actions to reduce the gaps between the predicted and the actual power consumptions.

In the field of speech and language technologies we deal with algorithms, i.e., achieving worse results at a greater search depth. We also identified several factors that influence the benefits of a deeper search. For path-finding algorithms we developed methods for the automatic selection of the optimal search depth and waypoints.

The system is based on new, ambient intelligence methods and tags attached to the ankles. With this unobtrusive surveillance, the system can detect falls or illnesses and call for help.

In collaboration with the companies INEA, Elektro Ljubljana and Količevo Karton we carried out the project “Development of an e-service for power flow optimization in the distribution network by adaptable power consumption and power generation” (OPEDiOm). The project is funded by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia, and the European Regional Development Fund. The result of the project is a prototype implementation of an innovative e-service intended for power distributors and industrial consumers. It supports coordinated actions to reduce the gaps between predicted and actual power consumption.

Within the “Intelligent Home Telekom” project we have developed a universal virtual interface for interactive user communications in various services and applications of the national telecom operator Telekom Slovenije. The virtual interface is implemented in a web-based intelligent conversational robot prototype and is experimentally available on the Jožef Stefan Institute’s web page at http://www.ijs.si. The conversational robot interactively answers visitors’ questions in natural language. The main advantage of our virtual user interface over similar commercially available applications is its adaptability for quick implementation in various applications where any kind of user interaction takes place, such as television, telemedicine, technical support help desks, web portals, etc.

A traditional activity of the Department of Intelligent Systems is the organization of the International Multiconference Information Society. In October 2008, the 11th multiconference was held in Ljubljana, consisting of eight independent conferences.
Some outstanding publications in the past three years

1. I. Fister, M. Mernik, B. Filipič, Optimization of markers in clothing industry, Engineering Applications of Artificial Intelligence, 21 (2008), 669–678

Awards and appointments

2. Boštjan Kaluža: Faculty Prešeren award, Faculty of Computer and Information Science, Ljubljana, Bachelor thesis: Analysis of pathological models of minimax and Pearl’s game.

Organization of conferences, congress and meetings

2. 11th International Multiconference Information Society IS 2008; independent conferences:
   - Intelligent Systems
   - Data Mining and Data Warehouses
   - Cognitive Sciences
   - Slovenian Demographic Challenges of the 21st Century
   - Collaboration, Software and Services in Information Society
   - Education in Information Society
   - BIOMA 2008 – The 3rd International Conference on Bioinspired Optimization Methods and their Applications
   - Language Technologies
   Jožef Stefan Institute, Ljubljana, 13–17 Oct. 2008
3. Meeting of the European FW7 project Confidence, Jožef Stefan Institute, Ljubljana, 13–14 Nov. 2008

INTERNATIONAL PROJECTS

1. Ubiquitous Care System to Support Independent Living CONFIDENCE
   7. FP 214986
   EC. Centro de Estudios e Investigaciones Tecnicas de Guipuzcoa, San Sebastian, Spain
   Prof. Matjaž Gams, Prof. Leon Žlajpah
2. Enhancing Western Balkan eGovernment Expertise We-Go
   6. FP 044747
   EC. Dr. Klaus Josef Gschwendtner, ARC Seibersdorf Research GmbH, Vienna, Austria
   Prof. Matjaž Gams
3. New Methods for Automatic Identification Based on Intelligent Devices and Intelligent Agents - IntelliDAM BI-08/08-09/0015
   Dr. Vlad Mădălă Stefan, Faculty of Automatic Control and Computer Science, University Politehnica, Bucharest, Romania
   Prof. Matjaž Gams

R & D GRANTS AND CONTRACTS

1. Forensic Speaker Identification
   Dr. Tomaz Šef
2. Intelligent home Telekom
   Prof. Matjaž Gams
3. The role of Luka Koper in logistic support of the Slovenian Armed Forces and allies
   Asst. Prof. Bogdan Filipič
4. AuDi: Audio Visual Identification and Detection of Speaker Credibility to Give an Assurance of Secure Communication
   Dr. Tomaz Šef
5. Commanders right hand
   Prof. Matjaž Gams
6. Knowledge technology and decision support in medical information portals
   Prof. Matjaž Gams
NEW CONTRACTS
1. Intelligent home Telekom Telekom Slovenije, d. d., Ljubljana Prof. Matjaž Gams
2. Intelligent home Telekom Telekom Slovenije, d. d., Ljubljana Prof. Matjaž Gams
3. A prototype application of Slovenian text to speech system GOVOREC Srsi, d. o. o., Ljubljana Prof. Matjaž Gams
4. Dr. Iman Velaž, Centro de Estudios e Investigaciones Técnicas de Gipuzkoa, San Sebastián, Spain, 13–14 Nov. 2008
5. Naïara Arrue, Centro de Estudios e Investigaciones Técnicas de Gipuzkoa, San Sebastián, Spain, 13–14 Nov. 2008
6. Dr. Michael Pietrzyk, Fraunhofer Institute for Integrated Circuits IIS, Erlangen, Germany, 13–14 Nov. 2008
7. Dr. Matthias Schaefer, Fraunhofer Institute for Integrated Circuits IIS, Erlangen, Germany, 13–14 Nov. 2008
10. Dr. Claudia Sdogati, OOSIS Marche Onlus, Ancona, Italy, 13–14 Nov. 2008
11. Dr. Narciso Gonzalez Vega, University of Jyväskylä, Jyväskylä, Finland, 15–14 Nov. 2008

STAFF
Researchers
1. Prof. Ivan Bratko*
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11. Erik Doğan, B. Sc.
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16. Roža Piltaver, B. Sc.
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Technical officers
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Technical and administrative staff
24. Liliana Lasić
25. Mitja Lasić
Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLES
1. Vadim Bulitko, Jožef Stefan Institute, 2008
REVIEW ARTICLES AND CHAPTERS IN BOOKS


PUBLISHED CONFERENCE PAPERS

Regular papers


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-hydraulic phenomena, thermal-hydraulic safety analyses of design-basis and severe accidents, structural safety analyses and probabilistic safety assessments. Most of the research activities are part of international cooperation programs. The research results are incorporated into projects for industry and for regulatory authorities, and in graduate studies programmes.

Modelling of basic thermal-hydraulic phenomena
In the field of fluid mechanics and heat transfer research, the computer codes NEPTUNE_CFD and CFX were used to analyze inter-phase heat, mass, and momentum transfer in a horizontally stratified flow of cold liquid and hot steam. The emphasis of the work was on the NEPTUNE_CFD code, which is being specially developed for multi-dimensional simulations of two-phase flow in nuclear facilities. A horizontal pipe filled with hot steam and flooded with a cold liquid, and a horizontal pipe partially filled with a cold liquid with an injection of hot steam were described. The activities were part of the EU 6FP project NURESIM, which will continue in 2009 within the new 7FP project NURISP.

Research activities were carried out for the post-ITER generation of fusion reactors in cooperation with Forschungszentrum Karlsruhe (Germany) within the frame of the European Fusion Development Association (EFDA). The design of a helium-cooled divertor was optimized using computational fluid dynamics. The heat transfer characteristics and pressure drop were analysed and compared with experimental data. In the field of research on water-hammer transients, the computer code WAHA, which was developed within the EU 5FP project WAIHALoads, has been upgraded. The following new models were tested: the valve model, the unsteady friction model and the boundary conditions with a time dependent state at the inlet or outlet of the pipe.

A steam explosion might occur during a hypothetical severe accident in a nuclear plant if the molten reactor core were to pour into the water in the reactor cavity. Within the OECD project SERENA, where we are leading the analytical activities, we performed comprehensive pre-test calculations of the first two steam-explosion tests with the European code MC3D. The experiments are being performed on the complementary KROTOS (Commissariat à l’Energie Atomique - CEA, France) and TROI (Korea Atomic Energy Research Institute) facilities. The main purpose of the pre-test calculations was to establish the optimal water subcooling and the optimal triggering time, maximizing the steam-explosion strength. We have also been developing appropriate melt droplets solidification models and the corresponding melt-droplets fragmentation criteria. These activities are being carried out within the EU 6FP SARNET Network of Excellence.

Thermal-hydraulic safety analyses
Best-estimate calculations with the RELAP5/MOD3.3 thermal-hydraulic computer code were performed to estimate the operator-action success criteria time windows. The time windows were needed for an updated human-reliability analysis for events in which human actions are supplemented to safety systems actuations. These were small or medium loss of coolant accidents (LOCAs) requiring a manual auxiliary feedwater (AFW) start, a loss of normal feedwater requiring an AFW start, and a LOCA requiring manual actuation of the safety injection.

An animation model of the Krško nuclear power plant was developed using SNAP, which is a suite of integrated applications designed to simplify safety analyses. The model allows a better understanding of the simulated physical phenomena and processes during an accident, and represents a useful tool for training new users of thermal-hydraulic codes.
Multi-scale simulations are used to predict the propagation of short cracks in polycrystalline materials.

In the field of modelling containment phenomena, which is also being carried within the SARNET network, simulations of experiments on containment sprays, performed on the TOSQAN facility at the Institut de Radioprotection et de Sûreté Nucléaire, France, with the Computational Fluid Dynamics code CFX, have been concluded. The emphasis was on the experiment TOSQAN 113 on atmosphere stratification break up. A blowdown experiment, which was performed in the Marviken Boiling Water Reactor containment experimental facility in Sweden, was simulated with the codes CONTAIN and ASTEC CPA.

**Structural safety analyses**

The long term research focus is the development of multi-scale computational simulation tools for polycrystalline metallic materials. An advanced constitutive model of crystal plasticity is combined with random grain sizes and shapes, represented by the Voronoi tessellation. The microscopic stress fields in randomly oriented and shaped grains are then obtained using the finite-element solver ABAQUS.

In 2008 we began the development of physical grain structures, based on experimental data. The purpose of the research is the development of computer models and codes for the prediction of intergranular crack initialization and growth. The spatial structure of grains is obtained using the diffraction-contrast tomography method, which has been developed together by the University of Manchester, UK, and the European Synchrotron Radiation Facility. Grain shapes must first be reconstructed from experimental data. The influence of the grain structure on the behaviour of the material is then estimated using the finite-element method. The crystallographic orientation and anisotropic behaviour of the grains are taken into account. Also, the development of three-dimensional models of aggregates was started in cooperation with CEA, France. These models will enable us to obtain a more complete picture of the influence of the microstructure on short cracks.

A method for the realistic estimation of the use of nuclear-power-plant components was conceived in 2008. The method can be used to support a possible life-time extension of the Krško nuclear power plant. The list of research partners includes the EU Joint Research Center in Petten, The Netherlands; Forschungszentrum Karlsruhe, Germany; and AIB-Vinçotte Nucléaire, Belgium. We are also members of the EU Network of Excellence on nuclear-plant lifetime prediction NULIFE.

**Probabilistic safety assessment**

Models for the probabilistic safety assessment of nuclear power plants were developed for modes other than full power operation; these include low-power operation mode, hot-standby mode and hot-shutdown mode. The results enable a more detailed assessment of nuclear power plant safety.

A procedure for the assessment of ageing and its application within probabilistic safety assessment models was developed. Probabilistic models that are based on a constant failure rate were modified, based on models that may include the time dependent increase of the failure rate as a consequence of ageing. The problem in new models is the large uncertainty of the results, which is caused by a lack of the necessary input data.

The new method for the assessment of power system reliability was investigated in two case studies: the standard IEEE (Institute of Electrical and Electronics Engineers) test problem and the Slovenian transmission power system. Both studies included an assessment of power-system reliability, its sensitivity to changes such as the insertion of new power lines or the addition of new power plants or both, and the contribution of power system reliability to the safety of nuclear power plants included in the system.

**Technical cooperation, consulting services and education**

In 2008 the Reactor Engineering Department researchers also cooperated in projects for industry and the state administration. The JSI issues permissions for rectorility and the regular operation of the Krško NPP after each regular outage. Members of the department are also actively involved in the Nuclear Engineering Graduate Programme at the Faculty of Mathematics and Physics at the University of Ljubljana. The programme is associated with the European Nuclear Education Network (ENEN) and the European project ENEN-II.
Some outstanding publications in the past three years:


Organization of conferences, congress and meetings

2. SARNET Containment Atmosphere Mixing 5th Workshop, Bled, 28–29 Feb. 2008
3. SARNET Governing Board Meeting, Bled, 14 Mar. 2008

INTERNATIONAL PROJECTS

1. BK - Fusion - Modelling of High Flux Helium Cooling - Diverter Design - 4.5.1.
   EURATOM - MiHES
2. FP, EURATOM, Slovenian Fusion Association - SFA
   3211-08-000102, FP07-CT-2007-00065
   EU, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   Dr. Boštjan Končar
3. Consolidation of European Nuclear Education, Training and Knowledge Management
   ENEN-II
   EU
   6. FP - EURATOM
   O36404
   EC, Dr. Peter De Regge, ENEN Association, Centre CEA de Saclay, Gif-sur-Yvette, France
   Prof. Leon Cizelj
4. Sustainable Nuclear Fission Technology Platform
   SNF-TP
   EU, 6. FP, O36460
   EC, Prof. Dan G. Cacuci, CEA Saclay, DEN/DIR, Gif-sur-Yvette, France
   Prof. Borut Mavko
5. Nuclear Plant Life Prediction
   NULIFE
   EU, FP, O364612
   EC, Valmon Teknillinen Tutkimuskeskus (VTT), Espoo, Finland
   Prof. Leon Cizelj
6. European Platform for Nuclear Reactor Simulations
   NURESIM
   FP, O36560
   EC, Maryline Rougier, CEA Saclay, DEN/DSOE, Gif-sur-Yvette, France
   Prof. Iztok Tiselj
7. Network of Excellence for Sustainable Integration of European Research on Severe Accident Phenomenology and Management
   SARNET
   FP, O36560-CT-2004-509065
   EC, Institut de Radioprotection et de Surete Nucleaire, Clamart, France
   Dr. Matjaž Leskovar
8. Full Condensation-Induced Water Hammer in Vertical Vessels
   INTAS
   Ref. No.: 95-1000008-8086
   INTAS - International Association for the promotion of co-operation with scientists from the New Independent States of the former Soviet Union, Brussels, Belgium; Prof. Francesco D’Auria, Dr. A. Bousba Salah, University of Pisa, Facoltà di Ingegneria, Dipartimento di Ingegneria Nucleare Meccanica e della Produzione (DIMNP), Pisa, Italy
   Prof. Iztok Tiselj
9. Steam Explosion Resolution for Nuclear Applications
   SERENA
   OECD/NEA
   Jean Gauvain, OECD Nuclear Energy Agency, Isy-les-Moulineaux, France
   Dr. Matjaž Leskovar
10. SETH-2 Project to Resolve Key Computational Issues for the Simulation of Thermal-Hydraulic Conditions in Water Reactor Containments
    SETH-2
    OECD/NEA
    Jean Gauvain, OECD Nuclear Energy Agency, Isy-les-Moulineaux, France
    Prof. Borut Mavko, Dr. Ivo Kljenak
    Dr. Andrew J. Saikewicz, Reactor and Plant Systems Branch, Division of Systems Technology, Office of Nuclear Regulatory Research, Dr. Ashok C. Thadani, Donna-Maria Perez, Office of Nuclear Regulatory Research, United States Nuclear Regulatory Commission (US NRC), Washington, USA
    Prof. Borut Mavko
12. PHEBUS Fission Products Agreement
    SLO-F-2003-2008
    Daniel Gruinat, Acting Director, Institut de Radioprotection et de Sûreté Nucleaire (IRSN), Clamart, France
    Dr. Matjaž Leskovar
13. Incorporation of Age-dependent Reliability Parameters and Data into Probabilistic Safety Assessment Models
    IE.B104899
    Sylwia Zamara, European Commission-Directorate General JRC, Institute for Energy, Petten, The Netherlands
    Asst. Prof. Marko Čepin
14. Modelling of Intergranular Damage in Polycrystalline Metals
    B-BG/08/010
    The University of Manchester, Department of Materials Performance Centre, School of Materials, Manchester, Great Britain
    Dr. Igor Simonovski

R & D GRANTS AND CONTRACTS

1. Direct Contact Condensation in Stratified Two-Phase Flow
   Prof. Iztok Tiselj
2. Multiscale model of Small Crack Initialization and Propagation in Pressure Boundary Components of a NPP
   Dr. Igor Simonovski
3. Modeling of Fluid Transport in Nanotubes
   Dr. Ivo Kjernej
4. Simulations of Two-phase Thermalhydraulic Phenomena in Nuclear Engineering by Computational Fluid Dynamics Methods
   Dr. Boštjan Končar
5. Application of methods and techniques to assess ageing and support safe operation of nuclear installations and radiation facilities
   Prof. Leon Čeželj
6. Improvement of Nuclear Safety with the Probabilistic Safety Assessment
   Asst. Prof. Marko Tomaz Čepin
7. Strategic Role of Nuclear Power Production in Comparison with other Sources and Impact on the Slovenian Economy
   Dr. Miroslav Babić, Ivo Kljenak, Borut Mavko
8. Development of Knowledge Indispensable for Evaluation, Assessment and Surveillance of Ageing Management in Nuclear Facilities
   Prof. Leon Čeželj
9. Conception of a Method for Monitoring of the Usage of NPP Components
   Dr. Boštjan Zafošnik
10. Use of CFD approach for safety analysis of nuclear reactor systems
    Dr. Boštjan Končar
11. Simulation of MISTRA containment tests with computational fluid dynamics and lumped-parameter codes
    Dr. Ivo Kjernej

RESEARCH PROGRAM

1. Nuclear engineering
   Prof. Borut Mavko

NEW CONTRACT

1. Cooperation in the international research program CAMP (Code Applications and Maintenance Program)
   Ministry of the Environment and Spatial Planning, Slovenian Nuclear Safety Administration, Ljubljana
   Dr. Andrej Prošek

VISITORS FROM ABROAD

1. Dr. Jurij Parfenvov, Electrogorsk Research and Engineering Centre of NPPs Safety, Moscow, Russia, 9–23 Jan. 2008
2. Prof.dr. Michel Giot, Université catholique de Louvain, Belgium, 19–20 Jun. 2008

STAFF

Researchers
1. Prof. Leon Čeželj
2. Asst. Prof. Marko Tomaz Čepin
3. Liubj Fabjan, M. Sc
4. Dr. Romana Jordan Cizelj
5. Asst. Prof. Ivo Kjernej
6. Dr. Boštjan Končar
7. Dr. Matjaž Leskovar
8. Prof. Borut Mavko, Head
9. Prof. Boštjan Končar
10. Dr. andrej prošek
11. Dr. Ivo Kljenak
12. Dr. Boštjan Zafošnik

Postdoctoral associates
13. Dr. Miroslav Babič, left 1 May 2008
14. Dr. Janes Gale, left 1 Apr. 2008
15. Duško Kančev, B. Sc
16. Zoran Petrič, B. Sc
17. Ika Strubež, B. Sc
18. Mitja Urušič, M. Sc
19. Dr. Andrej Volkanovski

Technical officers
20. Dr. andrej sušnik, B. Sc

Technical and administrative staff
21. Tanja Klopčič
22. Zlata Vrhovec Mikolič

Note:
" part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLES

Published Conference Papers

invited papers


Regular Papers


236

Ph. D. Theses


The TRIGA Mark II Reactor at the Jožef Stefan Institute has been operating since 1966. It is used for neutron research, training and for producing radioactive isotopes. Besides operating and maintaining the reactor, the members of the reactor’s staff cooperate in other activities requiring specialists skilled in working with sources of radiation and in reactor technology, such as the servicing of industrial radioactive sources and the surveillance of the fuel management in NPP Krško. A detailed technical description of the reactor is available at http://www.rcp.ijs.si/~ric/

In 2008 the reactor operated for 128 days. A total of 1295 samples were irradiated: 1071 of them in the rotary specimen rack and 224 in the pneumatic post system.

The reactor mainly operated in steady-state mode. There were no serious operational problems or events influencing nuclear or radiological safety. The reactor operators performed regular maintenance inspections and works according to the annual plan.

The Hot Cell Laboratories, mainly used for work with strong radioactive sources, were formally included in the reactor as a nuclear installation by the decree of the SNIA. The maintenance work in the hot cells was continued and accomplished in the first half of 2008. The operating license was issued by the SNIA. In the second half of 2008, the hot cells were commercially hired by the Slovenian Rad-Waste Agency for the EU project “Improvement of the management of institutional radioactive waste in Slovenia” within the framework of the EU project “Transition Facility”. The staff at the reactor and of the JSI health-physics services participated in a project carried out by the Belgian company LENIKO.

The reactor was mainly used for neutron-activation analysis. The reactor operated mainly for the needs of the Jožef Stefan Institute’s research departments: the Department of environmental science, the Department of reactor physics, the Department of experimental particle physics and the Department for Nanostructured Materials. The reactor was used in the following research:

- neutronics and reactor physics,
- activation analysis,
- neutron dosimetry and spectrometry,
- neutron radiography,
- activation of materials, nuclear waste and decommissioning,
- irradiation of materials for fusion reactors.

The reactor operators support 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 manipulation with radioactive samples.

The results of this research were published in approximately 20 scientific papers, and 3 young researchers performed their research at the reactor. Practical exercises were completed by students of physics at the University of Ljubljana. Post-graduate students of nuclear engineering attended some of these exercises as well. For these purposes the reactor operated for approximately 10 days. The reactor was also used for practical exercises within the training program of the NPP Krško reactor operators. Also, some post-graduate students of nuclear engineering at the Faculty of Mathematics and Physics of the University of Ljubljana participated in the exercises. The exercises were prepared and carried out by the reactor’s personnel in cooperation with IJIT and F-8.

In 2008 there were more than 50 short group visits to the reactor. The visitors were mainly foreign scientists, students and school children. Their total number was more than 500.

### STAFF

**Researchers**
1. Prof. Matjaž Ravnik, Head
2. Darko Kavšek
3. Bojan Huzjan
4. Bojan Oman
5. Marko Rosman

**Administrative staff**
6. Darja Stach

**INTERNATIONAL PROJECT**

1. Improvement of the Management of Institutional Radioactive Waste in Slovenia

   1145406-06-01-0001

   Agency for Radwaste Management, Ljubljana, Slovenia, Leniko bvba, Antwerp, Belgium
   Bojan Huzjan, Dr. Galper Tavčar, Bogdan Pucolj, M. Sc., Dr. Borut Smodiš
The basic function of the Centre for Network Infrastructure (CNI) is the management and maintenance of the JSI computer network, including planning, development, upgrades, maintaining contact with public networks, and providing security. CNI also houses and supports the local SigNet GRID cluster.

STAFF

Technical officers
1. Vladimir Alkalaj, M. Sc., Head
2. Mark Martinec, B. Sc.

Technical and administrative staff
3. Ivan Ivanjko
4. Matjaž Levstek
5. Janez Srakar
6. Matej Wedam

BIBLIOGRAPHY

Textbooks and Lecture Notes
The Jožef Stefan Institute’s Science Information Centre is the central Slovenian physics library and one of the largest specialist libraries in Slovenia. Our main tasks are the acquisition, archiving, and loan of books and periodicals, and the input, update and control of bibliographic data of the Institute’s staff, as requested by the funding ministry.

Our collection covers the fields of physics, chemistry, biochemistry, electronics, information science, artificial intelligence, nuclear technology, energy management and environmental science. We are a full member of the Slovenian library cooperative, COBISS, and use their services to catalogue and loan our materials. You can check what is new in the library, browse our online catalogue, or send inter-library loan requests using our website.

We supplement our comprehensive print collection of core journals with the electronic editions, offered through our website. We subscribe to the electronic collections offered by ScienceDirect, Springer Link, Stanford HighWire Press, ACS online editions, AIP electronic editions, IOP online journals, Wiley Interscience. We provide access to the SCOPUS, INSPEC, Crossfire Beilstein, and Web of Science databases, and the Dialog online database services.

We manage a bibliographic database of the Institute’s production. This database contains about 80,000 records, going back to the Institute’s inception in 1949. The records for 2008 are included as part of this report.

STAFF

Technical Officers
1. Katarina Modic, B. Sc.
2. Slavka Šmuc, B. Sc.
3. Alenka Štante, B. Sc.
4. Dr. Luka Šušteršič, Head
5. Marjan Verč, B. Sc.

Technical and administrative staff
7. Jasna Malalan
8. Joško Per
9. Jole Škulj
10. Branka Štrancar
11. Nada Tratnik
12. Saša Znidar

Figure 1: poster presented by A. Štante at 74th IFLA General Conference and Council
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 EEC’s activities is thus cooperation with state institutions in the field of efficient energy use, energy planning, environmental taxes and emission trading; nevertheless, it still remains strongly connected, by its consulting role in energy, with industrial companies and institutions.

Energy and the environment
In 2008 the key activities of the Energy Efficiency Centre were focused on different professional tasks in energy and on the reduction of the impact of energy use on the environment, especially in the field of greenhouse-gases emissions. The EEC has long experience in the fields of energy, energy use, electricity production and, in recent years, on the impact of the production and use of energy on the environment. As a result, in 2008 the EEC prepared various strategic studies for the Ministry of Environment and Spatial Planning and the Ministry of the Economy, necessary for the decisions of both ministries. These studies are from the fields of greenhouse-gases-emissions reduction, the introduction of cogeneration and renewable energy sources, the preparation of an overview for carrying out energy policy in Slovenia and similar.

In 2008 the Energy Efficiency Centre prepared a proposal for long-term energy balances of the Republic of Slovenia up to 2026, which has to be accepted by the government, according to the Energy Law. At the end of the year the centre started to prepare two documents based on these results: the Green Book, as a discussion document for a wider professional discussion, and the preparation of the starting points for the elaboration of a new National Energy Programme in 2009.

In autumn, the centre, in a consortium of ten research institutions, successfully started with a greater target development project “Slovenia, low-carbon society”, which should, in view of a new technological development and the guidelines of environment energy policy, map the direction for the future development of Slovenia. Regarding the planned budget for the project (€480,000 in three years), it is one of the largest of such projects, which is financed by the Research Agency of the Republic of Slovenia, the Government Office for Development, the Ministry of the Environment and the Ministry of the Economy.

In 2008, Slovenia entered in the first year of the target period of the Kyoto Protocol, when it has to, in accordance with the ratified protocol, reduce greenhouse-gases emissions by 8% compared to the base year, 1986. Due to negative trends in the fulfilling of the goal, the preparation of the document “Monitoring of the Carrying Out of the Operative Programme of Greenhouse-Gases-Emissions Reduction” for the Ministry of Environment was one of key documents which, based on a transparent quantitative analysis of the situation and the carrying out of planned measures of the programme, presented an integral insight in the problems and a good starting point for the planning of future activities. The development of efficient indicators of the situation estimation and achieving of the set goals and identification of the key factors of emissions growth is here a key instrument for the support of the ministry decisions.

The Directive on Energy Services and Accepted Climate - Energy Package also set obligatory goals for Slovenia regarding the increase of energy efficiency up to 2016 and 2020. In 2008 the centre started to carry out a greater project of preparation of methodologies for the evaluation of carrying out of efficient energy-use measures, that will be a key instrument for proving the fulfilment of set goals. The project, financed by the Ministry for Environment and Spatial Planning, is incorporated into other European projects for the preparation of evaluation methodologies. The EU wants to establish harmonized approaches in all member states in this field.

In the annual review of the Slovenian energy sector for 2007 the EEC drew attention to the fact that all energy use and supply indicators, despite the appeasing of some trends, show movements which are worse than energy politics’ expectations. This means that political energy mechanisms...
have not so far achieved the expected results and were not carried out as planned. That does not lead to the achievement of demanding goals of the energy–climate EU package up to 2020 (especially the increase in the share of renewables to 25% in the end energy, and the increase of energy efficiency by 20%). In the future, with active EEC participation, it will be necessary to focus on the execution of the mechanisms for energy-use management to improve competitiveness, reliability and the environment, which is one of key development directions in the current economic crisis.

Efficient support for electricity production from renewable sources and cogeneration with high efficiency is a key condition for the further development of electricity production that can significantly contribute to ensure supply reliability, the balanced development of Slovenia and to fulfil the goals of energy–climate policy. In 2008, cooperation with the Ministry of the Economy continued with the execution of two support studies to prepare a new support scheme that should start to function at the beginning of 2009.

Promotion of efficient energy use and energy consulting

The activities of the Energy Efficiency Centre in 2008 in the field of the promotion of efficient energy use and energy consulting in industry and institutions were particularly characterized by the establishment and carrying out of the first cycles of the training of energy managers in the framework of the European programme EUREM, which was successfully concluded in December by the first 24 participants. In October, the second cycles of education had already started. Due to a very positive reaction of the participants and their interest, 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 2008 the Energy Efficiency Centre carried out several consulting tasks in industry and a series of energy audits of enterprises to reduce energy use and costs as well as emissions. An important milestone was the beginning of the execution of the energy audit in Thermopower Plant Ljubljana, which confirmed the supposition that in larger units for electricity production there is still a great potential for energy-efficiency increases. Cooperation in the project “Impact of Demand Side Management (DSM) on the Use in the Transfer Network” (Client ELES) represented an important step in establishing the active role of system operators in carrying out measures of directing consumption and the inclusion of demand-side management into network planning and development.

The centre also prepared the programme of the tenth jubilee of the largest Slovenian conference for energy managers “Energy Managers’ Days”, the annual meeting of energy managers, with more than 200 participants, which confirms the quality and public profile of the EEC’s professional work. The centre continues to issue the Energy Efficiency Newsletter for the Ministry of the Environment and Spatial Planning. Individual EEC experts published numerous articles in magazines and newspapers and took part in radio and television broadcasts.

International cooperation

In 2008 the EEC carried out as many as 11 international projects, financed from European Union resources in the 6FP and the European Commission programme “Intelligent Energy for Europe”.

Projects cover activities in the fields of:

- new technologies and energy efficiency in EU research programmes - Scientific Reference Systems on New Energy Technologies and Energy End-Use Efficiency and Energy RTD (SRS NET & EEE),
- establishment of a European network for energy managers’ training – Training and network of European Energy Managers (EUREM.NET),
- compiling and elaboration of current data on renewable energy sources use - EurObserv’ER Barometer,
- carrying out of European programme of efficient lighting “New Greenlight” in Slovenia – The European Greenlight Programme in New Member States (New Greenlight),
- carrying out of the directive on energy services and the evaluation of energy-efficiency measures – Concerted Action - Energy Service Directive (CA – ESD)

Projects include cooperation with R&D 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. For Intelligent Energy for Europe projects, the EEC acquired partial co-financing from the Ministry for the Environment and Spatial Planning.
Some outstanding achievements in 2008

1. Preparation of several key support documents for the Government of the Republic of Slovenia in the field of energy efficiency (National Action Plan for Energy Efficiency), climate policy (Operative programme of GHG emissions reduction up to 2012) and energy policy (Proposal for Long-Term Balances of RS up to 2026)
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, Cinkarna Celje, Litostroj, TE-TOL etc.).
3. Cooperation in different international projects in the framework of European Commission programmes in the fields of energy efficiency, energy management, combined production of electricity and heat, promotion of energy-efficient technologies, external costs in energy, exploitation of wood biomass and others.

Organization of conferences, congress and meetings


INTERNATIONAL PROJECTS

1. Network for Promotion of RT Results in the Field of Eco-building Technologies, Small Polygeneration and Renewable Heating and Cooling Technologies for Buildings ProdcoPolyNet, PFNet
   FP7
   FP7/2007-2013
   Tisk/06/PFGEN/507.54455/020114
   EC, Michael Geißler, Berliner Energieagentur GmbH (BE), Berlin, Germany
   Tomaz Fatur, M. Sc.

2. Scientific Reference System on New Energy Technologies, Energy End-use Efficiency and Energy RTD
   SRS NET & EEE
   FP6
   FP6/006651
   EC, Dr. John Puaras, National Technical University of Athens, Zografou, Greece
   Tomaz Fatur, M. Sc.

3. New Energy Externalities Development for Sustainability NEEDS
   6. FP
   FP05/2687
   EC, Adele Versetti, Istituto di studi per l’Integrazione dei sistemi, Rome, Italy
   Dr. Mihael Gabrijel Tomšič

4. EuroObservE Barometer
   EuroObservE ER
   IEE Programme
   IEE/07/056/502.466634
   EC, Observatoire des Energies Renouvelables (ObservE ER), Paris, France
   Polona Lah, B. Sc.

5. Monitoring of Energy Demand Trends and Energy Efficiency in the EU ODYSSEEE MURE (EU-29)
   IEE Programme
   IEE/07/297/502.466291
   EC, Didier Bosseboeuf, Agence De l’Environnement et de la Maîtrise de l’Energie (ADEME), Angers, France
   Dr. Fouad al-Mansour

6. Training and Network of European Energy Managers EUREM.NET
   IEE Programme
   IEE/06/954/512.447464
   EC, Dr. Robert Schmidt, Tom Ankirchner, B. Sc., Industrie-und Handelskammer Nürnberg für Mittelfranken Geschäftsbereich, Innovation/Umwelt, Nürnberg, Germany

7. The European GreenLight Programme in New Member States NEW GREENLIGHT
   IEE Programme
   IEE/05/152/512.498984
   ES, Jarur Krivosiek, SEVEN, Stredisko za efektivni využívání energie, o.p.s., The Energy Efficiency Center, Prague, Czech Republic
   Evald Kranjčevič, M. Sc.

8. Cogeneration Observatory and Dissemination Europe C.O.D.E
   IEE Programme
   IEE/07/564/512.499462
   EC, COGEN EUROPE, Brussels, Belgium
   Stane Melše, M. Sc.

   CA ESD
   IEE Programme
   IEE/CA/08/001/512.503473
   EC, Rob Boeree, SentervNovem, Sittard, The Netherlands
   Damir Stanurić, M. Sc.

    584
    Dr. Fritz Unterpentering, Österreichische Energieagentur - Austrian Energy Agency, Vienna, Austria
    Evald Kranjčevič, M. Sc.

11. The Review of Permits, Monitoring, Plans, and Verification Reports in the EU Greenhouse Gas Emissions Trading Scheme at the Level of Member States
    SA DTD 15.1-2008 N01
    Günter Schock, TÜV Rheinland Immissionsschutz und Energiesysteme GmbH (TIE), München, Germany
    Evald Kranjčevič, M. Sc.

R&D GRANTS AND CONTRACTS

1. Slovenia - Low Carbon Society
   Andreja Urbančič, M. Sc.

2. Determination of Applied Potential of Agricultural Biomass and Definition of Environment Friendly Technologies Using for its Exploitation
   Dr. Fouad Al-Mansour

3. Establishment of an ErGIS system for Stimulation of Renewables and Preparation of a Multi-Sectoral Analysis of Energy Potentials
   Tomšič Fatur, M. Sc., Dr. Fouad Al-Mansour

RESEARCH PROGRAM

1. Environment Impact - Modelling and Assessment
   Dr. Borut Smočić, Dr. Fouad Al-Mansour

NEW CONTRACTS

1. Advising on the Coordination of Standpoints in the Field of Climate Changes
   Ministry of the Environment and Spatial Planning, Ljubljana
   Andreja Urbančič, M. Sc.

   Ministry of the Environment and Spatial Planning, Ljubljana
   Dr. Fouad Al-Mansour

3. Effect of Demand Side Management (DSM) on the Use in the Transfer Network
   University of Ljubljana, Electrotechnical Faculty, Ljubljana
   Stane Melše, M. Sc.

   Ministry of the Environment and Spatial Planning, Ljubljana
   Evald Kranjčevič, M. Sc.
5. Energy Audit of Combined Heat and Power Production Plant Ljubljana
   Combined Heat and Power Plant Ljubljana, Ljubljana
   Damir Stančič, M. Sc.
6. Editing of Energy Efficiency Newsletter
   Ministry of the Environment and Spatial Planning, Ljubljana
   Barbara Petelin Visočnik, M. Sc.
7. Methodology of Determining Referential Costs for By-Law Acts Regarding Subsidies
   Ministry of the Economy, Ljubljana
   Stane Merše, M. Sc.
   Producers from RS and from Combined Electricity Production with High Efficiency
   Ministry of the Economy, Ljubljana
   Stane Merše, M. Sc.
   Ministry of the Economy, Ljubljana
   Polona Lah, B. Sc.
    Ministry of the Economy, Ljubljana
    Andreja Urbančič, M. Sc.

VISITORS FROM ABROAD
1. Joris Thijsen, anti coal global action head, Greenpeace International, Amsterdam, the Netherlands, 8 Apr 2008
2. Alan Ryan, industrial programmes head, Sustainable Energy Ireland, Dublin, Ireland, 8 Apr 2008
3. Joris Thijssen, anti coal global action head, Greenpeace International, Amsterdam, the Netherlands, 8 Apr 2008
4. Marko Pečkaj, B. Sc.
5. Barbara Petelin Visočnik, m. sc.
6. Roberto Bini, vice president, Turboden, Brescia, Italy, 9 Apr 2008
8. Dr. Reinhard Paülinger, renewables research head, Joanneum Research, Graz, Austria, 9 Apr 2008
11. Dr. Na Zhang, research professor, Chinese Scientific Academy, Beijing, China, 9 Jul 2008
12. Dr. Na Zhang, research professor, Chinese Scientific Academy, Beijing, China, 9 Jul 2008

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2. Evald Kranjčevič, M. Sc.
3. Stane Merše, M. Sc., Head

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4. Dr. Fouad Al-Mansour
7. Marko Pečkaj, B. Sc.
10. Andreja Urbančič, M. Sc.

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11. Roza Pergaroč, B. A.
12. Igor Ribič
13. Milan Šimončič

BIBLIOGRAPHY

ORIGINAL ARTICLES

PUBLISHED CONFERENCE PAPERS
Invited Papers

Regular papers

REVIEW ARTICLES AND CHAPERS IN BOOKS
The Centre for Electron Microscopy (CEM) has the function of a supporting infrastructure center at the JSI that comprises the equipment for electron microscopy which is necessary for the research work of the departments K5, K6, K7, K8 and K9. Other JSI departments, research institutes, universities and industry also have access to the equipment. The users of the CEM equipment are the researchers in the field of materials science that are involved in the chemical and structural analysis of materials on the micro and atomic scales. The major pieces of equipment at the CEM are two scanning electron microscopes (JSM-840A and JSM-5800) and two transmission electron microscopes (JEM-2000FX and JEM-2010F).

Scanning electron microscopy (SEM) is used for morphological studies of either fractured or polished surfaces. Since both scanning electron microscopes are equipped with X-ray spectroscopy (EDXS, WDXS), qualitative and quantitative chemical analyses on the micro-scale are also possible. Since only a few µm³ of the material are nondestructively analyzed, the term electron-probe microanalysis (EPMA) is used for such analytical work.

When structural features on the nanoscale are investigated, however, various techniques of transmission electron microscopy (TEM) are used. In particular, the JEM-2010F is a state-of-the-art TEM/STEM microscope with a FEG (field-emission gun) electron source and with a point-to-point resolution below 0.19 nm, which is more than sufficient to observe the atomic columns in crystalline materials. The JEM-2010F is also equipped with an annular dark-field detector (HAADF-STEM) for so-called Z-contrast imaging, which enables chemical analyses of a single atomic column on the basis of the measured intensities. Both transmission electron microscopes are additionally equipped with analytical systems for chemical analyses (EDS, EELS). The CEM also comprises the equipment for SEM and TEM specimen preparation, which is the first step for all electron-microscopy observation procedures. Of particular importance are the high- and low-energy ion-millers, which are used to prepare thin foils that are transparent to high-energy electrons.

The analytical work that is performed on the CEM equipment varies, concerning both investigated materials and/or electron-microscopy techniques. While scanning electron microscopy is used mainly for the microstructural characterization and chemical analysis of polycrystalline ceramic materials (functional ceramics, engineering ceramics, bio-ceramics, and composites), magnetic materials, glasses, metals, alloys, etc., transmission electron microscopy is used for the structural and chemical investigations of grain boundaries, planar faults, dislocations and the formation of defects.

**Figure 1**: SEM-SEI micrographs of K₀.₅Na₀.₅NbO₃ (KNN) single crystals and matrix grains with: a) 0.5 and b) 2 mol % K₄CuNb₈O₂₃ after annealing at 1100°C for 10 hours. The microstructures show the effect of the addition of a K₄CuNb₈O₂₃ liquid-phase sintering aid on the growth of the matrix grains and KNN single crystals. (Journal of the European Ceramic Society 28, 2008, 1657–1663). The research was part of the EU 6FP project IMMEDIATE. (photo: A. Benčan Golob, K-5)

**Figure 2**: HRTEM image of idiomorphic PbSe nanocrystals (rock-salt structure), prepared by mechnochemical treatment (Dr. M. Achimovicová, Slovak Academy of Sciences). {100} interplanar spacing 0.3 nm. (photo: N. Daneu, K-7)

**Figure 3**: TEM micrograph of Si₃N₄ particles coated by nanosized ZrN particles after calcination at 1600°C, 2 h in flowing N₂. (photo: A. Maglica, K-6)
precipitates within the same materials. The structural and chemical analyses of grain boundaries are especially important since the final physical properties of a material, to a large extent, depend on the structure and chemistry of grain boundaries.

In order to be able to perform electron microscopy investigations it is imperative that the equipment in the CEM is well maintained. With regard to this, one on the center's main tasks is to attain the maximum possible operational time for the microscopes. This complex and expensive equipment needs regular daily maintenance in addition to specialized servicing. Other activities of the CEM include the organization of training courses for operators and the implementation of new analytical methods, which is realized with the help of CEM co-workers.

Figure 4: High-resolution electron micrograph of nanocomposite particle composed of magnetite (marked with broken line) intergrown into Ba-hexaferrite. The particle was prepared using hydrothermal decomposition of BaFe₁₂O₁₉ (photo: D. Makovec, K-8).

Figure 5: CTEM micrograph of multiwalled Ca-Ti-based nanotubes prepared by hydrothermal synthesis (100°C, 12 hours). EDXS analysis showed the presence of ~11 at% of calcium in the nanotubes (photo: I. Bracko, K-9).
By partnering and actively engaging in various European research projects the centre successfully extends its activities to R&D. 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 2008 the centre was active in several European projects from the EU FP6: “Pattern Analysis, Statistical Modelling and Computational Learning” (PASCAL), “Lifecycle Support for Networked Ontologies” (NEMON), “Extended Enterprise management in Enlarged Europe” (Ex), “Open Source Enterprise Resource Planning and Order Management System for Eastern European Tool and Die Making Workshops” (TOOLEAST), “Semantic Web Services Interoperability for Geospatial Decision Making” (SWING), “Image-based Navigation in Multimedia Archives” (IMAGINATION), “Transitioning Applications to Ontologies” (TAO), and “Statistical Multilingual Analysis for Retrieval and Translation” (SMART); and from the EU FP7: “Pattern Analysis, Statistical Modelling and Computational Learning 2” (PASCAL2), “Enabling the Knowledge Powered Enterprise” (ACTIVE), “Collaboration and Interoperability for networked enterprises” (CIOIN) and “European Inter-Disciplinary Research on Intelligent Cargo for Efficient, Safe and Environment-friendly Logistics” (EURIDICE).

We prepare and organize carefully designed educational events, such as conferences, seminars, workshops, and summer schools. These 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 the network organizations, ecology, medicine, business decisions, finance, marketing, automation and process control. A special consideration is given to the managers and decision makers who are aware of the strengths and benefits of the success of their business.

All educational events are designed to transfer basic, additional and the latest expert knowledge to companies, research institutes 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/, which now offers more than 6000 recorded tutorials from different scientific events and is visited daily by an average of 3500 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. This year we have started a successful collaboration with some of the top ten American universities, including MIT (Massachusetts Institute of Technology), the University of California - Berkeley, YALE and CMU, as well as with the European CERN and ETH from Zurich.

The centre also operates a web portal http://www.ist-world.org that offers services for automatic data collection and analyses of European research. The user can perform several simple and complex analyses, predictions and detect trends in research. The database currently contains data from about 100,000 research organizations, 42,500 research projects and around 2 million experts from Europe. This is an exceptional web service that is being visited daily by an average of 15,000 unique visitors.

In 2008 we organized the “PASCAL Symposium” with 90 participants from around the world, the 3rd Student Competition in Computer Science, attended by 130 students from Slovenian secondary schools, and four seminars for participants from industry. We have also organized an international seminar “Analysis of Environmental Data with Machine Learning”.

The centre is operating two web portals. The first one is http://videolectures.net/, which is now becoming a reference portal, presenting high-quality scientific lectures, and the second one is http://www.ist-world.org, which offers services for automatic data collection and analyses of European research.

From 2008 onwards the portal http://videolectures.net/ will be collaborating with the Massachusetts Institute of Technology (MIT), YALE, the University of California - Berkeley, the University of Ljubljana, and with the European Organization for Nuclear Research (CERN).
Learning Methods”, and six project meetings for various EU projects. We have started with intensive preparation activities for ECML/PKDD 2009, which will take place from 7 to 11 September 2009 in Bled http://www.ecmlpkdd2009.net/.

Our role in the FP7 Integrated Projects “Collaboration and Interoperability for networked enterprises” (COIN), “European Inter-Disciplinary Research on Intelligent Cargo for Efficient, Safe and Environment-friendly Logistics” (EURIDICE), “Enabling the Knowledge Powered Enterprise and in one network of excellence” (ACTIVE) and “Pattern Analysis, Statistical Modeling and Computational learning” (PASCAL2) is to coordinate all the educational and dissemination activities as well as knowledge transfer.

Some outstanding publications in past three years:


Organization of conferences, congress and meetings

1. Meeting of the EU project TAO (Transitioning Applications to Ontologies), Bled, 21–23 Jan. 2008
3. Project meeting of the EU project NeON, Bled, 19–22 Feb. 2008
5. Project meeting of the EU project ACTIVE, Bled, 10–12 Mar. 2008
7. 3rd Student competition in computer science, Ljubljana, 29 Mar. 2008
14. Project meeting of the EU project EURIDICE, Ljubljana, 2–3 Nov. 2008
INTERNATIONAL PROJECTS

1. European Inter-Disciplinary Research on Intelligent Cargo for Efficient, Safe and Environment-friendly Logistics
   EU/RIDICE
   7. FP, 216271
   EC, INSIEL - Informatica per il Sistema Degli Enti Locali s.p.a., Trieste, Italy
   Mitja Jermol, M. Sc., Marko Grobelnik, Asst. Prof. Dunja Madelonić

2. Enabling the Knowledge Powered Enterprise
   ACTIVE
   7. FP, 251040
   EC, Philip Hewitt, British Telecommunications plc, London, Great Britain
   Mitja Jermol, M. Sc., Marko Grobelnik, Asst. Prof. Dunja Madelonić

3. Pattern Analysis, Statistical Modelling and Computational Learning
   2
   PASCAL
   2
   EC, Eileen Simon, University of Southampton, Southampton, Great Britain
   Mitja Jermol, M. Sc., Asst. Prof. Dunja Madelonić, Marko Grobelnik

4. Collaboration and Interoperability for Networked Enterprises
   7
   EC, Claudia Gagie, Infornt Systems, Milan, Italy
   Mitja Jermol, M. Sc., Ass. Prof. Dunja Madelonić, Marko Grobelnik

5. Stimulating Policy Debate on Women and Science Issues in Central Europe
   5
   WS DEBATE
   5
   EC, Dr. Dora Groo, Exeter Papp, Hungarian Science and Technology Foundation; Tudomanyos es Technologiak Alapítvany, Budapest, Hungary
   Mitja Jermol, M. Sc., Asst. Prof. Dunja Madelonić, Marko Grobelnik

6. Statistical Multilingual Analysis for Retrieval and Translation
   6
   SMART
   6
   EC, Nicola Cancoi, Xerox Research Centre Europe, Meylan; Xerox, Aulnay-Sous-Bois, France
   Mitja Jermol, M. Sc., Asst. Prof. Dunja Madelonić, Marko Grobelnik

7. Image-Based Navigation in Multimedia Archives
   7
   IMAGINATION
   7
   EC, Clemens van Dinten, Forschungszentrum Informatik an der Universität Karlsruhe, Karlsruhe, Germany
   Mitja Jermol, M. Sc., Ass. Prof. Dunja Madelonić, Prof. Marko Mikuž

8. Extended Enterprise Management in Enlarged Europe
   E4
   8
   EC, Roberto Tarditi, Centro Ricerche Fiat Società Consortile per Azioni, Orbassano (TO), Italy
   Mitja Jermol, M. Sc., Asst. Prof. Dunja Madelonić, Marko Grobelnik

VISITORS FROM ABROAD

1. Francesco Magnini, University of Florence, Italy, 3 Jun. 2008
2. Giuseppe Gatti, University of Florence, Italy, 5 Jun. 2008
8. Fulvio Sarsoni, Oracle, Poland, 21 Apr. 2008
10. Michael Witbrock, Ccorp, USA, 21 Apr. 2008
15. Ivan Tomanc, Insil, Italy, 4–5 Feb. 2008
17. Radoslav Kolev, IT partners, Bulgaria, 4–5 Feb. 2008

STAFF

Postgraduates
2. Mitja Jermol, M. Sc., Head

Technical officers
4. Spela Sitar, B. Sc.

Technical and administrative staff
5. Tira Aničič
6. Sebastian Molej

Note:
* part-time JSI member
The mission of our training centre is training in the field of nuclear technologies and radiation protection. In addition, we are actively informing the public about those technologies.

Training in the area of nuclear technologies is our primary mission. After a couple of relatively modest years, the demand for this type of training has increased substantially this year. Two courses, Basics of nuclear technology, were conducted. These courses are intended for non-control-room personnel of NPPs, and there were also many participants from other organizations working in the area. The course Nuclear technology, which is the initial training of future control-room operators, started in the autumn. This course will end in the spring of 2009.

There were 17 radiological protection training courses for the medical, industrial and research use of radioactive sources. Among them there was a course for officers of the Slovenian Army and a course on the security of nuclear materials during transport.

Public information is becoming an increasingly important part of our activities. Groups of children and other visitors were coming regularly, and in large numbers, to listen to a lecture about nuclear technology, about radioactive waste, or about fusion, and to visit our exhibition. Altogether, there were 167 groups or 7606 visitors this year. Since 1993 our information centre has been visited by a total of 111,813 pupils, teachers and other visitors. We have started to monitor and analyze media reports on nuclear energy, and we have also published a leaflet “The future of nuclear energy in Slovenia”.

We have prepared a study “Technologies of potential reactors for the project of a second unit of Krško nuclear power plant – Krško 2”.

In 2008, the demand for training in nuclear technologies has increased substantially, and our public information activity has intensified as well.
### Table of training activities at Nuclear Training Centre in 2008

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Participants</th>
<th>Lecturers</th>
<th>Weeks</th>
<th>Participant x weeks</th>
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</thead>
<tbody>
<tr>
<td>10.-14.3.</td>
<td>Radiation protection for medical and veterinary workers - Nuclear medicine workers</td>
<td>3</td>
<td>11</td>
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<td>10.-12.3.</td>
<td>Radiation protection for industrial and other practices (unsealed sources)</td>
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<td>0.6</td>
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<td>10.-12.3.</td>
<td>Radiation protection for industrial and other practices (sealed sources)</td>
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<td>0.6</td>
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<td>18.3.</td>
<td>Radiation protection for industrial and other practices (sealed sources) - Refresher Course</td>
<td>3</td>
<td>4</td>
<td>0.2</td>
<td>0.6</td>
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<tr>
<td>18.3.</td>
<td>Radiation protection for industrial and other practices (unsealed sources) - Refresher Course</td>
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<td>18.3.</td>
<td>Radiation protection for industrial and other practices (radiography) - Refresher Course</td>
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<td>0.6</td>
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<td>20.3.</td>
<td>Training Extension for RP Officers</td>
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<td>2</td>
<td>0.2</td>
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<td>31.3.-25.4.</td>
<td>Basics of nuclear technology, theory</td>
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<td>15.-16.4.</td>
<td>Training for Slovenian Army officers (2008)</td>
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<td>5.-30.5.</td>
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<td>16.6.</td>
<td>Radiation protection for industrial sources - Refresher</td>
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<td>Security during transport of nuclear materials - refresher course</td>
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<td>13.-15.10.</td>
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<td>11.4</td>
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<td>13.-15.10.</td>
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<td>0.6</td>
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<tr>
<td>13.-17.10.</td>
<td>Radiation protection for medical and veterinary workers - radiological diagnostic</td>
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<td>23.10.</td>
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<td>0.2</td>
<td>1.4</td>
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<td>10.11.-</td>
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<td>18</td>
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<td>18.-22.12.</td>
<td>Radiation protection for workers of JSI RP group - Refresher course</td>
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<td>0.4</td>
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<td>124</td>
<td>29.2</td>
<td>456.4</td>
</tr>
</tbody>
</table>

### INTERNATIONAL PROJECTS

1. Permanent Fusion Exhibition at JSI Nuclear Training Centre - 6.1.1-FU EURATOM – MHEST
   Gen d. o. o., Krško Prof. Igor Jenčič
   7. FP EURATOM, Slovenian Fusion Association – SPA
   3211-08-000002, FP07-CT-2007-00065
   EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   Prof. Igor Jenčič

2. Fusion Expo Activities under an EFDA EURATOM – MHEST
   Gen d. o. o., Krško Prof. Igor Jenčič
   7. FP EURATOM, Slovenian Fusion Association – SPA
   3211-08-000002, FP07-CT-2007-00065
   EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   Melita Lemšek, B. Sc.; Sabina Markelj, B. Sc.; Dr. Igor Lengar, Asst. Prof. Saša Novak
   Krmpotič, Stefan Kolesnik

### NEW CONTRACTS

1. Co-financing of the Nuclear Information Centre in 2008
   Gen d. o. o., Krško Prof. Igor Jenčič
   1. Co-financing of the Nuclear Information Centre in 2008
   2. FP EURATOM, Slovenian Fusion Association – SPA
   3211-08-000002, FP07-CT-2007-00065
   EC, RS, Ministry of Higher Education and Technology, Ljubljana, Slovenia
   Melita Lemšek, B. Sc.; Sabina Markelj, B. Sc.; Dr. Igor Lengar, Asst. Prof. Saša Novak
   Krmpotič, Stefan Kolesnik

2. Implementation of 2008 Training Program for Krško NPP
   Krško Nuclear Power Plant Prof. Igor Jenčič
   2. Implementation of 2008 Training Program for Krško NPP
   3. Operation of the Nuclear Information Centre in 2008
   Agency for Radwaste Management, Ljubljana Prof. Igor Jenčič
   3. Operation of the Nuclear Information Centre in 2008
   4. Preparing a study - Technologies of possible reactors for the project of the Krško-2 Nuclear Power Plant
   Gen d. o. o., Krško Prof. Igor Jenčič
   4. Preparing a study - Technologies of possible reactors for the project of the Krško-2 Nuclear Power Plant
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3. Peter Jan, B. Sc.
5. Andrej Kavčič, B. Sc.

8. Melita Lenošek, B. Sc.
9. Tomaz Skoče, B. Sc.

Technical and administrative staff
10. Saša Bobič

BIBLIOGRAPHY

ORIGINAL ARTICLES

REVIEW ARTICLES AND CHAPTERS IN BOOKS

PUBLISHED CONFERENCE PAPERS

Regular papers


THESSES

B. Sc. Theses
The SVPI has been involved in ionizing-radiation measurements and radiation protection since the beginning of TRIGA Reactor’s operation in 1966. The responsibility of the SVPI is the radiation control of all the activities at the Institute dealing with ionizing radiation. So our main task is the supervision of Reactor and the 17 laboratories that use sources of radiation in their research work. More than a hundred different sources are used, such as sealed sources, open sources, X-ray units and the accelerator TANDETRON, which need regulatory control.

The SVPI is qualified to perform control in medical, industrial and research institutions dealing with open and sealed sources. In industry and research we are also qualified to control X-ray units. The measurements of dose rate and contamination are performed with an accredited method (EN ISO/IEC 17025).

Personal dosimetry

Personal doses of around 120 workers that regularly or occasionally deal with ionizing radiation were monitored with Thermo Luminescent Dosimeters (TLDs). The maximum individual yearly dose was 0.86 mSv. This is only 4 % of the regulatory limit for occupational workers (20 mSv per year) and less than the limit for the general public (1 mSv per year).

Supervision of reactor and laboratories

The controlled area of the 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). In 2008 we performed 18 inspections of radiation levels and contamination in the JSI laboratories. At present, 101 sources of radiation are used, which require regulatory control of the Nuclear Safety Administration. A large number of low-activity sources are also used. For each laboratory a dose-assessment report and the required radiation-protection measures were prepared. All the workers were categorized according to potential and normal working conditions.

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 could be measured in the controlled areas. Gamma spectrometry was used to monitor solid, liquid, aerosol and gas samples as well as radioactive waste.

Environmental measurements

Environmental monitoring of the Reactor Center was performed by measurements of external radiation levels, measurements of environmental samples and effluent measurements (gas discharges from the reactor operation and liquid discharges in the Sava River).

With environmental TLDs the radiation levels in the surroundings of the reactor and all the buildings on the site were monitored. Outside of the controlled area only normal, natural background radiation levels could be measured.

Based on the effluent measurements and a conservative, environmental transfer model the effective dose to the reference group in the public was estimated to be less than one micro-Sievert per year. The public exposure in 2008 due to activities at the Reactor Center was insignificant.

Radiological measurements for outside customers

The Radiation Protection Unit is qualified for radiological control in other institutions. In the past year 15 radiological control investigations were carried out in industrial, medical and research institutions. Some exposure assessment reports for occupational workers were prepared as well.
INTERNATIONAL PROJECT

1. Improvement of the Management of Institutional Radioactive Waste in Slovenia
   Agency for Radwaste Management, Ljubljana, Slovenia; Leniko Ivba, Antwerp, Belgium
   Bogdan Pucelj, M. Sc., Dr. Gašper Tavčar, Bojan Huzjan, M. Sc., Prof. Borut Smodiš

STAFF

Technical officers
1. Emira Bašić, B. Sc.
2. Thomas Breznik, B. Sc.
3. Dr. Tinkara Bučar
5. Matjaž Stepišnik, M. Sc., Head

BIBLIOGRAPHY

ORIGINAL ARTICLES


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PUBLISHED CONFERENCE PAPERS

Regular paper

THESIS

Ph. D. Thesis

M. Sc. Thesis
The core activities of the Technology Transfer Office include assistance in technology and knowledge transfer from the Institute to businesses, the implementation of expert projects, the implementation of specific technology projects, communication and the promotion of science.

The Technology Transfer Office’s mission is:

- the continuous creation of partnerships between the Jožef Stefan Institute’s researchers, industry and education,
- supporting knowledge and technology transfer from research to the business and educational spheres,
- raising the awareness of the importance of research and intellectual property protection, enabling a higher rate of commercialization for the JSI’s intellectual property.

In 2008 we continued with activities for technology and knowledge transfer to the business and educational spheres as part of the JSI’s core mission. The goal of our projects is to establish a comprehensive strategy and procedures for technology and knowledge transfer and assist researchers in the execution of these projects. An overview over the JSI’s potentials will enable technology and knowledge management, better visibility and the promotion of scientific research activities. In addition, we want to establish better links with industry and identify their needs for cooperation with the JSI.

Our activities are:

- technology and knowledge transfer to the business and educational systems,
- research in this field.

We carried our work out within the projects “JSI Technology Transfer”, “Regions for Research” (R4R), “Communication of Technology”, “Enterprise Europe Network”, “Form-it”, “Lean TTT”, “Boost IT”, “JSI Cyclotron” and “Research of the State of Innovation Activities in Slovenia” (R.SID) with suggestions for active measures (to improve the current state in business). The newly acquired project “ACT Clean” will enable an overview and the management of environment-friendly technologies in Central Europe and cooperation with the JSI departments O-2 and K-1.

Technology transfer activities

Under technology-transfer research we:

- analysed situations and proceedings for technology transfer at the JSI and in the world. We compared the JSI’s situation with North Carolina State University and CERN and presented it at an international conference [PODIM, Maribor, 2008]
- investigated the state of innovation activities in Slovenia and suggested active measures for the improvement of the current state in business. This was done for the Public Agency of the Republic of Slovenia for Entrepreneurship and Foreign Investments [project R.SID]
- developed a model for identifying and modelling the transfer and evaluation of good practice in the field of technology projects for the integration of the academic sphere and the economy [collaboration with Ministry of Higher Education, Science and Technology, project R4R].

These research activities enable our active involvement in the creation of innovation and development policies, knowledge and technology transfer, familiarity with business needs and connection with several Slovenian and international organisations that are active in the same fields.
In the field of the JSI’s technology and intellectual property commercialisation we are establishing an internet entry point with a list of the JSI’s competences for their marketing and for communication with business and the general public. In order to better exploit the innovative potential of the Institute, our office, together with the JSI’s Commission for Intellectual Property Protection, looks for appropriate intellectual property commercialisation strategies.

We assisted:
- in the process of writing patent applications,
- in assessing the possibilities of commercialisation,
- in the process of document preparation for acquiring financial sources for patenting abroad,
- in the promotion of some of the JSI’s applied results to potential users.

Like with experts for the commercialization of RTD results, other inventors, researchers and entrepreneurs from Slovenia were approaching us for advice. In 2008 we have helped several tens. Of these, we helped four in the signing of contracts on technology transfer.

To connect scientists from the Institute with scientists from abroad we organised seminars and workshops. In addition, we lectured at some of these events.

The most important ones are:
- the meeting “Technology Transfer - the Possibilities and Duties of Researchers - Industrial Partners”, for the presentation of technology-transfer activities. Over 100 researchers and entrepreneurs attended.
- at the round table “The Transfer of Knowledge from Public Research Institutes to Industry” organised within the 3rd Slovenian Forum of Innovation, we presented three of the Institute’s scientists and three experts from the support environment for innovation.
- the seminar “Smart Structures and Intelligent Materials”
- the workshop “New Materials for Medicine”, in Zagreb, to connect researchers from the JSI, Ruder Bošković, Croatia, and Joanneum Research, Austria.
- The workshop “Nanotechnologies” organised together with the institute Veneto Nanotech and Veneto Innovazione, Italy.
- The working visit “7FP” (together with MHEST) to connect researchers from the environmental sciences in the Balkan region.

We also conducted a number of individual promotions of various R&D projects, and together with the Technology Park Ljubljana we plan to extend this activity.

In addition we assisted JSI departments with the preparation and submission of EU projects. In collaboration with the Center for the Transfer of Knowledge in Information Technologies (CT-3) we encouraged the participation of small and medium-sized enterprises and members of technology parks and incubators in the projects for the European Framework Programmes.

Within the project “JSI Cyclotron” we performed a preliminary study of the opportunities and the impact of installing a cyclotron at the JSI. We also organized presentations and working meetings. The results were presented at an international conference [Nuclear Science Symposium, Dresden, 2008]. The purchase of the cyclotron would open the way to a series of new research activities in the field of physics, environmental sciences, chemistry and biology, while the cyclotron could also be used for the production of radiopharmaceuticals in medical diagnostics.

Figure 3: Number of visitors to the Institute’s departments during the period 30 September 2007 to 31 October 2008. The average number of visits per department is 12. (Source: K. Žagar and Š. Stres)
Knowledge transfer activities

To expand and facilitate visits to the Institute at Jamova we have established an internet entry point for visits to the JSI and a network of coordinators for these visits. Since 1 October 2007 a total of 331 presentations of different departments were carried out. Each department was visited an average of 12 times (Figure 3). The visits are split according to the type of visitors into different groups:

- enterprises (Danfoss, Iskraemeco, etc.): our researchers met representatives from companies at workshops and/or in their laboratories,
- pupils and students from Slovenia and abroad,
- foreign researchers and different delegations, such as a visit of attaches for the information society within the framework of the Slovenian Presidency to the EU, Ministerial Conference participants, EUREKA, etc.,
- open day in the context of the Jožef Stefan Days, when the Institute was visited by more than 1100 people,
- scientific-cultural events such as the celebration of the 100-year anniversary of the birth of Anton Peterlin.

We are editors of the information centre for journalists, the Institute's online newsletter ISplet. We regularly publish an online newspaper ISNewsletter, received by more than 140 journalists. We have prepared and published several hundred press releases, articles and interviews for Slovenian print media and tens of recordings for various television and radio programmes. Our contributions were also published in the media of the European Union. A total of 77 researchers at the Institute, out of 560 recipients, receive eNews Enterprise Europe Network, 36 of the JSI's researchers receive technology offers and requests from the database of the Enterprise Europe Network. We have also participated in the preparation of the process for informing the public in the event of an accident at the Reactor Center.

We are ranked among the JAPTI and TIA reviewers and perform the evaluation and control of technology projects. We are enrolled in the voucher system of advisory services.

In 2008 the NATO RESCA project was continued jointly with collaborating partners from Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan, according to the project work plan. All of the planned radiological field-assessment missions were carried out and the analytical services of the most important radionuclides in representative specimens of the investigated environments were provided, thus enabling a basis for a preliminary assessment of the radiation doses on populations of the general public living in these environments. The results obtained were favourably evaluated by NATO’s committee of radiological experts.

Organization of conferences, congress and meetings

1. NATO Training Course on Radon and Advanced Gamma Spectrometric Measurements, Ljubljana, 12–23 Feb. 2008
4. Educational Workshop and Laboratory Visit for Programme Unit “Material” Graduate School Professors, Ljubljana, 10 Mar. 2008
INTERNATIONAL PROJECTS

1. EC&IBC Services in Support of Business and Innovation EAC/EC&IBC Slovenia 1
   7. FP
   European Commission, Executive Agency for Competitiveness and Innovation (EAC),
   CIP Network Project Management Unit, Brussels, Belgium
   Prof. Peter Stegnar

2. Regions for Research R&I
   6. FP, 042988
   EC, Joanna Szyfter, Stockholm Region Office, Brussels, Belgium, Stockholmmregionen
   Europekommittie, Stockholm, Sweden
   Dr. Spela Stres, Mateja Rus, R. Sc.

3. Eliminating Waste and Boosting Productivity in Transnational Technology Transfer LearnIT
   6. FP, 030648
   EU, Bjorn Westling, IVF Industrial Research and Development Corporation, Moehn, Sweden
   Dr. Marjeta Trobec, Spec. for International Affairs

4. Set-up of a Collaborative Permanent Network for Boosting the Participation of Incubated SMEs in Innovation Processes under FP6 Activities Boost-IT
   6. FP, 025437
   EC, Enrique Neves, Inovamais - Servicos de Consultoria em Inovacao Technologica,
   Matosinhos, Portugal
   Prof. Peter Stegnar, Mitja Jermol, M. Sc.

5. Innovation Relay Centre of Slovenia S3-IRC-04-08
   6. FP, 510419 (IRC 6)


15. The Hundredth Anniversary Birth of Academician Prof. Dr. Anton Peterlin, Founder of Jožef Stefan Institute, Ljubljana, 27 Sep. 2008


20. JSI Lab Visits for EARTO Conference members, Ljubljana, 23 Oct. 2008

21. Visit Representatives from ETA Cerknovo Enterprise, Ljubljana, 6 Nov. 2008


NEW CONTRACT

1. Research of the state of innovation support activities in Slovenia and active measure proposal for innovation and competitiveness increased in Slovene economy

   Public Agency of the Republic of Slovenia for Entrepreneurship and Foreign Investments Dr. Spela Stres

   Alice Wu, European Commission, DG Enterprises and Industry Innovation Policy D/2,
   Support for Innovation, Brussels, Belgium
   Prof. Peter Stegnar, Prof. Leon Žlajpah

   6. Access to Technology and Know-how in Cleaner Production in Central Europe ACT CLEAN

   Central Europe Programme
   EU, Jakob Gross, Horst Poth, Federal Environment Agency, Dessau-Roßlau, Germany
   Dr. Andrej Stergaršek, Andrej Gyergyek, B. Sc., Dr. Sonja Lohen

   7. Technological Innovation Network in the Field of Information Systems TINS INTERREG III-B, West Zone

   EC, Veronique Pirot, INFOPOLE Information Systems, Namur, Belgium
   Prof. Peter Stegnar

   8. Uranium Extraction and Environmental Security in the Central Asian Republics NATO SP - Uranium Extraction Legacy

   NATO Public Diplomacy Division, North Atlantic Treaty Organisation, Brussels, Belgium
   Prof. Peter Stegnar

   9. Assistance in the Development of Conceptual Design for LILW Repository in Slovenia 2005/5812.08.01

   Michael Egan, Quintessa Limited, Oxfordshire; Warrington, Great Britain
   Prof. Peter Stegnar

VISITORS FROM ABROAD


   Andrea Reichel, European Commission, Brussels, Belgium, 29 Feb. 2008


   4. Prof. dr. Muzafar Yunusov, Chkalovsk, Tajikistan, 11–18 May 2008

   5. Dr. Christian Bartmann, Andrejka Kodele, Joanneum Research Forschungsgesellschaft mbH, Graz, Austria, 27 Oct. 2008

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STAFF

Researchers
1. Prof. Peter Stegnar, Head
Technical officers
2. Andrej Gyergyek, B. Sc.
3. France Podobnik, B. Sc.
4. Matjaž Rus, B. Sc., left 1 Jul. 2008
5. Dr. Špela Stres
6. Marjeta Trobec, B. Sc.

Technical and administrative staff
7. Sonja Živkovič

BIBLIOGRAPHY

ORIGINAL ARTICLES

PUBLISHED CONFERENCE PAPERS

Regular papers