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Present and Future Perspective of Centres of Excellence

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Introduction

In order to facilitate promote breakthroughs in an increasingly globalised world, now more than ever, countries and regions need to focus on fostering research excellence and competencies in certain priority fields. Therefore, the Ministry of Higher Education, Science and Technology has allocated 77 million Euros to eight Centres of Excellence, characterised by scientific excellence and innovative industry. Considered by many as a rather daring move, especially in times of economic crisis when funds are scarce, these Centres were mainly financed by the funds from the European Regional Development Fund (ERDF).

Centres of Excellence are defined as a high quality multidisciplinary group of researchers from the academic and business spheres, combining a critical mass of knowledge and adequate research infrastructure for potential breakthrough of Centres to the top of world science and/or for the inclusion in international networks of excellence.

The first steps towards smart specialisation were taken in 2006, when the Government of the Republic of Slovenia decided to allocate approximately 15 million Euros to ten Centres of Excellence for a period of three years. Evaluation undertaken on the economic viability of the Centres established that they are, despite some shortcomings, a valuable instrument in strengthening cooperation between the public and industrial sectors. The evaluation recognized the Centres of Excellence as one of the few instruments that promote an interdisciplinary approach to research and development and are, therefore, well-suited to the needs of the economy where disciplines tend not to be mutually exclusive. They are an instrument that determines research and development (R&D) priorities in an innovative manner and support the concentration of resources in those areas of technology that are vital for ensuring the competitiveness of the economy.

In spring 2009 the second round of Centres of Excellence programmes was launched. The call for proposals represented the biggest and most concentrated investment into Slovenian R&D thus far – the funds available for the call amounted to nearly 80 million Euros. The call's objective were at the interdisciplinary research programmes with special focus on horizontal priority of fostering the transformation into energy efficient economy based on low carbon society. There are eight operating Centres, composed of 107 partners, 68 from business sphere and 39 from research organisations. They also employ over 400 researchers, with every fourth researcher being employed by an industrial partner organisation.

After less than two years the activities of the Centres have resulted in 47 innovations and 22 patent applications. In the future the efficient flow of knowledge and applications into products and services is also expected. However, the Ministry will follow further activities and achievements of the Centres and the assessment will show whether the decision of the Ministry to support the programmes was right.

Urban Krajcar
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1. EN-FIST Centre of Excellence

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EN-FIST Centre of Excellence is a private research organization with a cutting edge research and development expertise.We cover various multidisciplinary areas of life sciences and advanced new materials in chemistry, physics, pharmacy and other interdisciplinary fields and specialize in creating new compounds and materials (determining their structure and characterization with modern NMR, X-ray, VS and other analytical methods). We develop our own know-how and intellectual property assets as well as provide quick and high quality research support to companies.

We face challenges from the "innovativity" perspective (innovativity = innovation + creativity) and give special care and focus to customer's needs.

1.1 NMR studies of structure and dynamics of (bio)(macro)molecules

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Nuclear Magnetic Resonance (NMR) spectroscopy is an important method for studying the structure and dynamics of small organic molecules and large(r) biomolecular assemblies as well as their interactions with nucleic acids, proteins and ions in solutions. Nucleic acids adopt a great number of topologies including multi-stranded helical structures in order to perform different biological functions from transport of genetic information to catalysis and regulation. Guanine rich oligonucleotide DNA sequences exhibit the potential to form four-stranded DNA structures called G-quadruplexes. Recent genome wide sequence analyses have revealed important information on the occurrence and location of sequences with potential to form stable G-quadruplexes. Both prokaryotic and eukaryotic genomes from yeast to human are rich in such sequences. Bioinformatics' analyses have shown that human genome possesses as many as 376.000 sequences with the ability for the formation of these unusual structures. The location of G-rich sequences is non-random and seems to correlate with functional genomics domains. The highest occurrence of sequences with the ability of G-quadruplex formation is in repetitive DNA regions such as telomeres. Interestingly, promoter regions of eukaryotic genes are also enriched in such sequences. Over 40% of human gene promoters contain at least one G-rich sequence. Using NMR we can – in addition to characterizing 3D structures with atomic resolution – study dynamics of individual parts of the structure, especially loop regions. Structural information is important in the design of new small molecule ligands with the potential to regulate expression of a gene through (de)stabilization of G-quadruplex structure.

1.2 DNA guided assembly line

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Living organisms are experts in synthesizing complex and useful compounds. Classical metabolic engineering was successful in strain improvement, but is constrained by the naturally existing components. Synthetic biology provides tools for designing completely new biosynthetic pathways to improve the yield and allow production of heterologous or new compounds.

We invented a new platform of biosynthetic scaffolding by the use of DNA as a scaffold. DNA binding domains fused on different biosynthetic enzymes allow defined ordering of biosynthetic enzymes along the DNA that encodes the desired order of reactions. We designed chimeric enzymes for biosynthesis of a plant antioxidant trans-resveratrol. Each chimeric enzyme of the biosynthetic pathway consisted of an enzyme and DNA binding zinc finger domain genetically fused together. The yield improvement of biosynthetic pathway was 3 fold in comparison to control without the scaffold. Production of resveratrol achieved by the DNA-based scaffold was also significantly improved in comparison to direct fusion of biosynthetic enzymes. DNA scaffolding therefore represents a powerful tool of synthetic biology to control the flow of different types of biological information including metabolic pathways, signal transduction or information processing.

1.3 Physicochemical Studies and Biological Activity of Ruthenium Complexes

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The use of metals and their compounds has a long tradition in medicine. A story of success of cisplatin, cis-[$PtCl_2(NH_3)_2$] started in the late 1960s when there was a strong impetus for a design of several novel metal based drugs. Rosenberg has serendipitously discovered the anticancer activity of cis-platin and even today this is one of the world`s best selling anticancer drugs. On the other hand, it is also known that cis-platin has many disadvantages. In the past two decades ruthenium coordination compounds have attracted considerable interest as potential anticancer agents due to their low toxicity and their efficacy against platinum-drug-resistant tumors, which resulted in promising results in various stages of preclinical to early clinical studies. Also in our laboratories several ruthenium complexes have been prepared. We have characterized them by various physico-chemical methods and tested for biological activity.

2. LOW – CARBON TECHNOLOGIES (CO NOT) Centre of Excellence

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The Consortium of the Centre of Excellence for Low-carbon Technologies (CO NOT) was selected for funding following the Slovenian Public tender for Centres of Excellence for the period 2009-2013 which was launched in mid-2009. The ultimate goal of CO NOT is to research, develop and extend low-carbon technologies within the Slovenian society and also within the wider scope.

CO NOT consists of 22 partners 12 of which are academic laboratories (located at the National Institute of Chemistry (NIC), Institute Jožef Stefan and two Universities, University of Ljubljana and Nova Gorica), while 10 partners (Cinkarna, Domel, INEA, Iskra Tela, Mebius, Silkem, Petrol, TEŠ and RCVT) are Slovenian companies working in the field of new energy technologies.

CO NOT has set four main ambitious goals:

a) to join the leading Slovenian researchers and producers in the field of new technologies that are going to replace the present technologies based on fossil fuels,
b) to carry out intensive and coherent R&D projects that will allow for fast advances in the research field defined under point a),
c) to encourage cooperation of CO partners with external partners (both national and international),
d) to acquire further financial resources that will further intensify the R&D in the field and allow continuation of the CO program also after the completion of the financing in the end 2013.

CO NOT is bringing together key Slovenian potentials in the field of new, low-carbon energy sources and the use of such sources in both stationary and mobile applications. In these technologies, solar energy is converted either into electricity which is then stored in secondary batteries and supercapacitors (Lithium Technologies) or, alternatively, into hydrogen which is then used to power fuel cells (Hydrogen Technologies). Lithium and Hydrogen technologies can be viewed as a winning combination that will cover a substantial portion of energy needs, in particular in future hybrid and electric vehicles, energy supply for houses etc. In the intermediate period the same energy needs will be covered by alternative low-carbon solutions, such as water power, biomass etc. CO NOT covers the whole R&D vertical – from theory to basic materials research, development of technologies and, finally, engineering leading to production of real devices. The advantages of our CO are its orientation into-low carbon technologies, multidisciplinarity and also, the complementary skills of the partners who master a wide range of skills needed for the development of solar, lithium and hydrogen technologies.

There are two major CO NOT projects areas. The first is dedicated to Lithium technologies and the second to Hydrogen technologies.

Lithium Technologies

In recent years, the research of new materials for Li and solar technologies has witnessed extreme intensification. One of the reasons is the decision of major world car producers to enhance the development of hybrid and full electric vehicles. With decreasing resources of fossil fuels and increasing environmental pollution, batteries are rapidly gaining attention as one of the most attractive future sources that could replace substantial portion of energy demands that are presently covered by fossil fuels. Of all possible storage devices the lithium-based devices are the most attractive because they have the highest theoretical energy density, they have no memory effect and they have the lowest degree of self discharge. At the same time, the resources of lithium are quite big. We intend to produce the electricity needed for recharging of batteries by using solar technologies. Among the various possibilities, we focus on the development of Graetzel cells which have a great potential to replace the current silicon-based solar cells. Alternatively, we are also investigating the possibility of exploitation of thermal solar energy. The partners cooperating in this project are already connected to many other groups and companies that also cover some topics proposed in this CoE. On the international level, the present partners have connections to companies such as Renault, Volkswagen, Honeywell, Umicore, Saft, Varta etc. Beside the national governments and car companies, the EU has also recognized the significance of these green technologies, so more and more money is available for such purposes.

Hydrogen technologies

Hydrogen technologies including fuel cell development are nowadays recognized as one of the most perspective areas of activity towards ensuring long-term and environmentally friendly energy production. There is one quite big and holistic R&D Project in the framework of Hydrogen Technologies: "Holistic design of PEM fuel cell based systems". The project includes all kinds of research, from basic materials investigation to production of prototypes and even development of bigger modules. Finally, the project aims at real implementation of hydrogen technologies in everyday life in Slovenia. Development of the whole system of activities requires a holistic approach which considers requirements on reliability, durability and safety together with requirements in high energy and cost efficiency. The partners in the project have already established collaborations with various European and American companies, active in the field of development and applications of fuel cells (Ballard, Hydrogenetics, PlugPower, Vaillant, NedStack) in the form of different projects and contracts. All partners are also members of Slovenian platform SHIFC – Technological platforms for hydrogen technologies and fuel cells. CO NOT is open for various kinds of cooperation on the national as well as on the international level. In particular, we look forward to start implementing joint projects with the Slovenian and European partners in all areas of our expertise.

Expected results and impact

Typical achievements of CO NOT during the past 2 years can be classified into the following categories:

- High quality research as evidenced from publications in highly ranking journals, such as Nature Materials (2 papers in 2010), Journal of the Electrochemical Society, Energy and Conversion Management and similar journals covering the CO NOT research topics.
- Important inventions protected in appropriate patent applications (for example »Electrocatalytic Composite(s), Associated Composition(s), and Associated Process(es)« US Appln No.: 61/510,452, 2011).
- Building up prototype devices (for example (a) a prototype of energetically autonomous solar cell battery device for use in traffic, pastures etc.; (b) a prototype of commercially viable bending electrochemical solar cell etc.).
- Optimization of systems using innovative hardware and software solutions (e.g. 10% improved efficiency of a fuel cell system used in real environment).
- Demonstration projects such as (a) introduction of a first hydrogen pump in Slovenia, (b) bringing together major Slovene producers of car components to create a testing platform for electric cars; c) organization of big international conferences on topics covered in CO NOT.
- Education of young experts by creating research teams (e.g. a team making their own electric vehicle).
- Integration of CO NOT into national and international projects to provide resources for the work of Consortium after 2013.

3. COBIK Centre of Excellence for Biosensors, Instrumentation and Process Control

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The Centre of Excellence for Biosensors, Instrumentation and Process Control, established in 2009, is a private-founded research institution that employs more than 90 highly qualified researchers from the most challenging and promising fields, such as bio-chemistry, bio-instrumentation, optics and advanced new cleaning processes in pharmacy. All laboratories are horizontally bounded through the Laboratory for Open Innovation Systems which provides basic business knowledge and sets a model of innovations acceleration.

The Centre consists of six laboratories with state-of-the-art equipment and currently runs 20 research projects. The focus of the Centre is to create cutting-edge solutions and implement them both, into partners` industrial processes or upgrade them through new partnership. This focus results in a broad, world-wide network. In the near future some of the projects will generate spin-offs.

3.1 Trends in Control Systems for Large Experimental Facilities

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We note that recently, wherever possible, off-the-shelf frameworks - ideally open Source ones - are chosen (e.g., EPICS, TANGO, Control System Studio, etc). Also, a major breakthrough occurred with the entrance of the FPGA technology into control system hardware domain. This brings several benefits, including reduced risks during integration and improved potential for reuse. Furthermore, more and more vendors are providing COTS equipment which can be used fairly easily for simple system designs. In addition, the result of in-house development tends to be generic platforms which can be used on more than one system using the FPGA technology.

Engineering resources are assigned to activities such as: 1) top-down approach –the idea is to automatically generate as much of the control system's artifacts as possible from a high-level description of the system (e.g. the accelerator's lattice); 2) configuration management, i.e. being able to determine what software is installed where and to upgrade to the recent/stable version without needing to worry whether a certain software package will compile for the target platform; 3) integration with software packages used by end-users and engineers (e.g. Matlab, LabView, etc.);

4) more stress on quality (e.g. with continuous integration, more rigorous source code management techniques and development processes, etc.) and 5) use of software/hardware co-design techniques where performance is paramount.

Although this approach is used to achieve practically any functionality, we must be aware of often underestimated effort and expertise requirements needed for efficient development. Development requires much more than just basic programming skills and spans from knowledge of high level system integration to low level electronics. Such development also calls for well-defined system design processes where rudimentary mistakes are often made in the system requirements and design stages.

3.2 From numerical modelling of production to numerical modelling of use of carbon nanomaterials

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The molecules from fullerene family have garnered a lot of attention in scientific and engineering community due to their unique properties and possible applications. Recently, the fullerenes are increasingly applied in improving the properties of classical materials such as steel and aluminium. A respective high demand for these improved materials has revealed a necessity to understand, computationally model and optimize the process chain of fullerene formation and industrial production on the one hand, and the process steps of production of the fullerene enhanced classical materials, and their properties on the other.

Such computational modelling is in both cases extremely involved (from the physical modelling and computational intensity aspects), due to multiscale (nano-macro) and metaphysic (coupled mass, momentum, energy and species transfer) character of the underlying processes that range from modelling of the arc discharge process of fullerene production to blending of steel and aluminium products, and respective process steps such as casting, rolling, extrusion, and heat treatment.

In addition to the physics based computational approach, also an alternative approach has been established. This approach consists of complementing, replacing and/or tuning the physical models with artificial neural networks in areas where the physical models do not exist, are too expensive to numerically evaluate or give insufficient response. The learning of the network is done on experimental results and physical models. The direct downstream (seeking of the proper properties as a function of given process parameters) and inverse upstream optimization capabilities (seeking of the proper process parameters for given properties) are established by constructing an appropriate combined product quality and productivity objective functions, and by running the neural network model artificial intelligence model of the process step or coupled subsequent process steps. An evolutionary algorithm can be used to automatically and iteratively guide the search towards near-optimal objective function values.

A demonstration of this new computational concept and its benefits are shown on the examples of the arc-discharge production of fullerenes, and processing of aluminium and steel semi products.

3.3 Aptamer biosensors

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Aptamers are short in vitro selected RNA or single-stranded DNA species useful in biotechnological and therapeutic applications. Since there is a high demand for convenient methodologies for detecting and measuring the levels of specific molecules, because of their high affinity and sensitivity aptamers appear as alternative candidates to antibodies as efficient biomarker molecules as well as bioreceptors in biosensing assays and devices for quantitative and qualitative detection of selected analytes. By connecting fields of biology, biochemistry, chemistry, microbiology, physics and electrical engineering our lab is directed towards product(s): commercially viable and potent series of bioreceptors and biosensors, based on aptamers.

A biosensor consists of three elements: biological receptor, transducer part and signal processor. The development of the most important part, the sensitive biological element, involves selection of aptamers specific for binding target molecules in a procedure called SELEX (Systematic Evolution of Ligands by Exponential Enrichment). Molecules involved in cancer and migraine pathogenesis, markers for stem-cell isolation and characterisation, metabolites in bioreactors and food toxins are being used as analytes for selecting nucleic acid sequences with optimal binding affinities. Most promising transducer part at the moment, developed and tested in our lab, is based on fluorescence emission signal. Two-component detection system involves an aptamer DNA sequence labelled with fluorophore reporter and a complementary DNA strand labelled with a quencher molecule. A change in conformation, induced by analyte binding on aptamer, relies on the competition between the complementary strand and the analyte which results in the separation of fluorophore and quencher molecules thus creating a 'light-up' signal. Accompanying studies are already being conducted for immobilisation of aptamer signalling complex on different surfaces. Finally, associated instrumentation, electronics, software and user interface, designed in our lab in the future, will create complete solutions based on aptamer biosensing technology.

Using universal approach for sensing target molecules, aptamers are very promising as very specific and sensitive bioreceptors in all life sciences fields, such as biotechnology (up- and down-stream processing, process monitoring), bio-pharmaceutics (isolation and purification of molecule of interest, especially in development and production of biosimilars), biomedical researches (disease pathogenesis, complex interaction studies), disease diagnostics and treatment, water purification, environmental safety monitoring, food safety monitoring and others.

3.4 Bacteriophages-rediscovered tools to fight bacteria

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Bacterial diseases were historically treated with substances derived from plant, animal, fungi and inorganic origin. Discovery of antibiotics made them a dominant and practically the only substances used in treatment and prevention of bacterial infections in human health care systems. Immense success in fighting against bacteria has probably caused that some disadvantages of antibiotics were overlooked and neglected. In addition the ability of bacteria to resist and adapt to selective pressure was underestimated. ts, and respective process steps such as casting, rolling, extrusion, and heat treatment.

As a consequence of excessive use of antibiotics in the past decades incidence of antibiotic resistant pathogenic bacteria increased to the level that it became a significant problem often difficult or impossible to control. For example, WHO in 2011 reports on approximately 440.000 new tuberculosis cases every year caused by multi-resistant bacterial strains. Therefore, alternative approaches to control bacterial infections and contaminations are being studied with bacteriophage therapy being one of them.

Bacteriophages are a group of viruses with the ability to invade different bacterial species as their specific host. They are widespread in nature and are observed in waters, sediments, soil and the bodies of humans, animals and insects. They were isolated in 1917 and soon they were used to successfully treat bacterial dysentery. This was followed by several other trials targeting different bacteria in 1920s and 1930s. After WWII clinical application of bacteriophages were largely abandoned due to the introduction of broad spectrum antibiotics and only partial success of bacteriophage therapy trials at that time. Nevertheless, bacteriophage therapy flourished in the former Soviet Union and was adopted as a standard part of health care system in that part of the world. Previously described increased incidence of antibiotic resistant bacteria as well as actions of regulatory bodies prohibiting the use of antibiotics in food chain directed research towards bacteriophages also in the Western part of the world. Antibiotic resistance of bacteria belonging to Staphylococcus, Escherichia, Salmonella, Clostridium, Enterococcus, Pseudomonas, Mycobacterium, Klebsiela, and Acinetobacter are the causing of the majority of problems, therefore these bacteria have become major targets in bacteriophage therapy trails. Although a lot of efforts were directed to the development of bacteriophage preparation there is still no breakthrough of technology. The use of bacteriophages to treat and prevent bacterial infections has several advantages over antibiotics such as specificity, low environmental impact, auto-dosing, low inherent toxicity, lack of cross-resistance with antibiotics, formulation and application versatility, and safety for humans, plants and animals. At the same time there are some concerns such as narrow host range and the need for precise bacteria identification before bacteriophage application, resistance development and the need to use more bacteriophages during treatment (phage cocktail), concerns regarding human immune response to bacteriophages etc. Until now these concerns prevailed and at the moment there is no bacteriophage based products for use in humans on the market with some being in clinical trials.

Another application niche for bacteriophages is food production in animal and plant systems. For example bacteria of the genus Campylobacter are most frequent agents responsible for human enteric diseases in the West. Campylobacters colonize chicken intestine in relatively large number and during processing release of intestinal content leads to contamination of poultry meat.

Use of antibiotics can be a way to control contamination with Campylobacter but a valid EC directive prohibits the use of antibiotics in animal breeding for food. Therefore, bacteriophages are being explored to control Campylobacter contamination in poultry production. Bacteriophages can also be applied to plant disease where the control is a major challenge in plant production which causes significant economic losses. Bactericides and antibiotics can be replaced by bacteriophages which have the potential for use in integrated disease management strategies with other bio-control agents.

Bacteriophages have a number of properties that make them an attractive alternative or supplement to antibiotics. With today's understanding of bacteriophage biology and existing standards in research and medical investigation, bacteriophage applications have a second chance to show their true potential. Even if it is difficult to imagine that bacteriophages will replace antibiotics, there are medical and non-medical niches in which bacteriophages can play a significant role in the future.

3.5 Hierarchically structured porous materials – enabling technology for production of biological drugs and regenerative medicine

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Over the past decade there has been a rapid development in different pharmaceutical and biotechnological fields. Biological drugs, based especially on monoclonal antibodies, are now more and more often used in treatment of heavy diseases. Also many other ways of treatment are being investigated, especially in the field of vaccines, antibiotic resistance, gene and cell therapy and regenerative medicine. Viruses like particles (VLP) are intensively investigated for their potential use in vaccination. A little less examined in this field are bacteriophages which are on the other hand extremely interesting as an antibiotic alternative. Besides, stem cell research is now increasing due to the potential use in tissue engineering, cell therapies and regenerative medicine.

Recent surveys in biotech and pharmaceutical industry clearly demonstrate that purification of above mentioned molecules represents serious bottleneck of the entire production process. The main reason is that large amounts and very high purity of these molecules are required. This can be achieved only with the usage of chromatography as part of down-stream processing. However, to provide high specific binding capacity, chromatographic supports are commonly made of porous particles exhibiting high specific surface area.

Pores are closed, therefore, the liquid inside them is stagnant and molecules move into the pore only through their own diffusion mobility prolonging purification time for several orders of magnitude when large molecules like DNA or viruses are being purified. An alternative supports monoliths which exhibit high capacity for extremely large molecules like plasmid DNA and viruses. Monolith consists of a single piece of highly porous material.

There are plethora of different types of monoliths -- they differ in chemistry of their skeleton and also in their microscopic structure such as methacrylate monoliths, cryogels, polyacrylamide monoliths, silica monoliths, xerogels, monoliths prepared with ROMP, "template" monoliths, ceramic monoliths with polyacrylamide coating, urea-formaldehide monoliths, graphitized-carbon monoliths, cellulose monoliths, polyHIPE monoliths, superporous agarose monoliths, cryogels, and also monoliths from anorganic oxides based on titania oxide, and zirkonia oxide. The main reason for such diversification of monolithic supports is in their interesting features which can be summarized as:

- low pressure drop,
- transport based on convection,
- high capacity for extremely large molecules.

High porosity results in low pressure drop on the column meaning milder purification conditions. Convection based transport is an extremely important feature that accelerates separation and purification process, especially pronounced for large molecules. Pores in the monoliths are open and highly interconnected forming a network of channels. The mobile phase is forced to flow through them transporting the molecules to be separated onto the active (binding) site by liquid stream – by convection. Since there are normally no dead-end pores in the monoliths, there aren't any stagnant regions and the mass transfer between stationary and mobile phase is extremely fast. This is especially beneficial for the purification of very large molecules having small mobility like large proteins, polynucleotides or viruses. Furthermore, monoliths also exhibit high binding capacity for extremely large molecules such as large proteins, DNA and viruses.

3.6 Timing Systems based on Optical Technologies

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In the particle accelerator environment, the needs for precise synchronization are greater each year due to the fast development of the machine physics science. For the Free Electron Laser (FEL) machines the required short (jitter) and long term (drift) stability are now in a few 10 fs range. In addition to the reference clock transfer, precisely synchronized acquisition is required. Especially in large experiments it would be much easier if local sampling which is globally synchronized would be used. In this way the distributed acquisition and processing system can be realized with a precision in a few 100 fs range. This is roughly two orders of magnitude better than what current systems are offering. In such applications the data link performance needs to be deterministic in terms of jitter. For every sample to be acquired at a precise time, propagation delay needs to be evaluated and time stamping used accordingly. Optical fibre with high bandwidth, low loss and various length compensation applicable techniques is almost an ideal transfer media for timing and synchronization applications.

The basic principle of reference clock transfer has already been integrated into a commercially available unit. Further research and development is needed to reach the advanced performance level. Effort is dedicated to improving jitter and long term stability. In addition to the research work the measurement methods had to be developed. For the low frequency phase noise (drift) a prototype of a special measurement device called "phase detector" has been developed with confirmed precision and stability in the range of 3 fs. For the frequencies closer than 100 Hz from the carrier the measurement of the added jitter is not easy to perform. Well-known correlation based method was realized to evaluate progress in reduction of the added jitter of the reference clock transfer system. Nevertheless, besides the advanced design of the analogue and digital circuitry and optical fibre connections, several mechanical and thermal issues are being solved which makes this research and development truly interdisciplinary.

4. Centre of Excellence in Nanoscience and Nanotechnology – CENN Nanocenter

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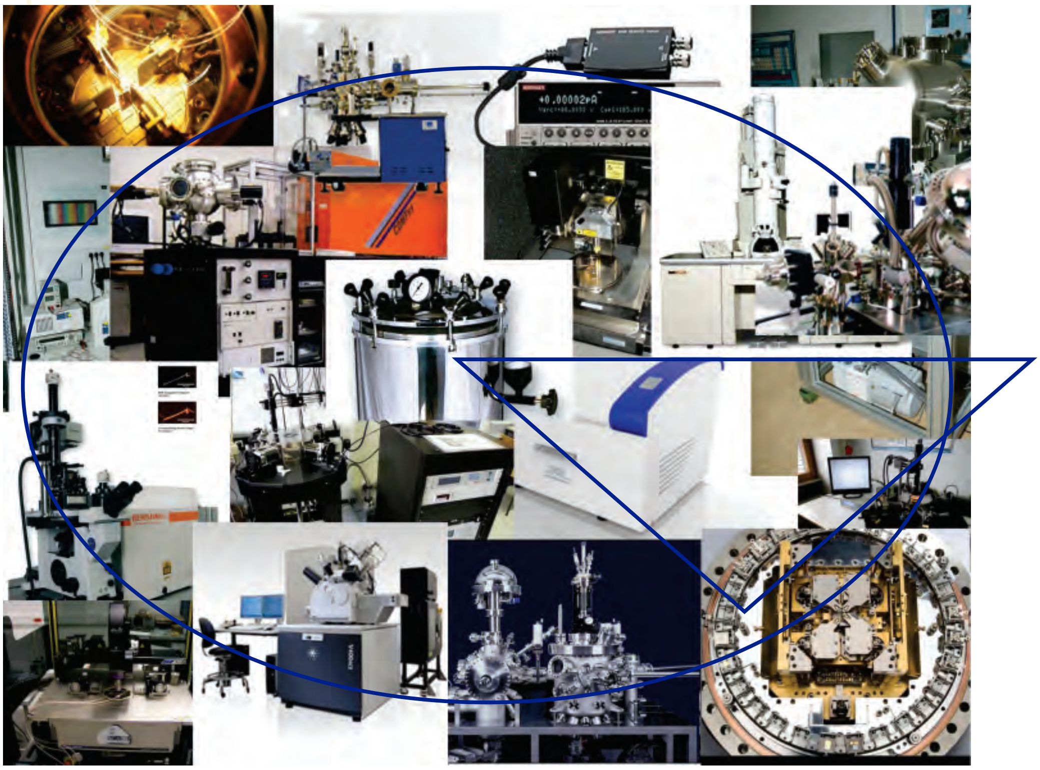
The CENN Nanocentre is designed to address the challenge imposed by extremely rapid development of N&N in the world by joining together the efforts of all the leading research groups and industry leaders in the field into a consortium of 4 leading research establishments and 15 companies, the common goal of which is to set up a technological infrastructure platform for the competitive development of N&N in Slovenia in the next decade. One of its main goals is to bridge the gap between what academia can offer and what the industry can absorb in order to achieve a higher level of technological development in industry and increase the added value of its products. The project focuses on synthesis, nanofacturing, characterisation and modelling facilities on an internationally competitive level. The CENN Nanocentre is a continuation of the highly successful but much smaller CoE in Nanoscience and Nanotechnology funded in the period 2004-2008 from the European restructuring funds.



The CENN Nanocentre builds on experience and good working practices developed in the previous founding period, and now includes the equipment infrastructure of the original CoE. The present investment in infrastructure is designed to ensure medium-term technological opportunities and should be viewed in light of the competition from other centres in other developed countries, particularly those which are in direct competition. The size of the present investment is significantly smaller than similar nanocentres and represents an initial but absolutely crucial investment into a new technology, allowing the industry to access knowledge and infrastructure. The choice of equipment in the CENN Nanocentre is adapted to the needs of the consortium. The timing is already critical but in the first period of the centre (2004-08) the relatively modest investments of 1.5 M into NT infrastructure has provided a focal point for the development of new technology and joint activities. We foresee that current programme CoE nanocentre will significantly expand this and new products in the industry which crucially rely on the equipment in the centre continuously on the horizon. We support the government's initiative to set up supported infrastructural centres with long-term funding and training programmes based on our model.

The modes of cooperation with new external partners which are envisaged for future are:

- Direct projects (new nanomaterials, characterisation of nanomaterials)
- Advancement of the core knowledge base
- Development of new nanofacturing technologies
- Technology transfer (new technologies)
- Development of new instrumentation (nanolitography, processing equipment, etc.)
- Training
- Personnel transfer
- Startups and spinoffs

All of these modes can lead to new partnerships within the CoE. The CoE has an open door policy, subject to settlement of legal issues related to the intellectual property, and approval by the science council of the CoE. New partners are encouraged to join the CoE, particularly when joint projects with existing members of the consortium are envisaged. The same applies to Slovenian and external partners. The officers of the CoE are pursuing a pro-active policy of cooperation with international organisations and related facilities which can provide complementary activities to the CoE Nanocentre. Synchrotron facilities for nanostructure determination, such as EXAFS and other local probes are of particular interest. The aim is to facilitate complementary training activities as well.

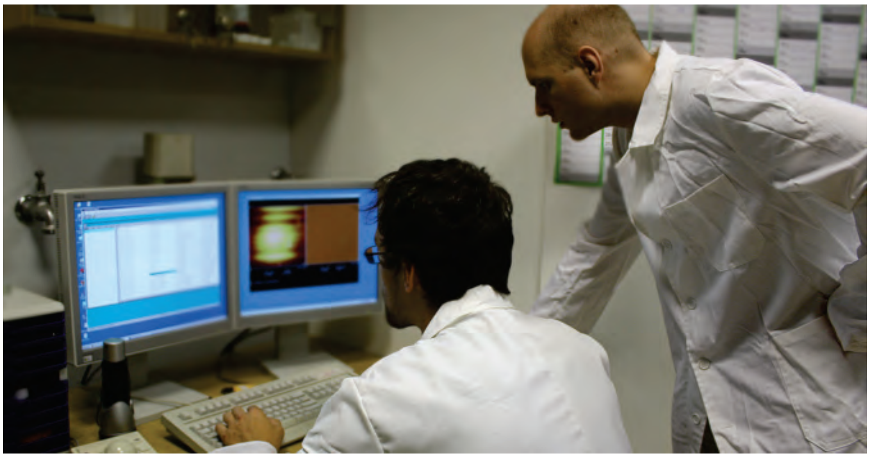
Nanotechnology is an emerging field which is developing extremely rapidly both scientifically and industrially. The present programme in CoE Nanocentre aims at creating a real breakthrough in a number of technologies in Slovenia aiming at world-class excellence. Utilising recent successes (in nanomateirals such as nanowires and nanotubes for example) and long term experience in inorganic compounds of different kinds, such as ferroelectrics, ferromagnets and superconductors we aim to achieve a breakthrough by quickly moving into nanostructures and nanodevices. The recent publication record of the members of the consortium show a number of potential breakthroughs may be expected within the scope of the present programme, particularly in lubricating nanomaterials, polymer nanocomposites and potentially revolutionary advances in molecular electronics. These breakthroughs are related to very intense research in transition metal chalcogenide nanowires such as MoSI. The advancement of these areas crucially depends on advanced synthesis, characterisation and nanofacturing equipment proposed here.

Another important area where a breakthrough is expected is optical nanolithography, where a prototype device is to be developed in the first year based on existing optical tweezers technology for sub-lambda lithography (Aresis, LPKF and FMF). Three recent papers in Science (all published on 15 May 2009) have shown how to improve the resolution down to less than 20 nm by using the specific advantages of the Aresis/LPKF machine offering a potential commercial breakthrough.

A number of new technologies are to be set up for the first time in Slovenia, such as Pulsed Laser Deposition (PLD) and MBE. Particularly MBE is a technology which is experiencing a revival with oxide thin film nanostructures. With decades of experience in oxide sciences in Slovenia, we may expect breakthroughs in this area.

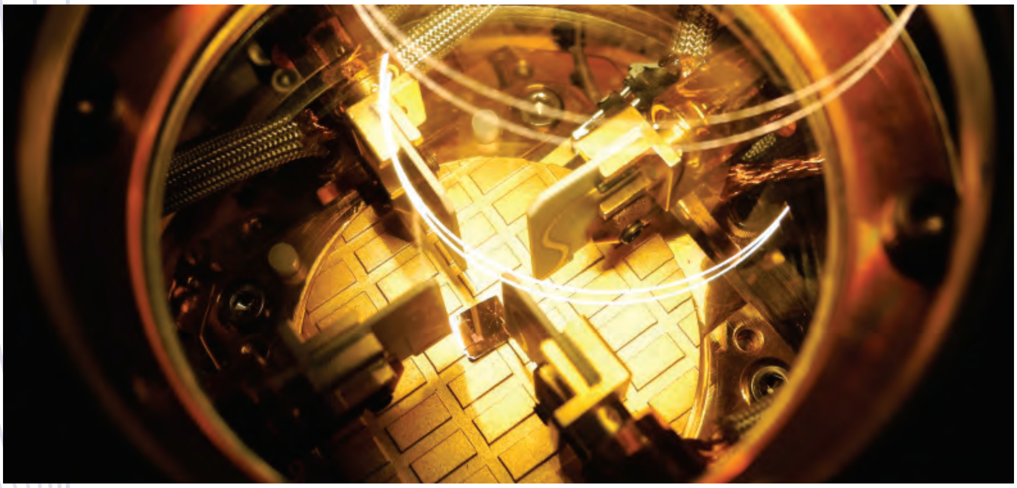
Services

We offer open access infrastructure for academics, researchers and representatives of the industry. For the European users we provide a technological platform for pretentious nanofacture and characterization of the nanostructures with defined metrological standards for synthesis and other protocols. We are developing a data base for N&N and protocols for metrology, synthesis and analysis.



Access to superior equipment

CENN Nanocentre offers infrastructure with open access to academic, research, industry and civil subjects to the facility purchased in the framework of the Centres of Excellence 2009–2013 and also to the facilities financed with the EU founds in the framework of the operation Centres of



Synthesis of new materials

Synthesis of new nanomaterials is especially important for ultimate industrial applications. New materials, discovered and synthesised within the CENN can be the basis for new technologies and products, which give the members a competitive advantage. The synthesis of nanomaterials requires modern equipment, such as molecular beam epitaxy, pulsed laser deposition and high pressure and temperature synthesis methods. The Nanocenter encompasses different synthesis projects from molecular nanotechnology to nanocomposites and nanostructures, coatings and films. Important research areas and directions in nanomaterials from the point of view of applications within the Nanocentre are:

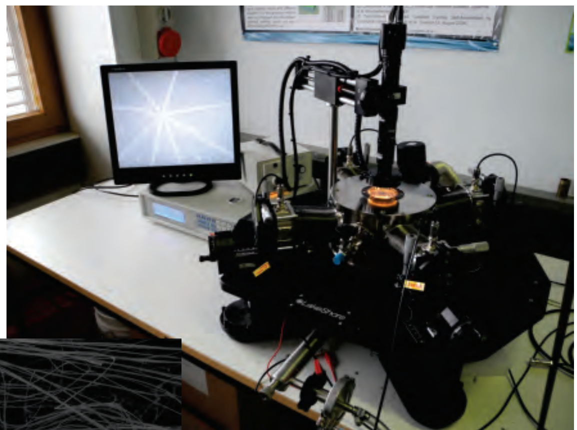
- nanomaterials for electronics, informatics and communications,
- thin films and nanostructures, for electronics and sensors,
- nanomaterials for biochemistry and medical applications,
- nanomaterials for energy, batteries, fuel cells and photovoltaics,
- nanomaterials for transport, particularly nanocomposites, smart materials and lubricants.

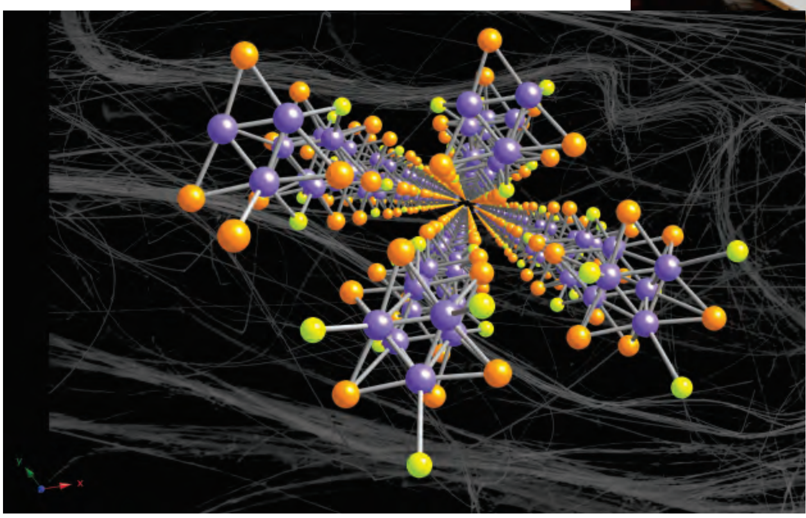
Processing

Nanofacturing technologies for nanotechnology are very diverse. The most important are nanolithographic processing methods and technologies which directly lead to industrial processes. This type of equipment is developing very rapidly and part of the activity in this CoE is the development of a new and very competitive optical nanolitographic (ONL) technology based on recently published multi-colour laser techniques (three papers in Science, May 15, 2009). The ONL machines are to be developed to the level of a commercialproducts by LPKF and ARESIS.

We intend to set up facilities also for self-assembly technologies as newly developing area with potential industrial impact, especially in the context of the development of SMEs within the Slovenian environment. The main nanofacturing technologies which the Nanocentre will facilitate are:

- nanoelectronics, molekular electronics devices for nanoelectronics,
- functional nanostructures in nanocomposites,
- nanostructured surfaces,
- multilayer nanostructures,
- fotocatalitic materials,
- one-dimensional material (mainly inorganic nanotubes in nanowires),
- hybrid materials,
- thin film devices (MEMS, NEMS),
- molecular tehnologies,
- tehnologies at the level of single atoms in molecules,
- bionanosensors,
- nanocomposits in nanoparticles,
- nanocoatings on surfaces,
- nanocomposite hard coatings,
- nanostructures in holographic document protection.





Characterization

Characterisation is the core of all progress in nanotechnology, which requires state of the art techniques. The modern characterisation equipment end methods which are assembled within the CE allow the partners to use high technology which would otherwise be inaccessible to them individually because of high cost. The basic equipment for characterisation is assembled based on the needs of the partners and includes microscopy of different kinds, advanced spectroscopic characterisation methods, surface probes of different kinds, nanoscale characterisation tools and advanced techniques for the investigation of dynamical processes in nanomaterials:

- scanning probe microscopies (STM, AFM, MFM, Kelvin probe etc.),
- electron microscopy and microanalysis (particularly advanced and combined HRSEM-SPM adapted techniques especially designed for nanomaterials),
- spectroscopies (from X-rays to THz and STS),
- diverse optical spectroscopies (Femtosecond spectroscopy, Raman, confocal fluorescence microscopy).

Modelling

During the past two years, the demonstrated limits of controlled, coherent electron dynamics in nanosystems have been extended by an order of magnitude. Examples include: single spin dynamics in semiconductor quantum dots on timescale up to a microsecond, electronic interferometers in GaAs, micrometer-scale coherent transport in nanotubes. The eventual realisation of molecular electronics will provide ultra-dense, low-power, low-cost circuitry and novel sensor technologies for pressure, acceleration and radiation, along with chemical sensors capable of detection and analysis of a single molecule. The proposed research aims to develop new modelling techniques for reliably predicting and controlling electronic charge and spin transport through single molecules which will enable the rational design of future molecular-electronic devices. Such numerical methods will be developed in particular for the modelling of properties of coupled quantum dots with both Coulomb and electron-phonon interactions which will yield accurate solutions for regimes hitherto unreachable. Detailed ab initio calculations based on our experience will be used to implement new treatment of correlation effects in these systems by further increasing the functionality of available theoretical tools, e.g. spin-density-renormalization theory (spin-DFT) developed recently for the analysis of quantum point contacts. Using the ab-initio methods based on the DFT we will simulate new materials including metallic or semiconducting nanowires and metallic nanowires attached to the steps on silicon or sapphire surfaces. All these materials represent a base for the development of quantum computing or molecular sensors. The output of such DFT simulations are reliable electron energies and energies which enable one to determine the crystal or molecular structures as well as to predict different physical, e.g. mechanical or electrical properties.

4.1 Optical Nanolithography

Blaž Kavčič [1]

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Small scale fabrication of devices in experimental research (e.g. microfluidics) and in device design (e.g. electronic circuits) require optical lithographic techniques with higher flexibility, lower cost, and small size, due to frequent device design changes as work progresses. A suitable alternative to mask lithography is laser direct imaging (LDI) that exposes photoresist with a focused ultraviolet laser beam directly. We developed an LDI method which uses an acousto-optic deflector to steer the laser beam in two dimensions. The technique enables patterning of common resists with 1 or 3 μm-diameter beams, sub-nm beam positioning precision and sub-μm resolution. Produced patterns have well-defined edges that can achieve smoothness on the nanometre scale. Advantages of LDI over conventional techniques lie in low initial costs, high speed and flexibility, high beam positioning precision and no waiting associated with manufacturing high-resolution masks. The technique is suitable for daily use in research laboratories and has evolved into a commercial product.

4.2 Synthesis in CENN Nanocenter

Spomenka Kobe [1]

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Synthesis of new nanomaterials is especially important for ultimate industrial applications. New materials, discovered and synthesised within the CENN Nanocentre can be the basis for new technologies and products, which give the members a competitive advantage. The synthesis of nanomaterials requires modern equipment, such as molecular beam epitaxy, pulsed laser deposition and high pressure and temperature synthesis methods. The CENN Nanocentre encompasses different synthesis projects from molecular nanotechnology to nanocomposites and nanostructures, coatings and films.

4.3 Methods of characterization

Igor Muševič[1,2]

[1] Jožef Stefan Institute, Slovenia
[2] CENN Nanocenter, Slovenia

Characterisation is the core of all progress in nanotechnology which requires state of the art techniques. The modern characterisation equipment end methods which will be assembled within the CENN Nanocentre will enable the partners to use high technology which would otherwise be inaccessible to them individually because of high cost. The basic equipment for characterisation is assembled based on the needs of the partners and includes microscopy of different kinds, advanced spectroscopic characterisation methods, surface probes of different kinds, nanoscale characterisation tools and advanced techniques for the investigation of dynamical processes in nanomaterials.

5. SPACE-SI: Centre of Excellence for Space Sciences and Technologies

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5.1 SPACE-SI

Rodič Tomaž, Oštir Krištof, Nedjeljka Žagar, Zwitter Tomaž, Matko Drago, Hubert Fröhlich, Malič Barbara and Peljhan Marko

Abstract

In Slovenia a new Centre of Excellence for Space Sciences and Technologies SPACE-SI has been established in 2010 with the main focus on nano and micro satellite technologies. This presentation is aimed at informing the international community about the RTD goals and opportunities for collaboration with SPACE-SI programme in 2010-2013 as well as about the new laboratory and ground station infrastructure that will be developed in the region together with the new network based services for near real time processing of remote sensing satellite data. The RTD goals of the SPACE-SI consortium consisting of academic institutions, high-tech SMEs and large industrial and insurance companies are focused on nano and micro satellite technologies that are enabling high precision interactive remote sensing and precise maneuvering of small spacecraft in formation flying missions. For the development of these technologies an advanced RTD infrastructure is being set up including a multidisciplinary laboratory for closed loop investigations of materials, structures, micropropulsion systems, electronic components and visual based control algorithms in simulated space environments. The experimental techniques will be combined with virtual models for primal and sensitivity analyses of components, subsystems and platforms as well as for their characterisation by inverse numerical analyses and optimisation of their design with respect to performance and reliability. A development of a technology demonstration mission is envisaged for which synergies and potential partners are sought at the international level. The SPACE-SI consortium believes that further developments of small satellite technologies will on one hand make scientific investigations in astrophysics and cosmology more feasible and will on the other hand enable new types of end user services in meteorology and Earth observation. This will improve local and global situational awareness in the society about important environmental and socio-economic issues related to climate change, weather, hydrology, forestry, agriculture, urban development and natural disasters risks. Although data processing steps for these applications are usually well defined, the automatic processing of satellite data is mainly available for meteorology, while several other application

fields lack fast satellite to end-user transfer of data and products. In the SPACE-SI programme the near real time automatic data processing procedures will be developed to convert raw remote sensing data to map ready imagery and products (e.g. vegetation state, soil humidity etc.) and deliver them by means of a GIS portal in standard formats that will be applicable not only to specialists but also to general public. Therefore, the new space related RTD activities in Slovenia are expected to enhance creative paradigms in the science-society realm as well as to contribute to cost effective socio-economic and environmental benefits.

5.1.1 Introduction

The interest of Slovenian researchers in space sciences and technologies has very deep roots dating back to 1929 when Herman Potočnik-Noordung published his fundamental book "The Problems of Space Flying – The Rocket Motor" [1-4]. Since those early days a number of Slovenian scientists, engineers and even artists dedicated their efforts to space related activities. They have participated in foreign satellite projects [5], published books on satellite technologies [6] and remote sensing applications [7] as well as performed arts and art/science projects in microgravity [8]. However, until recently this intellectual potential remained rather fragmented and limited only to niche applications developed by specialised RTD laboratories and high tech companies in Slovenia while there was no common RTD strategy to integrate space sciences and technologies to derive synergetic effects. This is because space related RTD was for a long time reserved predominantly to large entities from economically powerful nations. This situation is now radically changing and we will show that newly emerging micro and nano satellite technologies are offering completely new and affordable RTD paradigms where Slovenian researchers and industry can make relevant contributions to the international state of the art. For this purposes a Centre of Excellence (CE) for Space Sciences and Technologies SPACE-SI was established and is strategically positioning itself to enable the integration of Slovenian industry and RTD into the international aerospace complex through the establishment of collaborative interdisciplinary infrastructure, science and technology applications and demonstrations and even end user case study piloting.

Researchers and industrial partners working on computer aided optimisation of microthruster technologies for the precise manoeuvring of orbital platforms, visual based control of satellites, research of tunable ferroelectric thin films for wireless communications and phase shifting arrays, functionally graded materials and engineers working in data acquisition, processing, analysis, post-processing and control are joining forces with scientists from Earth observation, meteorology and astrophysics to streamline their RTD efforts from fundamental sciences to technological research all the way up to the end-user applications in the field of acquisition, analysis and distribution of remote sensing data for environmental analysis and insurance industry expert models.

The SPACE-SI work programme is organised around nine work packages with strong interdependences as shown in Fig. 1.

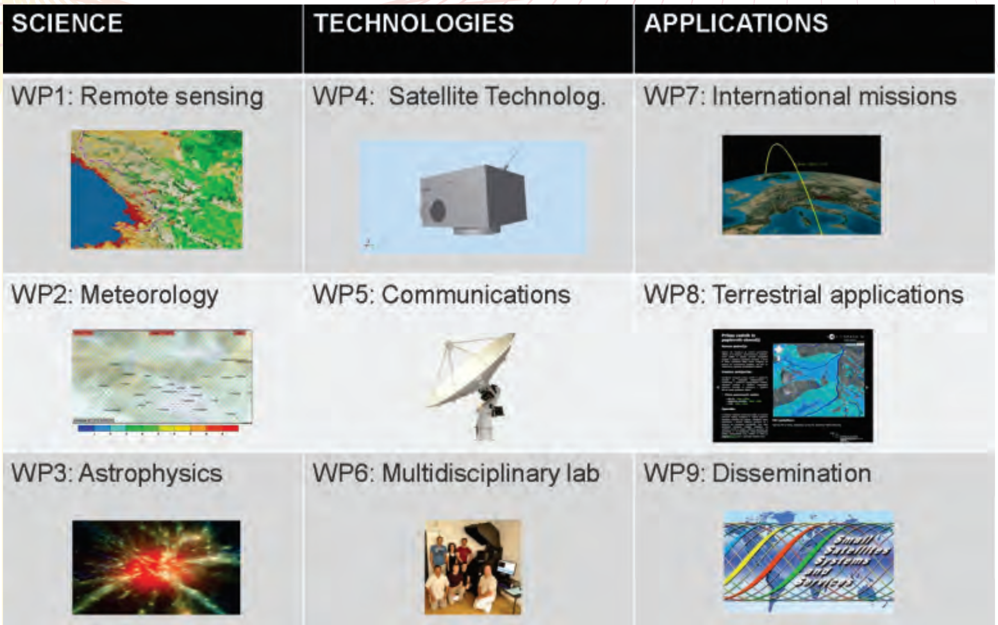

Fig.1: SPACE-SI work programme structure

The SPACE-SI consortium has identified opportunities for micro/nano satellite technologies in remote sensing, meteorology and astrophysics which could benefit from new types of missions including interactive high precision earth observation, disaster monitoring, deployment of constellations of small satellites for global coverage and frequent revisit times [9-10]. Further opportunities include advanced autonomous formation flying missions [11-13] and operationally responsive space missions, inspection of large satellites with daughter nano satellites, proximity operations with near earth objects, dispersed deep space scientific explorations with high pointing accuracies, narrow band communications as well as low risk technology demonstration tests. Nano satellites such as the Cubesat family, for example, are also very popular and affordable means for training young scientists and engineers at universities with ambitious multidisciplinary goals in space RTD. Introduction of COTS components has reduced the costs of small satellites to such a level that failure of a satellite system is no longer considered as catastrophe but rather as a manageable risk. This allows introduction of new creative paradigms permitting high risk – high benefit approaches in space system design and mission planning which are expected to accelerate technology development in unprecedented ways. The indicated transitions have opened opportunities for newcomers to the space arena, including RTD players from economically less powerful and aerospace developed regions.

The potential of micro and nano satellites technologies has been already recognised in technically advanced countries and the micro and nano satellite technologies are included in the ESA technology development visions. By carefully analysing the NANOSAT CDF study report [14] and the NEOMEx [15] concept for micro and nano satellites we can see that they clearly identify RTD challenges that require a strategic approach to meet very ambitious but realistic quantitative objectives. For the NEOMEx strawman mission for close-up investigations of near earth objects the challenge of this mass critical mission is to integrate large fraction of payload on a nano satellite platform with fairly complex propulsion and AOCS by respecting extreme mass constraints for satellite platform (<5kg) and payloads (2-4 kg) as well as for the power consumption (10-15W). In order to achieve such an ambitious goal one would need to develop and optimally integrate several microsystem technologies where critical issues include micro propulsion with high precision cold and hot gas micro-thrusters or hollow cathode technologies, structure with integrated harness and MFS, thermal control with smart materials enabling minimum power consumption for thermal management, as well as power systems for thermal management of batteries and advanced avionics subsystems.

In a similar way one could define RTD challenges for other types of missions which offer great S&T opportunities for small satellite sector. This opens very large RTD areas where we have identified the the most promising RTD targets with an additional added value, that will be achieved by harmonising individual RTD strategies of laboratories by focussing on a common multidisciplinary goal targeted on enabling technologies for advanced platform manoeuvring.

5.1.2 Multidisciplinary approach for enabling technologies

In its current structure, SPACE-SI has the S&T potential to streamline the prospective RTD niche areas of individual laboratories into a closed loop solution (Fig.2) for the development of enabling technologies for advanced space craft manoeuvring during formation flying as well as for high precision remote sensing in Earth observation and photometry in astrophysics. Since all these important applications have a common requirement for precise micropropulsion and advanced control of micro/nano satellite platforms, the SPACE-SI strategy is to integrate these areas into a multidisciplinary laboratory infrastructure for on-ground testing where investigations can be streamlined into closed loop solutions ranging from micropropulsion to micro/nano platform design and vision based control/servoing (VBS) to the applications in high precision remote sensing, formation flying and astrophysics.

Modular laboratory for multidisciplinary hardware in the loop tests

The laboratory will integrate a distributed data acquisition matrix encompassing fixed and transient data recording solutions, dynamic signal analysis including frequency response testing, telemetry and power analysis developed in conjunction with a high-technology SME DEWESoft. The on-ground testing in simulated space environment (vacuum, sun, Helmholtz cage, etc) will be complemented with real space technology tests performed during the partnership with PRISMA [16-18] and LAPAN-TUBSAT [19-22] missions, to enable Slovenian scientists to gain in-depth understanding and experience in space RTD. These studies, supported by our strategic partners will start in the early stages of SPACE-SI programme.

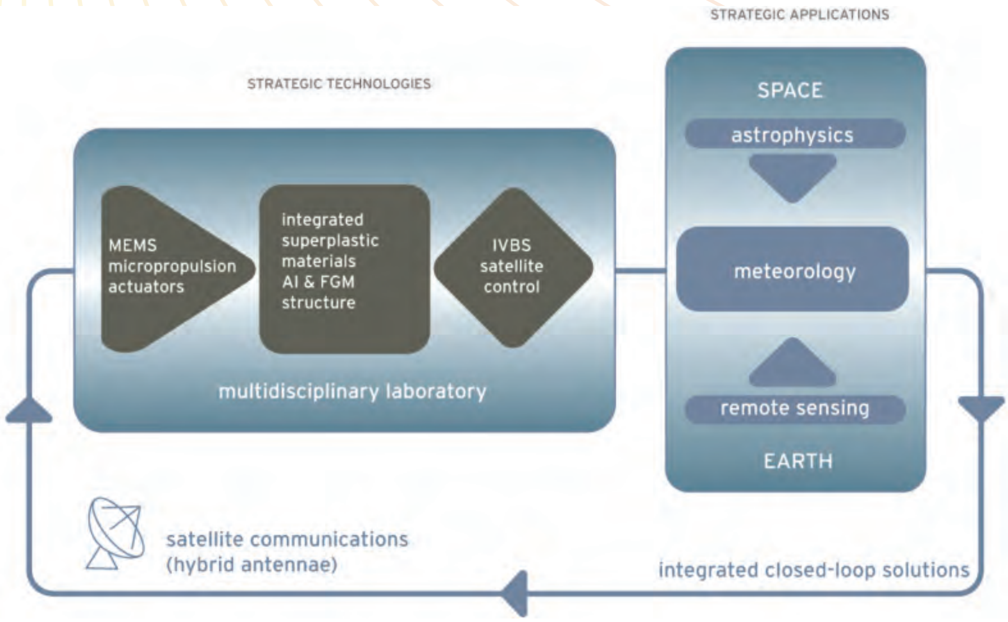

Fig. 2: Multidisciplinary laboratory and approach to the development of enabling technologies

The laboratory will serve as an incubator for the integration of micro-satellite systems with functionally graded materials and advanced thermomechanical and dynamic testing of FGM and superplastic aluminium alloys for structural components. It will also have the capability for the development and testing of MEMS micropropulsion technologies and optimisation of microfluidic systems through an experimental setup for characterisation of actuator performances in a simulated space environment. Furthermore, satellite control and visual based servoing scenarios and a variety of communications and sensing systems development will be investigated through closed loop high precision manoeuvring simulation. In partnership with the Institute Jozef Stefan, one of the SPACE-SI consortium partners, ferroelectric based phased arrays for satellite applications will be tested, developed and experimentally integrated with photovoltaics.

Ground Control Station

An advanced universal ground control station (GCS) infrastructure is one of the main priorities in the first phase of the establishment of the CE and an integral part of the multidisciplinary strategy. The universal architecture of the GCS will enable all of the utilisation partners to make the best possible use of existing and future platforms and programs, with which the CE will partner and associate. The main characteristics as envisioned now are:

- Flexibility to communicate with a wide variety of satellites (all orbits, frequency ranges, different fields of research and observation, »Mailbox Ground Station capability« [23])
- RX:TX C4i capabilities
- High precision tracking system
- Dislocation of receiver from antenna due to size – remote access
- Transmitting antenna: reflector 1,8 m, 40dB gain, X-Y positioning, frequency bands VHF/UHF/S
- Receiving antenna: reflector 5m, 40-50 dB gain, X-Y positioning, monopulse tracking system
- Horn antennas for primary feed: left-circular and right circular polarisation, frequency bands L/S/C/X/Ku/Ka, G/T 20 dB/K

This infrastructure will also be made available as geographic gap filler for satellite data RX:TX to partnering space research organizations throughout the world.

Space testing and on orbit technology demonstrations

To accelerate the experiential curve of the participating scientists and engineers, the space tests and on orbit technology demonstrations will be performed through collaboration and participation in international space missions such as but not limited to:

- TUBSAT: Interactive remote sensing by vision based control tracking of targets.
- PRISMA: Vision based control of 3D proximity operations in formation flying missions.

Fine-tuning of RTD strategies

The fine-tuning of RTD strategies will be an iterative optimisation procedure in which human and infrastructural development plans of individual laboratories and multidisciplinary team as a whole will be optimised with respect to the results of feasibility studies that will take into account current technological gaps, critical space technologies and prospective niche markets in order to maximise sustainability of medium to long term RTD roadmaps.

The feasibility studies will be focused on those types of missions where advantages of small satellites appear natural. This includes:

- autonomous formation flying missions
- constellations of small and agile satellites for global coverage and frequent revisits
- high precision remote sensing by interactive operation of the spacecraft by observer
- near Earth object explorations by micro and nano satellites
- in-orbit inspections, servicing and assembly of larger satellites by small spacecrafts
- responsive space missions
- synthetic aperture radars

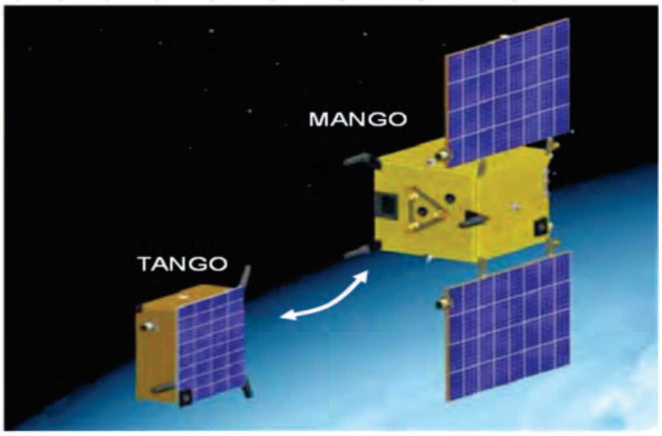

Fig. 3: SPACE-SI formation flight experiment (21.9.2011): Prisma satellites Mango and Tango from OHB-Sweeden; SPACE-SI formation flight experiment where an image of Tango is made from Mango while the satellites are aligned with a predefined target on ground – distance between satellites is 10 meters (Cape Town - IAC 2011 example)

5.1.3 Scientific, technological and applicative breakthroughs

We envision that the main S&T breakthroughs will be achieved in four domains that combine optimized MEMS microthrust actuators and integrated platform structures made of superplastic and FGM materials with IBVS technology for high precision interactive satellite maneuvering, and hybrid antennas integrating phase shift arrays and solar cells. These breakthroughs are expected to be interesting for many missions and strategic partners. The SPACE-SI consortium will also perform a feasibility study for an indigenous micro-satellite mission with main goal to perform technology demonstration in space for all four S&T breakthroughs developed in Slovenia. The RTD programme aimed at this main S&T goal will in the course of development generate many breakthroughs in different fields of sciences, technologies and applications briefly presented below.

Scientific

- A theory for multi-scale and multi-physics modelling of microfluidic systems
- Image based visual servoing algorithms for interactive high precision remote sensing
- New method for multivariate data assimilation in the tropics
- Participation in Gaia mission of ESA

Technological

- On-ground laboratory for closed loop investigations of high precision manoeuvring
- Simulations of space craft manoeuvres in virtual and simulated space environment
- First space flight demonstrating Slovenian IBVS technology for interactive remote sensing
- Hybrid technology combining solar cells and microwave antennas
- Universal ground control station for communication with wide range of satellites
- Astrophysical observations

Applicative

- Near-real time processing of remote sensing data
- Prototype end-user service to deliver satellite images
- Terrestrial applications of space technologies

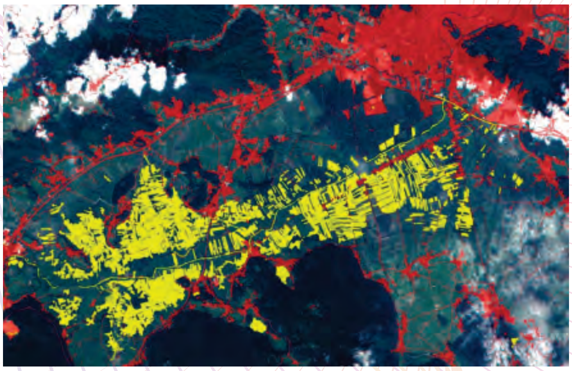

Fig. 4: Mapping floods around Ljubljana in September 2010

5.1.4 Conclusion

With the suggested structure, strategic partnerships, international activities, the dissemination program and through the work within the M-Thrust consortium, the SPACE-SI actively connects with the programs and projects within ESA, FP7-SPACE, NASA, missions that are currently running and missions that ESA plans and actively pursuits. For the labs and partners involved in the CE, its multidisciplinary structure is enabling a multi level partnership accession to the already existing international programs and projects and the focus on the S&T challenges that are connected to the individual domains of the consortium members.

The focusing on the critical technologies and the establishment of advanced multidisciplinary ground test and communications infrastructure will enable the CE to actively integrate in international cooperative measures and missions by providing a range of S&T competences and filling identified gaps in the field. From the applicative, technological and scientific breakthroughs that we are planning to accomplish, the integral connectivity of the CE with the wider European and global S&T concepts in space technologies and earth based applications is evident, despite its compact structure.

This kind of structure will also enable the establishment of conditions for the founding of a future coordinating body, the Slovenian Space Platform, which should become the central RTD focal point for space S&T in the region in the future.

References

[1] Noordung H., *Das Problem der Befahrung des Weltraums//Der Raketten Motor/.*, Berlin: Schmidt and Co., 1929.

[2] Noordung, G, *Problema Puteshestviya v Mirovom Prostranstvie*, Moscow short edition, 1935.

[3] Noordung, H., *The Problem of Space Travel: The Rocket Motor/. Edited by Ernst Stuhlinger and J. D. Hunley with Jennifer Garland. Washington, D.D.,* Government Printing Office, NASA SP-4026, 1995.

[4] Noordung, H. P., *Problem vožnje po vesolju. Edited by Sandi Sitar*. Ljubljana: Slovenska Matica, 1986.

[5] Vidmar M., *Participation construction & build team for AMSAT P3D amateur satellite project 2000 and MICROSAT amateur-radio satellite project,* 1990.

[6] Matko D., et al. (ed.). *Uporaba vesoljskih tehnologij,* Radovljica: Didakta, 1996.

[7] Oštir K., *Daljinsko zaznavanje,* Ljubljana: ZRC SAZU, 2006.

[8] Peljhan M., *Projekt Atol Flight Operations*, Zero Gravity – A cultural user's guide, The Arts Catalyst, 2005.

[9] Sandau R., Paxton L., Esper J., *Trends and Visions for Small Satellite Missions*, Small Satelllites for Earth Observation, Springer, 27-39, 2008.

[10] Neeck. S.P., Hammer T.F., NASA *Earth Observation Programs for Small Satellites*, Small Satelllites for Earth Observation, Springer, 3-12, 2008.

[11] Sephton T., Wishart A., Strauch K., Teston F., EO *Formation Flying Applications for Small Satellite Missions,* Small Satelllites for Earth Observation, Springer 153-162, 2008.

[12] Berge S., Jakobsson B., Bodin P., Edfors A., Persson S., *Rendezvous and formation flying experiments within the PRISMA in-orbit testbed*, www.prismasatellites.se

[13] Larsson R., Berge S., Bodin P., Jönsson U., *Fuel Efficient Relative Orbit Control Strategies for Formation Flying and Rendezvous within PRISMA*, 29th ANNUAL AAS GUIDANCE AND CONTROL CONFERENCE, Colorado February 4-8, 2006.

[14] Santandrea S., et all., *CDF Study Report NanoSat Development of a Highly-Capable Modular Miniaturised Platform*, CDF Study Report: CDF-84(A), ESA/ESTEC/TEC-ECC, 2009.

[15] Köhler J., *System of Microsystems nanospacecraft as a focus for TRP activities – The NEOMEx strawman*, 6th ESA Round Table on MNT for Space Applications, 2007.

[16] Clacey E., Pokrupa N., Persson S., *Using Small Satellites for New Applications: Next Generation Swedish Space Corporation Spacecraft*, Small Satellite Conference, Utah, 2006.

[17] Persson S., Jacobsson B., Gill E., PRISMA – *Demonstration Mission for Advanced Rendevouz and Formation Flying Technologies and Sensors*, Proceedings of the 56th International Astronautical Congress (IAC-05-B5.6.B.07), Fukuoka, Japan, October 2005.

[18] Persson S., Jacobsson B., "PRISMA - Swedish in-orbit testbed for rendezvous and formation flying," Proceedings of the 57th IAC/IAF/IAA (International Astronautical Congress), Valencia, Spain, Oct. 2-6, 2006, IAC-06-D1.2.02

[19] Renner U., Buhl M., *High Precision Interactive Earth Observation With LAPAN-TUBSAT*, Proceedings of the 4S Symposium Small Satellites, Systems and Services, Rhodos, Greece, 26-30 May 2008.

[20] Renner U., Buhl M., *First Flight Results with LAPAN-TUBSAT*, 6th IAA Symposium Small Satellites for Earth Observation, Berlin, 2007.

[21] Hardhienata S., Salatun A.S., *Launch and First Six Month's Orbital Performance of LAPAN-TUBSAT Satellite*, Earth Observation Small Satellites for Remote Sensing Applications (eoss2007), Kuala Lumpur, Malaysia, 2007.

[22] W. Hasbi, R. Widyastuti, *The Use Of LAPANTUBSAT Satellite Video Data For EarthObservation*, Earth Observation Small Satellites for Remote Sensing Applications (eoss2007), Kuala Lumpur, Malaysia, 2007

[23] Brand B., Zehetbaure T., *The « Mailbox Ground Station » - A Procedure to Improve the Operational Key Requirements of Earth Observation Systems*, Small Satelllites for Earth Observation, Springer, 285-292, 2008.

[24] Courtois M., *Small Satellites, to do what?* How the technology improvements are changing the landscape, Space Days, Liege, 2008.

6. Centre of Excellence for Integrated Approaches in Chemistry and Biology of Proteins

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The Centre of Excellence for Integrated Approaches in Chemistry and Biology of Proteins (CIPKeBiP) will connect the top available expertise, know-how, and technology of Slovenian research laboratories in protein science, thus emphasizing biomedical relevance of the applied project (priority health and life sciences). The Centre is coordinated by the Department of Biochemistry and Molecular and Structural Biology at JSI, the leading edge of Slovenian biochemical science and includes institutions from central and north-eastern region of Slovenia as well as small, medium and large industrial entities.

Extensive international collaborations and memberships in international bodies such as the pan European infrastructure project INSTRUCT will help us to access and adapt cutting edge technologies and know-how to our needs. In the areas such as protein production, analysis and structure determination, high throughput/output (parallel) methodological approaches will be applied by minimizing the required volumes. These technologies will be used in studies with a specific biological focus of high scientific relevance and of high biomedical (infectious diseases, signalling pathways) and environmental (adaption mechanisms of extremofiles) importance. High profile research will drive and assure the development of technological expertise and know-how which will be applied in several projects relevant for industrial partners, with drug discovery, optimisation and drug synthesis being the target technology developments.

The created knowledge will be continuously monitored and evaluated as a driving force for increasing competitiveness of small biotech as well as medium/large pharmaceutical companies. The enhanced synergy of this partnership will foster education of highly qualified and skilled personnel at the beginning of their scientific careers for the needs of academic and industrial research.

6.1 The protection of intellectual assets

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The protection of intellectual assets is essential to the competitiveness of most organisations, private or public, and to their attractiveness for investors. Hence, there is a need to properly balance intellectual property systems, to ensure that they offer suitable incentives to invest in research and innovation, while at the same time ensuring that the diffusion and further development of research results are not stifled. However, in the European research policy perspective, the proper management of knowledge (such as R&D results) and intellectual property also raises further issues.

On the one hand, there is possibility to make the European intellectual property systems more responsive to the rapid evolution of both research processes and emerging technological areas. This calls for a number of R&D-related IPR questions to be tackled (e.g. the research exemption). In addition, special emphasis needs to be put on specific issues relevant for R&D collaborations and technology transfer between public research organisations and industry, as "Mediators" are an increasingly important way of enhancing the impact of scientific achievements on the European competitiveness.

On the other hand, actions are needed to promote the optimal use of intellectual property rights systems in Europe, by suitable awareness and training actions, with a special emphasis on academic institutions and small businesses.

6.2 Host and pathogen associated factors involved in development of Clostridium difficile infection

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C. difficile is currently one of the most important pathogens causing health care-associated infections. It is also increasingly documented as a community-associated disease and is being recognised as an important cause of enteric disease in animals. Most significantly, the incidence and severity of *C. difficile* infection (CDI) has shown a 30% increase in the historical average since 2003. Clinical outcomes can range from asymptomatic colonization to mild diarrhoea and more severe disease characterized by inflammatory lesions and pseudomembranes in the colon, toxic megacolon or bowel perforation, sepsis, shock, and death. The spectrum depends on host factors (immune response and gut microbiota) and bacterial virulence factors (toxins and additional virulence properties).

Two large protein toxins, toxin A (TcdA) and toxin B (TcdB) are the main virulence factors and contribute to the development of secretory diarrhoea and inflammation of colonic mucosa. Both toxins are cytotoxic destroy the intestinal epithelium and decrease colonic barrier function by disruption of the actin cytoskeleton and tight junctions resulting in a decreased transepithelial resistance allowing fluid accumulation. The role of the third toxin produced by *C. difficile*, binary toxin CDT in the development of human disease is not well understood. Additionally, some strains negative for all three known *C. difficile* toxins, but showing atypical cytopathic effect on cultured cells are currently studied in our group to define possible new toxic molecules in *C. difficile*.

In addition to both toxins other bacterial virulence factors such as sporulation, surface layer protein, other cell wall proteins and antibiotic resistance are of importance for the emergence of *C. difficile* strains with increased virulence potential that are associated with higher relapse rates, increased mortality, and increase severity of the disease.

Toxinogenic strains are found in asymptomatic carriers and in entire spectrum of disease severity. Therefore, in addition to bacterial virulence factors the host factors has to be involved in the the development of the disease. The role of the host immune response in CDI is just starting to be better understood and studies are focused mainly on toxin specific antibody response that is important in development of vaccines.

It has been known from the first descriptions of CDI that disturbance of normal intestinal microbiota is a prerequisite for successful colonization of *C. difficile* and hence the association of the infection with antibiotic therapy. In addition to bacterial microbiota that was so far described by others we study changes in bacterial, fungal and archaeal gut populations during *C. difficile* colonization in human and animal hosts.

Studies of virulence and host factors are contributing to the development of vaccines and new diagnostic methods.

LIVIMODE – LIght-based functional in VIvo MOnitoring of Diseases related Enzymes

Understanding the molecular processes in living cells during the formation and progression of diseases such as cancer, rheumatoid arthritis and osteoarthrosis is crucial for the development of new diagnostic tools and treatments. LIVIMODE (Light-based Functional In Vivo Monitoring of Disease-related Enzymes) is a European research consortium with scientists from universities, research organizations, and a global healthcare leader, sanofi-aventis. This consortium recently began operating.

LIVIMODE is developing novel powerful imaging agents which are intended for direct visualization and investigation of disease-related molecular processes in living cells and in diagnostic imaging. The LIVIMODE consortium focuses particularly on highly sensitive optical imaging methods which allow such direct visualization of specific molecular events in the living cell. Typical examples are disease-related enzyme activities. Such methods would allow earlier diagnosis and improved treatment of diseases.

Furthermore, the methods to be developed will be used to identify new targets for drug development such as particular enzymes or receptors on cell surfaces. If their role in diseases is known precisely, it is possible to search for molecules which act on the targets and consequently alleviate or even cure diseases. Once the targets can be tracked down unequivocally, their role in the cause and progression of disease can be explored. In this context, LIVIMODE will help to build important bridges between drug development in the test tube and that with living cells and organisms.

A total of ten research groups from seven countries are working together. The project is coordinated by Prof. Boris Turk, PhD from the Jozef Stefan Institute (Slovenia), whereas the other groups are from the University of Zurich (Switzerland), the Universitat Autonoma Barcelona (Spain), Imperial College London (England), the Freie Universität Berlin (Germany), the Commissariat à l'Énergie Atomique (France), the European Molecular Biology Laboratory Heidelberg (Germany) and the Centro de Investigacion Principe Felipe (Spain). Scientists from sanofi-aventis in Germany and in France, a leading global healthcare company, are the industrial partners in the LIVIMODE consortium. The European Union is providing LIVIMODE with a total of five million Euros of sponsorship over three years in the 7th Framework Program "Health 2009".

6.3 Extremophilic microorganisms - source of biotechnologically important proteins

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Extremophilic organisms are microorganisms that not only tolerate, but optimally grow in extreme environments that are markedly inhospitable for life of other organisms. In such environments they are exposed to high temperatures, extreme pH values, high pressures and salt concentrations. Its survival depends on macromolecules (proteins, nucleic acids, lipids), that unlike their mezophilic homologues retain the native structure and activity in such extreme environments. In recent years, extremophilic microorganisms became an interesting source of enzymes, among which many are of an industrial importance. Up to date we found that the proteases (pernizine) expressed extracellularly by A. pernix are capable to degrade protein aggregates, which cannot be degraded by protease K. The recombinant proteins can be successfully applied at higher temperatures for many biotechnological processes (for sterilization of surgical equipment in medicine and in the food-processing industry). After determining the complete sequence of the genome of many extremophiles (e.g. H. werneckii, W. ichthyophage) the number of the research on the field of proteomic has been increasing. The overview of the potential use of some proteins from halophilic yeast such Hal2 (determinant of halotolerance) and protein signal pathway HOG (response to increased salinity in the environment) will be presented. The knowledge of enzymatic activity and stability at higher salt concentrations and temperatures will contribute significantly to our understanding of their metabolic roles and regulation of their activities.

6.4 Perspective of integrated approaches in chemistry and biology of proteins: following destiny of proteins maturation and degradation

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With the turn of the millennium, a new era begun for biological sciences. The available genomes are providing the possibility to decipher physiological and pathological processes in the living organisms at the molecular level. From genomes we have learned that the complexity of life lies in organization. Now the time has come to grasp it with the novel tools and approaches. Within the last decade we are seeing a change in strategy from single task oriented research towards increasingly integrated approaches targeting numerous targets in parallel. There are two general approaches: 1.) identification of potential players by means of cell biology, proteomics, genetic modifications of the organism, 2.) expression of a number of proteins from an organism based on sequence and structural homology and try to propose their function with the help of their biochemical characterization. To pursue these aims in the Centre of excellence for Integrated approaches in Chemistry and Biology of Proteins we have joined our efforts and resources to purchase the up to date equipment for light microscopy, mass spectrometry, crystal structure determination, protein production and characterization and analysis, synthesis of organic compounds by means of biological as well as organic synthesis. With the current expertise and novel equipment our research is aiming at 3 different areas:

- Mechanisms and molecular interactions in immune response,
- Intra and inter-cellular communication,
- Adaption mechanisms of extremofiles to environment.

My research group interest is to reproduce the biological environment in vitro. In particular we aim at the mechanisms of immune response, where molecular mechanisms of endosomal antigen degradation and loading of MHC class II molecules are studied. Therefore, we are developing a high throughput technological platform for protein production and characterization. In these efforts we are exploiting the expertise and collaborate with the world leading groups in protein expression (MidWestCenter for structural genomics, USA; Welcome Trust Center for Human Genetics, Oxford University and Diamond. Oxford, UK) and structure determination – including collaborative efforts within the European Infrastructural Roadmap Program INSTRUCT, for which we hope that Slovenia will join in the future.

6.5 Fusion pore: An Evolutionary Invention of Eukaryotic Cells

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When nucleated cells evolved from a prokaryotic precursor 1000 to 2000 million years ago, this was associated with a cell volume increase by 3 to 4 orders in magnitude. The increased size dictated a new organizational make-up, since signalling and communication between cells and parts of cells could no longer be supported mainly by diffusion-based processes. For example, rapid communication between nucleated cells with chemical messengers appears to require secretory organelles which store concentrated amounts of signalling molecules. These get discharged swiftly and locally from membrane-bound vesicles following a trigger. The secretory organelle function is of particular interest since it consists of a process that exhibits, at least in neurons, one of the fastest biological reactions known. The aim of this presentation is to describe some of the recent views of the biological nano-machinery that regulates the release of signalling molecules from secretory organelles in pituitary cells and astrocytes, the most abundant cell type in the central nervous system.

To release stored molecules, membrane of secretory organelle fuses with the plasma membrane. This process is termed exocytosis and leads to the formation of a fusion pore, a water filled channel mediating the export of secretions. Given the critical role of compartmentalization in eukaryotic cells and that high energy barriers are involved in merger of biological membranes, it is perhaps not unexpected that the mechanism of membrane fusion appears to be highly conserved. Therefore, the use of in vitro model systems enables a more direct analysis of the nature of the single secretory organelle fusion with the plasma membrane. We have been studying endocrine anterior pituitary cells that are specialized in the release of hormones into the blood stream. Their function is essential for many important bodily functions including growth, development, reproductive behaviour, responses to stress. We are also studying astrocytes, which release gliotransmitters in the CNS. The advantage of these model systems is that it permits single vesicle studies by optical and electrophysiological techniques. For decades, it was thought that spontaneous and stimulated exocytosis exhibit similar properties at elementary level, differing only in the probability of occurrence. However, recent studies indicate that spontaneous exocytosis differs from the stimulated one in many respects. Perhaps the most interesting feature is that fusion pore may be an energetically stable structure, exhibiting subnanometre diameters at rest, too small to allow the exit of some signalling molecules, but can enlarge following stimulation. Moreover, fusion pore kinetics is subject of regulation as well. These properties raise questions of how the molecular machinery of the fusion pore of tens of nanometres mediates these functional changes.

6.6 Biosynthetic engineering for drug discovery and process development

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Structurally highly diverse secondary metabolites of polyketide origin possess a wealth of pharmacological effects, including antibacterial, antifungal, antiparasitic, anticancer and immunosuppressive activities. Many of these compounds and their semi-synthetic derivatives are widely used today in the clinic. The first complete gene cluster encoding the polyketide antibiotic actinorhodin was cloned already thirty years ago. The erythromycin gene cluster followed in 1990, and since then most of the gene clusters encoding commercially important drugs have been cloned, sequenced and their biosynthetic mechanisms studied in great detail. Recent advances in the area of biosynthetic engineering and synthetic biology of the enzymes involved in secondary metabolite biosynthesis in the last decade enables a significant progress in the fields and are now generating important novel drug-leads. The biosynthesis of a typical polyketide can be divided into three separate steps, including (i) choice of starter unit, (ii) the choice of extender units and the degree of beta-keto group reduction, and (iii) post-PKS tailoring of the basic polyketide backbone. Each of these steps represents a potential opportunity for the introduction of structural modification. The technologies to achieve this have now been highly developed and transferred

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Centre of Excellence Polymer Materials and Technologies – CoE PoliMaT – is a research consortium of 22 Slovenian partners. It successfully integrates the previously dispersed capacities of the leading Slovenian public research groups and successful small, medium and large enterprises in the field of polymer materials. Currently, CoE PoliMaT employs more than 80 top-level experts from higher education research institutions and industry, with a 50% female employment rate. The critical mass of scientific knowledge and expert staff as well as modern equipment is providing excellent conditions for leading edge research and development.

In pursuing the goal of developing innovative and commercially successful products, which support sustainable development and low-carbon society of the future, research is being carried out in four globally most current areas:

- technically advanced applications and energy,
- coatings and adhesives,
- renewable resources, degradation and stabilization,
- polymers for health care and medicine.

The area of technically advanced applications and energy is focused on the development of high-tech materials with high added value that will allow for radical innovations in certain technical applications. The emphasis is on nanocomposites and nano-organised materials that allow the achievement of specific properties.

In the area of Coatings and adhesives primary focus is given to the synthesis of functional polymers used in paints, coatings and adhesives. This area is of prime importance for the chemical industry. The emphasis is on the improved synthesis and the reduction of organic solvents in production as well as technological processes, final formulations, and water-based formulations for advanced applications.

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Renewable resources, degradation and stabilisation are topics dedicated to the implementation of renewable resources for polymer production, as well as to degradation processes and stabilisation of natural or modified natural materials.

The focus is on the biomass uses that include liquefaction and the modification and processing of products to serve as viable feedstocks for materials or fuels. A closely related emphasis is given to the study of degradation processes from the aspect of biomass transformation, biodegradation and preservation.

Polymers for healthcare and medicine are divided into the following main research directions: development of multifunctional materials for use in surgical care as well as faster post-operative treatment of superficial wounds, functional polymer surfaces with specific antithrombogenic properties for the manufacture of cardiovascular (vascular) implants, and biodegradable and biocompatible drug carriers, along with chromatographic macroporous polymeric materials for cleaning of biomacromolecules, such as peptides, proteins, viruses and DNA. Below, three research projects are presented in more detail.

7.1 Preparation and characterization of nano-to-submicrometer-sized ZnO particles and their incorporation into polymer matrices for different applications

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With recent climate changes and the thinning of the ozone layer, UV radiation dosage, including both UVB and UVA radiation, has greatly increased. Consequently, research has focused on the development of UV-protective materials such as UV-shielding transparent plates or glasses which can be made by incorporating suitable UV-absorbing materials into a transparent polymeric matrix. Such a material is zinc oxide, ZnO, which is environmentally friendly and represents one of the most technologically important and attractive semiconductor materials. The preferences in using ZnO in amorphous polymeric matrices are in its high transparency in visible spectral region as well as its efficient protection against UV radiation at the wavelengths up to 400 nm at very low contents, below 1%. Development of simple procedures for the production of transparent UV-protective nanocomposites still represents a great scientific challenge aiming at complete compatibility of ZnO nanoparticles with the polymeric matrix. Besides UV shielding properties, ZnO nanoparticles improve also thermal and mechanical properties.

In this contribution, the preparation (batch reactors and in the continuous segmented flow tubular reactor –SFTR)[1] of stable and non-agglomerated ZnO nano-to-submicrometer sized particles of different shapes (spherical, wires, needles, rods, etc.) and sizes with narrow particle size distribution will be presented. All experiments were performed in reactor at controlled temperature. The starting concentration of precursors, type of solvents, temperature, and pH influence the size and morphology of the final particles. The morphological and crystalline properties of the obtained solids were characterized by IR, XRD, SEM, TG and HRTEM. We will present the tentative growth mechanism of ZnO particles. It follows the "non-classical crystallization" concept as it was observed by the combining of the advance in-situ SAXS method and the ex-situ electron microscopy (FE-SEM and TEM). The mechanism predicts the self-assembling of nanobuilding units (5-10 nm) into larger microstructures with prompt crystallization as presented in Fig. 1. At the same time, the growth based on the direct attachment of ions from the solution also occurs in minor extension. Particle growth was also monitored indirectly via in-situ pH measurements.

ZnO nanoparticles of different sizes (from 20 to 200 nm in length) and morphologies (from nanorods to complex coral-like structures) were synthesized via a simple one-pot synthesis of refluxing an oversaturated solution of zinc acetylacetonate hydrate in 1-butanol, isobutanol and *tert*-butanol[2].

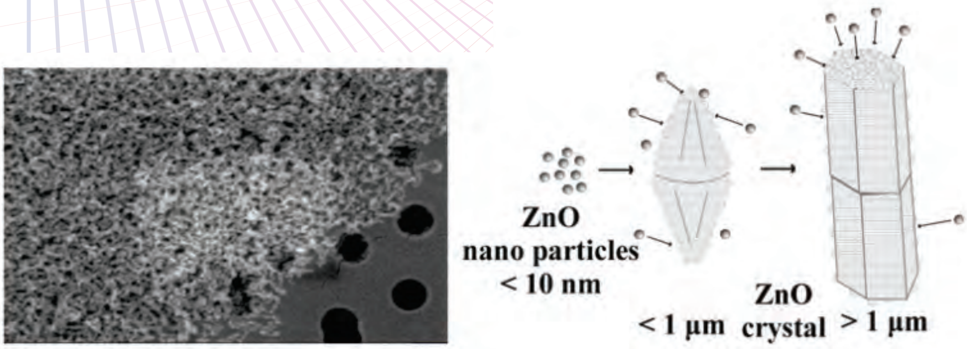

Fig. 1: FESEM micrograph of ZnO based particles with schematic description of ZnO growth mechanism.

We also studied the role of p-toluenesulfonic acid (p-TSA) as a catalyst and/or morphology-directing agent for the formation of ZnO particles in 1-butanol. The catalytic role of the p-TSA was pronounced when the p-TSA concentration was kept low, while an elevated acid concentration inhibits the reactivity of the ZnO precursor toward the alcoholysis, presumably due to the adhesion of the p-TSA on its surface. The abundance of ZnO surface chelation with the p-TSA controls the ZnO particle growth and shape as well as the self-assembly of ZnO nanocrystals into complex architectures.

The synthesized ZnO nanoparticles were further used for the preparation of polymer/inorganic-material-based nanocomposites. Most commonly, poly (methyl methacrylate) (PMMA) was used as the polymer phase due to its good transparency and other favourable physical and chemical properties. ZnO based/PMMA nanocomposites were tested for UV-shielding, thermal and other properties. We found that the presence of a very small quantity (0.04 wt. %) of ZnO based nanomaterial in the PMMA showed sufficient UV shielding (efficiently absorb UV light up to 370 nm) and at the same time good transparency in the visible-light region. According to TEM, homogeneous dispersion of ZnO particles in the amorphous PMMA matrix was achieved. Thermal stability of the ZnO/PMMA nanocomposites is considerably improved for particle sizes below 100 nm, even at very low ZnO contents, and increases with increasing ZnO content. The onset of ZnO/PMMA decomposition shifts for 20 - 40 °C to higher temperatures as compared to pure PMMA. The addition of low concentrations (0.05 - 0.1 wt.%) of nano ZnO enhanced the impact resistance of nanocomposites for 5 - 10% while higher concentrations (0.5 wt.%) of ZnO did not give additional improvement which was ascribed to intense particle aggregation[(3)].

References

[1] Orel, Z. C., Bitenc, M., Podbršček, P., Dubček, P., Bernstorff, S., Dražić, G., Orel B., Pejovnik, S. (2010). In and Ex Situ Studies of the Formation of Layered Microspherical Hydrozincite as Precursor for ZnO, *Chemistry-a European Journal,* 16: 11481-88.

[2] Ambrožič, G., Škapin, S. D., Žigon, M., Orel, Z. C. (2011). The Formation of Zinc Oxide Nanoparticles from Zinc Acetylacetonate Hydrate in tert-Butanol: a Comparative Mechanistic Study with Isomeric C4 Alcohols as the Media. *Mater. Res. Bull.*, in Press.

[3] Anžlovar, A., Kogej, K., Orel, Z. C., Žigon, M. (2011). Polyol mediated nano size zinc oxide and nanocomposites with poly(methyl methacrylate). *eXPRESS Polym. Lett.,* 5(7): 604-19.

7.2 Main trends in the wound dressings market and development

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The global advanced wound management market is forecast to exceed $12.3 billion by 2016, with a compound annual growth rate (CAGR) of 4.5% during the period 2009-2016 (Advanced Wound Care Management to 2016 - Increased Adoption of Advanced Wound Care for Chronic Wounds and Diabetes to Drive the Market published by GBI Research in February, 2011). The advanced wound management market is expected to be primarily driven by an increase in incidence of chronic wounds, a growing elderly population across the globe and greater adoption of technological advancements by surgeons and patients. In 2010, there were approximately 11 million venous ulcers, 11.3 million diabetic ulcers and 5.2 million pressure ulcers in the world requiring treatment which will provide ample opportunities for advanced wound management products to penetrate into the market. The growth is being driven by advancement in technology and products that are more clinically efficient and cost effective than their conventional counterparts. As technology advances, clinicians gain the ability to select dressings that simplify the selection process by providing multiple features and benefits. These products take less time to heal wounds when compared with low cost traditional wound care products, thereby reducing the hospital and healthcare professional's bills, which account for a substantial portion of the total patient billing.

A big part of the costs emerge on the account of improper care in various health-care related areas as a consequence of avoidable and unavoidable circumstances. The field of providing the most room for improvement is the wound care, where several technological drawbacks lower the success rate of the healing process. Recent recession contributed to the common awareness of the extremely high treatment costs, especially in relation to the care of chronic wounds.

Many improvements have already been made in the field of wound dressing preparation, like the use of more stable and biocompatible materials, inclusion of intelligent drug delivery system into the dressing to allow for more efficient delivery and the use of different diagnostical tools to follow the ongoing healing process. Additional improvement as modern treatment shows a tendency toward one single wound dressing, which would be at the same time more effective, multifunctional (assuring the perfect conditions for efficient healing – hydrophilicity, pH and ionic etc.), it would enable controlled and intelligent (triggered by external stimuli) delivery of desired drugs and all this at a lowered changing frequency. Such requirements for a single product demand state-of-the-art materials and knowledge to be employed, making an interdisciplinary consortium a necessary basis for such development.

We, therefore, focus on the preparation of a multilayered - multifunctional wound dressing. Such a system will exhibit several characteristics, which will exceedingly contribute to the much needed improvement and to a much more cost/efficiency ratio in the field of wound care. It will allow the following functionalities and characteristics:

- bio-compatibility,
- novel safe bio-compatible, -degradable and –available materials,
- inert synthetic surface (specially treated materials' outer surface will exclude possible unwanted skin reactions/irritations, lowering the possible accompanied pain experienced by the patient),

- super-hydrophilicity (will be obtained by plasma treatment; it will provide an optimal environment for a successful healing process and sufficient ion transport,),
- safe antimicrobial activity (several novel approaches will be developed which will supply the wound dressing a safe antimicrobial activity),
- controlled binding and release of drugs (control over the binding process will be achieved by novel and rationalized binding concepts),
- in-vitro evaluation of the new wound dressing.

References

[1] Stana-Kleinschek, K., Peršin, Z., Maver, T. (2011). Modification of non-woven cellulose for medical applications using non-equlibrium gassious plasma = Modifikacija celuloznih kopren, uporabnih v medicinske namene, z neravnovesno plinsko plazmo. *Mater. tehnol.*, 45(3): 253-57.

[2] Maver, U., Maver, T., Žinidaršič, A., Peršin, Z., Gaberšček, M., Stana-Kleinschek, K. (2011). Use of AFM force spectroscopy for assessment of polymer response to conditions similar to the wound, during healing = Uporaba AFM-spektroskopije sil za spremljanje odziva polimernih molekul na v rani podobna okolja med celjenjem. *Mater. tehnol.*, 45(3): 259-63.

[3] Peršin, Z., Stenius, P., Stana-Kleinschek, K. (2011). Estimation of the surface energy of chemically and oxygen plasma-treated regenerated cellulosic fabrics using various calculation models. *Tex. res. j.*, Published online June 15, 2011.

7.3 Biomass waste – a source of raw materials and energy

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Biomass represents an immense and renewable source for the production of bio-fuels and valuable chemicals. A little amount of this is used in industry and the remaining is leftover in huge quantities. Agricultural crop residues, such as straw, corn stover, wood and wood wastes such as leftovers from timber cutting, broken furniture, sawdust, residues from paper mills etc. contain appreciable quantities of cellulose, hemicelluloses and lignin. A town with 350.000 inhabitants generates 5.700 tons of different wood waste materials per year, mainly broken furniture and packaging materials. Besides that, 2.300 tons of forest residues are deposited, manly tree branches, bark and larger pieces of timber. Much effort has been devoted to converting these

One of the main practical values of our research is the utilization of the liquefied lignocellulosic materials in adhesives for the wood particle boards, veneer boards and plywood boards. By measuring the mechanical properties of selected particle boards and by measuring the formaldehyde release, it was found that even a 50% addition of the liquefied wood met the European standard quality demands for particle boards. Formaldehyde release was lower than 3mg/100g in all experiments due to the positive influence of the liquefied wood components. It can be concluded that the products of the liquefied lignin with their aromatic character behaved as a formaldehyde scavenger. Lower formaldehyde emissions from particle boards due to the use of the liquefied wood, are extremely important in the provision of better quality of life. Such adhesives have been used at lower pressing temperature, thus, reducing the energy consumption. Practical examples will be given with resulting formaldehyde concentrations and mechanical and physical properties.

Special attention was given to the utilization of the liquefied lignocellulosic materials as a new energy source with high heating value. Most of liquefied products have a heating value higher than 22 MJ/kg, that is in the range of pure ethanol and higher than brown coal. Initial tests have indicated that these products could also be used as a motor fuel. Since the production of such liquid fuel utilizes a huge variety of lignocellulosic wastes and takes place under very mild reaction conditions, an overall energy output is high. Several possible applications in energy production were identified and explored by our group.

The utilization of liquefied lignocellulosic materials can at least partially reduce the crude oil consumption, thus increasing the use of the renewable resources to a large extent.

References

[1] Kunaver, M., Jasiukaityte, E., Čuk, N., Medved, S. (2011). Biomass waste - a source of raw materials and new energy source. V: World Renewable Energy Congress 2011 - Sweden, Linköping 8-13 May 2011.

[2] Čuk, N., Kunaver, M., Medved, S. (2011). Properties of particleboards made by using an adhesive with added liquefied wood = Lastnosti ivernih plošč, izdelanih z uporabo lepila z dodanim utekočinjenim lesom. *Mater. tehnol.*, 45(3): 241-45.

[3] Kunaver, M., Medved, S., Čuk, N., Jasiukaityte, E., Poljanšek, I., Strnad, T. (2010). Application of liquefied wood as a new particle board adhesive system. *Bioresour. technol.*, 101(4): 1361-68.

8. Centre of Excellence NAMASTE: Advanced Materials and Technologies for the Future

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Overview

CoE NAMASTE is a multi-disciplinary and trans-disciplinary consortium of research institutions and industry who decided to merge academic, technological and business expertise, skills, and equipment in order to foster crucial technological progress in selected areas relating to inorganic non-metallic materials and their application in electronics, optoelectronics, photonics, and medicine. This should lead to a substantial increase in added value, research relevance and scientific excellence.

The strategic goals of CoE NAMASTE are: continuity in research excellence, multidisciplinary interconnection, knowledge dissemination and technology transfer. Maintaining and constantly upgrading our excellence in research, technology and business is an important guideline.

The research in the Centre is conducted within six projects, which are briefly described as:

RRP1: Ceramic 2D and 3D structures,
RRP2: Materials for overvoltage and EM protection,
RRP3: Materials, micro- and nano-systems for sensors,
RRP4: Soft composites for optical, electronic, photonic and sensor applications,
RRP5: Bioactive, biocompatible and bioinert materials,
RRP6: Project of new opportunities, which allows the inclusion of new partners.
All the projects are carried out with partners from the business/private sector.

Partners and synergies

There is a history of successful collaboration between most partners and various research groups. The new projects were, therefore, designed on the basis of good experience and confidence (the former CoE Materials for Electronics of Future Generations and Other Emerging Technologies was ranked among the top 5% in Europe, as recognized by the foreign reviewer).

The members are:

3 research institutions with 11 research groups:

- Institute "Jožef Stefan" (Electronic Ceramics Department, IJS-K5; Department for Nanostructured Materials, IJS-K7; Condensed Matter Physics Department, IJS-F5; Engineering Ceramics department, IJS-K6);
- University of Ljubljana (Faculty of Electric Engineering, UL-FE with Laboratory for Microelectronics, LMFE and Laboratory for Microsensor Structures and Electronics, LMSE; Faculty of Mathematics and Physics, UL-FMF; Biotechnical Faculty, UL-BF; Veterinary Faculty, UL-VF; Faculty of Medicine, UL-MF, Faculty for Chemistry and Chemical Technology, UL-FKKT);
- University of Maribor (Faculty for Chemistry and Chemical Technology, UM-FKKT).

3 non-profit organizations:

- HIPOT- R&D Research and Development in Technologies and Systems;
- NANOTESLA INSTITUTE - R&D Center for Nanotechnologies in the Field of Magnetic Materials and Composites;
- TC SEMTO Development Center for Circuits, Components, Materials, Technologies and Equipment for Electrotechnics.

3 large companies and 10 SMEs:

- ISKRAEMECO Energy Measurements and Management, d.d.;
- ISKRA AVTOELEKTRIKA, d.d.;
- ETI Electroelement d.d.;
- ISKRA TELA d.o.o.;
- HYB Production of Hybrid Circuits;
- KEKON Ceramic Capacitors, d.o.o.;
- KEKO Equipment d.o.o;
- VARSI d.o.o. Varistor Manufacturer;
- ISKRA ZAŠČITE d.o.o. Surge Voltage Protection Systems, Engineering and Cooperation;
- KOLEKTOR MAGMA Magnetic and Nanomaterials d.o.o.,
- BALDER d.o.o., Optoelectronic Elements and Measuring Systems;
- PANVITA d.o.o.;
- NANOTUL d.o.o.

Fig. 1: The locations of the partners of CoE NAMASTE are shown on the map

The main criteria in selecting our partners were:

1. Connecting various research fields, companies, regions,
2. Scientific-technological-business excellence.

The research programmes of CoE NAMASTE are led in a variety of research areas, such as Solid State, Soft Matter, Biophysics, Photonics, Zoology and Zoophysiology, Chemistry, Biochemistry and Molecular Biology, Chemical Engineering, Inorganic Non-Metallic Materials, Electronic Components & Technologies, Materials for Electronic Components, Textiles and Technical Fibres, Microbiology and Immunology, and Health protection - food animal sources.

There are many possibilities for synergy between the projects. One of the main goals of our operation is to work in interdisciplinary teams, share and transfer knowledge and learn from each other. The funding of the CoE represents a small fraction of the overall required financing for research in the areas where the academic and research partners have traditionally cooperated with the industrial partners. The majority of the projects are financed from other sources, yet additional financing from the centre offers access to a new and better infrastructure for the partners from industry and private research institutions, as well as working in interdisciplinary teams; that was also one of the important reasons why we were able to attract 16 non-academic partners to the centre. This additional funding helps the interdisciplinary groups to achieve more and to develop top expertise with the instrumentation and techniques.

The implementation of new R&D equipment is of extreme importance to the centre, since it makes it possible to maintain research and technological excellence. The collaboration in the CoE will help partners to solve specific problems – the CoE is creating the opportunity to do something more and something extra. As a result of the CoE, even the collaboration between industrial partners is gaining a new dimension. In order to establish new co-operations with the partners in the consortium it was essential to establish a new infrastructure, enabling new possibilities and developments. It is important to emphasize that the equipment is located at research institutions as well as in the facilities of our partners. The specific research infrastructure has nearly been established as proposed. Overall, more than 90% (in terms of value) of the planned equipment has been installed or ordered by Q3 of 2011; we expect to have the remaining equipment ordered by the end of 2011. On average, the percentage of use for the existing equipment has been increased by between 20 and 25%. For the new equipment, the usage varies between 50% and 90% so far. The list of equipment is provided on our website: http://www.conamaste.si.

The results of our common activities are well acknowledged in the international environment, since the members of the CoE have so far produced in collaboration with their partners some major breakthroughs in the scientific and innovation fields, which are represented by numerous scientific papers, patents, patent applications, innovations, prototypes and demonstration projects. We will emphasize some of the most important results here.

Some important achievements

The partners in the Project RRP1: Ceramic 2D and 3D structures are: Electronics Ceramics Department IJS-K5, Faculty for Chemistry and Chemical Technology, UL-FKKT, Hyb, HIPOT-R&D, Kekon, KEKO-Equipment. They are organized in a value chain consisting of ceramic-tape technology, equipment development and component design and development in the field of ceramic microsystems based on low-temperature co-fired ceramic (LTCC) technology. This new application of LTCC technology requires innovative research activities on materials, device architecture, design, electronics, technology, fabrication, and the characterization of materials and devices. The key research activities are carried out in the project RRP1.

The important technical achievements at the industrial partners are:

- fabrication and integration of functional and secondary materials into 3D ceramic structures,
- know-how on the design of ceramic-based pressure sensors within a very wide pressure range (from 0-100 mbars up to 0-100 bars),
- development of application-specific multilayer ceramic devices,
- development of various LTCC-based pressure sensors,
- enhanced reputation of the companies on the market.

As an example, for the innovation in Project RRP1: Ceramic 2D and 3D structures, the processing of a large membrane on a buried cavity with a large aspect ratio for sensor applications a PATENT APPLICATION has been filed. (the process of manufacturing cavities in ceramic multilayer structures, Appl. No. P-201100202).

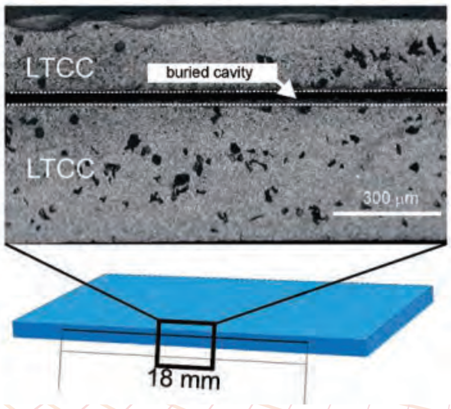

Fig. 2: Buried cavity processed by low-temperature co-firing

Large membranes in the LTCC structure are important for the realization of very sensitive pressure sensors. To avoid any deformation of the LTCC during processing a new temporary material was used in the cavity for the production of the large membrane. The new material does not react with the LTCC material at the processing temperature and allows very simple removal by chemical etching. The LTCC membrane with a diameter of 18 mm has been realized over the cavity of only 35 micrometers in height, as presented in Figure 2 above.

The partners in Project RRP2: Materials for overvoltage and EM protection are: Department for Nanostructure Materials, IJS-K7, Faculty for Chemistry and Chemical Technology, UM-FKKT, Varsi, Iskra Zaščite, Kolektor Magma, Nanotesla Institute. The project is aimed at ensuring the undisturbed use of electric and electronic equipment, enabling protection against transient surges or overvoltages and electromagnetic radiation.

ZnO varistors are well known surge protective elements, yet the dopants needed are not environmentally friendly. The discovery of researchers from IJS that inversion boundaries (IBs) have key influence on the grain-growth and microstructure development in ZnO-based ceramics, while the role of secondary phases (spinel phase) is subordinated, enabled the development of low doped material for ZnO varistors. Grains with IB preferentially grow on expanse of normal grains and finally completely prevail in the microstructure (N. Daneu, A. Rečnik, S. Bernik, Grain-growth phenomena in ZnO ceramics in the presence of inversion boundaries, J. Am. Ceram. Soc., 94 (5), (2011), 1619-1626). With very low amount of dopant, such as Sb_2O_3, that triggers the formation of inversion boundaries, the amount of grains infected with IBs can be influenced, which enables preparation of either coarse or fine-grained ZnO ceramics, as presented on Fig.3.

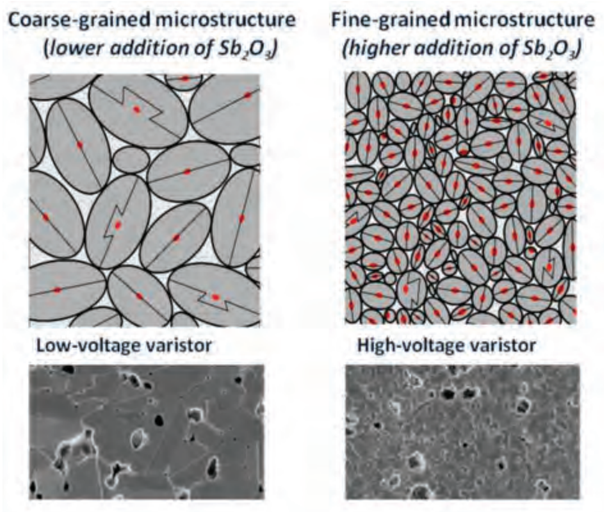

Fig. 3: Microstructure development controlled by the inversion boundaries (IBs) induced grain growth mechanism enable preparations of coarse- or fine-grained ZnO-based ceramics and hence either low- or high-voltage varistors

Low-doped varistor ceramics containing only 3 – 4 wt.% of varistor dopants added to ZnO (nowadays typical additions are 7 – 10 wt.%) with break-down voltages in the range from 60 to 350V/mm, high coefficient of nonlinearity in the range from 35 to 55 and low leakage current < 1•A were developed (fig. 4). Such varistor ceramics have minimal amount of secondary phases at the grain boundaries and hence significantly enhanced effective contact among conducting ZnO grains, which are separated only by boundaries with high current-voltage (I-U) nonlinearity. As a result, the I-U and energy characteristics of various types of low, medium and high voltage varistors can be improved. Significantly reduced amount of varistor dopants (oxides of Bi, Sb, Co, Mn, Ni, Cr) results also in lower production costs and ecological benefits.

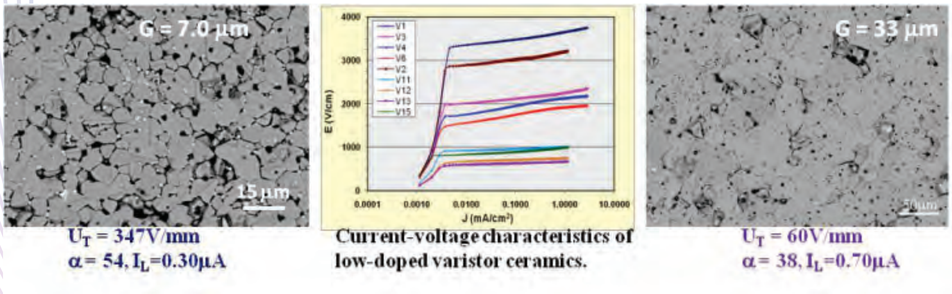

Fig. 4: The current-voltage (I-U) characteristics of low-doped varistor ceramics having broad range of break-down voltages and typical microstructures with minimum amounts of secondary phases of high-voltage varistor (left) and low-voltage varistor (right)

The long-term collaboration between the research group from the IJS and the R&D group from Varsi resulted in the development of special ZnO varistors with long-term stability of the leakage current under DC voltage and severe environmental conditions in the field of photovoltaic systems and windmill applications – the characteristics are presented in Fig. 5.

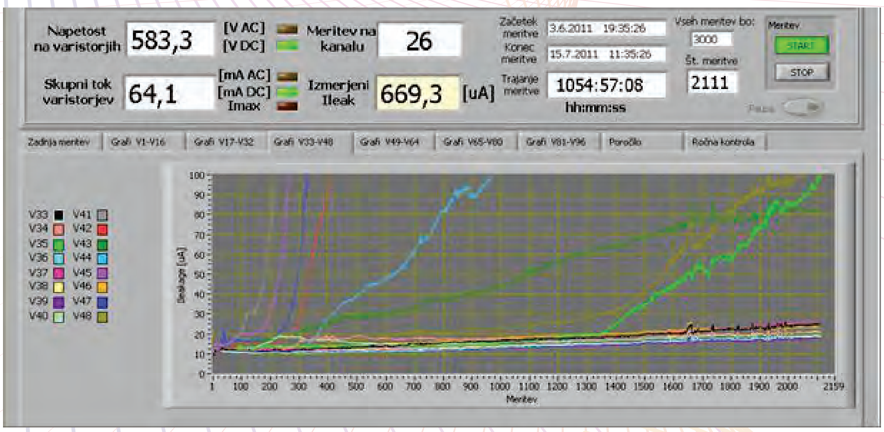

Fig. 5: Leakage current: comparison of the stability between non-stable and highly stable ZnO varistors

Electromagnetic absorbing material for use in architect coatings were developed by our partner the Nanotesla institute: The everyday use of different devices/wireless-technology results in electromagnetic radiation and, consequently, the level of electromagnetic radiation is continuously increasing. The European Pre-standard ENV 50166-2:1995 – Human exposure to electromagnetic fields – High frequency states that electromagnetic fields interact with the human body and other systems through a number of physical mechanisms. Therefore, the need to protect people or devices from harm and to keep something from being detected by other instruments is focusing attention on the development of novel EM-waves absorption materials. Electromagnetic protection coatings are interactive responsive coatings and can offer advances in coatings such as absorbing electromagnetic waves and creating a level of protection from radiation. A resin compact containing ferrite powders can be used as an electromagnetic wave absorber in the frequency range from 400 kHz up to 2 GHz.

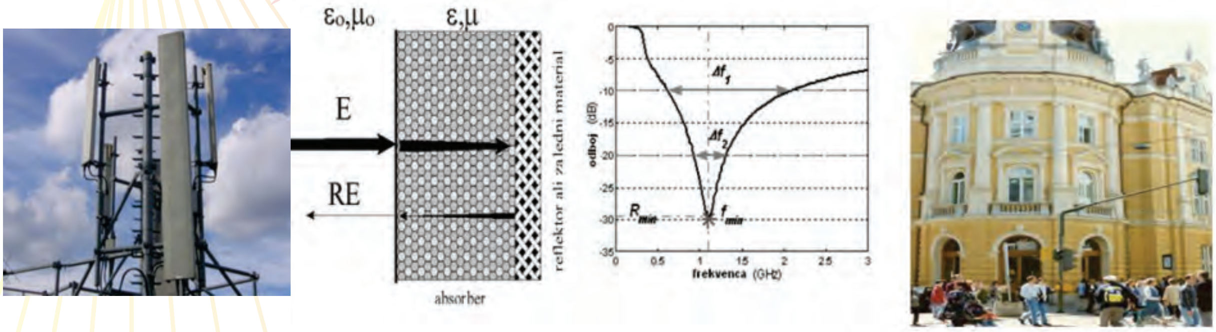

Fig. 6: Demonstration of the effect of an electromagnetic absorbing material, added to an architect coating - the graph shows the reduction of harmful EM radiation in the building, using the new material architect coating

The partners in Project RRP3: Materials, micro- and nano- systems for sensors_are: Laboratory for Microelectronics, LMFE and Laboratory for Microsensor Structures and Electronics, LMSE; Iskra Avtoelektrika, Iskra TELA, Iskraemeco.

As an example of successful cooperation between some partners in the past, the last of these partners successfully applies a new integrated circuit as a core metrology building block for a new family of watt-hour meters. The expected quantities of integrated circuits are 1 million pieces per year for the next 5-10 years.

A new cutting-edge technology is being developed in the field of surveillance systems, for example, there have been achievements in the THz field. As a result of the co-financing of CO NAMASTE within the Project RRP3: Materials, micro- and nano- systems for sensors, the Ti microbolometer has been designed and manufactured as a crucial building block for a surveillance system designed for THz radiation monitoring. Radiation in the THz range (between the micro and millimeter range) is not invasive for living organisms. It penetrates fabric and other shielding materials; it can therefore be employed in all spectra that are applied for the protection of people and cargo. The microbolometre presents a very crucial element in the matrix of scanning the scene at a frequency of 300 GHz (1mm wavelength). It operates at room temperature and its noise-equivalent figure exceeds by an order of magnitude the best published results. When presented to the THz expert community, it was declared to be a "world champion".

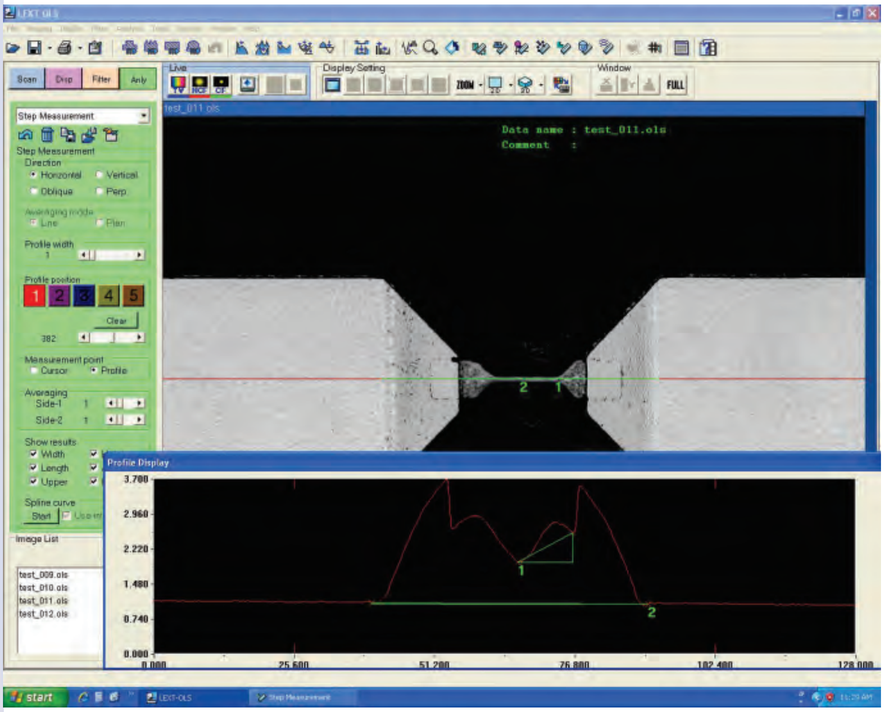

Fig. 7: Picture of Ti microbolometre showing the 3D measurements of the cross-section dimensions.

The partners in the Project RRP4: Soft composites for optical, electronic, photonic, and sensor applications are: Condensed Matter Physics Department, IJS-F5, Faculty of Mathematics and Physics, UL-FMF, Balder and Nanotul. Several major breakthroughs (published in the most prestigious journals) were noted in the project RRP4. Here we select four of them.

Knots and Links (published in Science)

The journal Science published, on July 1 2011, a scientific manuscript entitled "Reconfigurable Knots and Links in Chiral Nematic Colloids", from Jožef Stefan Institute and Faculty of Mathematics and Physics, University of Ljubljana (http://www.sciencemag.org/content/333/6038/62.abstract).

Researchers show that topological defect lines in a liquid crystal may become tangled and form knots sporadically, or by forcing liquid crystal molecules into a certain state by laser tweezers. This action forces defect lines to form loops around particles, like rope encircling a ball. Using laser tweezers the team tied the lines into knotted systems – nematic braids of chosen complexity. The formation of these stable braided structures is enabled by using a nematic cell similar to that commonly used in liquid crystal display technology. The findings could pave the way for the development of complex structures for novel devices in the field of photonics.

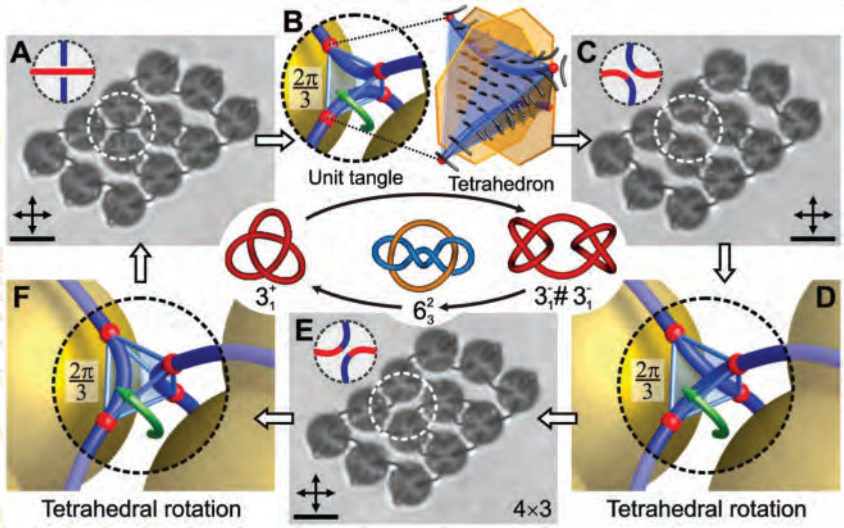

Fig. 8: The mechanism of forming knots and links via tetrahedral rotation (Fig. 9 from the paper)

Science: (http://www.sciencemag.org/content/333/6038/46.summary) In the same issue of the Science journal the paper is highlighted with a Science Perspectives Commentary "Knot Your Simple Defect Lines?" written by Professor Randall Kamien from University of Pennsylvania (USA), one of the world-leading experts in the field of the topology of soft matter. Only few papers in an issue are highlighted so that this clearly indicates the great impact of Slovenian scientists in this research field. Soft Matter World Newsletter: Report on the paper can be the find the August newsletter:
http://www.softmatterworld.org/archives/newsletter_pdfs/SMWNewsletter32_August2011.pdf.

Nature Materials: Short commentary is published in August issue on research highlights page (http://www.nature.com/nmat/journal/v10/n8/index.html#rhighlts).
Photonics.com web site published news describing the main achievements of the paper http://www.photonics.com/Article.aspx?AID=47609.
Delo July 21 on pages Znanje in Razvoj:
http://www.delo.si/arhiv/tiskanocs/Delo/2011/0721/18.

Skyrmion lattices in a chiral nematic liquid crystal

In the journal Nature Communications the paper "*Quasi-two-dimensional Skyrmion lattices in a chiral nematic liquid crystal*" was published on March 22 2011. Skyrmions are particle-like topological entities in a continuous field that have an important role in various condensed matter systems, including two-dimensional electron gases exhibiting the quantum Hall effect, chiral ferromagnets and Bose–Einstein condensates. Here we show theoretically, with the aid of numerical methods, that a highly chiral nematic liquid crystal can accommodate a quasi-two-dimensional Skyrmion lattice as a thermodynamically stable state, when it is confined to a thin film between two parallel surfaces imposing normal alignment. A chiral nematic liquid crystal film can thus serve as a model Skyrmion system, allowing direct investigation of their structural properties by a variety of optical techniques at room temperatures that are less demanding than Skyrmion systems discussed previously.

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Quasi-two-dimensional Skyrmion lattices in a chiral nematic liquid crystal

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NATURE COMMUNICATIONS | 2:246 | DOI: 10.1038/ncomms1250 | www.nature.com/naturecommunications 1

3D microlaser (FIRST IN THE WORLD): The first 3D microlaser based on liquid crystals to be developed was demonstrated in December 2010. It is a dye-type microlaser in the form of a microdroplet of a liquid crystal doped with a fluorescent dye, and dispersed in a liquid medium, that does not mix with the liquid crystal. Because of its nature, the liquid crystal self-organizes inside the microdroplet in the form of concentric shells with different optical properties, thus forming an optical microresonator. When illuminated with external light, the fluorescent molecules emit light, which is back-reflected from the concentric optical shells. This results in increased spontaneous emission and lasing. The microlaser emits light uniformly in 3D, and is the first laser of its kind ever developed. We expect that these microlasers will be used as a light source in holography, but more importantly, we explore their application in photonic microcircuits, where the flow of electricity will be replaced by the flow of light.

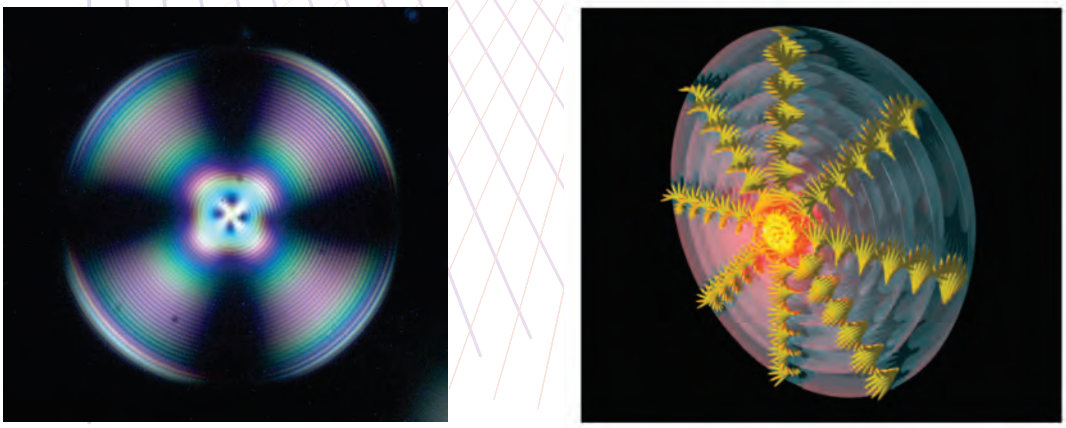

Fig. 9: Lasing droplet and an artist´s representation of the polarization (Fig.10 in the manuscript)

When the paper which describes the structure and properties of this novel 3D microlaser was published in Optics Express, the Optical Society of America (OSA), which is the world's most important optical society, published a press release on December 8 2010 describing the significance and importance of this work

(http://www.osa.org/About_Osa/Newsroom/News_Releases/Releases/12.2010/Microlaser3D.aspx).

According to OSA, this press release has reached more than 35 million readers across the world. The key word "First 3D microlaser" now has more than 250 000 Google hits. A tremendous number of comments were recently published on this topic. Here, we specifically mention only the view that appeared in Nature Photonics: News and Views: Liquid crystals: Tiny tuneable 3D lasers by Rachel Won

(http://www.nature.com/nphoton/journal/v5/n3/full/nphoton.2011.27.html).

Another breakthrough within this project is noticeable in the field of the ISO expert group: Participation in the International Standard Organization (ISO) expert group – preparation of the International (ISO) standard "Occupational Eye and Face Protection" - International Standard Organization (ISO) invited IJS F-5 and Balder Ltd, Partners of Center of Excellence NAMASTE to participate in the ISO expert group (ISO/TC94/SC6/WG2 in WG4) preparing of the new ISO Standard: "Occupational eye and face protection". The invitation was based on the recent research results and technological achievements in the field of light-intensity modulation by LC light shutters and their application in the field of personal protection (protective welding helmets, etc.).

Fluorescence microspectroscopy – tracking nanoparticles in live cells is one of the important themes of Project RRP5: Bioactive, biocompatible and bioinert materials. The partners in the Project RRP5 are: Condensed Matter Physics Department IJS-F5, Engineering Ceramics department IJS-K6, Biotechnical Faculty, UL-BF; Veterinary Faculty, Nanotul, and Panvita. The continuously growing number of new discoveries in the field of nanomaterials opened one striking new dilemma, namely how safe these systems are when we do not control their location and they diffuse into our environment. Sooner or later they enter our bodies. But how do they interact with our cells? According to the properties of their macroscopic analogue materials, they should be more or less inert. But are they really inert?

There have been many attempts to answer this simple and at the same time complex question. From the experimental point of view, this is far from being simple to answer. Why? Because one needs to identify and localize these very small particles in the environment of a living cell. On the one hand, detection is difficult due to the small size of the nanomaterial, which calls for methods of high spatial resolution in localization, which is usually enabled by high-energy light or particle beam (X-ray methods and electron microscopy). On the other hand, the detection is difficult due to the conditions of the living cells, meaning no vacuum, water systems, osmotically balanced conditions, low flow, physiological pressure and temperature, etc. These conditions can be fulfilled almost exclusively by optical microscopies. At first glance, it seems almost impossible to solve this puzzle.

The solution, however, comes through the coupling of optical microscopy and spectroscopy, both based on fluorescence phenomena. The former enables the localization within the cell with a resolution still much better than the cell-organelle size, and the latter solves the problem of identification, since the fluorophore light can be made specifically to identify its location by distinguishing specific and nonspecific binding. Altogether, nanoparticle tracking has therefore been realized through fluorescence microspectroscopy, as shown in the picture below. The spectroscopic analysis in terms of spectral maximum nicely resolves the source of the fluorescence light, whether this comes from membrane, particle aggregates or mono particles, which is not possible in the case of standard fluorescence microscopy, due to the application of broadband filters.

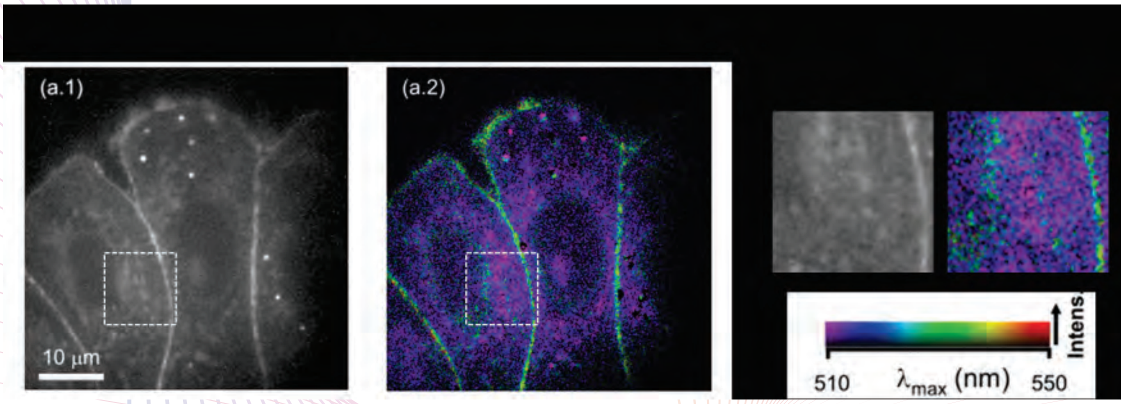

Fig. 10: Fluorescence image (a.1), spectrally-contrasted image (a.2) and enlarged parts of the two images (right) of nanoparticles in cells. The improvement of the basic setup of fluorescence microspectropscopy system has been financed through the CO NAMASTE in the project RRP5

The partners in Project RRP6: Project of new opportunities, which allows the inclusion of new partners, are: Electronic Ceramics Department, IJS-K5; Condensed Matter Physics Department, IJS-F5; ETI Elektroelement and TC SEMTO.

Technological Centre SEMTO is the initiator of Virtual electromagnetic compatibility (EMC) lab project: The properties of materials, being developed in CoE NAMASTE for various special applications, such as sensors, protective elements, actuators and others, need to be carefully designed. The process of the integration of materials with elements and products is clearly defined. The requirements for electromagnetic compatibility, robustness and safety have to be taken into consideration in order to achieve the optimal results. Predefined values in the fields of electromagnetic compatibility for elements, parts and products can be achieved by the targeted research and development of materials.

The project of establishing a Virtual electromagnetic compatibility lab project will improve the environment for measurements and/or tests and enhance problem-solving skills by connecting the knowledge, equipment and procedures in the field of EMC. The aim of the project is to provide a database with measurements and the capabilities of all the leading laboratories in the fields of EMC and security, enabling access to potential users. The information on the availability and utilization of equipment, measurement procedures, various security tests and the capacity of measurements will be provided. Additional information on a certain laboratory would be enriched by user experiences and their problem-solving skills. Thus, by sharing their knowledge the end-users will be able to solve their problems more effectively. The electrocaloric effect has become popular again in the past two years due to its importance for applications in cooling and heating new-generation systems. A research group studying electrocalorics has just been established.

Dissemination of knowledge, ecology

CoE NAMASTE has organized or co-organized 21 events up until July 2011, such as strategic conferences, seminars, international and domestic conferences, presentation conferences for partners exploring new ideas for development, an invited lecture in the Slovenian Parliament by the CoE Director.

The dissemination of knowledge – in particular teaching and lecturing – is an important activity. More than 40 invited researchers and lecturers have visited the centre, there are 24 lecturers and 20 mentors of higher-education programs among the participating researchers in the CoE and the CoE's researchers have been invited to lecture at and chair international conferences and scientific meetings. As a result of the international activity of CoE NAMASTE we produced 41 scientific publications integrating foreign partners (6 affiliated CO NAMASTE). The CoE researchers are successfully integrated into 32 international projects and they published 19 papers (3 affiliated CO NAMASTE) in collaboration with industrial partners. By developing new technologies the CoE contributes to the reduced consumption of energy. For example, LTCC ceramic materials enable firing at substantially lower temperatures, which helps to reducing greenhouse-gas emissions, the use of soft composite materials will reduce the amount of energy for the operation of new devices, the development of varistor ceramics and varistors for dc applications in the surge protection of energy systems based on renewable sources (photovoltaic systems, solar power plants, wind turbine generators).

Conclusion

The partners are strongly committed to reaching the strategic goals of CoE NAMASTE. As already mentioned, we are working closely with the consortium members. We also work with other CoEs in order to promote the exchange of good practices, creating and transferring new knowledge in scientific research as well as in technology. We believe that the maintaining and upgrading of research–technology–business excellence is key in major breakthroughs in creating high-value-added products for a successful economy in the future. In summary, we are proud of the results of the research and development teams which have proven their scientific excellence and ability to innovate in a variety of areas, such as:

- large aspect ratio of the dimensions of a buried cavity, which will make possible the fabrication of highly sensitive ceramic membranes;
- new developments in materials for low-doped ZnO varistors for high-voltage protection and prototypes for electromagnetic radiation protection;
- being "world champions" in THz field detection;
- being first in the world to create a 3D microlaser;
- being the leader in studying phenomena in chiral nematic liquid crystals;
- developing new methods for investigating the interaction between nanomaterials and living cells.

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