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Naložba v vašo prihodnost
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Mid-term Evaluation of the Centre of Excellence Advanced Materials and Technologies for the Future (CoE NAMASTE)

1. Introduction

The midterm evaluation included both the assessment of the documentation provided by the Centre of Excellence (CoE) on their achievements during the first period of operation, as well as a site visit to discuss these achievements and any other aspects of the midterm evaluation, and to obtain an impression of the premises and the laboratories of the CoE.

A standardised self-assessment form was prepared and distributed by the evaluator before the site visit, and the answers to this self-assessment were evaluated before the site visit.
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Also, an overview of the numeric indicators for the midterm assessment of the CoEs was provided by the MVZT of the Republic of Slovenia, supporting the evaluators in their work.

The site visit of CoE NAMASTE took place on July 20, 2011 and the entire day was spent at the Department of Electronic Ceramics (KS) at the Institute "Jozef Stefan" in Ljubljana, with several extended visits to the laboratories of this and the other involved departments at US where current experimental set-ups were demonstrated and time was allocated to the discussion with the group leaders and principal investigators of the individual tasks.

The site visit was prepared by the Managing Director of the CoE, Dr. Alenka Rozaj, and Prof. Dr. Marija Kosec, Director of the CoE NAMASTE, gave the introductory presentation and led through the programme of the site visit with presentations from all individual work package leaders. During and following the presentations, discussions on the achievements of the individual work packages were led.

The evaluation presented in this report combines the information obtained by the evaluator in both, the self-assessment by the CoE, the data provided by the MVZT, and the actual site visit.

2. Scientific and technological excellence and quality of the consortium

The CoE NAMASTE (Napredni nekovinski materiali s tehnologijami prihodnosti / Advanced Non-Metal Materials with Technologies of the Future) is a consortium of ten research groups in the areas of materials, physics, chemistry, electronics, medicine, biology and veterinary science made up from the two major Siovenian universities, the Jozef Stefan Institute, three non-profit organisations, three large companies, eight small and medium-sized companies, plus two spin-off companies from different parts of Slovenia.

It is the vision of the centre to foster major progress in important areas of technology, related to inorganic non-metallic materials and their implementation in electronics, optoelectronics, photonics and medicine: the most prominent fields of application including ceramic 2 and 3D structures, materials for overvoltage and EM protection; materials, microand nano- systems for sensors, soft composites for optical, electronic, photonic and sensor applications;

bioactive, biocompatible and bioinert materials. Based on the background and particular expertise of its partners, the consortium is multi- and trans-disciplinary.

This is well reflected in the list of the founding members of the CoE who are the following partners:

1. Institut »Jožef Stefan« (RES)
    - Electronic Ceramics Department, IJS-K5;
    - Department for Nanostructure Materials, IJS-K7;
    - Condensed Matter Physics Department, IJS-F5;
    - Engineering Ceramics Department, IJS-KG

2. University of Ljubljana (Faculty of Electrical Engineering, UL-FE (Laboratory for Microelectronics, LMFE; Laboratory for Microsensor Structures and Electronics, LMSE); Faculty of Mathematics and Physics, UL-FMF; Biotechnical Faculty, UL-BF; Veterina Faculty, UL-VF; Faculty of Medicine, UL-MF; Faculty for Chemistry and Chemical Technology, UL-FKKT- (HES)
3. University of Maribor (Faculty for Chemistry and Chemical Technology, UM-FKKT) - (HES)
4. HIPOT-R&D Research and Development in Technologies and Systems, d.o.o. (RES)
5. TC SEMTO Development Centre for Circuits, Components, Materials, Technologies and Equipment for Electrotechnics (RES)
6. NANOTESLA INSTITUTE - R&D Center for Nanotechnologies in the Field of Magnetic Materials and Composites (RES)
7. Iskra Avtoelektrika d.d. (IND)
8. ISKRATELA d.d. (IND)
9. ISKRAEMECOEnergy Measurements and Management, d.d (IND)
10. ETI Electroelement d.d. (IND)
11. HYB Production of hybrid circuits (IND)
12. KEKON Ceramics Capacitors, d.o.o (IND)
13. KEKO Equipment d.o.o (IND)
14. VARSI d.o.o., Varistor Manufacturer (IND)
15. Iskra ZASCITE d.o.o., Surge Voltage Protection Systems, Engineering and Cooperation (IND)
I6. KOLEKTOR MAGMA d.o.o. (IND)
17. BALDER Optoelectronic Elements and Measuring Systems, Ltd. (IND)
18. NANOTUL d.o.o. (IND)
19. SKUPINA PANVITA d.o.o. (IND)

The activities of CoE are organized in three segments:
A: Management, development and promotion of the CoE
B: Research and Development Projects (RRP) (abbreviated):
- RRP1:Ceramic 2 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:The project of new opportunities that allow the integration of new partners

C: Investment in R&D equipment

The actual research and development of the CoE is carried out under activity (segment) B which is further subdivided into the six research projects RRPI-G. This report reflects on both, the evaluation of the individual research projects, as well as the implementation of the CoE infrastructure, and the coherence and collaboration shown so far, and its prospect for the second period of funding.

It can be said as a general consensus for all projects that were presented and discussed during the midterm evaluation that the activities and the results that have been demonstrated are impressive in all areas without exception. They do certainly build on previous achievements, but all involved scientists and staff have used the new possibilities offered by the installation of CoE NAMASTE in the best possible way. Investments in modern instrumentation was essential not only to replace outdated instruments, but has also opened completely new possibilities which have greatly enabled new developments, or at least significantly contributed to their development.

The progress of the actual research work shall be discussed shortly by workpackage.

• *WP1/RRD1: Ceramic* 2 *and 3D structures*
Dr Darko Belavič (Hipot R&D) reported on the progress in the field of 2- and 3-dimensional ceramic structures. At the current time, it is still very difficult to produce ceramic structures with highly complex 2- and 3-diemnsional structure. The approach presented by the research team of WPl is to use Low Temperature Cofired Ceramics (LTCC)technology which is especially convenient for complex ceramic structures. LTCC materials in green state (or green tapes, that is, before sintering) are soft, flexible, and are thus easily manipulated and mechanically shaped. By laminating a large number of layers, 3 D structures can be formed that are highly interconnected or geometrically complex, such as cantilevers, bridges, diaphragms, channels and cavities. These laminates are sintered in a one-step process (cofiring) at relatively low temperatures (850-900°C) to form a rigid monolithic ceramic multilayer module. Although there are still problems to be solved (related, e.g. to the dimension change of the green material when sintered) this technology is, highly promising for various applications in microsystems technology.

The project team has developed a concept of improving the resolution for 2D-structures which at the current time is limited by screen-printing the masks for the application of the materials. Through the introduction of their new technology, based on Inkjet-printed masks, a significant improvement in lateral resolution of the 2D-structures can be expected.

A further challenge of this work package is to produce 3D-structures with extreme geometry, "extreme" being defined here as e.g. high aspect ratios (e.g. the depth to width of a channel), or buried cavities. These structures are important in the production of sensors and microelectromechanical devices. Here, promising results have been achieved by using permanent or temporary sacrificial materials to fill the void volumes.

The projected aims of this work package have thus successfully been reached, and the developments will be of great direct relevance to the industrial partner(s) using this technology. The industrial partners emphasised for this reason the excellent cooperation between research institutions and industry.

The continuation of this RRPwill be important for the entire CoE as it directly leads into a / several new technology/technologies which will directly be adopted and implemented by the industrial partners.

Defined milestones of this WP have been reached, and it is to be expected that the development will continue in a successful way.

• *WP/RRP2: Materials for overvoltage and EM protection*
Results of this WP were presented by Mr Andrej Pirh (VARSI d.o.o.) and Mr Bregar. The WP has two major aims, the development of new overvoltage surge protection materials,

elements and devices (activity SP), and the development of new electromagnetic (EM) absorbing materials and EM protection (activity EM). Both parts of the work package require a profound theoretical understanding of the important parameters to be able to develop devices that can be applied practically. The technical relevance of this work package is evident, and the two sub-projects have advanced to a significant stage in this first period of the CoE. With respect to the sub-workpackage SP, studies are ongoing to develop improved surge protection devices, based on doped ZnO varistors. These devices will improve the market situation ofthe VARSI company in this very competitive field.

Also in sub-WP EM new materials and structures have been developed and are tested now (in cooperation with company Kolektor) for electromagnetic protection. Tested materials / structures are: EM absorbing particles (powders), and composite materials which can be either soft (sheets) or rigid, the latter allowing to be machined in various geometrical shapes. As a further development in this WP, structures and prototypes have been developed for improved RFID purposes in the HF and UHF range (again in collaboration with Kolektor).
This WP has been highly prolific in the production of new materials, devices and prototypes.

• *WP/RRP3: Materials, micro- and nano- systems for sensors*
This WP has defined three research tasks, namely:
1) *Suitability of sub-l00nm CMOS technology for the implementation of high precision – lownoise measurement channel with integrated preamplifier and SD modulator together with DSP.*
The objective of this sub-task is essentially, to develop an integrated circuit for a high precision, low noise electron counting device (electric power meter). This task has successfully been realised by the Laboratory of Microelectronics of the University of Ljubljana (Head: Prof. J. Trontelj) in cooperation with the Iskraemeco company. Although perhaps not representing a scientific breakthrough, such developments are of great value for the industrial partner as they will improve their competitive position on the market.

2) Chemical sensors suitable for integration with appropriate sensors signal acquisition and processing
In the frame of this sub-task, a chemical sensor was developed for ethanol, which can be used as a tracer to monitor disinfection activities in the hospital environment. In cooperation with the University Clinical Centre, such a prototype was developed by A. Pletersek. With the feasibility of the principal sensor device demonstrated, further steps will have to be made to prepare this device for data logging and communication using RFID, and to fully integrate it into standard wireless clinical infrastructure.

Very interesting in this respect is also the work on THz spectroscopy performed in this group. This allows for remote sensing of chemical agents (e.g. explosives) over extended distances. If this technology is improved and particularly made more sensitive, there is great potential for devices based on this technology, particularly in (homeland) security applications.

3) Advanced MEMS technologies
Here, both the improvement of existing processes and R&D of new processes in 3D wet and dry micromachining of silicon microstructures and related thin film materials for MEMS are foreseen. The existing laboratory infrastructure already allows these processes to be performed, but the upgrading of new instrumentation (also for control of the processes) is expected to lead to an improvement of the quality of these processes.

• *WP/RRP4: Soft composites for optical, electronic, photonic and sensor applications*
This work package is divided in the following five tasks:
T-1: Composite surface layers for special liquid crystal light modulators

T-2: Optical resonators and sensors based on liquid crystal colloids
T-3: light transport and manipulation in confined colloidal systems
T-4: Electro-optical stimulation of sub-microparticles doped liquid crystal elastomers
T-5: Nanowire composites of transition metal sub-oxides for electronic applications
Results of these tasks were presented by some of the task leaders (Prof. I. Musevic, Prof. A. Remskar). Particularly impressive were the results obtained related to the magnetic surface ordering of thin liquid crystal layers (TI-CI), the optical switching of liquid crystal orientation on topologically structured surfaces (TI-C2), and the experiments towards achieving optical detection of the resonance spectrum inside colloidal liquid crystal resonators (T2-CI) on the one hand, and on the other hand the results obtained in the synthesis of sub-stoichiometric oxides Mo, W in Nb in a fibrous shape (TS-CI). This is highly relevant, fundamental research at the cutting edge of science which the evaluator would consider as top level and highly relevant on international level.

The contributors of this work package are encouraged to continue their research which on the medium to long term will also have great importance for new technologies, materials and applications.

• *WP/RRP5: 8ioactive, biocompatible and bioinert materials*
The R&D activities of this work package do not focus on the production or (chemical, physical, structural) characterisation of the advanced materials, but on the study of their interaction with biological systems. In this respect, biocompatibility, bioactivity and - as the opposite to the former - also bioinertness are studied. These aspects are also highly relevant for the assessment of human safety when working with the new type of nanomaterials. Different approaches for the testing of the interactions and effects of nanomaterials (nanoparticles) and cells were presented by Prof. Remskar and Dr. Arsov, where the use of optical tweezers allowing the manipulation of interactions between particles and cells under the microscope was particularly impressive.

The bundle of different and complementary methods developed and applied in this workpackage will allow a comprehensive assessment of the interaction of nanomaterials and cells, and more generally speaking, the assessment of their bioeffects. This will be an important tool to estimate the toxicity or hazard for humans of these materials which are increasingly used both in technological processes, but also in products of our daily life.

• *RRP6: The project of new opportunities that allow the integration of new partners*
It is the stated aim of this work package to improve competitiveness of industrial partners with the activities which are not included in the projects RRPI - RRPS.This shall be done by advising, education, servicing, preparing project proposals for different calls, by performing small-scale R&D projects for smaller consortiums etc. It is considered an asset of this CoE that the work programme has been kept open to include possible new opportunities that were not considered at the time of submitting the CoE proposat and that also do not fall within the five previously discussed work packages. By its nature, this WP is thus hardly defined in its actual activities which are largely to be defined still. At the current time, this work package is difficult to assess, and it remains for the second half of the operation period of this CoE to see how well the opportunities offered by having such an open WP as part of the CoE work programme have been utilised.

From the above discussion it should have become clear that the CoE has been highly active in this first period of operation before midterm evaluation. Throughout the largest parts of the project the schedule of the work plan was kept. The values of the key indicators for the performance of the CoE (e.g. number of publications} innovations} patents) are exactly achieved according to the workplan for 2010 (and the original project application)} and in some cases even exceeded.

From the presentations during the midterm evaluation} as well as from the numerous joint publications it becomes clear that the cooperation of industrial partners and academic partners within this CoE is strong and successfut even if often only in a bilateral way.
It appears that many of the technologies and products developed at the research partners within this CoE can be transferred successfully to the commercial (industrial) partners.

The technological excellence of this CoE NAMASTE is clearly demonstrated by the number of innovations and patents achieved so far} as well as by the number of prototypes and demonstration projects. The number of publications is remarkable} and so is the rank of the journals which have been chosen for publication} including *Proc. Nat. Acad. Sci. USA} Nature Comm.} Phys. Rev. Lett.}* or *Chem. Comm.*

	RRP1	RRP2	RRP3	RRP4	RRP5	RRP6	TOTAL
Publications	8 (1)#	2 (1)	0	20 (3)	15 (1)	0	45 (6)
Innovations	1	0	2	2	0	0	5
Patents	2	3	0	3	2	0	10
Patents Applications	1(1)*	8(1)	1	3	4	0	17 (2)
Prototypes & Demo Projects	0	4	3	4	2	0	13

()# publication with CoE NAMASTE affiliation - otherwise publication of CoE partner(s)
()* application after 30.4.2011- data from self-assessment report of CoE NAMASTE

2.3. International cooperation

The CoE is strongly integrated and interlinked within the European and international scientific landscape. There is a strong exchange of scientists and staff from and to the CoE}s partner institutions. During the reporting period} 25 visiting researchers and 8 lecturers (+2 after April 30th) came to stay at the CoE for up to one week} and 17 for more than 1 week.

In addition to that, CoE partners are currently participating or coordinating 32 international projects. It is clear that most if not all the projects have been submitted and started already earlier than the CoE NAMASTE starting date. However, this number is still very suitable to indicate the strong international relations that the CoE project consortium has.

2.4. Participation in the process of education of new cadres

There is a strong contribution of CoE members to train young researchers, and to act as mentors of their post-graduate and doctoral research. The following table (next page) gives an overview how many of the researchers of this CoE are lecturers and/or mentors of master and PhD theses:

	RRP1	RRP2	RRP3	RRP4	RRP5	RRP6	TOTAL
Lecturers	5	2	5	5	6	-	24
Mentors	2	5	4	2	6	-	20

3. Quality of the proposed CoEprogramme (all parts)

The evaluator is very pleased with the scientific, technological and educational aims of the CoE reached so far. The performance of the scientific programme of the CoE is going very much according to plan. This is also true for the acquisition ofthe instrumentation proposed in the application: In the proposal there were 39 positions for the equipment/instrumentation, where in some cases, there is more than 1 piece of instrumentation under one position. The situation as of July 2011 was the following:

- 28 positions have been concluded,
- 8 positions: in the process- contracts signed
- 2 in the process of preparing the technical specifications
- 1 tender in preparation
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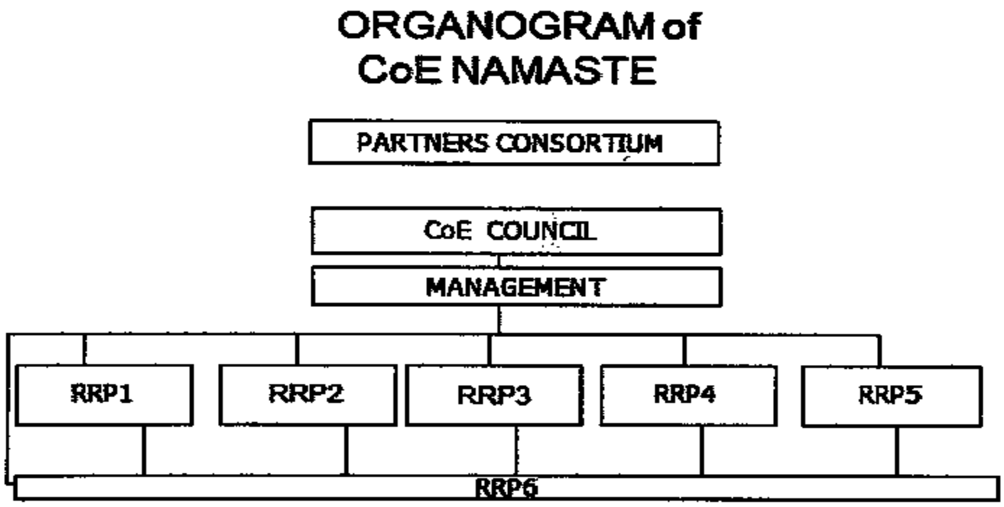
Considering that the financial regime (terms of reference for the acquisition of equipment) was defined only after he start of the CoE, this is an excellent situation. Much of the new instrumentation is already in intensive use and has contributed significantly to achieving the results in the individual work packages.

4. Competence for implementation of the CoE programme, financial feasibility and economic eligibility

There is high competence for implementing the programme of this CoE. The Scientific Director of the CoE is a person of outstanding scientific position with rich experience in project organisation and administration on national and international scale. She is assisted by the Managing Director who also has due to her work experience excellent competence and high efficiency in running the administration of this CoE. The CoE council, formed by highest-level representatives of the research institutions, the Ministry of Higher Education, Science and Technology, and industrial partners further ensures that the strategic direction of the CoE is in agreement both with the work plan, but also with the larger aims of the EU Cohesion Policy.
The organisational structure that has been chosen is depicted in the organogram reproduced on the next page:



Strong attention is paid within the CoE to the education of new cadres, and also to the dissemination of the results and achievements within and outside of the scientific community.

The website of the CoE is nicely designed and informative. It is permanently updated with a news stream that informs about the latest news and achievements of the CoE members.
The system of IPR management is found sufficient in the proposed way, following standard practices, although it may be subject to further consideration with regard to the financial sustainability of the CoE on the long term.

Quality of dissemination plan is good; however, CoE members and management may consider increasing their activities in informing also the lay audience about the significance of the CoE results (while the dissemination of results within the scientific audience is excellent).

5. General assessment (recommendation to finance)

CoE NAMASTE has decided to go its own way in the operation of this Center of Excellence which is between an absolutely "lean management", meaning that only a minimum of personal is employed and financed by the CoE, and the option to also employ a larger number of staff from the CoE budget. According to the financial plan of this CoE, about one half of the available funds are used for the acquisition of equipment, the remaining part of the budget is used to employ staff for the administration and management of this CoE, and to perform research (up to the evaluation date ca. 16.2 FTE) and for the other activities as defined in the proposal and work plan.

The investment in instrumentation is vital to the success of the CoE, and the largest part of the foreseen instrument acquisitions has already been concluded with that have already been delivered and installed, or were about to be delivered (at the date of evaluation). This is a proof of very effective management of the scientific and financial matters of the CoE, since the procedures for large-scale acquisition only become clear during the operation of the CoE. The instrumentation that has been acquired with the grant for this CoE has significantly improved the available measurement, testing / characterisation and production infrastructure. Larger pieces of instrumentation are concentrated at the research institutions participating in this CoE where both the technical infrastructure as well as the expertise is available to run these instruments. Smaller pieces of instrumentation are also installed at the various (industrial) partner sites. While much of the instrumentation acquired in the frame of this Centre of Excellence is related to materials characterisation and testing, it appears that techniques and instruments that provide structural and chemical analysis would also be important to perform the individual tasks. It is therefore suggested that a close cooperation is searched with other CoEs, and in particular CoE Nanocenter who offers both the required expertise and the instrumentation to assist in this type of investigations. It is highly recommended that the cooperation between CoEs will be actively searched and strengthened to develop synergistic effects not only between the partners of one CoE, but also between Centres of Excellence which are thematically related.

CoE NAMSTE has demonstrated during the first period of operation a truly excellent performance. The organisational structure was established and implemented, and allowed for the frictionless and efficient operation of this Centre of Excellence.

The scientific results of the CoE partners are considered excellent as well, not (only) considering the quantitative output but the quality of results produced and published. Particularly the fundamental research of work package (RRP) 4 has received highest international visibility and attention. Other work packages are considered equally successful, but with different objectives: Research in work packages 1 and 2 are strongly applicationoriented. The success of these work packages is demonstrated by the large number of innovations, applied or granted patents, or demonstrators produced in the frame of these WPs, and the strong involvement of industrial partners. Many of the developments of these work packages will directly lead to new products.

It is a particular strength of this CoE that it has an excellent balance between fundamental and applied research. While the applied research delivers solutions that can be transformed into technical products or services on a relatively short timescale, fundamental research will provide the basis for future technologies which not necessarily can already be anticipated at the current time.

The combination of the two - basic and applied research - could also be the basis for the sustainability of the CoE beyond the duration of the funding period. Here, the evaluator feels that a clearer regulation will have to be implemented. The CoE has clearly demonstrated that it can produce results of both scientific and technological relevance which may be commercialised (although on different time scales). It would be important to discuss and define within the CoE if this intellectual property is property of the contributing institutions, or rather could be transferred to the CoE. In such case, patents could, for example, be sold to companies that have interest in using this technology, and thereby create a source of income for the CoE. As for the other CoEs, an important question to answer is what happens after the funding period. Given the fact that the largest part of the CoE budget was used for building up a modern instrument infrastructure, this asset will be left to the partners who have to agree then on reasonable terms of usage, e.g. charging usage fees to cover running costs of this instrumentation. On top of that, however, a certain amount of income must be generated, because much of the administrative and organisational infrastructure that has been built up to coordinated and assess research activities, to monitor educational activities, to disseminate results, to allow networking and to develop synergistic effects within the consortium and outside may be lost.

While the really excellent scientific and technological achievements of this CoE are one pillar for the sustainability of this CoE, the overarching administrative / organisational structure is the other, and therefore CoE partners and management are strongly encouraged to develop a strategic plan how this issue will be dealt with.

Based on all indicators of the performance of this Centre of Excellence, a strong recommendation of continuing the funding and the operation of Centre of Excellence "NAMASTE" is given.