DEPARTMENT FOR NANOSTRUCTURED MATERIALS K-7

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

Head:
Prof. Spomenka Kobe

In 2012 we were awarded the EU FP7 project "Replacement and Original Magnet Engineering Options" (ROMEO) in which we are the coordinator and an active research group in grain-boundary engineering (GBE) and the characterization of magnets using magnetic-properties measurements and high-resolution electron microscopy on the nano and atomic levels. The project has two goals: firstly, decreasing and/or completely avoiding the use of heavy rare earths in Nd-Fe-B high-energy magnets and, secondly, inventing new magnets that will have properties between ferrites and high-energy magnets based on rare earths and transition metals.

We began to work on another EU FP7 project, **Nanocrystalline Permanent Magnets Based on Hybrid Metal-Ferrites** (NANOPYME), which will focus on developing new permanent-magnet materials that fill the gap between conventional ferrite magnets and high-energy, rare-earth-based Nd-Fe-B and Sm-Co-based magnets. The department is responsible for producing nanoscale powders and for technology transfer to industry.

In 2012 we began our role as coordinators of the EU FP7 project "Replacement and Original Magnet Engineering Options" (ROMEO). The project aims to reduce the dependence of European industry on expensive and erratic supplies of rare-earth raw materials, primarily from China.

As part of our work on improving the corrosion-resistance properties of bonded and injection-moulded rare-earth-based magnets we have coated Nd-Fe-B melt-spun powders with SiO_2 and Al_2O_3 using the sol-gel technique. Highly accelerated stress tests were conducted to compare the corrosion properties of the ribbons. The compositions and microstructures of the ribbons and surface layers were determined by AES, XPS, Raman spectroscopy, SEM and EDS. The magnetic properties were measured with a vibrating-sample magnetometer. Both the SiO_2 and Al_2O_3 coatings resulted in superior corrosion resistance and magnetic properties. This technique should expand the range of use of Nd-Fe-B bonded magnets to applications with temperatures as high as 110 °C and 90% humidity.

Our work on the hydrogenation of amorphous rare-earth-based hard-magnetic amorphous materials was focused on studying the effects of a range of hydrogen pressures and temperatures on the magnetic and structural changes in Nd-Fe-Al alloys with compositions close to $Nd_{60}Fe_{30}Al_{10}$, using vibrating-sample magnetometry, x-ray diffraction and transmission electron microscopy.

In collaboration with the Department for Inorganic Chemistry we managed to coat Nd-Fe-B melt-spun ribbons with a thin (3 nm) layer of DyF_3 using an innovative **fluorolythic sol-gel reaction** with Dy-isopropoxide as a precursor. The powder will be used as a basic material for bonded magnets with improved coercivity.

We successfully used electrophoretic deposition as a method to effectively coat the surface of a Nd-Fe-B sintered magnet with Dy(Tb)F_3 powder and achieve 30 % higher coercivities with an optimized amount of expensive heavy rare earth (Fig. 4).

Nano-dimension, intermetallic, hard magnetic systems of Fe-Pd and Co-Pt were electrodeposited and investigated for their **magnetic shape memory** (MSM) effect ($Fe_{70}Pd_{30}$) in a national project with the NIC and as part of an MNT-ERA-NET project, and due to their potential for use in perpendicular recording (Co-Pt). Since the MSM effect is composition sensitive, an electrochemical kinetic study of the Fe-Pd deposition was made on flat and porous templates. It was found that the deposition of both ions is irreversible and diffusion controlled, with the diffusion and kinetics being faster on the flat electrode. Based on the obtained parameters pulsed-plated conditions for achieving $Fe_{70}Pd_{30}$ nanowires with constant composition were proposed. Deposited $Fe_{70}Pd_{30}$ nanowires had a face-centred tetragonal crystal structure, which was successfully transformed to a face-centred cubic structure via thermal annealing and quenching, which is the basis for the MFM effect. For the biomedical purposes the Fe-Pd nanowires were additionally coated with SiO_2, which increases their functionality. Co-Pt nanowires with different

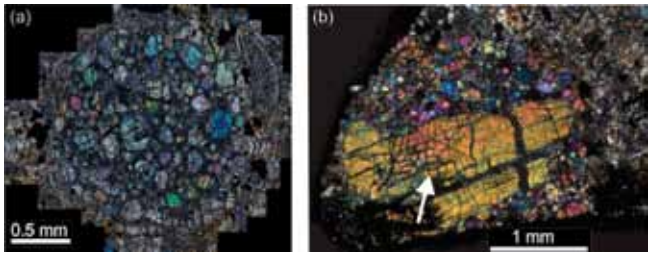

Figure 1: Meteorite Jesenice. (a) Typical porphyritic olivine chondrule and (b) porphyritic olivine chondrule containing relict olivine grain (marked by arrow). Transmitted light microscopy, crossed polars.

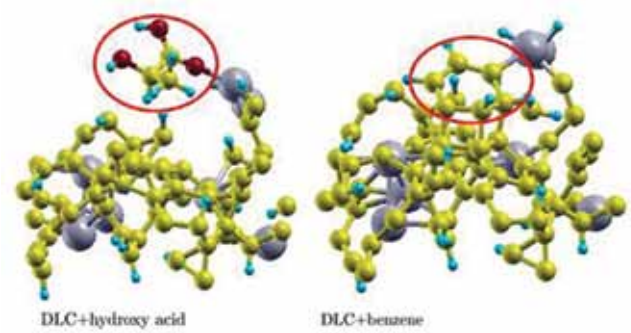

Figure 2: Bond formation between the surface of a doped DLC and hydroxy acid or benzene.

aspect ratios were electrodeposited into porous alumina templates. It was found that the direction of the magnetization easy axis can be tailored from parallel to perpendicular, taking into account all the involved anisotropies. The magnetic force microscopy study revealed that by increasing the aspect ratio, the Co-Pt system transforms from a mono-domain to a multi-domain structure, leading to a coercivity reduction for high aspect ratios. The ability to tailor the easy magnetization axis direction finds applications in perpendicular recording, since more information can be stored in a perpendicular geometry.

In our research on **magnetocaloric materials** based on $Gd_5(Si,Ge)_4$ we found that the microstructure has a large effect on the magnetic properties. The orthorhombic-monoclinic structural change, which occurs under the influence of an external magnetic field, usually happens at a field below 1 Tesla. If we modify the microstructure with small substitutions of iron and fast cooling of the melt, we modify the microstructure in such a way that the structural change occurs at higher magnetic fields. It was also found that for a correct calculation of the magnetic entropy change from the magnetic data one has to use thermo-magnetic data measured at a constant magnetic field.

In the research on intermetallic magnetocaloric materials based on amorphous iron alloys with added transition metals we want to achieve a compromise between a high magnetocaloric effect and a low magnetic ordering temperature. Adding metals usually increases the magnetocaloric effect, but also increases the magnetic ordering temperature much above room temperature. We focused our research on adding nickel to the alloy $Fe_{89}Ni_xZr_{10}Cu$ (x=0-8) and achieved a remarkable increase in the magnetocaloric effect with a modest increase in the magnetic ordering temperature.

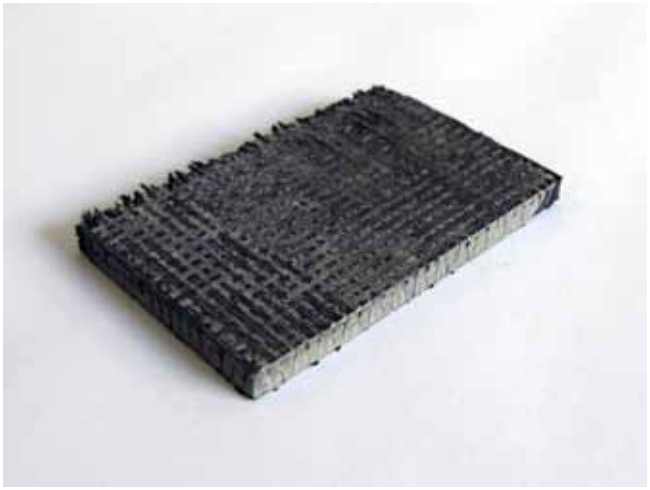

Figure 3: The SITE-SiCf/SiC plate

MgH_2-based systems have the highest potential to be used as hydrogen storage material. The DOE goal for 2015 is 4.5 wt.% of H, whereas pure MgH_2 yields 7.6 wt.%. However, the sorption kinetics is very slow, which restricts its application either in hydrogen fuel-cell powered vehicles or NiMH batteries. Therefore, numerous attempts are performed worldwide to improve sorption kinetics by the addition of various dopants, i.e., pure transition metals (and rare earths) in nano-from, their alloys, oxides, carbides and halogenides, via surface modification using gentle planetary milling in order to achieve a catalytic effect. Most of these additives improve the sorption kinetics and as expected lower the capacity, as well. Nevertheless, to the best of our knowledge there are no reports in the literature about using quasicrystals of any kind or any system for this purpose. Thus, we prepared icosahedral Ti-Zr-Ni-based quasicrystals and mixed them with commercial MgH_2 and ball-milled the mixture for several hours. In parallel, we milled pure MgH_2 in order to eliminate the effect of particle size reduction on the kinetics. Using mass spectrometry we found a 60°C lower temperature of hydrogen desorption after 36 hrs of milling in the case when (5 wt.%) quasicrystals were used as compared to pure MgH_2.

Within the European fusion programme, in which we have already collaborated for eight years, the most important result is the optimisation of the SITE-P process developed in our laboratory. The process involves the electrophoretic infiltration/deposition of SiC powder to fill the voids within the SiC-fabric and enables the fabrication of a 3-dimensional SiCf/SiC composite for the first-wall blanket in future fusion-power plants.

In 2012 we modelled the absorption molecules present in lubricants at the DLC surface and found that the strongest bonds were formed between the metallic dopants from the DLC and the oxygen atoms from the molecule COOH or OH groups (Fig. 2). On the basis of *ab-initio* calculations we determined the most probable muon stopping-sites in some complex magnetic systems. We also worked on the implementation of the density-matrix-renormalization-group method (DMRG).

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Electrophoretic deposition was also used in the fabrication of a SiC-based ceramic composite reinforced with carbon nanotube (SiC-CNT), where we achieved a homogeneous distribution of CNT within the ceramic matrix. A comprehensive study of the electrokinetic properties of suspensions also resulted in the successful electrophoretic deposition of bulk parts of thermoplastic polymer polyether-ether-ketone (PEEK), which is a topic of research in collaboration with the Mechanical Engineering Faculty, University of Ljubljana. The same process has also been tested as a method for coating metallic gears with PEEK (collaboration with the Mechanical Engineering Faculty, University of Maribor).

In the frame of research of **materials for use in medicine**, we continued the study of the properties of TiO_2 coating on a Ti_6Al_4V alloy formed by a hydrothermal treatment of the alloy. It was confirmed that the thin crystalline (anatase) coating significantly reduces the leaching of aluminium and vanadium ions from the alloy, improves the wetting and contributes to improved bone attachment. Special attention has been paid to the photocatalytic properties in correlation with the bacteriostatic behaviour (BioTiNet, FP7-ITN).

Results of the research of **bioactive glass**, which was developed within the scope of the FP6-IP-SME project "Meddelcoat", have been published in International Orthopaedics, where the observed beneficial effect of a bioactive glass coating on a metal implant on osseointegration was presented. The research of bioactive glass was also carried on within an informal collaboration with Educell d.o.o., where bioactive glass has been studied as a candidate material for use in bone-tissue engineering regeneration. The effect of powder and sintered bioactive glass on cells has been evaluated and compared. In addition, research with bioactive glass in the form of a paste or gel for the reduction of dentine hypersensitivity after professional teeth bleaching was started as an informal collaboration with Dental Studio (Fig. 5).

Within the frame of the COST action **NAMABIO** "From nano to macro biomaterials (design, processing, characterization, modelling) and applications to stem cells regenerative orthopaedic and dental medicine" a collaboration was established with a world-leading research group in the field of tissue engineering at the University of Minho in Portugal. A set of biodegradable and bioactive nano-composite scaffolds was prepared and characterised. The composite scaffold, supposed to be used as a cell-support in the regeneration of large osteochondral defects, is composed of natural polymer (gellan gum) reinforced with nanoparticulate bioactive glass powder. With the addition of bioactive glass we achieved bioactivity (precipitation of hydroxyapatite in body fluid) and favourable biodegradation, which are both important for new bone formation. A significant improvement of the mechanical properties was also observed: Young's modulus was five times higher for the composite material than for biopolymer material alone. This is ascribed not only to the presence of particles but also to the increased concentration of calcium ions, allowing the more intensive cross-linking of monomer gellan gum molecules (Fig. 6).

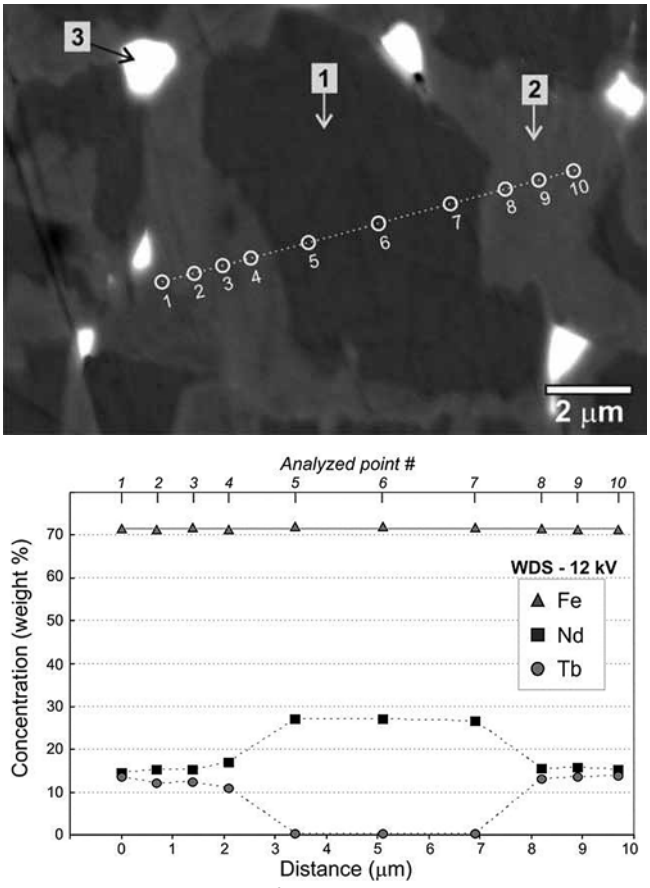

Figure 4: Core-shell structure of the grains in Nd-Fe-B magnets and WDS analysis, which shows the Tb distribution that contributes to the coercivity improvement of 30%.

In the field of **ZnO-based varistor ceramics** we studied the influence of the $Bi_4Ti_3O_{12}$ (BIT) addition on grain growth and microstructure development. A homogeneous microstructure development was achieved during the rapid release and efficient distribution of TiO_2, which triggered the formation of inversion boundaries (IBs) in ZnO grains. It can be achieved by instant decomposition of the BIT to TiO_2-rich Bi_2O_3 liquid phase in samples suddenly exposed to temperatures above 1100°C. The results are important for the development of varistor ceramics with very low breakdown voltages below 50V/mm.

The development of thick-film varistors was focused on studying the influence of organic vehicles and the amount of added varistor powder filler on the rheological characteristics of pastes and their screen printing performance.

Simple and cheap low-temperature hydrothermal synthesis at 90°C enabled the preparation of ZnO films with high optical transparency over 80% and a low resistivity. For the growth of a smooth, dense and highly (0001) oriented polycrystalline ZnO film from a solution of Zn-nitrate during the addition of Na-citrate a proper nucleation layer of ZnO on glass is required. The formation of a ZnO nucleation layer and the influence of its characteristics on the growth and optical properties of the ZnO films were studied. A highly homogeneous and continuous nucleation layer of well-connected ZnO grains with sizes from 30 to 100 nm, which enable the hydrothermal growth of a highly transparent ZnO film, can be prepared from a Zn-acetate layer with a thickness of at least 90 nm at temperatures of calcinations between 350 and 600°C. The higher is the number of the ZnO nuclei per unit area, the thinner the

ZnO film with higher density, superior (0001) orientation and hence higher transparency can be obtained in hydrothermal growth. At lower thicknesses of Zn-acetate layer and higher calcination temperatures a discontinuous nucleation layer formed from larger and separated ZnO grains, resulting in a poorly textured and porous ZnO film with a low optical transparency. Economical ZnO films can replace transparent-conductive ITO (In-Sn-O) films with rare and hence expensive In, which nowadays dominates in technologies of flat-panel displays and solar cells.

We continued with a study of the nucleation and crystallization of **ZnO nanoparticles** using electron microscopy and SAXS (small-angle X-ray scattering) and explained the mechanisms of crystallization and the transformation of zinc-hydrocincite to zinc oxide.

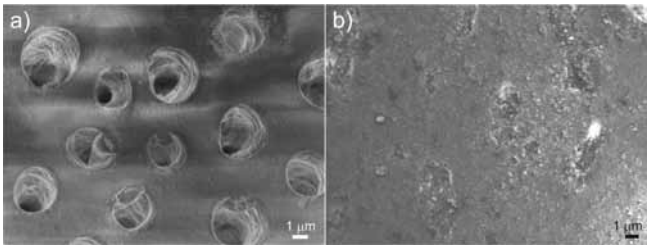

Figure 5: a) Open dentin tubules causing dentin hypersensitivity and b) dentin tubules closed due to the re-mineralization after treatment with bioactive glass.

In collaboration with the company VARSI we continued the development of nano-varistors and special varistors with a high stability of leakage current under a dc field for applications in the overvoltage protection of renewable energy systems (solar panels and wind-turbine generators).

The development of oxide **thermoelectric materials** of n-type was focused on studying the influence of composition and firing temperature on the formation of the phases in the $(ZnO)_xIn_2O_3$ homologous series, microstructure, structure and consequently thermoelectric characteristics. In the development of p-type thermoelectric materials the preparation of highly textured samples of $Ca_3Cu_4O_9$ compound was studied and its synthesis using spark plasma sintering (SPS) method. A Z-meter was constructed for measurements of the thermoelectric characteristics up to a temperature of 1000K. The first test measurements of our samples up to temperatures of 750°C were made and the obtained results are comparable with the results obtained on commercial instruments.

Within the investigation of other potential thermoelectric materials we synthesized n-type thermoelectrics based on $SrTiO_3$, Sr_2TiO_4 and $Sr_3Ti_2O_7$ doped with different amounts of Nb_2O_5 in Gd_2O_3. We expect that the incorporation of dopants will beneficially increase the electrical conductivity of these perovskite-based ceramics. Additionally, by controlling the intergrowth of Ruddlesden-Popper layers within the perovskite matrix in non-stoichiometric Sr_2TiO_4 and $Sr_3Ti_2O_7$ we intend to reduce the thermal conductivity.

The synthesis of perovskite **$BaTiO_3$ nanorods** via sol-gel electrophoretic deposition into anodic aluminium oxide (AAO) membranes has proven to be very successful and useful. When measuring the electrical properties of BaTiO3 nanorods we have come up with interesting scientific findings, which were published in the journal Nanotechnology. In the article "Characterization of Individual Barium Titanate Nanorods and Their Assessment as Building-Blocks of New Circuit Architectures" we reported on the integration of individual $BaTiO_3$ nanorods into simple circuit architectures. At the beginning of 2012 this work received the title of "Best journal highlights articles". The Slovenian journal Finance also published an article on the **$BaTiO_3$** humidity nanosensors.

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We continued the study of nucleation and synthesis of **titania nanoparticles** in anatase and rutile crystal form and thin-titania films on metal substrates using hydro and solvothermal methods. The influence of process parameters (the used solvents were water, isopropoxide, glycerol, etc.) on the size, morphology and photocatalytic efficiency of particles and thin films were studied. We were able to tailor the morphology of titania nanoparticles in the form of rods, bipyramids, stars, flowers, sea-urchins, etc. The explanation of the nucleation and growth of anatase particles to the specific morphologies were published in Journal of Crystal Growth.

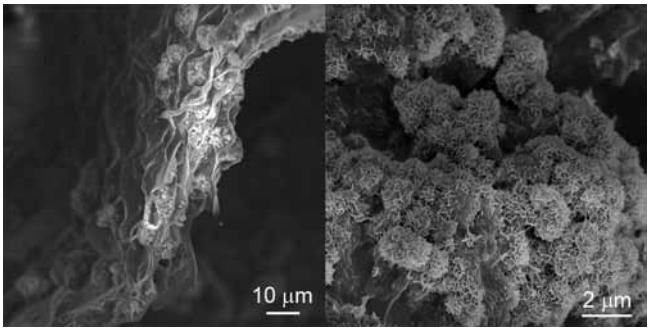

Figure 6: Wall of composite scaffold (left) and hydroxyapatite on the composite as evidence of bioactivity (right).

In the field of photovoltaics we assembled and tested the semi-flexible DSSC (dye-sensitized solar cells) solar cells. For the flexible substrate the titanium foil was used and anodized. The produced thin oxide layer of 2-D ordered TiO_2 nanotubes serves as an active component of DSSC cells.

We optimized the parameters for the anodization of aluminium foil and alloys. The obtained oxide layer was coloured by the selected ion. In the case of copper ions we get ampurple colour of the oxide layer. This work is a cooperation with the department of thin films and surfaces (F3) and Impol industry within an ARRS project.

In collaboration with colleagues from Department of Materials Physics, Montanuniversität Leoben and Erich Schmid Institute of Material Science, Austrian Academy of Sciences, Leoben, Austria a systematic study of the effect of focused ion beam (FIB) fabrication on the mechanical properties of miniaturized mechanical tests by means

of advanced analytic and *in situ* transmission electron microscopy (TEM) was performed. This study deals with the influence of a few nanometre sized crystal defects on the mechanical properties of miniaturized components. Although the formation of these defects is unwanted, they represent an inevitable side effect in the material manipulation by the focused ion beam, a very common technique used worldwide, especially in microelectronics. Through a combination of mechanical and atomic-resolution analytical techniques a mechanism was determined on how these defects degrade the material properties, but much more important a suitable heat treatment was established that can drastically reduce the amount of such defects, which provides an extremely usefully procedure for the material healing. This work was published in Philosophical Magazine. The importance of the study of the effect of FIB fabrication on the mechanical properties of miniaturized mechanical tests by means of advanced analytic and *in situ* TEM was recognized by the Austrian Society for Electron Microscopy by awarding the associated paper with the **Fritz Grasenick Award 2012**, which represents the highest national award in the field of electron microscopy.

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In collaboration with the University of Ljubljana, NTF, Department of Geology systematic electron microscopy studies of the meteorite Jesenice were initiated. Meteorite Jesenice (3.61 kg), which hit Slovenia in 2009 represents the most preserved stony meteorite - chondrites in Slovenia and probably also in Europe, which provides an unique opportunity for better understanding of the formation and the evolution of our Solar system in the period of ~4.6 billion years ago. As a result of first studies, interestingly, inside one of the chondrula a relict crystal grain composed of olivine mineral was found. Relict is a possible remnant of previous generation of chondrules, which can date even before the existence of our Solar system and therefore represents one of the oldest if not the oldest object ever found on our planet (Fig. 1).

We characterized semiconducting BiSe, Bi_2Se_3 and PbSe obtained by mechanochemical synthesis for applications in optoelectronic devices. In our latest research work we focused on the MgO-Al_2O_3-BeO ternary system. The two end-members of this system - $MgAl_2O_4$ spinel and $BeAl_2O_4$ chrysoberyl - are both well-known and technologically interesting materials, whereas the ternary Be-Mg-Al oxides (taaffeites) are recognized mainly in the geological community as naturally occurring precious minerals. In our experimental work we directly revealed for the first time that twinning in $MgAl_2O_4$ is chemically triggered by the addition of BeO and that the structure of twins is closely related to the structure of taaffeites. The nucleation and growth mechanism of twinned crystals is explained on the so-called twin-induced exaggerated grain growth theory. Our findings will be important for future engineering of spinel-based materials. A paper on this subject is submitted to CrystEngComm.

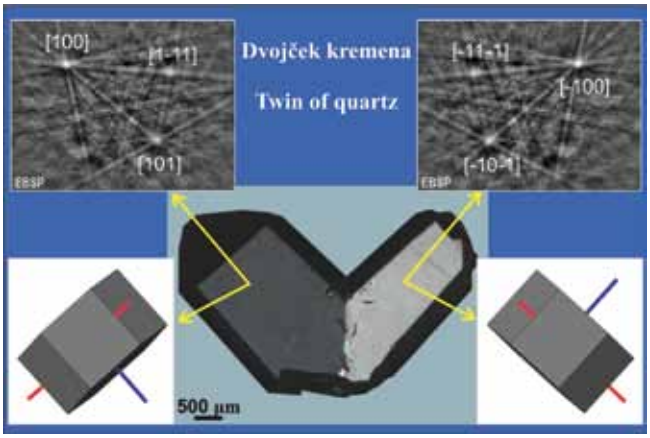

Figure 7: Twin of quartz - using the electron backscatter diffraction (EBSD) method we have accurately determined the crystal orientation and so directly confirmed the presence of Japanese twin in this natural quartz crystal.

A scientific monograph entitled **Minerals of the mercury ore deposit Idria** was published in three languages, Slovene, German and English, the latter by the renowned international scientific publisher Springer Verlag. Mineralogy is explained in terms of geological processes that were active during the formation of the ore deposit. The central part of the book is dedicated to the main mineral of the ore deposit, cinnabar. It occurs in a variety of crystal forms, of which the most special are the lateral interpenetration twins. The book is written for a broad readership, and is interesting for geologists, mineralogist and crystallographers, as well as for those interested in the history of mineral collecting in Idria.

One of the most important research areas of the group is the implementation of various electron microscopy analytical techniques within the existing EU project **ESTEEM2**, such as electron energy-loss spectroscopy (EELS), high-resolution scanning transmission electron microscopy (STEM, HAADF-STEM) electron holography and mechanical preparation of the TEM samples. The research group is additionally strongly involved in managing the Center for Electron Microscopy within the frame of the national infrastructure Center for Microstructural and Surface analysis. Implementation of various electron microscopy analytical techniques and the possibility for researchers to access research infrastructure for electron microscopy is of utmost importance for numerous research institutions, industrial partners, as well as for graduate and post-graduate education.

In the frame of this research we have also successfully implemented the advanced, improved methods of high-resolution scanning electron microscopy (FEGSEM) and energy-dispersive and wavelength-dispersive X-ray spectroscopies (EDS, WDS) for the materials characterization on sub-micrometre and nanometre scales, such as TiO_2 and ZnO nanoparticles, FePd and CoPt nanorods and thin films and Tb-doped NdFeB sintered permanent magnets. Using the electron backscatter diffraction (EBSD) method we have analysed the grains orientation and

texture in polycrystalline ZnO-ceramic thin films. With EBSD we have quantitatively evaluated and determined the type of twins in natural quartz (SiO_2) crystals (Fig. 7).

For industrial partners and other research institutions we have performed the analyses and expertise related to microstructural characterization of various materials in order to solve technological problems in production and/or in the research and development of new products. The main collaborations were realized with SwatyComet Maribor, Cinkarna Celje, ITW Metalflex Tolmin, IFB Inštitut za fizikalno biologijo Ljubljana, Belinka Ljubljana, RC SIMIT Kidričevo, UL-NTF Oddelek za tekstilstvo Ljubljana, Ortopedska Bolnišnica Valdoltra Ankaran.

Some outstanding publications in the past year

1. Novak, S., Iveković, A.: SiC-CNT composite prepared by electrophoretic co-deposition and polymer infiltration and pyrolysis process. J. phys. chem., B Condens. mater. surf. interfaces biophys., [in press] 2012, p. 6
2. Žužek Rožman, K., Pečko, D., Šturm, S., Maver, U., Nadrah, P., Bele, M., Kobe, S.: Electrochemical synthesis and characterization of $Fe_{70}Pd_{30}$ nanotubes for drug-delivery applications. Mater. chem. phys., 2012, vol. 133, issue 1, pp. 218-224
3. Kiener, D., Zhang, Z., Šturm, S., Cazottes, S., Imrich, P. J., Kirchlechner, C., Dehm, G.: Advanced nanomechanics in the TEM: Effects of thermal annealing on FIB prepared Cu samples. Philos. mag., 2012, vol. 92, no. 25-27, pp. 3269-3289
4. Drnovšek, N., Novak, S., Dragin, U., Čeh, M., Gorenšek, M., Gradišar, M.: Bioactive glass enhances bone ingrowth into the porous titanium coating on orthopaedic implants. Int. orthop., 2012, vol. 36, no. 8, pp. 1739-1745
5. Podlogar, M., Richardson, J. J., Vengust, D., Daneu, N., Samardžija, Z., Bernik, S., Rečnik, A.: Growth of transparent and conductive polycrystalline (0001) - ZnO films on glass substrates under low-temperature hydrothermal conditions. Adv. funct. mater. (Print), 2012, vol. 22, no. 15, pp. 3136-3145

Awards and appointments

1. Martina Lorenzetti, Saša Novak, Spomenka Kobe, 2nd best oral presentation in Young researchers section, 20th Jubilee Conference on Materials and Technology, 17.–19. 10. 2012, Portorož, Slovenia, given by the conference committee. Awarded contribution: Investigation of the properties of Titania coatings on Ti-based alloys substrates for body IMP.

Organization of conferences, congresses and meetings

1. The 20th Jubilee Conference on Materials and Technology, Portorož, Slovenia, 17.–19. 10. 2012 (co-organisation)
2. C-MAC Days 2012, AGH University of Science and Technology, Krakow, Poland, 10.–13. 12. 2012 (membership in Science Board and General Assembly and European integrated Center for the Development of New Metalic Alloys and Compounds (C-MAC))
3. Fusion Expo: Energie Fusion, Energie du futur, Faculté des Sciences et technologies, Nancy, France, 26. 1.–4. 2. 2012 (co-organisation)
4. Fusion Expo: Energie Fusion, Energie du futur, Printemps des Sciences, Centre de Culture Scientifique, Coulliet, Charleroi, Belgium, 16. 3.–20. 4. 2012 (co-organisation)
5. Fusion Expo, Stefan Days, Jožef Stefan Institute, Ljubljana, Slovenia, 24. 3. 2012 (co-organisation)
6. Fusion Expo, La Fusion, l'Energie du futur, Visiatome, CEA Marcoule UCCAP, Bagnols-sur-Cèze, France, 12. 5.–8. 7. 2012 (co-organisation)
7. Fusion Expo, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany, 3.–14. 9. 2012 (co-organisation)
8. 27th Symposium on Fusion Technology 2012 - SOFT, Fusion Expo, Fusion, Énergie du futur, Palais des Congrès of Liège, Liège, Belgium, 19. 9.–5. 10. 2012 (co-organisation)
9. Light12 event - European Night of Research, Planetario e museo astronomico, Rome, Italy, 29. 9. 2012 (co-organisation)
10. Fusion Expo: Energia da Fusione, Per il Futuro, Festival della Scienza, Universitaria di Genova, Genoa, Italy, 25. 10.–4. 11. 2012 (co-organisation)
11. Fusion Expo: ITER et la Fusion, L'Energie du Futur, Aix-en-Provence, France, 13.–28. 11. 2012 (co-organisation)

Patents granted

1. Saša Novak, Nataša Drnovšek, Gregor Murn, Bone implants with multilayered coating and process of their preparation, SI23420 (A), Urad RS za intelektualno lastnino, 31.1.2012

INTERNATIONAL PROJECTS

1. 7. FP - ROMEO, Replacement and Original Magnet Engineering Options
   European Commission
   Prof. Spomenka Kobe
2. FP - NANOPYME; Nanocrystalline Permanent Magnets Based on Hybrid Metal-Ferrites
   European Commission
   Asst. Prof. Paul John McGuiness
3. 6. FP - ESTEEM; Enabling Science and Technology through European Electron Microscopy
   European Commission
   Prof. Miran Čeh
4. FP - EURATOM; Public Information; Research Unit, Administration and Services RU-FU; Annex 3 to Contract 3211-08-000102, FU07-CT-2007-00065
   Ministry of Higher Education, Science and Technology
   Asst. Prof. Saša Novak Krmpotič
5. 7. FP - EURATOM; Development of Beta SIC Fibres with W Core - 4.1.1.1.-FU; Annex 2 to Contract 3211-08-000102, FU07-CT-2007-00065
   Ministry of Higher Education, Science and Technology
   Asst. Prof. Goran Dražić
6. 7. FP - BioTiNet; Academic-Industrial Initial Training network on Innovative Biocompatible Titanium-based Structures for Orthopaedics
   European Commission
   Prof. Spomenka Kobe
7. 7. FP - 2020 Interface; Nanoscale of Tribological Interfaces for Clean and Energy-Efficient Diesel and Gasoline Power Trains
   European Commission
   Asst. Prof. Matej Andrej Komelj
8. 7. FP - MACAN; Merging Atomistic and Continuum Analysis of Nanometer Length-scale Metal-oxide Systems for Energy and Catalysis Applications
   European Commission
   Asst. Prof. Aleksander Rečnik
9. 7. FP - ESTEEM 2; Enabling Science and Technology through European Electron Microscopy
   European Commission
   Prof. Miran Čeh
10. FP - EURATOM; Development of Dense Beta SIC Matrix in 3D Preform - 4.1.1.2.-FU; Annex 2 to Contract 3211-08-000102, FU07-CT-2007-00065
    Ministry of Higher Education, Science and Technology
    Asst. Prof. Saša Novak Krmpotič
11. Fusion Expo Support Action under EFDA Work Programme, Task Agreement WP10-PIN-FUSEX
    Ministry of Higher Education, Science and Technology
    Asst. Prof. Saša Novak Krmpotič
12. 7. FP - EURATOM, MHEST Association; Development of Dense Beta-SiC Matrix in 3D Preform - 4.1.1.2. – FU
    Ministry of Education, Science and Sport
    Asst. Prof. Saša Novak Krmpotič
13. 7. FP - EURATOM, MHEST Association; Development of Beta-SiC Fibres with W-CORE SiC Functional Materials - 4.1.1.1. – FU
    Ministry of Education, Science and Sport
    Asst. Prof. Goran Dražić
14. COST MP1005, NAMABIO; From Nano to Macro Biomaterials (Design, Processing, Characterization, Modelling) and Applications to Stem Cells Regenerative Orthopedic and Dental Medicine
    COST Office
    Asst. Prof. Saša Novak Krmpotič
15. MODEF - Creazione e sperimentazione congiunta di modelli per l"ottimizzazione dell"utilizzo di energia fotovoltaica
    Unindustria Rovigo
    Dr. Zoran Samardžija
16. Electron Energy-Loss Spectroscopy of Boron Incorporation in Strontion Aluminate
    Slovenian Research Agency
    Asst. Prof. Sašo Šturm
17. Minerals as a Precursors for Advanced Technologies
    Slovenian Research Agency
    Asst. Prof. Nina Daneu
18. Microstructural Investigation of Materials for Hydrogen Storage and Correlation with Desorption Properties
    Slovenian Research Agency
    Asst. Prof. Sašo Šturm
19. Experimental and Theoretical Investigation of Hydrogen Sorption in Mg-Zr-Fe-Ni and Ti-Fe-Ni Systems
    Slovenian Research Agency
    Dr. Andraž Kocjan
20. NSFM: Novel Smart Filtration Media
    Dr. Kristina Žužek Rožman

RESEARCH PROGRAM

1. Nanostructured Materials
   Prof. Spomenka Kobe

R & D GRANTS AND CONTRACTS

1. New metallic materials for thermal storage of digital information
   Dr. Andraž Kocjan
2. Near-net shape nanoparticle-reinforced polymer-composites for highly-loaded advanced mechanical components with superior tribological performance
   Asst. Prof. Saša Novak Krmpotič
3. Novel functionalized nanomaterials for applications as nano- or biosensors/actuators/bioresponsive (carrier) systems
   Dr. Kristina Žužek Rožman
4. Twinning, epitaxy and phase transformations in minerals
   Asst. Prof. Nina Daneu
5. Electron microscopy and microanalysis of materials on submicrometer scale
   Dr. Zoran Samardžija
6. Hydrothermal synthesis of strongly adhered TiO2 photocatalytic coatings on metallic substrates
   Asst. Prof. Goran Dražić
7. Microbial adhesion management on material surfaces
   Asst. Prof. Goran Dražić
8. Development of the model of the system for intelligent support of the selection of suitable powder material when developing sintered products
   Asst. Prof. Saša Novak Krmpotič
9. Modification of TiO2 nanoparticle surface: prevention of agglomeration and preservation of intrinsic properties
   Asst. Prof. Aleksander Rečnik
10. Innovative production systems for vaccines and regenerative medicine
    Asst. Prof. Aleksander Rečnik
11. Exploration and preservation of mineralogical heritage
    Asst. Prof. Aleksander Rečnik
12. High-coercivity Nd-Fe-B bonded magnets for automotive applications
    Prof. Spomenka Kobe
13. Protected Permanent Magnets for Advanced High-Temperature Applications
    Asst. Prof. Paul John Mcguiness
14. Materials and technologies for applications of ZnO-based thick-film varistors and oxide thermoelectrics
    Asst. Prof. Slavko Bernik
15. Colour, absorption and protective nanolayer coatings for aluminium alloy
    Prof. Miran Čeh

NEW CONTRACTS

1. Cofinancing of the L2-4097 application project: High-coercivity Nd-Fe-B bonded magnets for automotive applications
   Kolektor Group, d. o. o.
   Prof. Spomenka Kobe
2. Cofinancing of the L2-4192 application project: Materials and technologies for applications of ZnO-based thick film varistors and oxide thermoelectrics
   Varsi, d. o. o. and Kekon, d.o.o.
   Asst. Prof. Slavko Bernik

Cofinancing the L2-4099 application project: Protected permanent magnets for advanced high-temperature applications
Magneti Ljubljana, d. d.
Asst. Prof. Paul John McGuiness

VISITORS FROM ABROAD

1. Prof. Jean-Marie Dubois, Institut Jean Lamour, Nancy, France, 17.–22. 2. 2012
2. Prof. Michael Gasik, Aalto University School of Science and Technology, Faculty of Chemistry and Materials Science and Engineering, Espoo, Finland, 15.–17. 4. 2012
3. Süleyman Kahraman, M.Sc., Mustafa Kemal University, Physics Department, Hatay, Turkey, 29. 3.–1. 9. 2012
4. Prof. Jean-Marie Dubois, Institut Jean Lamour, Nancy, France, 26. 4. 2012
5. Prof. Aldo R. Boccaccini, Universität Erlangen, Erlangen, Germany, 6.–11. 5. 2012
6. Prof. Hans Jorg Meisel, BG Clinic Bergmannstrost, Department of Neurosurgery, Halle, Germany, 27.–29. 5. 2012
7. Prof. Mauro Alini, AO Research Institute, Davos Platz, Switzerland, 27.–29. 5. 2012

8. Prof. Thimios Mitsiadis, University of Zürich, Institute of Oral Biology, Zürich, Switzerland, 27.–29. 5. 2012
9. Prof. Andras Dinnyes, BioTalentum Ltd., Godollo, Hungary, 27.–29. 5. 2012
10. Prof. Dinko Mitrečič, School of Medicine, University of Zagreb, Zagreb, Croatia, 27.–29. 5. 2012
11. Prof. Adrian Manescu, Università Politecnica delle Marche, Dip. DISCO, Ancona, Italy, 27.–29. 5. 2012
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14. Prof. Vitor Corello, Department of Polymer Engineering, University of Minho, Caldas das Taipas, Guimarães, Portugal, 27.–29. 5. 2012
15. Prof. Janis Locs, Riga Technical University, Riga Biomaterials Innovation and Development Centre Leading Researcher, Riga, Latvia, 27.–29. 5. 2012
16. Prof. Robert Zorec, Laboratory of Neuroendocrinology - Molecular Cell Physiology, Medical Faculty, University of Ljubljana, Ljubljana, Slovenia, 27.–29. 5. 2012
17. Asst. Prof. Mehmet Ali Gülgün, Melike Mercan Yildizhan, Sabanci University, Istanbul, Turkey, 27. 5.–3. 6. 2012
18. Asst. Prof. Cleva Ow-Yang, Faculty of Engineering and Natural Sciences, Sabanci University, 27. 5.–3. 6. 2012, 24. 10. 2012, 19.–23. 12. 2012
19. Dr. Goran and Dr. Zorica Branković, Institute for Multidisciplinary Research, Belgrade, Serbia, 19.–27. 8. 2012
20. Hattori Yuto, Tokyo Institute of Technology, Tokyo, Japan, 29. 9. 2012–1. 3. 2013
21. Dr. Jelena Pantić, Vinča Institute of Nuclear Sciences, Beograd, Serbia, 9.–14. 9. 2012
22. Dr. Aleksandar Devečerski, Vinča Institute of Nuclear Sciences, Beograd, Serbia, 9.–14. 9. 2012
23. Dr. Branko Matović, Vinča Institute of Nuclear Sciences, Beograd, Serbia, 9.–14. 9. 2012
24. Prof. A. C. Cefalas, National Helenic Research Foundation - NHRF, Athens, Greece, 22.–25. 10. 2012
25. Prof. Dragica Stojić, Vinča Institute of Nuclear Sciences, Beograd, Serbia, 23.–26. 9. 2012
26. Katarina Čirić, Vinča Institute of Nuclear Sciences, Beograd, Serbia, 23.–26. 9. 2012
27. Jana Radaković, Vinča Institute of Nuclear Sciences, Beograd, Serbia, 23.–26. 9. 2012
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32. Dr. Branislav Zlatkov, Volkswagen, Wolfsburg, Germany, 5. 10. 2012
33. Dr. Wolfgang Kochanek, Kochanek Entwicklungsgesellschaft, Neustadt, Germany, 5. 10. 2012
34. Dr Zoran Djinovic, Austrian Center for Medical Innovation and Technology, Wiener Neustadt, Austria, 5. 10. 2012
35. Prof. Rok Romih, Institute of Cell Biology, Medical Faculty, University of Ljubljana, Ljubljana, Slovenia, 24. 10. 2012
36. Dr. Olga Kazakova, National Physical Laboratory, Teddington, United Kingdom, 24. 10. 2012
37. Dr. César de Julián Fernández, CNR - Institute of Molecular Science and Technologies (ISTM), Sesto Fiorentino, Italy, 24. 10. 2012
38. Prof. Josef Vleugels, Katholieke Universiteit Leuven, Leuven, Belgium, 20. 12. 2012
39. Asst. Prof. Mehmet Ali Gülgün, Sabanci University, Istanbul, Turkey, 19.–23. 12. 2012
40. Dr. Anne de Baas, European Coimmission, Brussels, Belgium, 19.–20. 12. 2012
41. Prof. Oliver Gutfleisch, Technische Universität Darmstadt, Darmstadt, Germany, 19.–20. 12. 2012
42. Dr. Nora Dempsey, Institut Néel CNRS/UJF, Grenoble, France, 19.–20. 12. 2012
43. Damien Le Roy, Institut Néel CNRS/UJF, Grenoble, France, 19.–20. 12. 2012
44. Dr. Thomas Schrefl, Fachochschule St. Pölten, St. Pölten, Austria, 19.–20. 12. 2012
45. Prof. Stefano Sanvito, Trinity College Dublin, Dublin, Ireland, 19.–20. 12. 2012
46. Prof. Josef Fidler, Technische University of Wien, Wien, Austria, 19.–20. 12. 2012
47. Dr. Boris Saje, Kolektor Group, d.o.o., Idrija, Slovenia, 19.–20. 12. 2012
48. Dr. Manfred Rührig, Siemens, Erlangen, Germany, 19.–20. 12. 2012
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57. Adjelka Djukić, Vinča Institute of Nuclear Sciences, Beograd, Serbia, 17.–21. 12. 2012

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34. Marko Soderžnik, B. Sc.
35. David Sojer, B. Sc.**
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38. Sanja Fidler, B. Sc.
39. Medeja Gec, B. Sc.

** postgraduate financed by industry

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ORIGINAL SCIENTIFIC ARTICLE

1. Marcela Achimovičová, Francisco Jose Gotor, Concepcion Real, Nina Daneu, "Mechanochemical synthesis and characterization of nanocrystalline BiSe, Bi_2Se_3 semiconductors", *J. mater. sci., Mater. electron.*, vol. 23, no. 10, pp. 1844-1850, 2012.
2. Bojan Ambrožič, Sašo Šturm, Miha Jeršek, Breda Mirtič, "Klasifikacija kamnitih meteoritov in hondrul - primer meteorita Jesenice", *Geologija*, knj. 55, no. 2, pp. 163-180, 2012.
3. Marko Bitenc, Peter Podbrščček, Pavo Dubček, Sigrid Bernstorff, Goran Dražić, Bojan Orel, Zorica Crnjak Orel, "The growth mechanism of zinc oxide and hydrozincite: a study using electron microscopies and in situ SAXS", *CrystEngComm (Camb., Online)*, vol. 14, issue 9, pp. 3080-3088, 2012.
4. Iva Bogdanović-Radović, Maja Buljan, M. Karlušić, N. Skukan, Iva Božičević, Milko Jakšić, Nikola Radić, Goran Dražić, Sigrid Bernstorff, "Conditions for formation of germanium quantum dots in amorphous matrices by MeV ions: comparison with standard thermal annealing", *Phys. rev., B, Condens. matter mater. phys.*, vol. 86, no. 16, pp. 165316-1-165316-8, 2012.
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morphologies and textured assemblages", *J. nanopart. res.*, vol. 14, no. 10, pp. 1150-1-1150-10, 2012.
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