DEPARTMENT FOR NANOSTRUCTURED MATERIALS K-7

One of our biggest advantages is our interdisciplinary team. The basic and applied research of the Department for Nanostructured Materials includes metals, intermetallic alloys, biomaterials, ceramic materials and minerals. Our research encompasses conventional processing as well as the development of new technologies and methods for preparing new materials with advanced 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

Magnetic Materials

One of the research topics of the **Marie Skłodowska-Curie Action European Training Network (DEMETER)** is the **recycling of critical raw materials**. We successfully produced novel permanent magnets based on the recycled Nd-Fe-B and Sm-Co systems. Rare earths such as Nd and Sm, as well as the transition metal Co, are at the top of the global scale for critical raw materials. With the implementation of a novel sintering technique (Spark Plasma Sintering - SPS), we produced **Nd-Fe-B permanent magnets** from recycled powders obtained after HDDR (hydrogenation-disproportionation-decrepitation-recombination) processing. A 30% increase of the initial coercivity (H_c=1190 kA/m), with remanent magnetization B_r = 0.79, and BH_{max} = 110 kJ/m^3 were achieved. The SPS method was also successfully used in the compacting of recycled HD (hydrogenation-decrepitation) powders based on **$SmCo_5$**, where we achieved a coercivity H_c > 1200 kA/m, measured at 180°C, an improvement over the initial powder properties. In the frame of this EU training network, also chemical recycling, i.e., the processing of the rare earth has been investigated. The electrodeposition of Nd and Fe elements from ionic liquids based on 1-ethyl-3-methylimidazole dicyamide was evaluated. We found that Nd can be reduced only in the presence of Fe, which most probably catalyses the further reduction of Nd, and we also proposed an appropriate mechanism.

In 2017, we started with the new **European project AMPHIBIAN** ("AnisoMetric Permanent HybrId magnets Based on Inexpensive And Non-critical materials"). The goal of the project is to achieve an energy product BHmax higher than 50 kJ/m^3. The upper limit so far is 45 kJ/m^3. We are focusing on the preparation of ferrite-based hybrid anisotropic magnets with enhanced magnetic performance, which would be installed in a flywheel (electric energy storage device). Such an achievement would open up an entirely new field of possible applications. The first steps towards achieving this goal were made. We studied systematically the influence of various processing methods on the magnetic properties of Sr-hexaferrite and determined the densification methods. On the basis of the density-functional theory we investigated the stability of magnetic nanostructures by comparing the calculated total energies for various, experimentally possible, configurations. We studied novel Ba-hexaferrite structural variations stabilized on the nanoscale as building blocks for epitaxial bi-magnetic hard/soft sandwiched maghemite/hexaferrite/maghemite nanoplatelets with out-of-plane easy axis and enhanced magnetization.

In collaboration with the Solid State Physics Department we contributed strongly to the prediction of the hyperfine-coupling tensor and quadrupole frequencies for the interpretation of the measured electron-paramagnetic-resonance (EPR) spectra. The results were published in *Nanoscale (IF = 7.4)*.

In the frame of an ARRS post-doc project, we studied the influence of processing parameters on the final magnetic properties of new **permanent magnets based on nanocrystalline $YCo_{4.8}Fe_{0.2}$ grains**. Using metallic binders, we made a magnet that is suitable for recycling after the end of the working cycle. Furthermore, such magnets without heavy rare earth represent a huge market potential. Zn and eutectic Zn/Al-alloy effectively

In the European project REProMag, which ended in 2017, we have successfully achieved the goal of developing a resource-efficient manufacturing route for rare-earth magnets out of recycled magnetic material that allows for the economical and efficient production of net-shape magnetic parts with complex structures and geometries. The new Shaping, Debinding and Sintering (SDS) process, which we developed, is an innovative automated manufacturing route to realize complex 3D and multi-layered parts. First, the recycled magnetic powder is mixed with a patented polymer to achieve a suitable feedstock for different Additive Manufacturing processes, like Metal Injection Moulding (MIM) and 3D printing. After the shaping of the material into a specific form, the polymer binder is removed, and the final green compact is sintered. After the process, the magnet is fully dense and has a magnetic coercivity of H_c = 1120 kA/m, which falls in the same range as conventionally sintered recycled magnets. The project received a prestigious German award for the effective use of raw materials in 2017 (Deutscher Rohstoffeffizienz-Preis 2017), and was also awarded the "Ecotech Award" in Germany.

improve the mechanical properties, i.e., the Vickers hardness, which was comparable to the Nd-Fe-B sintered magnets (460±20 Vickers units). The magnetic measurements in vibrating-sample magnetometer have shown a significant improvement in coercivity from 0.75 T to 0.87 T, which was explained after a thorough microstructural analysis using scanning and transmission electron microscopy. Clusters of ~20-nm $YCo_{4.8}Fe_{0.2}$ grains were surrounded by non-magnetic Zn or Zn/Al alloys, which magnetically isolate the $YCo_{4.8}Fe_{0.2}$ nanograins and suppress the propagation of reverse domains.

We also studied the coercivity of ultra-fast hardened Nd-Fe-B ribbons. Different concentrations of TbF_3 powder were applied to the surface of the Nd-Fe-B ribbons by electrophoretic deposition (EPD) followed by a thermal treatment. Magnetic measurements showed a more than 5% improvement in the coercivity. An important factor leading to the improved coercivity is the high-quality coating, which is the key-factor in the diffusion process taking place at 500 °C to 700 °C.

A novel type of magnet was prepared from a spherical magnetic powder, obtained using inert-gas atomization. The material was successfully consolidated to full density with the SPS technique. Good overall magnetic properties, comparable to other types of isotropic Nd-Fe-B magnets (melt-spun and HDDR-processed materials), were achieved with a combination of sieving and post-consolidation heat treatment. A microscopy study of the raw powder and dense samples was performed. The mechanical properties of the bulk magnets were characterized and compared to other types of Nd-Fe-B magnets, prepared by established manufacturing routes. Another set of experiments was designed with the aim being to develop a new generation of Nd-Fe-B magnets with a reduced amount of critical heavy-rare-earth elements. Bulk magnets with regions containing a Dy-based eutectic alloy were prepared from the HDDR powder. The subsequent heat treatment enabling the diffusion of Dy into the other parts of the sample was achieved by the formation of high-anisotropy regions in the matrix phase. Consequently, the intrinsic coercivity was increased.

Complex Intermetallic Alloys

In the frame of the International Associated Laboratory (LIA) PACS2, which connects CNRS and JSI, we have expanded our studies of the **Al-Cr-Sc system**, resulting in the discovery of two (so far unknown) **ternary phases**. One of them is the Al_8Cr_4Sc phase, which shows similarities to other Al_8Cr_4RE compounds with a tetragonal I4/mmm crystal structure (Figure 1). The second ternary phase has been indexed by the hexagonal prototype crystal structure (space group 194) of $Al_{0.2}Hf_{0.8}Mo_2$.

We have continued our studies of the crystallization mechanisms of a glass prepared by melt-spinning in the **Al-Ce-Fe-Cu** alloys system. Namely, the addition of immiscible Fe and Cu in the stoichiometric $Al_{20.5}Ce_{41.5}(Fe_YCu_{1-Y})_{38}$ alloys have been systematically varied, aiming to trace their impact on the structure, microstructure, thermal properties, and magnetism. While Fe-rich alloys do not completely hinder crystallization and yield nanocrystalline precipitates, Cu-rich alloys are found to be better glass formers. Magnetic measurements show that Fe-rich alloys (y=1, 0.87) are ferromagnetic, while alloys with a lower y value (0 ≤y ≤0.74) exhibit paramagnetic behaviour.

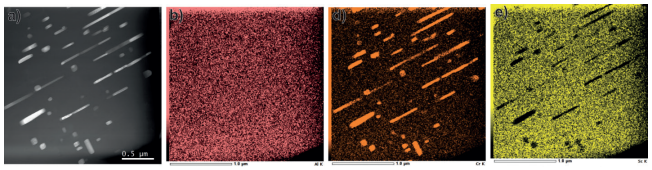

Figure 1: Al-Cr-Sc ternary system: a) High-angle annular dark-field scanning TEM (HAADF-STEM) image of newly discovered hexagonal ternary phase enriched with Al-Cr precipitates. The spatially resolved composition was determined from the elemental energy-dispersive x-ray spectroscopy (EDXS) maps using the following elements: b) Al, c) Cr and d) Sc.

In collaboration with the research team from the Jean Lamour Institute, Nancy, France, we conducted investigations on the Al-Fe-Ir system, where we have successfully identified a new ternary phase with an average composition of $Al_{50}Fe_{32}Ir_{18}$. The crystal structure deduced by XRD corresponds to a face-centred cubic phase, prototype to the $FeRu_2Si$ crystal structure.

In collaboration with the group from the Faculty of Natural Sciences and Engineering (Department of Materials and Metallurgy), we have intensified studies on a potential new family of light alloys based on quasicrystals (QCs) embedded in Al-based alloys. Within this frame we initiated detailed TEM studies of interfacial properties between QCs and the matrix, which control the overall strength, and thus can strongly affect the further development of these high-strength Al-based alloys reinforced with Qc phase appropriate for the automotive and aerospace industries.

Structural Materials

Large efforts are related to the selection and optimization of suitable structural materials capable of withstanding extreme conditions to achieve high efficiency and safe operation of the **future fusion power plants**. One of the key problems is the selection of materials for the **divertor**, which is subjected to very high heat fluxes. The main task of the High-Heat-Flux Materials (HHFM) division within the **EUROfusion program**, in which we are a partner, is thus the development of the components for the DEMO divertor. Tungsten, W, is considered as a primary candidate for high-heat-loaded structural parts in DEMO, mainly due to its very high melting point, good

thermal conductivity and relatively low activation regarding long-term waste management. Unfortunately, these advantages are accompanied by a low fracture toughness in lower temperature regimes and the onset of recrystallization resulting in the loss of strength at high temperatures. We are trying to overcome the disadvantages of pure W by the incorporation of SiC fibres (to increase the fracture toughness) and W2C nanoparticles (to prevent the recrystallization and grain growth of W) into the W matrix. The synthesis and consolidation of W-W2C composites were optimized, and our samples were sent to partner institutions for the measurements of thermal conductivity and mechanical properties at temperatures up to 1000 °C. Additionally, high-heat-flux tests and a determination of the recrystallization temperature are in progress. In 2017 we also started a new Enabling project (part of EUROfusion) in which we want to prepare cemented carbides (WC) with or without a low-activation binder phase. The first part was successfully implemented using SPS as a consolidation method, and in the second we are collaborating with the Institute of Metals and Technology.

Materials for Health and a Clean Environment

In the frame of the national project "Bio-responsive **magneto-optically coupled nanomaterial-based systems** for innovative skin cancer treatments", an innovative theranostic material based on FePt/SiO_2/Au hybrid nanoparticles was developed and its high potential for both, **photo-thermal therapy and magnetic resonance imaging (MRI)** was demonstrated (Figure 2). The cytotoxicity together with the internalization mechanism and the intracellular fate of the hybrid NPs were evaluated in vitro on normal (NPU) and a half-differentiated cancerous cell line (RT4). The control samples, as well as the normal cell line incubated with the nanoparticles, showed no significant temperature increase during the in-vitro photo-thermal treatment ($\Delta T < 0.8$ °C) and thus the cell viability remained high (~90%). In contrast, due to the high nanoparticles uptake by the cancerous RT4 cell line, significant heating of the sample was observed ($\Delta T = 4$ °C) and, consequently, after laser irradiation, cell viability dropped significantly to ~60%. These results further confirm that the hybrid FePt/SiO_2/Au nanoparticles were not only efficient but also highly selective photo-thermal agents. Furthermore, the improvement in the contrast and the easier distinction between the healthy and the cancerous tissues were demonstrated with the in-vitro MRI experiments, proving that hybrid nanoparticles have an excellent potential to be used as a contrast agent.

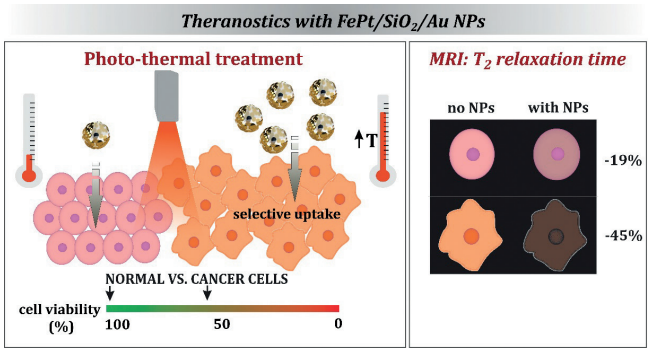

Figure 2: Innovative hybrid FePt/SiO_2/Au NPs as both a highly efficient and selective photo-thermal therapy agent and an MRI contrast agent.

Within the project "Evaluation of possible harmful effects of nanoparticles and underlying mechanisms – from physical-chemical and in vitro toxicity characterization to innate immune system activation" in cooperation with the Faculty of Electrical Engineering, we performed the *characterization* of industrial nanoparticles and their effect on cells.

Research in the field of **biomaterials and three-dimensional (3D)** scaffolds continued with the development of fibroin material and structures for advanced applications in tissue engineering, regenerative medicine, pharmacy, and the preparation of bio-ink for 3D printers. One of the applications is the development of fibroids with enhanced mechanical properties suitable for bone cell growth. We connected more closely with the Slovenian researcher at the Ludwig Boltzmann Institute for Experimental and Clinical Traumatology (LBIT).

With the company Animacel Ltd, we upgraded the cooperation with the successful development of three-dimensional fibroin silk scaffolds, which without the necessary functionalization of the surface of the material caused the osteogenic differentiation of animal stem cells from the fat tissue. Using a scanning electron microscope (SEM), we monitored the behaviour of cells depending on the method of planting (Figure3). Experimental treatments on animals are in progress.

In cooperation with the National Institute for Biology, three-dimensional carriers of natural materials (silk, gel gum, methyl cellulose) were developed, which was the basis for toxicological tests on liver cells. By optimizing the form of the carriers, we achieved improved results in

We pushed the silk fibroin development in the field of pharmacy, more specifically in the field of advanced delivery systems with the controlled release of active substances (estradiol). We studied the interaction of the active substance with the delivery system, the design of the 3D delivery system and the release profile of estradiol in vitro. The project involves the cooperation of the Department for Nanostructured Materials with the Faculty of Pharmacy and the Faculty of Veterinary Medicine.

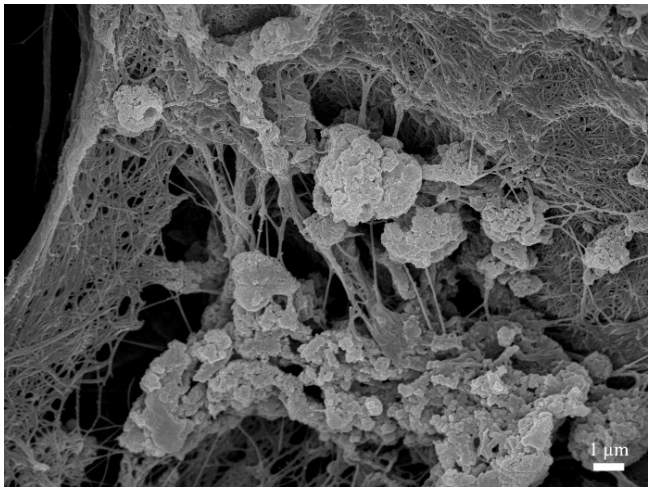

Figure 3: SEM image showing the behaviour of cells depending on the method of planting.

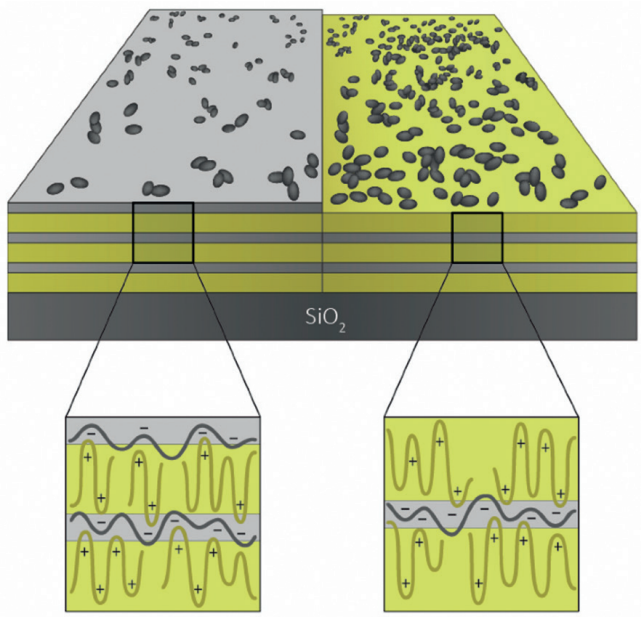

Figure 4: Schematic presentation of PAH/PSS polyelectrolyte multilayers terminating with PSS (6 layers) and PAH (5 layers). 50% less bacteria adhere to a negatively charged surface compared to a positive one.

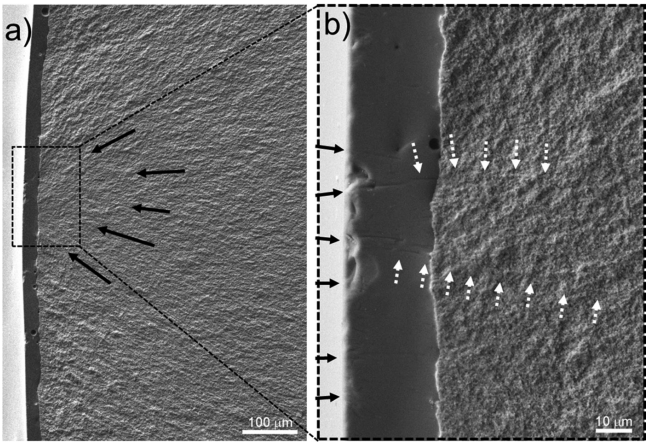

Figure 5: a) Fractographic study of a new generation 3Y-TZP; b) a self-glazed zirconia.

determining the toxicity of substances, as we simulated an appropriate 3D environment, mimicking living tissues.

We continued with the **3D printing of scaffolds for cells** and the development of innovative biological inks. Based on rheological research and the research of mechanical properties, we have developed an improved composite Bio-ink based on silk fibroin and gellan gum. As part of this project, a diploma paper was prepared in cooperation with the Faculty of Natural Sciences and Engineering. In cooperation with the Institute for the Development of Advanced Application Systems, we are developing innovative bio-ink, based on silk fibroin and gelatin, wherein the gelatin represents a carrier phase and support for the silk fibroin during printing.

In collaboration with the Faculty of Health Sciences of the University of Ljubljana, we carried out a series of studies to describe the link between bacterial adhesion *(E. coli, P. aeruginosa, S. aureus and others)* and the surface properties of materials. The influence of the roughness and wetting angle on the adhesion of bacteria was studied on variously treated stainless-steel substrates. It turns out that adhesion is better on surfaces with higher roughness, but the final surface morphology after surface treatment (textured cracks against an electropolished pits with the same roughness) also has a great impact. In the second set of studies, the bacteria adhesion was studied on samples coated with polyelectrolytic layers (poly(allylamine hydrochloride)/sodium poly(4-styrenesulfonate) - PAH/PSS). Samples were prepared with layer-by-layer deposition and terminated with either a positively or negatively charged final layer. It turns out that 50% less bacteria adhere to a negatively charged surface compared to a positive one (Figure 4). Our work was published in *Polymers (IF= 3.34)*.

In the field of **dental ceramics**, we were involved in the research on zirconia (3Y-TZP) as well as other dental materials. We have published several studies in the leading journals for ceramics, dental- and bio-materials; *Journal of the European Ceramic Society, Journal of Prosthodontic Research, Dental Materials*, and *Acta Biomaterialia*. We were reporting on the influence of yttrium-segregation-dependent phase partitioning, residual stresses and airborne-particle abrasion on the aging and fracture behaviour of 3Y-TZP. We have investigated the effect of mechanical fatigue and accelerated aging on the fracture resistance of glazed monolithic 3Y-TZP dental bridges and were involved in a fractographic study of a new generation 3Y-TZP, self-glazed zirconia with improved reliability (Figure 5). A study of the effect of thermo-mechanical cycling on porcelain bonding to Co-Cr and Ti alloys fabricated by casting, milling, and selective laser melting was also performed.

Formaldehyde (HCHO) is one the initial products of the oxidation of methanol, which has technological significance in industrial catalytic processes. However, it has a detrimental impact on human health. We are developing modified printed electrodes via nanostructuring of **the receptor elements based on transition-metal material oxides** that serve as the base for an autonomic sensor platform suitable for in-situ HCHO analytical studies. With applying a novel oxalate-based method, the specific electrochemical surface of the nanostructured Ni was determined for the first time, which represents the basis for investigating the kinetics of the electron-transfer processes. The developed nanostructured NiOOH electrode displays a remarkable electro-catalytic activity for the oxidation of HCHO with 1 µmol/l, which is comparable to the precious metal-based receptor elements, which have until now shown the lowest LODs for formaldehyde detection, but exhibit high prices. The proposed **sensor platform** makes it easy and inexpensive to detect pollution such as formaldehyde in realistic environments.

We continued with the development of innovative reactors for water purification that are based on the process of the **photoelectrocatalysis**. The devices allow for the degradation of organic substances that are potentially present in various wastewaters. Their main part is a photocatalytically active film of titanium oxide nanotubes, which is firmly bound to the titanium metal. The active material is synthesized by the anodic oxidation process. We developed both water-purification and air-purification systems. In the area of water purification, we cooperated with Gorenje d.d. and developed a device that is suitable for photoelectrocatalytic purification of waste water from washing machines. In the field of air purification, we developed photocatalytic devices within the framework of

Climate-KIC accelerator. We were members of the EIT (**European Institute of Technology**) program for the second year for which we were awarded financial support. We presented our air-purification devices at the 10th International Conference on Technology Transfer and won the **award for the best invention for the economy.**

Engineering and Functional Ceramics

The naturally self-driven AlN powder hydrolysis was exploited as an easy and extremely pure synthesis for the preparation of hierarchically assembled, nanocrystalline alumina powder in the form of micron-sized bundles of agglomerated 2D nanosheets, forming flower-like structures. The as-prepared powder was subsequently consolidated to form high-performance hierarchical mesoporous–macroporous alumina monoliths exhibiting exceptionally high flexural strength for an unsintered, porous green body obtained via homogenous, dense packing of the primary crystallites. The work was published in the *Journal of Materials Science*.

When exposed to intense electromagnetic radiation activated by the SPS set-up providing rapid heating, the assembled crystallites were subjected to further agglomeration, coalescence, and sliding. All these effects lead to rapid densification in the absence of extensive diffusional processes, cancelling out the grain growth during the initial sintering stages and providing a zirconia nanoceramic in only 2 minutes at 1300 °C. The work was published in Scientific Reports and announced in the renowned Ceramic Tech Today portal of the American Ceramic Society.

We showed how primary crystallites could be used as the building blocks for homogenous packing and rapid sintering. Namely, the ordered agglomeration of zirconia primary crystallites into secondary particle assemblies ensured their homogeneous packing, while also preserving the high surface energy to higher temperatures, increasing the sintering activity.

In the field of n-type **oxide thermoelectric materials**, we continued with the development of **ZnO-based ceramics**. **In the ZnO-In_2O_3** system, we determined the formation mechanism of $Zn_kIn_2O_{k+3}$-type homologous phases (k = 5, 11, 18) and showed how it affects grain growth, microstructure development, structural and chemical homogeneity, and consequently thermoelectric properties. In the case of **doping with Al**, we found that Al substitutes for In on both primary sites of the $Zn_5(In_{1-x}Al_x)_2O_8$ phase, the octahedral sites in basal-plane inversion boundaries and the trigonal bi-pyramidal sites in zig-zag inversion boundaries. We explained how substitution affects the thermoelectric characteristics.

In the field of **thermoelectrics**, we continued with studies of nanostructure and thermoelectric properties of n-type thermoelectric materials based on **Sr(Ti,Nb)O3**. The addition of various oxides to this structure caused the formation of a three-dimensional network of Rudlesden-Popper-type planar faults. The random stacking of planar faults increased the phonon scattering and lowered the thermal conductivity. Consequently, the material exhibited **an increased figure of merit ZT**.

In ZnO doped with low amounts of Ga, we found that non-periodic planar (2D) defects are formed already in amounts up to 1 at. %. They cause a strong phonon scattering and hence reduced thermal conductivity, while the electrical conductivity is preserved (article in ***Inorganic Chemistry, IF = 4.85***). We also studied the influence of selected dopants and sintering conditions on the **equilibria of defects and the thermoelectric properties of ZnO-based ceramics**. We found that under reductive sintering atmosphere and with SPS processing, the solid solubility of the donor dopant (Al^{3+}, Ti^{4+}) in ZnO grains is increased, while the presence of acceptor defects and hence Schottky barriers at the grain boundaries is eliminated, resulting in an increase of the electrical conductivity by several orders of magnitude. Furthermore, the increased concentration of point defects in ZnO grains results in reduced thermal conductivity. In the article *(Materials & Design, IF = 4.364)*, we explained the possibilities to enhance the thermoelectric properties of ZnO-based ceramics using the engineering of point defects.

In the nano area of ZnO, we exploited a cost-efficient hydrothermal synthesis to produce arrays of ZnO nanowires (NWs) with a high surface area. We showed, for the first time, that a thin carbon nitride (CN) layer can efficiently extract holes from ZnO, which leads to enhanced performance and stability in an alkaline solution. Detailed photoelectrochemical (PEC) characterization reveals that the CN acts as a protective shell and at the same time facilitates a hole transfer from ZnO-NWs to the electrolyte. We managed to increase the current densities by several times as compared to the pristine ZnO-NWs.

Within the frame of the collaboration with the research group from Vinča Institute of Nuclear Sciences, Belgrade, Serbia, we have studied the connection between the absorption kinetics and the structural and chemical **properties of the MgH2 thin films, as a potential hydrogen-storage material.** Processes taking place during hydrogen desorption from MgH_2 thin films were investigated in as-prepared samples and samples modified by argon-ion irradiation. Irradiation was used to produce well-defined defects with an in-depth distribution (Figure 6). It was shown that the size, shape,

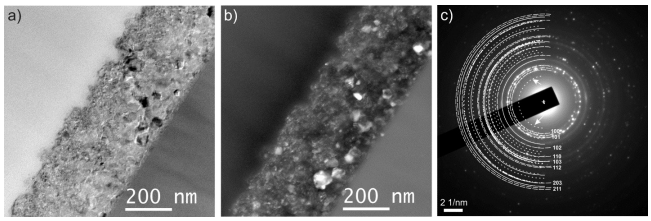

Figure 6: Magnesium hydride thin films: a) Bright-field and b) the corresponding dark-field transmission electron microscopy (TEM) image of the irradiated film. c) The selected-area electron diffraction (SAED) pattern acquired from the irradiated film, showing the presence of MgH_2 (short dashed line), MgO (full line) and Mg (long dashed line) phases.

and concentration of Mg nuclei formed during the hydrogen desorption from the MgH_2 thin films depend on the characteristics and distribution of the induced defects. Variations in sample colour were observed during hydrogen desorption and before the creation of the Mg nuclei. In relation to this, the DFT calculations showed that the observed variations in the optical properties of the samples can be explained by changes in the MgH_2 electronic structure.

Minerals

Within the basic research project "Initial stages of phase transformations in minerals" and different bilateral projects, we continued our investigations of growth-type planar defects in minerals. We studied the mechanisms of their formation, their atomic-scale structure and chemical composition and effects on crystal growth and microstructure development in different minerals and functional ceramic materials. The main topics of our research were: (1) twinning in cassiterite and the synthesis of SnO_2-based ceramics for varistor applications, (2) growth and twinning of rutile TiO_2 according to the principles of mesocrystals self-assembly, (3) growth defects in hydrothermally prepared crystals and (4) characterization of nanomaterials for different applications.

Cassiterite (SnO_2) is a technologically important material, which occurs in nature in the form of (101) twins. We have successfully synthesized SnO_2-based varistor ceramics with excellent nonlinearity and a low leakage current by the optimization of CoO and Nb_2O_5 additions and the sintering conditions. The addition of both aliovalent dopants in a suitable ratio results in their synergistic effect on densification and SnO_2 grain growth, leading to ceramics with almost theoretical density (>99%). The addition of Nb_2O_5, on the other hand, triggers the formation of numerous (101) twins within the SnO_2 grains, which have an important effect on the microstructure development in SbO_2-based ceramics and hence electrical properties. The formation of twin boundaries was explained by a series of topotaxial reactions in the initial growth stages due to the addition of Nb_2O_5. The local structure and chemical composition of the twin boundaries was analysed by different methods of electron microscopy. The results of this work are published in *Ceramics International (IF=2.986)*.

In collaboration with our colleagues from the Sobolev Institute for Geology and Mineralogy, we analysed the growth defects in hydrothermally prepared crystals of beryl and sapphire. The preparation of gem-quality crystals is by epitaxial growth on an oriented crystal seed. During the initial stages of crystal growth (close to the seed), defects are observed in the newly formed crystal. These defects were analysed by transmission electron microscopy and the results were published in *Crystal Growth and Design (IF= 4.055) and CrystEngComm (IF=3.474)*.

Analytical Electron Microscopy

For the microstructural characterization of modern materials, we have applied advanced high-resolution scanning electron microscopy (FEGSEM) and analytical methods of energy-dispersive and wavelength-dispersive spectroscopy (EDS, WDS) for qualitative and quantitative elemental analysis. With the implementation of the method of electron backscatter diffraction (EBSD), we have investigated the crystallographic characteristics of the materials: crystallinity, orientation of phases and texture.

The FEGSEM, EDS, WDS and EBSD methods were modified and optimized taking into account the specificity of the individual materials, with the aim being to achieve the most precise and accurate analytical results. By implementing correlative microscopy, i.e., by using an optimum combination of FEGSEM, AFM, EDS, WDS and EBSD methods and taking into account the characteristics of the individual materials, we achieved reliable, precise and accurate analytical results. We studied various materials such as ceramic thermoelectrics, complex metallic and quasicrystalline alloys, magnetic materials based on Nd-Fe-B, abrasives, piezoelectric perovskite ceramics. Among other things, we examined the influence of heat treatment on the microstructure and phase composition in alloys based on Al-Fe-Cu-Ce/Gd and Al-Cr-Sc. Using the microcrystallographic EBSD analysis, we directly confirmed the presence of icosahedral and decagonal quasicrystals in complex alloys based on Al-Mn-Cu-Mg/Si.

The ESTEEM (Enabling Science and Technology through European Electron Microscopy) consortium continued its activities in the field of materials characterization using state-of-the-art techniques of transmission electron microscopy, such as electron energy-loss spectroscopy (EELS), high-resolution scanning transmission electron microscopy (STEM, HAADF-STEM) and mechanical preparation of the TEM samples. The ESTEEM consortium has a status of EU Advanced Community, and a lot of effort was focused on the preparation of a new project proposal for ESTEEM3. The implementation of various electron microscopy analytical techniques and the possibility for the researchers to access research infrastructure for electron microscopy within the **Center for Electron Microscopy and Microanalysis (CEMM)** is of utmost importance for the research group. A member of our department is the scientific coordinator of the consortium.

Industrial partners

We have conducted analyses of innovative composite abrasives for industrial partner SwatyComet within the project "Microstructural investigations of abrasive materials", which are intended to develop and manufacture improved cutting and grinding tools with a prolonged lifetime.

Education and outreach activities

For the fifth year, the members of the department participated in science promotion activities within the framework of the Science on the Street project, which was held under the auspices of the SATENA Society. There were two cycles of popular science lectures, two science slams, and a round table.

Awards and appointments

1. Luka Suhadolnik and Miran Čeh, Best Innovation Award at the 10th International Conference on Technology Transfer, IJS, Ljubljana, Slovenia, 9–13 October 2017
2. Matej Kocen, Best Oral Presentation Award at the 25th International Conference on Materials and Technology, 25 ICM&T, Portorož, Slovenia, 16–19 October 2017 for the contribution "Inhibition of W grain growth in W-based material for fusion application (CM)" (co-authors: Petra Jenuš, Saša Novak, Andreja Šestan).
3. Rok Kocen, Best Scientific Presentation Award at the Joint Students' Conference of the Jožef Stefan International Postgraduate School and Young Researchers Day in the field of Chemistry, Materials, Biochemistry and Environment at the Jožef Stefan Institute for the contribution »3D printing biomaterials for regenerative medicine«, Ljubljana, 19–20 April 2017
4. Rok Kocen, "Science in front of the Microphone" Award given by SATENA - Slovenian Academic Society for Science and Engineering for the Best short presentation of PhD Thesis at the Joint Students' Conference of the Jožef Stefan International Postgraduate School and Jožef Stefan Institute, Ljubljana, 19 April 2017
5. Kristina Žužek Rožman, Finalist for the Best Mentor 2016 Award, given by Young Academy Association in cooperation with the Slovenian Research Agency (ARRS), Ljubljana, Slovenia, 22 March 2017

Organization of conferences, congresses and meetings

1. Project Meeting H2020 REProMag; Resource Efficient Production Route for Rare Earth Magnets, Ljubljana, Slovenia, 10 January 2017
2. The 2nd Slovene Microscopy Symposium, 11–12 May 2017, Piran, Slovenia (co-organisers)
3. The 13th Multinational Congress on Microscopy; MCM 2017, Rovinj, Croatia, 24–26 September 2017 (members of the International Advisory Board)
4. The 25th International conference on Materials and Technology – 25. ICM&T, 16–19 October 2017, Portorož, Slovenia (co-organisers)
5. Annual meeting within of LIA PACS2: International Associated Laboratory; Push-Pull AlloyS and Complex Compounds: from bulk properties to surface functions, 11–13 December 2017, Goriška Brda, Slovenia
6. Annual Meeting of Slovenian Fusion Association - SFA, Podgorica, Slovenia, 13 December 2017 (co-organisers)

INTERNATIONAL PROJECTS

1. Selective Laser Melting (SLM) and Spark Plasma Sintering (SPS) of Cost Effective Rare-earth based Permanent Magnets for Electrical Machines
   Prof. Spomenka Kobe
   ABB Switzerland Ltd
2. Spark Plasma Sintering (SPS) of Cost Effective and High Performance Rare-Earth Based Permanent Magnets for Electrical Machines
   Prof. Spomenka Kobe
   ABB Switzerland Ltd
3. 7 FP; ERA CHAIR ISO-FOOD - Era Chairs for Isotope Techniques in Food Quality, Safety and Traceability
   Prof. Saša Novak Krmpotič
   European Commission
4. COST MP1301 - NEWGEN; New Generation Biomimetic and Customized Implants for Bone Engineering
   Prof. Saša Novak Krmpotič
   Cost Office
5. COST ES1205; The Transfer of Engineered Nanomaterials from Wastewater Treatment & Stormwater to Rivers
   Prof. Saša Novak Krmpotič
   Cost Office
6. COST MP1407 - e-MINDS; Electrochemical Processing Methodologies and Corrosion Protection for Device and Systems Miniaturization
   Asst. Prof. Kristina Žužek Rožman
   Cost Office
7. H2020 - REProMag; Resource Efficient Production Route for Rare Earth Magnets
   Dr. Benjamin Podmiljšak
   European Commission
8. H2020 - DEMETER; Training Network for the Design and Recycling of Rare-Earth Permanent Magnet Motors and Generators in Hybrid and Full Electric Vehicles
   Asst. Prof. Kristina Žužek Rožman
   European Commission
9. H2020 - STEM4youth; Promotion of STEM Education by Key Scientific Challenges and their Impact on Our Life and Career Perspectives
   Dr. Kristina Žagar Soderžnik
   European Commission
10. H2020 - AMPHIBIAN; Antisometric Permanent Hybrid Magnets based on Inexpensive and Non-Critical Materials
    Dr. Petra Jenuš Brdnik
    European Commission
11. H2020 EUROfusion - Materials-PPPT-FU: WC and SiC reinforced tungsten
    Prof. Saša Novak Krmpotič
    European Commission
12. H2020 EUROfusion - Education-ED-FU
    Prof. Saša Novak Krmpotič
    European Commission
13. H2020 EUROfusion - ER-4-FU; Enabling Research: Low-activation cemented carbides for high heat flux applications
    Prof. Saša Novak Krmpotič
    European Commission
14. Advanced Methods and Technologies for Processing of a New Generation of ZnO-based Varistor Ceramics
    Prof. Slavko Bernik
    Chinese Academy of Sciences
15. Electron Microscopy Study of the Degradation Kinetics of Porous Bioactive Glass based Novel Drug Eluting Implants (Coating/3D Scaffolds) as a Function of Hard Tissue Regeneration for Treatment of Osteoporotic Fractures in Elderly Patients
    Asst. Prof. Nina Daneu
    Slovenian Research Agency
16. Nucleation and Photocatalytic Activity of Nanoparticles Studied in Actual Liquid Environment under Transmission Electron Microscope
    Prof. Sašo Šturm
    Slovenian Research Agency

17. 0D to 3D ZnO Nanostructures for Optical, Electonic and Energy Applications
    Dr. Matejka Podlogar
    Slovenian Research Agency
18. Synthesis of Core/Shell MgAl2O4 Spinel Powders for Transparent Armor and IR Applications – CSMASP
    Prof. Slavko Bernik
    Slovenian Research Agency
19. Processing of High-performance Zirconia Bioceramics for Dental Application
    Asst. Prof. Andraž Kocjan
    Slovenian Research Agency
20. Investigations of Twinning and Topotaxial Reactions in Sulphide Minerals
    Prof. Aleksander Rečnik
    Slovenian Research Agency
21. Crystal and Electronic Structure of NbS3 Phases
    Prof. Sašo Šturm
    Slovenian Research Agency
22. Crystallography, Twinning and Phase Transformations in Minerals with Aragonite-Type Structure ($CaCO_3$, $SrCO_3$, $BaCO_3$, $PbCO_3$)
    Prof. Aleksander Rečnik
    Slovenian Research Agency
23. Characterization of Structural Defects in Semiconductor ZnO Films Grown by Atomic Layer Deposition (ALD)
    Prof. Aleksander Rečnik
    Slovenian Research Agency
24. Advanced Electronic Ceramics for the Sustainable, Efficient and Safe Use of Energy
    Prof. Slavko Bernik
    Slovenian Research Agency
25. Hydrous Defects and Twinning in Silicates
    Asst. Prof. Nina Daneu
    Slovenian Research Agency
26. Tungsten-Based Composite for Fusion Applications
    Prof. Saša Novak Krmpotič
    Slovenian Research Agency
27. Atomic-Scale Investigations of Twinning and Polytypism in Natural Diamonds
    Prof. Aleksander Rečnik
    Slovenian Research Agency

RESEARCH PROGRAMS

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

R & D GRANTS AND CONTRACTS

1. Structure and Chemical Composition Study of Surfaces and Interfaces with Highresolution Scanning Transmission Electron Microscopy at Atomic Level
   Prof. Aleksander Rečnik
2. High-Performance Nanostructured Coatings - breakthrough in concentrated solar power
   Asst. Prof. Andraž Kocjan
3. Evaluation of possible harmful effects of nanoparticles and underlying mechanisms – from physico-chemical and in vitro toxicity characterisation to innate immune system activation
   Prof. Saša Novak Krmpotič
4. Atomic-scale studies of initial stages of phase transformations in minerals
   Asst. Prof. Nina Daneu
5. Bio-responsive magneto-optically coupled nanomaterial-based systems for innovative skin cancer treatments
   Prof. Sašo Šturm
6. W- and WC-based composites for high thermally loaded parts in the fusion demonstration power plant DEMO
   Prof. Saša Novak Krmpotič
7. Catalytically-assisted high efficiency and low-cost nanostructured sensors based on modified screen printed electrodes for analytical chemistry
   Asst. Prof. Kristina Žužek Rožman
8. UV sensors nanoparticles embedded into PA fibres
   Prof. Spomenka Kobe
9. From the synthesis of metal oxides to the humidity and oxygen prototype nanosensors
   Dr. Kristina Žagar Soderžnik
10. High-coercivity Nd-Fe-B permanent magnets with minimum amount of heavy rare earths
    Dr. Marko Soderžnik
11. Microscopy and microanalyses
    Dr. Zoran Samardžija
12. Technical ceramics
    Asst. Prof. Andraž Kocjan

NEW CONTRACTS

1. Research and development of dental materials
   Dr. Nataša Drnovšek, Asst. Prof. Andraž Kocjan
   Ustna Medicina d. o. o.
2. Microstructural investigations of abrasive materials
   Dr. Zoran Samardžija
   Swatycomet d. o. o.
3. Preparation of microvaristor powder for composites with nonlinear resistivity
   Prof. Slavko Bernik
   Razvojni Center Enem Novi Materiali d. o. o.
4. Photo(electro)catalytic cleaning of washing machine waste water
   Prof. Miran Čeh
   Gorenje gospodinjski aparati,d.d.
5. Analysing the effect of mechanical fatigue of ZrO_2 dental root posts
   Asst. Prof. Andraž Kocjan
   Vall-cer d. o. o.
6. Preliminary study of processing the varistor ceramics using tape casting
   Prof. Slavko Bernik
   Keko - Oprema d. o. o. Žužemberk
7. TiO_2 pigment
   Prof. Saša Novak Krmpotič
   Cinkarna Celje

VISITORS FROM ABROAD

1. Prof. Andrzej Dziedzic, Wrocław University of Science and Technology, Wrocław, Poland, 5–7 January 2017
2. Dr. Pavel Gavryushkin, Sobolev Institute of Geology and Mineralogy, Novosibirsk, Russia, 24–31 January 2017
3. Dr. Taisia Aleksandrovna Alifirova, Novosibirsk State University, Novosibirsk, Rusija, 7 February – 3 March 2017
4. Dr. Richard Wheeler, Edinburgh Scientific, Edinburgh, Scotland, 26 February–8 March 2017
5. Dr. Anouk Galtayries, Institut de Recherche de Chimie Paris, Paris, France, 3 March 2017
6. Dr. Matic Krivec, CTR Carinthian Tech Research AG, Villach, Austria, 21 March 2017
7. Dr. Tassilo Moritz, Fraunhofer-Institut für Keramische Technologien und Systeme IKTS, Dresden, Germany, 3 April 2017
8. Vesna Ribić, Institute for Mutidisciplinary Research, Belgrade, Serbia, 10 March – 13 April 2017
9. Martina Orefice, Katholieke Universiteit Leuven, Leuven, Belgium, 9 February – 12 April 2017
10. Juliane Moritz, University of Dresden, Dresden, Germany, 1 April – 30 September 2017
11. Dr. Ulrike Wolf, Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Dresden, Germany, 5–14 April 2017
12. Dr. José Alberto Padrón, Geosciences Montpellier, Université de Montpellier, Montpellier, France, 1– 14 April 2017
13. Dr. Julian Ledieu, Institut Jean Lamour, Nancy, France, 24–28 April 2017
14. André Baldissera, Universidade Federal de Santa Catarina - UFSC, Florianópolis, Brazil, 3–5 May 2017
15. Dr. Michael Ortner, Georg Franz, CTR Carinthian Tech Research in Technical Innovation Physical Solutions, Villach, Austria, 5 May 2017
16. Vesna Ribić, Institute for Mutidisciplinary Research, Belgrade, Serbia, 10–12 May 2017
17. Dr. Victor Gabrielevich Thomas, Sobolev Institute of Geology and Mineralogy, Novosibirsk, Russia, 13–28 May 2017
18. Dr. Richard Wheeler, Edinburgh Scientific, Edinburgh, Scotland, 2–15 June 2017
19. Laura Treccani in Paolo Vavassori, Petroceramics S.p.A, Bergamo, Italy, 9 June 2017
20. Prof. Guorong Li, Shanghai Institute of Ceramics, Shanghai, China, 9–13 June 2017
21. Dr. Goran **Štefanić** and Valentina Borko, Rudjer Bošković Institute, Zagreb, Croatia, 14–18 June 2017
22. Prof. Emmanuel Guilmeau, Laboratorie CRISMAT, Caen, France, 18–20 July 2017
23. Fabian Burkhardt, University of Applied Sciences Aalen, Aalen, Germany, 30 July – 30 September 2017
24. Pierre-Louis Julliard, École nationale supérieure des mines de Nancy, Nancy, France, 1–31 August 2017
25. Prof. Carlo Burkhardt, OBE Ohnmacht & Baumgartner GmbH & Co. KG, Ispringen, Germany, 30 August– 2 September 2017
26. Dr. Martina Lorenzetti, GE Healthcare, Cardiff, United Kingdom, 11 September 2017
27. Dr. Goran Branković, Dr. Danijela Luković Golić, Jelena Vukašinović and Vesna Ribič, Institute for Mutidisciplinary Research, Belgrade, Serbia, 18–22 September 2017
28. Prof. Zhijian Shen, University of Stockholm, Department of Materials and Environmental Chemistry, Stockholm, Sweden, 2–3 October 2017
29. Robert Ireson, GTS Glass Tehnologies Services Ltd., and Sarrawat Rehman, JRI Orthopaedics Ltd., Sheffield, United Kingdom, 4– 5 October 2017
30. Dr. Ildikó Cora and Dr. Zsolt Fogarassy, Hungarian Academy of Sciences, Institute of Technical Physics and Materials Science, Budapest, Hungary, 2–9 October 2017

31. Dr. Ulrike Wolf, Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Dresden, Germany, 3 October – 3 November 2017
32. Jelena Vukašinović, Institute for Multidisciplinary Research, Belgrade, Serbia, 9–12 October 2017
33. Blanca Malavé Alvarez, Universidad Rey Juan Carlos, Madrid, Spain, 17 October – 18 February 2018
34. Prof. Mehmet Ali Gülgün, FENS, Sabanci University, Istanbul, Turkey, 4–11 November 2017
35. Dr. José Alberto Padrón-Navarta, Géosciences Montpellier, Université de Montpellier, Montpellier, France, 11–18 November 2017
36. Prof. Michael Gasik, Aalto University, Espoo, Finland, 26–28 November 2017
37. Fabian Burkhardt, University of Applied Sciences Aalen, Germany, 10–12 December 2017

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Researchers
1. Prof. Slavko Bernik
2. Prof. Miran Čeh
3. Asst. Prof. Nina Daneu
4. Prof. Jean Marie Dubois
5. **Prof. Spomenka Kobe, Head**
6. Asst. Prof. Andraž Kocjan
7. Asst. Prof. Matej Andrej Komelj
8. Prof. Saša Novak Krmpotič
9. Dr. Benjamin Podmiljšak
10. Prof. Aleksander Rečnik
11. Dr. Zoran Samardžija
12. Prof. Sašo Šturm
13. Dr. Kristina Žagar Soderžnik
14. Asst. Prof. Kristina Žužek Rožman

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15. Dr. Anže Abram
16. Dr. Nataša Drnovšek
17. Dr. Ana Gantar
18. *Dr. Aljaž Iveković, on leave 01.03.16*
19. Dr. Petra Jenuš Brdnik
20. Dr. Nina Kostevšek
21. Dr. Matejka Podlogar
22. Dr. Marko Soderžnik

Postgraduates
23. Bojan Ambrožič, B. Sc.
24. Anja Drame, B. Sc.
25. *Dr. Sandra Drev, 19.09.17, transferred to Department CEMM*
26. Hermina Hudelja, B. Sc.
27. Awais Ikram, B. Sc.
28. Vanja Jordan, B. Sc.
29. Luka Kelhar, B. Sc.
30. Matej Kocen, B. Sc.
31. *Dr. Rok Kocen, left 01.12.17*
32. Matic Korent, B. Sc.
33. Ana Lazar, B. Sc.
34. Živa Marinko, B. Sc.
35. Muhammad Farhan Mehmood, B. Sc.
36. Luka Suhadolnik, B. Sc.
37. Sara Tominc, B. Sc.
38. Tomaž Tomše, B. Sc.
39. Špela Trafela, B. Sc.
40. Xuan Xu, B. Sc.

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41. Sanja Fidler, B. Sc.

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43. *Teja Đukić, left 30.09.17*
44. Darko Eterović
45. Tomislav Pustotnik

BIBLIOGRAPHY

Original Article

1. Marcela Achimovičová, Nina Daneu, Erika Dutková, Anna Zorkovská, "Mechanochemically synthesized cobalt monoselenide: structural characterization and optical properties", *Appl. phys., A, Mater. sci. process.*, **123**, 3, 154, 2017.
2. Muhammad Shahid Arshad, Špela Trafela, Kristina Žužek Rožman, Janez Kovač, Petar Djinović, Albin Pintar, "Determination of Schottky barrier height and enhanced photoelectron generation in novel plasmonic immobilized multisegmented (Au/TiO_2) nanorod arrays (NRAs) suitable for solar energy conversion applications", *J. mater. chem. C*, **5**, 40, 10509-10516, 28 Oct. 2017.
3. Matej Baláž, L'udmila Balážová, Nina Daneu, Erika Dutková, Miriama Balážová, Zdenka Bujňáková, Yaroslav Shpotyuk, "Plant-mediated synthesis of silver nanoparticles and their stabilization by wet stirred media milling", *Nanoscale res. lett.*, **12**, 83, 2017.
4. Matej Baláž, Nina Daneu, L'udmila Balážová, Erika Dutková, L'udmila Tkáčiková, Jaroslav Briančin, Mária Vargová, Miriama Balážová, Anna Zorkovská, Peter Baláž, "Bio-mechanochemical synthesis of silver nanoparticles with antibacterial activity", *Adv. powder technol.*, **28**, 12, 3307-3312, 2017.
5. Matej Baláž, Anna Zorkovská, Javier S. Blazquez, Nina Daneu, Peter Baláž, "Mechanochemistry of copper sulphides: phase interchanges during milling", *J. Mater. Sci.*, **52**, 20, 11947-11961, 2017.
6. Blaž Belec, Goran Dražić, Sašo Gyergyek, Benjamin Podmiljšak, Tanja Goršak, Matej Komelj, Julio J. Nogués, Darko Makovec, "Novel Ba-hexaferrite structural variations stabilized on the nanoscale as building blocks for epitaxial bi-magnetic hard/soft sandwiched maghemite/hexaferrite/maghemite nanoplatelets with out-of-plane easy axis and enhanced magnetization", *Nanoscale*, **9**, 44, 17551-17560, 2017.
7. Slavko Bernik, Matejka Podlogar, Saša Rustja, Mirjam Cergolj, "Influence of granulate and pressure on green compacts and the current-voltage characteristics of sintered ZnO-based varistor ceramics", *Inf. MIDEM*, **47**, 3, 171-177, 2017.
8. Ester Borroni, Marta Miola, Sara Ferraris, Giulia Ricci, Kristina Žužek Rožman, Nina Kostevšek, Angela Catizone, Lia Rimondini, Maria Prat, Enrica Verné, Antonia Follenzi, "Tumor targeting by lentiviral vectors combined with magnetic nanoparticles in mice", *Acta biomaterialia*, **59**, 303-316, 2017.
9. Dušan Bučevac, Tomaž Kosmač, Andraž Kocjan, "The influence of yttrium-segregation-dependent phase partitioni ng and residual stresses on the aging and fractur e behaviour of 3Y-TZP ceramics", *Acta biomaterialia*, **62**, 306-316, 2017.
10. Carlo Burkhardt, Oxana Weber, Benjamin Podmiljšak, Joamin Gonzalez-Gutierrez, Christian Kukla, Malik Degri, Ivor Rex Harris, Allan Walton, "Isotropic NdFeB hard magnets production using recycled: MIM production using recycled powders with and without Nd additions", *Powder inject. mould. int.*, **11**, 4, 75-80, 2017.
11. Enrico Catalano, Marta Miola, Sara Ferraris, Saša Novak, Francesca Oltolina, Andrea Cochis, Maria Prat, Enrica Verne, Lia Rimondini, Antonia Follenzi, "Magnetite and silica-coated magnetite nanoparticles are highly biocompatible on endothelial cells in vitro", *Biomed. phys. eng. express*, **3**, 2, 025015, 2017.
12. Jasna Cotič, Peter Jevnikar, Andraž Kocjan, "Ageing kinetics and strength of airborne-particle abraded 3Y-TZP ceramics", *Dent Mater*, **33**, 7, 847-856, 2017.
13. Rok Fink, Denis Okanovič, Goran Dražić, Anže Abram, Martina Oder, Mojca Jevšnik, Klemen Bohinc, "Bacterial adhesion capacity on food service contact surfaces", *Int. j. environ. health res.*, **27**, 3, 169-178, 2017.
14. Viviana Golja, Goran Dražić, Martina Lorenzetti, Janja Vidmar, Janez Ščančar, Maša Zalaznik, Mitjan Kalin, Saša Novak, "Characterisation of food contact non-stick coatings containing TiO_2 nanoparticles and study of their possible release into food", *Food addit. contam., Part A, Chem. anal. control expo. risk assess.*, 3, **34**, 421-433, 2017.
15. Emmanuel Guilmeau, Pablo Diaz-Chao, Oleg I. Lebedev, Aleksander Rečnik, Marion C. Schäfer, Fabian Delorme, Fabien Giovannelli, Mateja Košir, Slavko Bernik, "Inversion boundaries and phonon scattering in Ga:ZnO thermoelectric compounds", *Inorg. chem.*, **56**, 1, 480-487, 2017.
16. Matylda N. Guzik, Karol M. Golasiński, F. Javier Pedrosa, Petra Jenuš, Alberto Bollero, Bjørn C. Hauback, Stefano Deledda, "Influence of ultra-short cryomilling on the microstructural and magnetic properties of cobalt ferrite", *J. alloys compd.*, **721**, 440-448, 2017.
17. Špela Hajduk, Sean P. Berglund, Matejka Podlogar, Goran Dražić, Fatwa F. Abdi Abdi, Zorica Crnjak Orel, Menny Shalom, "Conformal carbon nitride coating as an efficient hole extraction layer for ZnO nanowires-

based photoelectrochemical cells", *Advanced materials interfaces*, **4**, 24, 1700924, Dec. 2017.
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19. László Janovák, Ágota Deák, Szabolcs Péter Tallósy, Dániel Sebök, Edit Csapó, Klemen Bohinc, Anže Abram, István Pálinkó, Imre Dékány, "Hydroxyapatite-enhanced structural, photocatalytic and antibacterial properties of photoreactive TiO[sub]2/HAp/polyacrylate hybrid thin films", *Surf. coat. technol.*, **326**, part A, 316-326, oct. 2017.
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22. Rok Kocen, Michael Gasik, Ana Gantar, Saša Novak, "Viscoelastic behaviour of hydrogel-based composites for tissue engineering under mechanical load", *Biomedical materials*, **12**, 2, 025004, 2017.
23. Andraž Kocjan, Luka Kelhar, Anton Gradišek, Blaž Likozar, Kristina Žagar, Jaafar Ghanbaja, Spomenka Kobe, Jean-Marie Dubois, "Solid solubility in $Cu_5Gd_{1-x}Ca_x$ system: structure, stability, and hydrogenation", *Adv. Mater. Sci. Eng.*, **2017**, 9203623, 2017.
24. Andraž Kocjan, Thomas Konegger, Aleš Dakskobler, "Hierarchical macroporous-mesoporous γ-alumina monolithic green bodies with high strength", *J. Mater. Sci.*, **52**, 19, 11168-11178, 2017.
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26. Mateja Košir, Miran Čeh, Cleva Ow-Yang, Emmanuel Guilmeau, Slavko Bernik, "Structural features and thermoelectric properties of Al-doped $(ZnO)_5In_2O_3$ homologous phases", *J. Am. Ceram. Soc.*, **100**, 8, 3712-3721, 2017.
27. Mateja Košir, Matejka Podlogar, Nina Daneu, Aleksander Rečnik, Emmanuel Guilmeau, Slavko Bernik, "Phase formation, microstructure development and thermoelectric properties of $(ZnO)_kIn_2O_3$ ceramics", *J. Eur. Ceram. Soc.*, **37**, 8, 2833-2842, 2017.
28. Matic Krivec, Ali Roshanghias, Anže Abram, Alfred Binder, "Exploiting the combination of 3D polymer printing and inkjet Ag-nanoparticle printing for advanced packaging", *Microelectron. eng.*, **176**, 1-5, 2017.
29. Daniel Kytýř, Nela Fenclová, Petr Zlámal, Ivana Kumpová, Tomáš Fíla, Petr Koudelka, Ana Gantar, Saša Novak, "Time-lapse micro-tomography analysis of the deformation response of a gellan-gum-based scaffold", *Mater. tehnol.*, **51**, 3, 397-402, 2017.
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37. Emina Požega, Pantelija Nikolić, Slavko Bernik, Lidija Gomidželović, Nenad Labus, Milan Radovanović, Saša Marjanović, "Síntesis e investigación del mono cristal BiSBTeSe dopado con Zr obtenido mediante el método de Bridgman", *Rev. metal. (Madr.)*, **53**, 3, e100, 2017.
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39. Matthias Schrade *et al.* (13 authors), "The role of grain boundary scattering in reducing the thermal conductivity of polycrystalline X NiSn (X = Hf, Zr, Ti) half-Heusler alloys", *Sci. rep.*, **7**, 13760, 2017.
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MENTORING

1. Anže Abram, *Synthesis and characterization of hydrothermally treated and functionalised zinc and aluminium surfaces:* doctoral dissertation, Ljubljana, 2017 (mentor Goran Dražić).
2. Jasna Cotič, *The influence of sintering protocol and airborne-particle abrasion on ageing of zirconia ceramics in vitro and in vivo:* doctoral dissertation, Ljubljana, 2017 (mentor Peter Jevnikar; co-mentor Andraž Kocjan).
3. Sandra Drev, *Twinning and polytypism in the spinel-chrysoberyl system:* doctoral dissertation, Ljubljana, 2017 (mentor Nina Daneu; co-mentor Aleksander Rečnik).
4. Viviana Golja, *Migration of nanoparticles from food contact materials:* doctoral dissertation, Ljubljana, 2017 (mentor Saša Novak Krmpotič; co-mentor Goran Dražić).
5. Rok Kocen, *Viscoelastic properties of hydrogel-based materials for tissue engineering scaffolds:* doctoral dissertation, Ljubljana, 2017 (mentor Saša Novak Krmpotič).
6. Mateja Košir, *Thermoelectric materials based on ZnO:* doctoral dissertation, Ljubljana, 2017 (mentor Slavko Bernik).