DEPARTMENT FOR ADVANCED MATERIALS K-9

The primary activities of the department are the development of new, materials and the development of new processes for the preparation of such materials in the form of nanostructures and nanocomposites. The main objective of current projects is the synthesis of new, environmentally friendly materials with special electrical and optical properties, with the emphasis on tunable materials that exhibit a dependence of the electric polarization on external electric, mechanical or magnetic fields. A significant part of the research is devoted to the development of new ceramic dielectrics that can be used at microwave frequencies. A new field of the department's research is aimed at the synthesis of photocatalytically active and antibacterial nanocomposites because of their wide area of potential application, from domestic appliances to medicine.

Head:
Prof. Danilo Suvorov

Development of materials with special electrical properties

We have investigated the structural and electrical characteristics of the novel $Na_{0.5}Bi_{0.5}TiO_3$–$KTaO_3$ ceramic system. $Na_{0.5}Bi_{0.5}TiO_3$ is a well-known relaxor material, while $KTaO_3$ has the characteristics of an incipient ferroelectric and can thus considerably shift the phase transition of $Na_{0.5}Bi_{0.5}TiO_3$. The results of our studies showed that in the investigated system a solid solutions exist across the whole concentration range of compositions. We observed that the formation of the matrix phase initially starts with the formation of $Na_{0.5}Bi_{0.5}TiO_3$- and $KTaO_3$-rich phases, which than react towards nominal compositions at higher temperatures. Due to the different elements present in the system additional firings at high temperatures were required in order to sufficiently improve the homogeneity of the resultant perovskite phase. However, using a solid-state reaction method it was not possible to obtain single-phase ceramics. In order to decrease the amount of secondary phases different synthesis conditions were tested, including surpluses of elements and the pre-reaction of intermediate phases. The dielectric and ferroelectric properties of samples from the investigated system showed that the addition of $KTaO_3$ shifts $Na_{0.5}Bi_{0.5}TiO_3$ phase transitions towards lower temperatures. In addition, the pronounced effect of phase homogeneity on different electrical properties was observed. Specifically, typical relaxor properties of the samples were observed only after high-temperature reactions led to the formation of a single phase $Na_{0.5}Bi_{0.5}TiO_3$–$KTaO_3$ solid solution. Electric measurements showed that samples change from ferroelectric through relaxor to paraelectric with the increasing content of $KTaO_3$.

Extensive studies of new piezoelectric materials have been focused on the development of lead-free perovskite solid solutions. Among them also the solid solution of the $Na_{0.5}Bi_{0.5}TiO_3$-based compositions. It is well known that some perovskite solid solutions form morphotropic phase boundaries (MPB) with the coexistence of two different structures, where the electromechanical properties of a piezo-material are enhanced. Such characteristics were observed for the $(1-x)Na_{0.5}Bi_{0.5}TiO_3$–$xK_{0.5}Bi_{0.5}TiO_3$ solid-solution system. Local crystal and domain structures were studied in detail in order to reveal the origin of the enhanced properties. Based on x-ray diffraction (XRD) the MPB was determined for the composition $x = 0.2$, with the coexistence of the rhombohedral and the tetragonal structures. However, detailed domain-structure analyses using transmission electron microscopy (TEM) and selected-area electron diffraction (SAED) methods, performed on various $(1-x)Na_{0.5}Bi_{0.5}TiO_3$–$xK_{0.5}Bi_{0.5}TiO_3$ solid-solution compositions, revealed some structural changes at/near the MPB. Based on the occurrence of the superstructure reflections in the SAED patterns, on the characteristic splitting of the reflections and on the domain morphology observations, the crystal structure in/near the boundary region was determined as a tetragonal structure with an in-phase oxygen octahedral tilt system. Further TEM investigations should confirm the nature and the origin of this structure.

During the synthesis of $K_{0.5}Bi_{0.5}TiO_3$ ceramics the volatilization of prone components (K,Na,Bi) and the formation of secondary phases are often observed, which result in a slow densification process. Thus, accurate knowledge of the synthesis parameters and the structure–electrical properties relations of these materials are of great importance. With the control of the parameters of the solid-state synthesis we were able to prepare dense ceramics with a minor content of secondary phases that exhibit better dielectric properties compared to the literature data. The properties were further enhanced by using finer powders and chemicals as raw materials that possess a higher reactivity. The use of amorphous or nano-crystalline TiO_2 results in a smaller concentration of secondary phases, a higher density of ceramics and an additional

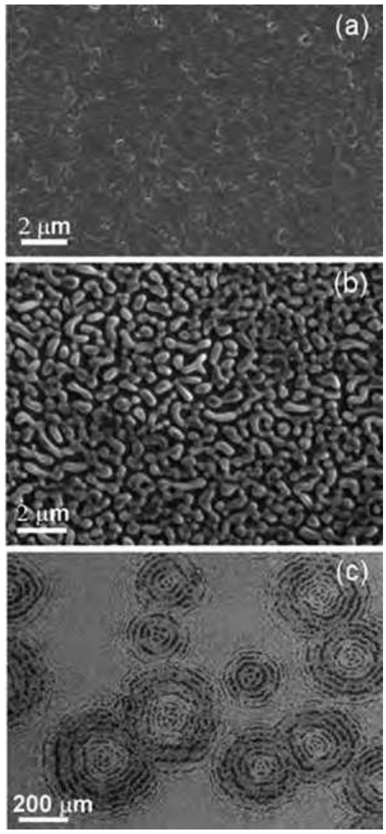

Figure 1: Microstructural development of BSO thin films deposited from sols using different precursors:
a) $Bi(NO_3)_3 \cdot 5H_2O$: well-defined dense microstructure with uniform grain size,
b) $Bi(CH_3COO)_3$: low solubility of the precursor after thermal treatment yields porous thin film
c) $Bi(C_7H_{15}COO)_3$: inhomogeneous dense microstructure with porous areas as a result of sol self-assembly process.

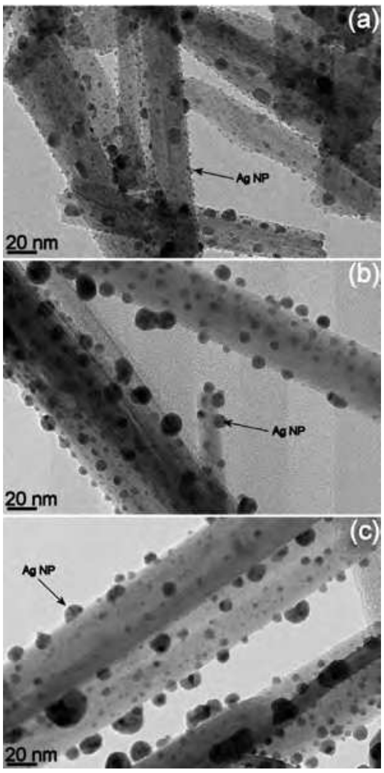

Figure 2. Composite Ag/Ti-nanobelts formed with the in-situ precipitation of Ag nanoparticles in a polyelectrolyte matrix on the surface of Ti-nanobelts after: (a) one, (b) two and (c) three precipitation cycles of Ag nanoparticles after annealing at 600°C. The average Ag nanoparticle size is increasing with the number of reaction precipitation cycles in contrast to the surface density of Ag nanoparticles, which is decreasing.

improvement of dielectric properties. The best results were obtained with the use of KNO_3 instead of K_2CO_3, which decomposes slowly and is therefore hard to control. In these samples no secondary phases were observed in the microstructure, the density was further improved and the dielectric properties were additionally enhanced.

In the process of miniaturization bulk ceramic components are being replaced by thin films. The 70mol%$Na_{0.5}Bi_{0.5}TiO_3$–30mol%$NaTaO_3$ thin films were synthesized using the sol-gel method and deposited by spin coating onto sapphire and Pt/TiO_2/SiO_2/Si substrates. The decomposition of the sol-gel system occurred in two steps: the organic matter decomposition between 250°C -400°C and the perovskite crystallization with removal of the remaining carbon dioxide at 550°C. The structural and surface morphology were observed to be very sensitive to the processing parameters, such as the addition of DCCA, pyrolysis and annealing. Well-crystallized films were obtained at relatively low temperatures, i.e. below 650°C. The microwave measurements performed at 15 GHz using a split-resonator measurement configuration showed values of the dielectric constant of 170 and the dielectric loss of 0.1.

In the scope of an applied project with EPCOS OHG, Deutschlandsberg, Austria, in investigations of potential materials for PTC tunable applications several ferroelectrics with the Curie temperature (T_c) between 130°C and 150°C, and dielectric constant maximum ε_r greater than 10 000 have been developed. The focus was on the perovskite ceramics based on $(1-x-y)Pb(Zn_{1/3}Nb_{2/3})O_3-xBaTiO_3-yPbTiO_3$ system. It was found that the addition of $BaTiO_3$ ($0.05 \leq x \leq 0.2$) and $PbTiO_3$ ($0 \leq y \leq 0.2$) to the $Pb(Zn_{1/3}Nb_{2/3})O_3$ suppressed the formation of the pyrochlore phase, which causes lowering of the dielectric constant ε_r maximum. The T_c changed with the amount of $PbTiO_3$ and $BaTiO_3$; namely, T_c shifts to lower temperatures with the increase of $BaTiO_3$ and the decrease of the $PbTiO_3$ content.

Development of microwave dielectrics

In the scope of low-dielectric-constant materials suitable for low-temperature co-fired ceramic (LTCC) processes, we investigated scheelite (MWO_4; M=Ca, Sr, Ba) ceramics and the $Mg_2B_2O_5$ compound that crystallizes as the main phase from the $MgO-B_2O_3-SiO_2$ glass. In the investigated glass system we studied the nucleation and crystallization processes formed by non-isothermal methods. For $MgO-B_2O_3-SiO_2$ glass nucleation occurred in the temperature range from 600°C to 750°C with the maximum nucleation rate at 700°C, whereas the nucleation and crystal growth processes overlapped at temperatures from 700°C to 750°C. The analyses of the non-isothermal data by the most common models (Ozawa, Kissinger, modified Kissinger, Ozawa-Chen) revealed that the crystallization of $Mg_2B_2O_5$ was three-dimensional bulk with diffusion-controlled crystal growth rate with n=m=1.5 and activation energy for crystallization (E) of 420–450 kJ/mol. The addition of TiO_2 to the $MgO-B_2O_3-SiO_2$ glass in the amount of 1–10 wt % was found to facilitate the formation of nuclei and changed the crystallization mechanism to bulk crystallization with an increasing number of nuclei (m=3, n=4). Both, permittivity and quality factor ($Q \times f$), increased with the TiO_2 content. The improvement of the $Q \times f$-values was attributed to the enhanced crystallization. The highest $Q \times f$-value of 16,500 GHz was measured for the glass-ceramics with 10 wt % of TiO_2 sintered at 1050°C. The $MgO-B_2O_3-SiO_2$-based glass-ceramics sintered in the range from 850°C to 950°C exhibited somewhat lower $Q \times f$-values of 5000–8000 GHz and a permittivity of 6.1–6.9.

The investigations of the low-temperature sintering of scheelite (MWO_4; M=Ca, Sr, Ba) ceramics revealed that the Li- or Na-containing sintering aids increased the susceptibility of the scheelites to water. It was found that already very low concentrations of Li or Na (<0.2 wt %) in the sintered ceramics caused the degradation of the ceramics in the presence of moisture and increased the solubility of tungstate in water by more than 50-times. The results showed that the physical and chemical properties of the ceramic materials meant for application in electronics should also be carefully considered in the case of additives in very low concentrations.

In $Bi_{12}SiO_{20}$ thin-film preparation we studied the influence of a bismuth precursor on the microstructural development. A sol was prepared using $Bi(NO_3)_3 \cdot 5H_2O$, $Bi(CH_3COO)_3$ or $Bi(C_7H_{15}COO)_3$ as the precursor. We observed that the choice of the precursor has a great influence on the microstructural development of $Bi_{12}SiO_{20}$ thin films. A different bismuth precursor has a different gelation path, which resulted in different microstructural development. In the case of the $Bi(NO_3)_3 \cdot 5H_2O$ precursor, the formation of a dense microstructure appeared. Thin films deposited from sols where $Bi(CH_3COO)_3$ was used as a precursor showed a rather porous microstructure development. While $Bi_{12}SiO_{20}$ thin films, deposited from sols where $Bi(C_7H_{15}COO)_3$ was used as precursor, exhibited inhomogeneous self-assembly microstructural development. In the future, the process will be thoroughly investigated with the use of a molecular LEGO approach to explain different gelation paths of sols and thin films.

In collaboration with Epcos OHG several ferroelectric materials for PTC tunable applications based on the perovskite $(1-x-y)Pb(Zn_{1/3}Nb_{2/3})O_3-xBaTiO_3-yPbTiO_3$ ceramic system with a Curie temperature between 130°C and 150°C, and dielectric constant maximum ε_r greater than 10,000 have been developed.

In the field of phase relations in ternary oxide systems where new compounds and/or solid solutions are stable and exhibit pronounced electric properties, we identified new compounds in tha La_2O_3–TiO_2–GeO_2 system and determined their composition. Additionally, in the La_2O_3–TiO_2–Ta_2O_5 system we prepared single-phased ceramics based on the new compound $LaTaTiO_6$ and determined the high-temperature monoclinic and low-temperature orthorhombic crystal structure and phase-transformation temperature.

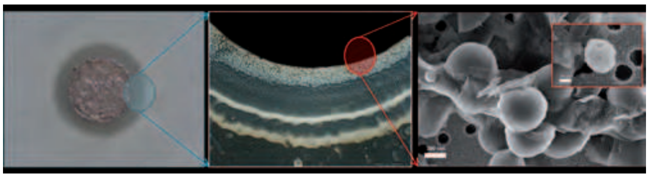

Figure 3. Antibacterial activity of Ag against Gram positive bacteria: (a) growth inhibition zone of Staphyloccocus aureus bacterial colony around hydroxyapatite/silver (HAp/Ag) nanocomposite, (b) gradient change in the density of modified bacterial colony within the zone of growth inhibition (c) morphological changes of individual bacteria induced by antibacterial action of silver in HAp/Ag composite in the zone of growth inhibition.

Research of nanostructured materials and nanocomposites

a.) Nanoparticles and nanopowders

The material synthesis approach turns out to be the key parameter in obtaining improved properties of the ceramics. Among other synthesis approaches is also a hydrothermal synthesis. The research of nanostructured materials has been focused on the synthesis of the relaxor perovskite $Na_{0.5}Bi_{0.5}TiO_3$, $Na_{0.5}Bi_{0.5}TiO_3$–$K_{0.5}Bi_{0.5}TiO_3$ and high-surface-area TiO_2 nanopowders.

The hydrothermal method was employed for the preparation of phase-pure nano-sized $Na_{0.5}Bi_{0.5}TiO_3$ particles as a separate component for their further integration in the form of thick or thin films. Considering that the $Na_{0.5}Bi_{0.5}TiO_3$-based solid solution exhibits enhanced piezoelectric properties, we further aimed to hydrothermally prepare $Na_{0.5}Bi_{0.5}TiO_3$–$K_{0.5}Bi_{0.5}TiO_3$ nano-powders. The synthesis of the $Na_{0.5}Bi_{0.5}TiO_3$–$K_{0.5}Bi_{0.5}TiO_3$ system requires a mixed alkaline environment of NaOH and KOH mineralizer, where the final stoichiometry of the obtained powders is controlled by the NaOH/KOH ratio of the starting solution. We observed that the starting solution NaOH/KOH ratio and preferential intercalation of sodium over calium cations induce the formation of secondary phases. The secondary-phase-free $Na_{0.5}Bi_{0.5}TiO_3$–$K_{0.5}Bi_{0.5}TiO_3$ composition was obtained with a NaOH/KOH ratio of 1:1.

Crystalline TiO_2 nano-powders were prepared using the sol-gel synthesis approach, followed by annealing at temperatures between 500 and 800°C. The sol-gel-derived precipitates were modified with triethanolamine, which affected the rate of the anatase-to-rutile phase transformation. As-prepared TiO_2 nano-powders consisted of anatase phase particles and rutile phase particles. Depending on the temperature of the thermal treatment the size of the two-phased nanoparticles varied between 11 and 36 nm for the anatase, and between 24 and 45 nm for the rutile phase particles. The photocatalytic activity of the prepared TiO_2 nano-powders was evaluated by monitoring the photocatalytic oxidation of isopropanol into acetone. TiO_2 nano-powders thermally treated at 700°C exhibit the highest photocatalytic activity under visible light irradiation. This sample was a mixture of anatase, with a particle size of 36 nm and rutile, with a particle size of 45 nm.

We also synthesized Zr- and Ce-doped anatase nanoparticles. The doping of the anatase crystal lattice resulted in stability of the anatase phase up to 1000°C. The doped nanoparticles sintered at this temperature showed enhanced photocatalytic activity.

b.) Nanocomposites

Besides the enhanced efficiency of nanocomposite materials obtained by combining two different components, the ability to achieve a high specific surface area is the key parameter that dictates the research of nanocomposites with improved applicable properties. In the scope of photocatalytically active and bio materials we synthesized nanocomposite materials composed of various metallic nanoparticles and metal-oxide nanostructures.

Nanostructured metallic (Ag) nanoparticle loaded titanate-based one-dimensional (1D) nanobelts were synthesized by the in-situ-precipitation of Ag nanoparticles on the surface of Ti-nanobelts. A polyelectrolyte multilayer was first formed on the surface of Ti-nanobelts by the sequential deposition of appositively charged polyelectrolyte chains. As the polyelectrolyte multilayer-coated Ti-nanobelts are exposed to the silver cation solution, Ag_2O nanoparticles are formed between Ag+ cations and OH^- ions due to the diffusion of OH^- groups detached from the surface of Ti-nanobelts. The control over the concentration and the size of the particles within the polymer matrix was obtained by cycling the synthesis process. By subsequent thermal treatment at 600°C for 30 minutes the polyelectrolyte multilayer is removed, which yields composite Ag/Ti-nanobelts with different concentrations and sizes of Ag-nanoparticles on the surface of Ti-nanobelts. The enhanced UV photo-efficiency was observed for the Ag/Ti-nanobelts nanocomposites in comparison to pure Ti-NBs. The As-fabricated Ag/Ti-nanobelts also exhibited visible photo-activity, assisted by the near-field amplitudes of the localized surface plasmon resonance (LSPR) of the silver nanoparticles in the 1D nanocomposite.

We developed a synthesis method for composite metal (Ag)/1D titanate nanostructure fabrication. By controlling the size and concentration of the metallic nanoparticles on the surface of 1D titanate nanostructures we were able to obtain enhanced photocatalytic activity for such nanocomposites.

Nanocrystalline Ag/TiO_2 composite thin films were synthesized using a two-step synthesis methodology: the in-situ precipitation of Ag nanoparticles followed by an in-situ sol-gel reaction of titanium iso-propoxide in a weak-polyelectrolyte-multilayer template formed by the layer-by-layer self-assembly of polyacryllic acid and polyallylamine. The polyelectrolyte-multilayer template assembled from weak polyions contains non-ionized carboxylic groups that are able to react with the inorganic precursors, resulting in the formation of a homogeneous Ag/TiO_2-polyion-multilayer precursor film. The content of Ag in the precursor film is controlled by repeating the Ag loading cycle. The subsequent annealing of the precursor yields nano-structured Ag/TiO_2 films with the thicknesses controlled by the polyion-multilayer template on the nanometre scale. The formed Ag/TiO_2 composite thin films exhibit high Ag nanoparticle/TiO_2 crystallite inter-contact area. Due to electron traps centres and a localized near field induced by the localized surface plasmon resonance (LSPR) of Ag nanoparticles in Ag/TiO_2 composite thin films enhanced UV and visible photo-catalytic behaviour of the as-synthesized Ag/TiO_2 films was obtained.

The sonochemical method was utilized for the synthesis of silver (Ag), gold (Au) and platinum (Pt) nanoparticulate/hydroxyapatite composites. The influence of different synthesis precursors on the morphological and structural properties of as formed composites was analyzed. The antibacterial activity of the composites was tested by the application of Gram-positive and Gram-negative bacteria. The results show that silver has the strongest effect against Gram-negative bacteria. In addition to the peptidoglycan layer onto the surface of Gram-negative bacteria their outer membrane contains lipopolysaccharides together with porins proteins which allow the transfer of small and hydrofile molecules and ions. According to the obtained difference in antibacterial effects these proteins may have an important role in the transport of silver ions inside bacteria.

Some outstanding publications in the past year

1. Mojca Otoničar, Srečo D. Škapin, Matjaž Spreitzer, Danilo Suvorov. Compositional range and electrical properties of the morphotropic phase boundary in the $Na_{0.5}Bi_{0.5}TiO_3$-$K_{0.5}Bi_{0.5}TiO_3$ systems. J. Eur. Ceram. Soc.. [Print ed.], 2010, vol. 30, no. 4, p. 971-979.
2. Manca Logar, Boštjan Jančar, Sašo Šturm, Danilo Suvorov. Weak polyion multilayer-assisted in situ synthesis as a route toward a plasmonic Ag/TiO_2 photocatalyst. Langmuir, 2010, vol. 26, issue 14, p. 12215-12224.
3. Asja Veber, Špela Kunej, Romana Cerc Korošec, Danilo Suvorov. The effects of solvents on the formation of sol-gel-derived $Bi_{12}SiO_{20}$ thin films. J. Eur. Ceram. Soc.. [Print ed.], 2010, vol. 30, no. 12, p. 2475-2480.
4. Boštjan Jančar, Jana Bezjak. High-temperature decomposition of B-site-ordered perovskite $Ba(Zn_{1/2}W_{1/2})O_3$. J. Am. Ceram. Soc., 2010, issue 3, vol. 93, p. 758-764.
5. Urban Došler, Marjeta Maček, Boštjan Jančar, Danilo Suvorov. A high-Q microwave dielectric material based on $Mg_3B_2O_6$. J. Am. Ceram. Soc., 2010, vol. 93, no. 11, p. 3788-3792.

Patents granted

1. Keramisches Material, gesinterte Keramik, Verfahren zur Herstellung und Verwendung der Keramik
   Pavol Dudešek, Christian Hoffmann, Danilo Suvorov, Matjaž Valant
   Patent No. DE 102006024231 (B4)
2. Ceramic material, sintered ceramic and component made therefrom, production method and use of the ceramic
   Pavol Dudešek, Christian Hoffmann, Danilo Suvorov, Matjaž Valant
   Patent No. US 7816293 (B2)

Awards and appointments

1. Mojca Otoničar: LOTTE-IEEE-UFFC Student Award at the 7th Asian Meeting on Ferroelectricity (AMF-7) and the 7th Asian Meeting on Electroceramics (AMEC-7), Jeju Island, Korea, granting by associations IEEE and UFFC, oral presentation "Morphotropic phase boundary in the $(Na_{1-x}K_x)_{0.5}Bi_{0.5}TiO_3$ system with its enhanced electrical properties".
2. Mojca Otoničar: Best contribution award at the 'European Conference Junior EUROMAT 2010', Lausanne, Switzerland, award granted by the Euromat Committee for the poster and oral presentation entitled 'In-situ-TEM and SAED analysis of the domain structure in $K_{0.5}Bi_{0.5}TiO_3$ perovskite ceramics'.
3. Vojka Žunič: The best presentation among young researchers, research field: Nanomaterials and Nanotechnologies, at the 18th Conference on Materials and Technology, Portorož, granting by Institute of Metals and Technology, oral presentation "Visible light active TiO_2 nano-powders prepared by sol-gel synthesis".

Organization of conferences, congress and meetings

1. Slovenia – Brazilian workshop Electron Microscopy Workshop, Ljubljana, 16 – 30 June 2010.
2. Materials Science & Technology 2010 Conference and Exhibition, Houston, ZDA, 17 – 21 October 2010 (co-organizers).
3. 18th Conference on Materials and technologies, Portorož, 15 – 17 November 2010 (co-organizers).

INTERNATIONAL PROJECTS

1. Development of Wear Resistant Coatings based on Complex Metallic Alloys for Functional Applications
   AppliCMA
   7. FP, 214407
   EC; Susanne Fuchs, Austrian Research Centers GmbH - ARC, Functional Materials, Seibersdorf, Austria; Aerospace & Advanced Composites GmbH, Wiener Neustadt, Austria
   Dr. Srečo D. Škapin, Dr. Miha Čekada, Prof. Janez Dolinšek, Dr. Kristoffer Krnel
2. Controlled Production of High Tech Multifunctional Products and their Recycling
   SAPHIR
   6. FP, NMP2-CT-2006-026666
   EC; Laurence Demoor, Christophe Goepfert, Compagne Industrielle des Lasers Cilas SA, Orleans, France
   Prof. Danilo Suvorov
3. Microwave Tunable Materials, Composites and Devices (Project Proposal)
   NATO SfP 984091
   NATO, North Atlantic Treaty Organisation, Brussels, Belgium
   Dr. Boštjan Jančar
4. Functional Nanostructured Ceramic Materials
   BI-AR/09-11-001
   Prof. Noemí Elisabeth Walsõe de Reca, CINSO (Centro de Investigaciones en Sólidos), CITEFA-CONICET, Buenos Aires, Argentine
   Prof. Danilo Suvorov
5. High Dielectric Constant Ferroelectric Material; Thermoelectric Oxide Materials
   Agreement IJS/EPCOS, NBT
   Dr. Guenter Engel, Dr. Andrea Testino, EPCOS OHG Ceramic Components Division, Deutschlandsberg, Austria
   Prof. Danilo Suvorov, Dr. Marjeta Maček Kržmanc, Dr. Boštjan Jančar
6. High K Dielectrics for Mobile Phone Base Stations
   Agreement IJS/EPCOS, Microwave Ceramics
   Dr. Christian Hoffmann, Pavol Dudesek, EPCOS OHG Ceramic Components Division, Deutschlandsberg, Austria
   Prof. Danilo Suvorov, Dr. Boštjan Jančar
7. High K Dielectrics for Mobile Phone Base Stations
   Agreement IJS/EPCOS, Microwave Ceramics
   Dr. Christian Hoffmann, Pavol Dudesek, EPCOS OHG Ceramic Components Division, Deutschlandsberg, Austria
   Prof. Danilo Suvorov
8. Biomimetic Preparation of Inorganic Nanomaterials
   BI-HR/09-10-037
   Dr. Ivan Sondi, Ruđer Bošković Institute, Zavod za raziskovanje morja in okolja, Zagreb, Croatia
   Dr. Srečo Davor Škapin
9. Ultra-low Dielectric Constant LTCC Material
   BI-CN/09-11-013
   Dr. Xing Hu, South China University of Technology, Guangzhou, China
   Dr. Srečo Davor Skapin
10. Synthesis of Piezoelectric Thin Films and Magnetoelectic Composites by a Layer-by-layer Self Assembly
    BI-KR/09-11-001
    Dr. Jae-Ho Jeon, Korea Institute of Materials Science, Changwon, Korea
    Prof. Danilo Suvorov
11. Mixed Rare Earth Oxide Nanoparticles: Synthesis, Characterisation, Applications
    BI-SR/10-11-016
    Dr. Bratislav Antić, "Vinča" Institute of Nuclear Sciences, Belgrade, Serbia
    Dr. Boštjan Jančar
12. Electric-field Tunable Ferroelectric Materials Based on $Na_{0.5}Bi_{0.5}TiO_3$
    BI-UA/09-10-007
    Prof. Anatolii Belous, SPE "Oxid" of V.I. Vernadskii Institute of General & Inorganic Chemistry NAS of Ukraine - Solid State Chemistry Department, Kyiv, Ukraine
    Prof. Danilo Suvorov
13. Materials World Network: Improved Lanthanide-based Filters for Mobile Telekommunications
    BI-US/08-10-005
    Prof. Rick Ubic, Boise State University, Boise, Idaho, USA
    Prof. Danilo Suvorov

R & D GRANTS AND CONTRACTS

1. Physis and Chemistry of Porous Aliminium for Al Panels, Capable of Highly Efficient Energy Absorbtion
   Prof. Danilo Suvorov
2. Functionalization of the Surface of Organic Pigments for Durable, Efficient and Colour-stable Paints
   Asst. Prof. Srečo Davor Škapin
3. Nanoengineering of Self-assembled Materials
   Prof. Danilo Suvorov
4. Self-cleaning Antibacterial Fotocatalitic Coating in Whitewear Production
   Prof. Danilo Suvorov

RESEARCH PROGRAM

1. Contemporary Inorganic Materials and Nanotechnologies
   Prof. Danilo Suvorov

NEW CONTRACTS

1. Antibacterial surface protection in water based media
   Gorenje Household Appliances d.d.
   Prof. Danilo Suvorov
2. Antibacterial surface protection in refrigirators
   Gorenje Household Appliances d.d.
   Prof. Danilo Suvorov
3. Self-Cleaning Antibacterial Fotocatalitic Coatings in whitewear productions
   Gorenje Household Appliances d.d.
   Prof. Danilo Suvorov

MENTORING

Ph. D. Thesis

1. Asja Veber, S*ynthesis and characterization of* $Bi_{12}SiO_{20}$ *thin films prepared by sol-gel method* (mentor Danilo Suvorov)

VISITORS FROM ABROAD

1. Dr. Wolfgang Athenstaedt, Pavol Dudešek, B. Sc., Dr. Günter Engel, Dr. Christian Hoffmann, EPCOS OHG, Deutschlandsberg, Austria, 8 March 2010.
2. Prof. Peter Day, University College London and Royal Institution of Great Britain, Great Britan, 22 March 2010.
3. Dr. Ivan Sondi, Institut Rudjer Bošković, Zagreb, Croatia, 14 May 2010.
4. Carl Hatton, B. Sc., Veeco Instruments, Plainview, USA, 27 May 2010.
5. Prof. Jose Arana Varela, UNESP´s Institute of Chemistry, Araraquara , Brazil, 17 - 20 June 2010.
6. Dr. Aleksandr Babak, Tomilino Electronic Factory, TEF-SPE Ltd., Moscow, Russia, 13 July 2010.
7. Dr. Smilja Marković, Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Belgrade, Serbia, 14 – 28 July 2010.
8. Pavol Dudašek, B. Sc., EPCOS, Deutschlandsberg, Austria, 27 July 2010.
9. Dr. Mario Bianchetti, Centro de Investigaciones en Solidos, Buenos Aires, Argentina, 4 – 18 August 2010.
10. Dr. Jae Ho Jeon, Korea Institute of Materials Science, Changwon, Korea, 10 - 14 September 2010.
11. Stefan Thumser, B. Sc., Netzsch GmbH, Selb, Germany, 13 - 14 October 2010.
12. Dr. Cristina Giordano, Max Planck Institute of Colloids and Interfaces, Potsdam, Germany, 21 October 2010.
13. Dr. Gertjan Koster, University of Twente, Enschede, Netherlands, 21 October 2010.
14. Dr. Bratislav Antić, Dr. Aleksandar Kremenović, Institute Vinča, Belgrade, Serbia, 8 – 13 November 2010.
15. Walter König, B. Sc., Ruben Zowada, B. Sc., Cascade Microtech, Munich, Germany, 23 – 25 November 2010.
16. Dr. Aleksandr Babak, Tomilino Electronic Factory, TEF-SPE Ltd., Moscow, Russia, 23 November 2010.
17. Prof. Egon Matijević, Clarkson University, Potsdam, USA, 25 November 2010.
18. Dr. Smilja Marković, Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Belgrade, Serbia, 29 November - 11 December 2010.

Visiting Researchers:

1. Dr. Jyoti Prosad Guha, University of Rolla, Rolla, USA, 27 May – 31 August 2010.
2. Mag. Marija Vukomanović, Institute of Technical Sciences of the Serbian Academy of Sciences and Arts, Belgrade, Serbia, 1 January – 31 December 2010.

STAFF

Researchers

1. Asst. Prof. Boštjan Jančar
2. Dr. Marjeta Maček Kržmanc
3. **Prof. Danilo Suvorov, Head**
4. Asst. Prof. Srečo Davor Škapin

Postdoctorial associates

5. Dr. Jakob König
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