DEPARTMENT FOR ADVANCED MATERIALS K-9

The main activities of the department encompass basic and applied research within the fields of energy materials, biomaterials and electronic materials. Among the important objectives are the development of new, efficient oxides for high-temperature thermoelectric energy conversion, materials with improved antibacterial and photocatalytic effects and the development of thin films and nanostructured powders of functional electronic oxides for various applications.

Head:
Prof. Danilo Suvorov

Thermoelectric oxides

The research of oxides as possible thermoelectric materials was triggered by the discovery that metallic layered cobaltate Na_xCoO_2 exhibits a large Seebeck coefficient combined with a high electrical conductivity and a low thermal conductivity, which was attributed to its layered crystal structure consisting of two-dimensional sheets of edge-sharing CoO_6 octahedra intercalated by Na ions. The highest reported zT values of Na_xCoO_2 are ~1.0 for single-crystalline and ~0.8 for polycrystalline material at temperatures in the vicinity of 800°C. With such properties it was considered to be a good candidate for the high-temperature p-type thermoelectric material. However, the chemistry of layered sodium cobaltates is governed by the high mobility of interlayer sodium, which reacts with atmospheric moisture and carbon dioxide. Furthermore, the layered crystal structure of $Na_xCo_2O_4$ enables the intercalation of molecules such as water, which can lead to exfoliation and thus degradation of the material. Because of this the focus of the research turned to a semiconducting misfit-layered cobaltate $Ca_3Co_4O_9$, the structure of which consists of triple Ca_2CoO_3 layers and single layers of CoO_2 analogous to CoO_6 sheets of Na_xCoO_2 compounds. The highest zT reported for this structural type was ~0.6. We found that the sheets of octahedrally coordinated Co ions, which are the common structural element of the Na_xCoO_2 and $Ca_3Co_4O_9$ phases, allow the spontaneous intergrowth of the two structures (Fig. 1) leading to a significant improvement of environmental stability. Furthermore, the coherent intergrowth of the two structural types results in effective texturing in polycrystalline material with the preferred grain growth aligned in-plane with common CoO_6 layers, thus allowing high electrical conductivity. The nanostructured intergrowths also result in a significant reduction of the thermal conductivity, which was at 700°C measured to be ~0.3 W/mK for the "out-of plane" and ~0.6 W/mK for the "in-plane" direction. With the measured power factor of ~$6.5 \cdot 10^{-4}$ W/mK^2 the calculated "in-plane" zT of the intergrowth structure material with the nominal composition $Ca_{2.2}Na_{0.8}Co_4O_9$ is ~1.0 at 700°C, which is higher than any so-far reported value for oxide thermoelectrics.

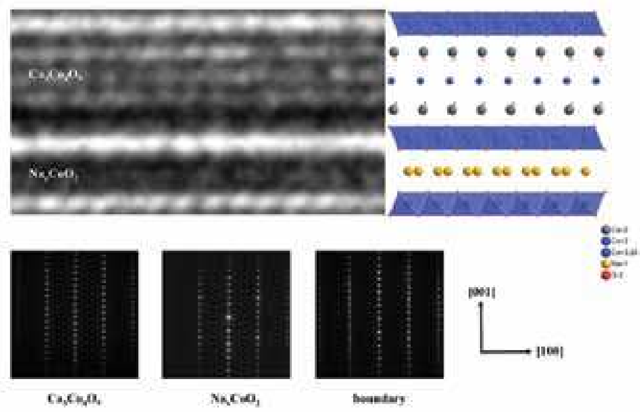

Figure 1: HRTEM image and SAED pattern of coherently intergrown Na_xCoO_2 and $Ca_3Co_4O_9$ structure types.

Antibacterial and photocatalytic materials

An innovative concept has been applied to develop human and environmentally friendly material with antibacterial properties. The material is a composite formed of bioceramic, metallic and organic phases that contain amino and thiol groups. Metallic nanoparticles have a functionalized surface and they are carriers of antibacterial activity. The efficacy of the antibacterial action of the composites depends on the type of surface functionalization that provides activity against Gram-positive and Gram-negative bacteria. The materials were prepared by a sonochemical method that was developed as a novel route for the synthesis of this type of material and belongs to green chemistry. The developed materials have a stronger antibacterial activity in comparison to silver-based materials that are frequently used in practice, which indicates the possibility of their replacement by novel, more effective and safer materials developed in our laboratory. The morphological properties of the newly developed material and its antibacterial activity are shown in Fig. 2.

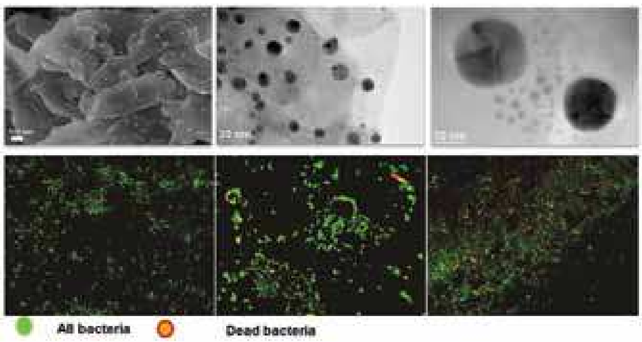

Figure 2: Morphological properties of a novel antibacterial material and its antibacterial effect on E. coli, developed at the Advanced Materials Department.

In the field of photocatalytic materials, hierarchically assembled nanostructured spherical anatase particles in the size range from 3 to 7 mm, using a solvothermal synthesis method, were prepared. The spherical particles are composed of nanosized primary crystallites with a size below 30 nm. The prepared anatase exhibits good photocatalytic properties and a high temperature stability, over 1000°C. Due to the large particle size, these particles are less harmful, compared to nanosized commercial anatase.

Functional electronic oxides

In the scope of the European project "Nanostructured Ferroelectric Films for Biosensors" we studied the synthesis and characterization of $Pb(Mg_{1/3}/Nb_{2/3})O_3$-$PbTiO_3$ thin films prepared on $Pt(111)/TiO_2/SiO_2/Si$ substrates using the sol-gel method for Film Bulk Acoustic Resonator (FBAR) sensor applications. In order to determine the influence of the coordination chemistry on the formation of the perovskite the conditions of the reagents were systematically varied. As a source of Mg-precursor $Mg(CH_3COO)_2{\times}4H_2O$, $Mg(AcAc)_2{\times}2H_2O$ and $Mg(NO_3)_2{\times}6H_2O$ were applied to reduce the concentration of the undesired pyrochlore phase that forms in addition to the perovskite phase. $Pb(NO_3)_2$, $Pb(CH_3COO)_2$, $Pb(PVP)_2$ and $Pb(AcAc)_2$ were used as a source of Pb. Changing the coordination sphere of Mg does not increase the reactivity of Mg ions towards Nb to the point that they will preferentially react, forming the Mg-O-Nb heterometallic structure. A pyrochlore-free $Pb(Mg_{1/3}/Nb_{2/3})O_3$-$PbTiO_3$ film was formed when the steric hindrance of the Pb precursor was increased. In this way the reactivity of Pb ions towards Nb ions is decreased, resulting in the formation of Mg-O-Nb heterometallic clusters, leading to the formation of a perovskite phase. Thus, $Pb(PVP)_2$ and $Pb(AcAc)_2$ were shown to be effective in the formation of pyrochlore-free thin films.

In collaboration with Epcos OHG, a member of the TDK-EPC Corporation, we developed a p-type thermoelectric oxide with zT ~1.0 at 700°C, which makes it superior to so-far reported polycrystalline thermoelectric oxides. The invention is EU patent pending.

It was observed that during the direct casting of the film on the $Pt(111)/TiO_2/SiO_2/Si$ substrate the films grow into a dense and crack-free microstructure. The relative permittivity and dielectric losses for the pyrochlore-free PMN-PT thin film were found to be 1650 and 0.12, respectively.

We further investigated the tunable properties of $(1\text{-}x)Na_{0.5}Bi_{0.5}TiO_3$–$xNaTaO_3$ thin films (0.05<x<0.3) prepared by a modified sol-gel method. A dense and homogenous microstructure, with the average grain size ranging between 70 and 110 nm, was obtained for the NBT-NTa thin films by using a Bi-propionate precursor in the sol-gel synthesis. It was observed that the dielectric permittivity increases with the annealing temperature for all the prepared NBT-NTa thin-film compositions. The decrease in the average grain size below 150 nm caused the appearance of single-domain grains, which then strongly affected the polarization behavior of the 5NTa thin films, giving them a relaxor-type response. The relaxor-type and paraelectric-type responses were observed for the 10NTa and 30NTa thin films, respectively. Comparable dielectric permittivity and relative tunability values were obtained for the 5NTa (e = 441, n_r = 42%) and the 10NTa (e = 440, n_r = 40%) thin films, whereas the 30NTa thin films showed lower values (e = 370, n_r = 23%).

In the scope of the Center of Excellence in Nanoscience and Nanotechnology we set up the first Pulsed Laser Deposition (PLD) laboratory in Slovenia dedicated to the layer-by-layer growth of inorganic thin films.

In the field of ferroelectric thin films, research is driven by demands to improve and tailor the inherent material's electrical response. The motivation behind our investigation was directed towards tuning the temperature-dependent dielectric behavior and improving the dielectric loss characteristics. In this attempt, we designed $SrTiO_3/Na_{0.5}Bi_{0.5}TiO_3/SrTiO_3$ (ST/NBT/ST) structured thin films, where the ferroelectric NBT phase is embedded within a low-dielectric-loss ST component. Using repeated thermal treatment we managed to prepare thin films with a temperature flat dielectric permittivity (te of 780 ppm/K in the temperature range between -50°C and 200°C), decreased dielectric losses, and a frequency undispersed response at room temperature. The obtained results were attributed to the compositional gradient between particulate ST and NBT layers, as determined by X-ray diffraction and X-ray photoelectron spectroscopy. As-structured thin films exhibit promising properties for functional devices that are required to produce stable performance in a broad temperature range.

Beyond sol-gel techniques we utilized diblock-copolymers (BCs) to synthesize multifunctional thin films. Due to the different chemical nature of the separate blocks they self-organize into different phases, where the type of the phase depends on the block fraction ratio, the monomer chemical nature, the temperature, etc. In our work we take advantage of a polystyrene-polyethylene oxide (PS-b-PEO) block-copolymer to obtain $Na_{0.5}Bi_{0.5}TiO_3$ (NBT) / $SrTiO_3$ (ST) or $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) / $CoFe_2O_4$ (CF) multifunctional thin films with in-plane interfaces. Using a different polarity of the precursors or specific casting procedures we can selectively direct inorganic components into the PS or PEO block. In the first part of the study we investigated the self-assembling properties of the BC solely. We observed that the morphology of the films is highly dependent on the casting conditions. Films cast under ambient conditions presented no preferential orientation. A short anneal in toluene vapor orients the PS-b-PEO into a hexagonal order. Subsequently, multifunctional thin films were prepared from the NBT and ST sols or the PMN-PT sol and CF nanoparticles. Using the proper casting conditions and thermal treatment we managed to prepare films, for which grazing incidence X-ray diffraction confirmed the presence of NBT/ST or PMN-PT/CF. This is especially important for NBT/ST, since they easily form a solid solution across the entire compositional range.

Within the European project "Novel Inorganic Inks for Hybrid Printed Electronic Demonstrators" we investigated the synthesis of differently shaped ferroelectric particles. The experimental conditions for the growth of shape-controlled $BaTiO_3$ particles in NaOH and barium salt ($Ba(NO_3)_2$, $BaCl_2$ or $Ba(CH_3COO)_2$) aqueous and water/ethanol solutions using various TiO_2-containing precursors (Ti-precursor) were studied. We found that different chemistries and physical characteristics of the Ti-precursors resulted in different $BaTiO_3$ formation rates, morphologies and phase compositions. Nanocrystalline anatase, TiO_2 aerogel and sodium titanates (NT) belts led to cubic $BaTiO_3$ at temperatures of 80-230°C, while tetragonal $BaTiO_3$ formed from potassium titanate (KT) at 150-230°C. The morphology of the $BaTiO_3$, prepared from KT at low temperatures (80-100°C), did not differ significantly from that obtained from NT belts and TiO_2 aerogel. These precursors, which reacted slowly in alkaline aqueous media, produced single-crystalline star-like particles. The fastest $BaTiO_3$ formation rate was observed for nanocrystalline anatase, which led to irregularly shaped $BaTiO_3$ particles. According to TEM investigations, the growth of the single-crystalline star-like $BaTiO_3$ particles occurred via the oriented attachment of nanocrystals, which formed from the dissolved barium and titanium species. The modification of the water solution by the addition of ethanol or excess of NaOH caused the morphological change from star- to square-like particles, which similar to stars became irregularly shaped above 100°C. The modifications of the solution are believed to influence both the nucleation and aggregation process and consequently changed the particle shape from star- to square-like.

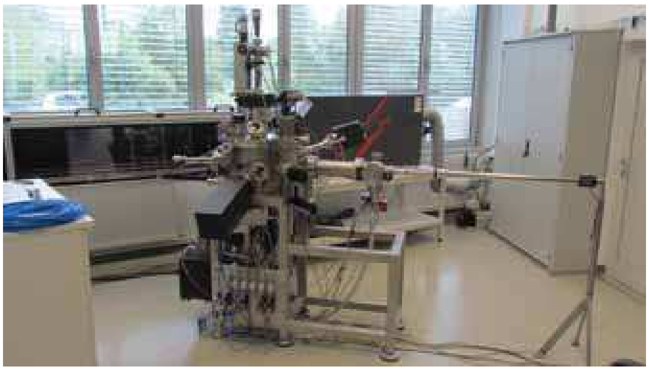

Figure 3: Pulsed laser deposition (PLD) system with laser and optical cabinet.

In the scope of the Center of Excellence in Nanoscience and Nanotechnology we set up the first Pulsed Laser Deposition (PLD) system in Slovenia, which is a powerful technique for the thin-film growth of inorganic materials (Fig. 3). The delivered system is dedicated for layer-by-layer growth and thus enables the preparation of high-quality thin films and structuring on a nanoscopic level. The system is equipped with the following major components: heater stage for laser and resistive heating of substrates, target scanning stage, loadlock for sample and target transfer, high-pressure reflection high-energy electron diffraction system, upgrade with UHV pumps (titanium sublimation pump, ion pump), oxygen plasma source, sputter source (1 x 1.3" target), connection with a glovebox. For the ablation of the target material a KrF excimer laser is used with an energy up to 700 mJ per pulse and a maximum repetition rate of 50 Hz. The system is mainly utilized for the deposition of functional oxides on silicone substrates. Interfacing an oxide with silicon is a great challenge that has attracted a lot of interest in the industrial and scientific community so far. Solving the interface problem would enable the further scaling of microelectronic devices to smaller dimensions and the growth of high-quality oxides with different functionalities on a silicon platform, which can be exploited in micro-electro-mechanical systems, random-access memories, and other oxide-based nano-electronic devices. In our study, pulsed laser deposition (PLD) was used to study the interfaces between $SrTiO_3$ (STO) thin films and silicon. Before the deposition the native oxide on the silicon was removed by HF dip, while in order to understand the interfacial structure in more detail, we performed kinematical simulations of the reflection high-energy electron diffraction (RHEED) patterns. The RHEED patterns were calculated for unreconstructed and reconstructed Si(001) surface with up to four atomic layers and for each of these models we used two different azimuth directions, [100] and [110].

Using a HF treatment of silicon substrate we obtained H-terminated surface, which prevents silicon from oxidising. On such substrates STO was deposited directly or using SrO as a buffer layer. The results show that the optimum conditions involve a two-step procedure, in which the initial vacuum and the lower deposition temperature have an important role. In the case of the direct deposition of STO the obtained films are preferentially textured with a (100) orientation. The application of SrO enabled partially epitaxial growth of STO with STO(110)||Si(100) and STO[100]||Si[110] (Fig. 4). The change of the growth orientation induced by SrO was governed by the formation of the SrO(111) intermediate layer and subsequently by the minimization of the lattice misfit between the STO and SrO.

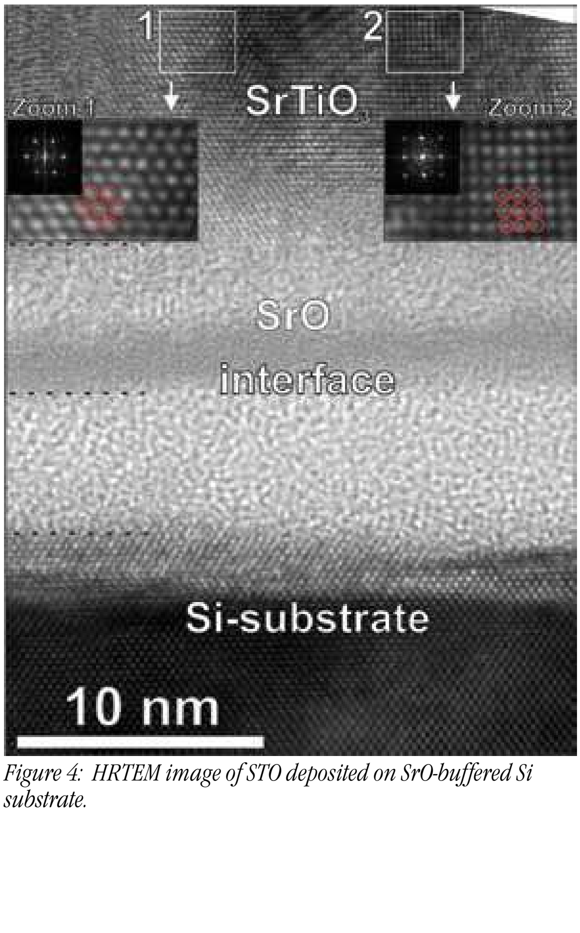

Figure 4: HRTEM image of STO deposited on SrO-buffered Si substrate.

Organization of conferences, congresses and meetings

1. Journal of European Ceramic Society Trust Meeting, Ljubljana, Slovenia, 2. 2. 2012.
2. Permanent Executive Committee of the European Ceramic Society Meeting, Ljubljana, Slovenia, 3. 2. 2012.
3. Materials, Science and Technology 2012 Conference and Exhibition, Pittsburgh, USA, 7.–11. 10. 2011, co-organizers
4. 20th Conference on Materials and Technologies, Portorož, Slovenia, 17.–19. 10. 2012, co-organizers

Patents granted

1. Aleš Dakskobler, Andraž Kocjan, Manca Logar, Method for the preparation of carrier colloidal powder with high specific surface area, SI23502 (A), Urad RS za intelektualno lastnino, 30.4.2012.
2. Aleš Dakskobler, Andraž Kocjan, Manca Logar, Method for the preparation of carrier colloidal powder with high specific surface area, SI23580 (A), Urad RS za intelektualno lastnino, 26.6.2012.

INTERNATIONAL PROJECTS

1. Thermoelectric oxide materials
   EPCOS OHG Ceramic Components Division
   Prof. Danilo Suvorov
2. Microwave tunable materials, composites and devices
   NATO - North Atlantic Treaty Organisation
   Asst. Prof. Boštjan Jančar
3. The synthesis of dielectric materials by chemical solution deposition and characterization of their dielectric properties
   Slovenian Research Agency
   Prof. Danilo Suvorov
4. Nanostructural designing of multifunctional and sintered electrical and biological functionally graded materials
   Slovenian Research Agency
   Asst. Prof. Srečo Davor Škapin

RESEARCH PROGRAM

1. Contemporary inorganic materials and nanotechnologies
   Prof. Danilo Suvorov

R & D GRANTS AND CONTRACTS

1. Nanoengineering of self-assembled materials
   Prof. Danilo Suvorov
2. Functionalization of the surface of organic pigments for durable, efficient and colour-stable paints
   Asst. Prof. Srečo Davor Škapin
3. Self-cleaning antibacterial fotocatalitic coatings in whitewear production
   Prof. Danilo Suvorov
4. Physics and chemistry of porous aliminium for Al panels, capable of higly efficient energy absorbtion
   Prof. Danilo Suvorov
5. New materials for power conversion: oxide semiconductor thermoelectrics
   Prof. Danilo Suvorov
6. INNOINKS: Novel inorganic inks for hybrid printed electronic demonstrators
   Prof. Danilo Suvorov
7. NAFERBIO: Nanostructured ferroelectric films for biosensor
   Prof. Danilo Suvorov

NEW CONTRACTS

1. New materials for energy conversion: oxide semiconducting thermoelectrics
   Gorenje Household Appliances, d. d.
   prof. dr. Danilo Suvorov
2. Development and characterisation of mineral wool fibres
   Knauf Insulation, d. o. o.
   Prof. Danilo Suvorov

VISITORS FROM ABROAD

1. Dr. Tim Jackson, School of Electronic, Electrical and Computing Engineering, University of Birmingham, Birmingham, Great Britain, 18.–20. 1. 2012
2. Prof. Anatolii Bilous, Dr. Oleg Ovchar, Vernadskii Institute of General and Inorganic Chemistry, Ukrainian National Academy of Sciences, Kiev, Ukraine, 18.–20. 1. 2012
3. Prof. Ivan Sondi, University of Zagreb, Zagreb, Croatia, 24. 2. 2012
4. Dr. Marija Vukomanović, Institute of Technical Sciences, Serbian Academy of Sciences and Arts, Belgrade, Serbia, 2.–6. 4. 2012
5. Dr. Christoph Auer, Hermann Gruenbichler, Dr. Yongli Wang, TDK EPCOS, Deutschlandsberg, Austria, 14. 6. 2012
6. Dr. Jae Ho Jeon, Korea Institute of Materials Science, Changwon, Korea, 20.–22. 6. 2012
7. Prof. Dragoljub Uskoković, Institute of Technical Sciences, Serbian Academy of Sciences and Arts, Belgrade, Serbia, 21.–22. 6. 2012
8. Prof. Jose Varela, São Paulo State University, Araraquara, Brazil, 22. 6. 2012
9. Dr. Marcelo Orlandi, São Paulo State University, Araraquara, Brazil, 29. 6.–15. 7. 2012
10. Dr. Smilja Marković, Institute of Technical Sciences, Serbian Academy of Sciences and Arts, Belgrade, Serbia, 23. 7.–3. 8. 2012
11. Prof. Dragoljub Uskoković, Institute of Technical Sciences, Serbian Academy of Sciences and Arts, Belgrade, Serbia, 26.–27. 7. 2012
12. Dr. Dragana Jugović, Institute of Technical Sciences, Serbian Academy of Sciences and Arts, Belgrade, Serbia, 25. 10. 2012
13. Dr. Miodrag Mitrić, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 25. 10. 2012
14. Dr. Jyoti Prosad Guha, Missoury University of Science and Technology, Rolla, ZDA, 9. 10.–15. 11. 2012
15. Miodrag Lukić, Dr. Smilja Marković, Institute of Technical Sciences, Serbian Academy of Sciences and Arts, Belgrade, Serbia, 31. 10.–14. 11. 2012

Visiting researchers

1. Dr. Ismael Fabregas, Centro de Investigaciones en Sólidos, CITEFA, Buenos Aires, Argentina, 1. 10.–31. 12. 2012
2. Dr. Zoran Jovanović, Faculty of Physical Chemistry, University of Belgrade, Belgrade, Serbia, 10. 9.–31. 12. 2012
3. Dr. Lei Li, Zhejiang University, Hangzhou, China, 31. 8.–31. 12. 2012

STAFF

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

Postdoctorial associates
6. *Dr. Urban Došler, left 01.05.12*
7. Dr. Jakob König
8. Dr. Uroš Kunaver*
9. Dr. Manca Logar
10. Dr. Matjaž Spreitzer
11. Dr. Marko Udovič*
12. Dr. Asja Veber
13. Dr. Marija Vukomanović

Postgraduates
14. *Dr. Ines Bračko, left 01.11.12*
15. Sonja Jovanović, B. Sc.
16. Dejan Klement, B. Sc.
17. Mario Kurtjak, B. Sc.
18. Mojca Otoničar, B. Sc.
19. Andreja Šestan, B. Sc.
20. Tina Šetinc, B. Sc.
21. Vojka Žunič, B. Sc.

Technical officers
22. Damjan Vengust, B. Sc.

Technical and administrative staff
23. Maja Šimaga, M. Sc.
24. Silvo Zupančič

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL SCIENTIFIC ARTICLE

1. Mostafa Baghbanzadeh, Srečo D. Škapin, Zorica Crnjak Orel, C. Oliver Kappe, "A critical assessment of the specific role of microwave irradiation in the synthesis of ZnO micro- and nanostructured materials", *Chemistry (Weinh., Print)*, vol. 18, issue 18, pp. 2724-2731, 2012.
2. Anatolii Belous, Oleg V. Ovchar, Boštjan Jančar, Danilo Suvorov, "Microwave quality factor of cation-deficient perovskites $Ba(M_{1/3}^{2+}Nb_{2/3})O_3$", In: Proceedinsg of the MMA 2012, 7th International Conference on Microwave Materials and Applications, 3-6 June, 2012, Taiwan, *Ferroelectrics,* vol. 435, no. 1, pp. 166-175, 2012.
3. Mario Bianchetti, Ines Bračko, Srečo D. Škapin, Noemi E. Walsöe de Reca, "Nanocrystalline Tin oxide to be applied in a gas sensor", *Sens. transducers*, vol. 137, no. 2, pp. 155-164, 2012.
4. Mario Bianchetti, Marjeta Maček, Ines Bračko, Srečo D. Škapin, Noemi E. Walsöe de Reca, "Synthesis and characterization of ZnO nanoparticles as prepared by gel-combustion and ZnO nanomorphologies by sol-gel", *Sens. transducers*, vol. 146, no. 11, pp. 36-11, 2012.
5. Mario Bianchetti, Marjeta Maček, Srečo D. Škapin, Noemi E. Walsöe de Reca, "Growth of well aligned tin oxide nanotubes by a sol-gel method", *Sens. transducers*, vol. 137, no. 2, pp. 189-198, 2012.
6. Igor Djerdj, Jasminka Popović, Jernej Stare, Gabriela Ambrožič, Srečo D. Škapin, Bojan Kozlevčar, Damir Pajić, Zvonko Jagličić, Zorica Crnjak Orel, "Nanocrystalline hybrid inorganic-organic one-dimensional chain systems tailored with 2- and 3-phenyl ring monocarboxylic acids", *J. mater. chem.*, vol. 22, no. 20, pp. 10255-10265, 2012.
7. Igor Djerdj, Srečo D. Škapin, Miran Čeh, Zvonko Jagličić, Damir Pajić, Bojan Kozlevčar, Bojan Orel, Zorica Crnjak Orel, "Interplay between the structural and magnetic probes in the elucidation of thestructure of a novel 2D layered $V_4O_4(OH)_2(O_2CC_6H_4CO_2)_4$ DMF", *Dalton trans. (2003. Print)*, vol. 41, issue 2, pp. 581-589, 2012.
8. Urban Došler, Marjeta Maček, Danilo Suvorov, "hase evolution and microwave dielectric properties of $MgO - B_2O_3 - SiO_2$-based glass-ceramics", *Ceram. int.*, vol. 38, issue 2, pp. 1019-1025, 2012.
9. Vilma Ducman, Vladimira Petrovič, Srečo D. Škapin, "Photo-catalytic efficiency of laboratory made and commercially available ceramic building products", *Ceram. int.*, 2012.
10. Metka Hajzeri, Angela Šurca Vuk, Lidija Slemenik Perše, Marija Čolović, Bettina Herbig, Uwe Posset, Marjeta Maček, Boris Orel, "Sol-gel vanadium oxide thin films for a flexible electronically conductive polymeric substrate", In: Proceedings of the 9th International Meeting on Electrochromism, September 5-9, 2010, Bordeaux, France, *Solar energy materials & solar cells,* vol. 99, iss. 1, pp. 62-72, 2012.
11. Nataša Jović, Marija Prekajski, Aleksandar Kremenović, Boštjan Jančar, V. Kahlenberg, Bratislav Antić, "Influence of size/crystallinity effects on the cation ordering and magnetism of α-lithium ferrite nanoparticles", *J. appl. phys.*, vol. 111, no. 3, pp. 034313-1-034313-5, 2012.
12. Dragana Jugović, Miodrag Mitrić, Maja Kuzmanović, Nikola Cvjetićanin, Smilja Marković, Srečo D. Škapin, Dragan Uskoković, "Rapid crystallization of $LiFePO_4$ particles by facile emulsion-mediated solvothermal synthesis", *Powder technol.*, vol. 219, pp. 128-134, 2012.
13. Stanislav Kamba, Veronica Goian, Viktor Bovtun, Dmitri Nuzhnyy, Martin Kempa, Matjaž Spreitzer, Jakob Koenig, Danilo Suvorov, "Incipient ferroelectric properties of $NaTaO_3$", *Ferroelectrics*, vol. 426, no. 1, pp. 206-214, 2012.
14. Marta Kasunič, Srečo D. Škapin, Danilo Suvorov, Amalija Golobič, "Polymorphism of $LaTaTiO_6$", *Acta chim. slov.*, vol. 59, no. 1, pp. 117-123, 2012.
15. Varužan Kevorkijan, Uroš Kovačec, Irena Paulin, Srečo D. Škapin, Monika Jenko, "Preparation of core foamed Al panels", *Metallurgical & Materials Engineering*, vol. 18, no. 1, pp. 29-41, 2012.
16. Varužan Kevorkijan, Srečo D. Škapin, Urban Došler, "An industrial thermogravimetric/differential thermal analysis (TG/DTA) for measuring humidity and organic content in incoming aluminium scrap", *Metallurgical & Materials Engineering*, vol. 18, no. 2, pp. 117-127, 2012.
17. Varužan Kevorkijan, Srečo D. Škapin, Urban Došler, "An industrial method for determining the amount of organics in representative samples of aluminium scrap", *Metall (Berl. West)*, jg. 66, 5, pp. 212-216, Mai 2012.
18. Varužan Kevorkijan, Srečo D. Škapin, Urban Došler, "An industrial method for determining the amount of organics in representative samples of aluminum scrap", *JOM (1989)*, vol. 64, iss. 8, pp. 916-922, Aug. 2012.
19. Varužan Kevorkijan, Srečo D. Škapin, Irena Paulin, Uroš Kovačec, Monika Jenko, "Effect of a foaming agent and its morphology on the foaming behaviour, cell-size distribution and microstructural uniformity of closed-cell aluminium foams", *Mater. tehnol.*, vol. 46, no. 3, pp. 233-238, maj-jun. 2012.
20. Jakob Koenig, Danilo Suvorov, "Uniaxial stress dependence of the dielectric permittivity of the $Na_{0.5}Bi_{0.5}TiO_3KTaO_3$ system", *Sens. actuators, A, Phys.*, vol. 182, pp. 89-94, 2012.
21. Aleksandar Kremenović, Boštjan Jančar, Mira Ristić, Milica Vučinić-Vasić, Jelena Rogan, Aleksandar Pačevski, Bratislav Antić, "Exchange-bias and grain-surface relaxations in nanostructured NiO/ Ni induced by a particle size reduction", *The journal of physical chemistry. C, Nanomaterials and interfaces*, vol. 116, no. 7, pp. 4356-4364, 2012.
22. Špela Kunej, Srečo D. Škapin, Danilo Suvorov, "Dielectric properties of the bismuth neodymium titanate pyrochlore solid solution", *J. Am. Ceram. Soc.*, vol. 95, no. 5, pp. 1201-1203, 2012.
23. Michael C. Langston, Nel P. Dasgupta, Hee Joon Jung, Manca Logar, Yu Huang, Robert Sinclair, Fritz B. Prinz, "In situ cycle-by-cycle flash annealing of atomic layer deposited materials", *The journal of physical*

chemistry. C, Nanomaterials and interfaces, vol. 116, issue 45, pp. 24177-24183, 2012.
24. Manca Logar, Andraž Kocjan, Aleš Dakskobler, "Photocatalytic activity of nanostructured $\gamma - Al_2O_3/TiO_2$ composite powder formed via a polyelectrolyte-multilayer-assisted sol-gel reaction", *Mater. res. bull.*, vol. 47, no. 1, pp. 12-17, 2012.
25. Miodrag Lukić, Ljiljana Veselinović, Marjeta Maček, Ines Bračko, Srečo D. Škapin, Smilja Marković, Dragan Uskoković, "Peculiarities in sintering behavior of Ca-deficient hydroxyapatite nanopowders", *Mater. lett.*, vol. 68, no. 1, pp. 331-335, 2012.
26. J. Mack, Philip B. Van Stockum, Yonas T. Yemane, Manca Logar, Hitoshi Iwadate, Fritz B. Prinz, "Observing the nucleation phase of atomic layer deposition In situ", *Chem. mater.*, vol. 24, issue 22, pp. 4357-4362, 2012.
27. Marjeta Maček, Urban Došler, Danilo Suvorov, "Effect of a TiO_2 nucleating agent on the nucleation and crystallization behavior of $MgO - B_2O_3 - SiO_2$ glass", *J. Am. Ceram. Soc.*, vol. 95, issue 6, pp. 1920-1926, 2012.
28. Djordje Mandrino, Irena Paulin, Srečo D. Škapin, "Scanning electron microscopy, X-ray diffraction and thermal analysis study of the TiH2 foaming agent", *Mater. charact.*, [29] pp., 2012.
29. Oliver Noguera, Jenny Jouin, Oliver Masson, Boštjan Jančar, Phillippe Thomas, "Phase formation and crystal structure determination in the $Y_2O_3 - TeO_2$ system prepared in an oxygen atmosphere", *J. Eur. Ceram. Soc.*, vol. 32, no. 16, pp. 4263-4269, 2012.
30. Oleg V. Ovchar, Dmitrii Durilin, Anatolii Belous, Boštjan Jančar, Taras Kolodiazhnyi, "Dielectric and relaxor properties of $Ba_9MNb_{14}O_{45}$ ceramics", *J. Am. Ceram. Soc.*, vol. 95, issue 10, pp. 3202-3206, 2012.
31. Vladimira Petrovič, Vilma Ducman, Srečo D. Škapin, "Determination of the photocatalytic efficiency of TiO2 coatings on ceramic tiles by monitoring the photodegradation of organic dyes", *Ceram. int.*, vol. 38, iss. 2, pp. 1611-1616, 2012.
32. Matejka Podlogar, Jacob J. Richardson, Damjan Vengust, Nina Daneu, Zoran Samardžija, Slavko Bernik, Aleksander Rečnik, "Growth of transparent and conductive polycrystalline (0001)-ZnO films on glass substrates under low-temperature hydrothermal conditions", *Adv. funct. mater. (Print)*, vol. 22, no. 15, pp. 3136-3145, 2012.
33. Magdalena Radovič *et al.* (12 authors), "Development and evaluation of ^{90}Y-labeled albumin microspheres loaded with magnetite nanoparticles for possible applications in cancer therapy", *J. mater. chem.*, vol. 22, no. 45, pp. 24017-24025, 2012.
34. Ana Stanković, Zoran Stojanović, Ljiljana Veselinović, Srečo D. Škapin, Ines Bračko, Smilja Marković, Dragan Uskoković, "ZnO micro and nanocrystals with enhanced visible light absorption", *Mater. sci. eng., B, Solid-state mater. adv. technol.*, vol. 177, no. 13, pp. 1038-1045, 2012.
35. Magdalena Stevanović, Igor Savanović, Vuk Uskoković, Srečo D. Škapin, Ines Bračko, Uroš Jovanović, Dragan Uskoković, "A new, simple, green, and one-pot four-component synthesis of bare and poly(α, γ, L-glutamic acid)-capped silver nanoparticles", *Colloid polym. sci.*, vol. 290, no. 3, pp. 221-231, 2012.
36. Magdalena Stevanović, Srečo D. Škapin, Ines Bračko, Marina Milenković, Jana Petković, Metka Filipič, Dragan Uskoković, "Poly(lactide-co-glycolide)/silver nanoparticles: synthesis, characterization, antimicrobial activity, cytotoxicity assessment and ROS-inducing potential", *Polymer (Guildf.)*, vol. 53, issue 14, pp. 2818-2828, 2012.
37. A. M. Torki, Dejan B. Stojanović, I. D. Živković, Aleksandar D. Marinković, Srečo D. Škapin, Petar S. Uskoković, Radoslav Aleksić, "The viscoelastic properties of modified thermoplastic impregnated multiaxial aramid fabrics", *Polym. compos.*, vol. 33, no. 1, pp. 158-168, 2012.
38. Marija Vukomanović, I. Šarčev, B. Petronijević, Srečo D. Škapin, Nenad Ignjatović, Dragan Uskoković, "Poly(D,L-lactide-co-glycolide)/hydroxyapatite core-shell nanosphere. Pt. 4, A change of the surface properties during degradation process and the corresponding in vitro cellular response", *Colloids surf., B Biointerfaces*, vol. 91, no. 1, pp. 144-153, 2012.
39. Marija Vukomanović, Vojka Žunič, Mojca Otoničar, Urška Repnik, Boris Turk, Srečo D. Škapin, Danilo Suvorov, "Hydroxyapatite/platinum bio-photocatalyst: a biomaterial approach to self-cleaning", *J. mater. chem.*, vol. 22, no. 21, pp. 10571-10580, 2012.

Published Scientific Conference Contribution

1. Sonja Jovanović, Matjaž Spreitzer, Mojca Otoničar, Danilo Suvorov, "Synthesis of cobalt ferrite nanoparticles using a combination of the co-precipitation and hydrothermal methods", In: *Zbornik*, 4. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 4th Jožef Stefan International Postgraduate School Students Conference, 25. maj 2012, Ljubljana, Slovenija, Dejan Petelin, ed., Aleš Tavčar, ed., Boštjan Kaluža, ed., Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2012, pp. 234-240.
2. Aleš Mrzel, Adolf Jesih, Andrej Kovič, Srečo D. Škapin, Maja Remškar, Damjan Vengust, "Molybdenum based nanowires and nanotubes by a two-step molybdenum/chalcogenide/halide approach", In: *Proceedings of the ICNS4*, 4th International Conference on Nanostructures, ICNS4, 12-14 March 2012, Kish Island, Iran, Alireza Zaker Moshfegh, ed., Teheran, Sharif University of Technology, 2012, pp. 477-479.
3. Mojca Otoničar, "Morfotropna fazna meja v $(Na_{1-x}K_x)_{0,5}Bi_{0,5}TiO_3$ piezoelektri ni keramiki", In: *Zbornik*, 4. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 4th Jožef Stefan International Postgraduate School Students Conference, 25. maj 2012, Ljubljana, Slovenija, Dejan Petelin, ed., Aleš Tavčar, ed., Boštjan Kaluža, ed., Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2012, pp. 282-287.
4. Matejka Podlogar, Damjan Vengust, Nina Daneu, Jacob J. Richardson, Aleksander Rečnik, Slavko Bernik, "Influence of seed layer on the properties of ZNO films prepared by low-temperature hydrothermal synthesis", In: *Proceedings*, 48th International Conference on Microelectronics, Devices and Materials & theWorkshop on Ceramic Microsystems, September 19 - September 21, 2012, Otočec, Slovenia, Darko Belavič, ed., Iztok Šorli, ed., Ljubljana, MIDEM - Society for Microelectronics, Electronic Components and Materials, 2012, pp. 345-350.
5. Tina Šetinc, Matjaž Spreitzer, Špela Kunej, Danilo Suvorov, "Dielectric and ferroelectric properties of sol-gel-derived $Na_{0.5}TiO_3$ thin films", In: *Zbornik*, 4. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 4th Jožef Stefan International Postgraduate School Students Conference, 25. maj 2012, Ljubljana, Slovenija, Dejan Petelin, ed., Aleš Tavčar, ed., Boštjan Kaluža, ed., Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2012, pp. 326-337.
6. Vojka Žunič, "Photocatalytic discoloration of the azo dye methylene blue in the presence ofirradiated TiO_2/Pt nano-composite", In: *Zbornik*, 4. študentska konferenca Mednarodne podiplomske šole Jožefa Stefana = 4th Jožef Stefan International Postgraduate School Students Conference, 25. maj 2012, Ljubljana, Slovenija, Dejan Petelin, ed., Aleš Tavčar, ed., Boštjan Kaluža, ed., Ljubljana, Mednarodna podiplomska šola Jožefa Stefana, 2012, pp. 345-353.

Patent Application

1. Aleš Dakskobler, Andraž Kocjan, Manca Logar, *Method for the preparation of carrier colloidal powder with high specific surface area*, WO2012053990 (A2), World Intellectual Property Organization, 26.4.2012.
1. Marija Vukomanović, Srečo D. Škapin, Danilo Suvorov, *Functionalized hydroxyapatite/gold composites as "green" materials with antibacterial activity and a process for preparing and use thereof*, P-201200204, Urad RS za intelektualno lastnino, 15.6.2012.

Patent

1. Aleš Dakskobler, Andraž Kocjan, Manca Logar, *Method for the preparation of carrier colloidal powder with high specific surface area*, SI23502 (A), Urad RS za intelektualno lastnino, 30.4.2012.
2. Aleš Dakskobler, Andraž Kocjan, Manca Logar, *Method for the preparation of carrier colloidal powder with high specific surface area*, SI23580 (A), Urad RS za intelektualno lastnino, 26.6.2012.

Mentoring

1. Ines Bračko, *Synthesis and functionalisation of one-dimensional titanate-based nanostructures:* doctoral dissertation, Ljubljana, 2012 (mentor Danilo Suvorov; co-mentor Boštjan Jančar).
2. Marija Vukomanović, *Sonochemical synthesis and characterization of hydroxyapatite/metal-based composite materials for biomedical applications:* doctoral dissertation, Ljubljana, 2012 (mentor Srečo Davor Škapin; co-mentor Dragan Uskoković).
3. Jože Katanec, *Antibacterial protections of refrigeration appliances:* master's thesis, Ljubljana, 2012 (mentor Danilo Suvorov; co-mentor Boštjan Pečnik).