DEPARTMENT FOR ADVANCED MATERIALS K-9

Research in the Department for Advanced Materials is focused mainly on synthesizing and characterizing new inorganic materials. The emphasis is on investigations of high-temperature phase equilibria, the identification of new compounds, and determining their crystal structures and properties. Investigations relating to ceramics with special electrical and magnetic properties and super-hard materials and glasses are of primary importance. In recent years, nanomaterials and nanotechnologies have become an important part of the department's activities.

Head:
Prof. Danilo Suvorov

In 2008 the investigations of the Department for Advanced Materials were directed to two main important fields, i.e., the research and investigation of materials exhibiting special electrical properties and the research of nanostructured materials and the processes for their preparation.

In the scope of the investigations of materials exhibiting special electrical properties we investigated tunable materials, microwave dielectrics and materials compatible with low-temperature co-fired ceramic (LTCC) technology.

The investigations of voltage-tunable materials by the scientific community have focused mainly on paraelectric modifications near ferroelectric transitions of the displacive type, in particular on $(Ba_{1-x}Sr_x)TiO_3$-based compounds. However, their high losses, dielectric constant and the temperature dependence of the dielectric constant limit their widespread use, leading us to search for novel materials. We focused our investigations of tunable materials on ferroelectrics of the relaxor type, in particular on $Na_{0.5}Bi_{0.5}TiO_3$. The temperatures of the $Na_{0.5}Bi_{0.5}TiO_3$ phase transitions and thus the intensities of the dielectric relaxations were modified by the addition of various incipient ferroelectrics, such as $SrTiO_3$, $KTaO_3$ and $NaTaO_3$. We observed that samples with the highest tunability also exhibit the highest dielectric relaxations as well as having a morphotropic phase composition. However, these samples also show increased dielectric losses. Improved figures of merit were obtained for samples with increased additive concentrations and paraelectric polar order. We determined that this improvement relates to the low-temperature dielectric relaxations and to the dynamics of nanosized polar regions. In addition, it might be expressed by the exceptionally high nonlinear coefficients β.

In the scope of tunable materials we investigated the mechanical-stress tunability of $Na_{0.5}Bi_{0.5}TiO_3$–$KTaO_3$ and $Na_{0.5}Bi_{0.5}TiO_3$–$K_{0.5}Bi_{0.5}TiO_3$ solid solutions. These solid solutions have potential applications in pressure sensing, due to their stress-dependent dielectric properties. Therefore, the effect of axial pressure on the permittivity of these materials was investigated. The responses of the different compositions were very different, which is connected with the materials` structural and electrical properties. According to the obtained results, the most interesting materials

- **Investigations of voltage-tunable and mechanical-stress-tunable materials based on $Na_{0.5}Bi_{0.5}TiO_3$ and $Na_{0.5}Bi_{0.5}TiO_3$–$KTaO_3$, $Na_{0.5}Bi_{0.5}TiO_3$–$K_{0.5}Bi_{0.5}TiO_3$, respectively.**
- **Investigations of microwave dielectrics based on complex perovskites ($Ba_3CoNb_2O_9$), hexagonal perovskites ($Ba_4Nb_2O_9$), $CaLa_4Ti_5O_{17}$, $SrLa_4Ti_5O_{17}$, $Mg_3B_2O_6$, scheelites ($BaWO_4$, $CaWO_4$, $NaLaW_2O_8$) and feldspars ($KxBa_{1-x}Ga_{2-x}Ge_{2+x}O_8$).**
- **Synthesis and characterization of $CaTiO_3$ and $Na_{0.5}Bi_{0.5}TiO_3$ low-dimensional nanostructures.**
- **In-situ synthesis of ZnS and Mn^{2+}-doped ZnS nanocrystallites in a polymer matrix.**
- **Investigations of hard materials based on Ti_3Al, TiAl and $TiAl_3$ with additions of TiB_2, TiC and B_4C.**

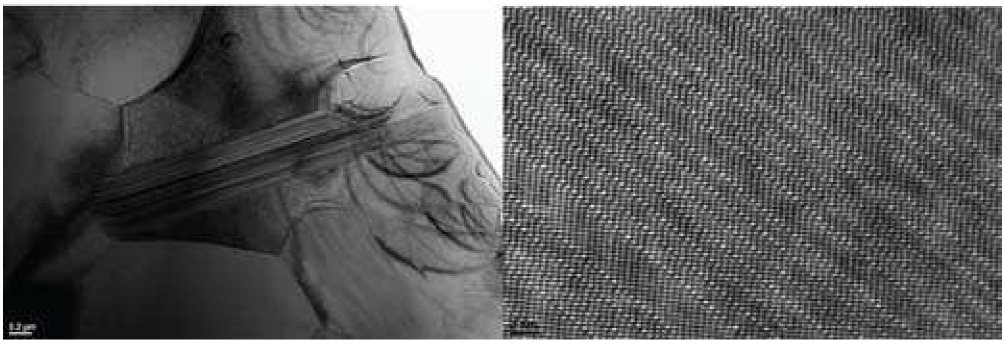

Figure 1: The coherent intergrowth of hexagonal-perovskite polytypes and the cubic perovskite $Ba_3CoNb_2O_9$ triggered by Co-deficiency.

are those which exhibit relaxor properties. In these materials, a high stress dependence of the permittivity and reversibility with changing stress were observed.

Special emphasis was also given to the solid-state synthesis of the $Na_{0.5}Bi_{0.5}TiO_3$–$KTaO_3$ and $Na_{0.5}Bi_{0.5}TiO_3$–$K_{0.5}Bi_{0.5}TiO_3$ solid solutions. Our investigations showed that during the synthesis of $K_{0.5}Bi_{0.5}TiO_3$ ceramics the potassium and bismuth components volatize, resulting in the formation of secondary phases, which were identified using X-ray powder diffraction. The sinterability of the material is low and at elevated temperatures a thermal decomposition of the matrix phase occurs. Scanning electron microscopy with wavelength-dispersive spectroscopy revealed that the matrix phase is non-stoichiometric; it is potassium deficient and contains an excess of bismuth. The secondary phase, i.e., potassium polytitanate, also forms during the synthesis of other compounds that contain potassium and bismuth oxides, e.g., the $Na_{0.5}Bi_{0.5}TiO_3$–$KTaO_3$ and $Na_{0.5}Bi_{0.5}TiO_3$–$K_{0.5}Bi_{0.5}TiO_3$ solid solutions. Therefore, the choice of the firing temperatures is important if we wish to obtain dense ceramics with a low fraction of secondary phases.

We investigated the piezoelectric properties of $(Na_{1-x}K_x)_{0.5}Bi_{0.5}TiO_3$ solid solutions. These materials are good candidates to replace lead-based piezoelectric materials, which are toxic for humans and the environment. As we know from previous studies, some solid solutions with the complex perovskite structure reach a morphotropic phase boundary (MPB) at a certain ratio of different A-site cations. This boundary region is important because of the higher remanent polarization, and therefore enhanced electromechanical properties for a material are possible at room temperature. As an example of such a ceramic material with more than one phase we chose the $(Na_{1-x}K_x)_{0.5}Bi_{0.5}TiO_3$ solid solution. It is known that pure $Na_{0.5}Bi_{0.5}TiO_3$ is rhombohedral, whereas pure $K_{0.5}Bi_{0.5}TiO_3$ is tetragonal. We found that there is a morphotropic phase, with the coexistence of the rhombohedral and tetragonal structures, in the region between 17 and 25 mol percent of potassium. The dielectric, ferroelectric and piezoelectric properties were measured for different compositions at and near the MPB. The investigated piezoceramic material has a high dielectric constant and a high transition temperature (near 300°C), a relatively high remanent polarization and a relatively high piezoelectric constant (up to 134pC/N).

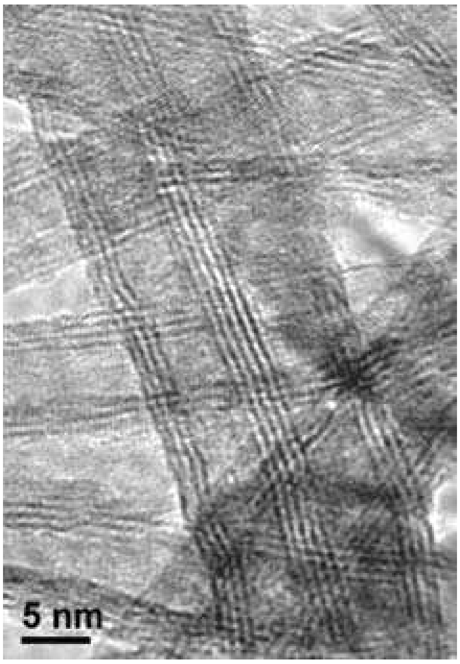

Figure 2: Hydrothermally synthesized titanate precursor in the form of nanotubes.

In the field of microwave dielectrics we investigated several materials, such as complex perovskites ($Ba_3CoNb_2O_9$), hexagonal perovskites ($Ba_4Nb_2O_9$), $CaLa_4Ti_5O_{17}$ and $SrLa_4Ti_5O_{17}$. Within the scope of the research of microwave dielectrics we found that Co-deficiency leads to an increase in the Q-value of $Ba_3CoNb_2O_9$ complex perovskite ceramics. Apart from exhibiting faster B-site cation ordering kinetics the Co off-stoichiometry causes the formation of hexagonal-perovskite polytypes that are coherently intergrown with a 1:2 ordered cubic-perovskite matrix. Such coherent intergrowth can also be understood as a sequence of two succeeding BaO layers arranged in the ABA hexagonal close-packing arrangement in a matrix of an ABC cubic close-packed crystal structure, where the B-site vacancies are ordered between the hexagonally packed layers. The experimental results indicate that an increase in Qxf can be mainly attributed to such a superstructure of ordered cation vacancies. The highest Q-value, Qxf >100000 GHz, was measured in the case of ceramics with the nominal composition $Ba_8CoNb_6O_{24}$, which was found to consist mainly of the intergrown cubic $Ba_3CoNb_2O_9$ and hexagonal $Ba_5Nb_4O_{15}$ perovskites.

The investigations of $Ba_4Nb_2O_9$ were focused on the study of high-temperature polymorphic phase transitions in $Ba_4Nb_2O_9$ and on the crystal-structure determination of individual polymorphs with the help of transmission electron microscopy (TEM) and a tilting experiment. We have isolated two stable polymorphs – the low-temperature α-modification and the high-temperature γ-modification – with a phase-transition temperature at 1160°C. The rate of cooling applied to the γ-$Ba_4Nb_2O_9$ sample strongly affects the nature of the phase transitions. The rapid cooling (quenching) of the γ-phase sample down to room temperature results in the γ-modification, while slow cooling (1-2°C/min) leads to the formation of a pure α-modification. Cooling the γ-phase at a rate of ~3°C/min results in the formation of the β-modification, which was also observed between 360-585°C after reheating the γ-modification and on the surface of the quenched γ-$Ba_4Nb_2O_9$ sample. Using HT-TEM experiments the orthorhombic β-$Ba_4Nb_2O_9$ has been proved to be a distorted γ-modification (γ'). All the polymorphs of $Ba_4Nb_2O_9$ are structurally closely related, implying that only minor structural perturbations are involved in the polymorphic phase-transformation processes in this system. Collected high-resolution electron images and electron-diffraction patterns along different low-index zone axes allowed us to propose the crystal-structural model of the α-modification. Regarding the stoichiometry of the $Ba_4Nb_2O_9$ compound and the discrepancy in the distance between the Ba-O layers along the hexagonal c-axis with respect to this distance in the conventional perovskite structures, we proposed a crystal-structural model that is closely related to the 2H-type perovskite structure. The proposed structure comprises alternating Ba_3O_9 and oxygen-deficient Ba_3O_6 close-packed layers along the c-axis. Such a stacking of the close-packed layers creates the infinite chains of octahedrally and trigonal-prismatically coordinated B-sites cations. Based on the data collected by SAED and HRTEM we confirmed the validity of the chosen structural model. In addition, based on the tilting experiment we reconstructed the orthorhombic unit cell for α-$Ba_4Nb_2O_9$ and measured the unit-cell parameters (a = 17.81 Å, b = 10.25 Å in c = 8.5 Å). We observed that the γ-$Ba_4Nb_2O_9$ in air partially decomposes to $Ba_5Nb_4O_{15}$ and BaO, which instantly reacts with CO_2 to form $BaCO_3$, whereas heating the $Ba_4Nb_2O_9$ sample in vacuum results the formation of $Ba_3Nb_2O_8$, due to the increased loss of BaO from the system.

A major part of our investigations of microwave dielectrics was focused on low-permittivity materials (ε<10), which, in comparison to high-permittivity materials, are more appropriate for high-frequency applications (>10 GHz). During a study of magnesium borates ($Mg_3B_2O_6$ and $Mg_2B_2O_5$) we focused on the synthesis conditions and correlations between the microstructural characteristics and the dielectric properties. We found that the synthesis of single-phase $Mg_3B_2O_6$ and $Mg_2B_2O_5$ required 11 and 14 wt.% excess of B_2O_3. The highest Qxf values of over 200,000 GHz were measured for $Mg_3B_2O_6$ ceramics with a grain size of around 1000 microns. In the scope of our study of low-temperature-sinterable, low-permittivity and low-loss materials we investigated materials based on $K_xBa_{1-x}Ga_{2-x}Ge_{2+x}O_8$ solid solutions with the paracelsian crystal structure and materials with the scheelite structure. In our study of $K_xBa_{1-x}Ga_{2-x}Ge_{2+x}O_8$ the focus was on determining the crystal structure with a Rietveld structural refinement and on determining the structural changes that occurred during the $P2_1/a \rightarrow C2/m$ phase transition. On the basis of the difference in the fundamental features of the topology between the P21/a and C2/m phase, we found that the tetrahedral T-O bonds in the crystal structure have to be partially disassociated and reconnected to form the new phase, which led to an intensive thermal effect during the phase transition.

A comparative microstructural and dielectric study of $BaWO_4$, $SrWO_4$ and $CaWO_4$ sheelite ceramics revealed some important differences between these materials in terms of the grain size, their growth and their sensitivity to humid air. Compared to $BaWO_4$ and $CaWO_4$, $SrWO_4$ ceramics were found to be hygroscopic and more incongruently soluble in water. These properties mean $SrWO_4$ ceramics are inappropriate as materials for electronic components. In contrast to $SrWO_4$, $BaWO_4$ and $CaWO_4$ ceramics were found to be resistant to water and humidity. Scheelite $LiLaW_2O_8$, $NaLaW_2O_8$ and $KLaW_2O_8$ ceramics could be densely sintered at temperatures as low as 700–800°C. Only $NaLaW_2O_8$ exhibits promising microwave dielectric properties, i.e., ε=11.7, Qxf=27900 GHz and τ_f=-20 ppm/°C.

In the scope of low-permittivity LTCC materials we investigated materials from the MgO-B_2O_3-SiO_2 system, which were in contrast to $K_xBa_{1-x}Ga_{2-x}Ge_{2+x}O_8$ and scheelites, prepared by recrystallization.

In the field of investigating LTCC ceramics with higher permittivity (ε=80) we studied the influence of Nb substitution in the compound Bi_3NbO_7 by Ta and the sintering conditions on the microwave dielectric properties of the resulting ceramics. We confirmed that the properties of the formed solid solution $Bi_3Nb_{1-x}Ta_xO_7$ depended on the Ta content: the permittivity of the ceramics decreased with Ta content, while the quality factor (Qxf) increased; however, the temperature coefficient of resonant frequency decreased and reached the value τ_f=12 ppm/K at x=0.6. Based on these properties our ceramics can be classified as commercially interesting materials.

The research on nanostructured materials was mainly focused on the synthesis of low-dimensional nanostructures, inorganic-organic composites and the preparation of thin films. The synthesis of low-dimensional nanostructures of $CaTiO_3$ and $Na_{0.5}Bi_{0.5}TiO_3$ was carried out under hydrothermal conditions. The synthesis of $CaTiO_3$ started from nanostructured, layered alkali metal titanates with tubular morphology. The layered structure of the titanate

- **In the scope of our investigations with TRIMO Trebnje we developed a new product - termoinsulation plate - which is made entirely from recycled waste mineral fibres.**
- **In a cooperation with researchers from Gorenje Velenje we investigated the possibilities of the application of recycled polymers in the production of household appliances and developed the method and technology for the production of refrigerators from recycled materials.**
- **In the scope of industrial research projects we developed several middle-permittivity LTCC materials, which are compatible with other already-commercialized LTCC materials. The compatibility includes, in addition to chemical compatibility, the matching of the thermal expansion coefficient and the kinetics of sintering.**

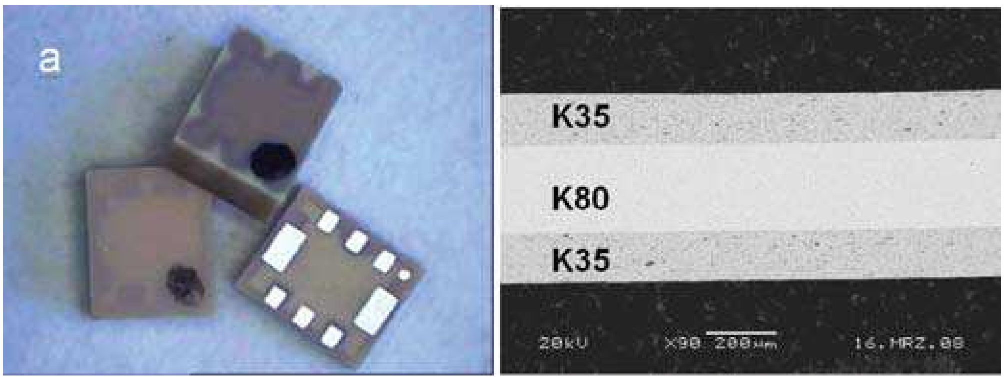

Figure 3: The application of K80 in a balun (a) and the perfect co-sintering of K35 and K80, without any reaction zone or cracks (b).

Figure 4: New Laboratories at the Department for Advanced Materials

In 2008 the Department for Advanced Materials was renovated and the building was completed with additional laboratories for the synthesis and characterisation of thin layers and nanoparticles.

precursor enables the ion exchange of an alkali metal cation with calcium under hydrothermal conditions. Hydrothermal treatment (100-150°C) of the tubular precursor with $Ca(OH)_2$ leads to the ion-exchange reaction of interlayer Na^+ cations with Ca^{2+} cations. The morphology is preserved but the chemical composition is changed. According to the EDS analysis, nanotubes prepared under these conditions contained about 10 at. % of calcium after the hydrothermal ion-exchange reaction. Increasing the temperature to 200°C led to the formation of well crystallised, anisotropic single crystals of $CaTiO_3$ with a length of 800 nm and a width of 100–200 nm. The hydrothermal synthesis of $Na_{0.5}Bi_{0.5}TiO_3$ was optimized by changing the concentrations of the reactants, the temperature and the duration of the synthesis. $Na_{0.5}Bi_{0.5}TiO_3$ with a crystallite size of 20–75 nm was successfully synthesized.

Nanocomposite inorganic/organic thin films were fabricated by the in-situ synthesis of ZnS and Mn^{2+}-doped ZnS nano-crystallites in a polymer matrix. The polymer network acts as a nanoreactor, where the morphology, size and volume density of the synthesized crystallites are controlled by the pH value of the polymer solution and the number of reaction cycles. By controlling the size of the semiconducting nanocrystallites a control over the optical properties is obtained, resulting in an efficient fluorescence of the composite films.

Thin $Bi_{12}SiO_{20}$ films were prepared by the Pechini and sol-gel methods. In the Pechini route the metallic precursors were prepared and then esterified with the addition of ethylene glycol. The prepared precursor solution was deposited on $Si/SiO_2/TiO_2/Pt$ substrates. We studied the influence of the precursor concentration, the number of deposited layers and the thermal treatment on the microstructure and thickness of BSO thin films. The thin films were thermally treated in three stages: drying, pyrolyzing and annealing. The results showed that for both precursor concentrations, 0.3 M and 0.2M, we obtained dense, homogenous BSO thin films. The difference between the precursor solutions was shown in the thickness and the grain size. Therefore, we obtained, in the case of a 0.3-M solution, a thickness of 200 nm and an average grain size of 450 nm, and for a 0.2-M solution, a thickness of 100 nm and average grain size of 300 nm.

For the preparation of thin $Bi_{12}SiO_{20}$ films by the sol-gel route two synthesis procedures using different solvents, 2-ethoxyethanol and acetic acid, were compared. The solvents actually behave as true chemical reagents; they are able to react with the precursors and change them at the molecular level, therefore changing the whole process, i.e., the stability and ageing time of the sols, the morphology and the thickness of thin films. We found that in sols prepared with the help of acetic acid, acetate groups bidentately bonded to bismuth ions. This shortened the gelation time (t_G) (c = 0.78 M, tG = 24 h) compared to sols prepared with 2-ethoxyethanol (c = 0.78 M, t_G = 192 h). The microstructure development of $Bi_{12}SiO_{20}$ thin films, prepared from sols using 2-ethoxyethanol, showed homogeneous and dense thin films. A porous microstructure was observed for $Bi_{12}SiO_{20}$ thin films deposited from a sol using acetic acid as the co-solvent.

In the field of hard materials we studied the influence of the additives TiB_2, TiC and B_4C on the compounds Ti_3Al, TiAl and $TiAl_3$. We determined the phase composition and the mechanical properties of samples fired at 800 to 1300°C.

In the research area of glass and mineral fibres our investigations were made for the industrial partners Gamma Meccanica, Knauf Insulation and Paroc. The investigations included the analysis of mineral rocks, glassy materials and fibres. The basic aim of the investigations was to determine the correlations between the composition and the glass-forming conditions in order to obtain the optimal melt properties of the glass for the production of fibres. We performed numerous melting tests on the samples to analyse the melting behaviour of various basalts and their compositions with dolomites. In the scope of the investigations with TRIMO Trebnje we developed new product, termoinsulation plate, which is made entirely from recycled waste mineral fibres.

In the scope of industrial research projects we developed several middle-permittivity LTCC materials that are compatible with other already-commercialized LTCC materials. The compatibility includes, in addition to chemical compatibility, a matching of the thermal expansion coefficient and the kinetics of sintering.

Some outstanding publications in 2008

1. Jana Bezjak, Boštjan Jančar, Aleksander Rečnik, Danilo Suvorov. The synthesis and polymorphic phase transitions of $Ba_4Nb_2O_9$ ceramics. J. Eur. Ceram. Soc., 28 (2008) 14, 2771-2776
2. Špela Kunej, Danilo Suvorov. Subsolidus phase equilibria in the pyrochlore-rich part of the Bi_2O_3-TiO_2-Y_2O_3 system. J. Am. Ceram. Soc., 91 (2008) 10, 3472-3475

3. Marjeta Maček Kržmanc, Boštjan Jančar, Danilo Suvorov. The influence of tetrahedral ordering on the microwave dielectric properties of $Sr_{0.05}Ba_{0.95}Al_2Si_2O_8$ and $BaM_2M'_2O_8$ (M = Al, Ga, M = Si, Ge) ceramics. J. Eur. Ceram. Soc., 28 (2008)16, 3141-3148
4. Qin Ni, Marjeta Maček Kržmanc, Danilo Suvorov. Glass-free $K_xBa_{1-x}Ga_{2-x}Ge_{2+x}O_8$ ceramics for low-temperature cofired ceramics technology: Synthesis, phase transitions, sintering and microwave dielectric properties. J. Am. Ceram. Soc., 91 (2008) 8, 2593-2600.
5. Srečo D. Škapin, Špela Kunej, Danilo Suvorov. Phase relations and electrical properties in the pseudo-ternary La_2O_3-TiO_2-Mn_2O_3 system in air. J. Eur. Ceram. Soc., 28 (2008) 16, 3119-3124

Awards and Appointments

1. Danilo Suvorov: Inauguration: Academician of the World Academy of Ceramics, The Council of the World Academy of Ceramics, Chianciano, Italy, 6 Aug. 2008
2. Danilo Suvorov: Inauguration: Fellow of the American Ceramic Society, Board of Directors of the American Ceramic Society, Pittsburgh, USA, 6 Oct. 2008.
3. Asja Veber: Award for the best poster on conference YUCOMAT 2008, Herceg Novi, Montenegro, Awarding Committee of the YUCOMAT 2008 Conference, poster entitled The Thickness, Morphology and Structure of Sol-Gel $Bi_{12}SiO_{20}$ thin films.
4. Mojca Žnidaršič: Award for the best contribution of young researchers, 1. International Conference on Materials and Technologies, Portorož, Awarding Committee of the Conference, contribution entitled The structural and electrical properties of a solid solution based on $Na_{0.5}Bi_{0.5}TiO_3$–$K_{0.5}Bi_{0.5}TiO_3$.
5. Srečo D. Škapin: Award for the poster presentation, Hot Nano Topics 08, 23-30 May, 2008, Portorož Slovenia, “Photocatalytic undoped and doped nanotitania for building applications”

Organization of conferences, congresses and meetings

1. Meeting of the EU 6FP project: Safe, integrated and controlled production of high tech multifunctional products and their recycling (SAPHIR), Ljubljana, 17–19 Mar. 2008
2. 2nd International Congress on Ceramics, Verona, Italy, 29 Jun. to 4 Jul. 2008 (co-organizers).
3. International Workshop on Contemporary Ceramics for Electronics, Verona, Italy, 30 Jun. 2008
4. International Symposium on Advanced Dielectric Materials at Materials Science and Technologies Conference and Exhibition, Pittsburgh, USA, 5–9 Oct. 2008
5. 1st International Conference on Materials and Technologies, Portorož, 13–15 Oct. 2008 (co-organizers)
6. 5th International Conference on Microwave Materials and Their Applications (MMA-2008), Hangzhou, China, 1–4 Nov. 2008 (co-organizers)

INTERNATIONAL PROJECTS

1. 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
2. Tantalum-Free Microwave Dielectric Resonators with Enhanced Quality Factor
   NATO SfP 980881
   NATO Public Diplomacy Division, North Atlantic Treaty Organisation, Brussels, Belgium; Prof. Peter Mascher, McMaster University, Department of Engineering Physics, Faculty of Engineering, Hamilton, Ontario, Canada
   Dr. Boštjan Jančar
3. Relaxor-based Tunable Materials
   T080038
   Dr. Christian Hoffmann, Dr. Andrea Testino, EPCOS OHG Ceramic Components Division, Deutschlandsberg, Austria
   Prof. Danilo Suvorov, Dr. Boštjan Jančar
4. LTCC Materials for High Frequency Applications
   T080033
   Pavol Dudesek, EPCOS OHG Ceramic Components Division, Deutschlandsberg, Austria
   Prof. Danilo Suvorov, Dr. Marjeta Maček Kržmanc
5. Characterisation of Bio Soluble Mineral Fibres
   T070032
   Markus Mente, B. Sc., Heraklith GmbH, Furnitz, Austria
   Prof. Danilo Suvorov
6. LTCC Materials for High Frequency Applications
   T070033
   Dr. Justinus Slakhorst, Christian Block, B. Sc., EPCOS OHG, Ceramic Components Division, Deutschlandsberg, Austria
   Prof. Danilo Suvorov
7. Characterization of Bio Soluble Mineral Fibres
   T070031
   Niklas Bergman, B. Sc., Paroc Group OY AB/R&D, Pargas; Vantaa, Finland
   Prof. Danilo Suvorov
8. Characterization of the Materials for Mineral Fibres Production
   T070001
   Giovanni Burini, B. Sc., Gamma Meccanica, Bibbiano, Reggio Emilia, Italy
   Prof. Danilo Suvorov
9. Designing of Functional Materials on Molecular and Nano Level
   BI-RS/08-09-027
   Prof. Dragan Uskoković, Institut tehničkih nauka Srpske akademije nauka i umetnosti, Belgrade, Serbia
   Prof. Danilo Suvorov
10. 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
11. 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
    Dr. Srečo D. Škapin, Dr. Miha Čekada, Prof. Janez Dolinšek, Dr. Kristoffer Krnel

R & D GRANTS AND CONTRACTS

1. Development of multi-functional B_4C-Al and B_4c-Mg composites for emerginig applications
   Prof. Tomaž Kosmač, Dr. Srečo Davor Škapin
2. Multifunctional composites based on Al-Mg-ti intermetallic compounds reinforced with ceramic particles
   Dr. Srečo Davor Škapin
3. Self-cleaning photocatalitic coatings
   Asst. Prof. Miran Mozetič, Dr. Srečo Davor Škapin
4. Smart functional coatings for increasing sustainability of structures and components for defense purposes
   Dr. Peter Panjan, Dr. Srečo Davor Škapin

RESEARCH PROGRAM

1. Contemporary inorganic materials and nanotechnologies
   Prof. Danilo Suvorov

NEW CONTRACT

1. Development of procedures for economically efficient use of waste mineral wool from Trimo production
   Trimo, Trebnje
   Prof. Danilo Suvorov

VISITORS FROM ABROAD

1. Dr Christian Hoffmann, Pavol Dudesek, B. Sc., EPCOS OHG, Deutschlandsberg, Austria, 1 Apr. 2008
2. Prof. Velimir Radmilovič, National Center for Electron Microscopy, University of California, Berkeley, USA, 13–15 Jun. 2008
3. Julie Cornette, B. Sc., University of Limoges, France, 26–29 Jun. 2008
4. Dr Philippe Thomas, University of Limoges, France, 26–29 Jun. 2008
5. Dr Jeon Jae-Ho, Korea Institute of Materials Science, Changwong, Korea, 4–6 Sept. 2008
6. Dr Ivan Sondi, Institut Rudjer Bošković, Zagreb, Croatia, 25 Sept. 2008
7. Christopher John Hull, M. Sc., European Association of Research and Technology Organisations, Brussels, Belgium, 23 Oct. 2008.
8. Prof. Erkki Leppävuori, VTT Technical Research Centre of Finland, Espoo, Finland, 23 Oct. 2008
9. Dr Michael Maurer, German Federation of Industrial Research Associations, Köln, Germany, 23 Oct. 2008
10. Dr Eugenio Otal, Universidad de Buenos Aires, Buenos Aires, Argentina 30 Oct. 2008
11. Manuela Leticia Kim, M. Sc., Universidad de Buenos Aires, Buenos Aires, Argentina 30 Oct. 2008
12. Dr Andrea Testino, EPCOS OHG, Deutschlandsberg, Austria, 19 Nov. 2008
13. Mathieu Antoni, B. Sc., EPCOS OHG, Deutschlandsberg, Austria, 19 Nov. 2008
14. Dr Kim Byoung- Kee, Korea Institute of Materials Science, Changwong, Korea, 20 Nov. 2008
15. Dr Jeon Jae-Ho, Korea Institute of Materials Science, Changwong, Korea, 20 Nov. 2008

Visiting Researchers:
1. Dr Qin Ni, Zhejiang University, Hangzhou, China, 1 Dec. 2006 to 30 Oct. 2008
2. Dr Olivier Noguera, Faculte des Sciences et Techniques, UMR-CNRS, Limoges, France, 1 Nov. 2007 to 31 Oct. 2008
3. Dr Jyoti Prosad Guha, University of Rolla, Rolla, USA, 3 Jun. to 31 Aug. 2008

STAFF

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

Postdoctoral associates
5. Dr. Uroš Kunaver*
6. Dr. Špela Kunej
7. Dr. Matjaž Spreitzer
8. Dr. Marko Udovič*

Postgraduates
9. Ines Bračko, B. Sc.
10. Urban Došler, B. Sc.
11. Jakob König, B. Sc.
12. Manca Logar, B. Sc.
13. Tina Šetinc, B. Sc.
14. Asja Veber, B. Sc.
15. Mojca Žnidaršič, B. Sc.
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BIBLIOGRAPHY

Original Articles

1. Jana Bezjak, Boštjan Jančar, Aleksander Rečnik, Danilo Suvorov, "The synthesis and polymorphic phase transitions of $Ba_4Nb_2O_9$ ceramics", *J. Eur. Ceram. Soc.*, issue 14, vol. 28, pp. 2771-2776, 2008.
2. Katarina Demšar, Srečo D. Škapin, Anton Meden, Danilo Suvorov, "Ritveld refinement and dielectric properties of $CaLa_4Ti_5O_{17} and SrLa_4Ti_5O_{17}$ ceramics", *Acta chim. slov.*, vol. 55, no. 4, pp. 966-972, 2008.
3. Teresa Jardiel, Marina Villegas, Angel Caballero, Danilo Suvorov, Amador C. Caballero, "Solid-state compatibility in the system $Bi_2O_3 - TiO_2 - Bi_2WO_6$", *J. Am. Ceram. Soc.*, vol. 91, no. 1, pp. 278-282, 2008.
4. Marija Jevtić, Miodrag Mitrić, Srečo D. Škapin, N. Ignjatović, Dragan Uskoković, "Crystal structure of hydroxyapatite nanorods synthesized by sonochemical homogeneous precipitation", *Cryst. growth des.*, vol. 8, no. 7, pp. 2217-2222, 2008.
5. Dragana Jugović, Miodrag Mitrić, Nikola Cvjetićanin, Boštjan Jančar, Slavko Mentus, Dragan Uskoković, "Synthesis and characterization of $LiFePO_4/C$ composite obtained by sonochemical method", *Solid state ion.*, vol. 179, no. 11-12, pp. 415-419, 2008.
6. Varužan Kevorkijan, Srečo D. Škapin, "Boron carbide-aluminum and boron carbide-titanium boride-aluminum composites reactively bonded with aluminum magnesium boride", *Am. Ceram. Soc. bull.*, vol. 86, no. 5, pp. 9301-9308, 2008.
7. Špela Kunej, Danilo Suvorov, "Subsolidus phase equilibria in the pyrochlore-rich part of the $Bi_2O_3 - TiO_2 - Y_2O_3$ system", *J. Am. Ceram. Soc.*, vol. 91, no. 10, pp. 3472-3475, 2008.
8. Marjeta Maček, Boštjan Jančar, Danilo Suvorov, "The influence of tetrahedral ordering on the microwave dielectric properties of $Sr_{0.05}Ba_{0.95}A_{l2}Si_2O_8$ and $BaM_2M'_2O_8$ (M = Al, Ga, M' = Si, Ge) ceramics", *J. Eur. Ceram. Soc.*, vol. 28, no. 16, pp. 3141-3148, 2008.
9. Roberto L. Moreira, Franklin M. Matinaga, Urša Pirnat, Danilo Suvorov, Anderson Dias, "Optical phonon characteristics of incommensurate and commensurate modulated phases of Bi_3NbO_7 ceramics", *J. appl. physi.*, vol. 103, no. 9, pp. 094108-1-094108-7, 2008.
10. Ni Qin, Marjeta Maček, Danilo Suvorov, "Glass-free $K_xBa_{1-x}Ga_{2-x}Ge_{2+x}O_8$ ceramics for low-temperature cofired ceramic technology: synthesis, phase transitions, sintering, and microwave dielectric properties", *J. Am. Ceram. Soc.*, vol. 91, no. 8, pp. 2593-2600, 2008.
11. Ivan Sondi, Srečo D. Škapin, Branka Salopek-Sondi, "Biomimetic precipitation of nanostructured colloidal calcite particles by enzyme-

catalyzed reaction in the presence of magnesium ions", *Cryst. growth des.*, vol. 8, no. 2, pp. 435-441, 2008.
12. M. Soulis, A. Mirgorodsky, T. Merle-Méjean, O. Masson, P. Thomas, Marko Udovič, "The role of modifier's cation valence in structural properties of TeO_2-based glasses", In: *11th international conference on the physics of non-crystalline solids: physics of non-crystalline solids 11*, (Journal of non-crystalline solids, Vol. 354, Issues 2-9, 2008), George Kordas, ed., Amsterdam, North-Holland, 2008, vol. 354, no. 2/9k, pp. 143-149, 2008.
13. Srečo D. Škapin, Špela Kunej, Danilo Suvorov, "Phase relations and electrical properties in the pseudo-ternary $La_2O_3 - TiO_2 - Mn_2O_3$ system in air", *J. Eur. Ceram. Soc.*, vol. 28, no. 16, pp. 3119-3124, 2008.
14. Srečo D. Škapin, Andrijana Sever Škapin, Danilo Suvorov, Miran Gaberšček, "A stabilization mechanism for the perovskite $La_{2/3}TiO_3$ compound with Fe_2O_3: a structural and electrical investigation", *J. Eur. Ceram. Soc.*, vol. 28, no. 10, pp. 2025-2032, 2008.
15. Matjaž Valant, Boštjan Podobnik, Drago Kovačič, Manca Logar, "Direct-laser writing of striplines on AgCl single crystals", *Mater. chem. phys.*, vol. 110, no. 2/3, pp. 280-284, 2008.

PUBLISHED CONFERENCE PAPERS

Regular papers

1. Andreja Gajović, Sašo Šturm, Boštjan Jančar, Miran Čeh, "Phase relations in the Fe-Bi-O system under hydrothermal conditions", In: *EMC 2008*, 14th European Microscopy Congress, 1-5 September 2008, Aachen, Germany, Silvia Richter, ed., Alexander Schwedt, ed., Berlin, Heidelberg, Springer, 2008, zv. 2, pp. 129-130.

THESIS

Ph. D. Theses

1. Matjaž Spreitzer , *Influence of synthesis and structural characteristics in electrical properties of $Na_{0.5}Bi_{0.5}TiO_3$*, Ljubljana, (Prof. Danilo Suvorov), 2008.

B. Sc. Theses

1. Tina Šetinc, *Electrical conductivity of porous LSM ceramic*, Ljubljana, [T. Šetinc], 2008. (Asst. Prof. Marjan Marinšek)
2. Vojka Žunič, *Mineralogy and usability of clay from deposite Boreci at Križevcih*, Ljubljana, (Asst. Prof. Meta Dobnikar), 2008.