DEPARTMENT FOR ADVANCED MATERIALS

K-9

Research in the Advanced Materials Department 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 2007 the investigations of the program group P2-0089 were directed to four important materials, i.e., magnetic nanoparticles for applications in technology and medicine, microwave magnetic ceramics for use in the area of telecommunications, semiconducting spintronic materials based on ZnO, and ferroelectric materials with a high Curie temperature for the preparation of high-temperature thermistors that would replace lead-containing materials.

The research on magnetic nanoparticles was mainly focused on their functionalization. For biomedical applications, the magnetic nanoparticles should be functionalized with a surface layer of organic molecules, which enables the selective bonding of different bioactive molecules to their surfaces, allows their compatibility with physiological fluids and prevents their agglomeration. The bonding of different organosilane molecules directly onto the nanoparticles' surfaces or on the surface layer of silica was systematically studied. We have continued with the research of different methods of nanoparticle syntheses, especially methods based on the thermal decomposition of organo-metal complexes and the method of hydrothermal synthesis.

In the field of magnetic materials for telecommunications the studies were focused on the development of materials suitable for magnetic microwave and mm-wave devices. The possibility of low-temperature co-firing ceramics (LTCC) based on Z-hexaferrites was studied. We showed that the compositions suitable for LTCC and compatible with Ag are thermally instable at 900–950°C. We proposed a mechanism for the Z-hexaferrites degradation based on a defect crystal chemistry. The influence of the partial degradation of hexaferrites on the electromagnetic behaviour was also evaluated. A new method for the synthesis of single-phase W-hexaferrites suitable for mm-wave applications was developed. The method is based on a two-step synthesis via intermediates. Based on this method, new nonreciprocal isolators (8x smaller than the state of the art) were developed in cooperation with TKI-Ferrit (Hungary). In 2007 we started with the development of a new type of electromagnetic absorbers using spraying technology and with the development of thick M-hexaferrite films for applications above 30 GHz.

With the cooperation of EPCOS Ohg., Deutschlandsberg, Austria, we developed a series of high-, middle- and low-dielectric ceramic materials on the basis of Bi-compounds for LTCC technology, which have shown various functional dielectric properties and a chemical compatibility between themselves and silver electrodes. The developed dielectric ceramic materials are protected with 12 international patents and were transferred to the regular production of multifunctional LTCC modules.

In the field of spintronic materials, high-temperature reactions, phase relations, structures and properties of different spinel phases in the ZnO–MnO_X system were studied. This research is important for understanding the magnetism of the semiconducting solid solutions of magnetic ions in ZnO.

In the field of high-temperature thermistors the processes of reduction and reoxidation related to the formation of temperature-dependent potential barriers at the grain boundaries of ferroelectric ceramics in the $BaTiO_3$–$BaNb_2O_6$ system were studied.

Investigations in the program group P2-0089 Advanced Materials and Nanotechnologies for 2007 were made on low-sinterable, low-permittivity and low-loss materials based on $K_xBa_{1-x}Ga_{2-x}Ge_{2+x}O_8$ solid solutions with the paracelsian structure ($P2_1/a$) and materials with the scheelite structure. We found that during the phase transition from the $P2_1/a$ to the C2/m modification the dielectric properties of $K_xBa_{1-x}Ga_{2-x}Ge_{2+x}O_8$ solid solutions changed; in particular the dielectric losses increased. With knowledge of the kinetics of the phase transitions and with the help of a minimal addition of the sintering aid, dense, low-permittivity material (ε=5.0-6.1) with a sintering temperature of 900–970°C, Qxf values of 110 000 to 150 000 GHz and a temperature coefficient of resonant frequency (τ_f) of around - 20 ppm/K was prepared. During a study of materials with the scheelite structure several new findings were made. One of them is the possibility to sinter under LTCC conditions. It was found that $SrWO_4$ is, in contrast to $BaWO_4$ and $CaWO_4$, hygroscopic. For practical applications this property is a major disadvantage.

- **Synthesis and functionalization of magnetic nanoparticles for applications in biomedicine.**
- **LTCC hexaferrite ceramics for microwave applications.**
- **Development of a two-step synthesis for W-hexaferrites and for new nonreciprocal isolators for mm-wave applications.**
- **Structures and properties of spinel phases in the $ZnO–MnO_x$ system.**

Part of the low-dielectric-materials research work involved studying the re-crystallization process for various compositions of the $MgO–B_2O_3–SiO_2$ system. This system is extremely interesting because of the applicable potential in LTCC technology, and it remains undiscovered. The majority of the experimental work was focussed on the following composition: 43 wt.% MgO, 35 wt.% B_2O_3, and 22 wt.% SiO_2. We confirmed that a higher sintering temperature also resulted in a smaller amount of glassy phase, which affects the dielectric properties. Increasing the sintering temperatures and a longer milling time has the effect of decreasing the permittivity. The lowest value of the permittivity, 4.7, achieved for 1000°C/5h. The highest value of Qxf was 9400GHz, which was achieved with a sintering temperature of 950°C.

Besides the above-mentioned research on low-dielectric materials, we also investigated the voltage-tunable characteristics of ferroelectric materials. We focused on the tunability of the dielectric constant, which is defined as the relative change of a dielectric constant under a DC-bias field ($n_r = (\varepsilon(0)–\varepsilon(E))/\varepsilon(0)$). Voltage-tunable materials are applicable in many radio-frequency and microwave electronic components, such as varactors, phase shifters, tunable filters, tunable resonators, etc. In our work we focused on relaxor ferroelectrics, especially on $Na_{0.5}Bi_{0.5}TiO_3$-based compounds. We determined the tunability of the dielectric constant for the $Na_{0.5}Bi_{0.5}TiO_3–NaTaO_3$ homogeneity region. As the concentration of $NaTaO_3$ increases from 0 to 10 mol% the tunability increases from 36% up to almost 50%. However, as the concentration of the additive increases further the tunability gradually decreases to 22%. High values of the tunability are related to the morphotropic compositions of the samples and the maximum dielectric relaxations. Samples with a high tunability were shown to also exhibit high dielectric losses and vice versa. The reduction of the dielectric losses relates to a decrease of the polar-cluster size. Samples with a high $NaTaO_3$ concentration also show a moderate temperature coefficient of the dielectric constant and are therefore attractive for practical applications.

As part of the research on voltage-tunable ferroelectric materials, we constructed a system for testing the axial pressure dependence of the permittivity and characterized this dependence for materials from the $Na_{0.5}Bi_{0.5}TiO_3$–$NaTaO_3$ system. Later we concentrated on the synthesis of the $Na_{0.5}Bi_{0.5}TiO_3–KTaO_3$ solid solution, in which the formation of the secondary phase takes place and is characteristic for the $K_{0.5}Bi_{0.5}TiO_3$ system. With the addition of $NaTaO_3$ we managed to increase the effect of the axial pressure on the permittivity, which was our basic objective in the research. During this testing, the mechanical polarization of the samples was observed, as the permittivity of the samples after the tests did not reach the value prior to testing. This is a consequence of the ferroelastic domain switching caused by the axial stress, which also changes the ferroelectric domain structure and influences the dielectric properties of the sample. Although in the $Na_{0.5}Bi_{0.5}TiO_3–NaTaO_3$ system single-phase ceramics can be prepared by the solid-state method, a secondary phase is formed in materials from the $Na_{0.5}Bi_{0.5}TiO_3–KTaO_3$ system prepared by a conventional method.

In the field of investigating the stabilization mechanism of the perovskite $La_{2/3}TiO_3$ compound, which is unstable due to the A-site vacancies, we confirmed that the addition of Fe_2O_3 stabilizes the perovskite $La_{2/3}TiO_3$. A single-phase ceramic is formed by the addition of 4 mol% $LaFeO_3$. This prepared $La_{2/3}TiO_3$ phase forms a solid solution with $LaFeO_3$ across the entire concentration range. Ceramics based on the $La_{2/3}TiO_3–LaFeO_3$ solid solution were characterized using impedance spectroscopy, in accordance with the composition and synthesis conditions. We found that the composition with 30 mol% of $LaFeO_3$ exhibited the highest electrical conductivity, which was ρ =0.0017 Scm^{-1} and so this material is a potential candidate for the cathode in a SOFC. In addition, we determined the subsolidus phase relations in the ternary $La_2O_3–TiO_2–Fe_2O_3$ system at 1300°C.

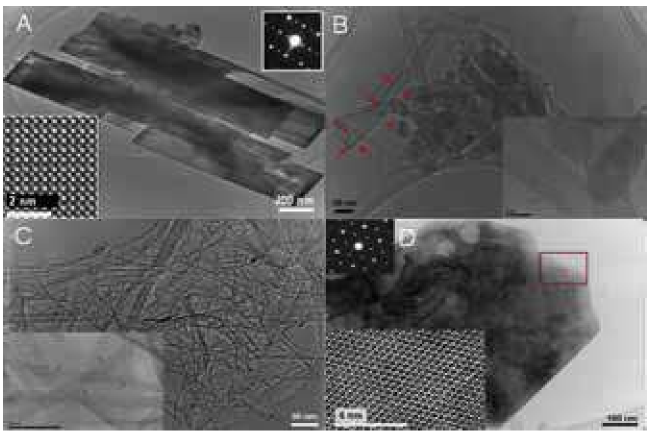

Figure 1: HRTEM images of A) well-crystallized plate-like crystals of $CaTiO_3$ and intermediate phases: B) partly crystallized nanowires and C) nanotubes and D) well-crystallized single-crystalline thin sheets

As part of the research on perovskite compounds, we focused on a study of the polymorphic phase transitions and the phase stability of $Ba_4Nb_2O_9$ polymorphs. We have isolated hexagonal (α) and two orthorhombic (γ, β) modifications and estimated the phase-transition temperature between them. The γ-modification was identified as the low-temperature polymorph, stable below 1160°C, while above this temperature the stable polymorph is the γ. The β-modification was identified as a metastable low-temperature phase, observed below 300°C after reheating the γ-modification. Transmission electron microscopy (TEM) revealed an intergranular BaO-rich amorphous phase and a nanocrystalline $Ba_5Nb_4O_{15}$ in all the polymorphs, most abundantly in the α-modification. Collected high-resolution scanning electron images and electron-diffraction patterns along different low-index zone axes allowed us to propose the crystal-structural model and prove the presence of superstructure ordering in 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 stacking of the close-packed layers creates the infinite chains of octahedrally and trigonal-prismatically coordinated B-site cations. Based on the data collected by SAED and HRTEM we confirmed the validity of the chosen structural model and measured the unit-cell parameters (*a = 1.023 nm* and *c = 0.846 nm*). Furthermore, the electron-diffraction patterns in the prismatic [010] zone axis revealed the presence of satellite reflections, the reciprocal-space vectors of which are slightly inclined with respect to the vectors of the main diffraction spots, indicating that the crystal structure of the α-modification is incommensurate.

Investigations were also made on the dielectric properties of pyrochlore-type solid solutions in the system Bi_2O_3–TiO_2–RE_2O_3 (RE= Y or Nd), which form in the following concentration range: $Bi_{(1.6-0.8x)}Y_xTi_2O_{(6.4+0.3x)}$ $(0.03 < x < 2)$ and $Bi_{(1.6-1.08x)}Nd_xTi_2O_{(6.4-0.11x)}$ $(0.25 < x < 0.96)$. The results of the dielectric measurements (1MHz) showed that the $Bi_{(1.6-0.8x)}Y_xTi_2O_{(6.4+0.3x)}$ pyrochlore solid solution (ε = 127.1, x = 0.06) has higher values of dielectric constant (ε) than the $Bi_{(1.6-1.08x)}Nd_xTi_2O_{(6.4-0.11)}$ pyrochlore solid solution (ε = 103.5, x = 0.35). The dielectric constant (ε) decreases with the increase of Y_2O_3 or Nd_2O_3 in the pyrochlore solid solution. With both pyrochlore solid solutions the dialectical loss (tanδ) is below 0.008. We observed similar behaviour for the dielectric properties at different frequencies.

The research also included a study and analysis of the pyrochlore formation in the ternary Bi_2O_3–TiO_2–WO_3 system. It has been revealed that the bismuth-titanate phase in the system can be stabilized by additions of W^{6+} ions, which incorporate on the B site in the crystal structure with the charge compensation occurring mainly through the formation of A-site vacancies in the pyrochlore structure. The results of our investigations suggest that by following such an incorporation mechanism a single-phase ceramic might be prepared with up to 8 mol % of WO_3 added, while further WO_3 additions result, besides the pyrochlore phase, also in the presence of kinetically based unstable secondary phases. Based on our results it can be concluded that W^{6+} incorporation occurs for up to 13 % of added WO_3. By analysing the $Bi_6Ti_5TeO_{22}$ compound we discovered that an isostructural compound can be formed by replacing the Te^{6+} by W^{6+}, thus forming the $Bi_6Ti_5WO_{22}$ compound. The former compound exhibits an even larger permittivity than the $Bi_6Ti_5TeO_{22}$ and a similarly large temperature coefficient of resonant frequency, which can, however, be tuned with isovalent substitutions of the Bi^{3+} ions by Y^{3+} and Nd^{3+}. With suitable additions the solid solutions can be formed, which allows the tuning of the dielectric properties of the obtained ceramics.

- **The preparation of environment-friendly lead-free thermistors on the basis of ferroelectric ceramics from the $BaTiO_3$–$BaNb_2O_6$ system.**
- **Investigations on low-sinterable, low-dielectric materials in the MgO–B_2O_3–SiO_2 system and solid solutions based on $K_xBa_{1-x}Ga_{2-x}Ge_{2+x}O_8$.**
- **Investigation of the voltage-tunable ferroelectric materials with electrical fields and axial pressure in the $Na_{0.5}Bi_{0.5}TiO_3$–$NaTaO_3$ and $Na_{0.5}Bi_{0.5}TiO_3$–$KTaO_3$ systems.**
- **Study of polymorphic phase transitions and phase stability for $Ba_4Nb_2O_9$ polymorphs.**

In addition to the investigations of dielectric materials, we also studied inorganic thin films, such as $Bi_{12}SiO_{20}$ and $Bi_{3-y}Nb_{1+y}O_{7+y}$. The preparation of $Bi_{12}SiO_{20}$ (BSO) thin films involved the sol-gel method. Thin films of BSO were coated on various substrates, such as sapphire (Al_2O_3), $Si/SiO_2/TiO_2/Pt$ and spinel ($MgAl_2O_3$). Results have shown that the most homogeneous BSO thin films are obtained on $Si/SiO_2/TiO_2/Pt$ substrates, less homogeneous films were formed on spinel, and on sapphire the thin films were very porous. The thickness of the BSO thin film increased from 200 nm on the $Si/SiO_2/TiO_2/Pt$ substrate to 300 nm on the spinel, and up to 400 nm on the sapphire substrate. However, the grain size of the thin films on the $Si/SiO_2/TiO_2/Pt$ substrate was around 1 μm, whereas for the spinel and sapphire substrates it was about 200 nm.

In the case of the preparation of solid-solution $Bi_{3-y}Nb_{1+y}O_{7+y}$ $(0.2 < y < 0.04)$ thin films and powders we used the Pechini method. In the first stage of the synthesis we prepared metallic precursors, which we then esterified with the addition of ethylene glycol. The gels were heat treated at different temperatures to obtain $Bi_{3-y}Nb_{1+y}O_{7+y}$ thin films or powders. Low calcination temperatures (≤500°C) led to the formation of cubic structured $Bi_{3-y}Nb_{1+y}O_{7+y}$, whereas at higher temperatures the tetragonal structure is obtained. In both cases the powders have nanosized particles. In the so-prepared $Bi_{3-y}Nb_{1+y}O_{7+y}$ thin films or powders the phase transformation from the cubic to tetragonal structure also occurred, but it was comparably faster that the one in the "bulk" samples.

Part of the thin-film research was done on a titanium dioxide (TiO_2) thin film, which was prepared by the in-situ-modified sol-gel method in a pre-fabricated organic template. The organic template was fabricated by the layer-by-layer self-assembly method, where the PE multilayer is formed by the sequential adsorption of appositively charged polyelectrolytes. The template thickness can be tuned at the nanometre level, depending on the number of polyelectrolyte layers deposited, which provides a means to control the final TiO_2 film thickness. After calcination at 500°C for 1hour the TiO_2 particles are expected to coalescence, resulting in a ¸relatively dense, uniform anatase TiO_2 film, with the thickness controlled on the nanometre scale. The TiO_2 particle size was determined to be below 10 nm.

Some of our research was focused on an investigation of the formation mechanism of 1D nanostructured calcium titanate, and from titanium(IV) isopropoxide and a calcium acetate aqueous solution in a highly alkaline environment we introduced the hydrothermal method. As a result of low-temperature reactions performed at different times we observed the formation of nanostructured $CaTiO_3$ with layered, well-crystallized single crystals and intermediate phases, which formed as amorphous nanoparticles, thin, well-crystallized nanostructured sheets, partly crystallized nanowires, and partly crystallized nanotubes. We determined the morphology and the crystal structure of the formed phases by the use of high-resolution transmission electron microscopy (HRTEM). For a determination of the composition and the electronic structure of the phases we performed electron energy-loss spectroscopy (EELS) and the energy-loss near-edge structure (ELNES) analysis on the Ti-$L_{2,3}$ and O-K edge. We determined that the nanotubes have a composition and an electronic structure closer to TiO_2. The amorphous nanoparticles, nanostructured sheets and nanowires all contained titanium and calcium, but they differed in terms of morphology, crystal structure and composition.

- **Investigated the dielectric properties of pyrochlore-type solid solutions in the system Bi_2O_3–TiO_2–RE_2O_3 (RE= Y or Nd).**
- **Preparation of $Bi_{12}SiO_{20}$ thin films by the sol-gel method and TiO_2 thin films by the in-situ-modified sol-gel method in a pre-fabricated organic template.**
- **Prepartion of $CaCO_3$ nanoparticles with a biomimetical synthesis.**
- **Investigation of hard materials of Al–Ti alloys with a ceramic component TiB_2, B_4C and TiC.**

Using a biomimetical synthesis reaction from chloride solutions we prepared $CaCO_3$ nanoparticles and studied the particles' growth mechanism and the influence of Mg on the particles' growth.

We started with experimental work in the field of hard materials, where we investigated the properties of composites based on different Al-Ti alloys and ceramic components, such as TiB_2, B_4C and TiC.

In the research area of glass, the investigations were made for several industrial partners, such as TERMO, Heraklith, Paroc and Gamma Meccanica. Research included analyses 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. Part of investigation was also made on the thermal stability of mineral fibres.

In the scope of the industrial research projects carried out in collaboration with EPCOS Ohg. from Austria, we developed low- and middle-permittivity LTCC materials, which are compatible with the already-developed high-permittivity materials. The developed materials were shown to have chemical compatibility, as well as matching thermal expansion coefficients and sintering behaviour.

Some outstanding publications in 2007

1. Jakob König, Boštjan Jančar, Danilo Suvorov. New $Na_{0.5}Bi_{0.5}TiO_3$-$NaTaO_3$-based perovskite ceramics. J. Am. Ceram. Soc., 2007, vol. 90, no. 11, pp. 3621-3627. [COBISS.SI-ID 21351975]
2. Manca Logar, Boštjan Jančar, Danilo Suvorov, Rok Kostanjšek. In situ synthesis of Ag nanoparticles in polyelectrolyte multilayers. Nanotechnology (Bristol), 2007, vol. 18, pp. 325601-1-32506-7. [COBISS.SI-ID 20902951]
3. Marjeta Maček, Anton Meden, Danilo Suvorov. The correlation between the structure and the dielectric properties of $K_xBa_{(1-x)}Ga_{(2-x)}Ge_{(2+x)}O_8$ ceramics. J. Eur. Ceram. Soc., 2007, vol. 27, issues 8-9, pp. 2957-2961. [COBISS.SI-ID 20703527]
4. Matjaž Spreitzer, Matjaž Valant, Danilo Suvorov. Sodium deficiency in $Na_{0.5}Bi_{0.5}TiO_3$. J. mater. chem., 2007, vol. 17, pp.185-192. [COBISS.SI-ID 20412199]
5. Darja Lisjak, Mihael Drofenik. Thermal stability of (Co, Cu)Z-hexaferrite and its compatibility with Ag at 900°C. J. Am. Ceram. Soc., 2007, vol. 90, no. 11, pp. 3517-3521. [COBISS.SI-ID 21182759]

Patents granted

1. Keramisches Material, gesinterte Keramik und Bauelement daraus, Verfahren zur Herstellung und Verwendug der Keramik
   Pavol Dudešek, Bad Gams, Christian Hoffmann, Danilo Suvorov, Matjaž Valant
   München, Deutsches Patent-und Markenamt, 2007.
2. UA patent 78081
   Composite microwave dielectric material based on magnesium titanate and calcium titanate
   Grigorovič, Bilous Anatoli, Ovchar, Oleg V., Oleksandrovič, Durilin Dmitro, Maček-Kržmanc, Marjeta, Valant, Matjaž, Suvorov, Danilo
   Kiev: Ukraine State Department of Intellectual Property

3. Patent DE 10325008.5
   Elektrisches Bauelement und dessen Herstellung
   Valant, Matjaž, Heinz, Florian, Gams, Bad, Reichmann, Klaus, Suvorov, Danilo
   München: Deutsches Patent- und Markenamt

Awards and appointments

1. Ines Bračko:Young scientists award, 15th Conference on materials and technology, Portorož, 8–10 October 2007, Institute of metals and technology, oral presentation: Understanding the formation of nanostructured perovskite $CaTiO_3$ under hydrothermal conditions.
2. Jakob König:Young scientists award, 15th Conference on materials and technology, Portorož, 8–10 October 2007, Institute of metals and technology, oral presentation: Increasing the effect of axial pressure on the permittivity of $Na_{0.5}Bi_{0.5}TiO_3$ by adding $NaTaO_3$.
3. Matjaž Spreitzer: Award for the best oral presentation, Herceg Novi, Montenegro, Yugoslav Materials Research Society, oral presentation: Influence of crystal symmetry on the volt-age-tunability of $Na_{0.5}Bi_{0.5}TiO_3$-based systems.
4. Matjaž Spreitzer: Award for the best paper contribution, Nara, Japan, The Committee of the 16th IEEE International Symposium on the Applications of Ferroelectrics, oral presentation: $Na_{0.5}Bi_{0.5}TiO_3$-based voltage-tunable materials.

Organization of conferences, congresses and meetings

1. XV. Conference on Materials and Technologies, 8. 10.–10. 10. 2005, Portorož, Slovenia (co-organizers)
2. Materials Science and Technologies Conference, 15. 9.–21. 9. 2007, Detroit, USA (co-organizers)

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4. Sabina Beranič, Irena Pribošič, Tomaž Kosmač
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   In: BIOCERAMICS 19, 19th International Symposium on Ceramics in Medicine (ISCM): October 10-13, 2006, Chengdu, China(Key engineering, vol. 330-332, 2007), [S. l.], Engineering Research Center in Biomaterials, Sichuan University, 2007, Vol. 330-332, pp. 773-776, 2007.
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27. M. Peiteado, A. C. Caballero, Darko Makovec
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33. Marko Udovič, Danilo Suvorov
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35. Vuk Uskoković, Mihael Drofenik
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36. Mojca Žnidaršič, Bojana Dolinar
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37. Ines Bračko, Boštjan Jančar, Sašo Šturm, Danilo Suvorov
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PUBLISHED CONFERENCE PAPERS

Invited Paper

1. Gorazd Hribar, Andrej Žnidaršič, Marjan Bele, Stanislav Čampelj, Darko Makovec, Miran Gaberšček, Vladka Gaberc-Porekar, Peter Venturini
Coordinative binding on different types of nanoparticles
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Regular Papers

1. Anatolii Belous, Oleg V. Ovchar, Boštjan Jančar, Jana Bezjak
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In: Papers Presented at the Fourth International Conference on Microwave Materials and their Applications - MMA2006: Oulu, Finland, 12 - 15 June 2006(Journal of the European ceramic society, Vol. 27, Issues 8-9, 2007), M. T. Sebastian, ed., Amsterdam, Elsevier, 2007, Vol. 27, no. 8/9, pp. 2933-2936, 2007.
2. Borut Bundara, Marko Udovič, Jelena Vojvodič-Tuma, Leon Cizelj, Bogo Pirš, Robert Cvelbar, Roman Celin, Igor Zabric, Igor Simonovski
Cooperative project on methods and technics for assessment of ageing and safety of nuclear objects
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3. Darja Lisjak, Andrej Žnidaršič, Anna Sztanislav, Mihael Drofenik
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4. Matjaž Spreitzer, Jakob König, Boštjan Jančar, Danilo Suvorov
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5. Sašo Šturm, Boštjan Jančar, Ines Bračko
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6. Polona Umek, Matej Pregelj, Alexandre Gloter, Pavel Cevc, Miran Čeh, Urša Pirnat, Denis Arčon
Titanate nanostructures doped with Cu^{2+} ions; EPR and TEM characterization
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PATENT APPLICATION

1. Patent Applications No. 200700122
Postopek priprave magnetnih nanokompozitov z visoko vsebnostjo nanodelcev dispergiranih v polimerni matrici
Makovec, Darko, Gyergyek, Sašo, Huskić, Miroslav, Drofenik, Mihael

THESES

Ph. D. Thesis

1. Urša Pirnat: Phase Transformations of incommensurate-commensurate modulated crystal structures in oxide systems based on Bi_2O_3 (mentor: Prof. Danilo Suvorov)

B. Sc. Theses

1. Slavko Kralj: Use of microcalorimetry and liquid chromatography in preformulation studies of stability of Ramipril (mentor: Prof. Vojko Kmetec)
2. Simona Ovtar: Quantitative determination of amorphous phase in samples of silicon carbide with X-ray powder diffraction (mentor: Prof. Anton Meden)
3. Darinka Primc: Synthesis and transformations of enaminone derivatives (mentor: Prof. Branko Stanovnik)
4. Mojca Žnidaršič: Evaluation of permeability of saturated cohesive soils based on their physical properties (mentor: Prof. Breda Mirtič)

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. New Generation Microwave Ferrite Thick Films for Absorbers
MATERA ABSOFILM
ERA-NET, 4302-31/2006/26
Dr. Darja Lisjak
4. Characterisation of Bio Soluble Mineral Fibres
T070032
Markus Mente, B. Sc., Heraklith GmbH, Furnitz, Austria
Prof. Danilo Suvorov
5. Characterization of Bio Soluble Mineral Fibres
N40/06
Ingram Eusch, B. Sc., Heraklith AG, Ferndorf, Austria
Prof. Danilo Suvorov, Dr. Marko Udovič
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. Temperature Stabile Dielectrics with Improved Dielectric Properties
T070003
Dr. Christian Hoffmann, EPCOS OHG, Ceramic Components Division, Deutschlandsberg, Austria
Prof. Danilo Suvorov, Dr. Srečo Davor Škapin
8. LTCC Materials for Multilayer LC Filters
N0042/06
Dr. Pavol Dudesek, EPCOS OHG, Deutschlandsberg, Austria
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9. Characterization of Bio Soluble Mineral Fibres
T070031
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10. Characterization of Bio Soluble Mineral Fibres
N0039/06
Dr. Michael Perander, Paroc Group OY AB/R&D, Pargas; Vantaa, Finland
Prof. Danilo Suvorov , Dr. Marko Udovič
11. Materials with improved High-frequency Magnetic Properties prepared from Silica-coated Ferrites
BI-FR/06-PROTEUS-014
Dr. Jeun-Lue Rehspringer, Institut de Physique et Chimie des Matériaux, Strasbourg, France
Asst. Prof. Darko Makovec
12. Control of Grain Size and Morphologies of Nanograined Oxides by Adaptation of the Synthesis Route: Precipitation in Microemulsions and Hydrothermal Synthesis
BI-FR/06-PROTEUS-010
Asst. Prof. Nadine Millot, LRRS, UMR 5613, CNRS/Université de Bourgogne, Dijon Cedex, France
Asst. Prof. Darko Makovec
13. Characterization of the Materials for Mineral Fibres Production
T070001
Giovanni Burini, B. Sc., Gamma Meccanica, Bibbiano, Reggio Emilia, Italy
Prof. Danilo Suvorov
14. Non Conductive Magnetic Materials for Microwave Absorbers
BI-IT/05-08-007
Dr. Enzo Ferrara, Instituto Elettrotecnico Nazionale Galileo Ferraris Torino, Torino, Italy
Dr. Darja Lisjak
15. Nanoferrites and Non-reciprocal Devices for Mm-wave Applications
BI-HU/06-07/003
Dr. Anna Sztaniszlav, TKI-FERRIT Development and Manufacturing Ltd., Budapest, Hungary
Dr. Darja Lisjak

R & D GRANTS AND CONTRACTS

1. Multifunctional composites based on Al-Mg-Ti intermetallic compounds reinforced with ceramic particles
Prof. Danilo Suvorov
2. Time- and position-controlled release of drug substances coated onto superparamagnetic nanoparticles
Asst. Prof. Darko Makovec
3. Synthesis of magnetic nanoparticles for the microwave absorbers and magnetic fluids
Asst. Prof. Darko Makovec
4. Smart functional coatings for increasing sustainability of structures and components for defense purposes
Dr. Srečo Davor Škapin
5. Self-cleaning photocatalitic coatings
Dr. Srečo Davor Škapin
6. Development of multi-functional B4C-Al and B4C-Mg composites for emerging applications
Dr. Srečo Davor Škapin

RESEARCH PROGRAMS

1. Advanced inorganic magnetic and semiconducting materials
prof. Mihael Drofenik
2. Contemporary inorganic materials and nanotechnologies
Prof. Danilo Suvorov

NEW CONTRACT

1. Co-founding of the project »Synthesis of magnetic nanoparticles for the microwave absorbers and magnetic fluids«
Kolektor Magma d.o.o.
Asst. Prof. Darko Makovec

VISITORS FROM ABROAD

1. Dr. Christian Hoffmann, Dr. Wolfgang Statteneter, EPCOS OHG, Deutschlandsberg, Austria, 22. 1. 2007
2. Prof. Hong Wang, Prof. Wei Ren, Dr. Peng Shi, Dr. Huanfu Zhou, Xi'an Jiaotong University, Xi'an, China, 12. 2. 2007
3. Prof. Enzo Ferrara, dr. Elena Olivetti, dr. Sergio Perero, INRIM, Turin, Italy, 26. 3. 2007
4. Dr. Vuk Uskoković, Clarkson University, Potsdam, USA, 18. 5. 2007
5. Burrini Giovani, B. Sc., Secchi James, B. Sc., Gamma Meccanicca, Bibbiano, Italy, 12. 6. 2007
6. Dr. Luc Berger, Fraunhoffer Institute, Dresden, Germany, 14. 6. 2007
7. Prof. Robert L. Moreiro, Federal University of Minas Geraias, Belo Horizonte, Brasil, 7. 9. – 8. 9. 2007
8. Prof. Jose Varela, University of Sao Paolo, Sao Paolo, Brasil, 3. 9. – 7. 9. 2007
9. Dr. Nadine Millot, Dr. Anne – Laure Papa, University of Burgundy, Dijon, France, 26. 9. – 29. 9. 2007
10. Dr. Christian Hoffmann, EPCOS OHG, Deutschlandsberg, Austria, 7. 11. 2007
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1. Dr. Marco Peiteado Lopez, Instituto de Ceramica y Vidrio, Madrid, Spain, 1. 10. 2005-31. 12. 2007
2. Dr. Svetoslav Mihaylov Kolev, Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria, 1. 9. 2006 - 31. 8. 2007
3. Dr. Qin Ni, Zhejiang University, Hangzhou, China, 1. 12. 2006 - 31. 12. 2007
4. Dr. Olivier Noguera, Faculte des Sciences et Techniques, UMR-CNRS, Limoges, France, 1. 11. 2007 – 1. 11. 2008
5. Prof. Maria A. Zaghete, Chemistry Institute Araraquara, University of Sao Paolo State, Araraquara, Brasil, 1. 9. 2007 - 31. 12. 2007

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10. Dr. Uroš Kunaver***
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18. Slavko Kralj, B. Sc.
19. Manca Logar, B. Sc.
20. Simona Ovtar, B. Sc.
21. Urša Pirnat, B. Sc.
22. Darinka Primc, B. Sc.
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