ELECTRONIC CERAMICS DEPARTMENT

K-5

The Electronic Ceramics Department is active in the research of the synthesis, properties and applications of materials for electronics and energetics, mainly complex multifunctional materials and structures that can perform multiple functions (multifunctional materials). The materials of interest include ceramic piezoelectrics, ferroelectrics, relaxors, multiferroics and conductive oxides. The emphasis is on the creation of the properties by the synthesis and structure on the nano-, micro- and macro-levels. The group also works on the principles of the basic technologies of ceramic pressure sensors, ceramic MEMS and flexible electronics.

Head:
Prof. Barbara Malič

In the framework of **lead-free piezoelectric materials** we were particularly interested in alkali-niobate-based ceramics. In collaboration with the National Institute of Chemistry, University of Ljubljana, University of Nova Gorica, Montanuniversität Leoben, Austria, and the University of Milan, Italy, we explained the mechanism of grain-growth inhibition in perovskite ceramics due to the addition of an aliovalent dopant for the case of strontium-doped ceramic $K_{0.5}Na_{0.5}NbO_3$ (KNN). The investigations of highly doped samples suggested that the system tends to segregate the A-site vacancies, which occur as a result of doping, in a secondary phase. Together with increasing lattice disorder and microstrain, these effects are correlated with the increasing number of low-angle grain boundaries, which finally limit the grain growth and consequently result in a significant grain-size decrease. Furthermore, the effect of the Sr dopant on the solid-state synthesis of KNN was studied by thermal analysis and in-situ high-temperature X-ray diffraction. Strontium doping had an insignificant influence on the course of the solid-state synthesis. On the other hand, the particle size distribution of the Nb_2O_5 reagent proved to be a crucial factor influencing the temperature interval of the KNN solid-state synthesis.

Researchers from the "Jožef Stefan" Institute and National Institute of Chemistry, in collaboration with colleagues from Switzerland and Japan, were the first to identify the accumulation of charged defects at domain walls in ferroelectric $BiFeO_3$. This finding explains the conduction at the domain walls in $BiFeO_3$ and thus represents the missing piece for explaining the intriguing electrical properties of domain walls in ferroelectrics. The study was published in Nature Materials, currently one of the highest-impact scientific journals.

Within the activities on **lead-based piezoelectric ceramics**, we studied the ferroelectric domain structure of the $Pb(Sc_{0.5}Nb_{0.5})O_3$ ceramics, prepared by mechanochemical activation of powder, by piezoresponse force microscopy. Micrometre-sized domains with different morphologies exist in the material at room temperature. Slightly below the ferroelectric–relaxor phase transition, i.e., at 90 °C, the fraction of micrometre-sized domains is reduced, while the nanometre-sized domains prevail in accordance with the ferroelectric–relaxor crossover at ~98°C.

The tilting of oxygen octahedra in perovskites has been proposed to profoundly affect the macroscopic domain switching behaviour in undoped, rhombohedral **$Pb(Zr,Ti)O_3$ (PZT)** ceramics, resulting in pinched ferroelectric hysteresis loops. A similar effect, however, is expected because of the presence of defect complexes involving oxygen vacancies. We revisited the early studies on rhombohedral PZT ceramics revealing that the observed pinched loops are likely associated with the presence of defect complexes and not octahedral tilts, as previously suggested.

Within the 7 **FP EU CERAMPOL** project and in collaboration with our research partner HIPOT-RR, we fabricated an innovative **vibrating system for wastewater purification**. The system is based on a porous ceramic membrane that vibrates under the influence of an electrically-driven PZT piezoelectric integrated into the membrane. We optimised the system's operation conditions using finite-element modelling and measurements of the displacement amplitudes of the system in a wide frequency range. We demonstrated with tests under real operating conditions that the novel vibrational system can be effectively used for water purification. With the project partner LEITAT, Spain, we submitted a PCT patent application.

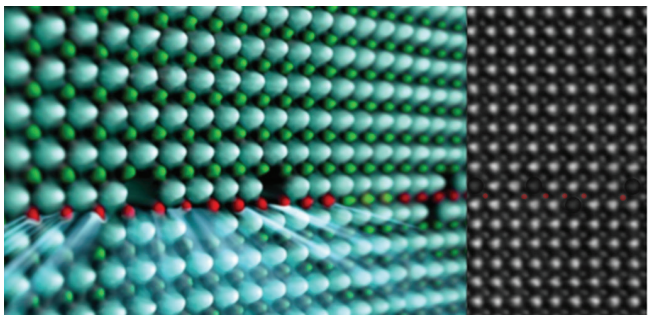

Figure 1: Artistic presentation of accumulated defects at a domain wall in $BiFeO_3$ (painter Mito Gegič) and image of bismuth (larger) and iron (smaller) atomic columns taken with a scanning transmission electron microscope.

Within the activities on **multiferroic ceramic $BiFeO_3$**, in cooperation with colleagues from the Department of Advanced Materials, Department of Inorganic Chemistry and Technology, National Institute of Chemistry, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland and the University of Shizuoka, Japan, we studied the mechanism of domain con-

ductivity in ferroelectric $BiFeO_3$. We were the first to identify the accumulation of charged defects at domain walls in ferroelectric $BiFeO_3$. This finding explains the p-type hopping conduction at the domain walls in $BiFeO_3$. The study was published in Nature Materials with a 2015 impact factor of 38.89, which currently makes it one of the highest-impact scientific journals. (Figure 1)

$BiFeO_3$-based ferroelectric solid solutions suffer from a high electrical conductivity, which represents one of the major obstacles for the use of these materials in high-temperature piezoelectric applications. We investigated this problem in $BiFeO_3$-$SrTiO_3$ ceramics and thus developed ways for controlling the electrical conductivity by annealing ceramics in different atmospheres. An alternative approach using manganese as a dopant has not only eliminated the original high conductivity but also stabilized the decreased conductivity against subsequent annealing in air and by the application of elevated electric fields.

The electrocaloric (EC) effect is defined as the adiabatic and reversible temperature change that occurs in a polar material upon the application of an external electric field. In collaboration with the Condensed Matter Physics Department and Laboratory for Refrigeration and District Energy, Faculty of Mechanical Engineering, University of Ljubljana, we analysed the energy efficiency of an EC cooling system in view of the polarization–electric field ($P-E$) hysteresis losses of the EC materials, and recovery of the electric energy needed to induce the EC effect. We showed that the energy efficiency of the materials with large hysteresis losses, i.e., $100(1\text{-}x)Pb(Mg_{1/3}Nb_{2/3})O_3$–$100x\ PbTiO_3$ (PMN-100xPT) compositions close to the morphotropic phase boundary, i.e., PMN-35PT, is significantly reduced as compared to the PMN-rich relaxor compositions. Therefore, we proposed that the EC materials with low $P-E$ hysteresis losses, such as PMN-100xPT with $x \leq 0.1$, and a high degree of the electric-energy recovery should be implemented in an EC cooling system in order to achieve a high energy efficiency.

Researchers from the "Jožef Stefan" Institute, in collaboration with colleagues from Poland and South Korea, prepared a multicaloric $0.8Pb(Fe_{1/2}Nb_{1/2})O_3$–$0.2Pb(Mg_{1/2}W_{1/2})$ material. The work is the first experimental confirmation of the electrocaloric and magnetocaloric coexistence in relaxor-ferroelectric and opens up new possibilities in the field of caloric cooling. The article was published in the journal Scientific Reports.

Electric-field amplitudes needed to reach EC temperature changes (ΔT), suitable for applications in cooling technology, that is at least 2K, are close to the dielectric breakdown strength of respective bulk ceramic materials, typically about 100 kV/cm. In order to reduce the applied voltage for a given EC ΔT, we prepared **multilayer cooling elements** of relaxor ferroelectric $0.9Pb(Mg_{1/3}Nb_{2/3})O_3$–$0.1PbTiO_3$ (PMN-10PT) with internal platinum electrodes by tape-casting and lamination in collaboration with the company KEKO-Equipment, Žužemberk. The thickness of the individual layers was about 60 μm. The EC temperature changes of multilayer elements were measured between 55 and 105 °C at electric field amplitudes of up to 100 kV/cm in a high-resolution calorimeter. The highest EC ΔT was 2.26 K at 100 kV/cm at 105 °C. The obtained result is in good agreement with the values obtained in the bulk ceramic of the same composition with typical thicknesses exceeding 100 μm, but it was obtained at a much lower applied voltage, thus presenting another step towards the application of EC ceramic materials in solid-state cooling.

Using the **finite-element** method we **modelled** the behaviour of an EC solid-state cooler for its possible use in microelectronics. The essential parts of the cooler are multifunctional **cantilevers** fabricated from PMN-10T, which exhibit simultaneous bending and change of temperature upon the application of an electric field. The results of the modelling confirmed that by introducing thermal contacts between the cantilevers a temperature gradient is formed across the structure, resulting in a promising cooling capacity.

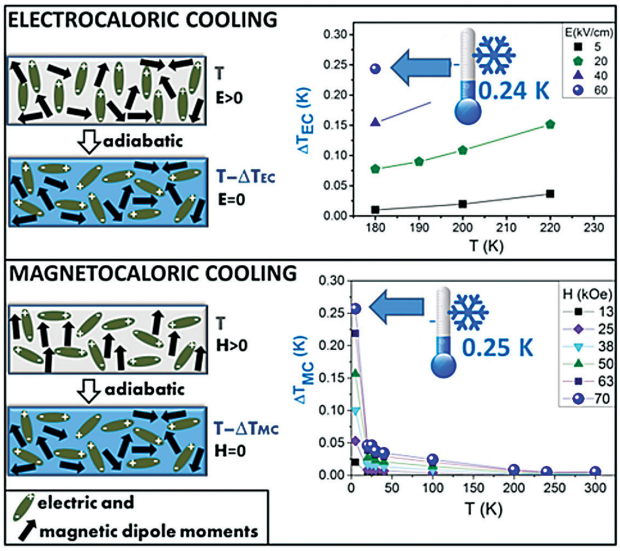

Figure 2: Multicaloric properties of $0.8Pb(Fe_{1/2}Nb_{1/2})O3$–$0.2Pb(Mg_{1/2}W_{1/2})$ material.

Furthermore, we prepared a **multicaloric ceramic material** $0.8Pb(Fe_{1/2}Nb_{1/2})O_3$–$0.2Pb(Mg_{1/2}W_{1/2})O_3$ that shows both an electrocaloric and a magnetocaloric temperature change. The work is the first experimental confirmation of the electrocaloric and magnetocaloric coexistence in relaxor-ferroelectric and opens up new possibilities in the field of caloric cooling (Figure 2)

In the frame of the **M-ERA.NET PiezoMEMS** project we continued the research of ferroelectric thin films based on lead-free perovskites for piezoelectric energy-harvesting applications together with partners from Poland and Romania. The influence of donor doping on microstructure, ferro- and piezoelectric properties of $K_{0.5}Na_{0.5}NbO_3$ films was studied.

In collaboration with LETI, Grenoble, France, Faculty of Physics, Vilnius University, Lithuania, School of Electronic and Information Engineering, Xi'an Jiaotong University, China, and the Condensed Matter Physics Department, JSI, we investigated the dielectric properties of $Ba_{0.5}Sr_{0.5}TiO_3$ (BST) thin films on alumina substrates with film thicknesses between 90 nm to 600 nm

and predominantly columnar microstructures. The dielectric permittivity measured at room temperature exhibited a non-monotonous thickness dependence that was connected to the residual biaxial stress, developed in the BST films due to the thermal expansion mismatch between the film and the substrate. The dielectric permittivity of 170-nm-thick films with 75-nm-sized grains was 1180 measured at 5 kHz, which is one of the highest reported values for BST films with similar microstructures.

By understanding the influence of different thermal expansion coefficients of the thick film and the substrate and by controlling the chemical interactions between them, we successfully prepared by screen printing a few-10-µm-**thick films of bismuth ferrite** ($BiFeO_3$) with appropriate phase composition and microstructure. Bismuth ferrite is difficult to pole because it requires the use of high external electric field. We suggested an alternative way of poling by sintering the $BiFeO_3$ films at a temperature above the ferroelectric-paraelectric phase transition. The presence of a compressive strain gradient across the film thickness cooled from above the ferroelectric-paraelectric phase transition was experimentally confirmed and was suggested to be responsible for the self-poling effect. These self-poled films exhibited a microstructure with randomly oriented columnar grains. (Figure 3)

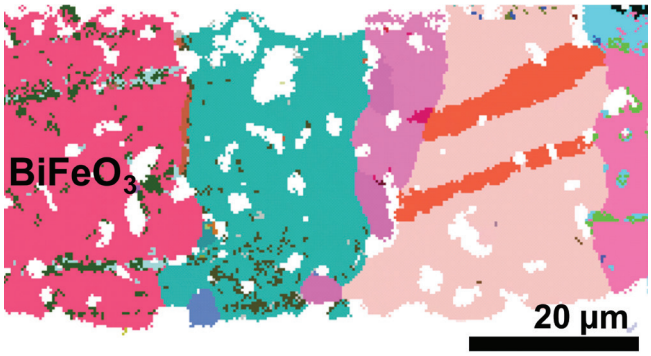

Figure 3: Distribution of the crystallographic orientations in columnar grains in thick $BiFeO_3$ film with pronounced domain structure.

Danjela Kuščer Hrovatin and Janez Holc, together with colleagues from ETI Elektroelement, Izlake, received a Silver recognition for the invention "Non-porous C410 cordierite materials for electrotechnics" by the Regional Chamber of Commerce Zasavje in June 2016.

We investigated the preparation of environmentally friendly **thick-film** piezoelectrics based on $K_{0.5}Na_{0.5}NbO_3$ on metallic substrates by the **electrophoretic deposition method**.

We prepared $Pb(Zr,Ti)O_3$-based thick-film structures by **inkjet printing**. We dispersed the ceramic powder in water and afterwards adjusted the viscosity and surface tension of the ink to be suitable for printing. We prepared arrays of linear structures with a line width of ~80 µm and a micrometre-sized distance between the lines. After sintering at 850 °C the 20-µm-thick structures exhibited a dielectric permittivity of 1100 and dielectric losses of 0.057, which are comparable to the properties of thick films prepared using screen-printing technology.

We inkjet printed **high-K dielectric** tantalum-aluminium-silicon-oxide nanostructures on indium-tin-oxide-coated glass as components for **transparent electronics**. The ink formulations with 2-methoxyethanol as the main solvent and highly viscous glycerol and/or 1,3-propanediol co-solvents exhibited the optimal values of the viscosity and surface tension for piezoelectric inkjet printing. By a suitable combination of all solvents in the ink the coffee-stain effet of the printed nanostructures could be avoided. We printed about 40-nm-thick, flat and uniform transparent capacitors with a good dielectric permittivity of ~15, tan(δ) ~0.034 at 100 kHz and a low leakage current density of 2.4×10^{-7} A cm^{-2} at 200 kV cm^{-1}. The study was performed in collaboration with the Condensed Matter Physics Department and the Department of Thin Films and Surfaces. (Figure 4)

In the framework of p-type **semiconductors**, the mechanism of formation of nanocrystalline Co_3O_4 powder by cobalt nitrate-glycine solution combustion synthesis was studied. By controlling the reaction conditions and by using the sub-stoichiometric amount of glycine we prepared phase-pure Co_3O_4. The prepared powder contained soft cauliflower-shaped agglomerates with a high specific surface area (64.4 m^2/g). In collaboration with researchers from Eberhard Karls University of Tübingen, Germany, thick-film sensors were produced from the respective powder by drop-coating. The sensor annealed at 600 °C showed an excellent sensing performance for acetone detection at a low operating temperature of 150 °C in a humid environment. Such a sensor would be suitable for the detection of diabetes in exhaled air. (Figure 5)

We continued investigations of **LTCC** (Low Temperature Co-fired Ceramics) and thick-film materials and processes, used for fabrication of three-dimensional structures for different micro-electro-mechanical systems (MEMS) and chemical microsystems. The traditional co-operation with our research partners HIPOT-RR and Centre of Excellence NAMASTE

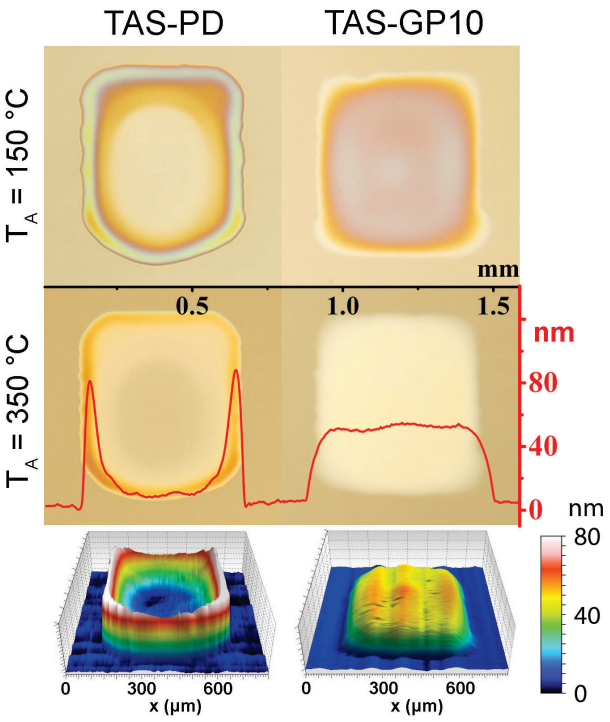

Figure 4: Optical images of the dried (150 °C) and heated (350 °C) inkjet-printed tantalum-aluminium-silicon oxide (TAS) based thin-film capacitors and the corresponding profilometry micrographs. By optimizing the TAS-ink formulation from 1,3 propanediol (PD)-based to a mixture of PD and glycerol (GP10) nano-structures with a uniform thickness of about 40 nm could be patterned.

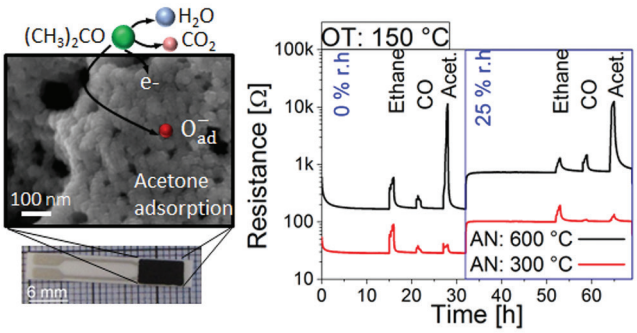

Figure 5: Image of a sensor surface of the active Co_3O_4 layer taken with a scanning electron microscope with the schematic representation of acetone adsorption (left). DC resistance of sensors annealed at 300 and 600 °C, during exposure to ethanol (Ethane), carbon monoxide (CO) and acetone (acetyl) at an operating temperature of 150 °C in dry and humid environments (right). Cooperation with Eberhard Karls University, Tübingen.

continued resulting in several test structures and demonstration products. Examples include microfluidic components for electrochemical sensors and ceramic packaging for piezoelectric elements in the frame of **INTcerSEN** and **PiezoMEMS** projects, respectively, both from the **M-ERA.NET** programme, and pressure sensors designed as demonstration products from LTCC tapes developed by the company KEKO equipment.

In collaboration with the company **ETI Elektroelement** d.d., Izlake, we studied the manufacturing of the non-porous cordierite ceramic, which is used in products exposed to high-temperature differences in short periods of time. The material is suitable for automatic, large-scale production.

Some outstanding publications in the past year

1. Rojac, Tadej, Benčan, Andreja, Dražić, Goran, Sakamoto, Naonori, Uršič, Hana, Jančar, Boštjan, Tavčar, Gašper, Makarovič, Maja, Walker, Julian, Malič, Barbara, Damjanović, Dragan. Domain-wall conduction in ferroelectric $BiFeO_3$ controlled by accumulation of charged defects. Nature materials, ISSN 1476-1122, [in press] 2016, 7 str., doi: 10.1038/nmat4799.
2. Khomyakova, Evgeniya, Šadl, Matej, Uršič, Hana, Daniels, John, Malič, Barbara, Benčan, Andreja, Damjanović, Dragan, Rojac, Tadej. Self-poling of $BiFeO_3$ thick films. ACS applied materials & interfaces, ISSN 1944-8244. [Print ed.], 2016, vol. 8, no. 30, str. 19626-19634, doi: 10.1021/acsami.6b05885.
3. Uršič, Hana, Bobnar, Vid, Malič, Barbara, Filipič, Cene, Vrabelj, Marko, Drnovšek, Silvo, Younghun, Jo., Wencka, Magdalena, Kutnjak, Zdravko. A multicaloric material as a link between electrocaloric and magnetocaloric refrigeration. Scientific reports, ISSN 2045-2322, 2016, vol. 6, str. 26629-1-26629-5, doi: 10.1038/srep26629.
4. Matavž, Aleksander, Frunza, Raluca-Camelia, Drnovšek, Aljaž, Bobnar, Vid, Malič, Barbara. Inkjet printing of uniform dielectric oxide structures from sol-gel inks by adjusting the solvent composition. Journal of materials chemistry. C, Materials for optical and electronic devices, ISSN 2050-7526. [Print ed.], 2016, vol. 4, no. 24, str. 5634-5641, doi: 10.1039/C6TC01090C.
5. Kuščer, Danjela, Bernardo, Mara, Santo-Zarnik, Marina, Malič, Barbara. Patterning of lead-zirconate-titanate thick-film structures by electrophoretic deposition from ethanol-based dispersions. Journal of the European ceramic society, ISSN 0955-2219. [Print ed.], 2016, vol. 36, no. 2, str. 291-297, doi: 10.1016/j.jeurceramsoc.2015.08.033.

Awards and Appointments

1. Darko Belavič: Elected to the serving member of Electrotechnical Association Slovenia, MIDEM – Proposer: Society For Microelectronics, Electronic Components And Materials, Ljubljana, Slovenia May, 2016
2. Ines Bantan, Jožі Prašnikar, Helena Razpotnik from ETI d.d., Danjela Kuščer, Janez Holc, from JSI, Electronic ceramics department K-5: Silver Award for innovation: "Neporozni kordieritni material C410 za elektrotehniko", Gospodarska zbornica Slovenije, Zasavje, Slovenia, June 8, 2016
3. Lovro Fulanovič: SHAPING VI, Student poster award winner, Montpellier, France, July 20, 2016
4. Andraž Bradeško: Best poster award, Institute of Electrical and Electronics Engineers (IEEE), ISAF/ECAPD/PFM Conference 2016 – IEEE, Darmstadt, Germany, August, 21-25, 2016
5. Tomaž Kos, Tadej Rojac (co-mentor): Prešeren's Award, Faculty of Electrical Engineering, Ljubljana, Slovenia, December 6, 2016

Organization of Conferences, Congresses and Meetings

1. MIDEM 2016: 52nd International Conference on Microelectronics, Devices and Materials with the Workshop on Terahertz and Microwave Systems, Ankaran Slovenia, September 28-30, 2016
2. COST TO-BE Fall Meeting 2016, Ljubljana, Slovenia, September 28-30, 2016

INTERNATIONAL PROJECTS

1. Feasibility Study and Fabrication of LTCC based PCB Multilayer
   Prof. Barbara Malič
   Ctr Carinthian Tech Research Ag
2. Fabrication of LTCC SAW Module Package and Plates
   Prof. Barbara Malič
   Ctr Carinthian Tech Research Ag
3. 7FP - CERAMPOL; Ceramic and Polymeric Membrane for Water Purification of Heavy Metal and Hazardous Organic Compound
   Asst. Prof. Danjela Kuščer Hrovatin
   European Commission
4. COST MP1308; Towards Oxide Based Electronics (TO-BE)
   Dr. Katarina Vojisavljević
   Cost Office
5. Functional Heterogeneity in Complex Oxides: Chemical Clustering, Atomic Displacements, and Polar Nanoregions
   Asst. Prof. Hana Uršič Nemevšek
   Slovenian Research Agency
6. Fabrication and Modelling of Integrated Piezoelectric Structures for High-frequency Ultrasound Applications
   Asst. Prof. Danjela Kuščer Hrovatin
   Slovenian Research Agency
7. Piezoelectric Films for Microelectromechanical Systems Based on Environment Friendly Perovskite Materials
   Prof. Barbara Malič
   Slovenian Research Agency

RESEARCH PROGRAM

1. Electronic Ceramics, Nano-, 2D and 3D Structures
   Prof. Barbara Malič

R & D GRANTS AND CONTRACTS

1. Nanostructures for high-efficiency solar cells and photovoltaic
   Prof. Barbara Malič
2. New advanced electrocaloric materials for novel environmentally-friendly dielectric refrigeration technology
   Prof. Barbara Malič
3. Multifunctional materials for actuator and cooling devices
   Asst. Prof. Tadej Rojac
4. Photovoltaic cell and modul inhomogenity analysis and performace monitoring in power plants through lifetime
   Prof. Barbara Malič
5. Tunable ferroelectric thin film capacitors for agile microwave antennas
   Prof. Barbara Malič
6. High-performance piezoelectric materials for sensors and actuators in high-temperature applications
   Asst. Prof. Tadej Rojac
7. Micro-electromechanical and electrocaloric layer elements
   Prof. Barbara Malič
8. Advanced electrocaloric energij conversion
   Prof. Barbara Malič
9. Integrated sensors with microfluidic features using LTCC technology
   Asst. Prof. Hana Uršič Nemevšek
   Piezoelectric MEMS for efficient energy harvesting
   Prof. Barbara Malič

NEW CONTRACTS

1. Research of compatibility of LTCC materials and conductive pastes, with the emphasis on appropriate adhesion of the conductive material on LTCC and on simultaneous densification of both materials
   Prof. Barbara Malič
   Keko - Oprema d. o. o. Žužemberk

VISITORS FROM ABROAD

1. Hugo Mercier, Université François-Rabelais de Tours, Tours, France, 1. Januar-8. October 2016
2. Mag. Stjepan Golubić, Visoka Tehnička Škola u Bjelovaru, Bjelovar, Croatia, 18. January 2016
3. Alen Britvić, Visoka Tehnička Škola u Bjelovaru, Bjelovar, Croatia,18. January-18. April 2016
4. Dr. Carmen Galassi, Istituto di Scienza e Tecnologia dei Materiali Ceramici (ISTEC), Consiglio Nazionale delle Ricerche (CNR); Faenza, Italy, 16.-18. March 2016
5. Prof. Franck Levassort, Université François-Rabelais de Tours, Tours, France, 16.-18. March 2016
6. Alexandre-Benoît Bourgoin, Université de y of Limoges, Limoges, France, 2. April-31. July 2016
7. Dragana Vasiljević, Univerzitet ua v Novoem Sadu, Novi Sad, Serbia, 3.-23. April 2016
8. Jelena Vukmirović, Univerzitet ua v Novoem Sadu, Novi Sad, Serbia, 3.-23. April 2016
9. Prof. dr. Hisao Suzuki, Research Institute of Electronics, Shizuoka University, Hamamatsu, Japan, 16.-18. April 2016
10. Prof. dr. Jacob L. Jones, North Carolina State University, Raleigh, US, 19.-22. June 2016
11. Dr. Vincenzo Buscaglia, Consiglio Nazionale delle Ricerche - IENI, Genova, Italy, 20.-22. June 2016
12. Prof. dr. Tomoya Ohno, Department of Materials Science, Kitami Institute of Technology; Kitami, Japan, 30. June-1. July 2016
13. Prof. Naonori Sakamoto, Research Institute of Electronics and Materials Science Course Department of Engineering, Graduate School of Integrated Science and Technology, Shizuoka University, Shizuoka, Japan, 30. June-8. July 2016
14. Mateusz Firynowicz, Politechnika Poznańska, Poznań, Poland, 4. July-10. October 2016
15. Anna Włódarkiewicz, Politechnika Poznańska, Poznań, Poland, 13. July-22. September 2016
16. Prof. Klaus Reichmann, Technische Universität Graz, Graz, Austria, 20. July 2016
17. Dong Hou, North Carolina State University, US, 29. August-3. September 2016
18. Reyhan Eşiyok, Yildiz Teknik Üniversitesi – Istanbul, Istanbul, Turkey, 1. September-26. November, 2016
19. Dr. Theodor Schneller, RWTH Aachen, Institut für Werkstoffe der Elektrotechnik II, RWTH Aachen, Aachen, Germany, 18.- 20. September 2016
20. Mihael Štefić, Visoka Tehnička Škola u Bjelovaru, Bjelovar, Croatia, 26. September-23. December, 2016
21. Prof. Anatoliy Panich, Southern Federal University, Rostov-on-Don, Russia, 24. October 2016
22. Dr. Julian Walker, Pennsylvania State University, USA, 27.-28. October 2016
23. Agnieszka Monika Paszkowska, Uniwersytet Marii Curie-Skłodowskiej, Lublin, Poland, 24. October-31. December 2016
24. Karolina Szymanek, Uniwersytet Marii Curie-Skłodowskiej, Lublin, Poland, 24. October-31. December 2016
25. Dr. Denis Alikin, Ferroelectric Laboratory, Institute of Natural Sciences, Ural Federal University, Russia, 5.-18. November 2016
26. Assoc. Prof. Sverre Magnus Selbach, Norges teknisk-naturvitenskapelige universitet, Trondheim, Norway, 23.-25. November 2016
27. Krunoslav Kušec, Visoka Tehnička Škola u Bjelovaru, Bjelovar, Croatia, 19.-31. December 2016

STAFF

Researchers

1. Asst. Prof. Andreja Benčan Golob
2. Asst. Prof. Goran Dražić*
3. Asst. Prof. Danjela Kuščer Hrovatin
4. **Prof. Barbara Malič, Head**
5. Asst. Prof. Tadej Rojac
6. Asst. Prof. Hana Uršič Nemevšek
7. Dr. Katarina Vojisavljević

Postdoctoral associates

8. Dr. Mirela Dragomir
9. Dr. Kostja Makarovič*
10. Dr. Mojca Otoničar
11. Dr. Tanja Pečnik
12. Dr. Marko Vrabelj

Postgraduates

13. Andraž Bradeško, B. Sc.
14. Lovro Fulanović, B. Sc.
15. *Dr. Jitka Hreščak, 01.10.16, transferred to Department CEMM*
16. Dr. Evgeniya Khomyakova
17. Uroš Prah, B. Sc.

Technical officers

18. Darko Belavič, B. Sc.
19. Silvo Drnovšek, B. Sc.
20. Brigita Kmet, B. Sc.
21. Maja Makarovič, B. Sc.

Technical and administrative staff

22. Tina Ručigaj Korošec, B. Sc.
23. Matejka Šmit, B. Sc.

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Anže Abram, Andreja Eršte, Goran Dražić, Vid Bobnar, "Structural and dielectric properties of hydrothermally prepared boehmite coatings on an aluminium foil", *J. mater. sci., Mater. electron.*, vol. 27, no. 10, pp. 10221-10225, 2016.
2. Moom Sinn Aw, Goran Dražić, Petar Djinović, Albin Pintar, "Transition metal pairs on ceria-promoted, ordered mesoporous alumina as catalysts for the CO_2 reforming reaction of methane", *Catalysis science & technology*, vol. 6, iss. 11, pp. 3797-3805, Jun. 2016.
3. Tina Bakarič, Barbara Malič, Danjela Kuščer, "Lead-zirconate-titanate-based thick-film structures prepared by piezoelectric inkjet printing of aqueous suspensions", *J. Eur. Ceram. Soc.*, vol. 36, no. 16, pp. 4031-4037, 2016.
4. Tina Bakarič, Tadej Rojac, Andre-Pierre Abellard, Barbara Malič, Franck Levassort, Danjela Kuščer, "Effect of pore size and porosity on piezoelectric and acoustic properties of $Pb(Zr_{0.53}Ti_{0.47})O_3$ ceramics", *Advances in applied ceramics*, vol. 115, no. 2, pp. 66-71, 2016.
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