ELECTRONIC CERAMICS DEPARTMENT K-5

The Electronic Ceramics Department is active in researching 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 principles of basic technologies of ceramic pressure sensors, ceramic MEMS and flexible electronics.

Head:
Prof. Barbara Malič

In the framework of **lead-free piezoelectric ceramics** we continued our research of sodium potassium niobate (**$K_{0.5}Na_{0.5}NbO_3$, KNN)-based** materials, which could replace the efficient lead-based piezoelectrics. Using a multi-scale approach, by combining electron microscopy together with analytical tools, we analysed the representative multiple-element-modified ceramic material (K,Na,Li)(Nb,Ta)O_3-$CaZrO_3$ for which MnO_2 was added either before, or after the calcination step. We proved that the functional properties are, to a large degree, sensitive to minor modifications of the synthesis route, and consequently to different material properties on all scales. We showed that all the features, defects and segregation from the micro to the atomic level could be the basis for the challenging reproducibility of modified KNN. (Figure 1)

The Demo Cooling Device Based on the Electrocaloric Effect was among the achievements 'Excellent in Science 2019' selected by Slovenian Research Agency. It is the result of the collaboration of researchers from the Electronic Ceramics Department, Condensed Matter Physics Department, JSI, and Laboratory for Refrigeration and District Energy, Faculty of Mechanical Engineering, University of Ljubljana. The invention has been patented in the EU, USA and China.

In collaboration with the Department for Nanostructured Materials, Department of Surface Engineering and Optoelectronics, JSI and Faculty of Chemistry and Chemical Technology, Ljubljana we prepared KNN-based ceramics by pressure-less spark plasma sintering in vacuum. After sintering the ceramic was electrically conductive due to the partial reduction of Nb^{5+} to Nb^{4+}. After post-annealing in oxygen, which results in the re-oxidation of Nb^{4+}, we obtained a material with piezoelectric properties comparable to those of a conventionally sintered ceramic, while better dielectric properties are attributed to the homogeneous microstructure with sub-micrometre-sized grains as a result of the rapid heating rate and the short dwell times of the sintering.

In collaboration with colleagues from the Advanced Materials Department, JSI, spark-plasma sintered Na(Nb,Ta)O_3 ceramics were produced and their structural behaviour with increasing Ta doping was studied, with the aim to find optimum energy storage properties of these materials. It was revealed that the doping pushes the material through various phase transitions that change the character of the materials from antiferroelectric (AFE) to ferroelectric (FE) to paraelectric. The highest energy density was obtained for the materials with 40–60 mole % Ta concentration (~0.9 J/cm3 with breakdown strength of 160 kV/cm and ~87% efficiency), which was at the boundary between the AFE/FE phases.

We continued with the work on **polycrystalline $BiFeO_3$**. Dopants with multiple oxidation states, such as Co and Mn, are often used in perovskites to control the defect chemistry and thus the electrical and electromechanical properties. In particular, doping with Co is efficient in tailoring the conductivity of multiferroic $BiFeO_3$. We studied in detail the surface defect states in undoped and Co-doped thin-film and ceramic $BiFeO_3$ using X-ray photoelectron spectroscopy (XPS) performed by our colleagues from the Technical University of Darmstadt in Germany. In particular, it was shown that Co is an excellent inhibitor of the surface reduction of $BiFeO_3$ to Fe^{2+} cations and metallic Bi when samples are exposed to water or by heat treatment in a low partial pressure of oxygen. The reason is the change of the oxidation state of Co from 3+ to 2+ upon reduction, which limits the upward shift of the Fermi energy above the reduction potential of $BiFeO_3$.

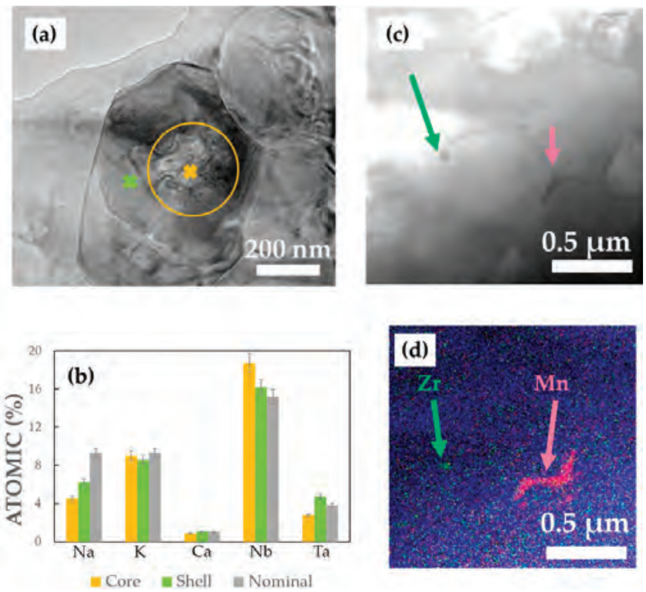

Figure 1:Nano-scale chemical inhomogeneity in multiple-elements modified potassium sodium niobate-based ceramics; a) SEM micrograph of a core-shell grain with b) corresponding EDXS analysis showing Nb-rich core and Ta-rich shell; c) STEM image with d) corresponding EDXS mapping showing nano-scale segregations of Zr-rich and Mn-rich phases.

Upon invitation from the journal Nature Materials, Mojca Otoničar and Brahim Dkhil, from Centrale Supelec, University of Paris-Seclay, wrote an opinion Electrocalorics Hit the Top for the News & Views section (published October 24, 2019). They commented on an article in which a team of researchers from the University of Cambridge, in collaboration with partners from Murata, Japan, reported on multilayer capacitors that exhibit an extremely high electrocaloric response, forecasting a breakthrough in this alternative cooling technology.

The results are important for applications of $BiFeO_3$ in photocatalytic water splitting, corrosion and gas sensing.

While promising for high-temperature applications, $BiFeO_3$ solid-solution-based piezoceramics are difficult to synthesize due to the persistence of secondary phases, known to be stabilized in $BiFeO_3$ due to a complicated interplay between kinetic and thermodynamic aspects of the system. To explore this processing problem, we used the $BiFeO_3$-$SrTiO_3$ (BFO-STO) ceramic system and performed a comparative study using three different synthesis approaches: i) conventional solid state from mixed oxides, ii) synthesis from pre-synthesized BFO and STO binaries and iii) mechanochemical activation. We found that the key element for the synthesis of homogeneous ceramics is to prevent the formation of Bi-rich phases during the diffusion reaction, which typically have low melting temperatures. We showed that this can be achieved either by using binaries as precursors, in which case pure Bi_2O_3 is avoided in the initial mixture, or by mechanochemical activation, which increases the homogeneity of the powder mixture, leading to a reaction between the activated constituents that is completed at lower temperatures.

In collaboration with researchers from Friedrich-Alexander-Universität, Erlangen, Germany, we studied the piezoelectric and ferroelectric properties of lead-free $(Na_{0.5}Bi_{0.5})TiO_3$-based ceramics using piezoresponse force microscopy (PFM). We were among the first to report ferroelectric domains in mechanically loaded relaxor ferroelectrics. In collaboration with the Advanced Materials Department, JSI, we continued with the PFM study of the piezoelectric and ferroelectric properties of micrometre-to-nanometre-sized $BaTiO_3$-based plates.

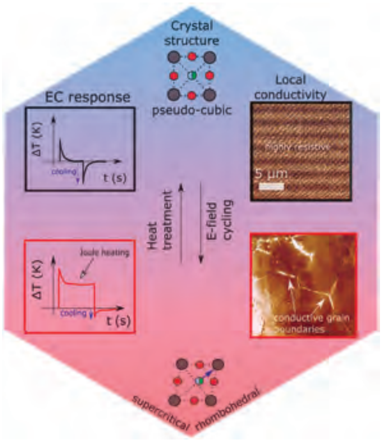

Figure 2: Electric-field cycling of electrocaloric material $Pb(Mg_{1/3}Nb_{2/3})O_3$ (PMN) leads to a transition from the pseudo-cubic to the supercritical-rhombohedral phase. This transition introduces a redistribution of charged point defects in the material, resulting in an increased electrical conductivity at the grain boundaries and, consequently, decreased cooling capacity. The transition is reversible with a heat treatment. In the paper we propose a novel approach to avoid the fatigue of PMN by controlling the field-cycling conditions using the electric-field-temperature phase diagram of PMN.

Research on **lead-based ferroic materials** continued with studies of the fatigue behaviour in the **electrocaloric (EC) response** of the prototypic relaxor lead magnesium niobate, $Pb(Mg_{1/3}Nb_{2/3})O_3$ (PMN). While still not fully addressed, fatigue resistance is the key aspect for future EC cooling devices considering that the active materials are expected to sustain not only large electric fields (several tens of kV/cm) but also a large number of such field cycles. Fatigue tests on PMN ceramics revealed the onset of Joule heating during continuous field cycling, originating from the increased grain-boundary conductivity, as found by conductive atomic-force microscopy analysis. A combination of multiscale characterization techniques clarified the mechanism of fatigue and showed that it is related to an unusual field-induced transformation of the relaxor to the ferroelectric phase in the ergodic PMN. We showed that the fatigue can be avoided by controlling this transformation using the electric-field-temperature phase diagram of PMN. (Figure 2)

One of the main problems in selecting efficient materials for EC applications is the emergence of self-heating during the electric field's application, often referred to as the Joule heating. Motivated to understand more about self-heating effects in ceramics, we performed a study focusing on the contribution to self-heating during EC cycling in different compositions, i.e., relaxor PMN and ferroelectric $Pb(Zr,Ti)O_3$ (PZT) in its "hard" and "soft" variant. The results showed that the self-heating effects have origins not only in the elevated electrical conductivity, as mostly discussed, but can also be extensive due to ferroelectric domain switching. The key parameter is the hysteresis loss, which should be more prominently considered in the selection and engineering of materials for future EC cooling devices.

We proceeded with an investigation of the **multicaloric effect in $Pb(Fe_{0.5}Nb_{0.5})O_3$** (PFN) ceramics. Ceramics were prepared by the mechanochemical activation of constituent oxides, followed by a thermal treatment. We investigated the influence of sintering conditions and doping with manganese on the functional properties of ceramics (Figure 3). In addition to multicaloric properties, we also investigated the piezoelectric response and ferroelectric domain structure of the prepared PFN ceramic samples.

Popularization of science: Hana Uršič, in collaboration with Emmanuel Defay from Luxembourg and Magdalena Wencka from Poland, organized a symposium titled Calorific Materials for Efficient Use of Heat: Progress and Challenges at the E-MRS Fall Meeting 2019 in Warsaw. Kristian Radan and Matic Lozinšek from the Department of Inorganic Chemistry and Technology attended in Genoa the "17th Festival of Science 2019" with an experimental show entitled "Kitchen Experiments". (Figure 5)

Studies of relaxor f**erroelectric $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) ceramics** continued this year, strengthening the ideas on the nonlinearities and hysteresis of the monoclinic compositions with specific nano-to-mesoscale structure. The studies were partly performed at the National Institute of Chemistry in Ljubljana, and in collaboration with prof. Jacob Jones from North Carolina State University, USA and prof. Dragan Damjanović from École polytechnique fédérale de Lausanne, Switzerland.

We studied **sodium niobate thin films** doped with manganese (NN), and their solid solutions with 5 or 10 mol % calcium zirconate (CZ) on platinized silicon substrates prepared by chemical solution deposition. The NN thin films exhibited well-shaped ferroelectric loops with a remanent polarization and coercive field of ~10 μC/cm² and ~100 kV/cm, respectively.

The modification with CZ strongly influenced the ferroelectric response of the films: the remanent polarization progressively decreased to around 2.5 μC/cm^2. The absence of an anti-ferroelectric response, characteristic for bulk NN and NN-CZ ceramics, was attributed to the nanoscale microstructure and residual thermal stresses. All the studied films exhibited a piezoelectric response with the highest piezoelectric d_{33} coefficient of 35 pm/V at 300 kV/cm bias field for the NN modified films with 5 mol % CZ.

Using **inkjet printing technology** we patterned multilayer **ferroelectric thin-film** capacitors consisting of layers of conducting lanthanum nickelate as top/bottom/internal electrodes and of ferroelectric layers of Pb(Zr,Ti)O_3 (PZT). The capacitors were successfully patterned on different substrates: silicon wafers, polycrystalline alumina and nickel foils. Compared to single-layer capacitors the multilayer components exhibit much larger capacitance density and the electromechanical response. The research was performed in collaboration with colleagues from the Departments of Condensed Matter Physics and Surface Engineering and Optoelectronics, and The Pennsylvania State University in the frame of a bilateral project. (Figure 4).

With colleagues from the Condensed Matter Physics Department, JSI, we employed a soft-chemistry approach to deposit **PZT thin films** with engineered macroporosity on platinized silicon **by spin-coating**. The presence of pores within the bulk of the films enabled local elastic relaxations, thus contributing to an enhanced electromechanical response. The value of the piezoelectric coefficient approached that of its bulk counterpart, which was attributed to both increased elastic compliance of the film and enhanced mobility of ferroelastic domain walls.

We continued the research of the **electrophoretic deposition of thick films** of environmentally benign piezoelectrics based on KNN on metallized corundum substrates for energy-harvesting applications in collaboration with researchers from the University of Tours, Tours, France.

We proceeded with the preparation of **thick films by the aerosol deposition method**. The aerosol deposition system is a part of the Laboratory for the Ultracool Preparation of Complex Oxides, for short **ULTRACOOL**, for which the financial support was granted by the Director's fund 2017 project. In collaboration with Faculty of Mechanical Engineering, University of Ljubljana, we prepared protective alumina coatings on magnetocaloric gadolinium elements. Together with researchers from Friedrich-Alexander-Universität, Erlangen, Germany we prepared porous lead-free $BaTiO_3$-based piezoelectric thick films. Current research is focused on the optimization of processing parameters for the preparation of functional PMN-PT thick films on metal and polymer substrates.

In the scope of the Ultracool laboratory, the equipment for '**Cold sintering**' was set-up, enabling the conducting of preliminary tests on real samples (i.e., pressing of wetted powders at pressures up to 600 MPa and temperatures up to 300 °C). Furthermore, systematic sintering experiments were launched first on lead-based perovskite ferroelectrics, then on multiferroic $BiFeO_3$ ceramics and also on composites of these two perovskite compounds. The obtained samples had high dielectric breakdown strength and high density, nevertheless, further analyses are needed to fully understand the mechanisms underpinning the cold-sintering technique. However, to the best of our knowledge, we were the first to successfully cold-sinter BFO ceramics with the help of molten hydroxide flux. The work on cold sintering is also performed in collaboration with colleagues from Penn State University (prof. Clive Randall), as well as with the group of Advanced Ferroics at Centrale Supelec, Paris (prof. Brahim Dkhil).

The "**Extreme Conditions Chemistry Laboratory**" **project** (ECCL, http://eccl.ijs.si/), led by Matic Lozinšek and Blaž Alič from the Inorganic

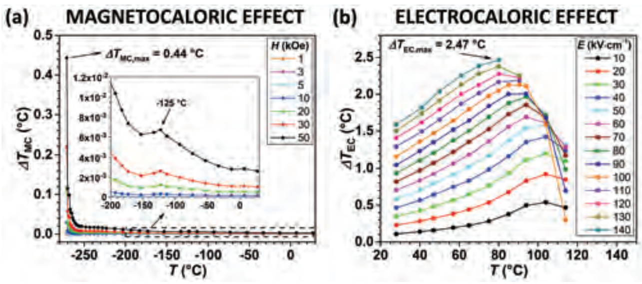

Figure 3: (a) Magnetocaloric and (b) electrocaloric effects of Mn-doped Pb($Fe_{0.5}Nb_{0.5}$)O_3 ceramics.

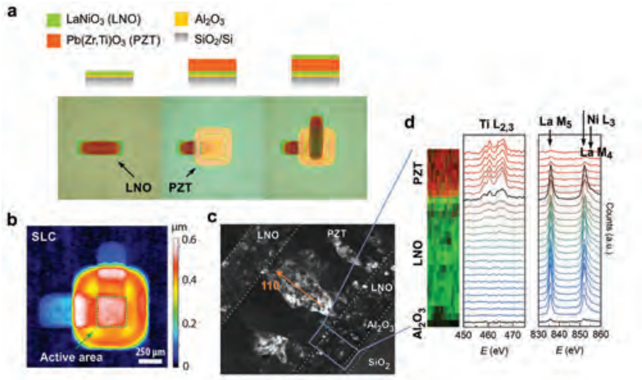

Figure 4: Inkjet printing of ferroelectric thin-film capacitors. (a) Optical images of sequentially printed LNO and PZT structures and a schematic of a corresponding cross section. (b) Contact profilometry 2-D scans of the printed capacitor. (c) Dark-field TEM image of the LNO/PZT/LNO capacitor cross section. (d) EELS map of a 100 × 170 nm^2 region across the Al_2O_3/LNO/PZT interface.

Barbara Malič was made a Fellow of the European Ceramic Society in recognition of her research of ferro- and piezoelectric ceramics and thin films.

Figure 5: "17. Festival of Science 2019" in Genoa "Kitchen Experiments" by Kristian Radan from the Electronic Ceramics Department and Matic Lozinšek from the Department of Inorganic Chemistry and Technology and the Faculty of Chemistry and Chemical Technology, University of Ljubljana.

Chemistry and Technology Department, and Mirela Dragomir and Kristian Radan from Electronic Ceramics Department was granted financial support from the **Director's fund for 2019**. Our colleagues proposed to set up a new laboratory with specialized equipment that would allow them to perform synthesis and characterization of new compounds and materials under extreme conditions, i.e., low temperatures or very high pressures. The project could provide completely new insights into the chemistry of materials.

Research and development work on **LTCC** (Low Temperature Co-fired Ceramics) technology has focused on the design and fabrication of three-dimensional ceramic structures for the packaging of microelectronic components and systems in cooperation with CoE NAMASTE, and the companies HIPOT-RR and KEKO Equipment.

Some outstanding publications in the past year

1. Bradeško, Andraž, Fulanović, Lovro, Vrabelj, Marko, Otoničar, Mojca, Uršič, Hana, Henriques, Alexandra, Chung, Ching-Chang, Jones, Jacob L., Malič, Barbara, Kutnjak, Zdravko, Rojac, Tadej. Electrocaloric fatigue of lead magnesium niobate mediated by an electric-field-induced phase transformation. **Acta materialia**, ISSN 1359-6454. [Print ed.], 2019, vol. 169, str. 275-283, doi: 10.1016/j.actamat.2019.03.017. [COBISS.SI-ID32250151]
2. Prah, Uroš, Rojac, Tadej, Wencka, Magdalena, Dragomir, Mirela, Bradeško, Andraž, Benčan, Andreja, Sherbondy, Rachel, Brennecka, Geof, Kutnjak, Zdravko, Malič, Barbara, Uršič Nemevšek, Hana. Improving the multicaloric properties of Pb(Fe0.5Nb0.5)O3 by controlling the sintering conditions and doping with manganese. **Journal of the European ceramic society**, ISSN 0955-2219. [Print ed.], 2019, vol. 39, no. 14, str. 4122-4130, doi: 10.1016/j.jeurceramsoc.2019.05.062. [COBISS.SI-ID 32459303]
3. Matavž, Aleksander, Benčan, Andreja, Kovač, Janez, Chung, Ching-Chang, Jones, Jacob L., Trolier-Mckinstry, Susan, Malič, Barbara, Bobnar, Vid. Additive manufacturing of ferroelectric-oxide thin-film multilayer devices. **ACS applied materials & interfaces**, ISSN 1944-8244. [Print ed.], 2019, vol. 11, no. 49, str. 45155-45160, doi: 10.1021/acsami.9b17912. [COBISS.SI-ID 32849447]
4. Nicole Bein, Pamela Machado, Mariona Coll, Feng Cheng, Maja Makarovič, Tadej Rojac, Andreas Klein, "Electrochemical reduction of undoped and cobalt-doped induced by water exposure : quantitative determination of reduction potentials and defect energy levels using photoelectron spectroscopy", **J. phys. chem. lett.**, vol. 10, no. 21, str. 7071-7076, 2019, doi: 10.1021/acs.jpclett.9b02706. [COBISS.SI-ID 32828199]
5. Condurache, Oana, Radan, Kristian, Prah, Uroš, Otoničar, Mojca, Kmet, Brigita, Kapun, Gregor, Dražić, Goran, Malič, Barbara, Benčan, Andreja. Heterogeneity challenges in multiple-element-modified lead-free piezoelectric ceramics. **Materials**, ISSN 1996-1944, 2019, vol. 12, no. 24, str. 4049-1-4049-12, doi: 10.3390/ma12244049. [COBISS.SI-ID 32977959]

Awards and Appointments

1. Barbara Malič: Fellow of the European Ceramic Society
2. Barbara Malič, Andrej Kitanovski (UL FS): Excellent in Science ARRS 2019, ARRS, "Demo cooling device based on the electrocaloric effect"
3. Mirela Dragomir, Kristian Radan, Blaž Alič (K1), Matic Lozinšek (K1): Director's Fund, Jožef Stefan Institute, "Extreme Conditions Chemistry Laboratory"

Organization of Conferences, Congresses and Meetings

1. E-MRS 2019 Fall Meeting: European Materials Research Society, Warsaw, Poland, September 16–19, 2019
2. MIDEM 2019: 55th International Conference on Microelectronics, Devices and Materials with the Workshop on Laser Systems and Photonics, Bled, Slovenia, September 25–27, 2019

INTERNATIONAL PROJECTS

1. EPCOS - Laboratory Measurements
   Asst. Prof. Hana Uršič Nemevšek
   Epcos Ohg
2. Laboratory Measurements
   Prof. Barbara Malič
   Tdk Electronics Gmbh & Co Og
3. Electric Measurements
   Prof. Tadej Rojac
   Tdk Electronics Gmbh & Co Og
4. Laboratory Measurements
   Prof. Andreja Benčan Golob
   Tdk Electronics Gmbh & Co Og
5. Electrocaloric Measurements of Ceramic Samples
   Prof. Barbara Malič
   Tdk Electronics Gmbh & Co Og
6. Atomic Force Microscope Measurements
   Asst. Prof. Hana Uršič Nemevšek
   Tdk Electronics Gmbh & Co Og
7. Environment Friendly Ferroelectric Materials in Bulk and Thin-Film Forms and Low-Temperature Processing Thereof
   Prof. Barbara Malič
   Slovenian Research Agency
8. Processing of Piezoelectric Thick Films by Aerosol Deposition Technique

Asst. Prof. Hana Uršič Nemevšek
Slovenian Research Agency
9. Novel Hardening Mechanisms in Lead-Free Piezoceramics
Prof. Tadej Rojac
Slovenian Research Agency
10. Cold Sintering of Complex Oxide Materials
Dr. Mojca Otoničar
Slovenian Research Agency
11. Low Bandgap Ferroelectric Solar Cell Absorbers: Synthesis and Characterization
Asst. Prof. Hana Uršič Nemevšek
Slovenian Research Agency
12. Interface Stability of Piezoelectric Ceramic Oxides
Prof. Tadej Rojac
Slovenian Research Agency
13. Environmental Benign Sodium Potassium Niobate-based Thick Films for Piezoelectric Energy Harvesting Applications
Prof. Danjela Kuščer Hrovatin
Slovenian Research Agency
14. Understanding Size Effects in Antiferroelectric Materials
Dr. Mojca Otoničar
Slovenian Research Agency
15. Multiferroics for Solid-State Cooling Applications
Asst. Prof. Hana Uršič Nemevšek
Slovenian Research Agency
16. Processing – Structure - Properties Study of Environmentally Friendly Piezoelectric Nanoparticles of Tailored Surface Morphology
Prof. Andreja Benčan Golob
Slovenian Research Agency
17. High-Pressure Synthesis and Characterization of Selected Ferroics
Dr. Kristian Radan
Slovenian Research Agency
18. Crystal Growth and Magnetic Properties of Double Perovskites
Dr. Mirela Dragomir
Slovenian Research Agency

RESEARCH PROGRAMME

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

R & D GRANTS AND CONTRACTS

1. Multicaloric cooling
Asst. Prof. Hana Uršič Nemevšek
2. Electrocaloric elements for active cooling of electronic circuits
Prof. Barbara Malič
3. Advanced inorganic and organic thin films with enhanced electrically-induced response
Prof. Barbara Malič
4. Advanced electrocaloric energij conversion
Prof. Barbara Malič
5. Domain engineered ferroelectric ceramic layer elements for efficient energy harvesting and energy conversion applications
Prof. Barbara Malič
6. Strategic Research & Innovation Partnership Factories of the Future (SRIP FoF)
Prof. Barbara Malič
Ministry of Economic Development and Technology
7. Public call for reimbursement of costs for scientific publications in golden open access (for 2019)
Prof. Barbara Malič
Slovenian Research Agency
8. Stay of Maja Makarovič in Trondheim - Interactions between Charged Defects and Domain Walls in Lead-Free BiFeO3
Maja Makarovič
Jecs Trust
9. Sample Preparation
Prof. Andreja Benčan Golob
Cern
10. Stay of Oana Andreea Condurache in AI CUZA Iasi, Romania - Functional Characterisation of Potassium Sodium Niobate-Based and Bismuth Ferrite-Based Ceramics
Oana Andreea Condurache
Jecs Trust
11. Stay of Kristian Radan in Leoben, Austria - Ramanska študija izbranih feroelektričnih perovskitov brez svinca
Dr. Kristian Radan
Jecs Trust

VISITORS FROM ABROAD

1. Yuji Matsushita, Osaka Prefecture University – Graduate School of Engineering, Department of physics and electronics, Osaka, Japan, October 10, 2018 – January 6, 2019
2. Prof. Raul Bermejo, Montanuniversität Leoben, Leoben, Austria, January 17, 2019
3. Ibrahim Gökdemir, Yildiz Technical University, Istanbul, Turkey, February 4– March 25, 2019
4. Dr Marco Deluca, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria, February 13, 2019
5. George Markou, University of Ioannina, Ioannina, Greece, March 1 – April 30, 2019
6. Chrisanthi Ikonomidi, University of Ioannina, Ioannina, Greece, March 1 – May 31, 2019
7. Dr Julian Walker, Norwegian University of Science and Technology (NTNU), Trondheim, Norway, March 16 – 21, 2019
8. Mathis Lechable, Université François-Rabelais Tours, Tours, France, April 1 – June 21, 2019
9. Rémy Lecomte, Université François-Rabelais Tours, Tours, France, April 1 –June 21, 2019
10. Valentin Roulaud, Université François-Rabelais Tours, Tours, France, April 2 – June 21, 2019
11. Marko Mudri, Bjelovar University of Applied Sciences, Department of Mechatronics, Bjelovar, Croatia, April 23 – October 22, 2019
12. Nicole Bein, Technische Universität Darmstadt (TUDa), Darmstadt, Germany, May 6–24, 2019
13. Hugo Mercier, Université François-Rabelais Tours, Greman CNRS, Tours, France, May 27 – June 8, 2019
14. Yao Minghai, Centrale Supélec, Université Paris-Saclay, Paris, France, June 1 – 30, 2019
15. Prof. Brahim Dkhil, Centrale Supélec, Université Paris-Saclay, Paris, France, June 3–5, 2019
16. Prof. Franck Levassort, Université François-Rabelais Tours, Greman CNRS, Tours, France, June 3 – 6, 2019
17. Prof. Dr. Angus I. Kingon, Brown University, Providence, Rhode Island, USA, June 10–11, 2019
18. Prof. Nava Setter, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, June 10 – 11, 2019
19. Prof. Hisao Suzuki, Shizuoka University, Hamamatsu, Japan, July 19 – 22, 2019
20. Dr Magdalena Wencka, Institute of Molecular Physics, Polish Academy of Sciences, Poznań, Poland, July 23 – August 2, 2019
21. Prof. Mariya Gancheva, Institute of General and Inorganic Chemistry, Sofia, Bulgaria, August 19 – 23, 2019
22. Udo Eckstein, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany, August 25 – September 15, 2019
23. Kristijan Kovačić, Bjelovar University of Applied Sciences, Department of Mechatronics, Bjelovar, Croatia, September 16, 2019 – May 21, 2020
24. Nicole Bein, Technische Universität Darmstadt (TUDa), Darmstadt, Germany, September 23 – October 17, 2019
25. Dr Marco Deluca, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria, September 30, 2019
26. Prof. Dr Andreas Klein, Technische Universität Darmstadt (TUDa), Darmstadt, Germany, October 10, 2019
27. Dr Marko Vrabelj, TDK Electronics GmhH & Co OG, Deutschlandsberg, Austria, October 21 – 22, 2019
28. Dr Kerstin Schmoltner, TDK Electronics GmhH & Co OG, Deutschlandsberg, Austria, October 21 – 22, 2019
29. Dr Marcus Albrecher, TDK Electronics GmhH & Co OG, Deutschlandsberg, Austria, October 21 – 22, 2019
30. Astita Dubey, Institute for Materials Science – Universität Duisburg-Essen, Essen, Germany, October 21 – December 8, 2019
31. Yao Minghai, Centrale Supélec, Université Paris-Saclay, Paris, France, November 3 – December 1, 2019
32. Mateo Miličević, Bjelovar University of Applied Sciences, Department of Mechatronics, Bjelovar, Croatia, November 4, 2019 – January 3, 2020
33. Federica Benes, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria, November 10 – 30, 2019
34. Prof. Brahim Dkhil, Centrale Supélec, Université Paris-Saclay, Paris, France, December 1–6, 2019
35. Marion Höfling, Technische Universität Darmstadt (TUDa), Darmstadt, Germany, December 9 – 13, 2019
36. Mihail Slabki, Technische Universität Darmstadt (TUDa), Darmstadt, Germany, December 9 – 13, 2019
37. Prof. Brahim Dkhil, Centrale Supélec, Université Paris-Saclay, Paris, France, December 19 – 21, 2019

STAFF

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

Postdoctoral associates
8. Dr. Mirela Dragomir
9. Dr. Kostja Makarovič*
10. Dr. Kristian Radan
11. *Dr. Tanja Vrabelj, left 01.02.19*

Postgraduates
12. Dr. Andraž Bradeško
13. Oana Andreea Condurache, B. Sc.
14. *Lovro Fulanović, B. Sc., left 01.02.19*
15. Sabi William Konsago, B. Sc.
16. Maja Makarovič, B. Sc.
17. Uroš Prah, B. Sc.
18. Samir Salmanov, B. Sc.
19. Matej Šadl, B. Sc.

Technical officers
20. *Darko Belavič, B. Sc., left 01.02.19*
21. Silvo Drnovšek, B. Sc.
22. Brigita Kmet, B. Sc.
23. Marija Šebjan Pušenjak, B. Sc.

Technical and administrative staff
24. Tina Ručigaj Korošec, B. Sc.

Note:
* part-time JSI member

BIBLIOGRAPHY

ORIGINAL ARTICLE

1. Boštjan Genorio, Katharine L. Harrison, Justin Grant Connell, Goran Dražić, Kevin R. Zavadil, Nenad M. Markovic, Dušan Strmčnik, "Tuning the selectivity and activity of electrochemical interfaces with defective graphene oxide and reduced graphene oxide", *ACS applied materials & interfaces*, 2019, **11**, 37, 34517-34525.
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