ELECTRONIC CERAMICS DEPARTMENT

K-5

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

Head:
Prof. Barbara Malič

We continued the work on **lead-free ferroics**. Sodium niobate ($NaNbO_3$) is an end member of the lead-free piezoelectric $KNbO_3$–$NaNbO_3$ solid solution (KNN)-based formulations and a prototypical antiferroelectric. In collaboration with colleagues from Technical University Darmstadt we studied the undoped and donor-doped sodium niobate (1 mol % Ca or Sr) to elucidate the role of dopants on the Fermi energy, electrical conductivity and energy gap of sodium niobate. The average grain size of sodium niobate is strongly reduced upon doping, from about 90 mm to about 1 mm , a phenomenon commonly observed in alkali-niobate ceramics and attributed to reduced grain-boundary migration. Both donor-doped materials exhibit good insulating behaviour, i.e., room-temperature conductivity of up to 10×10^{-10}S/cm, which is only slightly higher than that of the undoped material, suggesting that the energy gap of $NaNbO_3$ is substantially higher than the gap of 3.4 eV to 3.5 eV determined from optical spectroscopy reported in the literature.

We continued our investigations on the electric-field-induced microstrain mechanisms in **polycrystalline $BiFeO_3$**. Using in-situ X-ray diffraction analysis we discovered an unexpected decrease in the lattice strain with increasing field amplitude at sub-Hz driving frequencies. The response was assigned to a coupled effect of local domain-wall conductivity and elastic intergranular coupling, leading to an extensive redistribution of electric fields inside individual grains that ultimately results in the peculiar lattice-strain field dependence.

Barbara Malič received the Ferroelectrics Recognition Award 2022 from the IEEE Ultrasonics, Ferroelectrics and Frequency Control (UFFC) Society for her outstanding contribution to the elucidation of the relationships between chemical and physical properties of ferroelectric ceramics.

Together with colleagues from the National Institute of Chemistry in Ljubljana, Ecole Polytechnique Fédérale de Lausanne and Université Paris-Saclay, CentraleSupélec we performed an in-situ scanning-transmission electron microscopy study in which the response of domain walls in a $BiFeO_3$ single crystal in a capacitor-like configuration was directly observed. The dynamics of domain walls, in the presence of defects, revealed unique and complex phenomena at the atomic level (Figure 1). The study published in Nano Letters provides insight into the dynamic, atomistic processes at domain walls in ferroelectric materials.

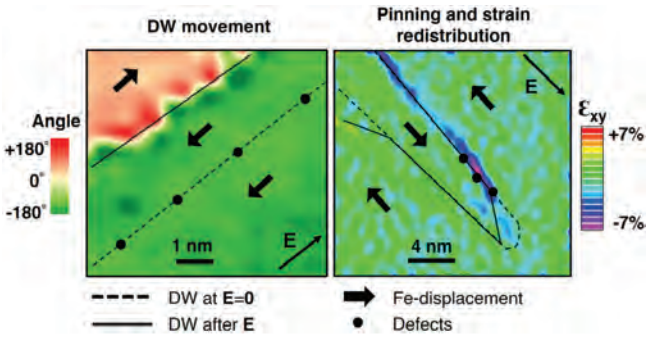

Figure 1: Response of domain walls (DWs) investigated with in-situ bias scanning transmission electron microscopy. Fe-displacement orientation (left) and strain distribution (right) were evaluated from the HAADF atomic resolution images. Defect segregation, changes in strain and the bound charge distribution at domain walls under electrical stimuli were observed.

Based on its efficiency in the mechanochemical synthesis of lead-based perovskites, we tested the so-called seeding approach in the synthesis of lead-free $BiFeO_3$–$BaTiO_3$ ceramics. The procedure involved the use of $BaTiO_3$ powder particle seeds during mechanochemical activation, which should promote the perovskite formation. In contrast to expectations, the use of $BaTiO_3$ seeds resulted in core-shell structured ceramics likely due to chemical segregation of the $BaTiO_3$-rich regions. Homogeneous ceramics were obtained by a conventional technique in which seeds were not used. While the homogeneous $BiFeO_3$-$BaTiO_3$ ceramic was characterized by larger, weak-field piezoelectric coefficients, the heterogeneous ceramics exhibited pronounced high-field strains due to greater reversibility in the response, which was correlated with the presence of chemical heterogeneities. The study was performed with colleagues from Denmark.

In collaboration with colleagues from the Department of Condensed Matter Physics, JSI, and the Department of Advanced Materials, JSI, as well as with colleagues from Morocco, France, and Ukraine, we studied the dielectric and piezoelectric properties of **barium-titanate-based ceramics**. Different compositions of the

$(1-x)Ba_{0.85}Ca_{0.15}Zr_{0.10}Ti_{0.90}O_3$–$xBaTi_{0.89}Sn_{0.11}O_3$ (xBTSn, x = 0.2, 0.4 and 0.6) solid solution were prepared. Ceramics with composition x = 0.2 exhibited the highest piezoelectric coefficient d_{33} = 228 pC·N^{-1}.

We further investigated the origins of the large piezoelectric response of **lead-based relaxor-ferroelectric ceramics** based on the $(1-x)Pb(Mg_{1/3}Nb_{2/3})O_3$–$xPbTiO_3$ (PMN-PT) solid solution. A systematic analysis of the piezoelectric nonlinear harmonic response of the relaxor-based PMN-PT ceramics and non-relaxor $Pb(Zr,Ti)O_3$ (PZT) samples across a great part of the respective phase diagrams revealed fundamental differences in the dynamic domain-wall contributions to the properties in these two systems. Although indirectly, we were able to identify for the first time the key nonlinear features related to the low-angle domain-wall dynamics and contrasted this behaviour with the dynamics of conventional domain walls in ferroelectrics such as PZT. The results were published in the form of a feature paper in J. Am. Ceram. Soc.

PhD students Oana-Andreea Condurache, Katarina Žiberna and Barbara Repič won awards for presenting their dissertation results at international conferences.

In collaboration with colleagues from the Reactor Physics Department, JSI, we investigated the feasibility of using $(1-x)Pb(Mg_{1/3}Nb_{2/3})O_3$–$xPbTiO_3$ (PMN–100xPT) **electrocaloric materials** in applications where the material is exposed to high neutron and γ radiation. For this purpose, PMN–100xPT ceramics (x = 0, 0.1, and 0.35) were irradiated with a neutron fluence of 10^{15} to 10^{17} neutrons/cm^2, which exceeds the largest expected neutron irradiation in the European Council for Nuclear Research (CERN) and simultaneously exposed to γ irradiation. The neutron and γ radiation partially affect the functional properties of the PMN–35PT. In contrast, the functional properties of the irradiated PMN and PMN–10PT samples are similar to those of the pristine samples; therefore, we concluded that these materials can be used as working materials in electrocaloric coolers exposed to such harsh environments.

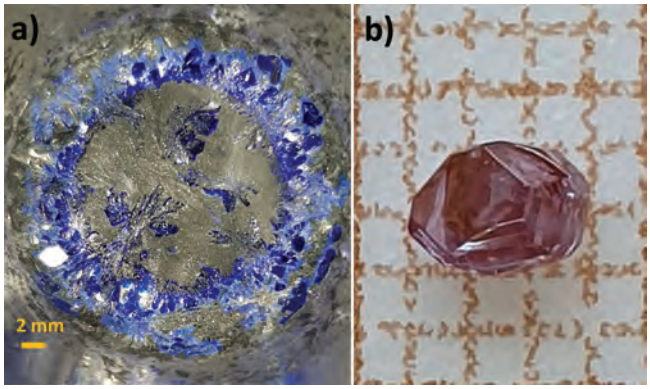

Figure 2: a) Milimeter-sized, blue $SrCu_2(BO_3)_2$ single crystals as grown by the flux method in a platinum crucible. b) A lilac single crystal of the quantum-spin-liquid candidate $NdTa_7O_{19}$ grown at K5.

Part of our research was focused on **single-crystal growth and magnetic studies of low-dimensional and frustrated magnetic materials such** as $SrCu_2(BO_3)_2$ and $NdTa_7O_{19}$.

We first synthesised polycrystalline $SrCu_2(BO3)_2$ and then developed a flux method to grow mm-sized, blue single crystals of $SrCu_2(BO_3)_2$ and doped-$SrCu_2(BO_3)_2$ (Figure 2a), which allowed us to investigate their magnetic properties further. On the other hand, we also performed the single-crystal growth of the Ising triangular-lattice antiferromagnet neodymium heptatantalate, $NdTa_7O_{19}$ (Figure 2b), which will be used to obtain a more complete understanding of the magnetic ground state of this compound. In collaboration with the Condensed Matter Physics Department, JSI, these crystals will be used for a series of measurements such as magnetization, heat capacity, μSR and inelastic neutron scattering.

The other part of our research focused on silver(II) compounds. Fluoride phases containing spin ½ $4d^9$ Ag^{2+} were predicted to have exotic magnetic properties similar to cuprates. Since Ag^{2+} is a very powerful oxidant, its synthesis techniques are limited to those that use F_2 or anhydrous HF. In addition, the thermal decomposition of the main Ag^{2+} precursor, AgF_2, further limits the methods for preparing these compounds. We therefore focused our efforts on developing an alternative synthesis technique to obtain new silver(II) phases.

Since 2022, Andreja Benčan Golob has been leading a three-year large interdisciplinary ARRS project, the purpose of which is to establish a platform for the development of a new methodology of scanning transmission electron microscopy (4D STEM) for characterizing the properties of energy-efficient materials down to the quantum level. The project connects scientists involved in the development of microscopy, the synthesis of various energy-efficient materials, computational methods and artificial intelligence methods from two leading Slovenian research institutions, the Jožef Stefan Institute and the National Institute of Chemistry.

In the quest for alternative piezoelectric materials to lead-based perovskites such as PZT, the large piezoelectric effect of $Ba(Zr,Ti)O_3$-$(Ba,Ca)TiO_3$ or BZT-BCT in a bulk form has been reported. The Chemical Solution Deposition (CSD) of BZT-BCT thin films is a cost-effective approach for the miniaturization of devices. In general, CSD of $BaTiO_3$ (BT) or BT-based thin films such as BZT-BCT, alkaline-earth carboxylates, and transition-metal alkoxide are dissolved and diluted, respectively, in carboxylic acid and alcohol solvents. The reactions of the solvents led to the formation of water and eventually the progressive hydrolysis of transition-metal alkoxide and precipitation. In order to resolve these problems, we developed a new synthesis route in which ethylene glycol (EG) is used as the solvent for alkaline-earth carboxylates. The EG-based BT coating solutions are stable for at least a few months. The films deposited from the EG-ethanol-based solution yield perovskite films with columnar microstructures and good dielectric and ferroelectric properties (Figure 3).

In collaboration with colleagues from the Department of Condensed Matter Physics, JSI, and the Department of Advanced Materials, JSI, as well as colleagues from Morocco, France, and Ukraine, we studied piezoelectric properties of $H_2(Zr_{0.1}Ti_{0.9})_3O_7$ nanowires. Piezo-response force microscopy (PFM) was used to determine the piezoelectric coefficient $d_{33} \sim 25$ pm·V^{-1} of a single nanowire. Furthermore, in collaboration with colleagues from the Department for Materials Synthesis, JSI, we investigated the functional properties of $Bi_4Ti_3O_{12}$ nanoplatelets and nanowires. Observations of the ferroelectric domains by PFM indicated the piezoelectric/ferroelectric nature of both nanostructures.

We continued research on **thick films** of environmentally benign piezoelectrics based on $K_{0.5}Na_{0.5}NbO_3$ (KNN) on ceramic substrates for energy-harvesting and ultrasound-transducer applications. The multilayer structure consists of a KNN substrate with a high attenuation coefficient of 0.5 dB/mm/MHz and a **screen-printed** KNN thick film. The electroacoustic response of the multilayer structure in water provides a central frequency of 15 MHz and a very large fractional bandwidth (BW) of 127% at -6dB. The multilayer structure is a candidate for imaging applications operating above 15 MHz. The research was conducted as part of the Proteus project in collaboration with researchers from the University of Tours, France.

We continued research on materials and technologies to realise an electrochemical sensor system (MES) for neonicotinoid pesticide detection. The miniature three-electrode systems on alumina substrates were fabricated by **screen printing**. We confirmed the electrochemical response of pure carbon-based working electrodes for neonicotinoid detection. In collaboration with the Faculty of Chemistry and Chemical Technology, University of Ljubljana, we improved the response by modifying the carbon-based working electrode with metal oxide particles.

We continued with the preparation of **thick films by aerosol deposition**. The aerosol deposition facility is a part of the Laboratory for the Ultracool Preparation of Complex Oxides, for which financial support was granted by **the Director's fund ULTRACOOL project**. In collaboration with colleagues from Friedrich-Alexander-University Erlangen-Nürnberg, Germany, and the University of Tours, France, we focused on the preparation and characterization of multifunctional $0.65Pb(Mg_{1/3}Nb_{2/3})O_3$–$0.35PbTiO_3$ (PMN–35PT) thick films deposited on stainless steel. The films annealed at 500 °C withstand electric fields of 1350 kV·cm^{-1} and exhibited promising room-temperature energy-storage properties; the recoverable energy density reached 15 J·cm^{-3}, and an electric-field cycling stability of 5 million cycles. Macroscopic displacement measurements revealed a maximum relative strain of 0.38% at 1000 kV·cm^{-1}, corresponding to an inverse effective piezoelectric coefficient of ~40 pm·V^{-1}.

Furthermore, we developed a procedure to study films in the cross-section by PFM. In this way, we investigated the relaxor-ferroelectric domain structure of **screen-printed and aerosol-deposited** PMN–35PT films. Due to the different preparation methods used for these two groups of films, the grain size and, thus, the relaxor-ferroelectric domain structures differ. Micron-scale domains are observed in the screen-printed films, while sub-micrometer-scale domains are found in the aerosol-deposited films. However, no change in the ferroelectric domain structures was observed across the thicknesses of the films.

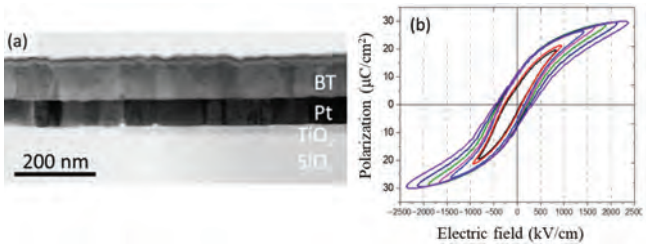

Figure 3: a) Cross-section transmission electron microscopy micrograph of a barium titanate (BT) thin film revealing a predominantly columnar microstructure. The ethylene glycol-ethanol-based coating solution was spin-coated on a platinized silicon substrate, dried, pyrolysed and annealed at 800 °C four times to reach a thickness of approximately 130 nm. b) Polarization vs. electric field hysteresis loops of the BT film with a gold top electrode.

A European patent entitled "A vibration system and a filtering plate for filtering substances" has been granted, co-authored by Danjela Kuščer, Tadej Rojac and Darko Belavič.

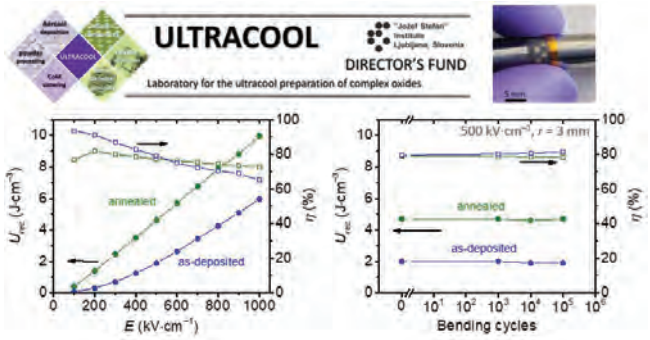

Figure 4: Room-temperature energy-storage properties of PMN-10PT thick films deposited on polymer substrates; (left) recoverable energy density (U_{rec}) and efficiency (η) as a function of electric field (E), (right) U_{rec} η as a function of mechanical bending cycles.

Using aerosol deposition, we also prepared $0.9Pb(Mg_{1/3}Nb_{2/3})O_3$–$0.1PbTiO_3$ (PMN-10PT) thick films on polymer substrates (Figure 4). After annealing at 400 °C, the films exhibit high polarization (38 μC·cm^{-2}) and low hysteresis losses, leading to a recoverable energy density of 10 J·cm^{-3} at 1000 kV·cm^{-1}. The excellent stability of energy-storage properties was confirmed after bending to a radius of 3 mm (1.1% bending strain) and after repeating 100,000 bending cycles. Such an energy-storage operation makes these thick-film structures promising for integration into a wide range of flexible electronic devices.

We progressed in our research on the **cold sintering** of functional oxides in our ULTRACOOL laboratory, expanding the sintering from $BiFeO_3$ ceramics to $(K,Na)NbO_3$ perovskites and composites with piezoelectric polymers (PVDF). While optimization of all parameters for successful cold sintering of the ceramic compounds is still an ongoing process, the first measured electromechanical properties of the sintered ceramics are very promising and show a great perspective of cold-sintered oxides for actuator and energy-storage applications. Preliminary studies

Mojca Otoničar and Tadej Rojac organized, with the help of colleagues and support of the MIDEM society, the 57th International Conference on Microelectronics, Devices and Materials with the workshop on Energy Harvesting: Materials and Application, which was held in Maribor. Invited lecturers from foreign and Slovenian institutions presented the state of the art in the field, followed by more than 30 regular contributions.

show that the main benefits of the cold sintering of ceramics are, besides the energy savings due to the low-temperature processing, their dielectric breakdown strength that allows high voltages applied to the materials without their disintegration, as well as high dielectric permittivity and low dielectric losses.

In collaboration with the National Institute of Chemistry from Ljubljana and RC eNeM we investigated the integration of transparent electronics on an industrial glass product for the next generation of transparent electronics. The project focuses on realising solution-manufactured indium-free conductors through a low-cost, environmentally friendly industrial process.

Some outstanding publications in the past year

1. Šadl, Matej, Lebar, Andrej, Valentinčič, Joško, Uršič Nemevšek, Hana. Flexible energy-storage ceramic thick-film structures with high flexural fatigue endurance. ACS applied energy materials, ISSN 2574-0962, 2022, vol. 5, no. 6, str. 6896-6902, doi: 10.1021/acsaem.2c00518. [COBISS.SI-ID 110882307]
2. Uršič Nemevšek, Hana, Prah, Uroš, Rojac, Tadej, Jazbec, Anže, Snoj, Luka, Drnovšek, Silvo, Bradeško, Andraž, Mirjanić, Anja, Vrabelj, Marko, Malič, Barbara. High radiation tolerance of electrocaloric (1–x) Pb(Mg1/3Nb2/3)O3–xPbTiO3. Journal of the European ceramic society, ISSN 0955-2219. [Print ed.], 2022, vol. 42, iss. 13, str. 5575-5583, ilustr., doi: 10.1016/j.jeurceramsoc.2022.05.051. [COBISS.SI-ID 111403011]
3. Kuščer, Danjela, Kmet, Brigita, Drnovšek, Silvo, Bustillo, Julien, Levassort, Franck. Lead-free sodium potassium niobate-based multilayer structures for ultrasound transducer applications. *Sensors*, ISSN 1424-8220, 2022, vol. 22, no. 9, str. 3223-1-3223-13, doi: 10.3390/s22093223. [COBISS.SI-ID 105730563]
4. Otoničar, Mojca, Dragomir, Mirela, Rojac, Tadej. Dynamics of domain walls in ferroelectrics and relaxors. Journal of the American Ceramic Society. Nov. 2022, vol. 105, iss. 11, str. 6479-6507, ilustr. ISSN 1551-2916. DOI: 10.1111/jace.18623. [COBISS.SI-ID 114034947] (pregledni članek)

Awards and Appointments

1. Oana-Andreea Condurache: Student Award for the contribution: Monitoring Bismuth Ferrite Domain Walls Behavior Under Electric Field With Atomic Resolution by In Situ Scanning Transmission Electron Microscopy, Organization board of the conference: Microscopy & Microanalysis 2022
2. Barbara Malič, Ferroelectric Recognition Award 2022 of the IEEE Ultrasonics, Ferroelectrics and Frequency Control Society (UFFC-S) for the outstanding contributions to the elucidation of the relationships between chemical and physical properties in ferroelectric, Ultrasonics, Ferroelectrics and Frequency Control Society (UFFC-S) in the frame of Institute of Electrical and Electronics Engineers (IEEE)
3. Barbara Repič, Best Contribution in Sensor Technology Award for the presentation entitled: Preparation and Electrochemical Characterization of Screen-Printed Graphite Electrodes, Organization Board of 14th Student Conference of Jožef Stefan Postgraduate School
4. Katarina Žiberna, Best Poster Award among the top three in the Materials Science section, Organization Board at 16th Multinational Congress on Microscopy

Organization of conferences, congresses and meetings

1. MIDEM 2022: 57th International Conference on Microelectronics, Devices and Materials with the Workshop on Energy Harvesting: Materials and Application, Maribor, Slovenia, September 14-16, 2022

Patent granted

1. Mirko Faccini, Morillo Martín, David Amantia, Danjela Kuščer, Darko Belavič, Tadej Rojac, A vibration system and a filtering plate for filtering substances, EP3454977 (B1), European Patent Office, 09. 02. 2022.

INTERNATIONAL PROJECTS

1. Hot Stage Microscope Measurements
   Prof. Barbara Malič
   Meggitt Sensing Systems
2. Laboratory Measurements for TDK
   Prof. Hana Uršič Nemevšek
   TDK Electronics GmbH & Co Og
3. H2020 - ATHENA; Implementing Gender Equality Plans to Unlock Research Potential of RPOs and RFOs in Europe
   Prof. Barbara Malič
   European Commission
4. H2020 - QMatCh; Towards Quantum States of Matter via Chemistry under Extreme Conditions
   Asst. Prof. Mirela Dragomir
   European Commission
5. Environment-Friendly Ferroelectric Oxide Thin Films for Energy Harvesting and Energy Storage Applications
   Prof. Barbara Malič
   Slovenian Research Agency
6. Realizing In-Situ Studies of Dynamic Mechanisms in Ceramic Oxides in the Reducing Environment in a Transmission Electron Microscope
   Prof. Andreja Benčan Golob
   Slovenian Research Agency
7. Engineering the Microstructure and Performance of Lead-Free Piezoelectrics for Energy Harvesting
   Prof. Barbara Malič
   Slovenian Research Agency
8. Environment-Friendly Processing of Lead-Free Functional-Oxide Thin Films for Micro-Electro-Mechanical Systems (MEMS) Applications
   Prof. Barbara Malič
   Slovenian Research Agency
9. Smart Design of New Multifunctional Composites with Optimized Energy Transfer Across Interfaces between the Components (SoMwOT)
   Prof. Barbara Malič
   Slovenian Research Agency
10. ABO3-Type Perovskite Structured Ferroelectric Ceramics for Future Sensors, Actuators and Solid-State Refrigerators
    Prof. Hana Uršič Nemevšek
    Slovenian Research Agency
11. Low Temperature Processing of Piezoelectric Thick Films for Medical Imaging and Energyharvesting Applications
    Prof. Hana Uršič Nemevšek
    Slovenian Research Agency
12. Ferroelectric and Antiferroelectric Ceramic Materials
    Prof. Hana Uršič Nemevšek
    Slovenian Research Agency
13. Single-Crystal Growth and High-Pressure Studies of Low-Dimensional Quantum Magnets
    Asst. Prof. Mirela Dragomir
    Slovenian Research Agency

RESEARCH PROGRAMME

1. Multifunctional materials and devices: from quantum to macroscale
   Prof. Barbara Malič

R & D GRANTS AND CONTRACTS

1. In situ atomic level Quantitative Scanning Transmission Electron Microscopy of Functional Materials
   Prof. Andreja Benčan Golob
2. TCCbuilder: An open-source simulation tool for thermal control circuits
   Prof. Barbara Malič
3. Electrocaloric elements for active cooling of electronic circuits
   Prof. Barbara Malič
4. Advanced inorganic and organic thin films with enhanced electrically-induced response
   Prof. Barbara Malič
5. The quest for high-temperature superconductvity and exotic magnetism in fluoridoargentates(II)
   Asst. Prof. Mirela Dragomir
6. Designing functionality of lead-free ferroelectrics through domain wall engineering
   Prof. Andreja Benčan Golob
7. The cool way to polarize
   Asst. Prof. Mojca Otoničar
8. Engineering of relaxor ferroelectric thin films for piezoelectric and energy storage applications
   Prof. Tadej Rojac
9. Structures of elusive noble-gas compounds elucidated by 3D electron diffraction
   Asst. Prof. Mirela Dragomir
10. All in One: Multi-caloric and Multi-scavenging Elements for Green Future
    Prof. Hana Uršič Nemevšek
11. High-pressure stabilization and phase transitions of elusive transition-metal fluorides
    Asst. Prof. Mirela Dragomir
12. Enhanced piezoelectricity via structural disorder in polycrystalline relaxor ferroelectrics
    Prof. Tadej Rojac
13. MIcrofluidic Sensor System for PESticides detection (MISS PES)
    Prof. Danjela Kuščer Hrovatin
14. Flexible elements with multi-physical properties
    Prof. Hana Uršič Nemevšek
15. Antiferroelectric materials for cooling and high power electronic applications
    Prof. Andreja Benčan Golob
16. 4D STEM of energy related materials down to quantum level
    Prof. Andreja Benčan Golob
17. Process intensification for the continuous synthesis of high purity hydrogen peroxide using a micro-scale electrocatalytic reactor
    Prof. Barbara Malič
18. Advanced materials and technologies for the sustainable printed electronics on glass
    Prof. Danjela Kuščer Hrovatin
19. Battery Thermal Management System Based on High Power Density Digital Microfluidic Magnetocaloric Cooling
    Prof. Hana Uršič Nemevšek
    University of Ljubljana
20. Minor Services - Foreign Customers
    Prof. Barbara Malič

NEW CONTRACT

1. Advanced materials and technologies for the sustainable printed electronics on glass
   Prof. Danjela Kuščer Hrovatin
   Razvojni Center Enem Novi Materiali d. o. o.

VISITORS FROM ABROAD

1. Nikola Tutić, University of Bjelovar, Bjelovar, Croatia, January 16 - April 15, 2022
2. Prof. Dragan Damjanovic, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, March 8 – April 2, 2022
3. Matheiu Fricaudet, CentraleSupelec, Paris, France, March 20 – June 6, 2022
4. Dr Ilona Zamaraite, Vilnius University, Vilnius, Lithuania, April 1 – 30, 2022
5. Justine Breuzard, Tours University, Tours, France, April 5 - June 24, 2022
6. Jeanne Gonzales, Tours University, Tours, France, April 5 - June 24, 2022
7. Meryem Lachhab, University Limoges, Limoges, France, April 19 - July 8, 2022
8. Longfei Song, Luxembourg Institute of Science and Technology, Luxembourg, Luxembourg, May 16 – June 15, 2022
9. Ivica Grgić, University of Bjelovar, Croatia, May 16 – July 14, 2022
10. Christine Farmer, Institute of Technology Blois, Blois, France, May 20, 2022
11. Prof. Marco Deluca, Materials Center Leoben Forschung GmbH, Leoben, Austria, May 24, 2022
12. Dr Xi Shi, Friedrich-Alexander-Universität Erlangen-Nürnberg. Nürnberg, Germany, May 29 – June 8, 2022
13. Marah Alqedra, Faculty of Science, Ankara University, Ankara, Turkey, July 5 – September 26, 2022
14. Matheiu Fricaudet, CentraleSupelec, Paris, France, August 23 – October 13, 2022
15. Dr Julian Walker, Norwegian University of Science and Technology, Trondheim, Norway, September 19 – 20, 2022
16. Prof. Jacob L. Jones, North Carolina State University, Raleigh, USA, September 23, 2022
17. Prof. dr Geoff Brennecka, Colorado School of Mines, Golden, USA, October 1, 2022 - February 28, 2023
18. Matheiu Fricaudet, CentraleSupelec, Pariz, France, October 25 – December 9, 2022
19. Alexander Kobold, Materials Leoben Forschung GmbH (MCL), Leoben, Austria, November 7 – 11, 2022
20. Luka Čubrilo, Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia, November 7, 2022 – February 7, 2023

21. Prof. Vera Gradišnik, Prof. Duško Čakara, University of Rijeka, Rijeka, Croatia, November 22, 2022
22. Dr Jaroslaw Kita, Faculty of Engineering Science, University of Bayreuth, Bayreuth, Germany, December 15 – 16, 2022
23. Dr Yongli Wang, Albertus Sutanto, Kyosuke Nakamura, TDK Electronics GmbH & Co OG, Deutschlandsberg, Austria, December 22, 2022

STAFF

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

Postdoctoral associates
10. Dr. Andraž Bradeško*
11. Dr. Antonio Iacomini
12. Dr. Soukaina Merselmiz
13. *Dr. Uroš Prah, on leave since 15.06.21*

Postgraduates
14. Matic Belak Vivod, B. Sc.
15. Oana Andreea Condurache, M. Sc.
16. Ivana Goričan, B. Sc.
17. Maja Koblar, B. Sc.
18. Sabi William Konsago, M. Sc.
19. Victor Regis De Moraes, M. Sc.
20. Barbara Repič, B. Sc.
21. Samir Salmanov, M. Sc.
22. Ankita Sarkar, M. Sc.
23. Dr. Matej Šadl
24. Lia Šibav, B. Sc.
25. Blaž Velkavrh, B. Sc.
26. Katarina Žiberna, B. Sc.

Technical officers
27. Silvo Drnovšek, B. Sc.
28. Brigita Kmet, B. Sc.
29. Izabela Stojanoska, B. Sc.

Technical and administrative staff
30. Andrej Debevec
31. Tina Ručigaj Korošec, B. Sc.

Note:
* part-time JSI member

Electronic Ceramics Department K-5

Original Scientific Article

1. Matthieu Fricaudet, Katarina Žiberna, Samir Salmanov, Jens Kreisel, Delong He, Brahim Dkhil, Tadej Rojac, Mojca Otoničar, Pierre-Eymeric Janolin, Andraž Bradeško, "Multifunctional properties of polyvinylidene-fluoride-based materials", *ACS applied electronic materials*, 2022, **4**, 11, 5429-5436, 10.1021/acsaelm.2c01091.
2. Matej Šadl, Andrej Lebar, Joško Valentinčič, Hana Uršič Nemevšek, "Flexible energy-storage ceramic thick-film structures with high flexural fatigue endurance", *ACS applied energy materials*, 2022, **5**, 6, 6896-6902, 10.1021/acsaem.2c00518.
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Patent

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Mentoring

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