# 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 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. To reduce or to avoid chemical heterogeneities, often encountered in the conventional solid-state synthesis of complex perovskites, the mechanochemical activation of reagent particles was introduced in the processing of the (K,Na,Li)(Nb,Ta)$O_3$-$CaZrO_3$ based ceramic. Partial amorphisation of the reagents contributed to a much lower final temperature of the solid-state reaction, the ceramic exhibited a higher level of chemical homogeneity and enhanced ferro- and piezoelectric properties in comparison to conventionally processed material.

The coupling between antiferromagnetic and ferroelectric/ferroelastic domain switching in **polycrystalline $BiFeO_3$** has been studied for the first time. Using in-situ neutron-diffraction analysis we directly observed the antiferromagnetic domain switching induced by non-180° ferroelectric/ferroelastic domain texturing during electric field application. Along with the orientation dependence of this coupled switching, these data represent the first step towards understanding and manipulating the antiferromagnetic order using the electric field in polycrystalline $BiFeO_3$.

In collaboration with colleagues from the School of Materials Science and Engineering, University of New South Wales, Sydney, Australia, the Swiss Federal Institute of Technology in Lausanne, Switzerland and ESRF—The European Synchrotron, Grenoble, France, we studied an unusual strain behaviour of individual grains inside a polycrystalline matrix of bismuth ferrite. In contrast to the frequency behaviour of the strain arising from domain-wall displacements, the lattice strain showed an unexpected decreasing magnitude with decreasing field frequency. This strain decoupling was explained by analytical modelling, confirming the key role of the anisotropy in the electrical conductivity caused by the different orientation of conductive domain walls in different grains within the polycrystalline matrix. *(Figure 1)*

In-situ synchrotron XRD analysis was used to gain an insight into the mechanisms of an electric-field-induced phase transformation in **samarium-doped $BiFeO_3$ ceramics**, which are believed to play the key role in the electromechanical response of this class of multiferroic materials. The results revealed two transformation pathways related to a reversible antiferroelectric-to-ferroelectric and irreversible paraelectric-to-ferroelectric phase transformations with slow dynamics (a time constant of minutes). The findings point to texturing and the elimination of the paraelectric phase as the origin of the enhanced electromechanical response.

We studied the influence of cobalt doping on the electrical conductivity and domain-switching behaviour of rare-earth-modified bismuth ferrite ($Bi_{0.91}Dy_{0.09}$)$FeO_3$ ceramics. Undoped samples showed exceedingly large leakage currents under switching field conditions that were successfully suppressed by cobalt doping. We tentatively attributed this effect to the binding of the Co-dopant into the defect complexes which suppresses the

**Projects INTcerSEN and PiezoMEMS have been awarded the title of "Success story M-ERA.NET"**

**M-ERA.NET is an EU-funded network with the mission to support and increase the coordination of European research and innovation programmes and related funding in materials science and engineering. Over the last three years, twenty M-ERA.NET European projects have been awarded the title of "Success story M-ERA.NET". At the Electronic Ceramics Department we have participated in two projects that last year received the "Success story" titles.**

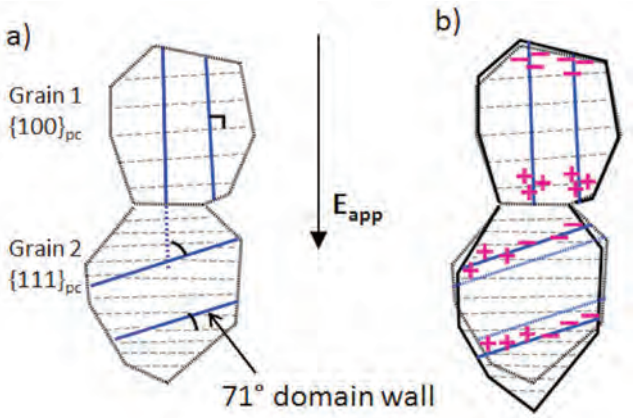


*Figure 1: Schematic of two representative grains in poled $BiFeO_3$. a) Illustration of 71° domain walls in two grains of different orientations forming different angles with respect to the electric-field axis $E_{app}$. b) Charge re-distribution in the two grains upon the application of the electric field $E_{app}$ arising due to the different orientation of the conductive domain walls with respect to $E_{app}$. This charge re-distribution and the corresponding change in internal fields are responsible for the peculiar frequency dependence and decoupling of strain mechanisms in $BiFeO_3$*

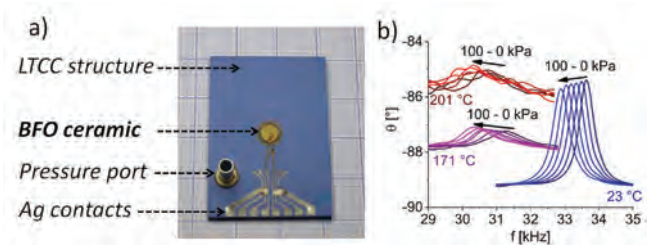


*Figure 2: a) Photograph of the pressure sensor with an integrated bulk $BiFeO_3$ piezoelectric actuator. b) Phase angle θ as a function of frequency for the sensor measured at three different temperatures. At each temperature, the measurement was performed by varying the differential pressures (from 0 kPa to 100 kPa). The arrows indicate curves for increasing differential pressure. The measurements confirmed a pressure sensitivity, i.e., resonance frequency shift of the sensor per unit of pressure, of –8.7 Hz/kPa up to 171 °C.*

charge de-trapping at high electric fields, effectively reducing the high-field leakage current by an order of magnitude with respect to undoped ceramics.

Later, we constructed a ceramic pressure sensor from the low-temperature co-fired ceramic (LTCC) with an integrated bulk $BiFeO_3$ piezoelectric actuator that could operate at elevated temperatures. In order to construct a sensor with a suitable pressure sensitivity, numerical simulations were used to define the optimum construction dimensions. The sensor's functionality was proven to be sufficient up to 171 °C. *(Figure 2)*

In collaboration with the Advanced Materials Department we studied the piezoelectric and ferroelectric properties of micrometre- to nanometre-sized $Ba_{1-x}Sr_xTiO_3$ plates using piezoresponse force microscopy (PFM). We found that $Ba_{1-x}Sr_xTiO_3$ plates with $0 \leq x \leq 0.175$ exhibited ferroelectric and piezoelectric characteristics, while the plates with a larger amount of strontium were non-piezoelectric. The study opens up new possibilities for the use of such plates in the field of miniature piezoelectric sensors.

Research on **lead-based ferroic materials** continued with $1\text{-}xPb(Mg_{1/3}Nb_{2/3})O_3\text{-}xPbTiO_3$ (PMN-100xPT) ceramics, processed by mechanochemical synthesis and sintering. The PMN-10PT relaxor ceramic is known for its high electrocaloric properties, yet it is quite challenging to obtain a phase-pure material. Adding the $PbTiO_3$ seeds to remaining oxide constituents prior to mechanochemical activation reduced the milling time needed to achieve a pure perovskite PMN-10PT by about a half. By following the perovskite crystallization process by X-ray diffraction (XRD) and transmission electron microscopy (TEM) analyses, we also demonstrated that a second, metastable, pyrochlore phase is taking part in the perovskite formation.

We further investigated a broad range of PMN-100xPT compositions, from ergodic relaxor to relaxor ferroelectric, their structure and their response to external fields at various length-scales using in-situ XRD, ex-situ TEM and PFM. From the observed changes in the crystal and domain structures, combined with macroscopic measurements of the responses to electric fields, we were able to determine the main contributions to the overall properties. These were shown to obviously differ in monoclinic compositions with the nanodomain texture ($0.2<x<0.33$) from the tetragonal compositions ($x>0.35$) with the lamellar domains and the more 'classic' ferroelectric behaviour. The results point out the significant extrinsic effects of the monoclinic nanodomains and their movement to the high electromechanical responses in relaxor ferroelectric ceramics. *(Figure 3)*

**MIDEM conference - Between the 3rd and 5th of October 2018, the 54th International Conference on Microelectronics, Devices and Materials with the Workshop on Sensors and Transducers was held at the Jožef Stefan Institute. The conference was chaired by Dr. Tadej Rojac and Dr. Hana Uršič and organized by the MIDEM society and SRIP Factories of the Future. Participants from seven European countries, North America and China contributed to the international scientific discussion.**

In collaboration with colleagues from North Carolina State University, USA, electric-field-induced changes in the PMN-30PT composition were followed by in-situ high-energy XRD and pair-distribution function (PDF) analyses. These measurements of the long-range and local scale responses, respectively, revealed that a field-induced polarization rotation occurs, which was shown for the first time in polycrystalline ferroelectrics.

In collaboration with colleagues from the Technical University Darmstadt, Germany, we aimed at exploring the possibility of optimizing the **electrocaloric** (EC) response with defect engineering. The impact of defects on the EC response was studied in $Pb(Zr,Ti)O_3$ (PZT) ceramics doped with acceptor and donor dopants. The highest EC cooling was observed in acceptor-doped PZT when the electric field was applied parallel to the aligned defect complexes. The origin of this largest EC response was attributed to the reduced hysteresis losses and the associated self-heating effects, which seem to play a key role in the EC response of PZT.

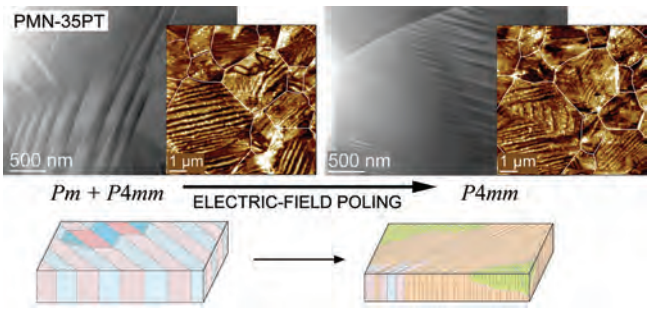


*Figure 3: Evolution of the domain structure of PMN-PT ceramics at the morphotropic phase boundary with ex-situ applied electric field. TEM micrographs and PFM images (and the corresponding sketch) show the reorientation and densification of the lamellar domain walls, which was simultaneous with a phase change from tetragonal and monoclinic coexisting symmetries to a more tetragonal one.*

We proceeded with an investigation of the **multicaloric effect** in $Pb(Fe_{1/2}Nb_{1/2})O_3$-based ceramics. The ceramics were prepared by the mechanochemical activation of constituent oxides, followed by a thermal treatment. We investigated the influence of manganese, lithium and cobalt doping on the functional properties of polycrystalline $Pb(Fe_{1/2}Nb_{1/2})O_3$.

In collaboration with the Luxembourg Institute of Science and Technology (LIST) we continued the research of solution-derived **tuneable ferroelectric $(Ba,Sr)TiO_3$ thin films**. The dielectric permittivity, losses and voltage tunability in the microwave range (~10 GHz) of the perovskite films with a columnar microstructure are effectively tailored by changing the Ba/Sr molar ratio and/or by manganese doping for a given microwave component. Together with colleagues from LIST and the Faculty of Elec-

trical Engineering, University of Ljubljana, we designed and fabricated a frequency-agile planar antenna based on a (Ba,Sr)$TiO_3$ thin-film varactor.

In collaboration with the Advanced Materials Department we studied the local piezoelectric and ferroelectric properties of **0.66Pb($Mg_{1/3}Nb_{2/3}$)$O_3$–0.33$PbTiO_3$ thin films** prepared by pulsed-laser deposition. Using piezoresponse force microscopy we confirmed the effective poling and ferroelectric domain switching in these films. The local piezoelectric response ($d_{33}^{local}$) of the surface structure reached values as high as 140 pm/V, while the average piezoelectric value was 28 pm/V. The results of this study offer an excellent starting point for the preparation of functional thin films for $d_{33}$-mode energy harvesters.

We investigated the **electrophoretic deposition** of **thick-films** of environmentally benign piezoelectrics based on $K_{0.5}Na_{0.5}NbO_3$ on metallized corundum substrates for energy-harvesting applications in collaboration with researchers from François-Rabelais University, Tours, France. After sintering at 1110 °C the ~ 20-µm-thick films with a relative density of 82 % exhibited promising electromechanical properties; a piezoelectric coefficient $d_{33}$ of 80 pC / N and an average thickness coupling factor $k_t$ of 40 %.

We proceeded with microstructural investigations of a few-µm to several-tens-of-µm thick $BiFeO_3$ films deposited on platinized Al2O3. The thick-films were prepared by **the screen printing method**.

Using screen printing we prepared test structures for single-chamber solid-oxide fuel cells. The (La,Sr)$MnO_3$ cathode, Ni anodes, and a mesh of platinum were screen printed on a crystal of $ZrO_2$ stabilized with $Y_2O_3$ (YSZ). Colleagues from the Synchrotron Elettra, Trieste, Italy, investigated the chemical state of the constituents of a fuel cell with X-ray photoelectron spectroscopy with a sub-micrometre resolution and at a pressure of ~1 bar. Understanding the chemical state of the electrode materials under operating conditions is of paramount importance for improving the energy efficiency of single-chamber fuel cells.

We have started with the **aerosol deposition** of functional-oxide thick films. The aerosol deposition system is a part of the **Laboratory for the ultracool preparation of complex oxides**, in short ULTRACOOL, for which financial support was granted by the **Director's Fund 2017** project. Current research is focused on the optimization of processing parameters for the preparation of functional 0.9Pb($Mg_{1/3}Nb_{2/3}$)$O_3$–0.1$PbTiO_3$ thick films on metal and ceramic substrates. *(Figure 4)*

We deposited **conductive oxide** $LaNiO_3$ (LNO) electrodes on top of ferroelectric Pb(Zr,Ti)$O_3$ (PZT) thin films on platinized silicon substrates using the technology of **inkjet printing**. We designed an LNO ink based on a combination of solvents with a range of viscosities, surface tensions and boiling points, which enabled us to reproducibly pattern LNO layers with lateral dimensions of a few 100 µm and a uniform thickness of a few 10 nm. The functional properties of thin-film capacitors with inkjet-printed LNO top-electrodes outperform those with sputtered gold top-electrodes (~40% higher dielectric permittivity, improved fatigue properties), which is probably related to the effective compensation of oxygen vacancies by the oxide electrode, thinner depletion regions at the LNO-PZT interface, and a lower concentration of charged defects due to the processing. The research was performed in collaboration with colleagues from the Departments of Condensed Matter Physics, Thin Films and Surfaces, and Surface Engineering and Optoelectronics. (Figure 5).

**LTCC** (Low Temperature Co-Fired Ceramics) and thick-film materials and processes have been investigated for the design and fabrication of three-dimensional ceramic structures for the packaging of microelectronic components and systems, so-called System in Package (SiP). An advantage of the LTCC is the heterogeneous integration of various electronic and other components, and at the same time high-quality protection in demanding environments. In cooperation with **CoE NAMASTE, HIPOT-RR and KEKO Equipment**, we successfully developed ceramic structures with integrated sensors and microfluidic elements for the packaging of microelectromechanical systems (MEMS). The results are useful in the designing and manufacturing of Smart Systems in Package, especially in emerging projects.

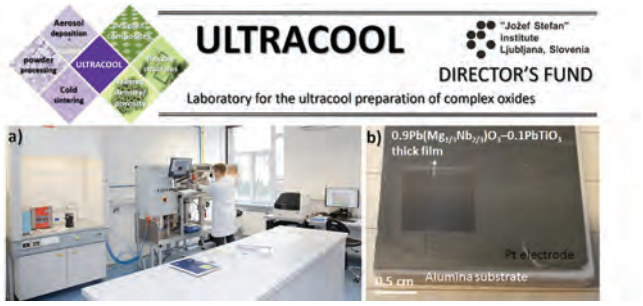


*Figure 4: a) Laboratory for the ultracool preparation of complex oxides, in short ULTRACOOL (Director's Council 2017). The image shows a device for the aerosol deposition of thick films that is based on accelerated particles heating the substrate and forming a dense thick film at room temperature. b) Photograph of a thick film prepared in the ULTRACOOL lab.*

**Our colleague Dr. Tadej Rojac received two awards: i) The Young Investigator Award of the IEEE Ultrasonics, Ferroelectrics and Frequency Control Society for his pioneering work in the processing of chemically complex ferroelectric ceramics and ii) the Zois Recognition for significant achievements in the research of the synthesis and characterization of high-temperature piezoelectric ceramics based on bismuth ferrite.**

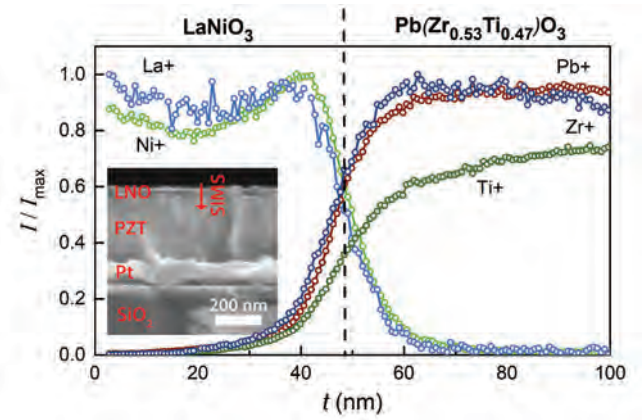


*Figure 5: ToF SIMS analysis of the chemical composition of a thin-film capacitor $LaNiO_3$/Pb($Zr_{0.53}Ti_{0.47}$)$O_3$ (PZT)/ Pt on a $SiO_2$/Si substrate in the direction marked by an arrow. Inset: scanning electron micrograph of the cross-section of the capacitor.*

## Some outstanding publications in the past year

1. Liu, Lisha, Rojac, Tadej, Damjanović, Dragan, Di Michiel, Marco, Daniels, John E.
Frequency-dependent decoupling of domain-wall motion and lattice strain in bismuth ferrite. Nature communications, ISSN 2041-1723, 2018, vol. 9, pp. 4928-1-4928-10, doi: 10.1038/s41467-018-07363-y. [COBISS.SI-ID 31884583]
2. Otoničar, Mojca, Uršič, Hana, Dragomir, Mirela, Bradeško, Andraž, Esteves, Giovanni, Jones, Jacob L., Benčan, Andreja, Malič, Barbara, Rojac, Tadej.
Multiscale field-induced structure of $(1-x)Pb(Mg_{1/3}Nb_{2/3})O_3-xPbTiO_3$ ceramics from combined techniques. *Acta materialia*, ISSN 1359-6454. [Print ed.], 2018, vol. 154, pp. 14-24, doi: 10.1016/j.actamat.2018.05.028. [COBISS.SI-ID 31410471]
3. Matavž, Aleksander, Kovač, Janez, Čekada, Miha, Malič, Barbara, Bobnar, Vid.
Enhanced electrical response in ferroelectric thin film capacitors with inkjet-printed $LaNiO_3$ electrodes. Applied physics letters, ISSN 0003-6951. [Print ed.], 2018, vol. 113, no. 1, pp. 012904-1-012904-4, doi: 10.1063/1.5037027. [COBISS.SI-ID 31521063]
4. Walker, Julian, Bayer, Thorsten J. M., Makarovič, Maja, Kos, Tomaž, Trolier-Mckinstry, Susan, Malič, Barbara, Rojac, Tadej.
Cobalt doping to influence the electrical conductivity of $(Bi_{0.91}Dy_{0.09})FeO_3$ ceramics. Materials letters, ISSN 0167-577X. [Print ed.], 2018, vol. 225, pp. 126-129, doi: 10.1016/j.matlet.2018.04.125. [COBISS.SI-ID 31357479]

## Awards and Appointments

1. Tadej Rojac: Young investigator award for his pioneering work in processing of chemically complex ferroelectric ceramics, IEEE Ultrasonics Ferroelectrics and Frequency Control Society
2. Tadej Rojac: Zois Award for significant achievements in research of the synthesis and characterization of high-temperature piezoelectric ceramics based on bismuth ferrite, Government of the Republic of Slovenia

## Organization of Conferences, Congresses and Meetings

1. MIDEM 2018: 54$^{th}$ International Conference on Microelectronics, Devices and Materials with the Workshop on Sensors and Transducers, Ljubljana, October 3 – 5, 2018

## Patents granted

1. Irena Ramšak, Marija Razpotnik, Katja Makovšek, Danjela Kuščer, Silvo Drnovšek, Janez Holc, Production method of steatite ceramics with improved electrical properties, EP3230232 (B1), European Patent Office, 15. 08. 2018.
2. Irena Ramšak, Marija Razpotnik, Janez Holc, Danjela Kuščer, Method for producing non-alkaline steatite ceramics with improved electrical properties, EP3233755 (B1), European Patent Office, 10. 10. 2018.
3. Barbara Malič, Hana Uršič, Marija Kosec, Silvo Drnovšek, Jena Cilenšek, Zdravko Kutnjak, Brigita Rožič, Uroš Flisar, Andrej Kitanovski, Marko Ožbolt, Uroš Plaznik, Alojz Poredoš, Urban Tomc, Jaka Tušek, Method for electrocaloric energy conversion, US9915446 (B2), US Patent and Trademark Office, 13. 03. 2018.

# INTERNATIONAL PROJECTS

1. COST MP1308; Towards Oxide Based Electronics (TO-BE)
Asst. Prof. Hana Uršič Nemevšek
COST Office
2. Minor Services - Foreign Customers
Prof. Barbara Malič
3. Advanced Electronic Ceramics for the Sustainable, Efficient and Safe Use of Energy
Prof. Barbara Malič
Slovenian Research Agency
4. Domain Structure of Complex Oxides
Asst. Prof. Hana Uršič Nemevšek
Slovenian Research Agency
5. Local Structure in Relaxor Ferroelectrics - The Key to Understanding their Functional Properties
Prof. Andreja Benčan Golob
Slovenian Research Agency
6. Environment Friendly Ferroelectric Materials in Bulk and Thin-Film Forms and Low-Temperature Processing Thereof
Prof. Barbara Malič
Slovenian Research Agency
7. Processing of Piezoelectric Thick Films by Aerosol Deposition Technique
Asst. Prof. Hana Uršič Nemevšek
Slovenian Research Agency
8. Novel Hardening Mechanisms in Lead-Free Piezoceramics
Prof. Tadej Rojac
Slovenian Research Agency
9. Cold Sintering of Complex Oxide Materials
Dr. Mojca Otoničar
Slovenian Research Agency

# RESEARCH PROGRAM

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

# R & D GRANTS AND CONTRACTS

1. Photovoltaic cell and modul inhomogenity analysis and performace monitoring in power plants through lifetime
   Prof. Barbara Malič
2. Multifunctional materials for actuator and cooling devices
   Prof. Tadej Rojac
3. Multicaloric cooling
   Asst. Prof. Hana Uršič Nemevšek
4. Advanced electrocaloric energy 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. Inkjet Printing of PZT Test Structures and Piezoelectric Characterization of Thin Films Double-Beam Laser Interferometer Measurement
   Prof. Barbara Malič
8. Stay of Maja Makarovič in Trondheim - Interactions between Charged Defects and Domain Walls in Lead-Free BiFeO3
   Maja Makarovič
9. Stay of Mojca Otoničar in Lausanne - Pursuing the Origin of the Large Irreversible Contribution to Piezoelectric Responsein the Monoclinic Phases of Pb(Mg1/3Nb2/3) O3–xPbTiO3 Ceramics
   Dr. Mojca Otoničar
10. Laboratory Measurements
    Asst. Prof. Hana Uršič Nemevšek
11. Sample Preparations
    Prof. Andreja Benčan Golob

# VISITORS FROM ABROAD

1. Hugo Mercier, François Rabelais University of Tours, Tours, France, January 22 – February 17, 2018
2. Marija Lovreković, Bjelovar University of Applied Sciences, Bjelovar, Croatia, February 19 – April 20, 2018
3. Dr. Julian Walker, Pennsylvania State University, Pennsylvania, USA, March 5 – 9, 2018
4. Dumitru Rotari, University of Petrosani, Petrosani, Romania, March 5 – May 25, 2018
5. Mirela Goncear, University of Petrosani, Petrosani, Romania, March 5 – May 25, 2018
6. Alan Mutka, Bjelovar University of Applied Sciences, Bjelovar, Croatia, March 15, 2018
7. Ivan Marušić, Bjelovar University of Applied Sciences, Bjelovar, Croatia, March 20 – 23, 2018
8. Ivan Sekovanić, Bjelovar University of Applied Sciences, Bjelovar, Croatia, March 20 – 23, 2018
9. Ivana Jurković, Bjelovar University of Applied Sciences, Bjelovar, Croatia, March 20 – 23, 2018
10. Paul Lechesne, Université François-Rabelais Tours, Tours, France, April 3 – June 22, 2018
11. Grégorie Levavasseur, Université François-Rabelais Tours, Tours, France, April 3 – June 22, 2018
12. Hanae Azeroual, University of Limoges, Limoges, France, April 9 – July 15, 2018
13. Prof. Kenji Uchino, Pennsylvania State University, Pennsylvania, USA, May 10 – 17, 2018
14. Rachel Sherbondy, Colorado School of Mines, Golden, Colorado, USA, May 21 – July 27, 2018
15. Toni Fak, Bjelovar University of Applied Sciences, Bjelovar, Croatia, July 2 – October 10, 2018
16. Antonio Lisičak, Bjelovar University of Applied Sciences, Bjelovar, Croatia, July 2 – December 31, 2018
17. Hicran Arslan, Yildiz Technical University Istanbul, Istanbul, Turkey, July 16 – October 14, 2018
18. Dr. Pedro Braga Groszewicz, Eduard-Zint Institut Darmstadt, Darmstadt, Germany, September 6, 2018
19. Dr. Marko Vrabelj, EPCOS OHG, Deutschlandsberg, Germany, September 11 – 14, 2018
20. Matija Buljan, Bjelovar University of Applied Sciences, Bjelovar, Croatia, September 24 – December 23, 2018
21. Antun Čordaš, Bjelovar University of Applied Sciences, Bjelovar, Croatia, September 24 – December 23, 2018
22. Prof. Dragan Damjanovic, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland, September 30 – October 4, 2018
23. Prof. Franck Levassort, Université François-Rabelais Tours, Tours, France, October 3 – 5, 2018
24. Dr. Alexander Martin, Friedriech-Alexander Universität Erlangen-Nuernberg, Nuernberg, Germany, October 7 – 20, 2018
25. Prof. Angus I. Kingon, Brown University, Providence, USA, October 5, 2018
26. Nicole Bartek, Universität Druisburg-Essen, Essen, Germany, October 8 – November 2, 2018
27. Yuji Matshushita, Osaka Prefecture University, Osaka, Japan, October 10 – December 31, 2018
28. Kevin Riess, Friedriech-Alexander Universität Erlangen-Nuernberg, Nuernberg, Germany, November 5 – 23, 2018
29. Dr. Neamul Hayet, Friedriech-Alexander Universität Erlangen-Nuernberg, Nuernberg, Germany, November 5 – 23, 2018
30. Dr. Denis Orosel, EPCOS OHG, Deutschlandsberg, Germany, November 6, 2018
31. Dr. Marko Vrabelj, EPCOS OHG, Deutschlandsberg, Germany, November 12 – 16, 2018
32. Dr. Jurij Koruza, Technische Universität Darmstadt, Darmstadt, Germany, November 19 – 30, 2018
33. Marion Höfling, Technische Universität Darmstadt, Darmstadt, Germany, November 19 – 30, 2018
34. Milan Baričević, University of Bjelovar, Bjelovar, Croatia, December 17 – 31, 2018
35. Prof. Jürgen Rödel, Technische Universität Darmstadt, Darmstadt, Germany, December 17 – 19, 2018

# STAFF

**Researchers**
1. Prof. Andreja Benčan Golob
2. Prof. Goran Dražić*
3. Asst. 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, left 01.05.18*
9. Dr. Kostja Makarovič*
10. Dr. Kristian Radan
11. Dr. Tanja Vrabelj
12. *Dr. Marko Vrabelj, left 14.05.18*

**Postgraduates**
13. Andraž Bradeško, B. Sc.
14. Oana Andreea Condurache, B. Sc.
15. Lovro Fulanović, B. Sc.
16. Maja Makarovič, B. Sc.
17. Uroš Prah, B. Sc.
18. Matej Šadl, B. Sc.

**Technical officers**
19. Darko Belavič, B. Sc.
20. Silvo Drnovšek, B. Sc.
21. Brigita Kmet, B. Sc.

**Technical and administrative staff**
22. *Tamara Matevc, B. Sc., 06.10.18, transferred to Department E6*
23. Tina Ručigaj Korošec, B. Sc.

Note:
* part-time JSI member

# BIBLIOGRAPHY

## ORIGINAL ARTICLE


1. Primož Jovanovič, Marjan Bele, Martin Šala, Francisco Ruiz-Zepeda, Goran Dražić, Nataša Zabukovec Logar, Nejc Hodnik, Miran Gaberšček, "Corrosion protection of platinum-based electrocatalyst by ruthenium surface decoration", *ACS applied energy materials*, 2018, **1**, 7, 3190-3197.
2. Mario Špadina, Simon Gourdin-Bertin, Goran Dražić, Atiđa Selmani, Jean-François Dufrêche, Klemen Bohinc, "Charge properties of $TiO_2$ nanotubes in $NaNO_3$ aqueous solution", *ACS applied materials & interfaces*, 2018, **10**, 15, 13130-13142.
3. Mirela Dragomir, Matjaž Valant, "Room-temperature synthesis and optical properties of $NdVO_4$ nanoneedles", *Acta chimica slovenica*, 2018, **65**, 3, 679-686.
4. Mojca Otoničar, Hana Uršič, Mirela Dragomir, Andraž Bradeško, Giovanni Esteves, Jacob L. Jones, Andreja Benčan, Barbara Malič, Tadej Rojac, "Multiscale field-induced structure of $(1-x)Pb(Mg_{1/3}Nb_{2/3})O_3 - xPbTiO_3$ ceramics from combined techniques", *Acta materialia*, 2018, **154**, 14-24.
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## Mentoring

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