

ECAPD 2026 Oulu Conference Programme and Abstract Book

European Conference on Applications of Polar Dielectrics

7-10 June 2026

Linnanmaa Campus, University of Oulu, Erkki Koiso-Kanttilan katu 3, 90570 Oulu, Finland

Sponsored by

UFFC
IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society

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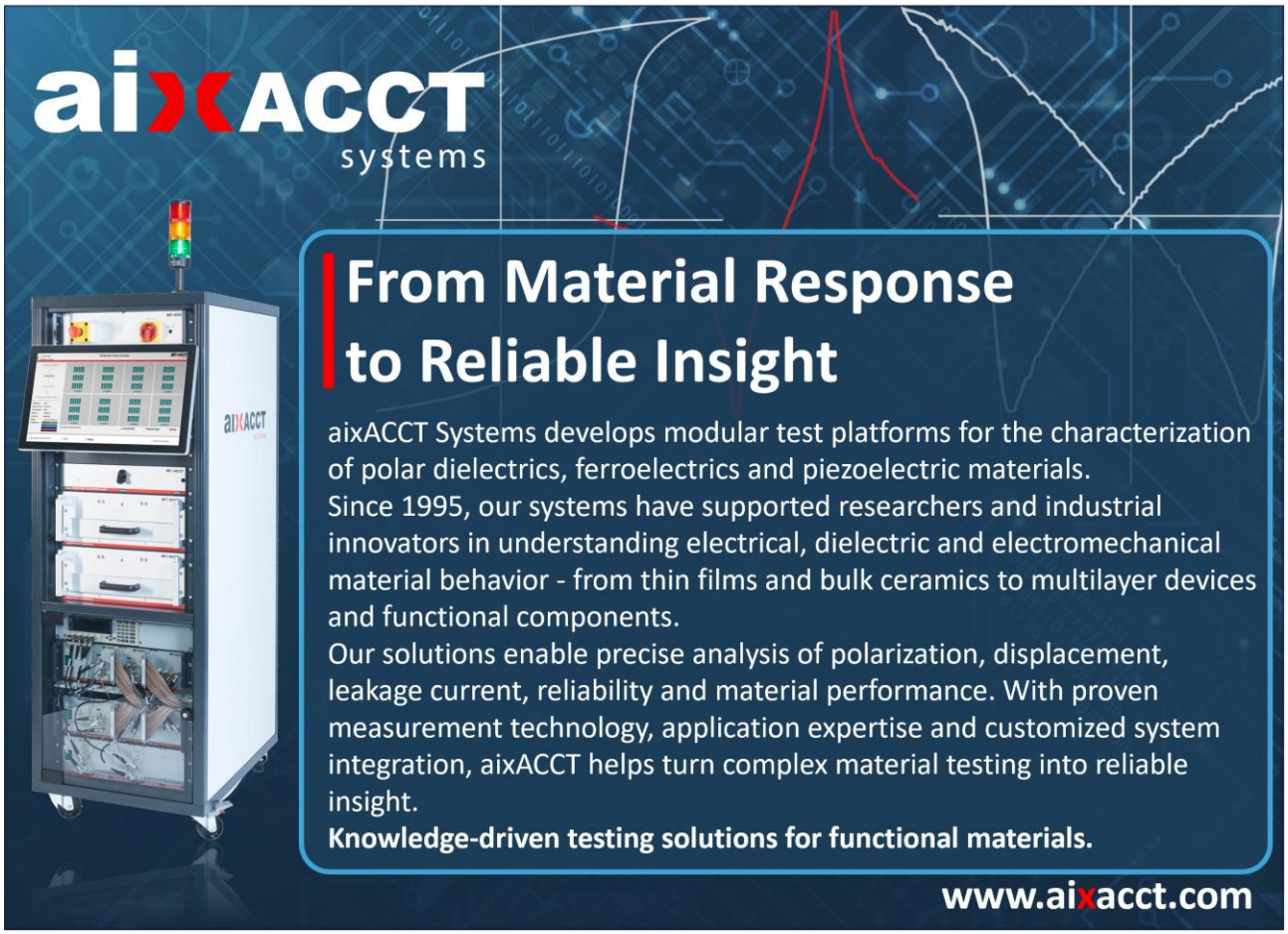
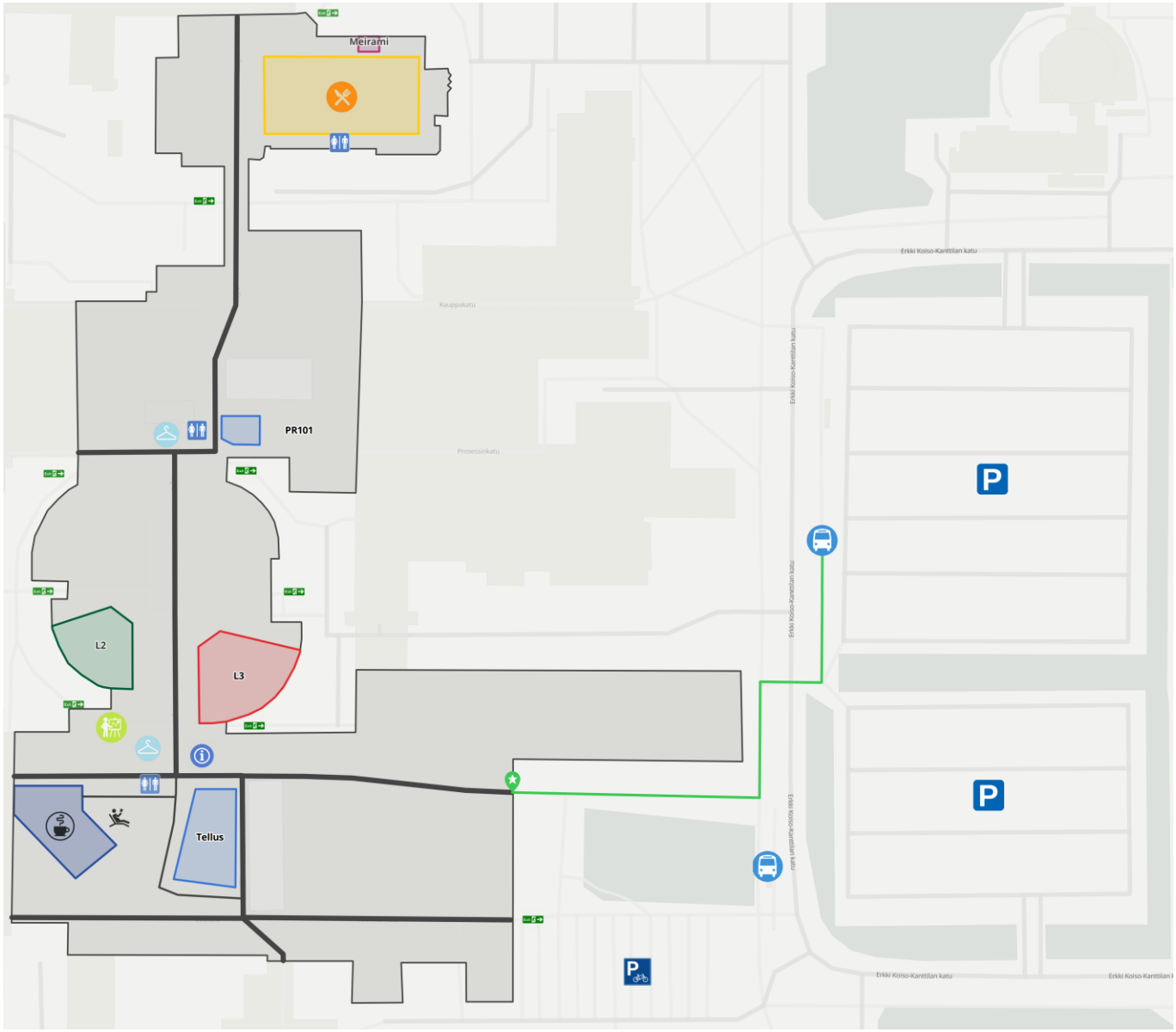


Specific map of the conference venue

Click here for an interactive map



Complete campus map

Oulu guide

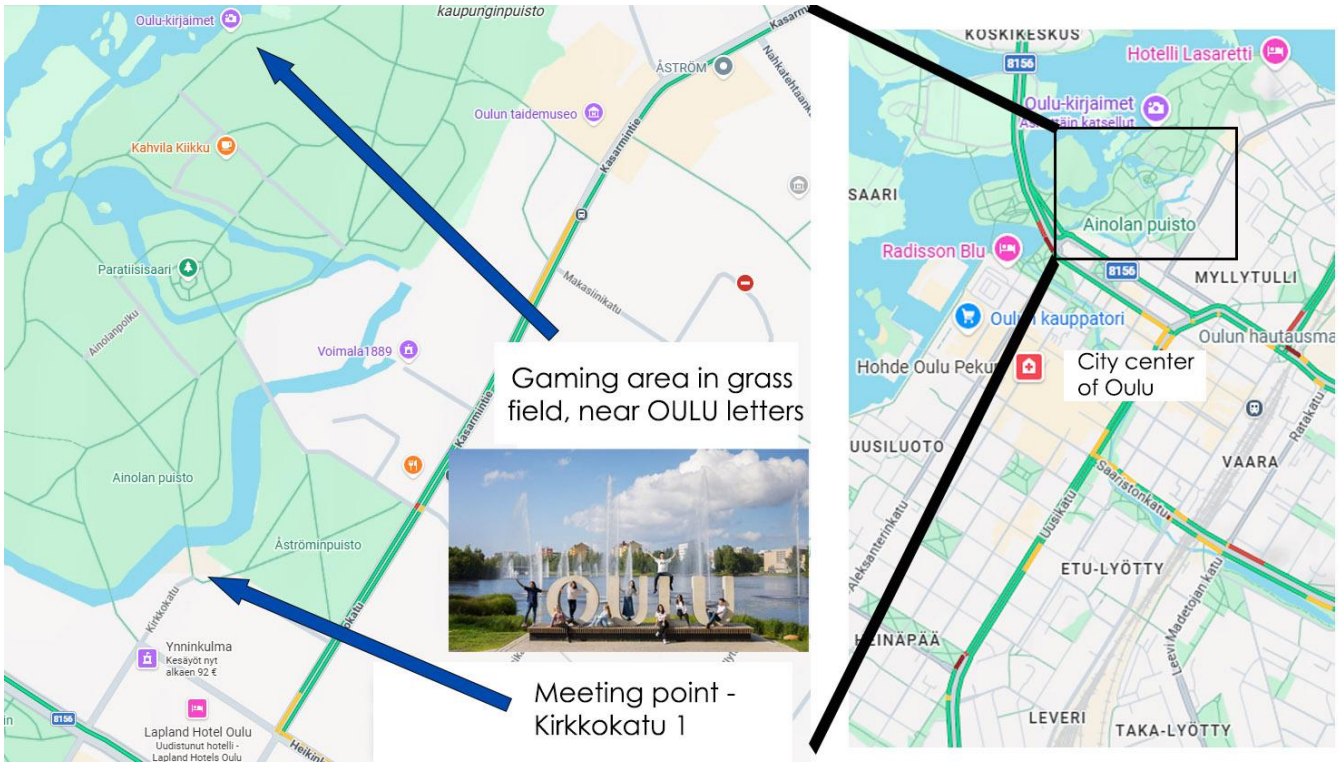
Conference venue map

Venue for the Summer Games

If you would like to attend the games, please meet at Kirkkokatu 1, 90100 Oulu at 18:00 on 8 June 2026.

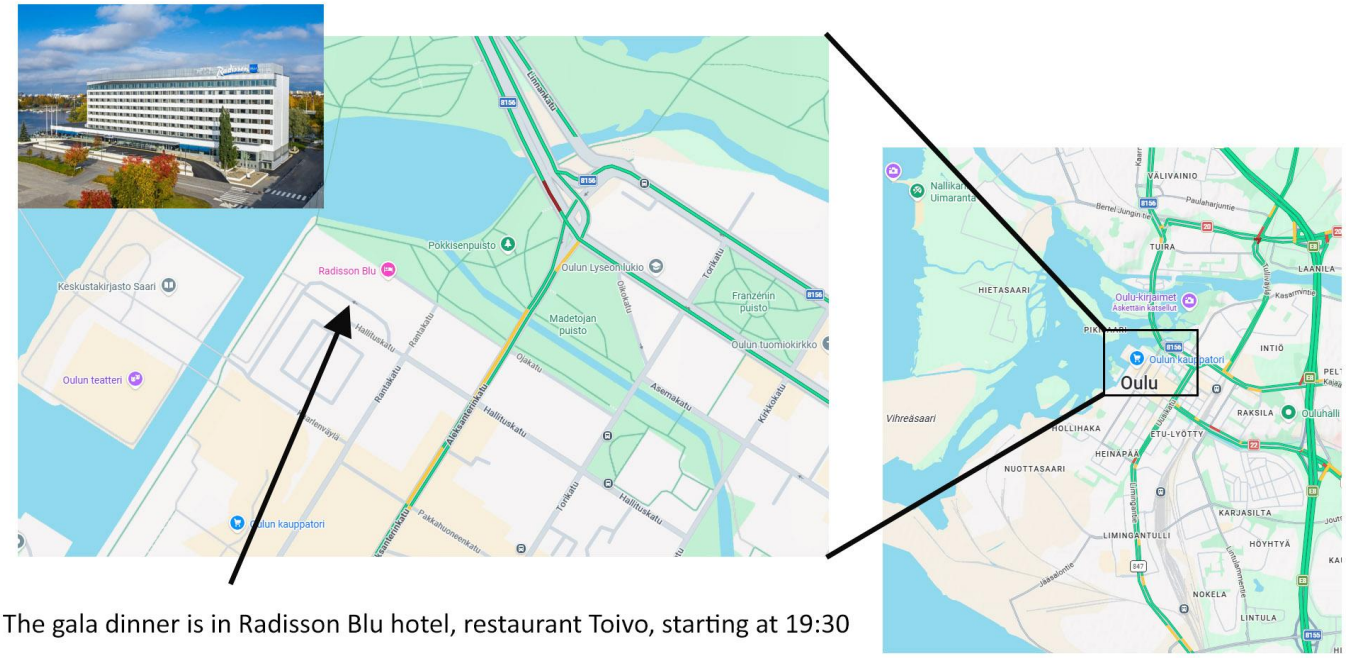
You may also come straight to the gaming area (see map below).

For a raining day, please meet at the conference registration desk.



Venue for the Conference Dinner

The conference dinner starts at 19:30 on 9 June 2026 in Restaurant Toivo, Radisson Blu Hotel, Hallituskatu 1, 90100 Oulu. Please see a map indicating the location below.



The gala dinner is in Radisson Blu hotel, restaurant Toivo, starting at 19:30

Programme overview

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Registration desk opens (near L3)</td></tr>
<tr><td colspan="3">8:30–9:10
Plenary sessions (L3)</td></tr>
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<tr><td colspan="3">Parallel sessions (L2/Tellus Stage/PR101),
including coffee break (Tellus Backstage)</td></tr>
<tr><td rowspan="2">13:00
Registration desk opens (near L3)</td><td rowspan="2">12:00–13:30
Lunch (Hilla Garden)
Registration desk temporarily closes and reopens at 13:30</td><td>12:00–13:30
ECAPD IAB meeting
(By invitation only)
(Garden Meirami)</td><td rowspan="2">12:00–13:30
Lunch
(Hilla Garden)
Registration desk closes</td></tr>
<tr><td rowspan="2">13:30–15:30
Tutorials (L2)</td><td rowspan="2">13:30–16:50
Parallel sessions (L2/Tellus Stage/PR101),
including coffee break (Tellus Backstage)</td><td>13:30–16:10</td></tr>
<tr><td>13:30
End of ECAPD 2026</td></tr>
<tr><td>15:30–16:30
Networking session with refreshments (near L2)</td><td>16:10–16:30
Poster flash presentations
(Tellus Stage)</td><td rowspan="4"></td></tr>
<tr><td>16:30
End of Day1
Registration desk closes</td><td>16:50
Group photo session (gather at registration desk);
End of scientific programme of Day 2
Registration desk closes</td><td>16:30–18:00
Poster session
(lobby near L2)</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">18:00–21:00
Summer games
(Ainolan puisto; Meeting point: Kirkkokatu 1, 90100 Oulu)
Backup place for a raining day: Meeting at the registration desk)</td><td>18:00
End of scientific programme of Day 3
Registration desk closes</td></tr>
<tr><td>19:30–22:00
Conference dinner and award gala
(Restaurant Toivo, Radisson Blue Hotel)</td></tr>
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Sunday 7 June</th><th>Day 2
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Programme overview – Day 1 Sunday 7th June 2026

Time	Activity
13:00	Registration desk opens (lobby near L3) Posters may be put up between 13:00–13:30
13:30– 14:30	Tutorial 1 (T-1-1, Emma McCabe, Durham University, UK) **Breaking inversion symmetry: strategies and consequences** Venue: L2 Chair: Heli Jantunen
14:30– 15:30	Tutorial 2 (T-2-2, Paula Huth, PI Ceramic, Germany) **Piezoelectric materials in practice: Principles, mechanisms, and application case studies** Venue: L2 Chair: Jani Peräntie
15:30– 16:30	Networking Refreshments will be served Posters may be put up between 15:30–16:30
16:30	Registration desk closes

Programme overview – Day 2 Monday 8th June 2026 – Morning

Time	Parallel Session 1	Parallel Session 2	Parallel Session 3
8:00	Registration desk opens (lobby near L3) Posters may be put up between 8:00–8:30 **Note**: If you are competing for the best poster awards, please make sure to put up your poster by this time the latest. Also make sure to stay with your posters during the coffee breaks at 10:10–10:40 and 15:00–15:30, during which the judges will come to evaluate your poster.		
8:30–9:10	Plenary talk 1 (PL-1-3, Hiroko Yokota, Institute of Science Tokyo, Japan) **Domain boundaries as polar objects: Symmetry breaking beyond the bulk** Venue: L3 Chair: Emma McCabe		
9:20–10:10	1-A: **Ferroelectrics; Fundamentals, theories, modelling, or machine learning/AI-based methodologies** Venue: L2 Chair: Subhajit Pal -Invited talk (P1-1-4, Guillaume Nataf) -Talk (P1-2-5, Olha Mazur)	2-A: **Piezoelectrics; Material design, fabrication, or processing** Venue: Tellus Stage Chair: Yonatan Calahorra -Invited talk (P2-1-6, Giovanna Canu) -Talk (P3-2-7, Sivagnana Sundaram Anandakrishnan)	3-A: **Electrocalorics & Pyroelectrics; Material design, fabrication, or processing** Venue: PR101 Chair: Ajeet Kumar -Invited talk (P3-1-8, Youri Nouchokgwe) -Talk (P3-2-9, Narayan Bastola)
10:10–10:40	Coffee/tea break Venue: Tellus Backstage Posters may be put up between 10:10–10:40 The judges evaluate the posters for the best poster awards		
10:40–12:00	1-B: **Ferroelectrics & Non-centrosymmetric materials; Fundamentals, theories, modelling, or machine learning/AI-based methodologies** Venue: L2 Chair: Hiroko Yokota -Talk (P1-3-10, Aldo Raeliarijaona) -Talk (P1-4-11, Brice Gautier) -Talk (P1-5-12, Rasool Akhtar Alias Osama) -Talk (P1-6-13, Sindre Mjøen Svendsen)	2-B: **Functional ceramics; Material design, fabrication, or processing** Venue: Tellus Stage Chair: Paula Huth -Talk (P2-3-14, Aurélie Lalagüe-Dardant) -Talk (P2-4-15, Catherine Elissalde) -Talk (P2-5-16, Elisa Mercadelli) -Talk (P2-6-17, Vladimir Shvartsman)	3-B: **Pyroelectrics & Piezoelectrics; Characterization and application of materials, devices, or systems** Venue: PR101 Chair: Wafa Amdouni -Talk (P3-3-18, Fan Ni) -Talk (P3-4-19, Kriti Batra) -Talk (P3-5-20, Ajeet Kumar) -Talk (P3-6-21, Ashwath Aravindhan)
12:00–13:30	Lunch Hilla Garden Registration desk temporarily closes and reopens at 13:30		

Programme overview – Day 2 Monday 8th June 2026 – Afternoon

Time	Parallel Session 1	Parallel Session 2	Parallel Session 3
13:30–15:00	1-C: **Ferroelectrics; Characterization and application of materials, devices, or systems** Venue: L2 Chair: Guillaume Nataf -Group invited talk (P1-7-22, Martina Müller, Oliver Rehm, Ella Dieball) -Talk (P1-8-23, Andra-Georgia Boni) -Invited talk (P1-9-24, Subhajit Pal)	2-C: **Antiferroelectrics & Other polar dielectrics; Material design, fabrication, or processing** Venue: Tellus Stage Chair: Giovanna Canu -Talk (P2-7-25, Mark Rambaran) -Talk (P2-8-26, Aadil Abass Shah) -Talk (P2-9-27, Benoit Guiffard) -Invited talk (P2-10-28, Abdullah Jabr)	3-C: **Multiferroics** Venue: PR101 Chair: Eric Langenberg -Talk (P3-7-29, María Paulina Morales-Ramírez) -Talk (P3-8-30, Houssny Bouyanfif) -Invited talk (P3-9-31, Joydipto Bhattacharya)
15:00–15:30	Coffee/tea break Venue: Tellus Backstage Posters may be put up between 15:00–15:30 The judges evaluate the posters for the best poster awards		
15:30–16:50	1-D: **Ferroelectrics & Hafnia-based thin films; Characterization and application of materials, devices, or systems** Venue: L2 Chair: Laurent Grenouillet -Talk (P1-10-33, Peter Reinig) -Talk (P1-11-34, César Magén) -Talk (P1-12-35, Stavros Kitsios) -Talk (P1-13-36, Paul Schwermer)	2-D: **Antiferroelectrics** Venue: Tellus Stage Chair: Aadil Abass Shah -Talk (P2-11-37, Nikola Novak) -Talk (P2-12-38, Elena Buixaderas) -Talk (P2-13-39, Lixu Xie) -Talk (P2-14-40, Sreelakshmi Prasanna)	
16:50	Group photo session (gather near the registration desk) End of scientific programme of Day 2 Registration desk closes		
18:00–21:00	Summer games Ainolan puisto (Ainola park); Meeting point: Kirkkokatu 1, 90100 Oulu Backup place for a raining day: Meeting at the registration desk		

Programme overview – Day 3 Tuesday 9th June 2026 – Morning

Time	Parallel Session 1	Parallel Session 2	Parallel Session 3
8:00	Registration desk opens (lobby near L3) Posters may be put up between 8:00–8:30		
8:30–9:10	Plenary talk 2 (PL-2-45, Laurent Grenouillet, CEA-Leti, France) **Ferroelectric $Hf_xZr_{1-x}O_2$ (HZO) as a game changer for ferroelectric random-access memories (FeRAM)** Venue: L3 Chair: Alfredo Blázquez Martínez		
9:20–10:20	1-E: **Lead-free piezoelectrics; Material design, fabrication, or processing** Venue: L2 Chair: Catherine Elissalde -Talk (P1-14-46, Jade Clement) -Talk (P1-15-47, Anna Paulik) -Talk (P1-16-48, Hareem Zubairi)	2-E: **Sponsor tutorial session (aixACCT)** Venue: Tellus Stage Chair: Jani Peräntie -Sponsor tutorial (P2-15-49, Roland Kessels)	3-E: **Device design or manufacturing** Venue: PR101 Chair: Juliette Cardoletti -Talk (P3-15-51, Torsten Granzow) -Talk (P3-16-52, Padraig Doyle) -Talk (P3-17-53, Mayara Cardozo dos Santos)
10:20–10:50	Coffee/tea break Venue: Tellus Backstage Posters may be put up between 10:20–10:50		
10:50–12:00	1-F: M**embranes & thin films; Material design, fabrication, or processing** Venue: L2 Chair: Pietro Galizia -Invited talk (P1-17-54, Greta Segantini) -Talk (P1-18-55, Ming Liu) -Talk (P1-19-56, María Paulina Morales-Ramírez)	2-F: **Polar dielectric catalysis** Venue: Tellus Stage Chair: Mark Rambaran -Invited talk (P2-17-57, Wafa Amdouni) -Talk (P2-18-58, Sangeeta Mahala) -Talk (P2-19-59, Lalit Kumar Jena)	
12:00–13:30	Lunch Hilla Garden Registration desk temporarily closes and reopens at 13:30 ECAPD International Advisory Board Meeting (by invitation only) Garden Meirami		

Programme overview – Day 3 Tuesday 9th June 2026 – Afternoon

Time	Parallel Session 1	Parallel Session 2	Parallel Session 3
13:30–14:50	1-G: **Functional ceramics** Venue: L2 Chair: Jani Peräntie -Talk (P1-20-63, Udo Eckstein) -Talk (P1-21-64, Lavinia-Petronela Curecheriu) -Talk (P1-22-65, Hicham Ait Laasri) -Talk (P1-23-66, Vijaya Bhasker)	2-G: **Ferroelectrics; Fundamental and characterization of local structures** Venue: Tellus Stage Chair: Stanislav Kamba -Talk (P2-20-67, César Magén) -Talk (P2-21-68, Olivia Baxter) -Talk (P2-22-69, Ruben Dragland) -Talk (P2-23-70, Himal Wijekoon)	3-G: **Ferroelectrics & Low-power nanoelectronics** Venue: PR101 Chair: Svitlana Kondovych -Group invited talk (P3-21-71, Jiri Hlinka, Mauro Goncalves, Vilgelmina Stepkova) -Talk (P3-22-72, Lynette Keeney) -Talk (P3-23-73, Niklas Wolff)
14:50–15:20	Coffee/tea break Venue: Tellus Backstage **All posters must be put up by this time**		
15:20–16:30	1-H: **Ferroelectrics; Material design, fabrication, or processing & Characterization and application of materials, devices, or systems** Venue: L2 Chair: Abdullah Jabr -Invited talk (P1-24-74, Sylvia Gebhardt) -Invited talk (P1-25-75, Lisa Legardinier)	2-H: **Magnetoelectrics & Antiferroelectrics** Venue: Tellus Stage Chair: Ilya Grinberg -Invited talk (P2-24-77, Yonatan Calahorra) -Talk (P2-25-78, Intissar Driouech) -Flash poster presentations (P2-26-79(1), Tetyana Ostapchuk; P2-26-79(2), Houssny Bouyanfif)	
16:30–18:00	Poster session Lobby the registration desk		
18:00	End of scientific programme of Day 3 Registration desk closes		
19:30–22:00	Conference dinner & award gala Restaurant Toivo, Radisson Blu Hotel, Hallituskatu 1, 90100 Oulu		

Programme overview – Day 4 Wednesday 10th June 2026 – Morning

Time	Parallel Session 1	Parallel Session 2	Parallel Session 3
8:00	Registration desk opens (lobby near L3)		
8:30–9:10	Plenary talk 3 (PL-3-83, Ilya Grinberg, Bar Ilan University, Israel) **Theoretical studies of composition-structure-property relationships of piezoelectric oxide ceramics: Separating and understanding the intrinsic and extrinsic effects** Venue: L3 Chair: Yang Bai		
9:20–10:30	1-I: **Ferroelectrics & Multiferroics; Fundamentals & Characterization and application of materials, devices, or systems** Venue: L2 Chair: Lynette Keeney -Invited talk (P1-27-84, Svitlana Kondovych) -Talk (P1-28-85, Eric Langenberg) -Talk (P1-29-86, Stanislav Kamba)	2-I: **Membranes & Thin films; Characterization and application of materials, devices, or systems** Venue: Tellus Stage Chair: Youri Nouchokgwe -Invited talk (P2-27-87, Juliette Cardoletti) -Talk (P2-28-88, Pietro Galizia) -Talk (P2-29-89, Oliver Rehm)	3-I: **Ferroelectric and multiferroic thin films; Material design, fabrication, or processing** Venue: PR101 Chair: Peter Reinig -Invited talk (P3-27-90, Alfredo Blázquez Martínez) -Talk (P3-28-91, Yesim Demirolmez) -Talk (P3-29-92, Luminita Mirela Hrib)
10:30–11:00	Coffee/tea break Venue: Tellus Backstage Registration desk closes		
11:00–12:00		2-J: **Lead-free ferroelectrics and non-centrosymmetric materials** Venue: Tellus Stage Chair: Greta Segantini -Talk (P2-30-97, Janina Roknic) -Talk (P2-31-98, Shuaib Bolaji Issa) -Talk (P2-32-99, Théo Nogueira)	
12:00–13:30	Lunch Hilla Garden		
13:30	End of ECAPD 2026 **All posters must be removed by this time**		

Detailed programme – Sunday 7th June 2026 (Day 1)

13:00 **Registration desk opens** (until 16:30)
Lobby area near lecture room L3
Posters may be put up between 13:00–13:30

13:30–15:30 **Tutorial session** (lecture room L2)

13:30–14:30 Tutorial 1 [*T-1-1*] (Chair: Heli Jantunen)
Breaking inversion symmetry: strategies and consequences
Dr. Emma McCabe, Durham University, UK

14:30–15:30 Tutorial 2 [*T-2-2*] (Chair: Jani Peräntie)
Piezoelectric materials in practice: Principles, mechanisms, and application case studies
Dr. Paula Huth, PI Ceramic, Germany

15:30–16:30 **Networking session**
Lobby area near L2
Refreshments will be served during the session

16:30 Registration desk closes
Day 1 ends

Detailed programme – Monday 8th June 2026 (Day 2)

8:00 **Registration desk opens** (until 16:50)
Lobby area near lecture room L3
Posters may be put up between 8:00–8:30

8:30–9:10 **Plenary talk 1** [*PL-1-3*] (Chair: Emma McCabe)
Lecture room L3
Domain boundaries as polar objects: Symmetry breaking beyond the bulk
Prof. Hiroko Yokota, Institute of Science Tokyo, Japan

9:20–10:10 **Parallel session 1-A** (Chair: Subhajit Pal)
Lecture room L2
Theme: Ferroelectrics; Fundamentals, theories, modelling, or machine learning/AI-based methodologies

9:20–9:50 Invited talk [*P1-1-4*]
Evolution of thermal conductivity under electric field in barium titanate single crystals and ceramics
Dr. Guillaume Nataf, University of Tours, France

9:50–10:10 Talk [*P1-2-5*]
Domain formation in uniaxial ferroelectrics: Stochastic versus phase-field modeling
Dr. Olha Mazur, Technical University of Darmstadt, Germany

9:20–10:10 **Parallel session 2-A** (Chair: Yonatan Calahorra)
Tellus Stage
Theme: Piezoelectrics; Material design, fabrication, or processing

9:20–9:50 Invited talk [*P2-1-6*]
Design of functional polymer matrix composites: Effect of processing and microstructure
Dr. Giovanna Canu, National Research Council of Italy – Institute of Condensed Matter Chemistry and Technologies for Energy (CNR-ICMATE), Italy

9:50–10:10 Talk [*P2-2-7*]
Recycled piezoelectric materials with competitive second-life functional properties
Dr. Sivagnana Sundaram Anandakrishnan, University of Oulu, Finland

9:20–10:10 **Parallel session 3-A** (Chair: Ajeet Kumar)

Lecture room PR101

Theme: Electrocalorics & Pyroelectrics; Material design, fabrication, or processing

9:20–9:50 Invited talk [*P3-1-8*]

Towards sub-ambient solid-state cooling with electrocaloric materials

Dr. Youri Nouchokgwe, Luxembourg Institute of Science and Technology (LIST), Luxembourg

9:50–10:10 Talk [*P3-2-9*]

High thermal current and figure of merit in diamond-filled porous pyroelectric ceramics through improved thermal diffusivity

Dr. Narayan Bastola, University of Bath, UK

10:10–10:40 **Coffee/tea break**

Tellus Backstage

Posters may be put up during the break

10:40–12:00 **Parallel session 1-B** (Chair: Hiroko Yokota)

Lecture room L2

Theme: Ferroelectrics & Non-centrosymmetric materials; Fundamentals, theories, modelling, or machine learning/AI-based methodologies

10:40–11:00 Talk [*P1-3-10*]

Unraveling the impact of different dopants on ferroelectric polarization rotation through first-principles and atomistic simulations

Dr. Aldo Raeliarijaona, Ruhr-University Bochum, Germany

11:00–11:20 Talk [*P1-4-11*]

Reinforcement learning-assisted automated ferroelectric domain wall controls

Prof. Brice Gautier, Lyon Institute of Nanotechnologies (INL), France

11:20–11:40 Talk [*P1-5-12*]

Atomic-scale engineering of ZnO via Mn, V, and Y doping: A combined electronic and vibrational study

Rasool Akhtar Alias Osama, The University of Edinburgh, UK

11:40–12:00 Talk [*P1-6-13*]

Symmetry influence on functional properties of H-DABCO based ferroelectric ionic plastic crystals

Sindre Mjøen Svendsen, Norwegian University of Science and Technology, Norway

10:40–12:00 **Parallel session 2-B** (Chair: Paula Huth)

Tellus Stage

Theme: Functional ceramics; Material design, fabrication, or processing

10:40–11:00 Talk [*P2-3-14*]

Effects of Spark Plasma Sintering on the microstructure and properties of $Na_{0.5}Bi_{0.5}TiO_3$–$xBaTiO_3$ piezoceramics

Aurélie Lalagüe-Dardant, Université de Tours, France

11:00–11:20 Talk [*P2-4-15*]

Unlocking low-temperature routes for lead-free piezoelectrics: Toward sustainable and flexible energy harvesting

Dr. Catherine Elissalde, ICMCB-CNRS, France

11:20–11:40 Talk [*P2-5-16*]

Critical factors in the freeze casting of porous BCTZ ceramics

Dr. Elisa Mercadelli, CNR-ISSMC, Italy

11:40–12:00 Talk [*P2-6-17*]

Tailoring of the dielectric energy storage performance of $BaTiO_3$ based relaxor ferroelectrics

Dr. Vladimir Shvartsman, Universität Duisburg-Essen, Germany

10:40–12:00 **Parallel session 3-B** (Chair: Wafa Amdouni)

Lecture room PR101

Theme: Pyroelectrics & Piezoelectrics; Characterization and application of materials, devices, or systems

10:40–11:00 Talk [*P3-3-18*]

Barium strontium titanate multilayer capacitors for high-performance waste-heat harvesting

Fan Ni, Luxembourg Institute of Science and Technology, Luxembourg

11:00–11:20 Talk [*P3-4-19*]

Electromechanical hardening of piezoelectrics induced by DC bias fields

Dr. Kriti Batra, Institute for Chemistry and Technology of Materials, Graz University of Technology, Austria

11:20–11:40 Talk [*P3-5-20*]

Lead-free porous freeze-casted $BaTiO_3$ platelet spheres for piezocatalysis applications

Dr. Ajeet Kumar, University of Bath, UK

11:40-12:00 Talk [*P3-6-21*]

Self-powered pyroelectric energy harvester based on lead scandium tantalate multilayer capacitors

Dr. Ashwath Aravindhan, Luxembourg Institute of Science and Technology, Luxembourg

12:00–13:30 **Lunch**

Hilla Garden

13:30–15:00 **Parallel session 1-C** (Chair: Guillaume Nataf)

Lecture room L2

Theme: Ferroelectrics; Characterization and application of materials, devices, or systems

13:30–14:10 Group invited talk [*P1-7-22*]

Unraveling microstructural and chemical evolution in pristine and fatigued ferroelectric AlScN thin films by synchrotron X-ray techniques

Prof. Martina Müller (**PI**), Oliver Rehm (**team member**), University of Konstanz, Germany; Ella Dieball (**team member**), Kiel University, Germany

14:10–14:30 Talk [*P1-8-23*]

Sequential switching and polarization-programmed electroresistance in HZO based ferroelectric–insulator–ferroelectric thin films

Dr. Andra-Georgia Boni, National Institute of Materials Physics, Romania

14:30–15:00 Invited talk [*P1-9-24*]

Photo-induced properties in ferroelectric oxides: From fundamentals to applications

Dr. Subhajit Pal, Queen Mary University of London, UK

13:30–15:00 **Parallel session 2-C** (Chair: Giovanna Canu)

Tellus Stage

Theme: Antiferroelectrics & Other polar dielectrics; Material design, fabrication, or processing

13:30–13:50 Talk [*P2-7-25*]

Selective synthesis of Cesium Niobate ($Cs_2Nb_4O_{11}$) and benefits for antiferroelectric and electrocatalytic applications

Dr. Mark Rambaran, Lund University, Sweden

13:50–14:10 Talk [*P2-8-26*]

Stabilizing antiferroelectric phase in $NaNbO_3$-based ceramics via dopant design

Dr. Aadil Abass Shah, Jožef Stefan Institute, Slovenia

14:10–14:30 Talk [*P2-9-27*]

Flexoelectricity in soft polymer films with tunable conductivity

Prof. Benoit Guiffard, CNRS IETR, France

14:30–15:00 Invited talk [*P2-10-28*]

Towards reliable dielectrics via the cold sintering process

Dr. Abdullah Jabr, Montanuniversitaet Leoben, Austria

13:30–14:40 **Parallel session 3-C** (Chair: Eric Langenberg)

Lecture room PR101

Theme: Multiferroics

13:30–13:50 Talk [*P3-7-29*]

Epitaxial growth and multiferroic behaviour of pseudocubic perovskite $BaMnO_3$ thin films

María Paulina Morales-Ramírez, Instituto de Nanociencia y Materiales de Aragón (INMA), CSIC- Universidad de Zaragoza, Spain

13:50–14:10 Talk [*P3-8-30*]

Hybrid phonons in hexagonal manganites

Prof. Houssny Bouyanfif, LPMC, Université de Picardie Jules Verne, France

14:10-14:40 Invited talk [*P3-9-31*]

First principles investigations of cation site preference, magnetic coupling and electronic correlation in multiferroic aurivillius phase $Bi_5Ti_3MnO_{15}$

Dr. Joydipto Bhattacharya, Tyndall National Institute, Ireland

15:00–15:30 **Coffee/tea break**

Tellus Backstage

Posters may be put up during the break

15:30–16:50 **Parallel session 1-D** (Chair: Laurent Grenouillet)

Lecture room L2

Theme: Ferroelectrics & Hafnia-based thin films; Characterization and application of materials, devices, or systems

15:30–15:50 Talk [*P1-10-33*]

Ion irradiation effects on ferroelectric properties of hafnia-based oxides

Dr. Peter Reinig, Fraunhofer IPMS, Germany

15:50–16:10 Talk [*P1-11-34*]

Substrate-orientation dependence of epitaxial stabilization of the orthorhombic phase in electrode-free $Hf_{1-x}Zr_xO_2$ thin films

Dr. César Magén, Instituto de Nanociencia y Materiales de Aragón (INMA), Spain

16:10–16:30 Talk [*P1-12-35*]

HZO-based ferroelectric devices for memory and neuromorphic applications

Dr. Stavros Kitsios, National Center for Scientific Research "DEMOKRITOS", Greece

16:30–16:50 Talk [*P1-13-36*]

Influence of Hf content on the ferroelectric properties of HZO and investigation of out-of-plane polarization

Paul Schwermer, NaMLab gGmbH, Germany

15:30–16:50 **Parallel session 2-D** (Chair: Aadil Abass Shah)

Tellus Stage

Theme: Antiferroelectrics

15:30–15:50 Talk [*P2-11-37*]

Enhanced dielectric tunability in antiferroelectric PNZST ceramics

Dr. Nikola Novak, Jožef Stefan Institute, Slovenia

15:50–16:10 Talk [*P2-12-38*]

Phonons in $NaNbO_3$-based antiferroelectric ceramics

Dr. Elena Buixaderas, Institute of Physics of the Czech Academy of Sciences, Czechia

16:10–16:30 Talk [*P2-13-39*]

Mechanistic insights into stress-induced antiferroelectric-ferroelectric phase transitions in polycrystalline $NaNbO_3$ ceramics

Lixu Xie, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany

16:30–16:50 Talk [*P2-14-40*]

Enhancing the antiferroelectric response of $AgNbO_3$ thin films

Sreelakshmi Prasanna, TU Darmstadt, Germany

16:50 **Group photo session**

Please gather near the registration desk

Registration desk closes

18:00–21:00 **Summer games**

Please meet at 18:00 at the entrance of Ainolan puisto (Ainola park)

Address: Kirkkokatu 1, 90100 Oulu

If it is raining, meet at the registration desk

Detailed programme – Tuesday 9th June 2026 (Day 3)

8:00 **Registration desk opens** (until 18:00)
Lobby area near lecture room L3
Posters may be put up between 8:00–8:30

8:30–9:10 **Plenary talk 2** [*PL-2-45*] (Chair: Alfredo Blázquez Martínez)
Lecture room L3
Ferroelectric $Hf_xZr_{1-x}O_2$ (HZO) as a game changer for ferroelectric random-access memories (FeRAM)
Dr. Laurent Grenouillet, CEA-Leti, France

9:20–10:20 **Parallel session 1-E** (Chair: Catherine Elissalde)
Lecture room L2
Theme: Lead-free piezoelectrics; Material design, fabrication, or processing

9:20–9:40 Talk [*P1-14-46*]
Lead-free KNN-based piezoelectric ceramics: Design and mechanical characterization
Jade Clement, GREMAN, France

9:40–10:00 Talk [*P1-15-47*]
Ferroelectric hardening of lead-free $(Ba,Ca)(Zr,Ti)O_3$ piezoceramics through acceptor-doping
Anna Paulik, Graz University of Technology, Austria

10:00–10:20 Talk [*P1-16-48*]
Engineering dynamics through field-induced transformations in lead-free NBT piezoelectric ceramics
Hareem Zubairi, The University of Manchester, UK

9:20–9:50 **Parallel session 2-E** (Chair: Jani Peräntie)

Tellus Stage

Theme: Sponsor tutorial session

9:20–9:50 Sponsor tutorial [*P2-15-49*]

From ferroelectric loops to reliable material data: Practical characterization of piezoelectric and ferroelectric materials – Best practices, common pitfalls, and application-driven measurement strategies from high-field testing to force-dependent electromechanical response

Roland Kessels, aixACCT, Germany

9:20–10:20 **Parallel session 3-E** (Chair: Juliette Cardoletti)

Lecture room PR101

Theme: Device design or manufacturing

9:20–9:40 Talk [*P3-15-51*]

Thin films, bulk and multilayer systems – Effects of geometry on ferroelectric material performance in different applications

Dr. Torsten Granzow, Luxembourg Institute of Science and Technology, Luxembourg

9:40–10:00 Talk [*P3-16-52*]

Design of flexible multilayer PVDF piezoelectric actuators

Padraig Doyle, University of Limerick, Ireland

10:00–10:20 Talk [*P3-17-53*]

Enhancing power output of a polymer-based piezoelectric energy harvester using nonlinear technique

Mayara Cardozo dos Santos, Luxembourg Institute of Science and Technology (LIST), Luxembourg

10:20–10:50 **Coffee/tea break**

Tellus Backstage

Posters may be put up during the break

10:50–12:00 **Parallel session 1-F** (Chair: Pietro Galizia)

Lecture room L2

Theme: Membranes & thin films; Material design, fabrication, or processing

10:50–11:20 Invited talk [*P1-17-54*]

Curvature-controlled polarization in adaptive ferroelectric membranes

Dr. Greta Segantini, University of Geneva, Switzerland

11:20–11:40 Talk [*P1-18-55*]

Free-standing ferroelectric single crystal membranes with super-elasticity

Prof. Ming Liu, Xi'an Jiaotong University, China

11:40–12:00 Talk [*P1-19-56*]

Novel bottom electrodes for epitaxial hafnia-based ferroelectric thin films

María Paulina Morales-Ramírez, Instituto de Nanociencia y Materiales de Aragón (INMA), CSIC-Universidad de Zaragoza, Spain

10:50–12:00 **Parallel session 2-F** (Chair: Mark Rambaran)

Tellus Stage

Theme: Polar dielectric catalysis

10:50–11:20 Invited talk [*P2-17-57*]

Achieving superior piezocatalysts: An innovative materials strategy

Dr. Wafa Amdouni, Université Paris-Saclay, CentraleSupélec, France

11:20–11:40 Talk [*P2-18-58*]

Tailoring $Ba_{1-x}Sr_xTiO_3$ for pyro catalysis through control of composition and particle morphology

Dr. Sangeeta Mahala, Luxembourg Institute of Scientist & Technology, Luxembourg

11:40–12:00 Talk [*P2-19-59*]

Unveiling the microstructural connection to the dielectric relaxation, conduction, photocatalytic, and energy harvesting properties in Ca-modified $Ba_{0.8}Sr_{0.2}TiO_3$ ferroelectrics

Lalit Kumar Jena, Indian Institute of Technology, Hyderabad, India

12:00–13:30 **Lunch**

Hilla Garden

13:30–14:50 **Parallel session 1-G** (Chair: Jani Peräntie)

Lecture room L2

Theme: Functional ceramics

13:30–13:50 Talk [*P1-20-63*]

Using accelerated ceramic synthesis to investigate the influence of starting materials on the energy storage properties of high-entropy oxide materials

Dr. Udo Eckstein, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

13:50–14:10 Talk [*P1-21-64*]

Using the core-shell approach to tailor DC-tunability in functional grade ceramics

Dr. Lavinia-Petronela Curecheriu, Alexandru Ioan Cuza University, Romania

14:10–14:30 Talk [*P1-22-65*]

Design of high-entropy lead-free $Bi_{0.5}Na_{0.5}TiO_3$-based relaxor ceramics for next-generation energy storage capacitors

Dr./Associate Prof. Hicham Ait Laasri, GREMAN UMR7347, CNRS, University of Tours, INSA Centre Val de Loire, France

14:30–14:50 Talk [*P1-23-66*]

Thermal conductivity switches based on $Ba_{0.85}Ca_{0.15}Zr_xTi_{1-x}O_3$ and $Sr_xBa_{1-x}Nb_2O_6$ ceramics

Vijaya Bhasker, GREMAN laboratory, CNRS, France

13:30–14:50 **Parallel session 2-G** (Chair: Stanislav Kamba)

Tellus Stage

Theme: Ferroelectrics; Fundamental and characterization of local structures

13:30–13:50 Talk [*P2-20-67*]

Microscopic origin of conductivity in 180° domain walls in PZT thin films studied by atomic-resolution electron microscopy

Dr. César Magén, Instituto de Nanociencia y Materiales de Aragón (INMA), Spain

13:50–14:10 Talk [*P2-21-68*]

Domain microstructures in improper ferroelectric hexagonal tungsten bronzes via piezo-response force microscopy

Dr. Olivia Baxter, University of St Andrews, UK

14:10–14:30 Talk [*P2-22-69*]

Local electronic reconstruction in a ferroelectric p-type semiconductor studied by correlated scanning probe microscopy

Ruben Dragland, Norwegian University of Science and Technology, Norway

14:30-14:50 Talk [*P2-23-70*]

Impact of edge dislocations on ferroelectric switching - an atomistic study on barium titanate

Himal Wijekoon, Interdisciplinary Centre for Advanced Materials Simulation (ICAMS), Ruhr Universität Bochum, Germany

13:30–14:50 **Parallel session 3-G** (Chair: Svitlana Kondovych)

Lecture room PR101

Theme: Ferroelectrics & Low-power nanoelectronics

13:30–14:10 Group invited talk [*P3-21-71*]

Hunting for skyrmions in polar oxides

Dr. Jiri Hlinka (**PI**), Dr. Mauro Goncalves (**team member**), Dr. Vilgelmina Stepkova (**team member**), FZU – Institute of Physics, Czech Acad. Sci., Czechia

14:10–14:30 Talk [*P3-22-72*]

Suppressing crystal twinning in $Bi_4Ti_3O_{12}$ via supersaturation control

Dr. Lynette Keeney, Tyndall National Institute, University College Cork, Ireland

14:30–14:50 Talk [*P3-23-73*]

How material understanding can unlimit future applications – Advanced structure characterization of AlN-based ferroelectrics

Dr. Niklas Wolff, Kiel University, Germany

14:50–15:20 **Coffee/tea break**

Tellus Backstage

Posters may be put up during the break

15:20–16:20 **Parallel session 1-H** (Chair: Abdullah Jabr)

Lecture room L2

Theme: Ferroelectrics; Material design, fabrication, or processing & Characterization and application of materials, devices, or systems

15:20–15:50 Invited talk [*P1-24-74*]

Development of PTCR materials and components for high-voltage heating systems in E-mobility

Dr. Sylvia Gebhardt, Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Germany

15:50–16:20 Invited talk [*P1-25-75*]

Towards an industrial lead-free ferroelectric KNN thin film for piezoelectric MEMS actuators

Dr. Lisa Legardinier, CEA-Leti, France

15:20–16:30 **Parallel session 2-H** (Chair: Ilya Grinberg)

Tellus Stage

Theme: Magnetoelectrics & Antiferroelectrics

15:20–15:50 Invited talk [*P2-24-77*]

Magnetoelectric composites operating in higher bending modes

Assistant Prof. Yonatan Calahorra, Technion – IIT, Israel

15:50–16:10 Talk [*P2-25-78*]

Structural insights into phosphate langbeinites: Foundations for future polar dielectric and magnetoelectric studies

Intissar Driouech, Univ. Bordeaux, CNRS, ICMCB, UMR 5026, France & Mohammed V University in Rabat, Morocco

16:10–16:30 Poster flash presentations

[*P2-26-79(1)*]

Broad-band dielectric spectroscopy of $NaNbO_3$-based antiferroelectric ceramics

Dr. Tetyana Ostapchuk, Institute of Physics, Academy of Sciences of the Czech Republic, Czech Republic

[*P2-26-79(2)*]

Anti-polar state and extra ordering in $BiFeO_3$ superlattices

Prof. Houssny Bouyanfif, LPMC, Université de Picardie Jules Verne, France

16:30–18:00 **Poster session**

Lobby near the registration desk

19:30–22:00 **Conference dinner & Award gala**

Restaurant Toivo, Radisson Blu Hotel, Hallituskatu 1, 90100 Oulu

Detailed programme – Wednesday 10th June 2026 (Day 4)

8:00 **Registration desk opens** (until 10:40)
Lobby area near lecture room L3

8:30–9:10 **Plenary talk 3** [*PL-3-83*] (Chair: Yang Bai)
Lecture room L3
Theoretical studies of composition-structure-property relationships of piezoelectric oxide ceramics: Separating and understanding the intrinsic and extrinsic effects
Prof. Ilya Grinberg, Bar-Ilan University, Israel

9:20–10:30 **Parallel session 1-I** (Chair: Lynette Keeney)
Lecture room L2
Theme: Ferroelectrics & Multiferroics; Fundamentals & Characterization and application of materials, devices, or systems

9:20–9:50 Invited talk [*P1-27-84*]
Critical properties of divergence-free ferroelectric materials
Dr. Svitlana Kondovych, Leibniz Institute for Solid State and Materials Research (IFW) Dresden, Germany

9:50–10:10 Talk [*P1-28-85*]
The coupling of ferroelectric polarization and oxygen vacancy migration enables electrically controlled thermal memories
Dr. Eric Langenberg, University of Barcelona, Spain

10:10–10:30 Talk [*P1-29-86*]
Frustrated antipolar correlations and magnetoelectric coupling in hexaaluminates
Prof. Stanislav Kamba, Institute of Physics of the Czech Academy of Sciences, Czech Republic

9:20–10:30 **Parallel session 2-I** (Chair: Youri Nouchokgwe)

Tellus Stage

Theme: Membranes & Thin films; Characterization and application of materials, devices, or systems

9:20–9:50 Invited talk [*P2-27-87*]

Polar oxide membranes: from tunable barium strontium titanate optical filters towards tunable lasers

Dr. Juliette Cardoletti, TU Darmstadt, Germany

9:50–10:10 Talk [*P2-28-88*]

Piezoelectric membranes for electrically assisted microfiltration based on lead-free BCTZ: Processing and structure-performance relationships

Dr. Pietro Galizia, CNR – ISSMC, Italy

10:10–10:30 Talk [*P2-29-89*]

Introducing true depth-sensitivity in HAXPES for chemistry analysis of ferroelectric devices: Experiment and simulation

Oliver Rehm, University of Konstanz, Germany

9:20–10:30 **Parallel session 3-I** (Chair: Peter Reinig)

Lecture room PR101

Theme: Ferroelectric and multiferroic thin films; Material design, fabrication, or processing

9:20–9:50 Invited talk [*P3-27-90*]

Ferroelectric switching in Mn-doped epitaxial $BaTiO_3$ films and $BaTiO_3/SrTiO_3$ superlattices integrated on silicon

Dr. Alfredo Blázquez Martínez, Helmholtz-Zentrum Berlin für Materialien und Energie, Germany

9:50–10:10 Talk [*P3-28-91*]

Structural and magnetic effects of magnetic-ion substitution in high-layer ($m \geqslant 5$) aurivillius-phase multiferroic thin films

Yesim Demirolmez, Tyndall National Institute, University College Cork, Ireland

10:10–10:30 Talk [*P3-29-92*]

Sc-doped AlN thin films: Electrical and ferroelectric properties

Dr. Luminita Mirela Hrib, National Institute of Materials Physics, Romania

10:30–11:00 **Coffee/tea break**

Tellus Backstage

11:00–12:00 **Parallel session 2-J** (Chair: Greta Segantini)

Tellus Stage

Theme: Lead-free ferroelectrics and non-centrosymmetric materials

11:00–11:20 Talk [*P2-30-97*]

Exploring the effects of Ti-doping in $(K_{0.5}Na_{0.5})NbO_3$ ceramics

Janina Roknic, Jozef Stefan Institute, Slovenia

11:20–11:40 Talk [*P2-31-98*]

Molecular-based ferroelectric plastic crystals for high-energy-density storage capacitors

Shuaib Bolaji Issa, Norwegian University of Science and Technology, Norway

11:40–12:00 Talk [*P2-32-99*]

Molten salt approach to stabilize alkaline earth titanate – sodium bismuth titanate perovskite

Théo Nogueira, ICMCB, Université de Bordeaux, France

12:00-13:30 **Lunch**

Hilla Garden

13:30 End of ECAPD 2026

All posters need to be removed by their presenters

ABSTRACTS – TUTORIALS

[*T-1-1*] Breaking inversion symmetry: strategies and consequences

Emma McCabe

Durham University, UK

Many properties of functional materials rely on structures with broken inversion symmetry (among other requirements). As we seek to design materials with more challenging combinations of properties (for example polar semiconductors for photovoltaic applications, or chiral magnetic systems for spintronics), it's useful to consider strategies we might use to design next generation functional materials. This talk explores some more traditional approaches and categories of materials before looking at strategies that allow us to use a wider range of compositions to design functional materials.

[*T-2-2*] Piezoelectric materials in practice: Principles, mechanisms, and application case studies

Paula Huth

PI Ceramic, Germany

Piezoelectric materials enable the mutual conversion between mechanical and electrical energy, underpinning a diverse range of technologies. Their functionality can be categorized into four principal application types: generators, which harvest mechanical energy for electrical power; sensors, which convert mechanical signals into electrical outputs for measurement and monitoring; actuators, which transform electrical input into controlled mechanical motion; and transducers, which link mechanical and electrical domains bidirectionally, as in ultrasonic devices. These categories arise from two fundamental physical mechanisms: the direct piezoelectric effect and the converse piezoelectric effect, and form a conceptual framework for understanding the breadth of piezoelectric applications. This tutorial will begin with a systematic introduction to piezoelectric applications, organized by these mechanisms and application principles. Functional distinctions, operating concepts, and key performance considerations will be presented within the context of real-world device classes. The second part of the lecture will provide an in-depth examination of three representative application fields: (1) Medical Ultrasonic Transducers – Imaging and therapy systems, from early designs to modern high-resolution arrays; (2) Precision Positioning Actuators – Piezo-based motion control solutions for nanometrology, semiconductor manufacturing, and other domains requiring sub-nanometer accuracy; (3) Vibration Sensors for Structural Health Monitoring – Piezoelectric devices that detect mechanical vibrations and stresses in bridges, aircraft, and machinery, enabling predictive maintenance and safety assurance. Each case study will present historical context, fundamental operating principles, and distinct challenges associated with each application. The tutorial concludes with a synthesis of how the classification by mechanisms and application principles can guide innovation across established and emerging fields of piezoelectric technology.

ABSTRACTS – PLENARY TALKS

[*PL-1-3*] Domain boundaries as polar objects: Symmetry breaking beyond the bulk

Hiroko Yokota

Institute of Science Tokyo, Japan

Ferroic materials are inherently characterized by the presence of domains, and in recent years, research interest has increasingly shifted from domains themselves to the properties of domain boundaries. Advanced experimental techniques such as transmission electron microscopy (TEM) and scanning probe microscopy (SPM) have played a central role in elucidating the exotic structures and functionalities emerging at domain boundaries. It is now widely recognized that domain boundary can exhibit physical properties distinct from those of bulk and can serve as functional elements for nanoelectronic devices. However, owing to the stringent requirement for spatial resolution, optical experimental techniques have traditionally been considered less suitable for domain-boundary studies compared to TEM or SPM. Recently, we have demonstrated that second harmonic generation (SHG) microscopy is a powerful optical probe for investigating ferroelastic, antiphase and twin boundaries, revealing the emergence of polar natures even in nominally nonpolar materials. Furthermore, we showed that this boundary-induced polar activity can be tuned by the external stimuli such as stress, electric field and temperature. In the present study, we extend these studies by combining SHG microscopy with complementary approaches, namely diffuse scattering experiments and molecular dynamic (MD) simulations, to gain deeper insight into the internal structure of domain boundaries and the microscopic origin of their polarities. We investigated calcite, antiferroelectric $PbZrO_3$ and $PbZr_{1-x}Ti_xO_3$ using SHG microscopy and found all systems exhibit SH activities exclusively originating from boundaries, consistent with symmetry lowering at boundaries. Diffuse scattering measurements suggest the formation of ferrielectric-like structures at antiphase boundaries, in which polarizations do not fully cancel. This interpretation is strongly supported by MD simulations, which reproduce the emergence of polar boundaries and further reveal a substantial suppression of the phase transition temperature at antiphase boundaries compared to the bulk. These results highlight the effectiveness of multimodal approaches in uncovering the hidden internal degrees of freedom at domain boundaries and demonstrate that boundary-induced polarity is a universal and tunable phenomenon in a wide range of ferroic materials.

[*PL-2-45*] Ferroelectric $Hf_xZr_{1-x}O_2$ (HZO) as a game changer for ferroelectric random-access memories (FeRAM)

Laurent Grenouillet

CEA-Leti, France

Perovskite-based (PZT) Ferroelectric Random-Access Memories (FeRAM) is a mature, low power consumption, high write endurance non-volatile memory technology. However, PZT FeRAM cannot scale beyond 130 nm node and offers poor CMOS compatibility. The discovery of ferroelectricity in hafnia-zirconia-based (HZO) films two decades ago is currently changing FeRAM paradigm. Indeed, HZO films are ferroelectric in the 5-10 nm thickness range allowing low voltage operation, can be deposited in a three-dimensional configuration by Atomic Layer Deposition (ALD) to improve density, and are fully CMOS compatible, which potentially allow their introduction at any technological node. In this talk, recent advancements in HZO FeRAM demonstrations will be reviewed, highlighting the opportunities but also the challenges at material, integration and design levels. The potential of HZO FeRAM in terms of applications will also be discussed.

[*PL-3-83*] Theoretical studies of composition-structure-property relationships of piezoelectric oxide ceramics: Separating and understanding the intrinsic and extrinsic effects

Ilya Grinberg

Department of Chemistry, Bar Ilan University, Ramat Gan, Israel

Ferroelectric perovskite oxides have been used in a wide range of applications in piezoelectric devices since their first discovery in 1940s. Last several decades have seen an intense effort to explore and design new ferroelectric solid solutions to achieve the desired piezoelectric properties. Several tools such as compositional variations, and changes in the synthesis and processing procedures can be used to achieve the desired properties for these solid solutions. Rational design of piezoelectric oxides requires a thorough understanding of how the composition and processing give rise to the crystal structure and microstructure of the material which in turn control its piezoelectric properties. Recent theoretical and experimental studies have enabled significant progress in understanding how the intrinsic properties of piezoelectric oxides are related to their crystal structure and composition. The characteristics of these materials at different length scales, starting at the level of the electronic structure and chemical bonding of the constituent ions can be analytically related to key properties such as Curie temperature Tc, polarization, and the relaxor-ferroelectric and rhombohedral-tetragonal (morphotropic) phase boundaries. These composition–structure–property relationships provide a unified quantitatively predictive theory for understanding compositional effects on piezoelectric solid solutions. In addition to compositional variations, microstructure and processing can strongly affect piezoelectricity in oxide ceramics. The complexity of the microstructure and its variation with processing make it challenging to separate the intrinsic and extrinsic (i.e. defect- and microstructure-related) contributions to the properties of piezoelectric ceramic so that understanding of the effects of composition and processing on the defects and microstructure and piezoelectric properties represents the next frontier in theoretical studies of piezoelectric oxides. Analysis of a large number of multicomponent solid solutions reported in the last two decades reveals the impact of extrinsic effects on some key properties of piezoelectric ceramics as well as the dependence of these effects on the chemical characteristics of the solid solution constituent ions and its synthesis and processing.

ABSTRACT – GROUP INVITED TALKS

[*P1-7-22*] Unraveling microstructural and chemical evolution in pristine and fatigued ferroelectric AlScN thin films by synchrotron X-ray techniques

Martina Müller (PI, presenting author)[1], Oliver Rehm (team member, presenting author)[1], Ella Dieball (team member, presenting author)[2]

[1]University of Konstanz, Germany

[2]Kiel University, Germany

The limited switching endurance of ferroelectric $Al_{1-x}Sc_xN$ thin films is currently the biggest challenge to enabling applications in energy efficient, all-nitride ferroelectric memory, regardless of whether these will be realized through FeFETs, FRAM oder FTJs. While ferroelectric non-volatile memory based on conventional perovskite ferroelectrics can withstand over 10^{13} read/write cycles at room temperature, integrating them into III-N technology is challenging due to competing temperature budgets and poor structural and chemical compatibility. Studies on sputtered AlScN films, including our own, have consistently noted/reported an early dielectric failure after at $< 10^5$ switching cycles. Despite first/initial attempts to elucidate the origin of the low switching endurance, a true mechanistic understanding of fatigue in AlScN is still lacking. This requires in-depth characterization and a fundamental understanding of the complex microstructural and chemical properties. In this contribution, we report on our latest efforts to identify (i) the complex microstructure of AlScN thin films using advanced X-ray diffraction (XRD) characterization methods and (ii) to resolve the electronic structure after ferroelectric switching using hard X-ray photoelectron spectroscopy (HAXPES) in combination with transmission electron microscopy (TEM), in order to establish a connection with real structure changes. In detail, we compared the microstructure features of epitaxial AlScN/GaN heterostructures, which were grown by metal-organic chemical vapor deposition (MOCVD) and magnetron sputtering, using nanofocused XRD and coherent X-ray diffraction imaging (CXDI) experiments. Analysis of the rocking curve and nanofocused XRD 2D mapping of the MOCVD-grown sample ($Al_{0.86}Sc_{0.14}N$/GaN) reveal a complex microstructure differentiating into lateral domains with two distinct out-of-plane lattice parameters. One possible explanation is defined variations of the local Sc-concentration of about ±1 percent. In contrast, uniform diffraction signatures from a single coherent lattice are recorded for sputtered films ($Al_{0.92}Sc_{0.08}N$/GaN), which allowed to reconstruct the three-dimensional distribution of the out-of-plane strain component by CXDI. Further, HAXPES measurements were performed on individual test structures to follow the changes to the electronic structure of the material within the bulk of MOCVD-grown AlScN films and to compare the discrete states of the material in pristine (0x) and after 400x, 1000x and 4000x switching cycles. To eliminate data from the pristine state, the cycled capacitor structures were ion-beam etched into freestanding micro-dots (50 µm diameter), which allowed direct probing by the HAXPES beam. The measurements

reveal a rigid shift of core level features towards lower binding energy, accompanied by a noticeable narrowing of the spectral peaks. These observations suggest an improvement in crystallinity and/or a reduction in chemical heterogeneity caused by repeated switching. These results highlight promising steps towards a fundamental understanding of the changes in the structural, chemical and electronic properties of AlScN thin films related to fatigue mechanisms.

[*P3-21-71*] *Hunting for skyrmions in polar oxides*

Mauro Goncalves (team member, presenting author), Vilgelmina Stepkova (team member, presenting author), Jiri Hlinka (PI, presenting author)

FZU – Institute of Physics, Czech Acad. Sci., Czechia

The increasing concern about the rising energy costs of information technologies is drawing attention to the miniaturization of memory and active computational devices. In this respect, the topological defects in the electric polarization textures of polar oxides promise one of the plausible avenues for future technologies. Our core team composed of M. Goncalves, V. Stepkova, M. Graf, M. Pasciak and J. Hlinka from FZU – the institute of Physics of the Czech Academy of science, is eager to contribute to these efforts by making realistic predictions based on material-specific atomistic and Ginzburg-Landau models. Here, we address the progress in modeling particular topological defects with nonzero skyrmionic numbers and clarify the advantages and disadvantages of various polar oxides as potential skyrmionic media. The last author will first introduce the concept, provide an overview of the state of the art, and highlight the principal achievements and opportunities that were targeted in several projects where his team participated. Then, the main methodology and results will be presented by early-stage members of the group. In particular, the first author will reveal the critical details of the computation methodology of searching skyrmionic defects and their properties in various materials, which enabled the observation of the very first polar skyrmion and antiskyrmion using atomistic simulations with shell-model potentials fitted from first-principles simulations. Building on this approach, he will show that stabilizing the appropriate nanodomain configuration, a simple columnar nanodomain with polarization opposite to the surrounding matrix, provides a general route to stabilize topological textures in a broad range of polar oxides. While the second author will focus on the processes of skyrmionic defect creation, annihilation and the possibility of its controlled motion by variously tailored applied electric fields. She will also present the critical aspects of the phase-field modelling approach to these problems. Dynamic clips bringing to the fore the very essense of the computational results obtained within our team should elucidate why and how an unexpected novel perspective for ferroelectric skyrmionics may emerge from both machine-learning and experimental chemistry/strain engineering material exploration approaches.

ABSTRACTS – INVITED TALKS

[*P1-1-4*] Evolution of thermal conductivity under electric field in barium titanate single crystals and ceramics

Guillaume Nataf

University of Tours, France

Materials with on-demand control of thermal conductivity are the prerequisites to build thermal conductivity switches required to develop solid-state refrigeration, energy harvesting, and the use of heat currents for computational purposes. Ferroelectrics appear as promising materials for thermal conductivity switches due to the tunability of their domain structures and crystallographic phases with electric fields. Here, we investigate how the thermal conductivity of barium titanate evolves under the application of an electric field. We present ab initio electronic structure calculations predicting different thermal conductivity values depending on the direction of heat propagation with respect to the ferroelectric polar axis. We then combine local thermal conductivity measurements by frequency-domain thermoreflectance and scanning thermal microscopy on ferroelectric domains in a single crystal of barium titanate to quantify the difference in thermal conductivity, confirming the theoretical prediction. Finally, we show that when an electric field is applied, ferroelectric domains reorient, yielding a thermal conductivity ratio of 1.6 at room temperature, thus creating a thermal conductivity switch. We also investigate barium titanate ceramics with different grain sizes, elaborated using conventional and spark plasma sintering. We adapted a commercial laser flash system to apply an electric field while measuring the thermal conductivity. These in-situ experiments reveal a change in thermal conductivity under electric field. This behavior is discussed based on the thermal conductivity of single crystals and the evolution of the ferroelectric domain structure probed by X-ray diffraction measurements under electric field.

[*P2-1-6*] Design of functional polymer matrix composites: Effect of processing and microstructure

Giovanna Canu

National Research Council of Italy – Institute of Condensed Matter Chemistry and Technologies for Energy (CNR-ICMATE), Italy

Ferro/piezoelectric polymer matrix composites, typically made of PVDF – poly(vinylidene fluoride) as a matrix and perovskite-type powders as the filler, gained popularity as they combine the high flexibility, chemical stability, breakdown strength of polymers with the higher permittivity of ferroelectric ceramic powders. Commonly studied for energy storage and harvesting, these composites are also considered for application as sensors and actuators, for flexible and lightweight wearable devices. A vast literature is available on the preparation and characterization of polymer matrix composites, involving various processing techniques. By varying the size, shape and volume fraction of the inclusions, the functional properties of the composite can be tailored. In general, by adding ferroelectric fillers, it is known that the permittivity of the composites significantly increases and that the filler promotes a higher amount of the β-phase, the polymorph of PVDF with the highest dipole moment. It is also observed that both composite processing and microstructure have a significant effect on the materials properties. We will first review the effect of processing, including advanced manufacturing techniques, on the properties relevant to applications. Then, we will review another important aspect in the composites preparation: the interface engineering between the dissimilar polymer matrix and inorganic nanoparticles. In particular, different strategies of modification of the filler surface can be envisioned, such as functionalization with various molecules, or coating with an oxide layer with a different permittivity value, which will modify the distribution of the electric field in the composite. We will discuss examples in the literature highlighting the role of microstructure engineering on the properties of polymer matrix composites, both from a theoretical and experimental point of view.

[*P3-1-8*] Towards sub-ambient solid-state cooling with electrocaloric materials

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Electrocaloric cooling is shaping up to be an exciting solid-state alternative to traditional vapor-compression systems. It promises not only greater energy efficiency but also the elimination of harmful fluorinated refrigerants. This potential is becoming more real as various prototypes have shown giant temperature ranges. For instance, one of the best-performing electrocaloric demonstrators can achieve a temperature difference of 20 °C while operating between 20 °C and 40 °C. In this cooling method, the refrigerants are actually electrocaloric materials that experience heating and cooling when an electric field is applied or removed. This effect peak around the material's phase transition temperature, where the polarization changes strongly with temperature. Lead scandium tantalate (PST) is often seen as the gold standard for electrocaloric materials, as it undergoes a ferroelectric-to-paraelectric phase transition close to room temperature. State-of-the-art electrocaloric prototypes take advantage of its roughly 2 °C electrocaloric response to achieve significant temperature spans, although this effect is limited to temperatures around and above room temperature. In this invited talk, I'll delve into the electrocaloric properties of PST and showcase its application in an electrocaloric regenerator. Lastly, I'll present a strategy to broaden PST's operational range below the freezing point of water through A-site calcium doping.

[*P1-9-24*] Photo-induced properties in ferroelectric oxides: From fundamentals to applications

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Interaction between light and ferroic order parameters in nanostructures leads to new physical functionality. In this respect, the quest for opto-electronic control of energy-efficient ferroelectric materials is gaining importance for fast memory applications. We explored the light-induced polarisation switching behaviour in epitaxial freestanding $BaTiO_3$ (18 nm) films. It is observed that after writing the domains with positive and negative voltage, the materials always return to their original downward polarisation state under illumination for both polycrystalline and epitaxial films. The material also exhibits significant enhancement in the amplitude response, which is confirmed by the imaging and spectroscopy analysis under dark and illumination conditions. Importantly, the freestanding $BaTiO_3$ film illustrates domain-switching immediately after illumination. The optically controlled domain switching response is compared between a clamped film and freestanding membrane. It is established that the fast domain switching response in the freestanding film compared to the clamped film is attributed to the removal of substrate-induced strain and the subsequent increase in domain wall velocity. Additionally, ferroelectric fatigue behaviour is not observed in our system even after 75 electrical and optical cycles, demonstrating the robustness of the observed phenomenon. Our work provides a step forward towards wireless sensing and dual optical and electronic control for computing. In addition, I will talk about a few other ferroelectric systems designed for photovoltaic (PV) applications and how strain influences the PV outcomes. Also, I will go through the strategy on how to design suitable PV materials for photovoltaic and optical control memory applications.

[*P2-10-28*] Towards reliable dielectrics via the cold sintering process

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The cold sintering process (CSP) densifies various ceramics at ultra-low temperatures (< 350°C) by using pressure and chemically active transient phases, enabling unprecedented microstructure and grain boundary engineering. However, the effect of the peculiar processing conditions in CSP on the mechanical and functional reliability of cold sintered ceramics remains unexplored. This study examines the mechanical and dielectric performance of cold sintered ZnO and $BaTiO_3$, comparing them to samples densified at high temperatures (>1000 °C) via other techniques like rapid, and spark plasma sintering. It was found that improper CSP conditions, such as temperature and pressure gradients, compromises the strength of cold sintered samples. The prevention of such defects is demonstrated by appropriate selection of CSP parameters, resulting in structurally reliable cold sintered ceramics with strengths exceeding 100 MPa. Cold sintered $BaTiO_3$ with grain size of 200 nm shows high room temperature relative permittivity values (~3000) and low dielectric losses (< 2%). This work demonstrates the significance of defect formation and chemical effects in CSP for reliable dielectrics.

[*P3-9-31*] First principles investigations of cation site preference, magnetic coupling and electronic correlation in multiferroic aurivillius phase $Bi_5Ti_3MnO_{15}$

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Single-phase multiferroic materials with the Aurivillius structure, that characterised by a naturally layered perovskite-related crystal structure ($Bi_{n-3}Ti_3Fe_{n-3}O_{3n+3}$), have attracted considerable attention in recent years due to the coexistence of ferroelectric and magnetic orders, as well as the associated magnetoelectric coupling between these two order parameters. This coupling makes the Aurivillius family promising for emerging applications such as magnetic sensors, multistate memory devices and spintronics, in addition to their use in ferroelectric random-access memory (FeRAM) and piezoelectric actuators. The ferroelectric behaviour of Aurivillius compounds is well established, with Curie temperatures well above room temperature (<500 °C). However, these materials typically exhibit antiferromagnetic or weak ferromagnetic interactions, primarily governed by superexchange mechanisms, resulting in intrinsically weak magnetic responses, as observed in the $Bi_5Ti_3FeO_{15}$ (BTFO) compound. Consequently, various transition-metal substitution strategies have been explored to enhance the magnetic properties and spin–lattice coupling. The $Bi_6Ti_xFe_yMn_zO_{18}$ system, featuring dual Fe/Mn substitution, stands out as a rare example of a single-phase room temperature multiferroic, exhibiting saturation magnetisation (M_S) values of 215 emu/cm^3 and in-plane saturation polarisation (P_s) values exceeding 26 μC/cm^2. However, the specific role of Mn in influencing magnetic properties remains unclear. These findings highlight the importance of determining the intrinsic properties of transition-metal-doped Aurivillius phases and elucidating the origin and nature of their magnetic behaviour. In this work, we present density functional theory (DFT) based calculations to investigate the Mn-substituted four-layer Aurivillius compound $Bi_5Ti_3MnO_{15}$ (BTMO). Our study explores the structural, electronic, and magnetic properties of BTMO, with a particular focus on the effect of Mn cation positions at different B-sites. Furthermore, we examine how different magnetic orderings influence the structure and energetics of BTMO. To determine the strength and nature of the magnetic interactions between Mn cations at various relative positions, the Heisenberg exchange coupling parameters (J_{ij}) are calculated as a function of interatomic distance using a real-space Green's function–based method. The influence of the on-site Coulomb repulsion parameter on the magnetic exchange constants is also analysed. In addition, we estimate the orbital-resolved energy splitting and find that the intra-orbital eg–eg interaction is significant due to Jahn–Teller distortion, demonstrating a strong correlation between the energy splitting of the two Mn eg orbitals and the magnetic order in BTMO. Based on these observations, we have identified a superexchange mechanism driven by orbital degeneracy, offering insights into the magnetic ground state in this BTMO material.

[*P1-17-54*] Curvature-controlled polarization in adaptive ferroelectric membranes

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In ferroelectric perovskite thin films, epitaxial growth enables control of the domain state through strain and electrostatic engineering. By selecting the growth substrate, strain can be tuned to induce complex domain patterns [1]. However, epitaxial growth imposes limitations on applicable strain due to constraints arising from lattice parameters and crystal symmetry. Releasing ferroelectric oxides from the growth substrate using sacrificial layers [2] opens new possibilities for domain configurations that emerge from changes in electrostatic and mechanical interactions, enabling controlled bending of the ferroelectric material. Here, we investigate the domain structure and mechanical properties of $SrRuO_3$/$PbTiO_3$-based heterostructures after the release from the growth substrate. The $SrRuO_3$/$PbTiO_3$ membranes are fabricated by growing a $Sr_3Al_2O_6$ sacrificial layer by pulsed laser deposition on a $SrTiO_3$(001) substrate. The $SrRuO_3$ bottom electrode and $PbTiO_3$ ferroelectric layers are synthesized by off-axis sputtering. The $Sr_3Al_2O_6$ layer is dissolved in deionized water, and the $SrRuO_3$/$PbTiO_3$ membranes are transferred onto a Nb:$SrTiO_3$(001) target substrate. Upon release, the membranes display a well-ordered adaptive ripple pattern. Their domain structure is studied at different length scales using second harmonic generation, piezo-force microscopy, and transmission electron microscopy. These techniques show the presence of in-plane a-domains, organized in super-domains composed of a1 and a2 domains in varying proportion at the top of the ripples, and an a/c domain structure elsewhere. Upon release, the ferroelectric polarization partially rotates in-plane due to changes in electrostatic and mechanical constraints, consistent with observation of previous studies [3,4]. The mechanical properties of the ripples are analyzed by contact-resonance AFM, revealing distinct mechanical characteristics of ripples compared to flat regions [5]. Ripples in bilayer bottom electrode/ferroelectric structures depend on the electrode's presence and thickness, as well as the ferroelectric layer thickness. By varying these parameters, changes in mechanical and electrostatic boundary conditions result in different material response, enabling tunable domain structures. Ferroelectric oxides membranes exhibit unique states not achievable through epitaxy, unlocking novel mechanical properties that hold great potential for next-generation electronic devices. References: [1] C. Lichtensteiger

et al., APL Mater. 11, 061126 (2023); [2] D. Lu et al., Nature Materials 15, 1255–1260 (2016); [3] Y. Li et al., Advanced Materials 34, 2106826 (2022); [4] S. Huang et al., Advanced Science 11, 2307571 (2024); [5] G. Segantini et al., Small 21, e06338 (2025)

[*P2-17-57*] Achieving superior piezocatalysts: An innovative materials strategy

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Piezocatalysis, which generally uses ferroelectric and piezoelectric materials, is an emerging means of tackling the energy crisis and protecting the environment. While the development of piezocatalysts has been typically focused on high piezoelectric coefficients and/or approaches similar to those used in photocatalysis (e.g., morphology modulation, heterostructure…), we have recently proposed a new strategy based on piezoelectric energy harvesting by selecting $BiFeO_3$, which requires increasing piezoelectric properties while minimizing dielectric response (to favor the figure-of merit), and all these properties must be preserved when reducing the size in order to obtain an ideal piezocatalyst.[1] Moreover, to enhance its piezocatalytic response, one of the material strategies that we have considered, more recently, is defect engineering by doping with slight amount of La^{3+} on the A-site, without altering its functionally useful properties required for efficient piezocatalysis.[2] Here, we report another original approach completely new in the field of piezocatalysis, which counter-intuitively considers antiferroelectrics to produce enormous charges under stress stimulus, strongly favoring the piezocatalysis process. The system we choose to meet these requirements is Sm and Nd-doped $BiFeO_3$ solid solution. Such original and innovative idea which offers exciting perspectives for the rational design of efficient piezocatalytic systems for wastewater treatment and green energy production such as H_2 and H_2O_2, will be presented in line with the physical properties involved in the mechanism. In addition to $BiFeO_3$-based, we will show how model antiferroelectrics ($PbZrO_3$ and $NaNbO_3$) display as well significantly greater efficiencies than previously reported ferroelectric and piezoelectric systems.[3,4] References: [1] W. Amdouni et al., Adv. Mater. 2023, 35, 2301841; [2] W. Amdouni et al., Small. 2024, 20, 2406425; [3] W. Amdouni et al., Nature, under review; [4] W. Amdouni et al., to be submitted.

[*P1-24-74*] Development of PTCR materials and components for high-voltage heating systems in E-mobility

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Due to the transformation of automotive industry from combustion to electrically driven vehicles, barium titanate-based ceramics with Positive Temperature Coefficient of Resistance (PTCR) properties have gained renewed interest mainly as self-regulating heating elements. Changes in application conditions, such as increasing operating voltages up to 800–1200 V, require adjustment of common PTCR materials. To facilitate PTCR components with high breakdown voltage, the influence of compositional changes and process parameters on ceramics microstructure and PTCR effect must be understood. In our contribution, we investigate the influence of alio- and isovalent doping on $BaTiO_3$-based PTCR ceramics in terms of crystallography, microstructure, temperature dependent resistivity and breakdown strength. Special emphasis is given to the effect of co-doping with strontium and calcium which shows co-dependencies of tetragonality and microstructure and determines the limits for the application in high voltage thermistors. Our results show no significant benefit of co-doping strontium and calcium to improve voltage stability since the benefit of strontium doping increasing the breakdown field strength is outweighed by the necessary increase in lead content for an otherwise lowered Curie temperature. To improve breakdown field strength, we also study the influence of SiO_2 addition in a range of 0 to 2.1 wt%. Already small amounts of SiO_2 lower the sintering temperature from T = 1400 °C to 1275–1300 °C through liquid phase sintering and thus significantly reduce the grain size. The reduction of grain size and the homogeneity of the SiO_2 phase in the ceramic microstructure determine the breakdown strength of the material. We show that a maximum breakdown strength of 1118 V/mm can be achieved by addition of 0.9 wt% SiO_2 which would allow for PTCR components with significantly higher breakdown voltage for applications up to 1200 V, depending on component thickness. Based on the above-mentioned material developments we therefore upscale powder synthesis of the most promising material composition from 100 g batches to 15 kg batch size. From this, PTCR components of 28.8 mm x 19.5 mm size and 2 mm thickness are fabricated using uniaxial pressing of green parts, sintering, hard machining and metallization. In our contribution, we will present the influence of processing parameters on temperature dependent resistivity and breakdown strength.

[*P1-25-75*] Towards an industrial lead-free ferroelectric KNN thin film for piezoelectric MEMS actuators

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Despite the RoHS (Restriction of Hazardous Substances) directives regarding the use of lead in many electronic applications, introduced 20 years ago, lead zirconate titanate (PZT) remains the most widely used piezoelectric material in actuator devices in the absence of a suitable alternative at the industrial level. Among lead free materials candidates, $K_{1-x}Na_xNbO_3$ (KNN) is the most promising to replace PZT. However, to this day, most functional KNN films in literature are grown at small scales and are often too complex for an industrial transfer. Volatility of alkali is one of the main issues to be addressed for obtaining good KNN films. In that regard, pulsed laser deposition (PLD) offers several advantages like allowing an easier transfer of the stoichiometry from the target to the film deposited, and a good control of structural characteristics. This deposition method, widely used in academia for developing complex thin film materials, but at small scales (few cm^2), is now available for large wafer scale, up to 200/300 mm in diameter, used in microelectronics industry. Our goal is to get KNN films with properties suitable for replacing PZT in piezoelectric actuators. In this work, KNN thin films were deposited by pulsed laser deposition (PLD) on $Pt/TiO_2/SiO_2/Si$ substrates using targets of various compositions (K/Na, doping) fabricated by spark plasma sintering (SPS) or conventional sintering (CS). An enrichment of the KNN target with $KNbO_3$ was necessary to avoid the presence of $K_4Nb_6O_{17}$ phase in the film, which is detrimental for the functionality of KNN capacitors [1]. Moreover, by adding a small amount of Mn in the target, the leakage current in the films was significantly decreased, leading to major improvement in the electric behavior of KNN devices. As a result, KNN films, 700 nm thick, showing a transverse piezoelectric $e_{31,f}$ coefficient of around 13 C/m^2 were obtained, thus close to best values reported in literature so far [2]. In this paper, we will present the results of this study including morphology, structure, composition, ferroelectric and piezoelectric characterizations. In addition, the scalability of the deposition process from laboratory PLD (20x10 mm^2 samples) to an industrial compatible PLD tool (200 mm in diameter wafer) will be also presented. [1] B. Carreño-Jimenez et al., J. Mater. Chem. C, 2025,13, 22712-22721; [2] H. Kuentz et al., Sens. Actuators, A, 2024, 372, 115370

[*P2-24-77*] Magnetoelectric composites operating in higher bending modes

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Magnetoelectric composites, combining piezoelectric and magnetostrictive phases, unlock new dimensions of operation for each constituent. For the magnetostrictive phase, this introduces an electrical handle for input and output; for the piezoelectric phase, it enables magnetic, and ultimately electromagnetic, wireless functionality. These capabilities open up many applications in sensing and transduction, particularly in miniaturized antennas, as will be discussed. Magnetoelectric coupling is fundamentally mediated through elasticity. Consequently, devices based on these composites typically operate near mechanical resonance to enhance coupling efficiency. Beyond high-frequency acoustic-wave operation, many devices adopt a single-clamped beam configuration and operate in bending resonance. This approach offers distinct advantages: bending motion induces higher strains in the device and allows operation at lower frequencies when required for challenging environments. In this talk, I will present nickel/PVDF-based magnetoelectric cantilever devices operating in bending mode, with a fresh focus on higher-order bending modes—an area often overlooked. We will begin by exploring how these modes can serve as powerful tools for materials analysis and device design, supported by a recently developed analytical model [1]. This model computes the frequency response of the device across the spectrum, both on and off resonance, making it highly useful for data fitting when a range spanning several modes is recorded. Next, we will examine the role of higher bending modes in power transduction, revealing how additional modes can enhance energy transfer by effectively opening more channels. Finally, we will discuss their impact on sensing performance, including insights into noise mechanisms and their dependence on modal behavior, demonstrating how higher bending modes can be advantageous for sensing due to inherently lower noise levels [2]. By broadening the operational landscape of magnetoelectric devices, this work opens new opportunities for advanced sensing, energy harvesting, and multifunctional systems. [1] Cohen, O., Calahorra, Y. (2025). An analytical frequency domain model for magnetoelectric composite devices including higher bending modes. APL Electronic Devices. https://doi.org/10.1063/5.0282933; [2] Cohen, Opal et al. In preparation.

[*P1-27-84*] Critical properties of divergence-free ferroelectric materials

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Phase transitions in ferroic materials are commonly described within the Landau-Ginzburg-Wilson (LGW) framework, where critical behavior follows from symmetry breaking and fluctuations of a local order parameter. In many ferroic systems, however, this conventional picture is modified by additional physical constraints that become especially important at the nanoscale. One key example is the high electrostatic cost of bound charges in nanoscale ferroelectrics, which effectively enforces local charge neutrality of the polarization field, expressed as $\nabla \cdot P = 0$. This divergence-free condition has far-reaching consequences. Rather than forming simple domain patterns, the polarization organizes into complex topological textures such as vortices and hopfions [1]. Due to the constraint, polarization lines cannot begin or end inside the material, thus they are forced to wind into closed, loop-like configurations. Such rotational arrangement of dipoles naturally gives rise to ferroaxial behavior [2], where the system develops an electric toroidal (ferroaxial) moment. In this sense, polar ordering under the constraint $\nabla \cdot P = 0$ is accompanied by an emergent ferroaxial order, enforced by the same local condition. As a result, both the equilibrium states and the nature of fluctuations near phase transitions differ from those expected in conventional ferroelectrics. In my talk, I will show how the zero divergence constraint reshapes the critical behavior of ferroelectrics within an otherwise standard LGW description. Near criticality, the zero divergence constraint causes polarization fluctuations to form closed loops [3], closely resembling vortex loops in superfluids, but arising from dipolar rather than superfluid physics. These polarization loops provide a natural bridge between ferroelectricity and topology, reflecting the emergence of nontrivial polarization textures near phase transitions. By explicitly accounting for the restricted configuration space imposed by $\nabla \cdot P = 0$, we find that the system flows to a new universality class characterized by strongly enhanced fluctuations and an unusually large anomalous dimension of the polarization in three dimensions [3]. Remarkably, this unconventional critical behavior does not rely on fractionalized quasiparticles or exotic microscopic interactions. Instead, it originates directly from the topology of the allowed polarization configurations. These results open new perspectives on the role of topology in ferroic criticality. Beyond their conceptual significance, they lead to experimentally accessible predictions for dielectric response and correlation functions near criticality, making nanoscale ferroelectrics a promising platform for observing non-Landau critical behavior in real materials. [1] I. A. Lukyanchuk, A. G. Razumnaya, S. Kondovych, et al., Phys. Rep. 1110, 1 (2025); [2] B. Singh, G. McNamara, K.-M. Kim, et al., Nat. Phys. 21, 1578 (2025); [3] S. Kondovych, A. Sudbø, and F. S. Nogueira, arXiv:2510.13960 (2025).

[*P2-27-87*] Polar oxide membranes: from tunable barium strontium titanate optical filters towards tunable lasers

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The recent developments in membrane technology have the potential to become a game changer in oxide electronics, opening new possibilities to create complex devices from oxides. In comparison with van der Waals-bonded materials, oxides display a wide range of functionalities and allow transfer of membranes with controlled thickness from the unit cell-level to hundreds of nanometers. The wafer transfer technology allows to overcome the challenge of combining highly crystalline functional oxide layers with other materials which cannot be grown in a conventional deposition process. To probe the potential of ferroelectric membranes, we explore the development of ultracompact, tunable, high stability 800 nm lasers based on non-critical chemical elements. To achieve the required intra-cavity tuning, materials exhibiting a large Pockels electro-optical effect, i.e., showing significant changes of their refractive index with applied electric field, are needed. Due to its highly tunable permittivity and low dielectric loss, barium strontium titanate (Ba,Sr)TiO_3 is widely used as a voltage-tunable capacitor (varactor) in various applications, including modulators, phase shifters and waveguides. Furthermore, just below its Curie temperature, tunable between -180 °C and 120 °C by material composition and stress, the electro-optical response by the converse piezoelectric response of (Ba,Sr)TiO_3 is maximal, improving its Pockels coefficient and making it an excellent candidate for laser intra-cavity tuning. One of the main challenges of this work is to obtain a (Ba,Sr)TiO_3 of high crystallographic quality on top of the optical cavity Bragg mirror. As epitaxial growth is not possible directly on the amorphous Bragg mirror, membrane transfer technology is a key component of the fabrication of these complex thin film optical devices. As the basis for the development of thin film lasers, we established a tunable notch optical filter with (Ba,Sr)TiO_3 integrated into a Fabry–Pérot cavity [1]. A 450 nm-thick paraelectric $Ba_{0.5}Sr_{0.5}TiO_3$ was grown by pulsed laser deposition on a $GdScO_3$ substrate on which a $Sr_2Al_3O_6$ water-soluble sacrificial layer was previously deposited. We demonstrate the transfer of a 5×5 mm^2 $Ba_{0.5}Sr_{0.5}TiO_3$ thin film between two Bragg mirrors using lift-off technology to prepare the optical filter. Designed to be operated at 2 μm, the filter displays a maximum transmittance of 67 %. Through an applied electrical field, a shift of 3.8 nm towards shorter wavelengths is obtained via the quadratic electro-optic effect under a 210 V DC bias. As the objective of this work, we explore the use of ferroelectric $Ba_xSr_{1-x}TiO_3$ with $0.7 < x < 1$ to develop a thin film laser with intra-cavity tuning. Benefitting from an enhanced Pockels coefficient, due to a Curie temperature close to room temperature, ferroelectric $Ba_xSr_{1-x}TiO_3$ properties are highly dependent on its strain state. As epitaxial strain relaxation has been reported in membranes, we investigate the ferroelectric properties of $Ba_xSr_{1-x}TiO_3$ membranes, aiming to demonstrate that the technological developments achieved with tunable optical

filters can be implemented into tunable lasers. [1] M. Vakili, et al. (2025). Preprint. Optica Open. https://doi.org/10.1364/opticaopen.29065067.v1

[*P3-27-90*] Ferroelectric switching in Mn-doped epitaxial $BaTiO_3$ films and $BaTiO_3/SrTiO_3$ superlattices integrated on silicon

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The monolithic integration of epitaxial ferroelectric oxides on silicon could enable the realization of low-power, CMOS-compatible novel nanoelectronic devices. Among these materials, barium titanate ($BaTiO_3$) is a prototypical perovskite ferroelectric with a high remanent polarization and a low coercive field, making it a strong candidate for non-volatile devices. Although molecular beam epitaxy (MBE) has enabled the epitaxial growth of $BaTiO_3$ thin films on silicon, large leakage currents in these heterostructures have so far hindered reliable ferroelectric switching and limited device functionality. In this work we reduce the leakage currents significantly by carefully tuning the Mn-doping concentration in epitaxial $BaTiO_3$ thin films grown by MBE on silicon substrates. We demonstrate a strong doping-dependent reduction in leakage currents of up to seven orders of magnitude without the need for post-deposition annealing. Robust ferroelectric switching is achieved in p++ Si / 4 nm $SrTiO_3$ / 20 nm $BaTiO_3$ / Pt capacitors without a bottom conducting oxide electrode. With the results of piezoresponse force microscopy and macroscopic electrical characterization, we will discuss the role of Mn-doping on reducing leakage currents and on the ferroelectric properties. Beyond single-layer films, we will discuss the structural and electrical properties (P-E and C-V curves) of Mn-doped $BaTiO_3/SrTiO_3$ superlattices, which host nanoscale vortex polar textures of few nanometers in diameter. The devices demonstrate closed and saturated P-E loops and excellent endurance up to 10^7 cycles under bipolar switching conditions, highlighting their suitability for functional ferroelectric and topological devices. Overall, this work establishes Mn doping as an effective strategy to reduce leakage currents in epitaxial $BaTiO_3$ films and superlattices, paving the way for monolithically integrated ferroelectric and topotronic devices on semiconductors that exploit nanoscale topological defects.

ABSTRACTS – TALKS

[*P1-2-5*] Domain formation in uniaxial ferroelectrics: Stochastic versus phase-field modeling

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Domain structures play a decisive role in determining the functional properties of ferroelectric materials; however, their formation remains a fundamentally nonequilibrium and stochastic process. A detailed understanding of domain formation and evolution is essential for the controlled design of materials with tailored properties. In most ferroelectrics, domain formation follows a first-order phase transition that proceeds abruptly, leaving the mechanisms of domain ordering insufficiently understood. Experimental observations of such systems are commonly well described by phase-field modeling, which successfully captures mesoscopic domain patterns. In contrast to perovskite ferroelectrics, uniaxial materials such as triglycine sulfate (TGS) exhibit domain structure formation over time scales ranging from minutes to hours, enabling direct experimental access to all stages of nucleation, growth, and coarsening. In this temporal regime, stochastic approaches offer a significant advantage over phase-field methods, as they enable the description of long-time domain evolution inaccessible to conventional phase-field approach. Nevertheless, phase-field modeling continues to offer unique capabilities, enabling the description of specific regimes and phenomena that are essential for the interpretation of current experiments and for assessing the predictive power of stochastic models. In this contribution, we analyze the role of initial disorder and weak external effects in the processes of domain ordering in uniaxial ferroelectrics, discuss the complementary strengths of stochastic and phase-field frameworks, and identify open problems and current challenges in modeling domain formation dynamics.

[*P2-2-7*] Recycled piezoelectric materials with competitive second-life functional properties

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EU directives currently impose restrictions on the use of hazardous elements such as lead in electronic devices and encourage their recycling. However, lead is currently exempt from these restrictions for essential piezoelectric materials due to its indispensable role, and recycling is rarely practiced for such materials. This work addresses these challenges by demonstrating the feasibility of recycling lead-containing piezoelectric ceramics, which hold the largest market share in the piezoelectric industry, and subsequently giving them a second life, so that the disposal of lead into the environment can be avoided or at least postponed. Among the various routes toward sustainable production of piezoceramics, the upside-down composite method has recently shown promising advances in recycling retired and/or discarded piezoelectric components with negligible energy consumption compared to conventional solid-state and cold sintering routes. The composites exhibited high piezoelectric voltage coefficients (g), making them intrinsically suitable for a second life in kinetic energy sensing applications. However, a major drawback of this recycling method is that the retired/discarded piezoceramics are crushed and reprocessed into composites as discrete filler particles embedded within a suitable matrix or binder, resulting in only about 10% retention of the piezoelectric charge coefficient (d). The inferior d values in upside-down composites, as in conventional piezocomposites, are attributed to the disparity in permittivity between the filler and the binder which has been experimentally confirmed and accurately modelled. The difference in permittivity causes the applied poling electric field to concentrate primarily in the low-permittivity binder phase. This effect becomes more pronounced and eventually saturates at higher filler permittivity values, limiting further improvements in the electrical properties of the composite. As high ceramic permittivity is unavoidable in most modern piezoelectric devices from which the fillers are sourced, further optimization of composite properties becomes increasingly bottlenecked. By extending the established modelling approach to higher binder permittivity values, this work proposes a strategy to overcome this saturation limitation. Upon experimental validation of the empty models, optimized piezoelectric properties among all known recycled materials are achieved by utilizing high-permittivity polymeric binders in the fabrication process. The performance is systematically compared with composites made from low-permittivity binders using three different lead containing fillers. After recycling, this work achieves up to 40% retention of the d and 100% retention of the g compared to the pristine ceramics prior to recycling. Furthermore, by modelling the experimental dataset using novel 3D graphical representations that map the variation of composite properties as a function of filler and binder parameters, this work provides valuable insights into

the future development of this recycling approach using commercial Pb-containing ceramics providing a predictive framework for material design and enabling translation to commercial waste streams.

[*P3-2-9*] High thermal current and figure of merit in diamond-filled porous pyroelectric ceramics through improved thermal diffusivity

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Pyroelectric materials offer promise for thermal energy harvesting and infrared and thermal detectors. Nevertheless, the energy harvesting figure of merit of conventional dense pyroelectric ceramic is limited by a high dielectric permittivity and a low rate of heat transfer which suppresses the rate of temperature change during thermal cycling. In this work, we explore porous (~58 vol%) barium titanate piezoceramics with aligned pores that were infiltrated with micrometre-scale diamond particles as a strategy to simultaneously reduce dielectric permittivity and enhance thermal diffusivity and study their effect on relevant pyroelectric figures of merit. Dense and porous barium titanate samples of varying thicknesses were prepared for comparison using uniaxial pressing and freeze-casting methods, respectively, and their dielectric, piezoelectric, and pyroelectric properties were evaluated. While the longitudinal piezoelectric coefficient (d_{33}) was comparable across dense, porous, and diamond-filled samples, indicating a similar level of polarisation, the porous and diamond-filled samples exhibited a lower relative permittivity (615 and 529 at 1 kHz, respectively) compared to dense samples (1552). Upon filling pores with diamond powder, the thermal diffusivity of the porous ceramics increased to 1.4 mm^2/s compared to dense 1.14 mm^2/s and porous 0.86 mm^2/s. When subjected to thermal oscillations of a fixed frequency, the short circuit pyroelectric current density was lower in the porous material, compared to the dense material, while the diamond-filled samples demonstrated the highest current density. The temperature change with time (dT/dt) was observed to be higher for the diamond-filled samples, compared to dense and porous, suggesting that heat transfer in the specimen has improved. A computational study on heat flow through the material when subjected to thermal oscillations also showed that the rate of temperature change through the material increases with increasing thermal conductivity and thermal diffusivity, but decreases with increasing heat capacity. The improved thermal diffusivity of the diamond-filled porous ceramics facilitates greater heat flux through the material, leading to enhanced polarization fluctuations and, consequently, an increased pyroelectric current when subject to an oscillating thermal source of fixed frequency. In addition, diamond-filled porous samples performed the best in the energy storage study, while the dense samples exhibited the least. Incorporating high-thermal-conductivity materials, such as diamond, into porous ceramics improves their pyroelectric figures of merit, demonstrating potential for advanced thermal energy harvesting and rapid sensing applications.

[*P1-3-10*] Unraveling the impact of different dopants on ferroelectric polarization rotation through first-principles and atomistic simulations

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Ferroelectrics (FE) materials are an important class of materials for various technological applications such as non-volatile random-access memory (NVFRAM) mainly due to spontaneous, switchable electric polarization. Polarization switching is key in many device applications. Defect dipoles in ferroelectrics can act like a bias field or restoring forces to rotation of the polarization after an electric field has been applied and then removed. Using ab initio molecular dynamics (AIMD), we compare polarization rotation induced by defect dipoles, in which divalent transition metal dopants on the perovskite B-site couple with neighboring oxygen vacancies, in the archetypical ferroelectric $BaTiO_3$. We compare the effects of Cu^{2+}, Mn^{2+}, and Fe^{2+} dopants. We find that copper is much more efficient at enhancing electromechanical coupling or restoring polarization direction, over manganese or iron. We relate this effect of chemistry to the shape and bonding of the transition metal cations. We also study polarization switching in the presence of single defect using atomistic simulations.

[*P1-4-11*] Reinforcement learning-assisted automated ferroelectric domain wall controls

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Precise control of ferroelectric domain walls (DWs) is a critical challenge for the development of DW-based memory and nanoelectronic devices. Although recent advances in scanning probe microscopy (SPM) – enabled automated experiments have improved tip manipulation efficiency, real-time optimization of tip trajectories for creating arbitrary domain configurations remains largely unresolved. In this work, we introduce a reinforcement learning (RL) framework for autonomous DW manipulation, leveraging a three-dimensional machine-learning-accelerated phase-field surrogate model to significantly speed up environment dynamics. Trained entirely within the phase-field simulator, the RL agent autonomously designs target domain states by dynamically adjusting tip biases and trajectories in real time. We further demonstrate the successful transfer of the pre-trained agent to real SPM experiments, enabling the creation of large-scale, user-defined domain structures. Notably, the agent can also reconfigure domain patterns on the fly, directly transitioning between arbitrary DW configurations without prior initialization. By enabling direct, real-time control of ferroelectric domain wall structures in PFM experiments, this approach opens new avenues for adaptive design and manipulation of DW-based functional devices.

[*P1-5-12*] Atomic-scale engineering of ZnO via Mn, V, and Y doping: A combined electronic and vibrational study

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This paper utilizes the first-principles density functional theory (DFT) to systematically explore the effect of transition-metal doping, that is, Manganese (Mn), Vanadium (V), and Yttrium (Y), on the structural, electronic, vibrational, and optical properties of Zinc Oxide (ZnO). Mn, V and Y substitutional incorporation at Zn lattice sites cause significant changes to the electronic band structure, increasing carrier concentration and dielectric response, which are essential in optoelectronic devices. In order to measure lattice dynamics and vibrational stability, phonon dispersion calculations are carried out and it is confirmed that there are no imaginary frequencies and hence dynamical stability of the doped configurations. Moreover, thermal stability at realistic operating conditions is tested under ab initio molecular dynamics in canonical (NVT) ensemble which shows strong structural integrity at high temperature. Satisfying Born criteria, mechanical stability is confirmed through the calculations of elastic constants, and all doped systems are satisfactory. Simulations of X-ray diffraction (XRD) patterns and optical parameter measurements – e.g. reflectivity, refractive index and electrical conductivity – have also been used as complementary analyses, which show large enhancements in light matter interaction properties. These results offer profound understanding of how Mn, V and Y dopants can be used to modify the properties of ZnO giving a theoretical basis of designing advanced materials in high-performance optoelectronic and dielectric devices.

[*P1-6-13*] Symmetry influence on functional properties of H-DABCO based ferroelectric ionic plastic crystals

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Organic ferroelectric materials have gained traction in the last decades due to their low fabrication temperature, mechanical flexibility and structural tunability compared to traditional ceramic material. A class of organic ferroelectric material, ferroelectric ionic plastic crystals also have the unique advantage of being easy to recycle due to their solubility in organic and aqueous solutions. Recyclability being of particular interest in the current push towards more sustainable electronics and reduction of electronic waste. Plastic crystals are characterized by the molecules in the structure having varying degree of rotational freedom in the solid crystalline phase with fixed center of mass. However, what influence this rotation has on the functional properties and phase transitions are not well understood in these materials. Using the ionic molecule H-DABCO+(1-4-diazabicyclo[2, 2, 2]octane) as a base component for material selection, the room temperature structure of the two isostructural orthorhombic crystals H-DABCOClO_4 and H-DABCOBF_4 were compared with the monoclinic crystal H-DABCOReO_4. These systems are ferroelectrics, where the anion and cation sublattices are displaced. The anions have tetrahedral coordination with Cl, B or Re in the center, and the organic molecules are connected through an ordered NH•••N chain. Molecular Dynamics simulations with Machine-Learned Force Field trained on Density Functional Theory data were used to study these materials in terms of electronic densities, phase transitions, electrical properties, polarization, proton order and molecular rotational freedom. H-DABCOReO_4 showed the highest retention of molecular order of the investigated systems, both with respect to anion rotation and proton transfer between the organic molecules. All systems showed a mixing state for the anions below the phase transition temperature, where the atoms in the anions rotates between minima positions. In the high-temperature phase, the anions have complete rotational degree of freedom giving randomly oriented tetrahedrons. All systems also showed proton transfer in the NH•••N chain occurring in the THz frequency range from below the phase transition temperature, 350 K, to the high-temperature phase at 500 K, but retaining some preferential site in the hydrogen bonded chain. The energy barrier for proton chain switching was small for all systems, with H-DABCOReO_4 showing the greatest asymmetry in the energy landscape resulting in preferential transfer of protons. Our study points out that careful consideration of anion species, which tune the molecular disorder, can increase the polarization and Curie temperature and have a large influence on the response properties in these systems. Thus, a deeper understanding of the functional properties of ferroelectric ionic plastic crystals can increase the viability of the materials for use in more sustainable electronic components.

[*P2-4-15*] Unlocking low-temperature routes for lead-free piezoelectrics: Toward sustainable and flexible energy harvesting

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Piezoelectric materials are at the cutting edge of a wide range of application and emerging technologies, from low-power electronics to energy systems and biomedical devices. As environmental constraints intensify, the transition toward lead-free piezoelectric materials and sustainable processing routes has become a strategic scientific and technological challenge. While low temperature approaches are essential for the fabrication of flexible devices - enabling the integration of ceramics with polymer substrates - they often result in degraded functional performance. The key scientific locks and technological levers enabling low-temperature processing of lead-free piezoelectric ceramics will be addressed. Focusing on $(K,Na)NbO_3$-based materials, we highlight recent advances in sintering and screen-printing strategies aimed at the fabrication of high-performance ceramics and thick films for flexible energy harvesting applications. In particular, our recent studies explore the unique features of Spark Plasma Sintering, such as pulse sequence and fast kinetics, to achieve controlled densification and microstructural optimization at temperatures below 700 °C. Beyond processing, this work provides new insights into the interconnected roles of chemistry, microstructure, and functional properties, offering design rules for low-temperature piezoceramics. The presentation will conclude with perspectives on the first steps toward a comprehensive Life Cycle Assessment, positioning low-temperature lead-free piezoelectrics as a key enabler for sustainable and flexible electronic systems.

[*P2-3-14*] Effects of Spark Plasma Sintering on the microstructure and properties of $Na_{0.5}Bi_{0.5}TiO_3$–$xBaTiO_3$ piezoceramics

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Lead-based ceramics remain the most widely used piezoelectric materials in industry due to their excellent and wide range of functional properties. However, in response to REACH regulations, lead-free alternatives are under intense investigation to achieve comparable performance. Among promising candidates, $Na_{0.5}Bi_{0.5}TiO_3$–$xBaTiO_3$ (NBT-xBT) perovskite compositions were shown to exhibit enhanced piezoelectric properties near their morphotropic phase boundary (MPB) where tetragonal and rhombohedral phases coexist. However, practical implementation of this material is challenged by a relatively high coercive field (~30 kV/cm) and low permittivity (ε_r<1000). NBT-xBT based systems also possess a well-known relaxor character which are non-ergodic at room temperature, yielding pseudocubic symmetry with frozen polar nanoregions in the non-poled state, while external stimuli (electric field or mechanical stress) induce an irreversible transition to a ferroelectric state through domain evolution. While the performance of lead-free ceramics sintered by conventional sintering still face challenges, alternative sintering techniques beyond conventional routes have been explored. Spark Plasma Sintering (SPS) and cold sintering process (CSP) are techniques that allow high densification rates of ceramics at much lower temperatures while controlling the grain growth. We performed and will present in this contribution the properties of NBT-6BT, NBT-8BT and NBT-12BT ceramics prepared by SPS and compare the structure and properties with conventionally sintered ceramics. Microstructural (SEM and EDS) and structural (XRD) characterizations showed a secondary phase of metallic bismuth present after SPS, which disappears after post-annealing at 600 and 800 °C in oxygen or air. XRD analyses also revealed that SPS influences the apparent symmetry of the material (tetragonal/rhombohedral vs. pseudocubic at MPB in conventionally non-poled state) as well as accumulated strains which are observed through additional broadening of the peaks that are prone to diminishing with time (aging) or annealing (relaxation). SEM analysis showed that the grain size of SPS-processed ceramics is smaller than in the conventionally sintered counterparts, limiting the development long-range domain structure and thus the piezoelectric response. This microstructural effect is also reflected in the dielectric behavior: permittivity measurements show a more pronounced frequency-dependent shift of the dielectric maximum in SPS samples, indicative of enhanced relaxor-like behavior. Moreover, the hysteresis loops of SPS NBT–xBT ceramics display a shift and asymmetry, characteristic of non-switchable imprinted defect dipoles. This phenomenon likely originates from oxygen and/or bismuth vacancies formed under the reducing conditions of the SPS process, that might remain in the material even after subsequent oxygen annealing. In the future we plan to optimize the SPS conditions to reduce the formation of bismuth and increase the grain size by adjusting the calcination process of the powder. This should lead to improved piezoelectric response in SPS ceramics.

[*P2-5-16*] Critical factors in the freeze casting of porous BCTZ ceramics

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The $Ba_{0.85}Ca_{0.15}Zr_{0.1}Ti_{0.9}O_3$ (BCZT) system is currently one of the most promising lead-free piezoelectric candidates due to its high spontaneous polarization, elevated permittivity, and excellent piezoelectric coefficients. Compared to conventional dense ceramics, porous BCTZ architectures offer unique advantages, such as a reduced acoustic impedance and a significantly enhanced piezoelectric energy harvesting Figure of Merit (FoM), making them ideal for low-power electronics and wireless sensor technologies. Among various processing routes, freeze casting (ice-templating) has emerged as a powerful technique for fabricating hierarchically porous structures with 3-1 type connectivity. By sublimating the solvent from a frozen ceramic slurry, this method yields highly aligned pore channels that are critical for directional performance. However, achieving a reliable and high-performance microstructure requires rigorous control over the complex interplay between slurry rheology and solidification kinetics. In this work, we address the fundamental technological challenges in the freeze-casting of BCTZ. The aqueous slurry formulation was optimized by evaluating the efficacy of different dispersants through zeta-potential and viscosity analyses to ensure high stability and homogeneity. We systematically investigated the influence of solid loading, cooling rates, and mixing protocols on the resulting pore morphology, total porosity, and degree of lamellar alignment. Furthermore, we highlight the critical role of the poling process in porous architectures, where traditional methods often lead to dielectric breakdown. The piezoelectric charge coefficient d_{33} and the longitudinal FoM were evaluated, demonstrating that carefully engineered porosity not only maintains functional integrity but significantly outperforms isotropic-porous and dense counterparts in harvesting efficiency.

[*P2-6-17*] Tailoring of the dielectric energy storage performance of $BaTiO_3$ based relaxor ferroelectrics

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Due to their high polarizability and low remanent polarization, relaxor ferroelectrics are considered promising materials for dielectric energy storage, particularly in power applications. Research has been focused on increasing the recoverable energy density and dielectric breakdown strength of these materials. Of particular interest are environmentally friendly lead-free materials, such as $BaTiO_3$ (BTO) based ceramics. In this ferroelectric composition, the relaxor state can be induced by chemical substitutions. One approach involves substitution the Ti^{4+} ions with Zr^{4+} or Sn^{4+} to disrupt the ferroelectric long-range order due to local strains caused by cation size mismatches. The ferroelectric phase transition shifts to lower temperatures and becomes more diffuse until the ferroelectric-relaxor crossover is completed. This is also beneficial for energy storage applications due to a high dielectric permittivity over a wide temperature range Another strategy is the addition of $BiMeO_3$ (where Me can be Mg, Ta, Zn, Nb, and Sc). This promotes relaxation behavior due to charge disorder while simultaneously increasing polarizability due to the strong covalent bond between Bi and oxygen.

We combine these approaches and sintered ceramic systems of Ba(Ti,Sn)-$BiYO_3$, Ba(Ti,Zr)-$BiZn_{1/3}Nb_{2/3}O_3$, and Ba(Ti,Zr)-$BiZn_{1/3}Ta_{2/3}O_3$. In all that systems, increasing the $BiMeO_3$ content drives a cross-over from the ferroelectric to the relaxor state. The structural, dielectric, and energy storage properties of the samples were characterized. The breakdown strength was evaluated, and the influence of the composition and microstructure on the breakdown strength were analyzed. The best energy storage characteristics show materials from the cross-over region, which combine relaxor and ferroelectric features.

[*P3-3-18*] Barium strontium titanate multilayer capacitors for high-performance waste-heat harvesting

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The global electricity consumption continues rising, while huge amounts of heat are wasted in industrial, commercial residential, and transportation activities. Recovering waste heat is critical for achieving sustainable electrification. The polarization of pyroelectric materials changes when their temperature changes, providing an opportunity to convert waste heat into electricity. Recent studies demonstrated that lead-containing pyroelectric materials can harvest 4.4 J cm^{-3} through electro-thermodynamic cycles, giving an effective route for waste heat recovery [1]. However, the environmental toxicity of lead limits large-scale application and highlights the need for eco-friendly alternatives. In this work, we report barium strontium titanate multilayer capacitors doped with 0.2% manganese ($Ba_{0.65}Sr_{0.35}Ti_{0.998}Mn_{0.002}O_3$ MLCs) as a lead-free candidate for pyroelectric energy harvesting. A maximum energy density of 4.0 J cm^{-3} has been achieved under an applied field of 306 kV cm^{-1} across a 190 K temperature span in an Olsen cycle. We identified the ferroelectric to paraelectric phase transition occurring near room temperature, around 293 K, and further analysed the influence of the phase transition to determine optimal operating temperatures. The high dielectric strength of these MLCs enables efficient energy conversion across a broad and practical temperature range. Our findings show that $BaSrTiO_3$-based materials can match the performance of benchmark lead-based systems, revealing their strong potential for environmentally friendly and sustainable energy harvesting applications. References: [1] Lheritier, P. et al. (2022) Large harvested energy with non-linear pyroelectric modules, Nature, 609(7928), pp. 718–721. https://doi.org/10.1038/s41586-022-05069-2.

[*P3-4-19*] Electromechanical hardening of piezoelectrics induced by DC bias fields

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Hard-type piezoelectrics with excellent electromechanical performance and minimal energy loss are highly desired for high-power actuator and transducer applications [1]. Conventionally, hardening in piezoelectrics, reflected by an elevated mechanical quality factor, is achieved by suppressing the ferroelectric domain wall motion through the introduction of defect complexes [2,3]. Despite their effectiveness, these approaches often result in reduced piezoelectric response and unstable electrical properties under high-drive conditions. Therefore, the exploration of alternative hardening mechanism that can preserve piezoelectric performance while minimizing losses remains an important challenge. In this work, an alternative hardening strategy based on ferroelectric domain-wall pinning induced by large DC bias fields is investigated. Unlike conventional piezoelectric hardening approaches, which primarily reduce extrinsic contributions associated with domain-wall motion, DC-bias-induced hardening influences both domain-wall mobility and the intrinsic lattice response at the atomic scale, leading to more effective hardening and enhanced electromechanical performance. We examined this approach in both lead-based $Pb(Zr,Ti)O_3$ (PZT) and lead-free $(1-x)(Na_{1/2}Bi_{1/2})TiO_3$-$x(K_{1/2}Bi_{1/2})TiO_3$ (NBT-KBT) piezoelectric systems with tetragonal, rhombohedral, and MPB compositions using a custom-designed measurement setup enabling precise resonance impedance spectroscopy under combined AC and DC electric field excitation [4]. The resonance behavior of the piezoceramic samples under the application of DC-bias was examined in transverse (31) vibration mode, and the DC-field dependent evolution of key electromechanical parameters was evaluated. Application of a DC electric field along the polarization direction (up to breakdown threshold) resulted in increased mechanical quality factor (Q_m), accompanied by decreases in the piezoelectric coefficient (d_{31}), elastic compliance (s_{11}), electromechanical coupling factor (k_{31}), and dielectric permittivity (ε_{33}), consistent with ferroelectric hardening. In contrast, reversing the field direction led to a reduction in Q_m and an increase in the electromechanical coefficients, demonstrating ferroelectric softening. Although single-phase NBT-KBT and PZT-based ceramics exhibited higher mechanical quality factors, the variations in electromechanical parameters were more pronounced in MPB compositions, which is attributed to the greater contribution of domain wall motion to the macroscopic strain. These results demonstrate that tuning the DC field can effectively influence domain wall dynamics, enabling precise control over the electromechanical response. References: [1] Y. Gao, K. Uchino, D. Viehland, Time dependence of the mechanical quality factor in “Hard” lead zirconate titanate ceramics: Development of an internal dipolar field and high power origin, Jpn. J. Appl. Phys. 45, 9119 (2006). https://doi.org/10.1143/JJAP.45.9119; [2] T.N. Nguyen, H.C. Thong, Z.X. Zhu, J.K. Nie, Y.X. Liu, Z. Xu, P.S. Soon, W. Gong, K. Wang, Hardening effect in lead-free piezoelectric ceramics, J. Mater. Res. 36, 996 (2021). https://doi.org/10.1557/s43578-020-00016-1; [3] L. Cangini, H. Huang, C. Zhao, J. Koruza, K. Wang, J. Rödel, L. Fulanović, Hardening

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[*P3-5-20*] Lead-free porous freeze-casted $BaTiO_3$ platelet spheres for piezocatalysis applications

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Electrical charges generated by piezoelectric material can be used for catalytic reactions (piezocatalysis). This work reports the piezocatalytic properties of porous $BaTiO_3$ platelet beads fabricated via a drip-freeze-cast method. The porosity increases the effective surface area, which results in improved piezocatalytic properties. Scanning electron microscopy images of the top surface and interior reveal that the platelets help to form a highly porous structure both on the surface and inside the beads, creating an interconnected pore network that enables rapid diffusion of reactants and products, thus facilitating more effective interactions at active catalytic sites. Brunauer-Emmett-Teller (BET) measurements confirm that porous $BaTiO_3$ platelet beads possess a specific surface area and porosity when compared with porous $BaTiO_3$ beads fabricated from $BaTiO_3$ powder. The frequency-dependent dielectric properties and ferroelectric polarisation vs electric field (P-E) hysteresis loops of the porous $BaTiO_3$ platelet beads were measured. These beads were corona poled to measure the piezoelectric charge coefficient (d_{33}). Rhodamine B (RhB), a commercial dye, was selected as the target pollutant to evaluate the degradation performance of the $BaTiO_3$ platelet beads. The RhB degradation shows that the unique combination of platelets and porosity significantly improves the efficiency of piezocatalytic processes. The easy recovery and reusability of these beads make this process cost-effective and environmentally friendly. This work is supported by UKRI New Horizons on Porous Piezoelectric Single Crystal Sensors (POPSICALS; Project No. EP/X018679/1) and UKRI Frontier Research Guarantee on “Processing of Smart Porous Electro-Ceramic Transducers - ProSPECT”, Project No. EP/X023265/1

[*P3-6-21*] Self-powered pyroelectric energy harvester based on lead scandium tantalate multilayer capacitors

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More than two thirds of the global energy is lost as heat, necessitating efficient thermal energy recovery systems to produce useful work [1]. Pyroelectric energy harvesting is one such technology, which can directly convert heat into electricity. Although the concept has been demonstrated at microscale, practical macroscopic implementations utilizing the nonlinear pyroelectric effects of the material remain limited. In our previous work, lead scandium tantalate (PST) multilayer capacitors (MLCs) were shown to deliver a maximum energy density of 4.4 $J \cdot cm^{-3}$ under the Olsen cycle [2]. In this work, we advance this concept by developing a self-powered macroscopic pyroelectric energy harvester based on PST MLCs operating under the Stirling cycle. The prototype was subjected to periodic temperature variations using a closed-loop fluidic thermal system. The energy harvested by the prototype was regulated through an integrated power management circuit comprising a step-down converter and stored in an external capacitor. The net electrical energy gain in the storage capacitor was nearly 100 mJ per cycle. The energy from the external storage capacitor was used to initiate successive Stirling cycles while autonomously powering a Bluetooth low-energy (BLE) communication device. This BLE device continuously transmitted data from its sensor board to a customized mobile application. The device operated for more than 30 minutes without any external energy input, demonstrating the feasibility of autonomous pyroelectric energy harvesters for practical applications in the near future. [1] Aravindhan A, et al. Converting heat to electricity with non-linear pyroelectrics: A review. International Materials Reviews. 2025 70(7):576-611. doi:10.1177/09506608251359364; [2] Lheritier P, et al. Large harvested energy with non-linear pyroelectric modules. Nature 609.7928 (2022): 718-721.

[*P1-8-23*] Sequential switching and polarization-programmed electroresistance in HZO based ferroelectric–insulator–ferroelectric thin films

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HfO_2-based ferroelectrics provide a CMOS-compatible route to scalable polar dielectrics, yet reliable access to multiple programmable states remains challenging. Here we explore a ferroelectric–insulator–ferroelectric (FE/I/FE) multilayer concept designed to enhance polarization control over low-bias transport: $Hf_{0.5}Zr_{0.5}O_2$ (HZO) / TiO_2 / HZO stacks grown by molecular beam epitaxy on conductive Ge and processed into Pt-electrode capacitors. Structural characterization using grazing-incidence X-ray diffraction, cross-section TEM, SAED, and FFT-assisted HRTEM analysis confirms the presence of orthorhombic HZO locally, while revealing a microstructural asymmetry between the bottom and top HZO layers. Electrical measurements show sequential ferroelectric switching manifested by two distinct switching-current peaks under one polarity and a single sharper peak under the opposite polarity, consistent with non-identical switching of the two ferroelectric layers and an internal-field-driven asymmetry. Importantly, preset polarization states translate into clearly separated low-bias conduction characteristics and near-rectangular resistance–programming loops, indicating polarization-programmed electroresistance in this FE/I/FE architecture. Complementary impedance spectroscopy supports a state-dependent redistribution of effective resistive/capacitive contributions associated with the internal interfaces, highlighting the central role of interface electrostatics and slow interfacial charge dynamics in shaping the readout. Ongoing work will establish design rules by direct comparison against control stacks with identical electrodes and comparable thicknesses, including single-layer HZO, FE/I (HZO/TiO_2) asymmetric multilayers, and TiO_2 replacement with Al_2O_3. These comparisons are expected to separate predominantly electrostatic (polarization/barrier) effects from defect- and trap-assisted contributions, and to guide optimization of switching symmetry and analog programmability in hafnia-based multilayer polar dielectric devices.

[*P2-7-25*] Selective synthesis of Cesium Niobate ($Cs_2Nb_4O_{11}$) and benefits for antiferroelectric and electrocatalytic applications

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Cesium niobate ($Cs_2Nb_4O_{11}$) is a known antiferroelectric material, which also exhibits photocatalytic properties. Considering this material is lead-free, intuitively it would be expected there would be a large body of research exploring the aforementioned properties which are intrinsic to this material. However, this is not the case. Rather, studies of cesium niobates – especially $Cs_2Nb_4O_{11}$ – are seldomly reported. It is surmised that the lack of extensive reported work for $Cs_2Nb_4O_{11}$ is influenced by the inherent challenges in the synthesis of alkali-niobates; which are well established. For brevity we elaborate the latter as encompassing the volatility of alkali salts, sluggish reactivity of crystalline Nb_2O_5, and the moisture sensitivity or metal-organic precursors. In particular, while metal-organic precursors are a viable alternative to circumventing the slow reactivity of Nb_2O_5, it carries the burden of working in controlled atmospheres (glovebox etc.) which is a formidable expense for early-career researchers, whom may only have access to limited resources. We have sought to establish robust and reproducible means of synthesising $Cs_2Nb_4O_{11}$, to provide a viable means of exploring the (anti)ferroelectric and electrocatalytic properties of this material. This was motivated by our previous work which elucidated the synthesis of the lead-free piezoceramic, sodium potassium niobate ($Na_{0.5}K_{0.5}NbO_3$, KNN), via a single-component precursor. Herein we report how $Cs_2Nb_4O_{11}$ can be made similarly --via a single-component precursor -- by utilising the polyoxometalate species hexaniobate [$(Nb_6O_{19})^{-8}$]. We characterise $Cs_2Nb_4O_{11}$ using PXRD, Raman spectroscopy, and in situ TEM with heating, to demonstrate crystallisation of $Cs_2Nb_4O_{11}$ from the amorphous precursor to orthorhombic $Cs_2Nb_4O_{11}$. We also report our investigations from ferroelectric characterisation and electrochemical studies, to characterise ferroelectric behaviour, as well as the propensity to support charge intercalation and electrocatalysis, respectively.

[*P2-8-26*] Stabilizing antiferroelectric phase in $NaNbO_3$-based ceramics via dopant design

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Lead-free antiferroelectric (AFE) materials are gaining significant attention for energy storage applications due to the high energy density of such capacitors [1-2]. AFE materials show reversible switching between the AFE and ferroelectric (FE) phases under applied electric field. Although sodium niobate ($NaNbO_3$) is known to crystallize with an orthorhombic perovskite structure and adopt characteristic AFE antipolar arrangements of atoms, it is difficult to stabilize its AFE state. It was previously shown that introducing a small concentration of dopant on the A and/or B sites of the ABO_3 perovskite, for example, by adding a small amount of $SrSnO_3$ to the $NaNbO_3$ matrix, stabilizes the AFE phase [3]. In this research work, our main goal was to stabilize the AFE phase in $NaNbO_3$ by co-doping with Ca or Bi on the A site and Mn on the B site, and to further investigate the effects of the dopants on the material's atomic and domain structures and energy storage properties. The ceramics were processed via solid-state synthesis and sintering and characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), and scanning transmission electron microscopy (STEM). We confirmed the incorporation of dopants into the perovskite structure and analyzed atomic-scale displacements of NbO_6 octahedra and A- and B-site cations by STEM, which revealed stabilization of a cationic antiparallel arrangement. Temperature-dependent phase transitions were studied using differential scanning calorimetry (DSC) and dielectric permittivity measurements, showing a noticeable downward shift in the polymorphic phase-transition temperatures in the doped $NaNbO_3$. The polarization– and strain-electric field hysteresis loops measured on the pure and doped materials, measured in the temperature range from 20 to 150 °C, demonstrated an effectively stabilized AFE phase in dopant-modified $NaNbO_3$, with reversible field-induced phase transitions to FE. We also observed the influence of sintering temperature and grain size on the stabilization of the AFE state. In the future, we will explore a broader range of dopants to maximize dielectric performance, reduce switching hysteresis to increase efficiency, and stabilize the phase in lead-free sodium niobate systems for high-efficiency energy storage devices. References: [1] L. Yang et al., Prog. Mater. Sci. 102, 72 (2019); [2] S. Aso et al., Sci Rep 13, 6771 (2023); [3] M. H. Zhang et al., Nat. Commun. 14, 1525 (2023).

[*P2-9-27*] Flexoelectricity in soft polymer films with tunable conductivity

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Flexoelectricity in matter is a two-way linear electromechanical coupling, like piezoelectricity, but direct flexoelectric effect corresponds to the electric polarization induced by a strain gradient (i.e. local curvature), whereas piezoelectric polarization is related to the strain itself. Similarly, converse flexoelectric effect is defined as an electric field gradient-induced strain or stress and piezoelectric effect is a coupling between strain or stress and electric field. Thus, due to the symmetry-breaking effect of the strain gradient, flexoelectricity may be observed in all dielectrics, while piezoelectricity can only be found in non-centrosymmetric materials. Besides, as strain gradients may dramatically increase when feature scale shrink down to the micro/nano range, direct flexoelectric response may become large and consequently has been widely studied in oxide thin films. However, strain gradients also inversely scale with elastic stiffness that may make flexoelectricity competitive with piezoelectricity in flexible soft polymer films. In this talk we will present the direct flexoelectric effect in specific polymer films, with flexoelectric coefficients up to 1000 times larger than those actually measured in dielectric polymers, thus possibly allowing an alternative to piezoelectric materials. The methodology consists in using semi-conducting conjugated structures exhibiting high polarizability. Hence, control of both electronic and ionic conductivities is a promising way to induce dipolar motion and free charges transport (i.e. large polarization changes) under strain gradient. The combination of the two functionalities- flexibility and enhanced flexoelectricity- enable integration of these films in task-oriented devices for low frequency (<100 Hz) mechanical energy conversion, such as large curvature sensors.

[*P3-7-29*] Epitaxial growth and multiferroic behaviour of pseudocubic perovskite $BaMnO_3$ thin films

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Multiferroic materials have attracted significant attention due to their ability to exhibit multiple ferroic orders simultaneously, offering great potential for next-generation low-energy spintronic devices. In particular, magnetoelectric multiferroics enable mutual control between electric polarization and magnetic order. A main goal in this field is to obtain single-phase multiferroic materials in which ferroelectric and magnetic orders coexist and are strongly coupled. Perovskite $BaMnO_3$ (BMO) has been theoretically predicted to exhibit robust multiferroic behaviour with a strong magnetoelectric coupling, arising from the coexistence of ferroelectricity and magnetism associated with the same Mn^{4+} ion. However, this perovskite phase is highly unstable and, to our knowledge, has never been synthesized before. In this work, epitaxial thin films of $BaMnO_3$ with a perovskite-like structure were grown by pulsed laser deposition, using an appropriate substrate to induce the strain necessary to stabilize the multiferroic phase. X-ray diffraction (XRD) measurements confirm the stabilization of a pseudocubic perovskite structure. Scanning transmission electron microscopy (STEM) and XRD were employed to identify optimal growth conditions and to determine the critical thickness beyond which the perovskite phase becomes unstable. The chemical composition was further verified using energy-dispersive X-ray spectroscopy (EDX) and electron energy-loss spectroscopy (EELS). The polar nature of the films, originating from the off-centering of Mn^{4+} ions, was investigated using a combination of high-angle annular dark-field (HAADF) and differential phase contrast (DPC) techniques. Finally, low-energy muon spin spectroscopy (LE-μSR) was used to probe the long-range magnetic order in selected films. These results demonstrate the strain-driven stabilization of a perovskite BMO phase with potentially ferroelectric and magnetic orders, providing new insights into the design of multiferroic materials. Our work opens promising pathways for the development of low-power spintronic and memory devices based on strain engineering of materials not stable in their bulk form.

[*P3-8-30*] Hybrid phonons in hexagonal manganites

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The exact mechanism responsible for the ferroelectricity in hexagonal manganite has been the subject of intense debate. Whether ferroelectricity and ferroelastic order appear at the same temperature and the role of covalency in the ferroelectric order have been discussed in several reports. High-temperature phase transitions are here investigated through the prism of lattice-dynamics evolution with temperature using polarized Raman spectroscopy. While previous analysis on $YMnO_3$ only showed partial softening and some anomalies for hard modes at two specific temperatures (900 K and fat 1200 K) no true soft mode could be identified. We here present new light scattering analysis demonstrating development of low energy excitations on heating and strong anharmonicity. We suggest phonon coupling mediated by acoustic phonons and discuss the high temperature behavior of in the context of the ferroelastic transition, order-disorder behavior and order-parameter fluctuations.

[*P1-10-33*] Ion irradiation effects on ferroelectric properties of hafnia-based oxides

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Fluorite based ferroelectric thin film materials are known as promising candidates for non-volatile memory (NVM) applications. They have a high potential to be integrated in novel chip architectures for beyond-Neumann approaches such as neuromorphic computing. Key CMOS-compatible ferroelectric materials are Hafnia-based oxides (HfO_2) with suitable co-doping elements (e.g. Zr, Si, Al, and others) [1]. A crystallographic phase transformation into the meta-stable ferroelectric orthorhombic phase can be achieved with a dedicated post metallization anneal. Many material-related electrical properties of Hafnia-based oxides have been elaborated in the recent years [2], however only limited knowledge is available concerning the ion irradiation effects on ferroelectric properties of Hafnia-based oxides. The latter is especially interesting and important for applications of NVM devices in radiation harsh environments. Thin ferroelectric films (10 nm, 12 nm) of HfO_2 with co-doping of Al and Si have been deposited via atomic-layer deposition (ALD) at Fraunhofer IPMS including bottom and top electrodes of TiN followed by Pt dot evaporation for electrical testing. Ion irradiation experiments have been conducted at GSI Helmholtzzentrum für Schwerionenforschung using Au ions (8.6 MeV/u) subjecting the thin film coupons to ion fluences ranging from 5·109/cm² up to 3·1012/cm² (at 1.635 GeV). Crystallographic thin film modification due to ion irradiation has been investigated by x-ray diffraction analysis. After ion irradiation the samples have been electrically investigated with standard dielectric-hysteresis measurement (DHM) and fatigue studies with subsequent field cycling up to 106 cycles. The investigated doped and undoped HfO_2 films both show a wake-up behaviour until 104 cycles (with the exception of Al-doped films at low concentration). For the classical 10 nm HfO_2 film a ferroelectric hysteresis loop was observed directly after ion irradiation with up to fluences of to 1012/cm². In contrast both for the Al- and Si-doped HfO_2 films ferroelectric hysteresis loops were observed after ion irradiation with all fluences up to 3·1012/cm². Further electrical field cycling up to 106 cycles showed no signs of fatigue in the co-doped films. The remanent polarization $2P_r$ was found to decrease with increasing ion fluence from about 30 µC/cm² down to 5 µC/cm² for all investigated thin films. Our investigations indicate that NVM devices based on Hafnia-based oxides (HfO_2) with suitable co-doping can also be operated under harsh ion radiation environments. References: [1] D. Lehninger et al., Al-Doped HZO: A BEoL compatible Ferroelectric Material for Automotive-Grade Memory, 2025 IEEE International Memory Workshop (IMW), Monterey, CA, USA, 2025, pp. 1-4; [2] Ferroelectricity in Doped Hafnium Oxide, Materials, Properties and Devices, edited by: Uwe Schroeder, Cheol Seong Hwang, and Hiroshi Funakubo, Woodhead Publishing Series in Electronic and Optical Materials, Second Edition, 2025.

[*P1-11-34*] Substrate-orientation dependence of epitaxial stabilization of the orthorhombic phase in electrode-free $Hf_{1-x}Zr_xO_2$ thin films

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Ferroelectricity in hafnia-zirconia ($Hf_{1-x}Zr_xO_2$, HZO) thin films has attracted significant attention due to its fundamental properties and potential technological applications, including compatibility with CMOS industry [1]. Under appropriate conditions, such as stress or the incorporation of dopants, HZO can stabilize an orthorhombic, non-centrosymmetric $Pca2_1$ phase that exhibits ferroelectric behavior. While most studies focus on polycrystalline HZO solid solutions, fewer have explored epitaxial growth to stabilize the polar, ferroelectric phase with different Hf/Zr ratios. Typically, HZO thin films were grown on perovskite- or fluorite-type substrates with bottom electrodes, which allows electrical characterization but can affect the film quality [2]. Here, we explore the deposition by pulsed laser deposition (PLD) of epitaxial $Hf_{1-x}Zr_xO_2$ thin films with several thicknesses directly on single-crystalline yttria-stabilized zirconia (YSZ) substrates with different crystallographic orientations. Extending the compositional range previously studied in the HZO system, this approach enables a systematic exploration of the effects of growth kinetics, substrate symmetry and epitaxial strain on phase formation and microstructure of the films. Our results reveal a strong substrate-orientation dependence of the phase stabilization across all three oxides studied (HfO_2, $Hf_{0.5}Zr_{0.5}O_2$ and ZrO_2). X-ray diffraction (XRD), reciprocal space mapping (RSM) and scanning transmission electron microscopy (STEM) have been utilized to confirm the presence of the orthorhombic or monoclinic polymorph as well as the high crystalline quality and epitaxial coherence of the films. On YSZ(001), films always stabilize in the equilibrium monoclinic phase, irrespective of their composition, in the entire thickness range explored. In contrast, for those films grown on YSZ(111) and YSZ(110), a polar orthorhombic phase is stabilized below a critical thickness, above which the thermodynamically stable monoclinic phase emerges. Our results demonstrate that Zr doping contributes to the stabilization of the orthorhombic phase, as the critical thickness increases with increasing Zr content. Remarkably, ferroelectricity in ZrO_2 films has been directly measured in 7 nm thick films on YSZ(111), taking advantage of the ionic conductivity of the substrate as a bottom electrode [3]. References: [1] U. Schroeder, M. H. Park, T. Mikolajick, C. S. Hwang, The fundamentals and applications of ferroelectric HfO_2, Nature Reviews Materials 7, 653–669 (2022); [2] I. Fina, F. Sánchez, Epitaxial Ferroelectric HfO_2 Films: Growth, Properties, and Devices, ACS Appl. Electron. Mater. 3, 1530 (2021); [3] E. Barriuso, R. Jiménez, E. Langenberg, P. Koutsogiannis, A. Larrea, M. Varela, C. Magén, P. A. Algarabel, M. Algueró, J. A. Pardo, Epitaxy-Driven

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[*P1-12-35*] HZO-based ferroelectric devices for memory and neuromorphic applications

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Ferroelectric tunnel junctions (FTJs) based on ultrathin $H_{0.5}Z_{0.5}O_2$ (HZO) have emerged as promising building blocks for non-volatile memory technology and neuromorphic computing, where the polarization-controlled transport enables multilevel resistance states. Although the HZO thickness in this work exceeds the tunneling regime, field-effect modulation governs the device operation and the structures are treated as ferroelectric field-effect diodes. Thus, this work is based on the investigation and integration of such devices on semiconductor platforms/substrates aiming at understanding the principles of fundamental transport mechanisms and demonstrating high-performance memory capability and synaptic functionality. Therefore, we employ p-type Ge and Si/$SrTiO_3$ (Si/STO) heterostructures as complementary model systems. Using p-Ge-based field-effect diodes, we focus on the fundamental thickness scaling behavior of ferroelectric devices. By systematically reducing the HZO thickness, we observe a pronounced increase in current while preserving ferroelectric switching and highlighting the relations between polarization, barrier thickness and carrier transport. The results provide insight into the limits of thickness scaling in HZO-based devices and specify the role of semiconductor screening and depolarization field effects in ultrathin ferroelectrics. On the other hand, devices fabricated on Si/STO exhibit adequate memory characteristics, including stable resistance states, high endurance up to 10^6 switching cycles at operation voltages of 2 V, and reproducible switching dynamics. The high quality of the semiconductor interface, combined with efficient field-effect modulation, makes these devices promising candidates for neuromorphic operations. They present stable synaptic behavior, including analogue conductance tuning and biologically inspired spike-timing-dependent plasticity (STDP) within a defined temporal window. In addition to ferroelectric polarization control, ionic motion within the STO layer contributes to the observed electroresistance, enabling gradual conductance modulation. Low-voltage operation ($\leqslant$2 V) and ultralow energy consumption of approximately ~8 fJ per programming event, further support the Si/STO platform as a reliable and efficient solution for neuromorphic devices. Additionally, retention measurements exceeding 10^4 s confirm the non-volatile nature of the synaptic states. To further assess the implications of the experimental results, simulations are performed using measured device characteristics. Experimentally extracted synaptic weights are incorporated in neural network models and exhibit high pattern recognition accuracy confirming that the observed behavior of the device directly translates into a functional neuromorphic performance. In conclusion, this study establishes a framework where p-Ge-based field-effect diodes serve as a platform to understand fundamental ferroelectric principles, while Si/STO-based devices enable high-performance memory capability as well as neuromorphic operation. These findings provide valuable guidelines for the design and integration of ferroelectric devices on semiconductor platforms for next-generation memory computing architectures.

[*P1-13-36*] Influence of Hf content on the ferroelectric properties of HZO and investigation of out-of-plane polarization

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Ferroelectricity in HfO_2 was discovered in 2011 and has experienced increasing interest ever since. Ferroelectric materials open promising possibilities for non-volatile memories and other electronic devices regarding functionality and energy-efficiency. Among ferroelectric materials, HfO_2, together with ZrO_2 and $Hf_{(x)}Zr_{(1-x)}O_2$ (HZO), stands out mainly due to its good compatibility with established CMOS processes and its scalability. The ferroelectric phase, which is a non-centrosymmetric orthorhombic phase (Pca21 o-phase), gives rise to the ferroelectric properties and can be stabilized in films of down to 5 nm thickness and below. However, non-centrosymmetric phases like the tetragonal (t-) and monoclinic (m-) phase are still present in those thin films and interfere with the ferroelectricity. One mayor challenge for successfully implementing HZO in memory and other devices is the wake-up effect. It describes the phenomena that the remanent polarization $2P_r$ increases with the number of field cycles. This modifies the memory window and introduces uncertainty in the read-out. The wake-up of the remanent polarization is associated with changes in the crystal structure of the HZO film, depinning of ferroelectric domain, and ferroelastic domain switching. Changing the ratio of Hf- and Zr-content in the HZO thin film affects the wake-up behaviour, together with the achievable maximal remanent polarization, the coercive field and the endurance. Therefore, we studied the effect of the composition of the HZO layer in ALD-deposited films of 6 and 12 nm thickness. We showed that the t- to o-phase transition in a thin film of HZO with an equal ratio of Hf and Zr appears at an electric field of approximately 1 MV/cm. For higher and lower Hf-contents, this transition happens at higher fields, indicating a reduced presence or stability of the ferroelectric o-phase. In addition, the presence of different crystal phases was observed by XRR and XRD measurements. One possible underlying mechanism of the wake-up effect is ferroelastic domain switching, where the polar axis of domains changes from in-plane orientation to out-of-plane. To get a better understanding of this mechanism, we fabricated and analysed coplanar finger structures, where the external applied electric field is orthogonal to the growth direction of the thin film. This allowed us to analyse the out-of-plane polarization in contrast to the already better described in-plane behaviour. The ferroelectric properties are a complex result of interfaces, lattice defects and the resulting stress and strain within the thin film. They therefore are influenced by the composition of the HZO layer, the neighbouring layers and the annealing conditions. Mainly the interfaces with neighbouring materials and the thereby introduced defects differ strongly in different directions. For the coplanar structures, we executed structural (GIXRD and EBSD) and electrical analysis together with stress-analysis and optoelectrical measurements to contribute to the understanding of the underlaying mechanisms of ferroelectricity in HZO.

[*P2-11-37*] Enhanced dielectric tunability in antiferroelectric PNZST ceramics

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DC-link, snubber, and filter capacitors are some of the most important components in high-power and high-speed electronics used in electromotive and renewable energy applications, medical equipment, and weapons platforms. Demands for these capacitors are typically high capacitance, which increases with DC bias, low losses at higher frequencies, high operational temperature, and no limitation of slew rate. Antiferroelectric ceramics meet these demands and are therefore used for the development of novel capacitors. In particular, the increase of the dielectric constant with DC bias, i.e., dielectric tunability, is one of the most interesting and still not fully understood properties of these materials. We investigated the origin of the dielectric tunability enhancement in antiferroelectric PNZST ceramics, using in-situ dielectric and thermal measurements. At low AC fields, the enhanced dielectric tunability is most likely related to intrinsic response and therefore exhibits its maximum value around the critical point of the antiferroelectric-to-paraelectric phase transition. However, by increasing the AC measurement signal, the dielectric tunability of 375% can be achieved in the vicinity of the phase coexistence point. The large enhancement is attributed to the enhanced nonlinear contributions indicated by the increased Rayleigh coefficient.

[*P2-12-38*] Phonons in $NaNbO_3$-based antiferroelectric ceramics

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The ability of antiferroelectric materials to attain both high power and high energy densities makes them especially promising for energy storage applications. However, attaining a proper antiferroelectric double hysteresis P-E loop at room temperature is, in practice, challenging. In some antiferroelectrics, the switching field is too high, or the dielectric breakdown of the sample prevents the switching field from being reached. The introduction of relaxor-like features by chemical modification is expected to result in slimmer antiferroelectric P-E loops and, consequently, reduced energy loss. Among antiferroelectric materials, $NaNbO_3$ is a particularly noteworthy substance due to its lead-free composition and the availability of a ferroelectric phase with a closely related energy level. From a fundamental perspective, it displays an intricate sequence of phase transitions triggered by varying temperature. At room temperature, the material exhibits an orthorhombic antiferroelectric phase very convenient for energy storage devices. However, this phase is predominantly stable in single crystals and in ceramic form. In ceramic form – depending on the processing and extrinsic factors such as grain size or defects – $NaNbO_3$ can develop a ferroelectric phase. In order to stabilise the antiferroelectric phase and obtain improved hysteresis loops, chemical substitution with $SrSnO_3$ in different amounts was tried. We have studied the effect of cationic substitutions on the phonon and dielectric properties using different spectroscopic techniques, such as Raman and infrared spectroscopy, as well as high-frequency dielectric spectroscopy. After analysing the dynamics of the main phase transitions during heating and cooling, the thermal hysteresis, and the behaviour of phonons in different samples, we can confirm that $SrSnO_3$ affects the energetic balance between the different structural phases and electrical properties. This shifts the permittivity maximum to lower temperatures and stabilises the antiferroelectric phase at room temperature. The P-E hysteresis loops become slimmer, and this effect is linked to the dielectric behaviour of the ceramics, which is mainly driven by phonons. Comparing the temperature behaviour of phonons in single crystals and ceramics reveals several soft modes that are responsible for the different phase transitions. This work is supported by a Lead Agency GAČR Czech Slovenian project (no. 24-10699K)

[*P2-13-39*] Mechanistic insights into stress-induced antiferroelectric-ferroelectric phase transitions in polycrystalline $NaNbO_3$ ceramics

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Due to the growing significance of energy storage, ceramics for high energy density capacitors have become an increasingly prominent area of research. For this reason, current research primarily focuses on enhancing the energy storage performance and efficiency. Despite the importance for implementation in applications, however, there remain few investigations on the mechanical properties. Here, we investigate the role of uniaxial compressive stress on polycrystalline $NaNbO_3$, a lead-free antiferroelectric with significant potential for advanced energy storage applications. Through ex-situ stress-dependent crystal structure analysis using XRD as well as Raman mapping, we demonstrate that $NaNbO_3$ ceramics, which initially exhibit an antiferroelectric P phase accompanied by a ferroelectric Q phase, undergo a stress-modulated change in the crystal structure and domain state. This is analogous to the well-known irreversible electric field-induced AFE-to-FE phase transition found in $NaNbO_3$. Ex-situ Raman mapping of unpoled and mechanically loaded samples revealed spatial variations in the AFE and FE phases, demonstrating the inhomogeneity of the stress-modulated structural phase transition in the polycrystalline microstructure. In addition, the large signal mechanical response of poled and unpoled samples was characterized, showing a significant decrease in the coercive stress of $NaNbO_3$ and an increase the backswitching rate due to the formation of a long-range ordered ferroelectric structure with orientation and non-180° domain switching. Revealing the complicated role of compressive stress on $NaNbO_3$ will help to understand real-world operating conditions and provide deeper insights into the underlying physical mechanisms, providing guidance for the design and application of antiferroelectric materials.

[*P2-14-40*] Enhancing the antiferroelectric response of $AgNbO_3$ thin films

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Dielectric materials are widely utilized in numerous advanced high/pulsed power electronic systems due to their distinctive features of high-power density, ultrafast charge/discharge capability, long storage lifetime, and excellent thermal stability. These materials developed for energy storage capacitors include linear dielectrics, ferroelectrics, antiferroelectrics, and relaxor ferroelectrics. Among them, antiferroelectrics have attracted extensive attention for energy storage applications because of their double hysteresis loop and zero remnant polarization. Within this class of materials $AgNbO_3$-based lead-free perovskites are promising candidates due to their environmentally friendly nature and strong intrinsic antiferroelectric response. In this work, we have grown $AgNbO_3$ thin films using pulsed laser deposition and examined their structural properties using X-ray diffraction (XRD) and scanning electron microscopy (SEM). The presence of metallic Ag particles on the $AgNbO_3$ surface with a size ranging from nanometres to micrometres indicates excessive Ag creating conductive pathways and severely compromise the electrical performance, suppressing the antiferroelectric behaviour. A high oxygen pressure post-annealing process is demonstrated to stabilize the $AgNbO_3$ phase and drive excess Ag to the film surface, followed by a post-deposition treatment that removes the residual metallic Ag while preserving the $AgNbO_3$ phase. This procedure reduces the leakage current significantly and enables the access to the antiferroelectric properties of $AgNbO_3$. Doping was also investigated to stabilize the antiferroelectric phase of $AgNbO_3$ and improve the performance of $AgNbO_3$ thin films. These methods offer an effective way to enhance the performance of $AgNbO_3$ thin films and open the way to their application in eco-friendly energy storage devices.

[*P1-14-46*] Lead-free KNN-based piezoelectric ceramics: Design and mechanical characterization

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For piezoelectric devices, materials such as lead zirconate titanate based ceramics (PZT), have nowadays dominated the industrial market thanks to their high and tunable piezoelectric properties. However, the lead contained in these ceramics and known for its toxicity, has become an issue for their use in the European Union, following its banishment in electronic devices in 2003. Therefore, research in alternative lead-free piezoelectric materials have been investigated while still not being introduced at an industrial scale on account of manufacturing processes or inequivalent response values of PZT. Among lead-free ceramics composition, the $(K,Na)NbO_3$ (KNN) system has been one of the most investigated and promising candidate that needs to be further investigated to introduce it at an industrial scale. For producing high quality ceramics, chemical modification such as doping is used, in addition to Spark Plasma Sintering (SPS) to limit alkali volatilization or excessive grain growth. It also allows a faster sintering step that gives time and energy consumption gain. However, it remains a lack of data on the mechanical behaviour to scale-up this material and to push forward its introduction at an industrial scale to fulfil European directives. This study aims to elucidate the influence of ferroelectric characteristics on mechanical behavior, thereby providing insight into the relationship between domain structure and mechanical properties. To this end, highly controlled in-situ SEM nanoindentation tests, with precise tip positioning and region-of-interest (ROI) selection, were conducted on KNN. The ROIs were first identified by Piezoresponse Force Microscopy (PFM) mapping of the ferroelectric domain structure. Subsequent in-situ SEM nanoindentation revealed that localized mechanical loading induces changes in the piezoresponse, as confirmed by PFM mapping of the affected ROIs. This work represents a significant step toward clarifying how external factors could affect electromechanical devices.

[*P1-15-47*] Ferroelectric hardening of lead-free (Ba,Ca)(Zr,Ti)O_3 piezoceramics through acceptor-doping

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The ferroelectric (Ba,Ca)(Zr,Ti)O_3 ceramic system (BCZT) has been a focus of interest in the field of lead-free piezoelectric ceramics since 2009, due to its potential to replace Pb(Zr,Ti)O_3 (PZT) in soft-type ferroelectric applications such as haptic devices, sensors, and precision actuators. To tailor its ferroelectric properties towards hard-type resonance applications, systematic doping strategies need to be developed. However, while the desired doping effect of ferroelectric hardening through acceptor-oxygen-vacancy defect complexes is well-established for the related $BaTiO_3$ system, past studies on doped BCZT show conflicting results, and the majority do not report any ferroelectric hardening at all. To this date, hard-type ferroelectric properties, comparable to or exceeding those of commercial PZT, have not been achieved for acceptor-doped BCZT. In our study, we investigated the influence of aging on the ferroelectric hardening in Fe, Mn, and Mg acceptor-doped and Fe/Nb co-doped BCZT and reported the influence of aging time on the piezoelectric performance of doped BCZT. We analyzed the microstructure development using optical microscopy and used X-ray diffraction, as well as scanning electron microscopy with energy dispersive X-ray spectroscopy, to ensure phase-purity. The temperature- and frequency-dependent dielectric permittivity was measured to clarify the phase transition temperatures in each sample. We measured the polarization and strain hysteresis and subsequently poled the samples. Changes in the piezoelectric coefficient d_{33}, as well as the resonance parameters k_p and Q_m, were monitored in regular intervals throughout the aging time. After aging, we re-measured the polarization hysteresis to confirm that the characteristic “pinched” shape is present and measured the high-power performance of the aged doped BCZT samples. Our study revealed that ferroelectric hardening in Mg-doped BCZT occurs after aging for a few days in both poled and unpoled samples, while Fe, Mn, and Fe/Nb co-doped BCZT show ferroelectric hardening only after three months in a poled state. In an unpoled state, these samples did not exhibit any signs of hardening, even after over a year of room temperature aging. We found that the figure of merit (FOM) for resonance applications of unaged acceptor-doped BCZT was only about 60% higher than that of undoped BCZT. However, after aging, Q_m more than tripled for some samples while the deterioration of k_p was small, leading to an increase in the FOM by over 250%. Notably, we also achieved considerably improved high-power behavior after aging, even exceeding the stability of commercial Pb(Zr,Ti)O_3 materials. In highly acceptor-doped BCZT, we also observed the formation of a relaxor-like phase with outstanding electrostrictive coefficients of up to 0.063 m^2/C^4. Our findings shed light on the important interplay between co-doping, aging, and defect complex formation, which leads to ferroelectric hardening. The improved figure of merit for resonance applications and high-power behavior, in aged acceptor-doped BCZT, mark an important step towards the development of environmentally friendly BCZT-based hard-type piezoelectrics.

[*P1-16-48*] Engineering dynamics through field-induced transformations in lead-free NBT piezoelectric ceramics

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The structural and functional evolution of the lead-free ceramic system (1–x)$Na_{0.5}Bi_{0.5}TiO_3$–6%$BaTiO_3$–x$Bi(Mg_{0.5}Nb_{0.5})O_3$ (NBT–6BT–xBMN) was investigated with a focus on compositions at x = 0, 1, and 2 mol%. While all three samples exhibit comparable dielectric properties, our analysis reveals that the source of exceptional piezoelectric performance is a field-induced, irreversible structural transformation. For the base NBT–6BT (0% BMN), the piezoelectric coefficient (d_{33}) is 125 pC N^{-1}, a baseline value for this material.[1] A minor compositional tweak to 1% BMN dramatically increases the d_{33} to a peak of 183 pC N^{-1}, representing not only a 46% enhancement over the base material but also the highest d_{33} for un-textured bulk ceramics ever reported to date. This remarkable improvement is directly linked to an observed irreversible pseudocubic-to-tetragonal+rhombohedral (T-R) "switch", followed by strong domain switching and lattice deformation. In stark contrast, the 2% BMN sample remains structurally locked in a stable pseudocubic phase, exhibiting minimal functionality with a d_{33} of just 35 pC N^{-1}. This study powerfully demonstrates that optimized piezoelectricity in this system is not an inherent property but is engineered by facilitating dynamic structural transformations under an electric field. The 1% BMN composition emerges as an up-and-coming candidate for applications requiring strong direct piezoelectric properties, such as medical ultrasonic devices.

[*P3-15-51*] Thin films, bulk and multilayer systems – Effects of geometry on ferroelectric material performance in different applications

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It is obvious that specific applications require specific material geometries: piezoelectric MEMS or ferroelectric RAMs are based on thin films, optical applications such as second harmonic generation typically use bulk single crystals, and electrocaloric applications work best in systems combining high thermal mass with low voltage requirements such as they are found in multilayer capacitors (MLCs). At the same time, each application has its own requirements to the stability of the ferroelectric polarization: while e.g. FE-RAMs need high remanent polarization stable for long times, emerging applications such as capacitive energy storage or electrocaloric cooling benefit from less stable domain structures, with high field-induced polarization and little remanence. This presentation demonstrates how material geometry and structural order influence domain stability and ferroelectric phase transitions and thereby help or hinder specific application cases. To this end, three different lead-based perovskite-structured materials are investigated: lead zirconate titanate ($Pb[Zr_xTi_{(1-x)}]O_3$, PZT) in the ferroelectric phase near the morphotropic phase boundary around x = 0.52 and in the nominally antiferroelectric phase at x = 0.04, and lead scandium tantalate ($Pb[Sc_{1/2}Ta_{1/2}]O_3$, PST). The interaction of PZT thin films prepared by solution deposition with light at visible wavelengths as well as ac electric fields in the radio frequency and millimeter-wave range is studied and compared with those of bulk systems. By combining electric bias, optical illumination, and thermal stimulation, high electrical tunability up to 23% at mm-wave frequency was obtained with low hysteresis. The results are rationalized based on the phonon structure of PZT. In contrast, the optical transparency of originally antiferroelectric PZT decreases upon repeated application of a bias field due to the stabilization of a ferroelectric phase by oxygen vacancy defects resulting from the high-temperature processing. This fatigue effect in thin films is not typically reported for bulk systems and significantly reduces the usefulness of the films for optical and electrical applications. In contrast, one of the most interesting features of PST is the possibility to modify the phase transition properties by varying the degree of crystallographic order: a random distribution of Sr and Ta ions on the perovskite B-sites makes the system a relaxor. A Rocksalt ordering of the B-site sublattice can be induced by thermal annealing and leads to a first-order ferroelectric phase phase transition. Here, a quantitative correlation between the degree of structural order and diffuseness of the phase transition is evidenced across multiple geometries – spin-coated thin films, bulk samples and multilayer capacitors. This has a profound influence of the applicability of PST in pyroelectric energy harvesting or electrocaloric applications. Financial support by the Fonds National de la Recherche (FNR) of Luxembourg through BRIDGES2021/MS/CECOHA/Defay and THERMODIMATC20/MS/Defay is gratefully acknowledged.

[*P3-16-52*] Design of flexible multilayer PVDF piezoelectric actuators

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Piezoelectric actuators are devices that directly convert an applied electric field to mechanical strain. Commercially available actuators are typically made of piezoelectric ceramics such as PZT or barium titanate, the brittle nature of which limits their suitability for applications involving flexural or tensile forces. PVDF is a synthetic piezoelectric fluoropolymer with a d_{31} of 8-22 pC/N depending on the phase composition of the polymer. While high for polymers the piezo response of PVDF is substantially lower than that of traditional ceramics whose values typically lie in the 100s of pC/N. Increasing the piezo response of PVDF is an ongoing challenge for its use an actuator, particularly if it is to compete with traditional ceramic materials. This work focuses on the development of a multilayered PVDF piezoelectric actuator, with the aim of increasing the force generation to levels usable for applications where the actuator will generate tensile or flexural forces. The multilayer structure serves to reduce the voltage requirements to drive the device while simultaneously increasing the force generation. PVDF is dissolved in DMF and spin coated to create a thin film. Metal electrodes are deposited via thermal evaporation. Additional PVDF and metal layers are deposited sequentially to form a multilayer structure of desired layer number. The laminate is cut to shape and alternating layers of the electrodes are then connected to form the device. The final device is then poled under DC voltage in silicone oil. The device is characterised by measurement of its D-E hysteresis loop and by direct actuation.

[*P3-17-53*] Enhancing power output of a polymer-based piezoelectric energy harvester using nonlinear technique

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Energy harvesting systems can extract local environment energy and convert it into electric energy. Piezoelectric materials are known for their ability to convert mechanical solicitation caused by ambient vibrations into electrical power, the so-called direct conversion microgenerators. Piezoelectric energy harvesters (PEH) usually generate power output in the micro to milliwatts range, making it a suitable alternative for powering low-energy electronics devices. However, the voltage generated by the PEH initially requires a signal conditioning step to produce a usable direct current (DC) voltage signal. This step includes the rectification of alternating current (AC) to DC voltage, followed by DC-DC conversion and storage of the energy generated. The standard rectification technique consists of using a full bridge diode followed by a smoothing capacitor. Despite the simplicity and ease of application of this standard circuit, the energy extraction can be optimized using nonlinear techniques characterised by the addition of a switch and inductance device to the rectification circuit. Through this technique the piezoelectric output voltage is artificially increased, resulting in the effect that if the charge of the piezo element is extracted at higher voltage, more energy is extracted. Examples of piezoelectric-based nonlinear circuits are series and parallel Synchronized Switch Harvesting on Inductor (SSHI) technique. Here we show a comparative study of electronic interface performance between the standard technique and synchronized switch harvesting on inductor (SSHI), implemented into a Polyvinylidenfluorid (PVDF) harvester with maximum RMS power output of 1.2 mW in the matched impedance and before rectification. In summary, results indicate that it is possible to enhance the power extraction after rectification of the polymer-based harvesters in three-fold for low-frequencies in between 10.5 Hz to 14.5Hz, simply by modifying the electronic interface, while keeping the same structure (shape, dimensions, mass…) of the PEH and achieve higher power output exclusively with more efficient rectification process.

[*P1-18-55*] Free-standing ferroelectric single crystal membranes with super-elasticity

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Oxides are usually inflexible and undergo brittle deformation, due to the larger bond energy and shorter bond length, which severely limits the application in flexible electronics. Recently, we prepared a set of ferroelectric single crystal oxide membranes, including BTO ($BaTiO_3$), BFO ($BiFeO_3$), PTO ($PbTiO_3$), PZO ($PbZrO_3$), PMNPT and PZT with a damage-free lifting-off process. Such ferroelectric membranes can undergo a nearly 180° folding during in-situ bending test, demonstrating a super-elasticity and ultra-flexibility [1-3]. We found that the origin of the super-elasticity was from the dynamic evolution of ferroelectric nanodomains in BTO, phase change in BFO and antiferroelectric to ferroelectric phase transition in PZO. High stresses modulate the energy landscape dramatically and allow the dipoles to rotate continuously in BTO. A continuous transition zone is formed to accommodate the variant strain and avoid high mismatch stress usually causing fracture. In addition, bilayer structure of BTO/LSMO is also prepared and shows a self-assembled spring shape due to the lattice mismatch as free-standing in the air. Such spring can undergo up 200 % of the length change upon a mechanic forced is loaded [4]. Very preliminary applications of such ultra-flexible epitaxial ferroelectric membranes have been explored in energy storage [5-6] and information storage [2]. [1] Dong, Liu, et al., Science 366, 475-479 (2019); [2] Guo, Peng, Liu, et al. Nature Communications 15, 4414 (2024); [3] Tao, Dong, Liu, et al., Advanced Materials (2026), https://doi.org/10.1002/adma.202515834; [4] Dong, Liu, et al., Advanced Materials, 2108419 (2022); [5] Liu, Peng, Liu et al, Advanced Materials 35. 2300962 (2023); [6] Yang, Dong, Liu et al, Nano-Micro Letters (2024), https://doi.org/10.1007/s40820-023-01233-z

[*P1-19-56*] Novel bottom electrodes for epitaxial hafnia-based ferroelectric thin films

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The continuous increase in global energy consumption, driven in part by the rapid development of data-intensive technologies such as artificial intelligence (AI) or the internet of things (IoT), has intensified the demand for low-power, energy-efficient memory technologies. Ferroelectric memories have emerged as promising candidates due to their high energy efficiency, low volatility, scalability, and compatibility with conventional CMOS processes. In particular, HfO_2-based ferroelectrics, especially the $Hf_{0.5}Zr_{0.5}O_2$ (HZO) solid solution in its metastable non-centrosymmetric orthorhombic phase, have attracted significant attention due to their chemical simplicity, CMOS compatibility and robust ferroelectric properties. Stabilization of this non-equilibrium polymorph can be achieved through epitaxial growth on suitable substrates; however, many conventional fluorite- or perovskite-based substrates are electrically insulating or poorly conductive, thus hindering the typical parallel-plate configuration needed for electrical characterization. Therefore, identifying a substrate that preserves epitaxial stabilization of the orthorhombic phase while enabling ferroelectric measurements is essential. In this work, commercial c-oriented sapphire (corundum) substrates with a doped GaN layer on top are used, providing both epitaxial growth support and sufficient electrical conductivity to act as a bottom electrode. Thin HZO films were deposited on these substrates by pulsed laser deposition, with film thickness ranging from 5 nm to 45 nm and deposition temperature between 350 °C and 850 °C to determine optimal growth conditions. X-ray diffraction confirms the stabilization of the orthorhombic phase under optimized deposition conditions. Scanning transmission electron microscopy in these samples reveals high-quality epitaxial growth of the non-centrosymmetric orthorhombic $Pca2_1$ structure. Preliminary piezoresponse force microscopy measurements show piezoelectric behaviour, confirming the suitability of GaN-doped corundum as a conductive bottom electrode as well as the possible ferroelectric behaviour of the HZO films. These results highlight the importance of optimizing deposition parameters for the development of epitaxial hafnia-based ferroelectrics, favouring their integration in low-power, CMOS-compatible memory devices.

[*P2-18-58*] Tailoring $Ba_{1-x}Sr_xTiO_3$ for pyro catalysis through control of composition and particle morphology

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Due to increasing environmental pollution and rising energy demand, there is a strong need for sustainable technologies that use very little external energy. Pyroelectric materials are emerging as attractive candidates for sustainable catalytic processes due to their ability to generate surface electric charges in response to temperature changes. Barium strontium titanate ($Ba_{1-x}Sr_xTiO_3$, BST) is attractive due to its composition-dependent paraelectric-ferroelectric phase transition. BST powders with varying Ba/Sr ratios were synthesized using controlled chemical routes to produce particles with defined sizes and shapes. X-ray diffraction (XRD) was used to confirm perovskite crystal structure, while particle morphology and their size were investigated using scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Selected area electron diffraction (SAED) and energy-dispersive spectroscopy (EDS) were used to determine the lattice orientation with respect to the crystal shape and compositional uniformity. Brunauer–Emmett–Teller BET method was used to analyse the surface area and porosity. Temperature-dependent Raman spectroscopy and differential scanning calorimetry (DSC) were used to determine the ferroelectric-paraelectric phase transition temperature and its dependence on particle size, shape and composition. The pyrocatalytic activity of BST is being tested by degrading Rhodamine B (10 ppm) under hot-cold cycles between 25-65 °C, with a stirring rate of 250 rpm. Each cycle lasts 10 minutes, with a heating and cooling rates of 16 °C/min and a total of 30-100 cycles are applied. Reaction kinetics are evaluated using dye concentration over time under optimized catalyst loading, initial dye concentration, and temperature cycling. In this contribution, we will show in detail how Sr content as well as particle size and morphology influence the phase transition temperature and its broadening, which in turn affects the pyroelectric response. In addition, we aim to analyse the recyclability of optimized BST powders to see their stability.

[*P2-19-59*] Unveiling the microstructural connection to the dielectric relaxation, conduction, photocatalytic, and energy harvesting properties in Ca-modified $Ba_{0.8}Sr_{0.2}TiO_3$ ferroelectrics

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In this work, the conduction and dielectric relaxation properties of Ca^{2+}-substituted $Ba_{0.8}Sr_{0.2-x}Ca_xTiO_3$ compositions, x = 0 (BST), 0.06 (BSCT06), and 0.08 (BSCT08), are investigated in relation to their microstructure using impedance spectroscopy. The Nyquist plots of impedance spectroscopy exhibit two semicircles in all compositions, representing relaxation mechanisms resulting from the contributions of grain interiors and grain boundaries. Moreover, a trail of an additional semicircular arc corresponding to the interfacial effect is observed at high temperatures in the Ca-modified compositions (BSCT06 and BSCT08). The large semicircular arc and corresponding prominent relaxation peak in the frequency-dependent impedance suggest the dominant influence of the grain boundary on the electrical properties of all the compositions. The Ca^{2+} substitution in parent composition BST leads to a reduction in the large semicircle arc and its relaxation peak of BSCT06 and BSCT08, resulting in decreased resistance from grain boundaries. It indicates an overall decrease in the insulating nature of the Ca-modified BST composition, which is further validated by their enhanced DC conductivity. This occurs due to the increased mobility of oxygen vacancies in the Ca-substituted compositions. This observation is supported by the reduction in activation energies of the Ca-substituted materials BSCT06 (1.13 eV) and BSCT08 (0.83 eV) with respect to pure BST (1.56 eV), calculated from the relaxation peak of grain boundaries, A similar decreasing trend was observed from the AC conductivity study, with activation energy values of 1.06 eV (BST), 0.98 eV (BST06), and 0.76 eV (BST08). In addition to electrical properties, the compositions also exhibit photocatalytic functionality. Among the compositions, 6 mol% Ca-modified composition (BSCT06) displayed the best photocatalytic activity of Methylene blue (MB), with 97 % efficiency and a reaction rate constant of 0.0147 min^{-1}. Also, energy harvesting potential of these ceramics incorporated with PVDF matrix have been investigated which showed a comparatively high output voltage of 10.6 V was obtained for BSCT06/PVDF at a constant force of 24 N. These results have been linked to microstructural variations, specifically a grain size and a reduced band gap.

[*P1-20-63*] Using accelerated ceramic synthesis to investigate the influence of starting materials on the energy storage properties of high-entropy oxide materials

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High-entropy perovskite oxides have attracted considerable attention due to their enhanced functional properties and improved thermal stability for energy storage applications. Among these materials, A-site–disordered, lead-free perovskite $(Bi_{0.2}Na_{0.2}Ba_{0.2}Sr_{0.2}Ca_{0.2})TiO_3$ (BNBSCT) has demonstrated excellent energy storage performance. However, detailed information on synthesis parameters remains limited, significantly constraining cross-study reproducibility. Solid-state synthesis is a well-established approach for functional ceramics, offering high scalability and transferability in both academic and industrial settings. Nevertheless, the vast compositional and processing parameter space of high-entropy materials, together with the selection of suitable precursor materials, presents substantial challenges for optimizing functional properties. Accelerated synthesis strategies are therefore required to explore property relationships across a broad process parameter space traditionally restricted by human capacity in terms of accuracy, repeatability, and labour cost. In this study, we systematically investigate the effects of different synthesis routes (based on carbonates, oxides, and pre-reacted compounds) as well as calcination and sintering temperatures on the crystal structure, macroscopic dielectric response, and energy storage properties of BNBSCT. This work employs a high-throughput powder-based synthesis, processing, and characterization platform. Using this approach, 240 distinct samples are synthesized and characterized. By integrating X-ray diffraction, small- and large-signal dielectric measurements, and density analysis, we provide unprecedented insight into the synthesis process induced effects on the macroscopic properties of the BNBSCT material system.

[*P1-21-64*] *Using the core-shell approach to tailor DC-tunability in functional grade ceramics*

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The capability to understand and manipulate materials has been fundamental to the technical evolution of humanity. Among the innovative materials, a special class is that of functionally graded materials (FGMs) due to their unique characteristics: the two or more materials are present, and the microstructure/composition/porosity varies in a discrete or continuous way over a definable geometry. FGMs have gained interest because their properties can be easily tailored due to the absence of well-defined boundaries or interfaces between different regions which are common in conventional composite materials. Considering the advantages of FGMs, we proposed to design tunable materials that fulfil technological requirements by exploiting microstructure particularities of FGCs obtained from core-shell structures. In this talk we will discuss the role of the local composition gradients generated by core-shell structure on the functional properties of $BaTiO_3$@$SrTiO_3$ ceramics from di-phase composites to solid solutions. The samples were prepared by two sintering strategies (traditional two step sintering and spark plasma sintering (SPS)) and the graded composition was checked by SEM technique. Impedance spectroscopy in the temperature range of 25 to 150 ºC shows a composition-induced ferroelectric-to-relaxor crossover with compositional-dependent shifts of the structural transition temperatures by comparison with the pure $BaTiO_3$. Polarisation vs. E loops indicate regular variation with graded composition, a reducing of loop area, remanent and saturation polarization (from P_{sat} = 14 μC/cm^2 for solid-solution to P_{sat} = 3 μC/cm^2 for di-phase composites). The dc-tunability for all ceramics shows a non-histeretic behaviour and a strong variation of tunability with applied fields mainly in case of graded ceramic, demonstrate that the core-shell approach can be a useful tool in controlling dc-tunability of $BaTiO_3$-based composite ceramics. Acknowledgement: The financial support of the PN IV-P1-PCE-2023-1192 is acknowledged.

[*P1-22-65*] Design of high-entropy lead-free $Bi_{0.5}Na_{0.5}TiO_3$-based relaxor ceramics for next-generation energy storage capacitors

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Dielectric capacitors are receiving increased attention for pulsed power applications thanks to their extremely power density and ultrafast charge/discharge rates. However, their relatively low energy storage density compared with batteries and supercapacitors remains a major limitation for practical uses. Therefore, exploring new materials with a higher energy storage density is essential to advance pulsed power applications [1]. Relaxor ferroelectrics which are characterized by the presence of polar nanoregions (PNRs), have emerged as promising candidates due to their high polarization, slim P–E loops, and high electrical breakdown strength (E_b) [2]. Recently, the high-entropy oxides (HEOs) approach has gained growing interest in designing high-performance relaxors for enhancing energy storage capability. This is due to their intrinsic chemical disorder, complex ionic valence states and severe lattice distortion. This makes it a promising and flexible strategy for generating smaller and more dynamic PNRs [3-4]. In this work, the high-entropy strategy is employed to design lead-free relaxor ceramics based on $Bi_{0.5}Na_{0.5}TiO_3$ (BNT). A single-phase perovskite ceramic, $(Bi_{0.2}Na_{0.2}Ba_{0.2}Sr_{0.2}Ca_{0.2})TiO_3$ (BNBSCT) was successfully synthesized. The material exhibits a pronounced relaxor behavior, as evidenced by its high dielectric permittivity ($\varepsilon_r \simeq 2700$) at room temperature and a slim P-E loop. Recoverable energy density of $W_{rec} \simeq 1$ J cm^{-3} with a high energy efficiency of $\eta \simeq 90\%$ was achieved under an applied electric field of 100 kV cm^{-1}. Furthermore, the effect of niobium (Nb) doping at the B-site of BNBSCT ceramics was studied. The results indicate that BNBSCT doping with Nb (BNBSCT-xNb; $0.01 < x < 0.04$) induces a slight lattice distortion accompanied by a reduction in grain size. This promotes the formation of smaller and highly dynamic polar nanoregions, which are essential for enhancing the electrical breakdown strength (E_b). These findings highlight the importance of this strategy for developing new lead-free relaxors with high electrical energy storage performance.

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[*P1-23-66*] Thermal conductivity switches based on $Ba_{0.85}Ca_{0.15}Zr_xTi_{1-x}O_3$ and $Sr_xBa_{1-x}Nb_2O_6$ ceramics

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Thermal conductivity switches are essential for the development of high efficiency thermoelectric devices, thermal refrigeration systems and new computing paradigms, if they exhibit high switching ratio in the ON/OFF thermal conductivity and fast switching on a wide range of operating temperature. However, tuning phonon transport and thus thermal conductivity still remains a challenge. Phonons (quantized lattice vibrations), being the primary heat carriers in insulators, cannot be directly manipulated by an external electric field due to their lack of mass and charge. Recently, a strategy based on ferroelectric oxides has been suggested to obtain a dynamic heat flow control. In this work, highly dense $Ba_{0.85}Ca_{0.15}Zr_xTi_{1-x}O_3$ (x = 0.05, 0.1) ceramics and $Sr_xBa_{1-x}Nb_2O_6$ (x = 0.25, 0.50) ceramics with single phase and uniform grain size were synthesised by conventional sintering and spark plasma sintering, respectively. In-situ laser flash analysis under electric field has been used to investigate the thermal conductivity variations and hence study the fundamental mechanism to design thermal conductivity switches. The thermal conductivity variation under electric field gives ratios $\kappa_{high}/\kappa_{low}$ of 1.01 and 1.03 in $(Ba_{0.85}Ca_{0.15})(Zr_{0.05}Ti_{0.95})O_3$ and $(Ba_{0.85}Ca_{0.15})(Zr_{0.1}Ti_{0.9})O_3$, respectively. The classical ferroelectric compositions of $Sr_xBa_{1-x}Nb_2O_6$ (x = 0.25, 0.50) ceramics, with only 180° ferroelectric domains, don't exhibit a thermal conductivity switching. Both results suggest that the change in thermal conductivity is not mediated by domain walls but by a change in the ferroelectric domain configuration combined with the intrinsic anisotropy of the thermal conductivity in ferroelectrics. The study reveals the possibility of tuning the thermal conductivity in ferroelectric oxides with an electric field. Thermal conductivity switch utilizing the thermal conductivity of ferroelectric material with phonon transport can be realized to make 'phononics' a reality.

[*P2-20-67*] Microscopic origin of conductivity in 180º domain walls in PZT thin films studied by atomic-resolution electron microscopy

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Conductive domain walls (DWs) between domains with different crystal orientations have been observed in numerous insulating materials, particularly ferroelectrics including $BiFeO_3$, $Pb(Zr,Ti)O_3$, $PbTiO_3$ and $LiNbO_3$. Their unique properties, such as high DW conductivity, nonvolatility and plasticity, which can be tuned by the application of electric fields, are key ingredients for novel applications of ferroelectrics in nanoelectronics. For instance, they have been postulated as the functional elements of new types of multistate memories or neuromorphic computing devices [1]. While DW conductivity in charged DWs is well known, nominally-neutral ferroelectric boundaries, such as 180º DWs in perovskite-type, tetragonal $PbZr_{0.1}Ti_{0.9}O_3$ thin films, can present giant non-thermally activated conduction, and have shown a clear memristive behavior [2,3]. However, the microscopic origin of these phenomena is yet to be fully understood [2]. Here we report an atomic-scale investigation of conductive, nominally-neutral 180° DWs in an epitaxial thin film of tetragonal $PbZr_{0.1}Ti_{0.9}O_3$, artificially created by piezoresponse force microscopy (PFM). Aberration-corrected scanning transmission electron microscopy (STEM) imaging by high-angle annular dark field (HAADF) and annular bright field (ABF) has been analyzed quantitatively to elucidate the complex polarization structure of these 180° DWs and their coupling with ferroelastic 90° domains [4]. Our results reveal that, after poling, the $PbZr_{0.1}Ti_{0.9}O_3$ present an intricate network of 90º and 180º DWs, where the strain induced by ferroelastic domains plays a key role. We observe that 180° DWs conductivity is associated with the emergence of polar discontinuities, due to strong lattice distortions and inclined DW orientation with respect to the expected crystallographic directions, which give rise to the formation of tail-to-tail charged segments. A modified electronic DW band structure with respect to the domains has been confirmed by electron energy loss spectroscopy. Additionally, we investigated the long-term stability of these domain boundaries. Our findings provide insights into the atomic-scale mechanisms that turn nominally neutral DWs into highly conductive channels, paving the way for their use in advanced nanoelectronic devices. References: [1] D. Meier, S. M. Selbach, Ferroelectric domain walls for nanotechnology. Nat. Rev. Mater. 7, 157 (2022); [2] Felix Risch, Yuri Tikhonov, Igor Lukyanchuk, Adrian M. Ionescu, Igor Stolichnov. Nat. Comm. 13, 7239 (2022); [3] F. Risch, P. Koutsogiannis, Y. Tikhonov, A. G. Razumnaya, C. Magén, J. A. Pardo, I. Lukyanchuk, and I. Stolichnov, ACS Nano 19, 6993-7004 (2025); [4] P. Koutsogiannis, F. Risch, J. A. Pardo, I. Stolichnov, and C. Magen, ACS Appl. Mater. & Interf. 16, 66341-66349 (2024).

[*P2-21-68*] *Domain microstructures in improper ferroelectric hexagonal tungsten bronzes via piezo-response force microscopy*

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In recent years, ferroelectric domain walls (DWs) have emerged as exciting, reconfigurable elements for nanoelectronics as their properties can often differ significantly from that of the surrounding material. The rare earth manganites ($RMnO_3$ R^{3+} = Dy, Ho, Er, Tm, Yb, Lu, Y, and Sc) are a class of geometric improper ferroelectrics that display a labyrinthian domain structure with meandering DWs which meet at six-fold clover leaf vertices. This results in conducting DWs which can travel in any direction within the sample, creating percolating conducting pathways throughout the depth of the material that can be functionalised for a wide array of applications. There is therefore a desire to search for more novel material systems with complex domain structures that can be exploited for device applications. One such novel family of materials are the hexagonal tungsten bronzes based on $CsNbW_2O_9$. They are also improper ferroelectrics, where the ferroelectricity arises from a unit cell tripling distortion mode, but in contrast to the manganites, this is driven by a second order Jahn Teller displacement. $CsNbW_2O_9$ displays a similar meandering domain structure to that of the manganites. This work seeks to further characterise the ferroelectric behaviour of this new material by using a combination of piezo-response force microscopy (PFM), powder X-ray diffraction (pXRD) and electron backscatter diffraction (EBSD), to understand how the structural properties of the system affect the domain microstructure. In particular, the impact of aspects such as crystallographic orientation, synthesis conditions, grain size and quenching rate on the ferroelectric microstructure of polycrystalline samples will be examined and discussed.

[*P2-22-69*] Local electronic reconstruction in a ferroelectric p-type semiconductor studied by correlated scanning probe microscopy

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Ferroelectric domain walls represent a natural type of interface with emergent functional properties, holding great potential as agile and ultra-small electronic elements for next-generation nanotechnology. Despite their outstanding application potential, little is known about the performance in actual device geometries and the contact phenomena that co-determine the current injection. In this study, we explore local electronic reconstruction effects at both (i) metal-semiconductor contacts for current injection and (ii) the domain walls themselves, using the ferroelectric p-type semiconductor erbium manganite as model system. By applying electron beam lithography and temperature-dependent mesoscopic probe techniques, we design and systematically characterize a range of metal-ferroelectric contacts. Complementary conductive atomic force microscopy (cAFM) and Kelvin probe force microscopy (KPFM) allow for probing the associated local redistribution of charge carriers and for comparing it with domain-wall related depletion effects. Our results provide new and robust experimental information concerning the carrier density of hexagonal manganites, as well as the electronic reconstruction at metal-semiconductor contacts and domain walls, being of fundamental importance for the utilization of ferroelectric walls and their integration into devices.

[*P2-23-70*] Impact of edge dislocations on ferroelectric switching - an atomistic study on barium titanate

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Ferroelectric switching and domain-wall motion, which are highly sensitive to defects such as vacancies and dopants, largely determine the functional properties of ferroelectric perovskites. However, due to the small active interaction volume of these zero-dimensional defects, domain walls can be readily depinned. Additionally, these defect configurations may evolve over time through diffusion and vacancy migration, leading to functional fatigue and aging. In contrast, larger and temporally stable modifications of domain nucleation and domain-wall motion can be expected in the presence of edge dislocations which generate pronounced strain fields and lattice distortions. Particularly, <001> dislocations play a significant role in ferroelectric perovskite oxides, as they can either be introduced at high temperatures or form to accommodate lattice mismatch at interfaces. Several studies have demonstrated that dislocations can substantially modify ferroelectric functionality. Despite this, dislocations remain underrepresented in the literature, and their impact on ferroelectric switching is not yet fully understood. In this study, we employ molecular statics simulations using core–shell potentials to investigate how <001> edge dislocations modify the ferroelectric hysteresis behavior of tetragonal Barium Titanate. By systematically applying external electric field in three directions relative to Burgers vector and dislocation line, we present that the dislocation cores can act as energetically favourable domain nucleation sites and that the most pronounced changes occur when the field is oriented parallel to the Burgers vector, arising from a combined effect of domain nucleation and domain-wall pinning by the dislocation-induced strain field. Further, we show that the effect of dislocations is minimum when the field is applied along the dislocation line.

[*P3-22-72*] Suppressing crystal twinning in $Bi_4Ti_3O_{12}$ via supersaturation control

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Crystal twinning presents a recurring challenge in the growth of ferroelectric oxide thin films, particularly in layered Aurivillius systems such as $Bi_4Ti_3O_{12}$ (BiT), where symmetry-breaking orientation variants degrade structural coherence and hinder polarisation switching. Here, we demonstrate a supersaturation-controlled growth strategy that suppresses crystal twinning in BiT thin films by regulating the balance between nucleation kinetics and surface diffusion during metal-organic chemical vapor deposition (MOCVD). By tuning the effective supersaturation through precursor flux, we achieve a transition from high-density, twinned microstructures to single-oriented, untwinned epitaxial films on (001)-oriented $NdGaO_3$ substrates. Comprehensive structural characterisation using atomic force microscopy, X-ray diffraction, and transmission electron microscopy reveals that high supersaturation promotes rapid, isotropic nucleation and misoriented domain formation, whereas reduced supersaturation enhances adatom mobility, favouring lattice-aligned, layer-by-layer growth. Ferroelectric switching measurements via piezoresponse force microscopy show robust, spatially coherent polarisation reversal only in untwinned films. These findings establish supersaturation as a critical thermodynamic and kinetic lever for suppressing twin formation in layered oxide thin films, providing a general and scalable route toward twin-free ferroelectric heterostructures for future oxide nanoelectronics.

[*P3-23-73*] How material understanding can unlimit future applications – Advanced structure characterization of AlN-based ferroelectrics

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After our discovery of the ferroelectric switching properties of Sc-alloyed AlN, thin film ferroelectrics with wurtzite-type structure emerged as promising alternative for realizing future low-power integrated devices. Wurtzite-type ferroelectrics are based on solid solutions with engineered structural and chemical properties, e.g. a structural divergence of hexagonal and cubic counterparts, e.g., AlN – ScN or ZnO – MgO, which does not only impact the materials stability itself but also has decisive influence on the ferroelectric properties, in particular. The ferroelectric characteristics of these materials - such as high spontaneous polarization and impressive scalability below 10 nm – as well as their compatibility to CMOS and nitride technologies make them ideal candidates for memory applications such as non-volatile ferroelectric diodes or field-effect transistors. For the transition from research to the real device level, key challenges remain to be studied. These are the limited understanding of functional fatigue, leakage current suppression and device operation around 1 V. Addressing these challenges requires a fundamental and holistic understanding of the materials' structural and chemical properties in order to enable new engineered approaches targeting the inherent defect-structure envisioned as being the key factor for restricting domain wall motion. In this contribution, the recent progress on our understanding of ferroelectric epitaxial AlScN/GaN heterostructures with a particular focus on the polar domain structures will be presented. We use atomic resolution scanning transmission electron microscopy in combination with spectroscopic methods such as energy-dispersive X-ray spectroscopy and electron energy-loss spectroscopy to investigate the atomic structure and chemical properties in dependence to the applied number of switching cycles. So far, our groundbreaking TEM investigations revealed the existence of polar domains in identifying that the switching mechanism is not digital, but domain wall motion can be precisely tuned by the applied electric field. In this regard direct observations of interfacial pinning of domains and incomplete polarization reversal was reported together with a pivotal identification of the IDB*-structure of the domain wall in these systems. The established domain wall configuration is either head-to-head or tail-to-tail depending on the initial film polarization and the present structural or chemical interfacial defect structures initiating polarization inversion. For example, we could evidence a zipper-analogue up(M)-to-down(N)-polar switching mechanism starting at the AlScN/GaN interface in sputtered films, while similar heterostructures grown by MOCVD show domain nucleation at the top electrode interface. Recent observations demonstrate that switching-cycle dependent pinning of interfacial domains could be tied to the accumulation of chemical defects at the hetero-interface and that defect evolution during switching can further constrain domain wall propagation or fundamentally alters the switching process. Hence, an in-depth understanding of the local defect structures is required to understand and predict domain wall activity in ferroelectric wurtzite films.

Here, we investigate the impact of the film thickness as a constraint on polarization inversion, domain wall geometry and functional fatigue. The results of these studies will not only foster a deeper fundamental understanding of ferroelectric domains in wurtzite-type ferroelectric nitrides but address one of the major challenges for device integration: the limited switching endurance.

[*P2-25-78*] Structural insights into phosphate langbeinites: Foundations for future polar dielectric and magnetoelectric studies

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Polyanionic compounds with langbeinite-type structures represent a versatile class of materials for the development of multifunctional oxides due to their structural flexibility and rich physical properties [1]. Their three-dimensional frameworks, built from interconnected phosphate groups, provide a favorable environment for accommodating various paramagnetic cations and inducing polar distortions [2,3]. In this study, the phosphate langbeinite compounds were synthesized via conventional solid-state reactions from powdered precursors containing different combinations of Pb, Mn, Fe, and Ba cations. Powder X-ray diffraction (XRD) confirmed the successful formation of langbeinite-type frameworks, demonstrating the purity and crystallinity of the synthesized powders. The choice of cations was guided by their potential to induce polar behavior and magnetic interactions, while heavy cations such as Pb^{2+} are expected to enhance polarizability through stereochemically active lone electron pairs. Local distortions around the cations were probed using Mössbauer spectroscopy, which revealed that iron is present as Fe^{3+} occupying two distinct crystallographic sites. Additional infrared (IR) and Raman spectroscopies further confirmed the presence and configuration of the polyanionic phosphate groups (PO_4) within the crystal framework, providing insights into lattice dynamics and local distortions. While the structural and local characterization presented here provides valuable insights into the langbeinite framework and the distribution of Fe^{3+} ions, the functional properties of these materials remain to be explored. Dielectric and magnetic measurements will be carried out in future studies to assess polarization response, dielectric permittivity, losses, and potential magnetocapacitive effects. Such investigations will allow a deeper understanding of the coupling between lattice structure, local distortions, and magnetic interactions, offering essential guidance for the rational design of multifunctional materials. The outcomes of these studies are expected to inform the development of polar dielectric and magnetoelectric compounds for applications in electronic devices, sensors, and energy-related technologies. [1] Morey, G. W., Rowe, J. J., Fournier, R. O. The System $K_2Mg_2(SO_4)_3$ (Langbeinite)-$K_2Ca_2(SO_4)_3$ (Calcium-Langbeinite). J. Inorg. Nucl. Chem. 1964, 26 (1), 53–58. https://doi.org/10.1016/0022-1902(64)80232-3; [2] Alloun, F.; Bouraima, A.; Kaaouass, A.; Hadouchi, M.; Assani, A.; Saadi, M.; El Marssi, M.; Lahmar, A.; El Ammari, L. Synthesis, Structural and Magnetic Investigation of the Mixed-Metal Langbeinite Phosphate $Ba_2FeCo(PO_4)_3$. Inorg. Chem. Commun. 2025, 180, 114955. https://doi.org/10.1016/j.inoche.2025.114955; [3] Balaji, D.; Mandlimath, T. R.; Chen, J.; Matsushita, Y.; Kumar, S. P. Langbeinite Phosphates $KPbM_2(PO_4)_3$ (M = Cr, Fe): Synthesis, Structure,

Thermal Expansion, and Magnetic Properties Investigation. Inorg. Chem. 2020, 59 (18), 13245–13253. https://doi.org/10.1021/acs.inorgchem.0c01597

[*P1-28-85*] *The coupling of ferroelectric polarization and oxygen vacancy migration enables electrically controlled thermal memories*

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The discovery of materials whose thermal conductivity (κ) can be tuned on demand by an electric field is crucial for the active control of heat currents in solid-state systems. Such thermally active devices are essential for applications including thermal energy storage and management, solid-state refrigeration and thermal regulation technologies, thermoelectric energy harvesting, and emerging concepts for information storage and processing based on heat currents. Here, we demonstrate electrically controlled and non-volatile switching of κ in epitaxial ferroelectric $Hf_{0.5}Zr_{0.5}O_2$ thin films and unveil a previously unexplored mechanism for active thermal conductivity control in polar dielectrics. This mechanism arises from the coupling between ferroelectric polarization, oxygen vacancy migration, and phonon scattering, positioning hafnia-based oxides as promising platforms for thermal memories and multifunctional thermal devices. Epitaxial $Hf_{0.5}Zr_{0.5}O_2$ films were grown on (111)-oriented Y_2O_3:ZrO_2 single-crystal substrates by pulsed laser deposition, with the polar phase confirmed by X-ray diffraction. Au top electrodes were deposited ex situ by sputtering. The thermal conductivity was measured using frequency-domain thermoreflectance, while polarization–electric field hysteresis loops were obtained with a home-built ferroelectric tester. The electric-field dependence of κ exhibits a pronounced hysteresis that closely mirrors the polarization–electric field response, including identical coercive fields. This behavior is incompatible with ferroelectric domain walls acting as the dominant phonon scattering centers, as reported in other ferroelectrics, where maximum κ values are expected at both large positive and negative fields under single-domain conditions. Structural analysis further confirms that the ferroelectric orthorhombic phase is preserved in both thermal states, ruling out electric-field-induced phase transitions as the underlying mechanism. Instead, we identify electrically driven oxygen vacancy migration as the dominant process, with vacancies acting as highly efficient phonon scattering centers. Ferroelectric polarization creates an electrostatic barrier that controls the redistribution and retention of these defects, stabilizing non-equilibrium vacancy configurations and giving rise to the observed hysteretic thermal response. This mechanism enables two distinct and non-volatile thermal states after removal of the electric field, corresponding to high (ON) and low (OFF) thermal conductivity. The reported κON/κOFF ratio is approximately 1.6, with switching achieved at voltages below ±5 V, compatible with thin-film device integration. Both thermal states exhibit excellent temporal stability over several days at room temperature, indicating strong suppression of vacancy back-diffusion in the absence of an applied field. Although the thermal switching speed is ultimately limited by ionic transport in the solid electrolyte electrode, the robustness, reversibility, and low operating voltages highlight the technological relevance of this approach.

[*P1-29-86*] Frustrated antipolar correlations and magnetoelectric coupling in hexaaluminates

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New type of frustrated antipolar phase has been recently discovered in the ferromagnet $EuAl_{12}O_{19}$ [1]. Strong relaxor ferroelectric-like dielectric dispersion was observed below 50 K, but detail structural studies revealed stable hexagonal structure (space group P63/mmc) down to 4 K. However, diffuse X-ray scattering revealed a three-order of magnitude increase at the K point of the Brillouin zone upon cooling below 50 K. This indicates strong ferrielectric correlations without the formation of a macroscopically ordered ferielectric phase. Both diffuse X-ray scattering and huge slowing down of dielectric relaxation from 1 THz (at 300 K) to 1 mHz (3 K) according to Arrhenius law is caused by anomalous vibration of Al ions in AlO_5 bipyramids and reminds dynamics of classical spin liquids. Quantum magnets $RMgAl_{11}O_{19}$ (R=Ce, Pr, Nd) display markedly divergent dielectric properties [2,3]. Although comparable negative thermal expansion to that of $EuAl_{12}O_{19}$ is exhibited, which could indicate antipolar correlations, the non-dispersive permittivity follows Barrett's law. This manifests itself as an increase upon cooling and subsequent saturation below 20 K, similar to quantum paraelectrics. However, it has been determined that at liquid He temperatures, permittivity experiences a decrease. A comparable phenomenon has been observed in antiferromagnetic $EuTiO_3$ and explained by spin-phonon coupling. Nevertheless, it has been discovered that hexaaluminates exhibit quantum magnetic properties down to mK temperatures without displaying long-range magnetic ordering. In the presence of external magnetic field, the low-temperature permittivity changes significantly due to biquadratic magnetoelectric coupling driven by the crystal electric field. The aforementioned properties render hexaaluminates a prototype for investigating quantum magnetoelectricity in frustrated dipolar and magnetic systems. [1] G. Bastien et al., A Frustrated Antipolar Phase Analogous to Classical Spin Liquids. Advanced Materials 36, 2410282 (2024); [2] S. Kumar et al., Crystal field driven magnetoelectricity in the triangular quantum magnet $CeMgAl_{11}O_{19}$, Phys. Rev. B, 112, 224431 (2025); [3] S. Kumar et al., Crystal-Field--Driven Magnetoelectric Coupling in the Non-Kramers Hexaaluminate $PrMgAl_{11}O_{19}$, arXiv:2511.12355; [4] S. Kamba et al., Magnetodielectric effect and optic soft mode behaviour in quantum paraelectric $EuTiO_3$ ceramics, EPL, 80, 27002 (2007)

[*P2-28-88*] Piezoelectric membranes for electrically assisted microfiltration based on lead-free BCTZ: Processing and structure-performance relationships

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Microfiltration (MF) membranes are widely used for water recovery from agro-food wastewater, but their performance is strongly limited by fouling, which reduces permeability and operating lifetime. Ceramic membranes provide higher chemical and mechanical stability than polymeric systems, yet their cost motivates the development of approaches that improve antifouling efficiency and extend service life. Piezoelectric ceramic membranes represent an emerging route in which electrically induced mechanical vibrations can promote foulant detachment and surface regeneration, enabling in *in situ* cleaning strategies. A key challenge is transferring piezoelectric functionality from dense ceramics to porous structures while retaining sufficient mechanical integrity and hydraulic permeability. This contribution reports first results on the relationships between microstructure and electromechanical response in porous lead-free $(Ba,Ca)(Ti,Zr)O_3$ (BCTZ) membranes produced by sacrificial template processing, freeze casting, and binder jetting. These routes enable different pore size distributions, connectivity, and anisotropy. The effects of porosity and pore morphology on dielectric and piezoelectric properties are discussed, together with the role of poling conditions in activating the porous network. Preliminary filtration tests under electrical excitation are presented, correlating electrically driven actuation with antifouling behaviour through permeability as a performance indicator.

[*P2-29-89*] Introducing true depth-sensitivity in HAXPES for chemistry analysis of ferroelectric devices: Experiment and simulation

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Ferroelectricity in thin-film devices is closely linked to intentional doping and defect chemistry. In HfO_2 thin films, dopants stabilize a metastable ferroelectric phase that is otherwise energetically unfavorable, enabling ferroelectricity at nanoscale thicknesses. In AlScN, ferroelectric switching arises from a modification of the energy landscape of the intrinsically polar wurtzite structure induced by Sc incorporation, rather than from defect-mediated phase stabilization. In both material classes, point defects such as vacancies strongly influence ferroelectric behavior and device performance, highlighting the need for reliable defect characterization. Understanding how these defects and dopants affect device functionality requires high-resolution structural and chemical analysis. Electron microscopy and spectroscopy (TEM, EDX, EELS) provide essential depth-resolved information, while hard X-ray photoelectron spectroscopy (HAXPES) offers a complementary, non-destructive and depth-sensitive approach that preserves the native defect and interface structures critical for ferroelectric properties. However, conventional HAXPES integrates photoelectron signals over an exponentially decaying "information cone" of up to ~25 nm, which can obscure depth-dependent chemical or electronic features in layered ferroelectric devices. To address this, we introduce a simulation-guided grazing-incidence GI-HAXPES approach. At GI angles of 0.3°–2°, X-ray refraction and total reflection produce angle-dependent interference effects that shift the weighted photoelectron contribution to well-defined depths, allowing targeted investigation of the dopant- and defect-related effects in thin film ferroelectrics. Our simulation tool enables a priori identification of experimental conditions for surface-, interface-, or bulk-sensitive measurements, providing selective depth tuning and clear separation of overlapping chemical and electronic contributions. At characteristic GI angles, photoelectron emission intensities increase by up to two orders of magnitude, enabling faster data acquisition while maintaining full elemental and chemical specificity. We demonstrate this methodology by GI-HAXPES measurements on a ferroelectric Pt/AlScN/Pt capacitor structure, highlighting its potential for advanced, depth-resolved characterization of functional ferroelectric devices and their defect-mediated behavior.

[*P3-28-91*] Structural and magnetic effects of magnetic-ion substitution in high-layer (m ⩾ 5) aurivillius-phase multiferroic thin films

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Multiferroic materials that simultaneously exhibit ferroelectric and ferrimagnetic properties offer a promising route to increase data storage capacity by up to eightfold. However, the scarcity of multiferroics demonstrating both functionalities at room temperature has hindered their widespread technological integration. Our group has previously reported a five-layered Aurivillius-phase multiferroic, $Bi_6Ti_xFe_\gamma Mn_zO_{18}$ (B6TFMO; m = 5), which uniquely exhibits room-temperature ferroelectric and magnetic ordering, with saturation magnetisation and in-plane polarisation values on the order of hundreds of 215 emu/cm^3 and >26 μC/cm^{-2}, respectively, as well as reversible magnetoelectric switching at room temperature. These materials hold great potential for next-generation data storage, sensor and spintronic devices. [1], [2], [3] To further enhance the magnetic functionality, this study explores the synthesis and characterisation of higher-layer Aurivillius phase thin films, where an increased number of perovskite layers (m = 6) enables greater incorporation of magnetic ions such as Mn. Six-layer $Bi_7Ti_xFe_\gamma Mn_zO_{21}$ (B7TFMO) films, were fabricated using Direct Liquid Injection Chemical Vapour Deposition (DLI-CVD). Atomic force microscopy (AFM) and X-ray diffraction (XRD) were used to characterise the morphological characteristics and crystal structure. SQUID (superconducting quantum interference device) magnetometry was used to measure the macroscopic magnetic properties, while piezoresponse force microscopy (PFM) and magnetic force microscopy (MFM) were used to examine the nanoscale electrical and magnetic behaviour. High-resolution transmission electron microscopy (HRTEM) was employed to investigate the local crystal structure and atomic-scale structural features. This presentation will discuss how increasing the number of layers may influences long-range magnetic ordering while maintaining ferroelectric performance in high-layer (m ⩾ 5) Aurivillius-phase multiferroics. The study aims to further explore the potential of these materials for future memory, sensor, and spintronic technologies, representing an important step toward the development of multiferroic thin films for future data storage applications. Keywords: Multiferroic, Aurivillius Phases, Ferroelectric, Data Storage, Direct Liquid Injection Chemical Vapor Deposition (DLI-CVD). References: [1] L. Keeney, Z. Saghi, M. O'Sullivan, J. Alaria, M. Schmidt, and L. Colfer, (2020), Persistence of Ferroelectricity Close to Unit-Cell Thickness in Structurally Disordered Aurivillius Phases, Chemistry of Materials, vol. 32, no. 24, pp. 10511–10523; [2] A. Faraz et al., (2017), Direct visualization of magnetic-field-induced magnetoelectric switching in multiferroic aurivillius phase thin films, Journal of the American Ceramic Society, vol. 100, no. 3, pp. 975–987; [3] L.

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[*P3-29-92*] Sc-doped AlN thin films: Electrical and ferroelectric properties

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Doped AlN thin films have attracted significant attention in recent years in both industrial and academic research. Among them, Sc-substituted AlN thin films exhibit enhanced piezoelectric performance and higher electromechanical coupling coefficients compared to undoped AlN. In addition, Sc incorporation enables ferroelectricity, a property absent in stoichiometric AlN thin films. These characteristics make Sc–AlN promising candidates for integration into next-generation electronic devices. Despite this potential, stabilizing the ferroelectric phase remains challenging because achieving the optimal composition and the correct crystalline structure is difficult. In this work, we present experimental results on Sc-doped AlN thin films and investigate the relationship between deposition conditions and their ferroelectric properties.

[*P2-30-97*] Exploring the effects of Ti-doping in $(K_{0.5}Na_{0.5})NbO_3$ ceramics

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Acceptor doping is a well-established chemical modification method in which a lower-valence element substitutes for a higher-valence element, creating a charge imbalance, which results in the formation of compensating defects [1]. Ti doping has been reported to induce a ferroelectric hardening effect, manifested by an increased mechanical quality factor and reduced dielectric loss, while also shifting phase transition temperatures to lower values and enhancing the piezoelectric properties of lead-free ferroelectric $K_{0.5}Na_{0.5}NbO_3$ (KNN). This work aims to clarify the effect of Ti substitution at the Nb site (0.1, 0.2, 0.5, and 1.0 mol%) on the functional properties and structural characteristics of KNN down to the atomic level. KNN powders were prepared by conventional solid-state synthesis, in which 0.1-1 mol% TiO_2 was added as a dopant and mixed directly with the starting powders. The resulting powders were isostatically pressed and sintered in air for 2 hours at 1120 °C for undoped KNN and at 1100 °C for Ti-doped KNN. X-ray diffraction confirmed the formation of a single perovskite phase in all compositions, with no pronounced peak shifts observed for Ti contents below 1 mol%, consistent with previous reports [2, 3]. However, energy-dispersive X-ray spectroscopy revealed Nb- and Ti-rich secondary phases, along with Ti segregation at grain boundaries in 1 mol% Ti-doped KNN. Increasing the Ti content reduced the grain size, with a bimodal grain size distribution observed in 0.1-0.5 mol% Ti-doped KNN, similar to that reported in [2, 4]. All compositions exhibited high relative density, exceeding 96 %. At the atomic level, in the undoped KNN, the most pronounced lattice distortions and the largest displacements are observed. Introducing Ti modifies the local lattice and reduces these distortions in a non-linear manner, depending on the Ti amount. Changes are also observed in the material's mechanical behavior, where 0.2-0.5 mol% Ti increases hardness and stiffness, whereas 1 mol% Ti enhances density but degrades mechanical performance. Dielectric losses follow a similar non-linear trend, with KNN-0.5Ti exhibiting the lowest dielectric loss. The observed microstructural, mechanical, and electrical behavior will be discussed in relation to local structural features.

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[*P2-31-98*] Molecular-based ferroelectric plastic crystals for high-energy-density storage capacitors

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Conventional inorganic ferroelectrics exhibit large spontaneous polarization and strong piezoelectric responses; however, their processing constraints and limited recyclability motivate the exploration of molecular-based ferroelectric plastic crystals as alternative materials for high electrical energy density storage (HEEDS) capacitors. Plastic crystals have flexible bonding networks, low-temperature solution processability, and improved recyclability. They also offer wide structural tunability, achievable by crystal and molecular engineering via the quasi-spherical theory. The structure and properties of two plastic crystals, $Me_3N(EtCl)FeCl_4$ (MNF) and $Me_3N(EtCl)ClO_4$ (MNC), are investigated as potential polar dielectric materials in HEEDS capacitors. MNF and MNC were synthesized by a simple precipitation from the reaction of equimolar amounts of precursors in aqueous solutions, followed by slow evaporation at room temperature and recrystallization. X-ray diffraction (XRD) revealed the structures of the compounds to be respectively orthorhombic (MNF) and monoclinic (MNC) at room temperature, with non-centrosymmetric space groups, Cmc21 and Cc respectively, suggesting their ferroelectric potential. Differential scanning calorimetry revealed distinct, reversible first-order phase transitions in the compounds. For MNF, the transitions were at ~479 K (heating) and ~475 K (cooling), with a small hysteresis of ~4 K and a transition enthalpy of ~63 J/g and ~62 J/g, respectively. In contrast, MNC displays two phase transitions: a mesophase transition at ~363 K (heating) and ~357 K (cooling) with respective transition enthalpies of ~39.4 J/g and ~40 J/g, preceded by a strongly hysteretic transition at ~332 K (heating) and ~316 K (cooling) with transition enthalpies of 10.5 J/g and 16.3 J/g. The phase transitions in the compounds were further confirmed to be first-order by in situ XRD. These findings establish a structural and thermodynamic foundation for further investigation into the material's dielectric and ferroelectric behaviour. Ongoing work also focuses on experimentally characterizing the ferroelectric and dielectric properties of these materials to provide insights into their dielectric relaxation behavior, which governs polarization dynamics and influences AC-field performance, and assess their potential for HEEDS applications.

[*P2-32-99*] *Molten salt approach to stabilize alkaline earth titanate – sodium bismuth titanate perovskite*

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Since almost 80 years, a lot of research on functional ferroelectric materials have been done. Until the 2000s, the properties improvement was the privileged factor with in particular the use of lead zirconate titanate (PZT) base materials which is an excellent insulator with significant polarization. Nevertheless since then a change of paradigm took place considering environmental issues [1] and allowing the emergence of new interest phases called lead-free ceramics. Among materials/phases of particular interest, certain compounds such as Potassium Sodium Niobate (KNN), Barium Titanate (BT) and/or Sodium Bismuth Titanate (NBT) -based materials are promising to replace PZT [1]. In this work, a focus is made on solid solution between alkaline earth (= Sr, Ca) titanate and Sodium Bismuth Titanate so called SNBT, CNBT and SCNBT phase for their dielectric permittivity higher than the one's shown by NBT [2-4]. In this presentation, considering the recent study underlying an intriguing interplay between local polarization, perovskite A-site ionic size and octahedral tilt [5], a cost-effective salt synthesis route « molten salt » was used allowing to significantly decrease both synthesis and sintering temperature keeping the high-density ceramic parameter. It will be addressed how our approach affects microstructure and properties regarding the literature near the Morphotropic Phase Boundary (MPB) compositions. [1] Rödel, Jing-Feng Li, Lead-Free Piezoceramics: Status and Perspectives, MRS Bulletin 43, no 8 (2018): 576 80, https://doi.org/10.1557/mrs.2018.181; [2] Rout, Moon, Kang, Kim, Dielectric and Raman Scattering Studies of Phase Transitions in the $(100-x)Na_{0.5}Bi_{0.5}TiO_3–xSrTiO_3$ System, Journal of Applied Physics 108, no 8 (2010): 084102, https://doi.org/10.1063/1.3490781; [3] Liu, Jia, Zhang, Yan, Jing, Li, Phase Evolution in $(1-x)(Na_{0.5}Bi_{0.5})TiO_3$-$xSrTiO_3$ Solid Solutions: A Study Focusing on Dielectric and Ferroelectric Characteristics, Journal of Materiomics 6, no 4 (2020): 677 91, https://doi.org/10.1016/j.jmat.2020.05.005; [4] Mesrar, M., Majdoubi, H., Le, Y, (1-x)$(Na_{0.5}Bi_{0.5})TiO_3$-$xCaTiO_3$ Ceramics: Investigating Structural and Microstructural Features for Enhanced Dielectric Properties, Heliyon 2024, 10 (5), e26463, https://doi.org/10.1016/j.heliyon.2024.e26463; [5] Sharma, Deepak, Pooja Punetha, Gobinda Das Adhikary, Maxim Avdeev, Rajeev Ranjan, Interplay of Local Polarization, Ionic Size, and Octahedral Tilt in $SrTiO_3$ – $Na_{0.5}Bi_{0.5}TiO_3$, Physical Review B 109, no 1 (2024), https://doi.org/10.1103/PhysRevB.109.014107

ABSTRACTS – POSTERS

[*P2-26-79(1)*] Broad-band dielectric spectroscopy of $NaNbO_3$-based antiferroelectric ceramics

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$NaNbO_3$-based ceramics are supposed to be promising lead-free candidates for energy storage applications. At the same time this system is a unique example of a severe competition between polar and antipolar ordering with the ability to tune the scale of interactions. The present study analyses the lattice phonon behavior and dielectric dispersion in pure $NaNbO_3$ (NNO) ceramics and NNO substituted with 5-9% $SrSnO_3$ (SSO) in an 80–700 K temperature range. Measurements were performed by means of Fourier-transform infrared (IR) reflectivity and time-domain terahertz (THz) transmission spectroscopy, covering together 1011-1014 Hz frequency range. These measurements were complemented by low-frequency dielectric data in the 1-109 Hz range. The complex dielectric function obtained via modeling experimental results across the whole 1-1014 Hz frequency range enables us to draw conclusions about the influence of doping on the dynamical properties of NNO and the dissipation mechanisms, which strongly impact the efficiency of energy storage.

[*P2-26-79(2)*] Anti-polar state and extra ordering in $BiFeO_3$ superlattices

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Antiferroelectrics are promising materials for high energy density capacitors and the search for environmentally friendly and efficient systems is actively pursued. An elegant strategy to create and design new (anti)ferroic system relies on the use of nanoscale superlattices. We report here the use of such strategy and the fabrication of nanoscale $BiFeO_3/LaFeO_3$. The atomic scale structural analysis demonstrates anti-polar ordering most likely described by an antiferroelectric-like Pbnm symmetry. Temperature dependence of anti-polar state and structural transition further hint that stability of the anti-polar state is controlled by the $BiFeO_3$ layer thickness and the interlayer strain. Discovery of such polar arrangement in superlattice and the possible generalization to the whole rare-earth family pave the way to new platforms for energy storage application as well as nano-electronic devices relying on negative capacitance. Last but not least we also revealed a new type of extra ordering using advanced synchrotron analysis and correlate this to previous discovery of new zone center phonon excitations.

A gear enhanced rotational frequency up conversion piezoelectric energy harvester for wind induced tree trunk sway

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Ambient mechanical energy from wind induced tree sway represents a promising yet underexploited source for powering autonomous environmental sensors in remote forested areas. Tree trunks, particularly in mature pine species, exhibit very low fundamental sway frequencies of approximately 0.2–0.4 Hz under typical wind conditions, as established by prior field measurements and biomechanical models. Conventional piezoelectric transducers, however, achieve optimal electromechanical conversion efficiency at significantly higher frequencies (>10–100 Hz), leading to poor performance under direct low-frequency excitation. Solution to overcome this frequency mismatch, a novel piezoelectric energy harvester incorporating mechanical frequency up-conversion was designed, fabricated, and experimentally evaluated. The device converts the slow oscillatory bending force from tree sway into continuous unidirectional rotation via a freewheel mechanism. This rotation is further amplified through a planetary gear train with a 1:20 reduction ratio, increasing the effective rotational frequency by a factor of 20. The high-speed output drives a hollow outer drum containing 20 radially arranged steel plates that revolve around a stationary central core. Ten bimorph piezoelectric cantilevers are fixed to this core, with their free tips positioned to experience periodic deflection and release by the passing steel plates, inducing vibrations at the cantilevers' well above the input sway regime. The prototype was initially characterized under controlled laboratory conditions using a computer-controlled pull device. Power output across optimized resistive loads, and frequency response characteristics were recorded. Subsequent field testing was conducted by mounting the harvester directly onto a ~20 m tall pine tree during moderate windy conditions, allowing capture of realistic irregular sway profiles. Laboratory measurements demonstrated successful frequency up conversion and the design exhibited robustness against irregular, non-sinusoidal excitations typical of natural wind gusts, with minimal performance degradation due to damping or misalignment. These results validate the efficiency of gear enhanced rotational frequency up conversion combined with passive plucking of stationary piezoelectric bimorphs for ultra-low-frequency tree sway energy harvesting. The approach offers a pathway toward self-sustaining, bio integrated power sources for long term forest monitoring.

Development of multilayer giant electrostrictive ceria for lead-free transducers

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In 2012, a new class of electrostrictive materials was identified in defective oxides, showing electromechanical responses far exceeding those predicted by Newnham's law, which gives an empirical correlation between the hydrostatic electrostrictive coefficient, the compliance and the permittivity. Among these materials, doped cerium oxide ceramics have attracted particular attention due to their so-called giant electrostriction, with reported electrostriction coefficients on the order of 10^{-16} to 10^{-18} m^2/V^2, comparable to high-performing PMN-PT ceramics. This behaviour is especially remarkable because ceria-based ceramics exhibit relatively low permittivity (ε_r ~30), high Young's modulus (~200 GPa), and a centrosymmetric cubic fluorite structure, which would not normally be expected to support strong polarization or large electromechanical coupling. Although the origin of this anomalously high response is still under debate, the most widely accepted explanation is that local defects introduced into the fluorite lattice create polarizable defect dipoles. Under an applied electric field, these dipoles may reorient and contribute to an intermediate structural state between the centrosymmetric fluorite and a non-centrosymmetric double fluorite structure, resulting in enhanced electromechanical coupling. Driven by the EU RoHS directive, the development of lead-free actuator and transducer materials has increased significantly in recent years. This work investigates the development of multilayer ceria-based electrostrictors, with a primary focus on zirconia-doped ceria (CZO), which has previously demonstrated superior electromechanical performance and stable frequency response. For that reason, a water-based tape casting system was successfully developed for CZO ceramics. The slurry composition was optimized to maximize solid loading and green tape density while maintaining adequate handling and stackability. Circular blanks of tape (10 mm diameter) were laminated into 1 mm-thick monoliths, followed by binder burnout and sintering at 1500 °C. The monoliths were successfully densified without delamination, confirming good lamination behaviour. Electromechanical characterization showed that samples produced under the optimized tape-casting conditions achieved an electrostriction coefficient of approximately 5×10^{-17} m^2/V^2 at 1 kHz, consistent with high-performance CZO ceramics reported in the literature. Based on these results, multilayer structures were fabricated using two electrode configurations: a niobium-doped ceria-based ceramic electrode, selected for its chemical compatibility, and platinum electrodes as a benchmark reference. Both multilayer configurations were successfully co-sintered without observable delamination, indicating promising compatibility between electrode and active ceramic layers. These results demonstrate the feasibility of processing multilayer CZO-based giant electrostrictors and represent an important step toward the industrial implementation of lead-free electrostrictive transducers.

Dielectric and piezoelectric properties of phosphate-bonded barium titanate

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Dielectric ceramics are essential to modern technology, with applications spanning dielectrics in capacitors, piezoelectric devices, memory systems, and sensors. Phosphate-bonded ceramics (PBCs) offer a more energy-efficient alternative to conventional ceramics, which are typically produced using complex and energy-intensive techniques such as spark plasma sintering or hot pressing. PBCs exhibit excellent thermal, chemical, and mechanical stability; however, they generally have lower density than traditionally manufactured ceramics. This study investigates the dielectric and ferroelectric properties of the material. Densification techniques are investigated by (1) varying compaction pressure and (2) using a dual grain-size mixture of the form (1–x)·coarse + x·fine. Samples were prepared as follows. The phosphate binder was produced by dissolving $AlPO_4$ in water until a mixture density of 1.40 g/cm^3 was achieved. Commercially available $BaTiO_3$ powders were obtained from US Research Nanomaterials (99.9% purity, 300 nm grain size) and Sigma-Aldrich (99.9% purity, nominal grain size <3 μm, later determined by SEM to be approximately 700 nm). The barium titanate powder was homogenized with 8.5% liquid binder and uniaxially pressed into pellets. Three sets of samples were fabricated: two sets using either coarse or fine powders pressed at different pressures, and one set using powder mixtures at a fixed pressure. The pellets were cured for 24 hours and then heat-treated at 300 °C for 1 hour to accelerate curing. To assess sample homogeneity in terms of dielectric permittivity, one surface was fully coated with silver via vapor deposition, while the opposite surface received a pattern of co-radial contacts. The influence of composition and pressure on key macroscopic properties—homogeneity, dielectric permittivity as well as deformation due to piezoelectric effect—were systematically examined.

Dielectric properties and triboelectric performance of $0.80Na_{0.5}Bi_{0.5}TiO_3$-$0.20BaTiO_3$/PDMS composite-based TENGs

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In recent years, triboelectric nanogenerators (TENGs) [1] have emerged as a promising technology for harvesting energy from ambient mechanical motions, operating through the combination of contact electrification and electrostatic induction. Polydimethylsiloxane (PDMS) is widely used in TENGs due to its strong negative triboelectric polarity, mechanical flexibility, low cost, and ease of fabrication. Moreover, the properties of PDMS-based TENGs can be further enhanced by incorporating various fillers, which has been the focus of numerous research studies. However, less attention is paid to the relations between the microscopic parameters (particle size [2], their arrangement), morphology (e.g., surface roughness [3]), and the performance of TENGs. This gap is partially addressed in the present work by considering solid-solution $0.80Na_{0.5}Bi_{0.5}TiO_3$-$0.20BaTiO_3$ (NBT-20BT) as filler in a PDMS matrix. This filler was selected since it is a novel lead-free ferroelectric solid solution with enhanced piezoelectric properties and tunable composition (NBT-xBT) for incorporating various inclusions. In this study, a series of 14 vol.% NBT-20BT/PDMS-based TENGs with different particle sizes will be prepared using a combination of simple dispersion and spin-coating methods. The NBT-20BT powder will be synthesized via a conventional solid-state reaction method, and its particle size will be subsequently reduced through wet planetary ball milling. The NBT-20BT/PDMS-based TENGs will be investigated from the point of view of morphology, temperature and frequency dielectric properties, as well as triboelectric output performance. The influence of NBT-20BT particle size on relaxation processes and triboelectric properties in NBT-20BT/PDMS system will be analyzed and discussed to identify potential correlations. Acknowledgements: This research has received funding from the Research Council of Lithuania (LMTLT), agreement No S-LLT-26-3. References: [1] F.-R. Fan et al., Flexible triboelectric generator, Nano Energy, 1(2) (2012) 328–334; [2] X. Meng et al., Effects of particle size of dielectric fillers on the output performance of piezoelectric and triboelectric nanogenerators, Journal of Advanced Ceramics, 10(5) (2021) 991–1000; [3] A. Šutka et al., Contact electrification between identical polymers as the basis for triboelectric/flexoelectric materials, Physical Chemistry Chemical Physics, 22(23) (2020) 13299–13305.

Dielectric properties of steel making by-products

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The dielectric properties of solid materials play a significant role in the process metallurgy industry, especially in heating under microwave radiation. The most crucial microwave parameters are real permittivity, imaginary permittivity, loss tangent, and half-power depth. These parameters are measured by cavity perturbation technique for different temperature ranges. Analysis of these dielectric properties enables accurate characterization of the microwave heating behavior of solid materials. During the study we analyzed five different samples; basic oxygen furnace slag (BOF slag), basic oxygen furnace sludge (BOF sludge), blast furnace sludge (BF sludge), electric arc furnace stainless steel dust (EAFSS dust), ferrochrome converter dust (CRC dust). Maxwell, Debye, and Jonscher have developed various equations to explain the microwave heating mechanism for solid materials. Traditional Debye equations for ε' and ε'' are derived from either (1) permanent dipole rotation mechanisms, which are rare in solids and typically involve molecules or radicals in cages or on surfaces, or (2) Maxwell-Wagner configurations in heterogeneous materials that exhibit Debye-like frequency dependencies. Developed the fractional power-law "universal" dielectric frequency response, which matched the data quite well, although the exact mechanism, likely related to ion or polaron hopping, is still not fully understood. We have studied five different types of steelmaking byproducts such as slags, sludges, and dust samples. The initial heating rate of these solid materials were heavily depended on the absorbed water (free water) and hydroxyl percentage (bound water) inside the sample. Moreover, increasing the microwave frequency led to higher heating rates at initial stage, as the lag between the applied electric field and the orientation of polar molecules increased. At the later stage, ionic bonds in remaining metal oxides such as iron oxide are the most significant compounds in the samples, which heat under ionic conduction, mainly due to their spinel and monoxide structures. According to the permittivity results, heating rate can be ranked as BF sludge > BOF sludge > EAF stainless steel dust > CRC dust > BOF slag. The high heating rate of BF sludge is attributed to the presence of fixed carbon (coke) and iron oxides, both of which are highly effective microwave absorbents. BOF sludge primarily contains iron oxides, particularly magnetite, which also exhibits strong microwave absorption. EAF dust contains iron oxides mainly in the form of franklinite, which has a spinel crystal structure. Similarly, CRC dust contains iron oxides predominantly as chromite, another highly stable spinel structure, resulting in good microwave absorption. The lowest heating rate is in BOF slag due to its relatively low iron oxide content.

Ferroelectricity in organic - inorganic TMCM-BCl (B=Mn, Fe, Zn) materials

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Hybrid organic-inorganic materials may combine multiple degrees of freedom including ordering of molecules, polar off-centering of ions in the inorganic frameworks and resulting (anti)-ferroelectric and magnetic orderings. These different types of degree of freedom may offer large entropy changes and electrocaloric responses. In this work, we explore the class of TMCM-BCl_3 (B=Mn, Fe, Zn, TMCM= Trimethylchloromethylammonium) for which a large piezoelectric response has been reported. So far, neither the energy landscape for molecular ordering and switching, nor the stability of different phases, nor ferroic properties are fully understood. We apply Density Functional Theory (DFT) with Van-der-Waals interactions and systematically compare atomic and electronic structures. We find that either G-type checkerboard anti-ferromagnetic or ferromagnetic ordering can be stabilized by Mn or Fe-atoms on the B site. Most importantly we report a large variety of metastable polarization directions including a so far overlooked metastable triclinic P1 phase.

Finite-temperature molecular dynamics of ferroelectric domain walls in perovskites

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Ferroelectric domain walls (DWs) in perovskite oxides, such as $PbTiO_3$ and $BaTiO_3$, may exhibit structural and polar features that differ from those of the surrounding bulk domains. While first-principles calculations have provided detailed insight into DW structures at zero temperature, the influence of finite temperature on DW properties remains less well understood. In particular, thermal fluctuations can affect polarization profiles, DW width, and the stability of polar states localized at the wall. In this contribution, we investigate ferroelectric DWs in $PbTiO_3$ and $BaTiO_3$ using molecular dynamics simulations based on an effective Hamiltonian derived from first-principles calculations. This approach enables access to finite temperatures while retaining a microscopic description of the relevant lattice degrees of freedom. We analyze the temperature dependence of polarization and strain across the DW region and compare the resulting finite-temperature DW structures with available zero-temperature *ab initio* results. The simulations show that increasing temperature leads to a gradual broadening of the DW and to quantitative changes in the magnitude and spatial distribution of polarization components confined to the wall. Particular attention is devoted to possible temperature-induced modifications of the DW structure and to the role of gradient electrostriction at finite temperatures. The results provide a finite-temperature description of ferroelectric DWs and contribute to assessing the relevance of specific coupling terms used in Landau–Ginzburg–Devonshire phenomenological models. Acknowledgements: This work was supported by the Czech Science Foundation (GAČR), project No. 25-18870L. W.S. acknowledges support from the Austrian Science Fund (FWF), project No. 10.55776/PIN2246224.

Flexoelectric response in conjugated polymer and biopolymers

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Given the urgent need to develop sustainable energy solutions, the exploration of new materials with advanced electromechanical properties has become a priority. Among these, flexoelectricity a phenomenon that couples a mechanical strain gradient with induced electrical polarization, stands out as a promising alternative to piezoelectricity, particularly for the conversion of ambient energy. Although this mechanism offers unique technological potential, its specific characteristics within polymer matrices remain largely unexplored. Whilst conventional polymers (PVDF, PET, epoxy) exhibit a modest flexoelectric coefficient (10^{-10} to 10^{-8} C/m), recent advances have pushed these limits. Indeed, the optimization of the PEDOT:PSS complex through mild treatments has increased its flexoelectric response by a factor of 1000, thereby paving the way for a new generation of high-performance materials. In this context, our study aims to optimize the flexoelectric properties of conjugated polymer systems in particular by analyzing the influence of the PEDOT:PSS mass ratio (varying from 2.5 to 20). At the same time, this research evaluates the response and of bio-based polymers (Starch, Alginate) in order to balance performance with environmental sustainability. This approach is based on an in-depth characterization of the dielectric, chemical and morphological properties of the samples to correlate the structure of the materials with their conversion efficiency.

Gradient electrostriction and polarity of domain walls in perovskite ferroelectrics

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The functional properties of domain walls (DWs) in ferroic perovskites have attracted growing interest, as these nanoscale interfaces may host polar, chiral, or electromechanically active states absent in the bulk material. Recent experimental progress has stimulated intensive theoretical efforts to identify the microscopic origin of such emergent DW functionalities. A variety of modeling approaches—including first-principles calculations, machine-learned force fields, phase-field simulations, and phenomenological Landau–Ginzburg–Devonshire (LGD) theory—are commonly employed, often supported by symmetry analysis based on layer groups. In several perovskite oxides, polarization localized at DWs has been predicted to arise from mechanisms such as flexoelectricity, rotopolar coupling, or biquadratic coupling between primary and secondary order parameters [1–3]. In this contribution, we present an *ab initio* investigation of 180º ferroelectric domain walls in representative perovskite materials, with $PbTiO_3$ and $BaTiO_3$ serving as model systems. Previous theoretical studies have shown that such DWs may adopt distinct structural configurations, including nonpolar Ising-type walls, Néel-like walls with asymmetric polarization profiles, and Bloch-type walls exhibiting a switchable polarization component within the wall plane. While LGD-based continuum descriptions can reproduce these possibilities, the microscopic mechanisms governing the stabilization of polar and chiral DW states remain under debate. Our first-principles calculations focus on the atomic-scale interplay between polarization, strain, and polarization gradients across the DW region. In particular, we assess the role of recently proposed inhomogeneous electromechanical coupling mechanisms, which extend conventional electrostriction by including a coupling between strain and the square of the polarization gradient, described by a sixth-rank tensor [3]. By comparing different DW configurations with analytical formulae, we demonstrate that DW width is a critical parameter controlling the relative importance of homogeneous versus gradient-driven electromechanical contributions. The results provide direct microscopic evidence that polarization gradients can generate sizable electromechanical responses within DWs, even in the absence of bulk polarity. These findings establish a quantitative link between *ab initio* modeling and continuum theories of DWs and contribute to a unified understanding of electromechanical couplings in perovskite ferroelectrics.

This work was supported by the Czech Science Foundation (GAČR), project No. 25-18870L. W.S. gratefully acknowledges support from the Austrian Science Fund (FWF), project No. 10.55776/PIN2246224. References: [1] W. Schranz, A. Tröster, and I. Rychetsky, *J. Appl. Phys.* 128, 194101 (2020); [2] I. Rychetsky, W. Schranz, and A. Tröster, *Phys. Rev. B* 104, 224107 (2021); [3] I. Rychetsky, W. Schranz, and A. Tröster, *Phys. Rev. B* 108, 104107 (2023).

Impact of target-substrate distance and thermal processing on the stoichiometry and phase purity of lead-free KNN thin films

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The development of high-performance lead-free ferroelectric thin films is essential for the next generation of sustainable microelectronic devices. Potassium Sodium Niobate ($(K,Na)NbO_3$ - KNN) has emerged as a primary candidate to replace lead-based ceramics due to its promising electromechanical properties. However, achieving the required perovskite phase and precise stoichiometry via RF magnetron sputtering is challenging, primarily due to the high volatility of alkaline elements (K, Na) and the preferential scattering of species during plasma transport. This study investigates the impact of target-substrate distance (WD) and thermal treatments on the properties of KNN thin films deposited on $Pt/TiO_2/SiO_2/Si$ substrates. Depositions were performed at powers ranging from 15–50W and argon pressures of 6–24 mTorr, with WD ranging from 1.5 to 8.0 cm. Chemical analysis (EDX) revealed that reducing the WD to the ballistic regime (<3 cm) was the decisive factor in mitigating Niobium enrichment, successfully decreasing the Nb concentration from >70 % at conventional distances to near-stoichiometric levels (~50 %), while achieving a Na:K ratio of 1.1 under optimized conditions. X-ray diffraction (XRD) confirmed that Rapid Thermal Annealing (RTA) at 650 °C for 5 minutes successfully promotes the crystallization of the ferroelectric perovskite phase with a strong (100) preferential orientation. Temperatures above 700 °C led to alkali re-evaporation and the formation of non-ferroelectric Na rich secondary phases. Morphological analysis (AFM and SEM) showed that shorter WD increases surface roughness due to higher energetic bombardment. These results define an optimized processing window for obtaining high-quality KNN thin films, providing a critical step for the development of lead-free ferroelectric micro-devices.

Improving the energy harvesting performance of organic piezoelectric materials via exploration of standardised electrode deposition

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Organic piezoelectric materials, particularly amino acids, their derivatives, and their multi-component and composite forms, are becoming a large area of research in the quest for sustainable materials and low-power energy sources. Across the many new discoveries of high-performance eco-friendly piezoelectrics, there has been a lack of consistency in electroding materials when validating organic piezoelectrics as sensors, actuators and energy harvesters, and a lack of in-depth comparison of electrode materials and deposition techniques. Following on from our team's standardisation of amino acid growth into macroscopic device elements of fixed dimensions, we now move towards standardisation of electrode procedures. By systematically investigating metal foils, sputtered metal, and conductive slurries across drop-cast and sublimated amino acid crystal discs, we increase the harvested open-circuit voltage by up to ten times. The goal of this research is to accelerate the technological uptake of molecular crystal piezoelectrics by demonstrating the dramatic effect of the device electrodes on the piezoelectric output, as well as the complexities and considerations for electroding organic crystal device layers.

Mapping the band structure of $KNbO_3$ ferroelectric ceramics

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The electronic band structure of potassium niobate ($KNbO_3$) is investigated in this work to deepen the fundamental understanding of the semiconducting behavior in ferroelectrics. $KNbO_3$ is an environmentally friendly ferroelectric material with an oxide perovskite structure. Photoferroelectrics (i.e., ferroelectrics interacting with light) like $KNbO_3$ show potential in optoelectrical applications such as self-powered multi-modal sensing and energy harvesting. A crucial property in question is the material's ability to absorb light and the resulting change in electrical conduction. This is determined by the band structure of the material. Most excellent photoferroelectrics are polycrystalline ceramics. However, band structure of these materials is complex to characterize and is hence insufficiently understood in the literature. This is because in such a context, it is essential to distinguish the electrical transport band gap from the fundamental gap and optical gap, as reported by Hu et al. [1]. Therefore, this work uses one of the simplest possible oxide perovskite compounds to define and map transport gaps of $KNbO_3$, and to investigate influences of potential in-gap states and possible charge traps introduced by grains, grain boundaries, domains, and domain walls on conduction mechanisms via experimental approaches. In particular, electrical measurements including current-voltage (I-V) curves (quasi-DC conduction) and impedance analysis (AC conduction) were carried out at 30 °C under different lighting conditions to facilitate probing into different electronic states and their origins in the band structure. A major difference between AC and DC conduction behaviors was observed in the photon energy range of 1.8–2.6 eV. This phenomenon helps to separate the contribution of grain boundaries and domain walls from that of grains and domains. Combining other methods including X-ray photoelectron spectroscopy (XPS) to identify the chemical states of the elements, ultraviolet photoelectron spectroscopy (UPS) to define the energy levels of the valence electrons, and scanning electron microscopy (SEM) to examine the grains, this work advances fundamental understanding of the band structure of photoferroelectrics, thus promoting development of next-generation multifunctional sensors and energy harvesters for Internet of Things (IoT). Reference: [1] P. Hu et al., Rep. Prog. Phys 89, 028004, 2026.

NBT-BT thin films by pulsed laser deposition: Structural and dielectric properties

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Ferroelectric thin films are widely used in capacitors, sensors, actuators, and piezoelectric microelectromechanical systems due to their dielectric and electromechanical properties. The increasing demand for environmentally friendly materials has motivated the development of lead-free ferroelectric thin films. Among these, $Na_{0.5}Bi_{0.5}TiO_3$–$BaTiO_3$ (NBT-BT) is considered a promising candidate, although achieving high-quality lead-free thin films remains challenging. The aim of this work is to study the growth reproducibility and dielectric properties of 0.8NBT-0.2BT thin films deposited by pulsed laser deposition.

In this work, 0.8NBT–0.2BT thin films were deposited on Pt/$LaNiO_3$/SiO_2/Si substrates using Demcon TSST equipment. In addition to deposition parameter optimization, a relationship between the number of laser pulses and film thickness was established, allowing improved control over film growth. The influence of substrate temperature, oxygen pressure and laser fluence on film structure and morphology was investigated using scanning electron microscopy (SEM) and X-ray diffraction (XRD). Dielectric properties were measured using an LCR meter. Films deposited under similar conditions exhibited comparable dielectric permittivity values. Results demonstrate that control of pulsed laser deposition parameters is essential for obtaining homogeneous NBT-BT thin films with reproducible dielectric properties. The presented findings contribute to the ongoing development of lead-free ferroelectric thin films for electromechanical applications.

Sodium bismuth titanate bulk and textured piezoceramics for high intensity focused ultrasound devices

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Bulk and textured sodium bismuth titanate (NBT)-based piezoceramics fabricated at CTS Denmark A/S based on CTS Pz12, CTS Pz12x, and Entekno supplied equiaxed NBT were developed and built into HIFU devices at Precision Acoustics. The piezo components were large form-factor lenses and discs (Diameter:Thickness > 30), the largest lead-free lenses developed to date at CTS Denmark. Devices based on standard PZT (CTS Pz54) components were built in parallel for benchmarking and comparison. Bulk devices were fabricated with Pz12 and Pz12x. These components were fabricated at CTS with a target resonance of 1 MHz and exhibited standard properties summarized in the table below. The Pz54 HIFU device proved to be the most efficient, in terms of electrical power required to reach 100 W total acoustic output. The Pz12 and Pz12x devices only required an extra 11% and 18% electrical power to the Pz54 device, respectively. The two lead-free alternatives at this frequency and geometry benefited from being naturally matched to 50 Ohms real impedance, requiring minimal reactive component. This resulted in a voltage-limited system where current was no longer a factor. In further comparison, the Pz12x device required 35 % lower peak to peak drive voltage, and Pz12 required 20% less voltage, with respect to the Pz54 device. To-date, textured NBT discs of have successfully been developed at CTS Denmark with properties also summarized below. Crystallographic texture was achieved through tape-casting by the addition of NBT platelets, provided by Entekno. Texture fraction was measured via Lotgering factor to be 98.4 %. These textured discs were received for evaluation and prototyping at Precision Acoustics. Textured NBT lenses of are currently under development at CTS Denmark. The process of forming a textured lens from ceramic tape was found to not be trivial and gave rise to two main possibilities. First, formation of a large thickness textured slug for machining into lens geometry (standard route), and second, form the tape into a near-net lens shape. Both tracks have basic practical challenges with potential drawbacks and challenges. The first track would result in a lens where the texture direction is not focused to the focal point of the lens, whereas the second track would result in a component where texture direction is focused to the focal point of the lens. Both tracks are being pursued as the lenses are currently under development. All the work done during this project was partially funded by the LIFE MED-U, a project funded by Eureka Eurostars, project # 4277.


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