MA 56: Focus Session: (Anti)ferroic states – Magnetic and magnetoelectric III (joint session FM/MA)

chair: Morgan Trassin (ETH Zurich, CH)

This focus session explores recent advances in understanding and control of (anti)ferroic states. Emphasis will be placed on theoretical modelling, advanced characterization techniques, and the engineering of emergent properties for use in nano-electronic devices. The session aims to bridge fundamental research with emerging device-relevant functionalities, bringing together experimental, and theoretical perspectives on ferroic materials.

Time: Friday 9:30–11:30 Location: BEY/0E40

Invited Talk MA 56.1 Fri 9:30 BEY/0E40

Mapping topological textures in compensated magnets with X-rays — •Claire Donnelly — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Extending spin systems to three dimensions promise significant opportunities for applications, for example providing higher density devices and new functionalities associated with complex topology and greater degrees of freedom. Until now, however, insight into three dimensional spin systems has mainly been limited to ferromagnetic and ferrimagnetic systems through X-ray magnetic tomography [1], where a variety of topological textures [1,2], as well as 3D dynamics [3,4], have been observed. In this talk I will describe our recent work mapping topological textures in compensated systems. I will first describe the development of X-ray linear orientation tomography [5], which we have harnessed to map three-dimensional orientation fields - both crystallographic [5], and antiferromagnetic - at the nanoscale. Second, I will present our recent mapping of topological textures in altermagnets [6], harnessing both X-ray circular and linear magnetic dichroism. These insights into the formation of topological textures in compensated magnets not only paves the way for enhanced understanding of these systems, but also towards the next generation of technological devices.

[1] C. Donnelly et al., Nature 547, 328 (2017). [2] C. Donnelly et al., Nat. Phys. 17, 316 (2021) [3] C. Donnelly et al., Nature Nanotechnology 15, 356 (2020). [4] S. Finizio et al., Nano Letters (2022) [5] A. Apseros et al., Nature 636, 354 (2024) [6] R. Yamamoto et al., Phys. Rev. Appl. 24, 034037 (2025)

MA 56.2 Fri 10:00 BEY/0E40

Exploring Magnetoelectric Effects in 1T-$FeCl_2$/bilayer-GaSe Multiferroic Heterostructures — •Fahmida Fakhera[1], Oliver J. Conquest[1], Carla Verdi[1,2], and Catherine Stampfl[1] — [1]School of Physics, The University of Sydney, NSW 2006, Australia — [2]School of Mathematics and Physics, The University of Queensland, QLD 4072, Australia.

Multiferroic materials exhibit multiple ferroic orders simultaneously, including ferromagnetism and ferroelectricity [1]. A recent study [2] on sliding ferroelectricity in bilayer GaSe adds a novel dimension, making it useful as a ferroelectric (FE) sublayer in multiferroic heterostructures. We employ first-principles density functional theory (DFT) to investigate the interlayer and intralayer sliding mechanisms of FE GaSe. Moreover, this study investigates the structural and electronic properties, energy band alignments, magnetic anisotropy, binding energies, electric dipole moments, and interfacial charge transfer of different stackings of 1T-$FeCl_2$/bilayer GaSe. For all stackings, the magnetic anisotropy energies indicate an in-plane easy axis of magnetization in both upward and downward polarization directions. The contact interfaces form Ohmic contacts, enabling sufficient charge transfer between the layers. As the first study on sliding-induced FE and ferromagnetic interfaces, this work offers new insights into the design and understanding of multiferroic materials for the future.

[1] X. Feng, J. Liu, X. Ma, and M. Zhao, Physical Chemistry Chemical Physics 22, 7489 (2020). [2] F. Fakhera, O.J. Conquest, C. Verdi, and C. Stampfl, Physical Review Materials 9, 054402 (2025).

MA 56.3 Fri 10:15 BEY/0E40

Nonlinear phononic slidetronics — •Pooja Rani and Dominik Juraschek — Eindhoven University of Technology, Eindhoven, Netherlands

We investigate ultrafast switching of ferroelectricity in bilayer hexagonal boron nitride using nonlinearly driven phonons. Conventional coherent phonon excitation mechanisms such as infrared absorption, Raman-based techniques, and terahertz sum-frequency excitation produce too small a shear-mode amplitude to overcome the barrier between stacking orders. Using first-principles calculations and phenomenological modeling, we demonstrate instead that strong excitation of high-frequency intralayer phonons dynamically tilts the interlayer potential, enabling efficient and deterministic switching at experimentally accessible pulse strengths. Our results establish nonlinear phononic slidetronics as a powerful method for ultrafast, energy-efficient control of stacking order and related electronic phases in van der Waals materials, with potential for future all-optical ferroelectric memory devices.

Coffee break

MA 56.4 Fri 10:45 BEY/0E40

Resolving the chemical depth profile of ultrathin EuO films by grazing incidence HAXPES measurements — •Katharina Wehrstein[1], Umut Parlak[1], Pia Düring[1], Oliver Rehm[1], Andrei Gloskovskii[2], Christoph Schlueter[2], and Martina Müller[1] — [1]FB Physik, Uni Konstanz — [2]DESY, Hamburg

Magnetic proximity effects enable control of magnetic order in ferromagnetic insulators without altering their intrinsic properties. Europium oxide (EuO) thin films coupled with heavy metals (HM) are promising systems for spintronic applications, in which spin-polarized states are induced, altered or converted via interface coupling. These systems require a sharp interface between the metal and the EuO layer, as well as stoichiometric EuO. As ferromagnetic Eu(II)O is metastable and tends to oxidize to paramagnetic $Eu(III)_2O_3$, investigating the depth-resolved chemical and thus magnetic nature of an EuO layer is mandatory to observe and eventually tune magnetic proximity effects.

Ultrathin EuO films (2-15 nm) were prepared by molecular beam epitaxy on $Pt/SrTiO_3$ and $W/SrTiO_3$ substrates. Grazing incidence hard X-ray photoelectron spectroscopy (GIXPES) enables high X-ray intensity at the sample surface due to reflection of the X-ray beam on the heavy metal layer, leading to the formation of X-ray standing waves. By changing the incidence angle of the X-ray beam, spectra with modulated depth-sensitivity were recorded, revealing variations in the Eu^{3+} content at different depths of the ultrathin EuO layer. This yields a chemical depth profile and thus a magnetic profile that provides insight into the magnetic behavior of the EuO/HM system.

MA 56.5 Fri 11:00 BEY/0E40

Optical manipulation of multiferroic phases in $BiFeO_3$ thin films — •Bixin Yan[1], Lauren J. Riddiford[1,2], Ales Hrabec[1,2], Annika Mechnich[3], Christian L. Degen[3], Manfred Fiebig[1], and Morgan Trassin[1] — [1]Department of Materials, ETH Zurich, Switzerland — [2]PSI Center for Neutron and Muon Sciences, Paul Scherrer Institute PSI, Switzerland — [3]Department of Physics, ETH Zurich, Switzerland

Employing light as a means of actively tuning material properties unlocks the potential for non-invasive, remote, and macroscopic control over technology-relevant functionalities. In our work, we demonstrate optical control over multiferroic phases in prototypical magnetoelectric $BiFeO_3$ (BFO) thin films, utilizing above-bandgap UV light illumination. Taking advantage of the enhanced response at the strain-driven morphotropic phase boundary, we show that by modifying the electrostatic boundary conditions with photoinduced charge carriers, the rhombohedral-like (R-like) phase of BFO can be selectively suppressed within the tetragonal-like (T-like) phase BFO matrix. Furthermore, the electronic origin of such an optical response permits a pronounced polarization-dependent R-to-T-phase conversion. Finally, using scanning nitrogen-vacancy magnetometry, we correlate optically induced ferroelectric phase conversion with a change from uncompensated magnetic ordering to G-type antiferromagnetic ordering. Our work thus

presents a novel approach to writing multiferroic states, which is key to magnetoelectric oxide electronics.

MA 56.6 Fri 11:15 BEY/0E40

Time resolved X-ray diffraction study of polarization reversal in uniaxial ferroelectric $BaMgF_4$ single crystals — •Nathan Leubner[1,4], Sara Polo-Filisan[2], Gaetano Bonetti[2], Hiroki Tanaka[2], Matthias Zschornak[3], Dirk C. Meyer[1], Carsten Richter[2], and Semën Gorfman[4] — [1]Institut für Experimentelle Physik, TU Bergakademie Freiberg — [2]Leibniz-Institut für Kristallzüchtung, Berlin — [3]Fakultät Maschinenbau, HTW Dresden — [4]Department of Materials Science and Engineering, Tel Aviv University, Israel

$BaMgF_4$ (BMF) is a uniaxial ferroelectric material crystallizing in the orthorhombic space group $Cmc2_1$ and being a compelling candidate for frequency conversion in far ultraviolet regime. In this work, we present time-resolved X-ray diffraction (XRD) studies of single-crystalline BMF under applied electric fields, enabling direct observation of atomic-scale structural changes during domain switching. Complementary dielectric measurements provide insights into the kinetics of domain wall motion. The XRD data reveal the electric-field dependence of strain, allowing for the determination of the components of the piezoelectric tensor of BMF. Furthermore, by exploiting the resonant Friedel pair contrast between oppositely polarized domains, we achieve a direct determination of the crystal structure of each domain. This approach eliminates the need for conventional correction factors (e.g., absorption, extinction), offering a robust and accurate alternative to traditional structure refinement methods. Our findings advance the fundamental understanding of ferroelectric switching in BMF.