KFM 16: Multiferroics and Magnetoelectric coupling II (joint session MA/KFM)

Time: Friday 9:30–11:45 Location: H39

KFM 16.1 Fri 9:30 H39

Reversible magnetoelectric interconversion of ferroic domain patterns in (Dy,Tb)FeO_3 — •Ehsan Hassanpour[1], Mads C. Weber[1], Yusuke Tokunaga[2], Yasujiro Taguchi[3], Yoshinori Tokura[3], Thomas Lottermoser[1], and Manfred Fiebig[1,3] — [1]ETH Zurich, Switzerland — [2]University of Tokyo, Japan — [3]RIKEN CEMS, Japan

Multiferroic materials can show a variety of exquisite effects due to hosting coexisting and complex magnetic and electric orders. Recently it was reported that a ferroelectric domain pattern from one layer is transfered to a ferromagnetic layer in a multiferroic heterostructure[1]. Here we show that we can reversibly interconvert magnetic and ferroelectric domain patterns in a single phase of multiferroic bulk system $Dy_{0.7}Tb_{0.3}FeO_3$. In this material, it was shown that a ferroelectric polarization is induced as a result of interaction of two magnetic sublattices of iron Fe^{3+} and rare-earth (Dy,Tb) R^{3+} via exchange forces. The strong coupling of these three order parameters creates a variety of composite domains and domain walls. Using magnetooptic imaging, we show that electric field pulses of specific speeds and amplitudes can generate and tune those domains/domain walls. Ultimately, by imprinting a domain pattern in the rare-earth's antiferromagnetic order, we transfer it from the ferromagnetic order of iron to the ferroelectric order and vice versa using magnetic and electric fields, respectively.

[1] De Luca *et al. Phys. Rev. Applied* **10**, 054030 (2018)

KFM 16.2 Fri 9:45 H39

Coupled electric and magnetic domains and domain walls in h-$R$$MnO_3$ at the microscale — •Marcela Giraldo, Thomas Lottermoser, and Manfred Fiebig — ETH Zurich, Switzerland.

Fundamental understanding of the cross-coupling between ferroic orders at the level of domains and domain walls is crucial for the manipulation of multiferroics. It was shown for the first time on h-$R$$MnO_3$ that coupling between ferroelectricity and antiferromagnetism –with order parameters P and l, respectively– occurs in a type-I multiferroic where ferroic orders emerge independently. At the macroscopic scale, it was observed that the antiferromagnetic domain pattern (l) is defined by two independent domain patterns formed by P and the multiferroic order parameter Pl [1]. Albeit, coupling on the microscopic regime, on the level of the ferroelectric vortex domains which are characteristic for these materials has remained under debate. For the first time, we investigate the coupling between electric and magnetic domains in h-$R$$MnO_3$ on the microscopic scale using second-harmonic microscopy. We reveal that two of the three order parameters (P, l and Pl) change their sign simultaneously at every domain wall while the third one retains its sign. This confirms the earlier observation [1] that P and Pl form independent domain patterns. In addition, we show a new type of domain wall where P and Pl change their sign, while l remains constant. Our observations solve the open debate about coupling of domains and domain walls at the microscale and add new findings to understand the unique coupling nature in a type-I multiferroic.

[1] M. Fiebig *et al.*, Nature **419**, 818 (2002).

KFM 16.3 Fri 10:00 H39

Magnetoelectric Polarizability in Magnetic Insulators — •Maximilian Merte[1,2], Frank Freimuth[1], Stefan Blügel[1], and Yuriy Mokrousov[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

In the field of spintronics, the interaction of insulators with external electromagnetic fields plays a crucial role for future prospects related to fundamental understanding and technological applications of magnetic oxides. In a situation of reduced symmetries, magnetic insulators can exhibit a finite electric polarization. Recently, a semiclassical approach describing the positional shift of Bloch electrons due to interband mixing induced by an external electromagnetic field was proposed [1]. These shifts can be computed via response matrices, which are constructed from interband velocity elements and band energies. Here we want to report on the implementation of this approach by means of Wannier interpolation, which can be applied as a postprocessing step to first-principles calculations performed with the Jülich DFT code FLEUR [2], an implementation of the FLAPW method. We apply the developed method to the study of magnetoelectric polarizability to selected magnetic insulators.

[1] Qian Niu *et al.*, Phys. Rev. Lett. 112, 166601 (2014).
[2] www.flapw.de .

KFM 16.4 Fri 10:15 H39

Artificial multiferroic domain walls in oxide heterostructures — •Elzbieta Gradauskaite, Manfred Fiebig, and Morgan Trassin — Department of Materials, ETH Zurich, Switzerland

Ferroelectric domain walls possess symmetry-dependent functional properties enabled by confinement. Enhanced conductivity, for instance, is observed in charged domain walls. Regrettably, domain walls of this type are very scarce in nature due to energetically unfavourable electrostatics, which hinders technological development of domain wall nanoelectronics. We propose ferroic thin film oxide interfaces as an alternative. The polar state of $BaTiO_3$ and $BiFeO_3$ ferroelectrics can be manipulated via atomically precise surface termination control and monitored with in-situ second harmonic generation (ISHG) during the growth. Using this approach, stable head-to-head and tail-to-tail polarization-oriented configurations of ferroelectric layers can be created. Their interfaces are charged and can be regarded as artificial domain walls. By inserting an ultrathin $La_{1-x}Sr_xMnO_3$ ferromagnetic film at the junction we design a magnetoelectric multiferroic interface. Using a combination of ISHG and SQUID magnetometry, we show that the interlayer magnetic moment can be enhanced or diminished when the artificial domain wall has a head-to-head or tail-to-tail configuration, respectively. Our work provides new insights into electrical control of magnetism in multiferroic oxide heterostructures.

KFM 16.5 Fri 10:30 H39

Complex magnon spectrum of the simple collinear antiferromagnet $Co_2Mo_3O_8$ — •Stephan Reschke[1], Dániel Farkas[2], Sandor Bordács[2], Vladimir Tsurkan[1], and István Kézsmárki[1] — [1]University of Augsburg, Augsburg, Germany — [2]Budapest University of Technology and Economics, Budapest, Hungary

$Co_2Mo_3O_8$ belongs to a family of hexagonal lattice type-I multiferroics, showing peculiar magnetoelectric effects. In this compound the magnetic Co^{2+} ions are in either tetrahedral or octahedral oxygen coordination and form honeycomb layers in the ab plane. Based on neutron powder diffraction, $Co_2Mo_3O_8$ is a 4 sub-lattice collinear easy-axis antiferromagnet below $T_N = 42$ K. By THz time-domain spectroscopy measurements the magnon excitation spectra of differently oriented single crystals were investigated in magnetic fields up to 7 T. Interestingly, we observed magnon spectra far more complicated than expected for the proposed simple antiferromagnetic structure, with more than 20 magnon modes. Most of these modes show a splitting for magnetic fields applied along the c axis, which supports the predominantly easy-axis character of the antiferromagnetic state. Furthermore, we also observed directional dichroism for some of the modes, a consequence of the dynamic magnetoelectric effects.

KFM 16.6 Fri 10:45 H39

Vacuum encapsulated high frequency magnetic field sensors based on the ΔE effect — •Benjamin Spetzler[1], Florian Niekiel[2], Fabian Lofink[2], Bernhard Wagner[2], and Franz Faupel[1] — [1]Kiel University, Kiel, Germany — [2]Fraunhofer ISIT, Itzehoe, Germany

Investigations into the ΔE effect of magnetoelastic materials have revealed the exciting promise of detecting low frequency and small amplitude magnetic fields [1]. Typical approaches are based on electrically exciting a resonator by applying an alternating voltage to a magnetoelectric composite structure with soft magnetic properties [2]. Previously presented sensors are operated either in the first or second bending mode with resonance frequencies in the lower kHz regime [3]. Due to the low resonance frequencies and comparatively large quality factors, the bandwidth of these sensors is too small for many biomedical applications. Here, we present vacuum encapsulated cantilever resonators operating at high frequency modes with bandwidths in the kHz regime. In addition to common bending modes, longitudinal and more complex modes are also used. The various modes are analyzed experimentally and theoretically for sensitivity, detection

limit, mechanical properties and loss mechanisms with a comprehensive magneto-electromechanical model. Important consequences for future sensor designs are derived.

[1] B. Gojdka, et al., APL, 99 (22), (2011)
[2] S. Zabel, et al., APL, 107 (15), (2015)
[3] J. Reermann, et al., IEEE Sensors, 16 (12), (2016)

KFM 16.7 Fri 11:00 H39

High magnetic field phases of magnetoelectric LiFePO4 and LiNiPO4 — •Botond Forrai[1], Atsuhiko Miyata[2], Dávid Szaller[3], Vilmos Kocsis[4], Yasujiro Taguchi[4], Yoshinori Tokura[4], István Kézsmárki[5], and Sándor Bordács[1] — [1]Department of Physics, Budapest University of Technology and Economics, Budapest 1111, Hungary — [2]Laboratoire National des Champs Magnetiques Intenses, Toulouse 31400, France — [3]Institute of Solid State Physics, Vienna University of Technology, Vienna 1040, Austria — [4]RIKEN Center for Emergent Matter Science (CEMS), Wako, Saitama 351-0198, Japan — [5]Zentrum für Elektronsiche Korrelation und Magnetismus, Institut für Physik, Universität Augsburg

Olivine-type orthophosphates has been attracting much attention due to their strong linear magnetoelectric effect. The low-field magnetic phases giving rise to the magnetoelelctric effect are well charachterized, however, their high field phase diagrams have not been fully explored. Therefore, we studied the magnetic phases of LiFePO4 and LiNiPO4 at 5K by magnetization measurements till their magnetization reach the saturation. The competing exchange interactions leads to several phase transitions in LiNiPO4, while in LiFePO4 a single spin-flop transition is detected due to the strong anisotropy. The magnetic phase diagrams are interpreted in a classical mean-field model, which allowed us to identify the key terms in spin Hamiltonian.

KFM 16.8 Fri 11:15 H39

Electric field control of the nonreciprocal light absorption in $Ba_2CoGe_2O_7$ — •Jakub Vít[1], Toomas Rõõm[2], Urmas Nagel[2], Johan Viirok[2], Vilmos Kocsis[1,3], Yoshinori Tokura[3], István Kézsmárki[1,4], and Sándor Bordács[1] — [1]Budapest University of Technology and Economics, Hungary — [2]National Institute Of Chemical Physics And Biophysics, Estonia — [3]RIKEN CEMS, Japan — [4]Experimental Physics 5, University of Augsburg, Germany

In crystalline solids where space inversion and time-reversal symmetries are simultaneously broken, the propagation of (quasi)particles can be different when the wave vector is reversed. Strong nonreciprocal light absorption has been observed on spin-wave excitations of multiferroics, i.e. ferroelectric and magnetic materials, where the sign and the magnitude of the effect were controlled by an external magnetic field. Here, we report an electric-field control of the nonreciprocal light absorption on THz excitations of $Ba_2CoGe_2O_7$. In the canted antiferromagnetic phase, we demonstrate that an electric field can be used to switch between low- and high-absorption states of magnetoelectric excitations. Our finding can facilitate the use of multiferroics in low-power consumption switchable optical diodes.

KFM 16.9 Fri 11:30 H39

Manipulating Coercivity and Mangetization Reversal in Bulk Ferromagnetic Metals with Small Voltages — •Xinglong Ye, Robert Kruk, and Horst Hahn — Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, Eggenstein-Leopoldshafen, 76344, Germany

Voltage control of magnetic properties in ferromagnetic metals is usually restricted to the scale of atomic layer due to their strong electric-field screening. Here we show that magnetic properties of bulk ferromagnetic metals can be hugely and reversibly tuned by small voltages through charging and discharging of hydrogen atoms. We manipulated the coercivity of micrometer-sized ferromagnetic metals by an amplitude of 2500 Oe with voltages only around 1 volt. Through this effect voltage-assisted and -gated magnetization reversal have been demonstrated. Experimental and density functional theory simulation results suggest that this phenomenon originates from the change of magnetocrystalline anisotropy at the surface layers with absorption and desorption of hydrogen atoms, which changes the nucleation field of reversed domains. This work may open up a new route for voltage control of magnetic properties in bulk metals, and voltage-assisted magnetization reversal also has implications for magnetic recording.