

MA 38: Multiferroics and Magnetoelectric Coupling II (joint session MA/KFM)

Time: Wednesday 15:00–17:00

Location: HSZ 401

MA 38.1 Wed 15:00 HSZ 401

Switching of magnetoelectric states in Y-type hexaferrite single crystals — ●VILMOS KOCSIS¹, TARO NAKAJIMA¹, MASAOKI MATSUDA², AKIKO KIKKAWA¹, YOSHIO KANEKO¹, JUNYA TAKASHIMA^{1,3}, KAZUHISA KAKURAI^{1,4}, TAKA-HISA ARIMA^{1,5}, YUSUKE TOKUNAGA^{1,5}, YOSHINORI TOKURA^{1,6}, and YASUJIRO TAGUCHI¹ — ¹RIKEN CEMS, Wako-shi, Japan — ²Oak Ridge National Laboratory, Tennessee, USA — ³Venture Lab TOKYO, Tokyo, Japan — ⁴CROSS, Tokai, Japan — ⁵Department of Advanced Materials Science, University of Tokyo, Kashiwa Japan — ⁶Tokyo College and Department of Applied Physics, University of Tokyo, Tokyo, Japan

In Y-type hexaferrites, magnetic interactions result in a complex phase diagram with non-collinear magnetic phases. The magnetoelectric (ME) properties are mainly dominated by a multiferroic FE3 phase [1,2]. The FE3 phase has been observed both as a metastable and stable phase close to room temperatures [3,4,5] and offers an ideal candidate to study the stability of ME phases and ME states. Here we explore the direct and converse ME effects in Y-type hexaferrites with different Sr doping levels. We demonstrate the isothermal switching between ME states, and discuss these new results as a possible way to measure the stability of the ME state in multiferroic materials. [1] T. Kimura, *Ann. Rev. Condens. Matter Phys.* 3, 93-110 (2012) [2] T. Kimura et. al., *PRL* 94, 137201 (2005) [3] S. Hirose et. al., *APL* 104, 022907 (2014) [4] T. Nakajima et. al., *PRB* 94 195154 (2016) [5] V. Kocsis et. al., *Nat. Comm.* 10, 1247 (2019)

MA 38.2 Wed 15:15 HSZ 401

Low-frequency magnetic resonances of the polar ferrimagnet Mn₂Mo₃O₈ — ●DÁVID SZALLER¹, LUKAS WEYMANN¹, ALEXEY SHUVAEV¹, ANDREI PIMENOV¹, JOHAN VIROK², URMAS NAGEL², TOOMAS ROOM², SÁNDOR BORDÁCS³, KRISZTIÁN SZÁSZ³, VLADIMIR TSURKAN⁴, and ISTVÁN KÉZSMÁRKI⁴ — ¹Institute of Solis State Physics, TU Wien — ²National Institute of Chemical Physics and Biophysics, Tallinn — ³Department of Physics, Budapest University of Technology and Economics — ⁴Experimental Physics V, University of Augsburg

The polar M₂Mo₃O₈ crystals with M=Fe,Co,Mn, exhibit various magnetic orders coupled to the electric polarization of the material. In the static limit, this magneto-electric coupling opens a new path for data storage[1], while in the dynamical range the spin-wave excitations offer a model system to study axion physics[2]. However, the microscopic description of the spin-wave resonances and the magneto-electric coupling in these material family is still an open task.

We followed the magnetic field dependence of the spin-wave resonances of the ferrimagnetic Mn₂Mo₃O₈ in three magnetic phases by combining far-infrared optical spectroscopy and backward-wave oscillators. Both the observed resonance frequencies and the field dependence of the magnetization were quantitatively reproduced by a relative simple anisotropic two-sublattice antiferromagnetic model.

[1]Y. Wang et al, *Sci. Rep.* 5, 12268 (2015).[2]T. Kurumaji et al, *Phys. Rev. Lett.* 119, 077206 (2017).

MA 38.3 Wed 15:30 HSZ 401

Signatures of electric dipoles in zig-zag spin chain β -TeVO₄ — MARTINA DRAGIČEVIĆ¹, ŽELJKO RAPLJENOVIĆ¹, DAVID RIVAS GÓNGORA¹, MIRTA HERAK¹, ●TOMISLAV IVEK¹, MATEJ PREGELJ², ANDREJ ZORKO², HELMUTH BERGER³, and DENIS ARČON^{2,4} — ¹Institute of Physics, Zagreb, Croatia — ²Jožef Stefan Institute, Ljubljana, Slovenia — ³Ecole polytechnique fédérale de Lausanne, Lausanne, Switzerland — ⁴Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia

Even though non-composite magnetoelectric materials appear to be rare, one promising way to achieve magnetoelectric effect is through spiral magnetic orders which can break the space inversion symmetry and allow electric dipoles to form. In this work we present the dielectric response of single crystal quasi-1D quantum magnet β -TeVO₄ at low temperatures and in the presence of external magnetic field. This zig-zag spin chain system with frustrated anisotropic interactions has a complex phase diagram: at $T_{N1} = 4.65$ K the paramagnetic phase gives way to an incommensurate spin-density wave; below $T_{N2} = 3.28$ K a superposition of two spin-density waves is observed with differing wave vectors, the so-called spin stripe phase; finally, at the low temperature

of $T_{N3} = 2.28$ K their two wave vectors coincide and a vector chiral ground state is established. Most interestingly, at T_{N3} there are tantalizing experimental indications of emergent electric dipoles. The magnetic phase diagram will be discussed in the context of dielectric properties and of ground state as a potentially multiferroic phase.

MA 38.4 Wed 15:45 HSZ 401

In-plane magnetoelectric response in bilayer graphene — ●PAUL WENK¹, MICHAEL KAMMERMEIER², and ULRICH ZÜLICHE² — ¹Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — ²School of Chemical and Physical Sciences and MacDiarmid Institute for Advanced Materials and Nanotechnology, Victoria University of Wellington, P.O. Box 600, Wellington 6140, New Zealand

A graphene bilayer shows an unusual magnetoelectric response whose magnitude is controlled by the valley-isospin density, making it possible to link magnetoelectric behavior to valleytronics. Complementary to previous studies, we consider the effect of static homogeneous electric and magnetic fields that are oriented parallel to the bilayer's plane. Starting from a tight-binding description and using quasidegenerate perturbation theory, the low-energy Hamiltonian is derived, including all relevant magnetoelectric terms whose prefactors are expressed in terms of tight-binding parameters. We confirm the existence of an expected axion-type pseudoscalar term, which turns out to have the same sign and about twice the magnitude of the previously obtained out-of-plane counterpart. Additionally, small anisotropic corrections to the magnetoelectric tensor are found that are fundamentally related to the skew interlayer hopping parameter γ_4 . We discuss possible ways to identify magnetoelectric effects by distinctive features in the optical conductivity.

[PRB **100**, 075421 (2019)]

MA 38.5 Wed 16:00 HSZ 401

In-situ switching of the magnetoelectric domain states in the cubic spinel Co₃O₄ — ●MAXIMILIAN WINKLER, SOMNATH GHARA, KORBINIAN GEIRHOS, PETER LUNKENHEIMER, STEPHAN KROHNS, VLADIMIR TSURKAN, and ISTVÁN KÉZSMÁRKI — Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany

We report a strong linear magnetoelectric effect in the collinear antiferromagnetic state of Co₃O₄ single crystals. Co₃O₄ crystallizes in the cubic spinel structure, with magnetic Co²⁺ at the A-sites, tetrahedrally surrounded by oxygen, and non-magnetic Co³⁺ at the B-sites in an octahedral environment [1]. In this work, we investigate all components of the magnetoelectric tensor and found that the largest value of is $\alpha = 14$ ps/m. We showed that the magnetoelectric monodomain state can be obtained by magnetoelectric poling across the Néel-temperature, $T_N = 30$ K. For the mono-domain state the sign of α depends on the sign of the product of the external electric and magnetic fields, E and H. We also demonstrated, that after the magnetoelectric poling below T_N the magnetoelectric domain state can be controlled in-situ by reversing either the external electric or magnetic field. The dynamics of this switching process leads to a deeper understanding of the linear magnetoelectric coupling in Co₃O₄.

[1] W. Roth, *J. Phys. Chem. Solids* **25**, 1-10 (1964)

MA 38.6 Wed 16:15 HSZ 401

Magnetoelectricity in Itinerant-Electron Paramagnets, Ferromagnets and Antiferromagnets — ●ROLAND WINKLER^{1,2,3} and ULRICH ZÜLICHE^{4,2} — ¹Physics, Northern Illinois University, USA — ²Materials Science Division, Argonne National Laboratory, USA — ³Materials Science and Engineering, University of Illinois at Urbana-Champaign, USA — ⁴School of Chemical and Physical Sciences and MacDiarmid Institute for Advanced Materials and Nanotechnology, Victoria University of Wellington, New Zealand

We present a detailed theory for magnetoelectricity in itinerant-electron paramagnets, ferromagnets and antiferromagnets, whereby an electric field can induce a magnetization and a magnetic field can induce a polarization. Accurate numerical calculations are complemented by analytical models that provide a detailed microscopic understanding of magnetoelectricity in itinerant-electron systems. Our realistic calculations suggest that an electrically induced magnetization can be

as large as one Bohr magneton per charge carrier.

This work was supported by the NSF under Grant No. DMR-1310199. Research at UIUC was supported by the Illinois MRSEC, NSF Grant No. DMR-1720633. Work at Argonne was supported by DOE BES under Contract No. DE-AC02-06CH11357.

MA 38.7 Wed 16:30 HSZ 401

Voltage-controlled on switching and manipulation of magnetization via redox transformation of beta-FeOOH nanoplatelets

— •MARTIN NICHTERWITZ^{1,2}, SABINE NEITSCH¹, STEFAN RÖHER¹, DANIEL WOLF¹, KORNELIUS NIELSCH^{1,2}, and KARIN LEISTNER¹ — ¹IFW Dresden, Germany — ²TU Dresden, Germany

Voltage control of magnetism by ionic approaches, such as the metal/metal oxide transformation in gated architectures, presents a promising pathway to low-power magnetic devices or magnetic actuation. Such magneto-ionic manipulation has been reported mainly for ultrathin films and nanoporous metal alloy structures so far.

We investigate electrodeposited porous beta-FeOOH nanoplatelets as starting material, known as active material from catalysis research. The FeOOH is polarized in 1M LiOH solution at room temperature. The voltage-induced structural and morphological changes are probed and correlated to the magnetic changes measured in an in situ anomalous Hall effect setup. This approach, starting from paramagnetic FeOOH, enables complete and non-volatile ON switching of ferromagnetic layers at a low voltage and large reversible magneto-ionic effects.[1] During the first reduction step, we transform FeOOH into a rough granular Fe layer. This high surface Fe layer is then switched reversibly via a redox transformation. As a result, large voltage-induced changes in magnetization are achieved, which exceed those obtained for sputtered Fe films and Fe nanoislands.[2]

[1] Nichterwitz et al., J. Phys. D (2019), accepted;

[2] Duschek et al., J. Mater. Chem. C 6 (2018) 8411

MA 38.8 Wed 16:45 HSZ 401

Magneto-ionic tunable hysteresis, magnetic domains and exchange bias in ironoxide/iron surface layers — •JONAS ZEHNER¹, RICO HUHNSTOCK², STEFFEN OSWALD¹, SEBASTIAN SCHNEIDER¹, IVAN SOLDATOV¹, SEBASTIAN FÄHLER¹, RUDOLF SCHÄFER¹, ARNO EHRESMANN², KORNELIUS NIELSCH¹, DENNIS HOLZINGER², and KARIN LEISTNER¹ — ¹IFW Dresden — ²Uni Kassel, Institut für Physik und CINSaT

The ubiquity and rise in the use of electronic devices demands low power operation modes. Voltage assisted ionic displacement and electrochemical processes offer large magnetic changes at room temperature. This so called magneto-ionic (MI) control shows promising characteristics to enable energy efficient spintronics, actuation and neuromorphic computing. In the current study, MI effects on coercivity and exchange bias (EB) are demonstrated for sputter deposited and natively oxidized FeOx/Fe films of up to 13 nm in thickness. In FeOx/Fe films, the uniaxial anisotropy constant K_u increases upon an electrochemical transformation of the oxide layer to metal iron. At the same time, consistent with the anisotropy change, the equilibrium magnetic domain size increases. This effect enables voltage-induced 180° magnetization switching. In a next step, this tunable FeOx/Fe layer is combined with an underlying antiferromagnet. Non-volatile and reversible changes in the EB are achieved this way. The mechanism is revealed via X-ray photoemission spectroscopy and links the observed changes to an increase in the Fe layer thickness. These results are exciting for designing EB systems and magneto-electric devices in general.