KFM 10: Multiferroics and Magnetoelectric Coupling II (joint session MA/KFM)

Time: Wednesday 15:00–17:00 Location: HSZ 401

KFM 10.1 Wed 15:00 HSZ 401

Switching of magnetoelectric states in Y-type hexaferrite single crystals — •Vilmos Kocsis[1], Taro Nakajima[1], Masaaki Matsuda[2], Akiko Kikkawa[1], Yoshio Kaneko[1], Junya Takashima[1,3], Kazuhisa Kakurai[1,4], Taka-hisa Arima[1,5], Yusuke Tokunaga[1,5], Yoshinori Tokura[1,6], and Yasujiro Taguchi[1] — [1]RIKEN CEMS, Wako-shi, Japan — [2]Oak Ridge National Laboratory, Tennessee, USA — [3]Venture Lab TOKYO, Tokyo, Japan — [4]CROSS, Tokai, Japan — [5]Department of Advanced Materials Science, University of Tokyo, Kashiwa Japan — [6]Tokyo 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)

KFM 10.2 Wed 15:15 HSZ 401

Low-frequency magnetic resonances of the polar ferrimagnet Mn2Mo3O8 — •Dávid Szaller[1], Lukas Weymann[1], Alexey Shuvaev[1], Andrei Pimenov[1], Johan Viirok[2], Urmas Nagel[2], Toomas Room[2], Sándor Bordács[3], Krisztián Szász[3], Vladimir Tsurkan[4], and István Kézsmárki[4] — [1]Institute of Solis State Physics, TU Wien — [2]National Institute of Chemical Physics and Biophysics, Tallinn — [3]Department of Physics, Budapest University of Technology and Economics — [4]Experimental 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).

KFM 10.3 Wed 15:30 HSZ 401

Signatures of electric dipoles in zig-zag spin chain β-$TeVO_4$ — Martina Dragičević[1], Željko Rapljenović[1], David Rivas Góngora[1], Mirta Herak[1], •Tomislav Ivek[1], Matej Pregelj[2], Andrej Zorko[2], Helmuth Berger[3], and Denis Arčon[2,4] — [1]Institute of Physics, Zagreb, Croatia — [2]Jožef Stefan Institute, Ljubljana, Slovenia — [3]Ecole polytechnique fédérale de Lausanne, Lausanne, Switzerland — [4]Faculty 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-$TeVO_4$ 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 $T_{N1} = 4.65\,\mathrm{K}$ the paramagnetic phase gives way to an incommensurate spin-density wave; below $T_{N2} = 3.28\,\mathrm{K}$ 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 $T_{N3} = 2.28\,\mathrm{K}$ 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.

KFM 10.4 Wed 15:45 HSZ 401

In-plane magnetoelectric response in bilayer graphene — •Paul Wenk[1], Michael Kammermeier[2], and Ulrich Zülicke[2] — [1]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]School 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)]

KFM 10.5 Wed 16:00 HSZ 401

In-situ switching of the magnetoelectric domain states in the cubic spinel Co_3O_4 — •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 Co_3O_4 single crystals. Co_3O_4 crystallizes in the cubic spinel structure, with magnetic Co^{2+} at the A-sites, tetrahedrally surrounded by oxygen, and non-magnetic Co^{3+} 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 Co_3O_4.

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

KFM 10.6 Wed 16:15 HSZ 401

Magnetoelectricity in Itinerant-Electron Paramagnets, Ferromagnets and Antiferromagnets — •Roland Winkler[1,2,3] and Ulrich Zülicke[4,2] — [1]Physics, Northern Illinois University, USA — [2]Materials Science Division, Argonne National Laboratory, USA — [3]Materials Science and Engineering, University of Illinois at Urbana-Champaign, USA — [4]School 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 complementd 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.

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KFM 10.7 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 Neitsch[1], Stefan Röher[1], Daniel Wolf[1], Kornelius Nielsch[1,2], and Karin Leistner[1] — [1]IFW Dresden, Germany — [2]TU 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. Chm. C 6 (2018) 8411

KFM 10.8 Wed 16:45 HSZ 401

Magneto-ionic tunable hysteresis, magnetic domains and exchange bias in ironoxide/iron surface layers — •Jonas Zehner[1], Rico Huhnstock[2], Steffen Oswald[1], Sebastian Schneider[1], Ivan Soldatov[1], Sebastian Fähler[1], Rudolf Schäfer[1], Arno Ehresmann[2], Kornelius Nielsch[1], Dennis Holzinger[2], and Karin Leistner[1] — [1]IFW Dresden — [2]Uni 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 Ku 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.