DF 18: Multiferroics (DF and MA)

Chair: Joachim Hemberger

Time: Thursday 15:00–17:15 Location: WIL B321

DF 18.1 Thu 15:00 WIL B321

THz study of the magnon spectra of $BiFeO_3$ — •Dániel Gergely Farkas[1], Sándor Bordács[1], Dávid Szaller[1], Laur Peedu[2], Johan Viirok[2], Urmas Nagel[2], Toomas Rõõm[2], and István Kézsmárki[1] — [1]Department of Physics, Budapest University of Technology and Economics and MTA-BME Lendület Magneto-optical Spectroscopy Research Group, 1111 Budapest, Hungary — [2]National Institute of Chemical Physics and Biophysics, Akadeemia tee 23, 12618 Tallinn, Estonia

Multiferroic materials with coexisting and strongly coupled magnetic and ferroelectric orders have attracted much interest due to the novel phenomena they possess, such as magnetoelectric effect [1] and directional dichroism [2]. Among these compounds $BiFeO_3$ has received special attention as it is one of the few known room-temperature multiferroics [3], which puts its technical applications within reach. Here we present an experimental study of the magnon excitations in single crystal samples of $BiFeO_3$. Using THz spectroscopy magnetic field dependence of the spin-wave frequencies are measured along all three high-symmetry axis up to 33T. This systematic study also allowed us to determine the electric and magnetic dipole strengths, i.e. the selection rules. In contrast to the previous theoretical models we found that the (111) plane of $BiFeO_3$ is isotropic and the magnetic field dependence of the excitation frequencies have hysteresis. References: [1] M. Tokunaga, et al., Nat. Commun. 6, 5878 (2015). [2] I. Kézsmárki, et al., Phys. Rev. Lett. 106, 057403 (2011). [3] J. Moreau, et al., J. Phys. Chem. Solids 32, 1315 (1971).

DF 18.2 Thu 15:15 WIL B321

Strain and electric-field mediated tuning of magnetism in self-assembled iron oxide nanoparticle - $BaTiO_3$ composites — •Liming Wang[1], Oleg Petracic[1], Emmanuel Kentzinger[1], Ulrich Rücker[1], Alexandros Koutsioumpas[2], Stefan Mattauch[2], Markus Schmitz[1], and Thomas Brückel[1,2] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, Jülich — [2]Jülich Centre for Neutron Science (JCNS) at Heinz Maier-Leibnitz Zentrum (MLZ), Forschungszentrum Jülich GmbH, Lichtenbergstr. 1, 85748 Garching, Germany

We report about the manipulation of magnetism of self-assembled iron oxide nanoparticle (NP) monolayers on top of $BaTiO_3$ (BTO) single crystals. Magnetoelectric coupling (MEC) as shown in both the magnetization and magneto-electric ac susceptibility (MEACS) measurements is observed. Both the magnetization and MEACS as function of temperature show abrupt jumps at the BTO phase transitions temperatures, which is attributed to strain-mediated MEC from the BTO onto the NPs. We find that a Ti sticking layer and an Au embedding layer play a crucial role to maximize the MEC effect. Moreover, using polarized neutron reflectivity (PNR) we observe a change of the in-depth magnetic scattering length density upon changing an applied electric field. Grazing incident small angle X-ray scattering (GISAXS) and scanning electron microscopy (SEM) confirm a hexagonal close-packed supercrystalline order of the NPs.

DF 18.3 Thu 15:30 WIL B321

Single domain multiferroic $BiFeO_3$ films — •Chang-Yang Kuo[1], Zhiwei Hu[1], Jan-Chi Yang[1], Tun-Wen Pi[2], Stefano Agrestini[1], Kai Chen[3], Philippe Ohresser[3], Arata Tanaka[4], Liu Hao Tjeng[1], and Ying-Hao Chu[5] — [1]MPI-CPfS, Dresden, Germany — [2]NSRRC, Taiwan — [3]Synchrotron SOLEIL, France — [4]Hiroshima University, Japan — [5]National Chiao Tung University, Taiwan

The strong coupling between antiferromagnetism and ferroelectricity at room temperature found in $BiFeO_3$ generates high expectations for the design of technological devices. However, the multi-domain nature of the material tends to nullify the properties of interest and complicates the thorough understanding of the mechanisms involved. Here we report the realization of a $BiFeO_3$ thin film which shows single domain behavior in both its magnetism and ferroelectricity: the entire film has its antiferromagnetic axis aligned along the crystallographic b-axis and its ferroelectric polarization along the c-axis. This allows us to reveal that the canted and net ferromagnetic moment due to the Dzyaloshinskii-Moriya interaction is parallel to the a-axis. Furthermore, by making a Co/$BiFeO_3$ heterostructure, we successfully demonstrate that the ferromagnetic moment of the Co metal film couples directly to the canted ferromagnetic moment of $BiFeO_3$. The realization of the single-domain multiferroic $BiFeO_3$ films thus provides new insights into the fundamental interactions in this functional material and opens a promising path for the engineering of novel functional devices[1]. [1]C.Y. Kuo *et al.* Nature Communications, 7, 12712 (2016).

DF 18.4 Thu 15:45 WIL B321

New multiferroic materials - oxyhalides & orthotellurates — •A. C. Komarek[1], L. Zhao[1], H. Guo[1], M. T. Fernández-Díaz[2], W. Schmidt[3], and L. H. Tjeng[1] — [1]Max-Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, D-01187 Dresden, Germany — [2]Institut Laue-Langevin, 71 Avenue des Martyrs, F-38042 Grenoble Cedex 9, France — [3]Jülich Centre for Neutron Science JCNS, Forschungszentrum Jülich GmbH, Outstation at ILL, 71 avenue des Martyrs, F-38042 Grenoble Cedex 9, France

Magnetoelectric multiferroics have attracted considerable attention in the past years due to their possible application in future devices. Especially certain spiral magnetic structures are often responsible for the cross-coupling between magnetism and ferroelectricity in these materials. So far multiferroicity has been found mainly in oxide materials. Here, we report the observation of multiferroicity in two other interesting classes of transition metal compounds: First, we found spin-induced multiferroicity with high critical temperature in a transition metal oxyhalide (Cu_2OCl_2 [1]), and second, we also observed multiferroic properties in a transition metal orthotellurate with a complex magnetic structure (Mn_3TeO_6 [1]).

—**References**— [1] L. Zhao, M. T. Fernández-Díaz, L. H. Tjeng and A. C. Komarek, Science Advances, **2**, e1600353 (2016). [2] L. Zhao, Z. Hu, C.-Y. Kuo, T.-W. Pi, M.-K. Wu, L. H. Tjeng and A. C. Komarek, Phys. Status Solidi RRL **9**, 730 (2015).

15 min. break

DF 18.5 Thu 16:15 WIL B321

Magneto-optic and electro-optic effects in multiferroic thin films — •Simon Wisotzki, Liane Brandt, Diana Rata, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics, Von-Danckelmann-Platz 3, 06120 Halle (Saale)

Jia *et al.* [1] proposed a magneto-electric coupling effect for ferromagnetic (FM)/ferroelectric(FE) composites. This phenomenon is purely charge-mediated and accompanied by the build-up of an interfacial spiral spin density. Depending on the FE polarization state in a FM/FE composite, the surface spiral spin density induced in the FM layer should change direction. For a suitable sample geometry, one can expect the reversal of the out-of-plane component of the magnetization at the FM/FE interface, with this effect decaying across the spin diffusion length. We utilize a setup that is sensitive to minute changes ($<10^{-6}$ rad) of the polarization state of reflected light from the multiferroic composite. In our experiments, magneto-optic effects (reflection on FM surface) as well as electro-optic effects (caused by the FE layer) may contribute to the measured change of the polarization state upon reflection. In a series of experiments on thin film multiferroic capacitors consisting of FM/FE/FM, we try to distinguish between the two effects and identify a possible magneto-electric contribution as suggested in [1]. The investigated samples include epitaxial LSMO/PZT/LSMO and LSMO/PZT structures with polycrystalline FM top electrodes.

[1] C.-L. Jia *et al.*, *Phys. Rev. B* **90**, 054423 (2014)

DF 18.6 Thu 16:30 WIL B321

Collective spin excitations in polar ferrimagnet $(Fe,Zn)_2Mo_3O_8$ — •Krisztián Szász[1], Dávid Szaller[1], Urmas Nagel[2], Toomas Rõõm[2], Sándor Bordács[1], and István Kézsmárki[1] — [1]Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Hungary — [2]National Institute of Chemical Physics and Biophysics, 12618 Tallinn, Estonia

In this work the magnetic excitations are investigated in Zn-doped hexagonal polar $Fe_2Mo_3O_8$ crystal using terahertz spectroscopy. This material is a promising candidate in realizing new generation electronic devices utilizing its giant magnetoelectric effect, i.e. high jump is observed in the polarization when the antiferromagnetic-ferrimagnetic spin-flop transition occurs. The different magnetic phases can be controlled by doping without losing the huge magnetoelectric effect. Microscopically, the Zn-doping fills the tetrahedral Fe sublattice while the octahedral Fe sites remain intact.

Our purpose is to understand the magnetic ground state which is still unclear. Furthermore, from the magnetic field dependence of the magnon modes we aim to deduce the most important exchange and anisotropy parameters to construct a spin model of $Fe_2Mo_3O_8$.

DF 18.7 Thu 16:45 WIL B321

Magnetic excitations in multiferroic $GdMn_2O_5$ — •Sergey Poghosyan and Sergey Artykhin — Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy

RMn_2O_5 compounds recently attracted attention due to non-collinear states and unconventional excitations. YMn_2O_5 with non-magnetic rare earth (RE) shows incommensurate spiral state with spins in the neighbouring chains aligned at 90-degrees to each other [1]. RE ions with unquenched angular momentum enable the control of polarization by magnetic field in the multiferroic materials, such as $TbMn_2O_5$ [2]. $GdMn_2O_5$ with magnetic rare earth in S=7/2, L=0 state, exhibits a spiral state below 40 K, that concedes to a commensurate state below $\sim$ 30K. The latter hosts large magnetically-induced polarization of $3600\,\mu C/m^2$ induced via Heisenberg exchange striction mechanism. This polarization changes by $5000\,\mu C/m^2$ under the external magnetic field [3]. Here we corroborate THz magnetoabsorption data with the microscopic modelling. The magnetic excitations are calculated using model Hamiltonian with parameters extracted from ab-initio simulations. The resultant magnon spectrum is rather counterintuitive and complex, thus providing new insights on design principles for materials with strong magnetoelectric couplings.

[1] J.-H. Kim et al., Phys. Rev. Lett. **107**, 097401 (2011).
[2] N. Hur et al., Nature **429**, 392 (2004).
[3] N. Lee et al., Phys. Rev. Lett. **110**, 137203 (2013).

DF 18.8 Thu 17:00 WIL B321

Simulation and investigation of polarization kinetics in polycrystalline ferroelectrics. — •Ruben Khachaturyan — Technische Universität Darmstadt, Department of Materials Modeling, 64295 Darmstadt, Stephanstr. 5

The understanding of polarization dynamics over a wide time scale plays a crucial role in a vast range of applications, from non-volatile memories (FeRAM) and sensors to fuel injection applications.

It was established that polarization process under applied voltage develops simultaneously in different parts of a material with different switching times [1]. As switching time is strongly field dependent [2] it was suggested that local switching time distribution is caused by local electrical field distribution [3-5].

There is currently no statistical concept that accounts for spatial correlations of local polarizations and fields during polarization switching in a ferroelectric polycrystalline material.

The main purpose of the work is to simulate dynamics of polarization switching in a polycrystalline material under applied electric field. The data extracted from the simulations, such as field and polarization distributions and their correlations at different times, provide necessary information to study influence of the local field distribution on local switching processes.