MA 3: Multiferroics I (with DF, KR, DS)

Time: Monday 10:15–12:45 Location: H3

Invited Talk MA 3.1 Mon 10:15 H3

Antiferromagnetic interlayer coupling in $La_{0.7}Sr_{0.3}MnO_3$ / $SrRuO_3$ superlattices — •Ionela Vrejoiu — Max Planck Institute of Microstructure Physics, Halle, Germany

Perovskite oxides are versatile materials with a broad spectrum of physical properties, such as (anti)ferromagnetism, (anti)ferroelectricity, superconductivity, and multiferroicity. As illustrating examples, $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) and $SrRuO_3$ (SRO) are both ferromagnetic perovskites with bulk ferromagnetic Curie temperatures of 370 K and 160 K, respectively. LSMO is a 3d transition metal double exchange ferromagnet, whereas SRO is a rare case of a 4d itinerant metallic ferromagnet and, in contrast to LSMO, SRO shows exceptionally strong magneto-crystalline anisotropy. Such differences make the interlayer coupling between LSMO and SRO epitaxial thin films an intriguing case. We report on LSMO / SRO superlattices (SLs) grown by pulsed-laser deposition on vicinal TiO_2-terminated $SrTiO_3$ (100) (STO) substrates. These SLs exhibit strong antiferromagnetic (AF) interlayer coupling at temperatures below 140 K, where the SRO layers become ferromagnetic. SLs in which an ultrathin nonmagnetic perovskite spacer was grown in between all the LSMO and SRO layers (so that the LSMO and SRO have no mutual interfaces) exhibited ferromagnetic coupling below 140 K. This indicates that the AF coupling occurs only in SLs with direct interfaces between LSMO and SRO. A joint study of structural characterization, SQUID magnetometry as well as first principles calculations was performed, in order to unravel the origin of this strong AF coupling.

MA 3.2 Mon 10:45 H3

Magnetic phase transition at a biferroic interface predicted from first principles — •Michael Fechner[1], Igor Maznichenko[2], Sergey Ostanin[1], Arthur Ernst[1], Jürgen Henk[1], and Ingrid Mertig[1,2] — [1]MPI für Mikrostrukturphysik Halle, Germany — [2]Fachgruppe Theoretische Physik, Martin-Luther-Universität Halle-Wittenberg

The interface magnetoelectric effect mediates the change of the magnetization at a ferromagnetic/ferroelectric interface when the electric polarization is modified. Using first principle methods, we investigate different ultrathin ferromagnetic films (Co and Fe) on top of ferroelectric $ATiO_3$ (A=Pb,Ba) perovskites upon the occurrence of it. The calculations show that at the interface a moderately change of the size of the total magnetization takes place [1]. Further the magnetic ordering of the Fe film is sensitive to its thickness, so an unexpected antiferrimagnetic ordering appears for 2ML Fe whereas for all other thicknesses ferromagnetic ordering is preferred. Hybridization and strain effects at the interface can explain all observations. An interesting perspective for further studies will be the investigation of thin films of a CoFe alloy. This may allow gaining control of the magnetic ordering by the electric polarization.

[1] Fechner et al.. PRB 78, 212406(2008)

MA 3.3 Mon 11:00 H3

Magnetoelectric coupling at modified Fe/$BaTiO_3$ interfaces — •Martin Hölzer[1], Michael Fechner[2], Sergey Ostanin[2], and Ingrid Mertig[1,2] — [1]Martin-Luther-Universität Halle-Wittenberg, Fachbereich Physik, D-06900 Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

Two-component multiferroics are gaining attention within the last years. These compound materials, consisting of ferromagnetic and ferroelectric layers, combine the advantages (e. g. high curie temperatures) of their components in a tuneable magnetoelectric structure.

Ab initio DFT studies of ultrathin Fe films on ferroelectric $BaTiO_3$ show that their magnetoelectric coupling can be enhanced considerably by means of interface alloying.

In these systems, the magnetoelectric coupling is related to structural changes in the interface region under polarisation reversal of the $BaTiO_3$ substrate. In one of the considered cases, a magnetic phase transition with high change in the total magnetization is triggered under polarization reversal.

MA 3.4 Mon 11:15 H3

Towards ferroelectric tunneling barriers with magnetic electrodes — •Daniel Pantel, Dietrich Hesse, and Marin Alexe — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle

The tunneling magnetoresistance (TMR) is a well-established quantum phenomenon in oxide electronics [1]. Recently, tunneling electroresistance was experimentally investigated in an oxide ferroelectric tunneling barrier [2, 3]. Combining both functionalities in one device, i.e. a ferroelectric barrier sandwiched in between two ferromagnetic electrodes, yields interesting properties, e.g. different effects of the ferroelectric polarization on the two spin channels [4]. However, experimental results are still lacking.

In this talk we report on the growth and the properties of perovskite oxide heterostructures consisting of a pulsed laser deposition-grown thin ferroelectric barrier layer sandwiched between two magnetic electrodes. First electrical measurements on capacitor-like tunneling junctions are presented.

[1] De Teresa, J.M., *et al.*, Science **286**, 507 (1999)
[2] Contreras, J.R., *et al.*, Appl. Phys. Lett. **83**, 4595 (2003)
[3] Garcia, V., *et al.*, Nature **460**, 81 (2009)
[4] Velev, J.P., *et al.*, J. Appl. Phys. **103**, 07A701 (2008)

MA 3.5 Mon 11:30 H3

Multiferroic materials with a non-collinear spin structure - A many-particle approach — •Thomas Michael[1], Julia M. Wesselinowa[2], and Steffen Trimper[1] — [1]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, Germany — [2]Department of Physics, University of Sofia, Sofia, Bulgaria

Multiferroic bulk materials with a conical spin structure are investigated in the framework of a many-particle approach. The analysis of the ferroelectric subsystem is based on a two-state quantum model. Magnetic moments interact via the Heisenberg model. The canting of the spins is incorporated by the Dzyaloshinski-Moriya interaction. A representation of the spin operators with an arbitrary quantization axis is chosen. Minimizing the free energy yields the direction of the quantization axis. The multiferroic coupling term is discussed. A Green's function technique in reciprocal space provides the temperature dependence of the magnetization, polarization and the energy of the excitations.

MA 3.6 Mon 11:45 H3

Manipulating ferroelectric domains of multiferroic $DyMnO_3$ by soft X-rays — •Victor Soltwisch, Enrico Schierle, Detlef Schmitz, Dimitri Argyriou, Fabiano Yokaichiya, Ralf Feyerherm, and Eugen Weschke — Helmholtz Zentrum Berlin

In multiferroic $DyMnO_3$, ferroelectricity is induced by cycloidal magnetic structures of a chirality coupled to the direction of the electric polarization. XRMS at the Dy-M5 resonance allows to distinguish surface regions of different chirality of the Dy-4f magnetic cycloid and, hence, can be used to image ferroelectric domains. Furthermore, the x-ray beam itself can be utilized to manipulate the distribution of domains at the crystal surface.

MA 3.7 Mon 12:00 H3

Evidence of electro-active excitation of the spin cycloid in $TbMnO_3$ — •Alexey Shuvaev[1], Viktor Travkin[2], Vsevolod Ivanov[2], Alexander Mukhin[2], and Andrei Pimenov[1] — [1]Experimentelle Physik 4, Universität Würzburg, D-97074 Würzburg, Germany — [2]General Physics Institute, Russian Academy of Science, 119991 Moscow, Russia

The coupling between the magnetic and ferroelectric orders in multiferroics is currently a topic of intense study. The materials of particular interest are those where the incommensurate cycloidal ordering of the spins drives the ferroelectricity. One of the consequences of multiferroicity is the existence of novel coupled magnon-phonon excitations called electromagnons. In addition to the electromagnon along the a-axis, the polarization analysis of the experimental spectra suggests the existence of an electro-active excitation for ac electric fields along the crystallographic c-axis. This excitation is possibly the electro-active eigenmode of the spin cycloid in $TbMnO_3$, which has been predicted within the inverse Dzyaloshinskii-Moriya mechanism of magnetoelectric coupling.

MA 3.8 Mon 12:15 H3

Neutron scattering studies on chiral multiferroics: magnetic structure and excitations — •T. Finger[1], M. Baum[1], A. C. Komarek[1], D. Senff[1], P. Link[6], K. Hradil[5], K. Schmalzl[4], W. Schmidt[4], L.-P. Regnault[3], D. N. Argyriou[7], P. Becker-Bohaty[2], L. Bohaty[2], and M. Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Kristallographie, Universität zu Köln — [3]CNG-Grenoble / ILL, Grenoble — [4]FZ Jülich, JCNS at ILL, Grenoble — [5]Universität Göttingen / FRM2 München — [6]FRM2, TU München, München — [7]HMI, Berlin

We present neutron-scattering experiments on IN12 and on IN14 using spherical polarization analysis directly documenting the poling of the elastic magnetic chiral terms for the spiral magnets $MnWO_4$ and $TbMnO_3$ by cooling in an electric field. In addition, we were able to observe a multiferroic hysteresis curve as function of electric field in both compounds and succeeded to switch the spiral at constant temperature, which is the central issue in view of future applications. Additionally, measurements of the diffuse scattering slightly above the multiferroic transition show some small chiral terms remaining in the collinear phase. The close coupling of ferroelectricity and magnetism in the multiferroic materials also results in new collective excitations, predicted almost 20 years ago: hybridised spin-phonon excitations, referred to as "electromagnons". After the first observations of potential electromagnon modes in infra-red and in neutron studies a conclusive interpretation is still missing. Our most recent neutron scattering measurements will be discussed.

MA 3.9 Mon 12:30 H3

Topological magnetoelectric memory effect in the spin-spiral multiferroic $MnWO_4$ — •Dennis Meier[1], Naemi Leo[1], Thomas Lottermoser[1], Petra Becker[2], Ladislav Bohatý[2], and Manfred Fiebig[1] — [1]HISKP, Universität Bonn — [2]Institut für Kristallographie, Universität zu Köln

Within the field of multiferroics, i.e. compounds with coexisting magnetic and electric order, so-called spin-spiral ferroelectrics attract tremendous attention. In these systems magnetic long-range order violates the inversion symmetry and induces a spontaneous electric polarization. Magnetic and electric domains are thus rigidly coupled so that “giant” magnetoelectric effects are obtained. However, up to now nearly nothing is know about the topology of the domain state in these systems. We report spatially-resolved measurements of the multiferroic domain topology in $MnWO_4$. For the first time, the full three-dimensional domain structure in a spin-spiral system is imaged. Our study reveals that the multiferroic domains in magnetically-induced ferroelectrics unify features that are associated to a magnetic domain state and others that point unambiguously to ferroelectric domains. Hence, a description in terms of ferroelectric or antiferromagnetic domains is incomplete and no longer appropriate. The novel concept of “multiferroic hybrid domains” is introduced. Annealing cycles reveal a topological memory effect: Due to phase coexistence at one phase boundary limiting the multiferroic state in $MnWO_4$, the entire multiferroic multidomain state can be reconstructed subsequent to quenching it. This work is supported by the DFG through SFB608.