MA 38: Multiferroics

Time: Thursday 15:15–19:30 Location: HSZ 103

MA 38.1 Thu 15:15 HSZ 103

Interface modification in LCMO-BTO superlattices — •Kai Gehrke, Vasily Moshnyaga, and Konrad Samwer — I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

At perovskite interfaces, electric, magnetic and multiferroic (MF) properties can be different from those in bulk. Especially in manganite thin films and superlattices (SL) it is well known that breakage of symmetry at interfaces lead to orbital, charge and spin reconstructions[1]. Moreover, interfacial stress, which leads to lattice distortions, greatly influences ferromagnetic as well as ferroelectric polarizations. $(LaCa)MnO_3-BaTiO_3$ SL have been grown by a metalorganic aerosol deposition technique on MgO and STO substrates. Besides the magnetic properties, Magnetocapacitance as well as third harmonic Voltages have been measured to clarify the influence of the interfaces and their relation to the formation of correlated polaros. We show that compositional grading of the $(LaCa)MnO_3$ at the interfaces modifies the magnetic, electric and MF properties in a positive way. The magnetisation is increased, the manganite resistance is strongly reduced and third harmonic voltages are depressed. The work was supported by the Deutsche Forschungsgemeinschaft via SFB 602, project A2.

[1] Luis Brey, "Electronic phase separation in manganite-insulator interfaces", PHYSICAL REVIEW B 75, 104423 (2007)

MA 38.2 Thu 15:30 HSZ 103

Colossal elastoresistance of phase separated $(Pr_{1-y}La_y)_{0.7}Ca_{0.3}MnO_3$ thin films — •Maartje Dekker, Steffen Oswald, Ludwig Schultz, and Kathrin Doerr — IFW-Dresden, Germany

The use of a piezoelectric substrate [1], PMN-PT (001) $(PbMg_{1/3}Nb_{/3}O_3)_{0.72}(PbTiO_3)_{0.28}$, allows us to biaxially compress as grown epitaxial films by as much as 0.2%. This reversible dynamic strain process gives a unique insight into the effect of strain on perovskite oxides, eliminating effects such as varying oxygen concentration, which may occur when several substrates with different lattice mismatch are used.

We have prepared phase separated PLCMO $(Pr_{1-y}La_y)_{0.7}Ca_{0.3}MnO_3$ films on PMN-PT for a range of y values. Around $y = 0.6$, the system exhibits a transition from an insulating to a metallic ground state. When partially releasing the as grown tensile strain of the PLCMO film by piezo-compression of the substrate, we find a huge reduction of the resistance, or "colossal" elastoresistance. The relaxed films show an enhanced magnetisation and an increase in magnetic transition temperature. Thus we can conclude that tensile strain efficiently suppresses the ferromagnetic conducting phase and favours the charge ordered state.

[1] C. Thiele et al., Phys. Rev. B 75, 054408 (2007)

MA 38.3 Thu 15:45 HSZ 103

Magnetism and magnetotransport of strained epitaxial $La_{1-x}Sr_xCoO_3$ (x = 0.18; 0.3) films — •Orkidia Bilani-Zeneli, Andreas Herklotz, Diana Rata, Ksenia Boldyreva, Ludwig Schultz, Nadja Kozlova, and Kathrin Dörr — IFW Dresden, Postfach 270116, 01171 Dresden

Perovskite cobaltites $La_{1-x}A_xCoO_3$ (A = Sr, Ca) have been investigated in bulk form for the temperature- and pressure-dependent spin state of Co ions for decades. Magnetic studies of epitaxially grown films are rare, but recent work on $LaCoO_3$ has indicated the potential for strain-controlled magnetism [1].

In this work, films of $La_{1-x}Sr_xCoO_3$ (x = 0.18; 0.3) have been grown epitaxially on substrates of various lattice mismatch ($SrTiO_3$, $LaAlO_3$, LSAT, PMN-PT) by off-axis pulsed laser deposition. Film lattice parameters reveal that large strains can be maintained up to thicknesses beyond 60 nm. The films (x = 0.18; 0.3) are ferromagnetic with huge coercive fields indicating large magnetic anisotropy. The effect of biaxial strain on the Curie temperature and the magnetization has been derived from statically strained films and from reversibly strained films on piezoelectric PMN-PT(001). Interestingly, the strain strongly affects the electrical conduction: tensile strain leads to reduced conductivity and a strain-induced insulator state (x = 0.3) [2]. Data on strain-dependent resistance and magnetoresistance in magnetic fields up to 50 T will be discussed. [1] D. Fuchs et al., PRB 75, 144402 (2007); PRB 77, 014434 (2008) [2] A. D. Rata et al., PRL 100, 076401 (2008)

MA 38.4 Thu 16:00 HSZ 103

Ising magnetism and ferroelectricity in Ca_3CoMnO_6 — •Hua Wu[1], T. Burnus[1], Z. Hu[1], C. Martin[2], A. Maignan[2], J. C. Cezar[3], A. Tanaka[4], N. B. Brookes[3], D. I. Khomskii[1], and L. H. Tjeng[1] — [1]II. Phys. Inst, Uni Köln — [2]Lab. CRISMAT, Caen, France — [3]ESRF Grenoble, France — [4]Hiroshima University, Japan

Among a variety of multiferroic materials discovered so far, see review articles [1,2], ferroelectric Ising chain magnet Ca_3CoMnO_6 is quite unique, because the ferroelectricity is driven by a magnetostriction in a collinear Ising spin chain consisting of the charge ordered transition-metal ions [3]. In this work, the origin of both the Ising chain magnetism and ferroelectricity in Ca_3CoMnO_6 is studied by *ab initio* electronic structure calculations and x-ray absorption spectroscopy. We find that Ca_3CoMnO_6 has the alternate trigonal prismatic Co^{2+} and octahedral Mn^{4+} sites in the spin chain. Both the Co^{2+} and Mn^{4+} are in the high spin state. In addition, the Co^{2+} has a huge orbital moment of 1.7 μ_B which is responsible for the significant Ising magnetism. The centrosymmetric crystal structure known so far is calculated to be unstable with respect to magnetostriction in the experimentally observed ↑↑↓↓ antiferromagnetic structure for the Ising chain. The calculated inequivalence of the Co-Mn distances accounts for the ferroelectricity. [1] S. W. Cheong and M. Mostovoy, Nat. Mater. **6**, 13 (2007). [2] D. I. Khomskii, J. Magn. Magn. Mater. **306**, 1 (2006). [3] Y. J. Choi *et al.*, Phys. Rev. Lett. **100**, 047601 (2008).

MA 38.5 Thu 16:15 HSZ 103

Quantum paraelectric-like behavior and giant magnetodielectric coupling in $NdFe_3(BO_3)_4$ — •Umut Adem[1], Liran Wang[1], Norman Leps[1], Rüdiger Klingeler[1], Christian Hess[1], Alexander Vasiliev[2], Leonard N. Bezmaternykh[3], and Bernd Büchner[1] — [1]Leibniz Institute for Solid State and Materials Research (IFW) Dresden, Germany — [2]Moscow State University, Moscow, 119992, Russia — [3]Kirensky Institute of Physics, Siberian Division, Russian Academy of Sciences, Akademgorodok, Krasnoyarsk, 660036, Russia

We have measured the dielectric constant in addition to specific heat, magnetostriction, and magnetization of magnetoelectric $NdFe_3(BO_3)_4$ single crystals and observed rare quantum paraelectric-like behavior. The dielectric constant increases with decreasing temperature in the temperature range 300 to 5K, more sharply upon the magnetic ordering of Fe spins below 30 K. Application of magnetic field strongly suppresses the additional increase below T_N, resulting at 5K, 8 % change in the dielectric constant under 3 Tesla. We speculate that the dielectric behavior originates from soft phonon mode behavior and the coupling of this soft phonon mode to the magnetic ordering causes the giant magnetodielectric coupling. We compare the quantum paraelectric (incipient ferroelectric) behavior and the magnetodielectric coupling of $NdFe_3(BO_3)_4$ to that of $TbFe_3(BO_3)_4$ single crystals.

MA 38.6 Thu 16:30 HSZ 103

Multiferroicity in Cu_2OSeO_3 studied by Raman scattering — •Vladimir Gnezdilov[1,2], Peter Lemmens[2], Yurii Pashkevich[3], Dietrich Wulferding[2], and Hemuth Berger[4] — [1]ILTP, Kharkov, Ukraine — [2]IPKM, TU Braunschweig, Germany — [3]Donetsk Physteh, Ukraine — [4]IPMC, Lausanne, Switzerland

The lone pair piezoelectric ferrimagnet Cu_2OSeO_3 is a unique example of a metrically cubic material that allows linear magnetoelectric coupling as well as piezoelectric and piezomagnetic coupling [1]. The metric cubic lattice excludes a magnetoelectric coupling mechanism involving spontaneous lattice strains. Raman spectra show drastic changes below Tc, namely the appearance of new lines, the splitting of some lines, and anomalies in their temperature behaviour. These observations are discussed in terms of a symmetry reduction and magnetic excitations.

[1]. J.-W. G. Bos, C.V. Colin, and T.T.M. Palstra, arXiv:0808.5955.

MA 38.7 Thu 16:45 HSZ 103

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], Patrick Bruno[3], and Ingrid Mertig[1,2] — [1]MPI für Mikrostrukturphysik

Halle, Germany — [2]Martin-Luther-Universität Halle-Wittenberg, Germany — [3]European Synchrotron Radiation Facility Grenoble, France

On the basis of first-principles electronic-structure calculations we predict that epitaxial multiferroic films—fabricated as ultrathin Fe films deposited on TiO_2-terminated (001) surfaces of $ATiO_3$ perovskites (A = Pb, Ba)—exhibit an unexpected change of their magnetic structure with increasing Fe-film thickness. The magnetic order changes from ferromagnetic, with a magnetization of about $3\mu_B/atom$ for the 1-monolayer system, to ferrimagnetic with almost vanishing magnetization upon deposition of a second Fe layer. Ferromagnetic order is restored for thicker Fe films but with significantly reduced magnetization as compared to Fe bulk. The effect is understood in terms of hybridization of electronic states and geometric structure. The magnetoelectric coupling affects the size of the magnetic moments moderately, a spin-reorientation transition is not found.

MA 38.8 Thu 17:00 HSZ 103

Ab-initio **prediction of room temperature multiferroic materials** — •Marjana Ležaić[1] and Nicola A. Spaldin[2] — [1]Institut für Festkörperforschung and Institute for advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Materials Department, University of California, Santa Barbara, California 93106-5050, USA

Recently a new ordered double perovskite, Sr_2CrOsO_6 was synthesized [1]. This compound is an insulating ferrimagnet with an unusually high Curie temperature of 725 K. With this experiment in mind, we investigate double perovskite compounds ($A_2BB'O_6$) from first principles, focusing on one of the main challenges for the applications of multiferroics: ferroelecticity accompanied by a net magnetization at room temperature. We demonstrate that ferroelectricity can be induced in these compounds by utilizing an A-site cation possessing a stereochemically active lone pair of electrons. Combining a 3*d* and a 5*d* element at the B and B′ sites in an ordered fashion leads to the increase of the magnetic ordering temperature of these ferrimagnets. We also indicate the possibility of strain-assisted switching between antiferroelectric and ferroelectric states.

[1] Y. Krockenberger *et al.*, Phys. Rev. B **75**, 020404(R) (2007).

15 min. break

MA 38.9 Thu 17:30 HSZ 103

X-ray diffraction studies on multiferroic *R*MnO3 compounds in high magnetic fields — •Jörg Strempfer[1], Britta Bohnenbuck[2], Ioannis Zegkinoglou[2], Nadir Aliouane[3], Dimitri N. Argyriou[3], Alexander Krimmel[4], and Martin von Zimmermann[1] — [1]HASYLAB at DESY, Notkestr. 85, 22603 Hamburg, Germany — [2]MPI/FKF, Heisenbergstr. 1, Stuttgart, Germany — [3]Helmholtz-Zentrum für Materialien und Energie, Glienicker Str. 100, Berlin, Germany — [4]Experimentalphysik V, Universität Augsburg, Augsburg, Germany

Investigations of the multiferroic compounds $TbMnO_3$, $DyMnO_3$ and $Y_{0.2}Eu_{0.8}MnO_3$ by x-ray diffraction in high magnetic fields, oriented along the *a* and *b*-directions of the crystal, are presented. The relation of the behaviour of first and second harmonic reflections to changes in ordering of the rare earth moments in applied field for $TbMnO_3$ and $DyMnO_3$ is discussed [1-3]. Observations below the ordering temperature of the rare earth moments without and with applied magnetic field suggests a strong interaction of the rare earth moments, the Mn moments and the lattice. Since structural first harmonic reflections are absent in $Y_{0.2}Eu_{0.8}MnO_3$, these reflections in the other compounds reflect the ordering of the rare earth moments.

[1] N. Aliouane et al. Phys. Rev. B 73, 020102 (2006)
[2] J. Strempfer et al. Phys. Rev. B 75, 212402 (2007)
[3] J. Strempfer et al. Phys. Rev. B 78, 024429 (2008)

MA 38.10 Thu 17:45 HSZ 103

Multiferrocity in $MnWO_4$: anomalous ultrasonic dissipation and spin phonon coupling — •Alexander Doering[1], Peter Lemmens[1], Dietrich Wulferding[1], Sergei Zherlitsyn[2], Christophe Payen[3], Jubo Peng[4], and Chengtian Lin[4] — [1]IPKM, TU Braunschweig, Germany — [2]FZD, Dresden, Germany — [3]IMN, CNRS, Nantes, France — [4]MPI-FKF, Stuttgart, Germany

Ultrasound spectroscopy on the multiferroic $MnWO_4$ show anomalies in the magnetic phase diagram crossing the PM/AF and the AF/spiralAF-polar phase. The scaling of the temperature dependence of the sound velocity is comparable to $YMnO_3$. The sound attenuation show an anomalous, strongly asymmetric peak attributed to excitations with coupled spin-polar character. Work supported by DFG and ESF-HFM.

MA 38.11 Thu 18:00 HSZ 103

Analysis of ferroelectric and magnetic chiral order in $MnWO_4$ — •Naëmi Leo[1], Dennis Meier[1], Thomas Lottermoser[1], Michael Maringer[1], Petra Becker[2], Ladislav Bohatý[2], and Manfred Fiebig[1] — [1]HISKP, Universität Bonn — [2]Institut für Kristallographie, Universität zu Köln

Spin spiral systems form a particularly interesting subgroup of magnetoelectric multiferroics since violation of inversion symmetry by long-wavelength magnetic order is responsible for the spontaneous electric polarisation. Such intrinsic coupling of magnetism and ferroelectricity is not only promising with respect to future spintronic applications. It also enables fascinating physical effects like the magnetic-field-induced polarisation flop in $TbMnO_3$ or $MnWO_4$.

In our studies we focus on $MnWO_4$, which is a remarkable example of a spin-spiral multiferroic because a single transition-metal ion is responsible for the coexistence of magnetic and electric order. We present a spectral analysis of its multiferroic phase by means of optical second harmonic generation (SHG). With respect to symmetry dependent selection rules we distinguish between crystallographic, antiferromagnetic (AFM) and ferroelectric (FE) SHG contributions of different multipole order. Characteristic temperature dependencies of the associated FE and AFM order parameters further support the attribution. This work is supported by the DFG through SFB 608.

MA 38.12 Thu 18:15 HSZ 103

First principle calculations of domain boundaries in multiferroic BiFeO3 — •Axel Lubk[1], Nicola Spaldin[2], Sibylle Gemming[3], and Hannes Lichte[1] — [1]Institute for Structure Physics, Technische Universität Dresden, Germany — [2]Materials Department, University of California, Santa Barbara, USA — [3]Institute of Ion Beam Physics and Materials Research,Forschungszentrum Dresden-Rossendorf, Germany

Domain boundaries in ferroic materials deviate from the bulk in both the structural and electronic properties. Their presence in the material influences the total energy of the system, the band structure and the magnetic and electric polarization. We report on a Density Functional Theory (DFT) approach within the Local Density Approximation on domain boundaries in multiferroic BiFeO3 (space group: R3c). Our model systems consist of the experimentally observed 71°, 109° and 180° domain walls. The calculations were performed within the DFT software VASP, incorporating standard pseudopotentials and a plane wave basis set. A complete electronic and ionic relaxation of the model structures has been performed to yield details of the charge and structure modulation at the boundary including the deformation of the Fe-centered oxygen octahedron, the formation of electric dipole layers leading to a jump in the electrostatic potential, band gap narrowing and a domain wall dependent modification of the small ferromagnetic effect present in BiFeO3.

MA 38.13 Thu 18:30 HSZ 103

Many-particle Approach to Multiferroic Bulk Systems — •Thomas Michael[1], Steffen Trimper[1], and Julia M. Wesselinowa[2] — [1]Institute of Physics, Martin-Luther-Universitaet, Halle (Saale), Germany — [2]Department of Physics, University of Sofia, Sofia, Bulgaria

Multiferroic bulk systems are studied in a many-particle approach. The magnetization, polarization, excitation energies, associated dampings of ferroelectric and magnetic modes are presented as a function of temperature. An anomaly in the ferroelectric quantities close to the magnetic phase transition is observed. The analysis of the ferroelectric subsystem is based on a two-state quantum model, the Ising model in a transverse field. The magnetic moments interact via the Heisenberg model. The corresponding multiferroic coupling term differs for hexagonal and orthorhombic materials. A Green's function technique in reciprocal space provides the static and dynamic properties. Furthermore, we present the dielectric function of the coupled model. The theoretical result are compared with experimental data.

MA 38.14 Thu 18:45 HSZ 103

Controlled manipulation and coupling of domains in a spin spiral multiferroic — •Dennis Meier[1], Michael Maringer[1], Naëmi 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

The intrinsically strong cross coupling between magnetism and ferroelectricity in spin spiral multiferroics suggests these systems as prime candidates for novel multifunctional devices. Comprehension and controlling of the correlated antiferromagnetic (AFM) and ferroelectric (FE) domain structures by external fields is an indispensible prerequisite for future device design. However, very few is know about the domain topology and switching of AFM spin spirals and the magnetically induced FE domains. Here we discuss the correlation of AFM domains and FE domains under external electric and magnetic fields in the spin spiral multiferroic $MnWO_4$. Correlations are revealed by optical second harmonic generation. Electric fields are used to uniquely control the magnetic domain structure, leading to an E-field driven hysteresis of the magnetic order parameter. Application of a magnetic field allows to conceal a ferroelectrically stored information, which reemerges as the field is removed. This work is supported by the DFG through SFB 608.

MA 38.15 Thu 19:00 HSZ 103

Strain-coupled multiferroic model system of magnetic films on piezoelectric PMN-PT(001) — •Andreas Herklotz, Diana Rata, Ksenia Boldyreva, Orkidia Bilani-Zeneli, Martina Cornelia Dekker, Ludwig Schultz, and Kathrin Dörr — IFW Dresden, Postfach 270116, 01171 Dresden

In many multiferroic composites the interrelation of magnetic and polar electric properties originates from joined elastic strain of the components. A straightforward model system for quantitative investigations of strain-modulated magnetic properties comprises of magnetic films epitaxially grown on high-strain piezoelectric single crystals [1,2].

In this work, we report on structural, ferroelectric and elastic properties of $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) (001) single crystals utilized as thin film substrates for dynamical strain control of up to 0.25% in complex oxide films [2]. A tunable buffer layer system of solid solutions of perovskite-type $LaScO_3$ and $LaAlO_3$ has been developed that serves to adjust the in-plane parameter of buffered PMN-PT in a range of several percent. Thus, various as-grown strain states of a given magnetic film can be prepared and studied under reversible strain. First examples for $La_{1-x}Sr_xBO_3$ (B = Co or Mn) films under both statically and dynamically varied biaxial strain will be discussed.

[1] C. Thiele et al., PRB 75, 054408 (2007)

[2] M. D. Biegalski, K. Dörr, H. M. Christen (submitted); A. Herklotz et al. (submitted)

MA 38.16 Thu 19:15 HSZ 103

Voltage controlled inversion of magnetic anisotropy in Ni thin films — •Mathias Weiler[1], Andreas Brandlmaier[1], Stephan Geprägs[1], Matthias Althammer[1], Matthias Opel[1], Christoph Bihler[2], Hans Huebl[2], Martin S. Brandt[2], Rudolf Gross[1,3], and Sebastian T. B. Goennenwein[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Walter Schottky Institut, TU München, 85748 Garching, Germany — [3]Physik-Department, TU München, 85748 Garching, Germany

The control of magnetic properties by means of an electric field is an important aspect in magnetism and magnetoelectronics. We here demonstrate a voltage control of magnetization orientation in Ni thin film/piezoelectric actuator hybrids via magnetoelastic coupling at room temperature [1]. Ferromagnetic resonance (FMR) spectroscopy shows that the in-plane uniaxial magnetic anisotropy of the Ni film is inverted upon changing the polarity of the voltage V_p applied to the actuator. Using SQUID magnetometry, we find that the magnetization orientation can be reversibly rotated in the Ni film plane within a range of approximately 70° by changing V_p alone – even at static external magnetic field strengths well below the Ni coercive field. All magnetometry data can be quantitatively modelled in a Stoner-Wohlfarth approach using the magnetic free energy determined from FMR.

We gratefully acknowledge financial support by the DFG via SPP 1157 (GR 1132/13), GO 944/3 and the German Excellence Initiative via the "Nanosystems Initiative Munich".

[1] M. Weiler *et al.* (2008) arXiv:0810.0389