DS 10: Multiferroics I (jointly with MA, DF, KR, TT)

Time: Tuesday 9:30–12:45 Location: BEY 118

DS 10.1 Tue 9:30 BEY 118

***Ab initio* study of electronic transport in the Co/PZT-based tunnel junctions** — •Vladislav Borisov[1], Sergey Ostanin[1], Igor Maznichenko[2], Arthur Ernst[1], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle, Germany

Magnetoelectric coupling at the multiferroic interfaces FM/FE (FM=Co,Fe, FE=$PbTiO_3$,PZT) was studied from first principles. The magnetic interfacial effect, which is controlled by the FE polarization, originates from the charge transfer and *d*-orbital redistribution of Co/Fe and Ti mediated by the *p*-states of interfacial oxygens. In PZT, the presence of Zr dopants may locally enhance the effect. We analysed also the spin polarization of tunneling electrons in Co/PTO/Co and Fe/PTO/Co junctions, in which the calculated four-state conductance can account for the ferroelectrically switchable TMR signal observed recently in LSMO/PZT/Co [1].

[1] D. Pantel *et al.*, *NATURE MATERIALS* **11**, 289 (2012).

DS 10.2 Tue 9:45 BEY 118

Tunneling transport and memristive effects in PbTiO3- based multiferroic tunnel junctions — •Andy Quindeau, Marin Alexe, and Dietrich Hesse — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

A gradually tunable resistance effect based on the tunnel electroresistance (TER) of multiferroic tunnel junctions is investigated. The ferroelectric tunnel barrier comprises, a PbTiO3 layer of a few nm thickness, is embedded between two different ferromagnetic layers, viz. La0.7Sr0.3MnO3 and cobalt. In this capacitor geometry an electric bias, applied perpendicularly to the films, results in a direct tunneling current flowing between the two electrodes. The tunnel resistance is dependent on the polarization of the ferroelectric, which is switchable via relatively high voltage pulses. Due to the variation of the pulse parameters a variety of non-volatile resistance states can easily be achieved. These gradually tunable resistance states, characteristic for a memristor device, can be explained by a ferroelectric domain distribution inside the ferroelectric film: Domains with different polarities can coexist inside one capacitor after partial polarization switching and act as parallel connected tunnel barriers with different tunnel resistances. Temperature dependent measurements show the influence of different electron transport mechanisms, which will be discussed. The impact of the memristive states on the tunnel magnetoresistance (TMR) can be shown.

DS 10.3 Tue 10:00 BEY 118

Lattice and polarizability mediated spin activity in EuTiO3 — •Annette Bussmann-Holder[1], Kevin Caslin[1,2], Patrick Reuvenkamp[1], Zurab Guguchia[3], Hugo Keller[3], Reinhard Kremer[1], and Jürgen Köhler[1] — [1]Max Planck Institute for Solid State Research, Heisenbergstr.1, D-70569 Stuttgart, Germany — [2]Brock University, 500 Glenridge Ave., St. Catharines L2S-3A1, Ontario, Canada — [3]Physik-Institut der Universität Zürich, Winterthurerstr. 190, CH-8057 Zürich, Switzerland

EuTiO3 is shown to exhibit novel strong spin-charge-lattice coupling deep in the paramagnetic phase. Its existence is evidenced by an, until now, unknown response of the paramagnetic susceptibility at temperatures exceeding the structural phase transition temperature TS=282K. The extra features in the susceptibility follow the rotational soft zone boundary mode temperature dependence above and below TS. In addition, novel magnetostriction experiments and dielectric constant measurements have been performed which both reveal giant anomalies related to the antiferromagnetic phase transition at TN=5.7K and the structural phase transition at TS. The theoretical modeling consistently reproduces these anomalies and provides evidence that EuTiO3 has considerable analogies to SrTiO3 but also substantial differences stemming from the Eu 4f spins which are lattice activated at high temperatures far above TN.

DS 10.4 Tue 10:15 BEY 118

Magnetoelectric coupling in a composite multiferroic structure revealed by Ferromagnetic Resonance — •Alexander Sukhov[1], Paul P. Horley[2], Chenglong Jia[3], and Jamal Berakdar[1] — [1]Martin-Luther-Universität Halle-Wittenberg, Halle/Saale, GERMANY — [2]Centro de Investigacion Materiales Avazados, S.C. (CIMAV), Chihuahua/Monterrey, MEXICO — [3]Lanzhou University, Lanzhou, CHINA

We theoretically study [1] a thin multiferroic junction related to a barium titanate (tetragonal or rhombohedral phase) layer in contact with an iron layer. Depending on the type of the magnetoelectric coupling at the interface - either due to screening charge or due to an epitaxial strain resulting in a strong magnetoelastic coupling - we present a detailed analysis of the response of the multiferroic structure to magnetic radio-frequency fields by means of ferromagnetic resonance as a function of the applied electric field.

[1] A. Sukhov, P.P. Horley, C.-L. Jia, J. Berakdar, J. Appl. Phys. **113**, 013908 (2013).

DS 10.5 Tue 10:30 BEY 118

Magnetoelectric monopoles in bulk periodic solids — •Michael Fechner[1], Eric Bousquet[1], Alexander Balatsky[2], Nicoal A. Spaldin[1], and Lars Nordström[3] — [1]ETH Zürich, Department for Materials Theory, Zürich, Switzerland — [2]NORDITA, KTH Royal Institute of Technology and Stockholm University, Stockholm, Sweden — [3]Department of Physics and Astronomy, Uppsala University, Sweden

The magnetoelectric (ME) response is described by a second rank tensor that can be decomposed into irreducible isotropic diagonal, antisymmetric and trace-free part. Here we show that the former component can be identified with a ferroic ordering of magnetoelectric monopoles[1]. We further develop a scheme to calculate the ME monopole in bulk periodic solids, by exploiting similarities to the ferroelectric polarization. Finally, as an example we present results for the series of lithium transition metal phosphate compounds ($LiMPO_4$, with M = Co, Fe and Ni), which include both ferromonopolar and antiferromonopolar ordered cases. We predict for the latter case a q-dependent diagonal ME effect.

[1] N . A. Spaldin et al., PRB 88, 094429 (2013)

DS 10.6 Tue 10:45 BEY 118

Different routes for enhanced control of ferroelectric polarization by magnetic field — •I. Fina[1,2], V. Skumryev[3,4], D. O'Flynn[5], G. Balakrishnan[5], N. Dix[2], J. M. Rebled[2,6], P. Gemeiner[7], X. Marti[8], F. Peiró[6], B. Dkhil[7], F. Sánchez[2], L. Fàbrega[2], and J. Fontcuberta[2] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Institut de Ciència de Materials de Barcelona, Catalonia, Spain — [3]Institució Catalana de Recerca i Estudis Avançats (ICREA), Catalonia, Spain — [4]Universitat Autònoma de Barcelona, Barcelona, Spain — [5]University of Warwick, Coventry, United Kingdom — [6]LENS - MIND/IN2UB, Barcelona, Spain — [7]Propriétés et Modélisation des Solides, Paris, France — [8]Faculty of Mathematics and Physics, Praha, The Czech Republic

I will focus on the direct magnetoelectric effect, control of polarization vector by magnetic field, in single-phase and composite multiferroic materials in thin film form.

In single-phase multiferroic materials, cycloidal magnet, we will see that strong coexistence of polar and non-polar regions allow large susceptibilities leading to a full control of the polarization vector by means of magnetic field [1]. In composite materials, ferromagnetic-ferroelectric heterostructures, the limiting factor is the substrate clamping effect. We will show that we can overcome this undesired effect, enhancing the presence of some small quantity of defects. These defects store the needed elastic energy, enhancing the magnetoelectric coupling, which result in huge effects near room temperature [2].

[1] I. Fina, et al., Phys. Rev. B 88, 100403(R) (2013). [2] I. Fina, et al., Nanoscale 5, 8037 (2013).

15 min. break

DS 10.7 Tue 11:15 BEY 118

Investigation of A-site Bismuth based double perovskites as potential room-temperature multiferroics — •Vikas Shabadi, Mehran VafaeeKhanjani, Mehrdad BaghaieYazdi, Aldin Radetinac, Philipp Komissinskiy, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, Ger-

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A-site Bismuth based double perovskites ($Bi_2BB'O_6$), where ferroelectricity arises from the stereochemically active $6s^2$ lone pair of electrons on the Bi^{3+} cations, provide a vital test bed to engineer room temperature multiferroicity. Here, different combinations of 3d-3d or 3d-5d cations may be introduced at the B-site in order to obtain an effective ferri/ferromagnetic moment. The 3d-3d compound Bi_2FeCrO_6 (BFCO) has drawn a heightened interest due to its large experimentally reported ferroelectricity and divergent observations of its magnetic properties. We report epitaxial BFCO thin films grown by pulsed laser deposition on single crystal $SrTiO_3(100)$ substrates. Detailed structural characterization was performed by X-ray Diffraction and the magnetic properties were studied with a SQUID magnetometer. We show that BFCO adopts a superstructure with the same unit cell as the chemically ordered double perovskite. The magnetization is a function of chemical but not of structural order.

DS 10.8 Tue 11:30 BEY 118

Room temperature magnetism and ferroelectricity in eps-Fe2O3 thin films — •I. Fina[1], M. Gich[2], A. Morelli[1], F. Sánchez[2], M. Alexe[1], J. Fontcuberta[2], and A. Roig[2] — [1]Max Planck Institute of Microstructure Physics D-06120 Hallle/Salle, Germany — [2]Institut de Ciència de Materials de Barcelona ICMAB, Consejo Superior de Investigaciones Científicas CSIC, Campus UAB 08193 Bellaterra, Catalonia, Spain

The quest for magnetoelectric multiferroics is driven by the promise of a novel generation of devices combining the best characteristics of ferromagnetic and ferroelectric materials. These cherished applications require materials displaying a substantial magnetization and electric polarization which are coupled and coexist well above room temperature. These properties are not commonly fulfilled by single phase materials and firm candidates for the development of these technologies are still sought.

In this contribution, we will report on epitaxial eps-Fe2O3 thin films grown by Pulsed Laser Deposition on (111) SrTiO3 and present recent data on its structural, magnetic and dielectric characterization. The films are ferromagnetic and ferroelectric at room temperature and display magnetization and polarization values at remanence of about 50 emu/cm3 and 1 uC/cm2 with a long retention. A magnetocapacitive response has also been detected indicating that the films present coupling between both ferroic orders.

DS 10.9 Tue 11:45 BEY 118

Time-resolved analysis of switching in spiral multiferroics — •Jonas Stein[1], Tobias Cronert[1], Jeannis Leist[2], Karin Schmalzl[3], A Agung Nugroho[4], Alexander C Komarek[5], Götz Eckold[2], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Physikalische Chemie, Universität Göttingen — [3]JCNS at ILL, France — [4]Institut Teknologi Bandung, Indonesia — [5]MPI für chemische Physik fester Stoffe

Multiferroic crystals are promising materials for future memory devices with extremely low power consumption. The rise time between two states is a crucial parameter for a possible application and was investigated in the spiral spin multiferroic $TbMnO_3$. Polarized neutron diffraction is able to determine the ratio of chiral domains, which can be controlled by an external electric field. Using the stroboscopic technique we can follow the reversion of chiral domains in the timescale of a few 100 microseconds to hours. In $TbMnO_3$ we find a clear logarithmic relation between the rise time and temperature that is fulfilled over 5 decades.

DS 10.10 Tue 12:00 BEY 118

Thermodynamic properties of the new multiferroic material $(NH_4)_2[FeCl_5(H_2O)]$ — •Matthias Ackermann[1], Daniel Brüning[2], Thomas Lorenz[2], Petra Becker[1], and Ladislav Bohatý[1] — [1]Institut für Kristallographie, Universität zu Köln, Germany — [2]II. Physikalisches Institut, Universität zu Köln, Germany

Multiferroic materials with coupled ferroelectric and (anti-)ferromagnetic order in the same phase have attracted considerable interest during the last decade. The search for new multiferroic materials is an important issue to further improve the understanding of the underlying coupling mechanisms. Here, we present a detailed investigation of the new multiferroic compound $(NH_4)_2[FeCl_5(H_2O)]$ [1]. Our measurements of pyroelectric currents reveal, that the electric polarization occuring in the antiferromagnetically ordered phase can drastically be influenced by applying magnetic fields. Based on the results of these dielectric investigations, together with measurements of thermal expansion, magnetostriction and specific heat, detailed magnetic field versus temperature phase diagrams are derived. Depending on the direction of the magnetic field up to three different multiferroic phases are identified, which are separated from the paramagnetic phase by a magnetically ordered, but non-ferroelectric phase.

This work was supported through the Institutional Strategy of the University of Cologne within the German Excellence Initiative.

[1] Ackermann M et al. 2013 *New J. Phys.* (in press, arXiv:1308.0285)

DS 10.11 Tue 12:15 BEY 118

Stoichiometric Effects on Crystal Quality in $LuFe_2O_4$ and $YbFe_2O_4$ — •Hailey Williamson[1,2], Geetha Balakrisnan[2], and Manuel Angst[1] — [1]Jülich Centre for Neutron Science JCNS-2 and Peter Grünberg Institut PGI-4, Forschungszentrum Jülich GmbH, Jülich, Germany. — [2]Department of Physics, The University of Warwick, CV4 7AL, Coventry, UK

The multiferroic rhombohedral $LnFe_2O_4$ (Ln=Lu, Y, Yb, Tm, Ho and Er) system, which can be described as stacked hexagonal Fe bilayers separated by Lu monolayers, has been in focus since the discovery of interesting magnetic and electrical characteristics in $LuFe_2O_4$. The specific CO configuration within the Fe bilayers was initially thought to produce a ferroelectricity through cross polarization of the two layers of the bilayer. However our recent investigations indicate that the CO configuration is actually non-polar. Extensive research highlighted a large sensitivity to oxygen stoichiometry, where crystals grown in an excess/deficient oxygen partial pressure environment exhibit smeared glassy magnetic transitions and diffuse CO. Through fine tuning of the atmospheric conditions, crystals exhibiting 3D CO and magnetism were produced. Interest then spread to isostructural $YbFe_2O_4$, which has currently few detailed investigations. Single crystals of $YbFe_2O_4$ were grown in four different partial pressure atmospheres to view the effects of oxygen stoichiometry on the magnetism and CO. A series of macroscopic and microscopic measurements provided a detailed look into the effects of oxygen stoichiometry on the intrinsic characteristics as well as a comparison to that of its predecessor $LuFe_2O_4$.

DS 10.12 Tue 12:30 BEY 118

Multiferroicity in Cu_2OSeO_3? — •Eugen Ruff[1], Stephan Krohns[1], Helmuth Berger[2], Peter Lunkenheimer[1], and Alois Loidl[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg — [2]Institute of Physics of Complex Matter, École Polytechnique Fédérale de Lausanne

Skyrmions are topologically stable vortex-like objects, for the first time detected in the B20 alloy MnSi [1]. Their electrical controllability via small currents qualifies skyrmions for applications in high-density magnetic storage devices. The recent discovery of magnetoelectric skyrmions in the insulating chiral magnet Cu_2OSeO_3 leads to another promising route to electrical control [2]. This system is suggested to carry a local electrical dipole, which implies that the skyrmions should be controllable by an external electrical field without losses due to Joule heating. Here we provide a thorough analysis of the magnetic and polar phases of this material, using SQUID and pyrocurrent measurements. In order to investigate the possible ferroelectric properties of Cu_2OSeO_3, we have performed dielectric spectroscopy in various magnetic fields in a broad frequency range below 70 K. Combining all these different techniques, we address the question whether Cu_2OSeO_3 is magnetoelectric or multiferroic. [1] S.Mühlbauer *et al.*, Science **323**, 915 (2009). [2] S.Seki *et al.*, Science **336**, 198 (2012).