DS 7: Multiferroics 2 (jointly with DF, KR, MA, TT)

Time: Monday 15:00–18:30 Location: H3

DS 7.1 Mon 15:00 H3

Magnetization control in thin two-phase multiferroic structures via external electric fields — •Alexander Sukhov[1], Paul P. Horley[2], Chenglong Jia[3], and Jamal Berakdar[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06120 Halle/Saale, Germany — [2]Centro de Investigation en Materiales Avanzados, S.C. (CIMAV), 31109 Chihuahua, Mexico — [3]Key Laboratory for Magnetism and Magnetic Materials of the Ministry of Education, Lanzhou University, Lanzhou 730000, China

We present a theoretical study of the coupled magnetization and polarization dynamics in a thin multiferroic junction related to a $BaTiO_3$ (rhombohedral phase) layer in contact with Fe-layer. The dynamical properties are discussed in the context of different interfacial magnetoelectric coupling mechanisms. For the magnetoelectric coupling induced by the screening of the spin-polarized electrons in Fe we investigate the minimum strength of the coupling constant which is required for the full switching of the magnetization [1]. In the case of a strain-induced magnetoelectric interaction we show an electric field-induced magnetic switching in the plane perpendicular to the magneto-crystalline easy axis while the total magnetization remains stable [2]. In addition, the response of the multiferroic structure to magnetic radio-frequency fields by means of ferromagnetic resonance and dependent on the applied electric field is studied. [1] P.P. Horley, A. Sukhov, C.-L. Jia, E. Martinez, J. Berakdar, Phys. Rev. B **85**, 054401 (2012). [2] C.-L. Jia, A. Sukhov, P.P. Horley, J. Berakdar, Europhys. Lett. **99**, 17004 (2012).

DS 7.2 Mon 15:15 H3

Magnetic field induced charge anisotropy in $CoFe_2O_4/BaTiO_3$ nanocomposite — •Carolin Schmitz-Antoniak[1], Detlef Schmitz[2], Sven Stienen[1], Pavel Borisov[3], Anne Warland[1], Bernhard Krumme[1], Wolfgang Kleemann[1], and Heiko Wende[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, D-47048 Duisburg — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, D-12489 Berlin — [3]Department of Chemistry, University of Liverpool, Liverpool L69 7ZD

The system of $CoFe_2O_4$ nanopillars in a $BaTiO_3$ matrix represents a multiferroic nanocomposite in which strong ferrimagnetism and strong ferroelectricity coexist at room temperature [1]. The magnetostrictive CFO nanopillars and the piezoelectric BTO matrix are coupled by strain so that it is possible to change the electric properties by a magnetic field and the magnetic properties by an electric field. The charge anisotropy of Ti ions is probed by x-ray linear dichroism (XLD) and the magnetisation of Co ions by x-ray magnetic circular dichroism (XMCD) giving the unique possibility to study the effect of the coupling on a microscopic level as a function of magnetic field strength and direction. The occurrence of significant in-plane components of the electric polarisation is discussed. They are due to shear forces acting on the $BaTiO_3$ matrix while taking into account non-diagonal piezoelectricity components.

Funded by DFG (SFB491) and BMBF (05 ES3XBA/5).

[1] H. Zheng et al., Science 303, 661 (2004)

DS 7.3 Mon 15:30 H3

Multiferroic CoFe2O4/ BaTiO3 with core shell structure nanoparticles — •Morad Etier[1], Vladimir V.Shvartsman[1], Yanling Gao[1], Joachim Landers[2], Heiko Wende[2], and Doru C.Lupascu[1] — [1]University of Duisburg-Essen, Institute for Materials Science, Essen, Germany — [2]University of Duisburg-Essen, Faculty of Physics, Duisburg, Germany

Multiferroic materials exhibit ferroelectricity and ferromagnetism simultaneously. Combining piezoelectricity and magnetostriction components in the same composite received more interests in the modern researches. In this work we report synthesis and properties of cobalt iron oxide barium titanate composite with a core shell structure. To synthesize the samples we combine co-precipitation and organosol method. Phases content, microstructure and morphology were studied by x-ray diffraction, SEM and TEM. Multiferroic properties were proved by home-built Sawyer-Tower circuit and SQUID magnetometry. Temperature dependence of magnetic moment was measured in zero field cooling (ZFC) and field cooling (FC) and compared with those cobalt iron oxide nanopowder. The dielectric properties were studied using impedance spectroscopy.

DS 7.4 Mon 15:45 H3

Strain-induced changes of magnetic anisotropy in epitaxial spinel-type cobalt ferrite films — •Stefania Florina Rus[1,2], Andreas Herklotz[2,4], Iuliu Grozescu[3], and Kathrin Dörr[4] — [1]Politehnica University of Timişoara, 300006 Timişoara, Romania — [2]IFW Dresden, 01171 Dresden, Germany — [3]Institute for Research and Development in Electrochemistry and Condensed Matter, 300224 Timisoara, Romania — [4]Martin-Luther-Universität Halle-Wittenberg, Institute for Physics, 06099 Halle, Germany

We present results on the effect of biaxial strain on the magnetic anisotropy of thin films of the parent compound CoFe2O4 and films with a partial substitution of Co and Fe by Zr and Pt, respectively. The strain states of the epitaxially grown films are controlled twofold: (i) statically by epitaxial misfit strain via an appropriate choice of substrates and buffer layers and (ii) reversibly by strain transfer from piezoelectric $Pb(Mg_{1/3}Nb_{2/3})_{0.72}Ti_{0.28}O_3$ (001) (PMN-PT) substrates. Due to large negative magnetostriction all films show an out-of-plane magnetic easy axis under tensile strain and an in-plane easy axis under compressive strain. Our reversible strain measurements show that the magnetic anisotropy can be efficiently altered by the application of an electric field to the ferroelectric PMN-PT substrates. The effect of substitution with Zr and Pt on the magnetoelectric effect will be discussed. This work is supported by the strategic grant POSDRU ID77265 (2010), co-financed by the European Social Fund, within the Sectoral Operational Programme Human Resources Development 2007-2013. Advising by P. Vlazan is greatly acknowledged.

DS 7.5 Mon 16:00 H3

***Ab initio* study of magneto-phonon interaction in $GaFeO_3$** — •Konstantin Z. Rushchanskii, Stefan Blügel, and Marjana Ležaić — Peter Grünberg Institut, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Magnetoelectric (ME) coupling provides a handle for manipulating the magnetization of a material with an electric field, giving a perspective for a new type of non-volatile memory. Unfortunately, materials with ME coupling that is large enough for industrial applications are scarce. Moreover, among the materials which are both ferroelectric and magnetic at room temperature, only $BiFeO_3$ is known. Unfortunately, the ordering of spins in this material is antiferromagnetic (whereas ferro/ferrimagnetic coupling is desired) and the ME coupling is small.

$GaFeO_3$ (GFO) is the first material observed to simultaneously present a strong ME coupling and a resulting magnetization in a single phase. It has the polar structure $Pc2_1n$, which allows disorder in A and B cation sites. By increasing the iron content its Curie temperature can be increased above room temperature [1].

To understand the mechanism of the strong ME coupling in $GaFeO_3$ at the microscopic level, we performed *ab initio* calculations based on density functional theory of the structural properties and magneto-phonon interaction in stoichiometric $GaFeO_3$ compounds in different structures, as well as with different occupancies of the A and B sites.

We acknowledge the support by Helmholtz Young Investigators Group Programme VH-NG-409 and GALIMEO Consortium.

[1] T. Arima *et al.*, Phys. Rev. B **70**, 064426 (2006)

DS 7.6 Mon 16:15 H3

The effect of ion doping on multiferroic $MnWO_4$ — •safa golrokh bahoosh[1,3], julia m. wesselinowa[2], and steffen trimper[3] — [1]Max Planck Institute of Microstructure Physics,Weinberg 2, 06120 Halle, Germany — [2]University of Sofia, Department of Physics,Blvd. J. Bouchier 5, 1164 Sofia, Bulgaria — [3]Institute of Physics, Martin-Luther-University, 06120 Halle, Germany

We have studied the ion doping effects on different transition temperatures in the multiferroic compound $MnWO_4$ based on a microscopic model and within the framework of Green functions technique. It is shown that the exchange interaction constants can be changed due to the different ion doping radii. This leads to reduction of the magnetic phase transition temperature T_N by doping with non-magnetic ions,such as Zn, Mg, whereas T_N is enhanced by doping withtransition metal ions, such as Fe, Co. The different behavior of the temperature T_1 (where up-up-down-down collinear spin structure appears) by Fe and Co doping could be explained taking into account the single-ion anisotropy.

15 min. break

DS 7.7 Mon 16:45 H3

Hybrid improper ferroelectricity in a Multiferroic and Magnetoelectric Metal- Organic Framework — •Alessandro Stroppa[1], Paolo Barone[1], Prashant Jain[2], Manuel Perez-Mato[3], and Silvia Picozzi[1] — [1]CNR-SPIN Via Vetoio, 67100, L'Aquila (Italy) — [2]Los Alamos National Lab, 30 Bikini Atoll Rd Los Alamos, NM 87545-0001 (505) 664-5265 — [3]Departamento de Fisica de la Materia Condensada, Facultad de Ciencia y Tecnologia, UPV/EHU, Bilbao (Spain)

Metal-organic frameworks (MOFs) show increasing promise as candidates for various applications. Of particular interest are MOFs with the perovskite topology showing hydrogen bonding-related multiferroic phenomena. By using state-of-the-art-ab-initio calculations, we show that in [C(NH2)3]Cr(HCOO)3 MOF, interaction between the cooperative antiferro-distortive Jahn-Teller distortions and the C(NH2)3 cations breaks the inversion symmetry through hydrogen-bonding and induces a ferroelectric polarization. Interestingly, the polar behavior arises due to a trilinear coupling between two unstable modes, namely a Jahn-Teller and a tilting mode, and one stable polar mode. Therefore, this compound represents the first example of hybrid improper ferroelectric in the family of metal-organic compounds. Since rotational modes in perovskite-inorganic compounds usually freeze-in at elevated temperatures (300 K), the trilinear coupling in MOF compounds may provide an interesting route to realize room temperature multiferroic. Last but not least, we show that switching of polarization direction implies the reversal of a large weak ferromagnetic component.

DS 7.8 Mon 17:00 H3

Ferroelectric properties of (Ba,Sr)TiO_3/$La_{0.7}Sr_{0.3}MnO_3$ multilayered thin films — •Markus Michelmann[1], Johannes Aprojanz[1,2], Arseni Buryakov[2], Elena Mishina[2], Markus Jungbauer[1], Sebastian Hühn[1], and Vasily Moshnyaga[1] — [1]I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen — [2]Moscow State Institute of Radioengineering, Electronics and Automation, Prosp. Vernadskogo 78, 119454 Moscow, Russia

$Ba_xSr_{1-x}TiO_3$ (BSTO) epitaxial thin films became feasible for room temperature applications in contrast to the bulk material due to a possibility to enhance the ferroelectric Curie temperature under biaxial compressive strain. Using $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) thin films as metallic electrodes, we have grown highly strained BSTO/LSMO bilayers and LSMO/BSTO/LSMO trilayers on $SrTiO_3$ (100) substrates with BSTO layer thicknesses of 10 - 200 nm by means of metalorganic aerosol deposition. Ferroelectric switching was studied both electrically and by nonlinear optics (second harmonic generation (SHG)). Capacitance-voltage characteristics in a frequency range of $f = 1 - 10^6$ Hz and PUND measurements prove a ferroelectric hysteretic behavior up to room temperature with a remanent polarization of several $\mu C/cm^2$ and a switching fields in the range of $10-100$ kV/cm. This was also supported by the SHG measurements. A detailed study of multiferroic properties will be performed for temperatures, $T = 10 - 400$ K, and applied magnetic field, $B = 0 - 9$ T. This work was supported by IFOX of the European Community's 7th Framework Programme.

DS 7.9 Mon 17:15 H3

Epitaxial thin films of the multiferroic double perovskite Bi_2FeCrO_6 — •Vikas Shabadi, Mehran Vafaee, Mehrdad BaghaieYazdi, Aldin Radetinac, Philipp Komissinskiy, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, Germany

Co-existence of magnetism and ferroelectricity was theoretically predicted in the ordered double perovskite Bi_2FeCrO_6 (BFCO) [1]. We report epitaxial BFCO thin films grown by pulsed laser deposition from a 20% Bi-rich ceramic target on single crystal $SrTiO_3$(100) substrates. The degree of the Fe-Cr cation ordering in the BFCO films was calculated based on the X-ray diffraction patterns. The magnetic moments of the BFCO films were measured with a SQUID magnetometer and analyzed as a function of the Fe-Cr ordering. The discrepancies in the previously reported values of the magnetic moment of BFCO [2,3] are most likely connected to the varying degree of the Fe-Cr cation ordering in the samples. In a recent experiment more than 90% spontaneous B-site ordering in a similar Fe-Cr based double perovskite system has been achieved [4]. Anti-site disorder control is a key challenge to design double perovskite multiferroics.

[1]P. Baettig and N. A. Spaldin, Appl. Phys. Lett. **86**, 012505 (2005)
[2]Kim *et al.*, Appl. Phys. Lett. 89, 102902 (2006)
[3]R. Nechache *et al.*, J. Appl. Phys. **105**, 061621 (2009)
[4]S. Chakraverty *et al.*, Phys. Rev. B **84**, 064436 (2011)
The authors acknowledge support from DAAD.

DS 7.10 Mon 17:30 H3

Growth of multiferroic heterostructures — •Sergiu Stratulat, Dietrich Hesse, and Marin Alexe — Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

Coupling two materials with different order parameters gives great flexibility in engineering multifunctional devices. In achieving the maximum interfacial effects, vertical heterostructures present the maximum potential. Creating well-ordered vertical multiferroic heterostructures is not a trivial task, especially on large areas. We are focusing our attention on the system comprising ferrimagnetic CoFe2O4 and ferroelectric/antiferromagnetic BiFeO3, using pulsed laser deposition as a synthesizing technique. Considering a time-viable process to create the pillar-matrix configuration, we used anodic aluminum oxide masks to pattern the nucleation sites for the cobalt ferrite on previously deposited SrRuO3 bottom electrode on SrTiO3. After removal of the mask, deposition by means of a mixed target leads to ordered arrays of CFO pillars embedded in a BFO matrix. Scanning electron microscopy was employed at every step of the experiments to show the development of the samples, and X-ray diffraction probed the structural parameters. Testing the ferroelectric and magnetic properties locally gives an indication on the coupling influences present in the thin films.

DS 7.11 Mon 17:45 H3

Self-assembled composite multiferroic films in controlled strain states — •Mohsin Rafique[1,2,3,4], Andreas Herklotz[3,4], Er-Jia Guo[3,4], Kathrin Doerr[3,4], and Sadia Manzoor[1,2] — [1]Magnetism Laboratory, COMSATS Institute of Information Technology, Park Road 44000, Islamabad, Pakistan — [2]Center for Micro and Nano Devices (CMND), COMSATS Institute of Information Technology, Park Road 44000, Islamabad, Pakistan — [3]IFW Dresden, Postfach 270116, 01171 Dresden, Germany — [4]Institute for Physics, Martin-Luther-University Halle-Wittenberg, 06099 Halle, Germany

Self-assembled thin-film nanocomposites of piezoelectric and magnetostrictive materials have stimulated increasing research activities because of their potential to exhibit a large magnetoelectric response exploitable in multifunctional devices. Epitaxial thin films of $CoFe_2O_4$ and $BaTiO_3$ (CFO-BTO) composites were grown on $SrTiO_3$ (001) and piezoelectric $Pb(Mg_{1/3}Nb_{2/3})_{0.72}Ti_{0.28}O_3$(001) (PMN-PT) substrates by pulsed laser deposition. Self-assembled nanostructures consisting of spinel nanopillars heteroepitaxially embedded in the ferroelectric perovskite matrix form. X-ray diffraction is utilized to estimate the lattice parameters. The magnetic properties studied by SQUID magnetometry show an out-of-plane easy axis of the CFO nanopillars and a strengthening of the out-of-plane anisotropy with increasing compression along the nanopillar axis. The magnetoelectric coupling in the composite film is revealed at a structural transition of the BTO matrix. Electrically controlled substrate strain of PMN-PT is applied to modify the magnetic anisotropy of the nanopillars.

DS 7.12 Mon 18:00 H3

Low-lying magnetic excitations in the distorted triangular lattice antiferromagnet α-$CaCr_2O_4$ — •Michael Schmidt[1], Zhe Wang[1], Sandor Toth[2], Bella Lake[2], A.T.M.Nazmul Islam[2], Alois Loidl[1], and Joachim Deisenhofer[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D-86135 Augsburg, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, D-14109 Berlin, Germany

We will discuss our results on α-$CaCr_2O_4$ obtained by FIR and Terahertz spectroscopy. This compound orders below $T_N = 42.6$ K in a proper screw 120° magnetic order, but shows additional low-lying magnetic modes indicative for the vicinity of a more complex magnetic order [1], [2]. Our spectra obtained by FTIR and THz-TD spectroscopy show several optical magnons appearing below the magnetic ordering with anomalous temperature dependence. We will discuss their polarization dependence and a possible magnetoelastic coupling of these modes.

[1] S. Toth *et al.*, Phys. Rev. B 84, 054452 (2011)
[2] S. Toth *et al.*, PRL 109, 127203 (2012)

DS 7.13 Mon 18:15 H3

Multiferroic $Ni_3V_2O_8$ measured in THz range at low temperatures and in high magnetic fields — •Malte Langenbach[1], Tobias Hissen[1], Komalavalli Thirunavukkuarasu[1], Holger Schmitz[1], Iván Cámara Mayorga[2], Rolf Güsten[2], Joachim Hemberger[1], and Markus Grüninger[1] — [1]II. Physikalisches Institut, Universität zu Köln, Köln, Germany; — [2]Max-Planck-Institut für Radioastronomie, Bonn, Germany;

THz spectroscopy in high magnetic fields is an important technique to probe materials with strong magneto-electric coupling. Here, we discuss the Kagomé-staircase compound $Ni_3V_2O_8$. The triangle-based lattice gives rise to a frustration of the short-range antiferromagnetic couplings. This causes a rich variety of magnetic and structural phases at low temperatures.
Below $T_N = 9.8$ K, a incommensurate phase with collinear sinusoidal spin structure is established. This phase is followed by a cycloidal spin structure which is accompanied by the onset of ferroelectricity. Finally, below 3.9 K, the structure changes to a commensurate canted antiferromagnetic phase [1].
We report on elementary excitations in the THz range observed between 2 K and 50 K in fields up to 8 T.

Work supported by the DFG through SFB 608.

[1] G. Lawes et al., Phys. Rev. Lett. **95**, 087205 (2005)