DF 12: Multiferroics I (DF with MA)

Time: Thursday 9:30–12:50 Location: H25

DF 12.1 Thu 9:30 H25

Room-temperature electric-field-induced magnetic anisotropy rotation in multiferroic heterostructures — •Gabriele De Luca, Peggy Schönherr, Manfred Fiebig, and Morgan Trassin — ETH Zürich, Department of Materials

The possibility to control magnetic anisotropy by using only an electric field has rendered compounds with interacting ferromagnetic and ferroelectric order a prime target of materials research. However, both orders hardly coexist at room-temperature in a single material phase, thus efforts focused on artificial heterostructures and magnetoelectric coupling as a composite effect. Here we design a multiferroic heterostructure Pt/CoFe/BiFeO3 (BFO) and we use a combination of magnetic force microscopy (MFM) and second harmonic generation (SHG) to detect the distribution of the ferromagnetic domains in CoFe and the buried ferroelectric domain state in BFO. With SHG we establish a unique relation between the BFO domains distribution and the nonlinear response and we perform the read-out without invading the system [1]. MFM reveals the one-to-one coupling of the ferroelectric/ferromagnetic domains. With an external electric field, we induce changes in the BFO ferroelectric state and we use magnetic field dependent MFM to probe the resulting effect on the CoFe domains and magnetic anisotropy. Previous work has unveiled in such systems that the net CoFe magnetization can be electrically reversed. Here we show that local magnetic anisotropy rotation can be achieved and correlated with the underlying ferroelectric domain state after voltage application. [1] M. Trassin, G. De Luca et al., Adv. Mater. 27, 4871 (2015)

DF 12.2 Thu 9:50 H25

Design and synthesis of a room temperature multiferroic bulk oxide — Pranab Mandal[1], •Michael Pitcher[1], Jonathan Alaria[2], Hongjun Niu[1], Pavel Borisov[1], Plamen Stamenov[3], John Claridge[1], and Matthew Rosseinsky[1] — [1]Department of Chemistry, University of Liverpool, Liverpool, UK — [2]Department of Physics, University of Liverpool, Liverpool, UK — [3]CRANN, Trinity College Dublin, Ireland

A new generation of low-power high-density information storage would be enabled by the development of multiferroic materials that combine switchable electrical polarisation (conventionally arising from second order Jahn-Teller distortion of d^0 cations) with spontaneous magnetisation (from long range ordering of unpaired d electrons) within a single phase material. Combining these properties at room temperature is very challenging due to their antagonistic electronic requirements and the need to maintain long range magnetic ordering to such high temperatures. We have demonstrated a new route to such materials, first by engineering competitive ferroelectric performance in a Bi-based perovskite by creating a PZT-like morphotropic phase boundary in the solid solution [1-x] $BiFe_{2/8}Mg_{3/8}Ti_{3/8}O_3$ - [x]$CaTiO_3$ ($0 < x < 0.40$); and then introducing long range magnetic order to this ferroelectric platform by increasing the concentration of Fe^{3+} above the threshold required for a percolating superexchange network. The resulting materials are magnetoelectric, ferromagnetic and ferroelectric above 300 K.

DF 12.3 Thu 10:10 H25

Multiferroic clusters: a new perspective for relaxor-type room-temperature multiferroics — •Leonard Henrichs[1,2], Oscar Cespedes[3], Wolfgang Kleemann[4], and Andrew Bell[2] — [1]Karlsruher Institut für Technologie, Institut für Angewandte Geowissenschaften, Germany — [2]University of Leeds, Institute for Materials Research, United Kingdom — [3]University of Leeds, School of Physics and Astronomy, United Kingdom — [4]University of Duisburg-Essen, Faculty of Physics, Germany

Multiferroics are promising for sensor and memory applications. However, no single-phase material displaying both ferroelectricity and large magnetization at room-temperature has hitherto been reported. This situation has substantially been improved in the novel relaxor ferroelectric (BiFe0.9Co0.1O3)0.4-(Bi1/2K1/2TiO3)0.6, where polar nanoregions (PNR) transform into static-PNR (SPNR) and simultaneously enable congruent multiferroic clusters (MFC) to emerge from inherent Bi(Fe,Co)O3 rich regions. The MFC supposedly are ferrimagnetic. On these MFC, exceptionally large direct and converse magnetoelectric coupling coefficients, α * 1.0 x 10-5 s/m at room-temperature, were measured by PFM and MFM respectively. We expect the non-ergodic relaxor properties which are governed by the Bi1/2K1/2TiO3 component to play a vital role in the strong ME coupling. The extremely high Neel temperature of approx. 690 K, as verified by neutron diffraction, further underlines the exceptional magnetic properties of the material. This new class of non-ergodic relaxor multiferroics bears great potential for applications.

DF 12.4 Thu 10:30 H25

Imaging of electric-field-induced magnetization reversal in $Dy_{0.7}Tb_{0.3}FeO_3$ — •Ehsan Hassanpour Yesaghi[1], Yusuke Tokunaga[2], Thomas Lottermoser[1], Yasujiro Taguchi[3], Yoshinori Tokura[3,4], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zürich, Zürich, Switzerland — [2]Department of Advanced Materials Science, University of Tokyo, Kashiwa, Chiba 277-8561, Japan — [3]RIKEN Center for Emergent Matter Science (CEMS), Wako 351-0198, Japan — [4]Department of Applied Physics and Quantum-Phase Electronics Center (QPEC), University of Tokyo, Tokyo 113-8656, Japan

Full control of the magnetic state via electric field was recently reported in $Dy_{0.7}Tb_{0.3}FeO_3$. This material undergoes several magnetic phase transitions, including a multiferroic phase in which the polarization is induced by the symmetric exchange interaction of the rare earth moments and Fe spins. It was shown that the magnetization reversal in this material depends on both the magnitude and the time-derivative of the electric field, such that the switching occurs only if the E-field is applied sufficiently fast. Such behavior, however, was never investigated at the level of domains, which is crucial for its understanding and application in devices. Here we investigate the underlying physics of the time-dependent switching process using Faraday imaging technique in order to spatially resolve magnetic domains and domain walls. The observation of two distinct types of domains and their relation to the magnetic Fe/Dy sub-lattices will be discussed. The electric field dependence on the magnetic ordering will be presented.

DF 12.5 Thu 10:50 H25

Influence of ferroelectric electron emission in BTO layer systems on measurements of core-level binding energies — •Paula Huth[1], Martin Welke[1], Alireza Bayat[2], Karl-Michael Schindler[2], Angelika Chassé[2], and Reinhard Denecke[1] — [1]Wilhelm-Ostwald-Institut, Universität Leipzig — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg

Barium titanate (BTO) is a well-known ferroelectric material with perovskite-like structure. During the phase transition from tetragonal to cubic crystal system at 120 °C, the spontaneous electrical polarization vanishes. In conventional x-ray photoelectron spectroscopy measurements, sudden shifts ("jumps") in core-level binding energies have been observed at the Curie temperature. This was proposed to originate from surface charge build-up[1], but by using high-kinetic energy XPS, the effect could be shown to occur for deeper layers and in the presence of covering non-conducting oxide layers, as well. Since the effect occurs at the ferroelectric-to-paraelectric phase transition, ferroelectric electron emission[2] is proposed as origin. Iron and Cobalt layers of different thicknesses have been prepared in-situ on BTO(001), to show that the effect vanishes if a conducting layer is present. Such core-level shifts have been found for all elements in BTO, except in the presence of thick metal overlayers. Additionally, a general difference of the electronic binding energy between the tetragonal and the cubic phase has been observed and confirmed by DFT calculations. [1] L. Makhova et al.: Phys. Rev. B, 83 (2011) 11540. [2] G. Rosenman et al.: J. Appl. Phys., 88 (2000) 6109.

20 min. break

DF 12.6 Thu 11:30 H25

Kibble-Zurek mechanism in hexagonal $RMnO_3$ — •Quintin Meier[1], Andres Cano[2], and Nicola Spaldin[1] — [1]ETH Zürich, Department for Materials Theory, Zürich, Switzerland — [2]CNRS, Université de Bordeaux, ICMCB, UPR 9048, 33600 Pessac, France

We present a theoretical study of the effect of cooling rate on the ferroelectric domain formation in the multiferroic hexagonal manganites,

RMnO3 (R is Y or a small rare-earth atom). The hexagonal manganites are of interest because of their unusual improper ferroelectricity, which allows multiferroism and promotes conducting domain walls. In addition, the associated structural phase transition has recently been shown to form topological defects according to the Kibble-Zurek scaling law [1], which describes the number of topological defects formed as a function of cooling rate. Here we investigate the Kibble-Zurek scaling for a range of compounds in the RMnO3 series by using first principles density functional theory to calculate trends in the scaling parameters. We present possible models that describe the experimentally observed deviations from Kibble-Zurek scaling at both very fast and very slow cooling rates.

[1] Griffin, S. M., Lilienblum, M., Delaney, K. T., Kumagai, Y., Fiebig, M., & Spaldin, N. A. (2012) Physical Review X, 2(4), 041022.

DF 12.7 Thu 11:50 H25

Theory of colossal magnetoelectric responses in Ni_3TeO_6 — •Sergey Artyukhin[1], Sang-Wook Cheong[2], and David Vanderbilt[2] — [1]Italian Institute of Technology, Genova, Italy — [2]Department of Physics and Astronomy, Rutgers University, USA

The manipulation of magnetic ordering with applied electric fields is of pressing interest for new spintronic and information storage applications. Recently, such magnetoelectric control was realized in multiferroics [1]. However, their magnetoelectric switching is often accompanied by significant hysteresis, resulting from a large barrier, separating different ferroic states. Hysteresis prevents robust switching, unless the applied field overcomes a certain value (coercive field). I will discuss the role of a switching barrier on magnetoelectric control, in particular, in a collinear antiferromagnetic and pyroelectric Ni_3TeO_6 [2,3]. The barrier between two magnetic states in the vicinity of a spin-flop transition is almost flat, and thus small changes in external electric/magnetic fields allow to switch the ferroic state through an intermediate state in a continuous manner, resulting in a colossal magnetoelectric response. This colossal magnetoelectric effect resembles the large piezoelectric effect at the morphotropic phase boundary in ferroelectrics.

[1] T. Kimura, T. Goto, H. Shintani et al., Nature 426, 5 (2003)

[2] Y.-S. Oh, S. Artyukhin J. J. Yang et al., Nature Communications 5, 3201 (2014)

[3] J. W. Kim, S. Artyukhin, E. D. Mun et al., Phys. Rev. Lett. 115, 137201 (2015)

DF 12.8 Thu 12:10 H25

Ab initio calculation of ARPES and SPLEED spectra for the multiferroic heterostructure $Co/BaTiO_3$ — •Stephan Borek[1], Jürgen Braun[1], Jan Minár[1,2], and Hubert Ebert[1] — [1]Ludwig-Maximilians-Universität München — [2]University of West Bohemia Pilsen

Multiferroic heterostructures possess promising properties concerning technical applications. It has been shown recently that the combination of x-ray absorption spectroscopy (XAS), x-ray magnetic circular dichroism (XMCD) and x-ray magnetic linear dichroism (XMLD) can be used to determine the magnetic properties of the Co surface layers of the multiferroic system $Co/BaTiO_3$ [1]. In this way an indirect investigation of the coupling mechanisms between the ferroelectric and the ferromagnetic materials gets possible. In our work we consider complementary spectroscopic methods which are suitable for the determination of the properties of multiferroic heterostructures. For this purpose we used the theoretical description of angle-resolved photoemission spectroscopy (ARPES) and spin-polarized low energy electron diffraction (SPLEED) to investigate the coupling mechanisms at the Co/BTO interface. We will show that both methods provide detailed insight into the behaviour of the electronic structure during a switching of the electric polarization of $BaTiO_3$.

[1] M. Hoffmann et al., Journal of Phys: Cond. Matter **27**, 426003 (2015)

DF 12.9 Thu 12:30 H25

Chaos and stochastic resonance during ferroelectric switching — •Martin Diestelhorst — Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, Von-Danckelmann-Platz 3, 06120 Halle, Germany

The Landau theory of second-order phase-transitions being taken into account, it gives motivation to look for effects like bifurcations, chaos and stochastic resonance in ferroelectrics. The main features of these effects may be understood based on the quartic double-well potential $V(x) = \frac{a}{2}x^2 + \frac{b}{4}x^4$, which is of the same form as the thermodynamic potential of a ferroelectric with second-order phase-transition near the Curie temperature. The predicted effects could be in principle found in ferroelectric TGS. It is shown that these effects are related to complicated regimes of domain switching and give rise to peculiarities which may not be understood in terms of the simple double-well potential. These effects must be attributed to the real processes which occur during switching.