DF 3: Focus: Ferroics with Mesoscopic Order

This focus session aims at bringing together scientists from both magnetism and dielectric communities to stimulate discussions about similarities and differences between mesoscopic phenomena in both fields.

Organizer: Leonard Henrichs KIT Karlsruhe

Time: Monday 9:30–13:00 Location: WIL B321

Topical Talk DF 3.1 Mon 9:30 WIL B321

Controlling core-shell formation in BNT-ST — •Till Frömling[1], Azatuhi Ayrikyan[2], Matias Acosta[1], Leopoldo Molina-Luna[1], Michael Dürrschnabel[1], Hans-Joachim Kleebe[1], Herbert Hutter[3], and Kyle Webber[2] — [1]Institute of Materials Science, Technische Universität Darmstadt, Alarich-Weiss-Straße 2, Darmstadt, Germany, 64287 — [2]Institute of Materials Science and Engineering, Friedrich-Alexander-Universität, Martensstraße 5, Erlangen, Germany, 91054 — [3]Institute of Chemical Technologies and Analytics, Technische Universität Wien, Getreidemarkt 9, Vienna, Austria, 1060

Apart from synthesizing solid solutions and doping of ferroelectric materials tailoring core-shell microstructures is an excellent opportunity for modifying ferroelectric and dielectric properties. Recently, the core-shell development in $Bi_{1/2}Na_{1/2}TiO_3$-$SrTiO_3$ (BNT-ST) and its extraordinary impact on achievable strain has been evaluated. About 3% strain at 4 kV/mm was reached which exceeds values obtained for commercially available soft Pb(Zr,Ti)O_3 (PZT). It is of major importance to gain more knowledge about possible ways to control the core-shell microstructure to actually be able to tailor the physical properties. Hence, the mechanism of core-shell formation in BNT-ST will be discussed in this work. With the help of secondary ion mass spectrometry (SIMS) and energy dispersive X-ray spectroscopy (EDX) interdiffusion experiments of BNT and ST diffusion couples are investigated. As a result, the species dominating the mass transport during sintering are qualitatively and quantitatively evaluated.

Topical Talk DF 3.2 Mon 10:00 WIL B321

Determining fundamental properties from diffraction: Electric field induced strain and piezoelectric coefficient — •Manuel Hinterstein[1,2], Markus Hoelzel[3], Andrew Studer[4], and Michael J. Hoffmann[1] — [1]Institut für Angewandte Materialien, Karlsruher Institut für Technologie, Haid-und-Neu Straße 7, 76131 Karlsruhe, Germany — [2]School of Materials Science and Engineering, UNSW Australia, Sydney, New South Wales 2052, Australia — [3]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany — [4]Bragg Institute, Australian Nuclear Science and Technology Organization, Locked Bag 2001, Kirrawee DC NSW 2232, Australia

Piezoelectric ceramics exhibit the remarkable property to couple elastic strain and polarization. Especially actuators rely on high electric fields to generate high strains and forces. The two most important characteristics of this class of materials are macroscopic strain and piezoelectric coefficient. Despite extensive studies and elaborated measurement techniques, the correlation between macroscopic strain and structural response is still not fully understood. Most of the relevant systems found up to now are compositions close to phase boundaries linking highly correlated phases. Apart from the well-known field induced structural responses such as domain switching and the converse piezoelectric effect we recently identified field induced phase transitions in different systems as an additional poling mechanism. The results not only separately reveal the contributions of each poling mechanism to the macroscopic strain, but also different behaviours of the phases.

DF 3.3 Mon 10:30 WIL B321

Mechanisms of thermal depolarization and electromechanical response of lead-free relaxor/semiconductor composites — Lukas Riemer, Lalitha Kodumudi Venkataraman, Jürgen Rödel, and •Jurij Koruza — Technische Universität Darmstadt, Darmstadt, Germany

Thermal depolarization, i.e., vanishing of the macroscopic piezoelectric properties, is one of the major issues limiting the wide application of many lead-free piezoelectrics based on non-ergodic relaxors [1]. An increase of the depolarization temperature, T_d, was recently achieved by the formation of (3-0) composites of the $(Na_{0.5}Bi_{0.5})TiO_3$-based relaxor phase and the ZnO semiconductor phase [2]. The aim of our work was to investigate the mechanisms responsible for this behaviour.

Composites consisting of the non-ergodic relaxor $0.94(Na_{0.5}Bi_{0.5})TiO_3 - 0.06BaTiO_3$ as the matrix phase and ZnO inclusions were prepared and a ferroelectric long-range order was found to be induced in virgin samples by residual thermal stresses. Moreover, an increase in the T_d of up to $\approx 40°C$ was observed. The ZnO inclusions had two counteracting influences on the thermal depolarization: stabilization of the induced ferroelectric state due to additional charges provided by the semiconductor and depolarization induced by residual thermal stresses. The results indicate possibilities for enhancing the thermal stability and operational range of lead-free relaxor piezoelectrics.

[1] J. Rödel et al., J. Eur. Ceram. Soc., 35, 1659 (2015)
[2] J. Zhang et al., Nat. Commun., 6, 6615 (2015)

DF 3.4 Mon 10:50 WIL B321

On the Jahn-Teller ferroelectric transition of GaV_4S_8 — •Jiri Hlinka — Institute of Physics, Czech Acad. Sci., Prague

Recently, the crystal of GaV_4S_8, a multiferroic system hosting a skyrmion lattice phase, has been investigated by polarized Raman and IR spectroscopy above and below the ferroelectric phase transition[1]. Phonon spectra were interpreted with the aid of ab initio calculations of the phonon spectra in the ferroelectric phase.

In this contribution, we shall mostly discuss the relevance of Jahn-Teller distortion for the mesoscopic phases and the character of phonon vibrations directly related to the Jahn-Teller distortion.

[1] J. Hlinka, F. Borodavka, I. Rafalovskyi, Z. Docekalova, J. Pokorny, I. Gregora, V. Tsurkan, H. Nakamura, F. Mayr, C. A. Kuntscher, A. Loidl, S. Bordacs, D. Szaller, H.-J. Lee, J. H. Lee, and I. Kezsmarki, Lattice modes and the Jahn-Teller ferroelectric transition of GaV4S8, Phys. Rev. B 94 060104(R) (2016).

20 min. break

DF 3.5 Mon 11:30 WIL B321

Multiferroic effects in nanoparticulate systems — •Soma Salamon[1], Joachim Landers[1], Marianela Escobar[2], Muhammad Naveed-Ul-Haq[2], Vladimir Shvartsman[2], Morad Etier[2], Doru C. Lupascu[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen — [2]Institute for Materials Science and CENIDE, University of Duisburg-Essen

Both intrinsic and composite multiferroic nanoparticles have been investigated using a variety of measurement methods. Representing an intrinsic multiferroic, bismuth ferrite ($BiFeO_3$) nanoparticles were examined by Mössbauer spectroscopy to analyze the size and temperature dependence of the cycloidal spin structure and its anharmonicity. This was done to investigate whether the cycloid can be inhibited by sufficiently small particle diameters, potentially inducing a net magnetic moment in the otherwise antiferromagnetic material. Results indicate that the spin cycloid exists even in particles small compared to the period length of the cycloid (ca. 62 nm). Representing a composite multiferroic, cobalt ferrite-barium titanate ($CoFe_2O_4$-$BaTiO_3$) core-shell nanoparticles were synthesized, resulting in a ferroelectric $BaTiO_3$ shell and a ferrimagnetic $CoFe_2O_4$ core. This was followed by the preparation of ceramics through sintering techniques, producing magnetostrictive regions in a piezoelectric matrix. The strain coupling between the two constituents was verified by successful measurements of the direct and converse magnetoelectric effect on these samples. This work was supported by the DFG (FOR 1509) and Stiftung Mercator (MERCUR).

DF 3.6 Mon 12:00 WIL B321

Superparamagnetism induced by polar nano region in relaxor magnet — •Minoru Soda — ISSP, Univ. of Tokyo, Japan

Strong coupling between magnetism and dielectricity has attracted much attention in the fundamental and applied physics. In order to search novel system exhibiting enhanced coupling between the dielectric and magnetic properties, we focused on relaxor ferroelectrics having magnetic ions, relaxor magnet. In the relaxor ferro-

electrics, there is the concept of Polar Nano Regions (PNRs), where ordered polarizations in nanoscale domains are randomly oriented. In the present study, the interaction between PNRs and the magnetic correlation was studied both by macroscopic properties and microscopic neutron-scattering measurements for two different compounds; perovskite 2/3 $BiFeO_3$ − 1/3 $BaTiO_3$ and triangular lattice system $LuFeCoO_4$. As a result, the obvious coupling between nuclear and magnetic correlations was identified, and a novel type of superparamagnetism induced by PNR was discovered. The growth of the antiferromagnetic correlation with ferromagnetic component is restricted inside the PNRs and the magnetic moments in nano-magnetic domain behave as superparamagnetic moments. For relaxor magnet, the dielectric and magnetic properties were dominated by the Multiferroic Nano Region.

Topical Talk DF 3.7 Mon 12:30 WIL B321

Ferroic glasses: polar nanoregions in relaxor PMN vs. magnetic nanoparticles in a discontinuous multilayer — •Wolfgang Kleemann — Fakultät Physik, Universität Duisburg-Essen, 47048 Duisburg

The term "ferroic glass" was coined [1] for martensitic, magnetic, and relaxor ferroelectric nanodomain states, which undergo glassy dynamic criticality at $T > T_g$ and non-ergodicity at $T < T_g$. While these features are also found in "superspin glass" systems of matrix isolated magnetic nanoparticles as in $[Co_{80}Fe_{20}(0.9nm)/Al_2O_3(3nm)]$ 10 multilayers [2], the mesoscopic "ferroic glasses" are generally more complex due to the much closer relationship of the nanodomains to the embedding matrix. This is shown for the archetypical relaxor PbMg(1/3)Nb(2/3)O(3) [3], where quenched electric random fields (RF) give rise to creation and growth of polar nanoregions (PNR) on cooling toward Tg with a spectrum of relaxation frequencies skewing from Lacroix-Béné to Cole-Davidson-type. It becomes replaced by relaxation and creep-like domain wall dynamics below Tg, where the PNR percolate and form a ferroelectric microdomain state under the control of the ferroelectric soft lattice mode.

[1] X. B. Ren, Phys. Stat. Sol. B 251, 1982 (2014).

[2] S. Bedanta, O. Petracic and W. Kleemann, Handbook Magn. Mater. 23, 1 (2015).

[3] W. Kleemann and J. Dec, Phys. Rev. B 94, 174203 (2016).