DF 10: Focus Session: Ferroic Domain Walls III

Time: Wednesday 15:00–18:00 Location: H25

Topical Talk DF 10.1 Wed 15:00 H25

Controlling domain wall motion as a route towards new functionalities in Pb(Zr,Ti)O_3 ferroelectric thin films — •Leo McGilly[1], Ludwig Feigl[1], Petr Yudin[1], Tomas Sluka[1,2], Alexander Tagantsev[1], and Nava Setter[1] — [1]Ceramics Laboratory, EPFL - Swiss Federal Institute of Technology, Lausanne, CH-1015 Switzerland — [2]DPMC-MaNEP, University of Geneva, 24 Quai Ernest Ansermet, 1211 Geneva 4, Switzerland

Ferroelectric domain walls offer the exciting prospect of truly nanoscale reconfigurable circuits owing to their small thickness, typically 1-5 nm, their inherently mobile nature and the functional properties they exhibit. However, to fully harness their potential as nanoscale functional entities, it is essential to achieve reliable and precise control of their nucleation, location, number and velocity. In this work we demonstrate an ability that allows extensive control of individual and multiple 180° domain walls in PZT thin films. Furthermore advances towards readout of domain wall position, via a read-restore technique will be presented. This method involves measurement of partial switching currents due to domain wall perturbations from an initial position through sub-switching voltage pulses. Finally, understanding the interaction of domain walls with defects is crucial to tailoring their properties. For future devices based on individual domain walls and their motion, defects could potentially kill or create functionality. We show that local nanoscale defect regions can be used to modify imprint and domain wall motion. This adds an additional dimension to the domain-wall-control toolbox.

DF 10.2 Wed 15:30 H25

Growth temperature as a tuning parameter for internal screening in ferroelectric thin films — •Christian Weymann, Céline Lichtensteiger, Stéphanie Fernandez-Pena, Jean-Marc Triscone, and Patrycja Paruch — DQMP, University of Geneva

In ferroelectric ultrathin films, the depolarization field arising from bound interface/surface charges must be compensated. This can be achieved by screening either by external screening, or by internal mobile charges from within the ferroelectric itself. In the absence of sufficient free charges, the ferroelectric can also form domains of opposite polarization.

Another frequently observed feature in ferroelectric thin films is built-in voltage, originating from asymmetrical screening, trapped charges, or strain gradients leading to flexoelectricity, and modifying the properties of the films. The resulting residual field will not only shift P-E hysteresis, but will also modify the intrinsic polarization configuration and domain stability.

By modulating the growth temperature of $PbTiO_3$ thin films, we engineered several series of ferroelectric samples with the same external electrical boundary conditions, but distinctively different internal screening. We used piezoresponse force microscopy to investigate the intrinsic domain configuration, written domain stability, and local ferroelectric switching loops of these samples. Our results open up a straightforward method to control the built-in field in such ferroelectric oxide thin films, which is crucial to applications.

DF 10.3 Wed 15:50 H25

Magnonic magnetoelectric coupling and domain wall formation in composite multiferroics — Alexander Sukhov[1], Chenglong Jia[1,2], and •Jamal Berakdar[1] — [1]Martin-Luther Universität, Halle-Wittenberg, 06099 Halle — [2]Key Laboratory for Magnetism and Magnetic Materials of the Ministry of Education, Lanzhou University, Lanzhou 730000, China

Control of magnetization by an external electric field or, vice versa, ferroelectric (FE) polarization by magnetic fields entails a clear understanding of the underlying coupling. For a multiferroic nanostructure composed of metallic ferromagnetic (FM) (e.g., Fe or Co) attached to a FE (e.g. BaTiO3), we predicted recently [1] the formation in FM of a non-collinear magnetic order in the FM/FE contact area extending to distances on the spin-diffusion length of the FM. Our predictions were recently confirmed in subsequent experiment and offer also an explanation for earlier findings [3]. Here we present further resutls and suggestions that structuring the FE offers the possibility to generate and control multiferroic domains.

[1] C.-L. Jia, T.-L. Wei, C.-J. Jiang, D.-S. Xue, A. Sukhov, and J. Berakdar, Phys. Rev. B 90, 054423 (2014).
[2]C.-L. Jia, F. Wang, C. Jiang, J. Berakdar, and D. Xue, Sci. Rep. 5, 11111 (2015).
[3] N. Jedrecy, H.J. Von Bardeleben, V. Badjeck, D. Demaille, D. Stanescu. H. Magnan, and A. Barbier, Phys. Rev. B 88, 121409(R) (2013).

20 min. break

DF 10.4 Wed 16:30 H25

Theoretical study of domain wall dynamics in multiferroic hexagonal manganites — •Urko Petralanda and Sergey Artyukhin — Istituto Italiano di Tecnologia. Via Morego 30, Genova (Italy)

Multiferroic hexagonal manganites are antiferromagnetic improper ferroelectrics where unit-cell-tripling buckling of oxygen bipyramids induces polarization and, in some compounds, weak ferromagnetism. Understanding the dynamical effects controlling motion of clamped structural, ferroelectric and magnetic domain walls (DW) in these materials is critical to design devices based on controlled switching of DWs. However, the study of DW dynamics in realistic multiferroics has been mainly focused on proper ferroelectrics and ferromagnetic materials so far, and for multiferroics was mostly limited to estimating switching barriers [1,2]. We develop a model Hamiltonian to describe the driven dynamics of DWs in hexagonal manganites, with parameters extracted from ab-initio calculations.

[1] Yu Kumagai, N. A. Spaldin Nature Communications 4, 1540 (2012)
[2] N. A. Benedek and C. J. Fennie, Phys. Rev. Lett. 106, 107204 (2011)

DF 10.5 Wed 16:50 H25

Landau theory of domain walls revisited — •Wilfried Schranz — University of Vienna, Faculty of Physics, Boltzmanngasse 5, 1090 Vienna, Austria

Domain walls and twin boundaries currently attract enormous attention, since they can host functional properties that are not present in the bulk crystal [1,2]. CaTiO3 is the first example, where it was succeeded in observing a ferroelectric polarization [2] inside a ferroelastic twin wall while the rest of the crystal remained centrosymmetric. There are many more examples demonstrating the application potential of functional domain walls in future information technologies. Modelling of functional twin walls ranges from ab-initio calculations [3] to phenomenological descriptions based on Ginzburg-Landau-Devonshire free energies [4]. The possibility of an electric polarization in ferroelastic twin walls was already predicted long time ago by V. Janovec [5,6], based on a group theoretical symmetry approach. In the present talk we show how we may use the layer-group approach of domain twins [7] to describe corresponding functional properties of domain walls.

Supported by the Austrian FWF (P28672-N36).

[1] Seidel, et al., R. Nature Materials 8, 229 Vol 34 (2009). [2] Van Aert, S., et al., Adv. Mater. 24, 523 (2012). [3] B. Meyer and D. Vanderbilt, Phys. Rev. B 65, 104111 (2002). [4] P. Marton, I. Rychetsky, and J. Hlinka, Phys. Rev. B 81, 144125 (2010). [5] V. Janovec, L. Richterová and J. Prívratská, Ferroelectrics 222, 73 (1999). [6] V. Janovec, W. Schranz, H. Warhanek and Z. Zikmund, Ferroelectrics 98, 171 (1989). [7] V. Janovec, Ferroelectrics 35, 105 (1981).

DF 10.6 Wed 17:10 H25

Ferroelectric Bloch walls and ferroelectric Ising lines — Vilma Stepkova, Pavel Marton, and •Jiri Hlinka — Institute of Physics, Czech Acad. Sci., Prague

In this contribution we would like to address geometry and properties of plausible topological defects chiral ferroelectric domain walls of perovskite ferroelectrics, in particular linear defects analogous to dislocations or disclination lines known from liquid crystals. We will present our investigations of the properties of such one dimensional objects obtained within the Ginzburg-Landau-Devonshire theory using phase-field simulations.

Topical Talk DF 10.7 Wed 17:30 H25

Domain Glass — •Ekhard Salje — Cambridge University, Cambridge UK

Ferroelastic materials often develop complex domain structures, which have properties of glassy systems (non-ergodicity, glass dynamics, glass transitions, and freezing). Four characteristic temperatures are defined for such domain glasses: the dynamical nucleation temperature Td where local correlated clusters can form glass states within a (tweed-) nano structure, To the Vogel Fulcher temperature of these precursor nano- structures, Tpt the phase transition temperature where the (ferroelastic) transition occurs, and TK the Kauzmann temperature where the complex domain structure freezes. Td exists in most ferroelastic materials whereas the other transitions depend on the complexity of the domain patterns and hence on their thermal history. Shear collapse and rapid thermal quench of ferroelastic crystals preferentially lead to domain glasses whereas slow anneal produces mostly highly correlated pattern such as stripe patterns or single domain crystals. Domain glasses are compared with structural glasses and several examples for domain glass features are discussed.