DF 8: Focus Session: Ferroic Domain Walls II

Time: Tuesday 14:00–16:00 Location: H25

Topical Talk DF 8.1 Tue 14:00 H25

Microscopic order parameters coupling at domain walls and its effect on macroscopic properties — •Saeedeh Farokhipoor — Device Materials Group, University of Cambridge, Cambridge, UK

Domain and domain wall (DW) engineering provides an alternative model to tune the physical properties of materials, typically done via conventional materials chemistry. The interplay of coexisting non-ferroelectric structural order parameters, ferroelectric and magnetic order parameters at the DWs in hexagonal manganites provides a new pathway to determine macroscopic properties by tuning the DW characteristics [1]. Here, I report different types of domain structures and DW types associated with the crystal growth conditions in hexagonal manganites. I show that differences in the DW polar state manifest themselves as variations in the conductivity measured macroscopically. In addition, local piezo force microscopy and X-ray diffraction enable us to determine the plane of the DWs and hence, their strain state. The latter findings are in very good agreement with the topographical study. Finally, these results show that DWs under strain lower the critical field of the magnetic phase transition compared to samples with strain-free DWs. In conclusion, I show that among all the complexity in the behavior and response of nano-features, it is possible to tune macroscopic responses by understanding the local state properties, which can be adjusted as easily as by thermal annealing and/or by the crystal growth method. [1] S. Artyukhin et al., Nat. Mater. 13 (2014)

DF 8.2 Tue 14:30 H25

Low-temperature study of semiconducting domain walls in hexagonal manganites — •Peggy Schönherr[1], Jakob Schaab[1], Andres Cano[2], Manfred Fiebig[1], and Dennis Meier[1] — [1]ETH Zürich, Switzerland — [2]CNRS, University Bordeaux, France

Unusual electronic properties arise at domain walls in semiconducting ferroelectrics due to the local electrostatics, their low symmetry and strain. The hexagonal manganites are a particularly interesting example as their improper ferroelectricity naturally leads to simultaneous formation of neutral side-by-side and charged head-to-head and tail-to-tail domain walls. These domain-wall states allow for accessing a wide variety of phenomena, so that the hexagonal manganites represent an ideal playground for studying domain-wall nanoscale physics.

Here, we will discuss temperature-dependent variations in the electronic domain-wall transport in the semiconductor $Er_{1-x}Ca_xMnO3$. Using low-temperature atomic force microscopy we monitor the ferroelectric domain pattern and investigate changes in the electronic properties of the domain walls for temperatures between 295 K and 4.2 K. Our data demonstrate that the domain walls adopt the basic p-type semiconducting properties of the host materials. Additional modulations in the Schottky barrier, electronic conductance and screening arise according to the local domain-wall charge state. Our result clarify pending questions about the low-temperature performance and stability of charged domain walls and provide new insight to the general domain-wall physics in semiconducting ferroelectrics.

DF 8.3 Tue 14:45 H25

Controlling electronic domain-wall conductance by charge-carrier doping — •Jakob Schaab[1], Andres Cano[2], Hatice Doganay[3], Daniel Gottlob[3], Ingo P Krug[4], Claus M Schneider[3], Ramamoorthy Ramesh[5], Manfred Fiebig[1], and Dennis Meier[1] — [1]ETH Zürich — [2]CNRS, Univ. Bordeaux — [3]FZ Jülich — [4]TU Berlin — [5]UC Berkeley

The electronic transport at ferroelectric domain walls bears great application potential in the field of nano-electronics. The precise control and optimization of domain-wall properties towards technologically useful regimes, however, remains a major challenge. A promising but largely unexplored route is to implant specific acceptor or donor atoms, as known from conventional semiconductor physics, and thereby tailor the performance of the domain-wall transport. Here, we discuss to the perspectives of charge-carrier doping for tuning the electronic transport properties at ferroelectric domain walls. In $Er_{1-x}Ca_xMnO_3$ we modify the domain-wall conductance by replacing trivalent Er^{3+} for divalent Ca^{2+}. A doping level of 1% is found to enhance the local conductance by a factor of ≈ 50. In addition, leakage effects at the domain walls are suppressed, reducing their effective width by about 50%. The higher conductance, together with the reduced domain-wall width, leads to a significant enhancement of the current density carried by the walls, which we characterize using scanning probe and photoemission electron microscopy. Our study demonstrates chemical charge-carrier doping as powerful and easily controllable approach for engineering and improving the functionality of ferroelectric domain walls.

DF 8.4 Tue 15:00 H25

Anisotropic Domain Wall Conductivity in $LiNbO_3$ single crystals — •Shuyu Xiao[1,2], Thomas Kämpfe[2], Yaming Jin[1], Alexander Haussmann[2], Xiaomei Lu[1], and Lukas Eng[2] — [1]Physics School, Nanjing University, 210093 Nanjing, P. R. China — [2]Institution of Applied Photophysics, Technical University of Dresden, 01062 Dresden, Germany

Nowadays, investigating the origin and nature of domain wall conductivity (DWC) in different ferroelectric materials such as BFO [1,2] and PZT thin films [3], but equally in $LiNbO_3$ (LNO) single crystals [4,5] are of broad scientific interest. The work presented here reports on anisotropic DWC found between head-to-head (h2h) and tail-to-tail (t2t) 180° DWs in z-cut PPLN single crystal, as measured with Tunneling AFM (ICON) and Optimized Resistance Conductance Amplifier (Cypher). The three dimensional polarization distribution is analyzed at the same position via Piezoresponse Force Microscopy and Cherenkov Second Harmonic Generation. The origin of the different DWC between h2h and t2t is studied by both phenomenological theories and dipole modeled tunneling simulations. As a conclusion, the different conductivities might arise due to the differently charged DWs, as results from the DW inclination with respect to the z-axes.

[1] J. Seidel et al., Nat. Mater. **8**, 229 (2009).
[2] S. Farokhipoor et al., Phys. Rev. Lett. **107**, 127601 (2011).
[3] J. Guyonnet et al., Adv. Mater. **23**, 5377 (2011)
[4] M. Schröder er al., Mater. Res. Express. **1**, 035012 (2014)

DF 8.5 Tue 15:20 H25

Enhancing the domain wall conductivity in lithium niobate single crystals — •Christian Godau, Thomas Kämpfe, Andreas Thiessen, Alexander Haussmann, and Lukas Eng — Institute of Applied Physics, Technische Universität Dresden, D-01062 Dresden, Germany

Highly conductive ferroelectric domain walls (DWs) were found for thin films [1] as well as single crystals [2]. In lithium niobate (LNO) this effect was forecast by theoretical considerations [3]. However, such a high conductivity has so far only been reported under support super band-gap illumination [4]. We show here that high voltage treatment of domain walls in bulk lithium niobate single crystals when applying voltage ramps of up to 1 kV to macroscopic electrodes, results in the desired high conductivity as well. An increase in domain wall conduction of several orders of magnitude can then be measured. High voltage treatment also affects the 3-dimensional domain wall shape, which was complementary delineated Cerenkov second harmonic generation (C-SHG) [5]. As a result, we are able to correlate the local domain wall conductive paths (measured by cAFM) to the DW inclination angle as deduced by C-SHG.

[1] J. Seidel et al., Nat. Mater. 8, 229 (2009)
[2] T. Sluka et al., Nat. Comm. 4, 1808 (2013)
[3] E. A. Eliseev et al., Phys. Rev. B 83, 235313 (2011)
[4] M. Schroeder et al., Adv. Funct. Mater. 22, 3926 (2012)
[5] T. Kämpfe et al., Phys. Rev. B 89, 035314 (2014)

DF 8.6 Tue 15:40 H25

Imaging of conducting domain walls in lithium niobate with energy filtered photoelectron microscopy — •Anna-Sophie Pawlik[1], Andreas Koitzsch[1], Thomas Kämpfe[2], Andreas Haussmann[2], Martin Knupfer[1], Lukas Eng[2], and Bernd Büchner[1] — [1]Leibniz Institute for Solid State and Materials Research Dresden, D-01069 Dresden, Germany — [2]Institute for Applied Photo Physics, Technical University Dresden, D-01069 Dresden, Germany

Conductive domain walls (CDWs) in ferroelectrics are an intensively investigated novel topic in solid state research. However, up to now the chemical structure of CDWs and the microscopic origin of conductance is still hidden. The conducting behaviour of the material is investigated by means of energy filtered photoelectron microscopy (PEEM).

We confirmed that head-to-head domain walls are more conducting than the hosting bulk insulator by means of secondary electron emission upon x-ray illumination. Yet tail-to-tail domain walls are insulating, in accordance to theory. The conductive property depends considerably on the DW inclination angle relative to the polar axis: the more the angle deviates from 90°, the lower the conductance.

Additionally we investigated 180° domain walls with energy filtered PEEM. We could resolve a contrast for different domains due to a work function difference of c^+ and c^- surfaces. The domain walls itself were not visible in PEEM measurements. With this we confirmed the insulating properties of the 180° domain walls