Ferroic domain walls as disordered elastic interfaces

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Propagating interfaces phenomena include fluid invasion in porous media, flame fronts, cracks, and domain walls in ferroic materials. Although these systems have very different microscopic descriptions, they share identical physics at the macroscopic scale and can be described under the unifying framework of disordered elastic systems (DES).[1] The rough morphology and complex response to driving forces of DES obey universal scaling laws which depend on the competition between elasticity and pinning by the disorderd medium.

Understanding the formation and propagation of domains in ferromagnetic and ferroelectric domain walls is technologically critical in increasingly more miniaturized devices. In this context, DES theory offers a complementary approach to study the role of defects on domain wall static and dynamic behaviour.[2,3]

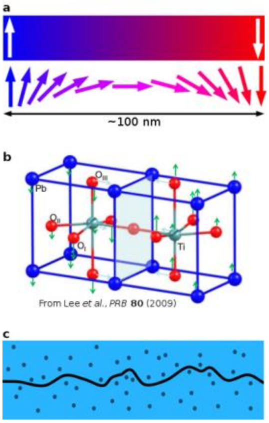

Fig. 1: Ferromagnetic (a) and ferroelectric (b) domain walls. (c) 2D disordered elastic interface.

Ferroelectric domains of nanometric dimensions can be created and imaged in ferroelectric samples using the very sharp tip of an atomic force microscope (AFM). Here, we present a study of the statics and dynamics of AFM-engineered domains in ferroelectric $Pb(Zr_{0.2}Ti_{0.8})O_3$ thin films with different defect densities. Because both the AFM tip and the surface charges of a ferroelectric are affected by the environment, we carried these measurements in ultrahigh vacuum (UHV) and ambient conditions. In samples with low defect density, domain walls present a smooth configuration in both conditions and significantly higher propagation rates in ambient. In contrast, higher-disorder samples show rougher domain walls in UHV and slow propagation rates in both environments. These observations are compatible with DES numerical simulations of 1D domain walls under varying disorder and dipolar interaction magnitude.

References

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Ferroic materials are defined by having an order parameter that can be oriented in more than one direction. Within a ferroic material, then, there can be regions (domains) with different orientation...Â The present book chapter outlines the basic physics of domain walls from their thickness and internal structure to their properties and dynamics. We will draw the connection between the fundamental properties and their experimental observation. The last section will discuss current unresolved challenges in this exciting and emerging field. Keywords. Domain Wall Strain Gradient Scanning Probe Microscope Piezoresponse Force Microscopy Magnetic Domain Wall. These keywords were added by machine and not by the authors. 3. Ferroic domain walls as pinned elastic interfaces. During the initial intense period of research on ferroelectric perovskites from mid-20th century onwards, fundamental studies focused primarily on single crystals, for benchmark measurements of their switching properties and domain structure and stability.Â Table 2: Experimental roughness and creep exponents measured in a selection of dierent disordered elastic systems, including ferromagnetic domain walls (FMDW) measured with polarised magneto-optic Kerr eect (MOKE) imaging, fractures, contact lines (CL), ux line lattices (FLL) in high TC superconductors (HTS), and imbibition fronts (IF). 1.4 Domain Walls as Disordered Elastic Systems . 1.5 Outline of the Present Thesis . . . References . . .Â Such regions of uniform order parameter state are called domains, and the interfaces separating them domain walls. Domains in ferroic materials may be naturally present for energetic reasons when a sample is made, in which case the sample is usually termed polydomain. In contrast, samples presenting a uniform state of the order parameter are said to be monodomain. In both cases, the ability to create domains by locally switching the state of the order parameter is at the root of significant modern industrial technologies.