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Advanced atomic force microscopy studies of ferroelectric domains and domain walls

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The nanoscale resolution of atomic force microscopy (AFM) makes it a powerful tool for local studies of ferroelectric domain nucleation and growth. In particular, domain walls provide a useful model elastic disordered system: their behavior is governed by the competition between their elastic energy, which tends to minimize the domain wall surface, and the randomly varying potential landscape due to disorder present in the samples, which allows pinning. The domain walls present a characteristic static roughness, and a complex dynamic response when subjected to a driving force (electric field), with non-linear creep observed for small forces [1]. In addition, as a result of different symmetries and electronic structure, as well as possible defect migration, these intrinsically nanoscale interfaces often show additional properties, beyond those of their already multifunctional parent material, opening new perspectives for device applications. I will present results of our AFM studies of the static and dynamic behavior of domain walls in epitaxially grown thin films of $Pb(Zr_{0.2}Ti_{0.8})O_3$ focusing in particular on thermal effects, and on the observation of a lateral piezoresponse signal specifically due to the shear displacement of 180° domain walls in this purely out-of-plane-polarized material [2], potentially useful for surface acoustic wave devices. I will also show how this same response can be more generally observed, necessitating care in the interpretation of lateral piezoresponse imaging in materials such as $BiFeO_3$, where it is superimposed on signal due to the in-plane polarization components. Finally, I will present our studies of the switching mechanisms in this latter material under the influence of the electric field applied by the AFM tip.

[1] P. Paruch et al., Phys. Rev. Lett 94, 197601 (2005); J. Appl. Phys. 100, 051608 (2006); T. Tybell et al, Phys. Rev. Lett. 89, 097601 (2002)

[2] J. Guyonnet et al., Appl. Phys. Lett. 95 132902 (2009)