Atomic mapping of domains and interfacial structures in ferroelectric thin films

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$PbTiO_3$ is a ferroelectric with a tetragonal structure. We have grown a number of $PbTiO_3$ and $BiFeO_3$ film samples on various substrates by pulsed laser deposition (PLD). We observe the as-grown epitaxial films in which the electric dipoles at domain-walls and interfaces are characterized by means of aberration-corrected scanning transmission electron microscopy [1-6].

We observe not only the atomic morphology of the flux-closure quadrant but also a periodic array of flux-closures in ferroelectric $PbTiO_3$ films, mediated by tensile strain on a $GdScO_3$ substrate. We directly visualize an alternating array of clockwise and counter-clockwise flux-closures, whose periodicity depends on the $PbTiO_3$ film thickness. In the vicinity of the core, the strain is sufficient to rupture the lattice, with strain gradients up to 10^9/m [2]. We also observe a 3D polarization texture of a four-fold flux closure domain. Ferroelectric displacement analysis based on aberration-corrected scanning transmission electron microscopic imaging reveals highly inhomogeneous strains with strain gradient above 10^7/m. In addition, we identify a giant linear strain gradient with extremely low elastic energy in a perovskite $BiFeO_3$ nanostructures array grown on $LaAlO_3$ substrate via a high deposition flux [4].

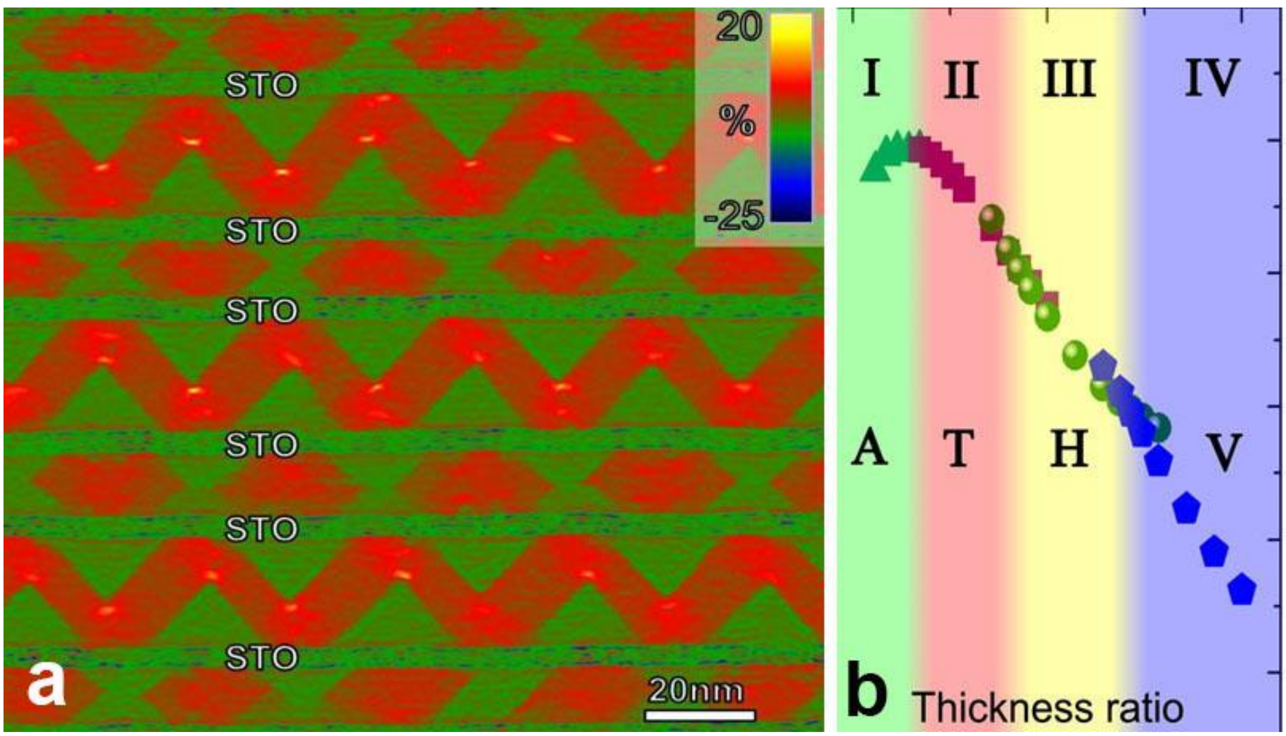

Figure 1. Identification of 2D regularly arranged veritcal and horizontal flux-closure quadrants. (a) Out-of-plane lattice strain maps of the $PbTiO_3/SrTiO_3$ multilayers; (b) Total energy density in the multilayered $PbTiO_3/SrTiO_3$ systems as the function of the thickness ratio of adjacent $PbTiO_3$ layers.

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References

1. Y. L. Tang, Y. L. Zhu, Y. J. Wang, W. Y. Wang, Y. B. Xu, W. J. Ren, Z. D. Zhang, and X. L. Ma, *Sci. Rep.* **4,** 04115 (2014).
2. Y. L. Tang, Y. L. Zhu, X. L. Ma, A. Y. Borisevich, A. N. Morozovska, E. A. Eliseev, W. Y. Wang, Y. J. Wang, Y. B. Xu, Z. D. Zhang, and S. J. Pennycook, *Science* **348**, 547-551 (2015).
3. Y. Liu, Y. L. Zhu, Y. L. Tang, Y. J. Wang, Y. X. Jiang, Y. B. Xu, B. Zhang, and X. L. Ma, *Nano Letters*, 17, 3619−362 (2017).
4. Y. L. Tang, Y. L. Zhu, Y. Liu, Y. J. Wang, and X. L. Ma, *Nature Communications*, 8:15994, DOI: 10.1038/ncomms15994 (2017).
5. S. R. Zhang, Y. L. Zhu, Y. L. Tang, Y. Liu, S. Li, M. J. Han, J. Y. Ma, B. Wu, Z. H. Chen, S. Saremi, and X. L. Ma, *Advanced Materials*, 1703543 (2017).
6. Y. Liu, Y. J. Wang, Y. L. Zhu, C. H. Lei, Y. L. Tang, S. Li, S. R. Zhang, J. Y. Li, and X. L. Ma, *Nano Letters*, online 2017.