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Domain scaling and coupling of structural distortions in tensile-strained $PbTiO_3$ heterostructures

Céline Lichtensteiger, Marios Hadjimichael, Ludovica Tovaglieri, and Jean-Marc Triscone

DQMP - University of Geneva, 24 Quai Ernest Ansermet, CH - 1211 Geneva 4

In ferroelectric thin films, the complex interplay between mechanical and electrostatic boundary conditions allows for the formation of a large variety of domain structures with fascinating properties. These domain structures not only change the properties of the ferroelectric itself, but can also be used to change the properties of other materials through electrostatic and structural coupling.
In this work, we use off-axis RF magnetron sputtering to deposit thin films of the prototypical ferroelectric $PbTiO_3$, sandwiched between top and bottom 55 unit cell-thick $SrRuO_3$ layers, on (110)-oriented $DyScO_3$ substrates. The thin films have a varying thickness, from 22 u.c. to 150 u.c. Using a combination of x-ray diffraction (XRD) and atomic force microscopy (AFM), we study the ferroelastic domain structure in these systems as a function of $PbTiO_3$ layer thickness. We find that the anisotropic strain imposed by the orthorhombic substrate creates a large asymmetry in the domain configuration, with domain walls macroscopically aligned along one of the two in-plane directions. We show that the periodicity as a function of film thickness estimated by XRD deviates from the Kittel law. Above a certain critical thickness, the large structural distortions associated with the ferroelastic domains propagate through the top $SrRuO_3$ layer, creating a modulated structure that extends beyond the ferroelectric layer thickness, with signatures observed both in XRD and AFM.