Ferroelectric/Ferroelastic Domain Wall Motion in Dense and Porous Tetragonal Lead Zirconate Titanate Films

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Direct evidence of ferroelectric/ferroelastic domain reorientation is shown in $Pb(Zr_{0.30}Ti_{0.70})O_3$ (PZT30/70) thin films clamped to a rigid silicon substrate using in situ synchrotron X-ray diffraction during application of electric fields. Both dense films and films with 3 to 4 vol% porosity were measured. On application of electric fields exceeding the coercive field, it is shown that the porous films exhibit a greater volume fraction of ferroelastic domain reorientation (approximately 12 vol% of domains reorient at 3 times the coercive field, E_c) relative to the dense films (~3.5 vol% at $3E_c$). Furthermore, the volume fraction of domain reorientation significantly exceeded that predicted by linear mixing rules. The high response of domain reorientation in porous films is discussed in the context of two mechanisms: local enhancement of the electric field near the pores and a reduction of substrate clamping resulting from the lowering of the film stiffness as a result of the porosity. Similar measurements during weak-field (subcoercive) amplitudes showed 0.6% volume fraction of domains reoriented for the porous films, which demonstrates that extrinsic effects contribute to the dielectric and piezoelectric properties.