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Static and Dynamic Properties of Ferroelectric Nanodomains

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The performance of ferroelectric devices is closely connected with the structure and dynamics of ferroelectric domains. In ultrathin ferroelectrics, very dense domain structures can arise naturally in response to the presence of a depolarizing field and are expected to exhibit unusual static and dynamic behavior. Superlattices composed of ultrathin ferroelectric blocks sandwiched between paraelectric layers offer an ideal system for investigating the structure and functional properties of such nanodomains. The electrostatic coupling between the ferroelectric layers can be controlled by modifying the thicknesses of the paraelectric layers and the domain structure can be tailored by exploiting Kittel's law. X-ray diffraction and transmission electron microscopy combined with electron energy loss spectroscopy were used to study the electrostatic interactions in $PbTiO_3$-$SrTiO_3$ superlattices, revealing highly inhomogeneous polarization and structural profiles that arise due to the presence of ferroelectric nanodomains. The superlattice geometry is also ideal for studying the response of the ultrathin ferroelectric layers to applied fields. Large uniform electric fields can be supported without significant leakage, while changes in the domain structure can be observed simultaneously using X-ray diffraction. The tiny, reversible displacements of the nanodomain walls were found to contribute to a large enhancement of the effective dielectric response that persists over a broad range of temperatures and exhibits low losses. The static and dynamic properties of nanodomains in $PbTiO_3$-$SrTiO_3$ superlattices will be discussed and compared with those of isolated thin films.