CHANGING DIELECTRICS INTO MULTIFERROICS—ALCHEMY ENABLED BY STRAIN

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Using epitaxy and the misfit strain imposed by an underlying substrate, we have strained dielectric thin films to percent levels—far beyond where they would crack in bulk. Under such strains, $EuTiO_3$ is predicted [C.J. Fennie and K.M. Rabe, *Phys. Rev. Lett.* **97**, 267602 (2006)] to transform from a boring dielectric into a multiferroic state where it is simultaneously a strong ferromagnet (spontaneous magnetization ~7 μ_B/Eu) and a strong ferroelectric (spontaneous polarization ~10 $\mu C/cm^2$). This new route to ferroelectric ferromagnets—transforming magnetically ordered insulators that are neither ferroelectric nor ferromagnetic, of which there are many, into ferroelectric ferromagnets—uses a single control parameter: strain. $EuTiO_3$ films grown by reactive molecular-beam epitaxy, the only technique that has been able to achieve the intrinsic properties of unstrained $EuTiO_3$ in as-grown films, on a variety of substrates to alter the imposed strain confirm these predictions. In particular, $EuTiO_3$ films strained commensurately to (110) $DyScO_3$ substrates are simultaneously ferromagnetic and ferroelectric in agreement with theoretical predictions. Strain layer superlattices enable these effects to be extended to strained $EuTiO_3$-containing films of arbitrary thickness.