Time-resolved x-ray microdiffraction imaging of nanosecond structural transformations in thin ferroelectric films

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The interaction of electric fields with ferroelectrics results in several phenomena, most importantly the piezoelectric effect and polarization switching. Both of these effects involve structural deformations including polarization domain walls propagating at speeds up to the acoustic wave velocity, a few km/s. Probing dynamics at this speed in micron size systems involves experimental challenges and requires high resolution in both space and time. The fundamental scales extend from device sizes of microns or more to domain wall widths of nanometers, and involve times as short as picoseconds.

Already time-resolved synchrotron x-ray microdiffraction with time resolutions of less than 600 ps and 110 nm spatial resolution can image the dynamics of the polarization switching in the single-crystal Pb(Zr,Ti)O₃ (PZT) ferroelectric thin film. We have found that the domain wall velocity scales with the magnitude of the electric field and at the field of 230 kV/cm the average velocity is 40 m/s. We will discuss these results and the potential extension of x-ray technique to higher resolutions in space and time.

Since x-ray scattering is sensitive to magnetic order as well as to structural order, time-resolved x-ray microdiffraction can address the dynamics of magnetic domains and the relationship between magnetic and structural transformations in systems such as multiferroics.