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X-Ray Microdiffraction and Near Edge X-ray Absorption Measurements of Ferroelectric Strontium Bismuth Tantalate

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Ferroelectric oxide materials are crucial for many electronic and optical devices. The local electronic polarization vector in a ferroelectric solid or thin film is often not uniformly oriented across a sample, giving a domain pattern. Observing this pattern remains one of the crucial experimental challenges in the study of ferroelectrics. Previous methods for observing domains [1,2] cannot do so for samples under realistic applied field conditions.

We have recently developed a technique that allows evolution of the ferroelectric polarization in a $SrBi_2Ta_2O_9$ thin film device to be observed with submicron resolution. Contrast between adjacent polarization domains can arise either from ferroelastic lattice distortion (e.g., $BaTiO_3$ or $PbTiO_3$) or lack of inversion symmetry (e.g., $SrBi_2Ta_2O_9$). Due to x-ray absorption in the sample, Friedel's law does not apply, and reflections related by inversion of (hkl) indices do not have equal intensities. This fact has been exploited to image the reversal of the electric polarization in $SrBi_2Ta_2O_9$ following application of an external electric field [3]. Figure 1 shows two maps of the intensity of the {2,2,12} reflections of $SrBi_2Ta_2O_9$ following pulses of opposite polarity to a Pt top electrode. The difference image, computed in analogy to the flipping ratio often used in neutron scattering (Fig. 1(b)), clearly shows the regions of the thin film that have reversed polarization.

A crucial element in understanding images such as those in Fig. 1 is knowing the structure factor of the reflections comprising the map. This is complicated because differences in intensities of reflections related by inversion are maximized at atomic resonances; the measurements in Fig. 1 were made at the Ta L_3 resonance at 9.884 keV. In complex oxide compounds, near-resonant optical x-ray optical constants are difficult to compute from first principles, so to obtain an accurate structure factor at resonance from $SrBi_2Ta_2O_9$ we have made near resonance x-ray absorption measurements. The near-edge data show that the Ta L_3 white line feature is prominent in $SrBi_2Ta_2O_9$ and that the contrast between domains of electrical polarization should reach nearly 60% [3].

Our novel method has exploited the detailed interplay between atomic absorption, the band structure of the ferroelectric oxide, and its crystal structure. We expect that the elemental sensitivity, potential time resolution, and ability to image through polycrystalline electrodes will allow this technique to be applied to a wide variety of problems in ferroelectric materials.

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[1] For example: K. Terabe, S. Takekawa, M. Nakamura, K. Kitamura, S. Higuchi, Y. Gotoh, and A. Gruverman, "Imaging and engineering the nanoscale-domain structure of a $Sr_{0.61}Ba_{0.39}Nb_2O_6$ crystal using a scanning force microscope", Appl. Phys. Lett. **81**, 2044 (2002).
[2] C. C. Battle, S. Kim, V. Gopalan, K. Barkocy, M. C. Gupta, Q. X. Jia, and T. E. Mitchell, "Ferroelectric domain reversal in congruent $LiTaO_3$ crystals at elevated temperatures", Appl. Phys. Lett. **76**, 2436 (2000).
[3] P. G. Evans *et al.* (in preparation).

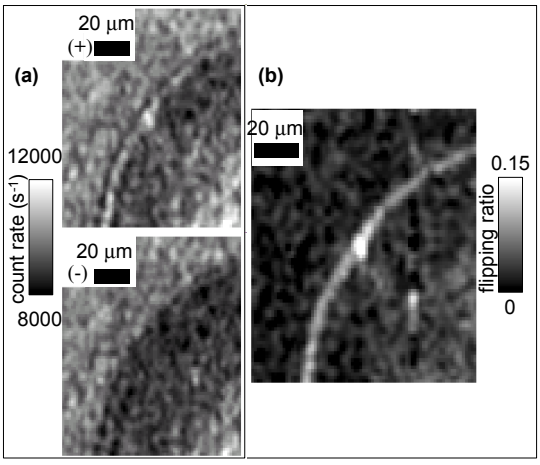

Fig. 1. (a) Images of {2212} reflections in a 100 μm × 100 μm region from a $SrBi_2Ta_2O_9$ film following positive and negative polarity voltage pulses. The ferroelectric capacitor device is formed by a circular Pt contact covering the portion of the image inside the arc from lower left to upper right. (b) The "flipping ratio" computed from the two images appearing in (a). The area in which the remnant ferroelectric polarization has switched appears as a bright streak through the image.