Backscattered Scanning Electron Microscopy Domain Imaging of Ferroelectric Films: *in operando* Ferroelectric Domain Structure Characterization

Jon F. Ihlefeld[1,*], Joseph R. Michael[1], Bonnie B. McKenzie[1], David A. Scrymgeour[1], Jon-Paul Maria[2], Andrew Kitahara[1], and Elizabeth A. Paisley[1]
[1]Sandia National Laboratories
P.O. Box 5800, Albuquerque, New Mexico, 87185
[2]Department of Materials Science and Engineering, North Carolina State University
Research Building I, 1001 Capability Drive, Raleigh, North Carolina, 27695
*Jon F. Ihlefeld: jihlefe@sandia.gov

There are a variety of methods that can be used to image domain structure in bulk ceramics and single crystalline ferroelectrics. However, as crystal dimensions decrease, the number of available methods also decreases to just a few and are even more limited if non-destructive evaluation is desired. In this presentation, we will show how backscatter scanning electron microscopy utilizing differential channeling and backscatter electron yield can be used to non-destructively image nano-scale domains in ferroelectric thin films. Using lead zirconate titanate (PZT) bilayer and epitaxial thin films as examples, we will outline the necessary imaging conditions and ultimate resolution limits of the technique. It will be shown that by combining backscattered electron imaging with electron backscatter diffraction one can identify individual grain and domain orientation information that is complementary information to that collected by more conventional methods to image domain structure in ferroelectric films, such as piezoresponse force microscopy (PFM). An additional advantage of this technique is the utility to observe ferroelastic domain structure changes through top electrodes in actual capacitor device structures. This is demonstrated in a bilayer PZT film by applying electric fields using 3 nm thick platinum electrodes. Interestingly, it is observed that the for most grains, the number of domains increases in the actual capacitor while the electric field is applied and that the number of domains decreases when the field is removed. Imaging of ferroelastic domain structure through an electrically conductive electrode would be difficult by other means and presents a new opportunity for understanding domain structure in functioning devices. Finally, we will show that 90° domains with domain wall spacings as small as 10 nm can be resolved in epitaxial films, making this technique a high-resolution alternative to PFM. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.