Effect of Temperature, Humidity and Thickness on Tip-induced Polarization Switching of Single Phase Multiferroic Thin Films

Dhiren K. Pradhan[1,3*], Rama K. Vasudevan[2], Evgheni Strelcov[2], Shalini Kumari[1], Sergei V. Kalinin[2], A.K. Pradhan[3], Ram S. Katiar[1]

[1]Department of Physics and Institute of Functional Nanomaterials, University of Puerto Rico, San Juan-00936, PR, USA

[2]Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA

[3] Center for Materials Research, Norfolk State University, 700 Park Avenue, Norfolk, Virginia 23504, USA

*Dhiren K. Pradhan: dhirenkumarp@gmail.com

Piezoresponse Force Microscopy (PFM) has emerged as a powerful tool for experimental investigations of ferroelectric materials. In the imaging mode, PFM allows visualization of static domain structures with nanometer spatial resolution. Application of a sufficiently large voltage through a conductive scanning probe microscopy (SPM) tip can induce local polarization switching and can be extended for creation of tailored domain structures and ferroelectric data storage. Finally, acquisition of the piezoresponse signals during polarization reversal allows measurement of local hysteresis loops, which can be used for characterization of the switching process in the nanoscale area in the vicinity of the tip. The broad application of PFM for probing domain structures and polarization reversal in ferroelectrics demands deep understanding of the basic mechanisms involved. PFN ($Pb(Fe_{0.5}Nb_{0.5})O_3$) is a well known multiferroic material with high dielectric constant, very good ferroelectric properties, low dielectric loss value at room temperature.PFN thin films were grown by optimized pulsed laser deposition (PLD) . The highly c-axis oriented growth containing only (00l) diffraction peaks of PFN films along with in plane epitaxial relationship were confirmed by high resolution X-ray diffraction measurements. PFN thin films possess well saturated ferroelectric hystersis and weak ferromagnetism at room temperature. The existence of ferroelctricity at nanoscale is confirmed by band excitation PFM. The local polarization reversal by an electric field produced by a conductive SPM tip as a function of the relative humidity and temperature in an SPM chamber has been studied. The decrease of piezoresponse is observed with increase of relative humidity and temperature. The observed phenomena are attributed to the existence of a water meniscus in the vicinity of the tip–surface contact. The ferroelectric phase transition is also probed by the temperature dependence of piezoresponse studies. In addition to the temperature dependence of piezoresponse studies the phase transition is also confirmed by temperature dependent dielectric spectra. The thickness dependent studies on polarization switching have been carried out at ambient conditions.The out of field and in field band excitation polarization spectroscoy (BEPS) along with poling experiment conclusively confirm the existence of ferroelectricity down to 5 nm. Detailed studies on effect of thickness, humidity and temperature on coercive field, imprint, switchable polarization, nucleation bias of PFN will be discussed in the meeting.