Domain growth kinetics in ferroelectric crystals studied by piezoresponse force microscopy

B. J. Rodriguez[1], J. D. Waldrep[1], R. J. Nemanich[1], L. Eng[2], S. V. Kalinin[3], K. Terabe[4], K. Kitamura[4], and A. Gruverman[1]

[1]*Department of Physics and Department of Materials Science, North Carolina State University, Raleigh, NC 27695-8202*

[2]*Institute of Applied Physics, University of Technology Dresden, Germany*

[3]*Condensed Matter Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831*

[4]*National Institute of Materials Science and Technology, 1-1 Namiki, Tsukuba-shi, Ibaraki 305-0044, Japan*

The kinetics of sidewise domain growth in an inhomogeneous electric field generated by the probing tip has been investigated in ferroelectric crystals of barium titanate $BaTiO_3$ (BTO), lead germanate $Pb_5Ge_3O_{11}$ (PGO), and stoichiometric lithium niobate $LiNbO_3$ (LNO). Experiments have been performed by measuring the lateral domain size as a function of the voltage pulse magnitude and duration using piezoresponse force microscopy (PFM). In contrast to macroscopic ferroelectric capacitors where a number of domains nucleate at the electrodes, in PFM, the electric field generated near the tip results in the nucleation of a single domain at the tip-surface junction. Subsequent domain evolution includes forward domain propagation along the polar axis toward the bottom interface as well as lateral domain growth. Switching resulting from the inhomogeneous electric field near the tip allows for the fabrication of small domains and improved PFM writing resolution, which is critical for increasing the data recording density and for decreasing the feature size in lithography. The fabricated

domain size is found to increase linearly with the voltage magnitude, suggesting that the domain size is kinetically limited in a wide range of pulse magnitudes, durations and materials. In addition, it is shown that the 180º domain wall kinetics in PFM can be described as an activation process by calculating the field distribution using the charged sphere model under the assumption of an exponential field dependence of the wall velocity. The activation energy is found to be a function of the external field. It is suggested that the switching behavior can be described by a universal scaling curve which reflects the general character of the observed domain kinetics. Differences in materials properties and in activation fields can be investigated by comparing the size of the smallest stable domain and the domain growth kinetics in BTO, PGO and LNO crystals.