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Nanoelectromechanics of Piezoresponse Microscopy: Contact Properties, Fields below the Surface and Polarization Switching

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Piezoresponse Force Microscopy (PFM) has become the primary tool for characterization and domain engineering in ferroelectric materials at nanoscale dimensions. To achieve quantitative interpretation of PFM, knowledge of elastic and electrostatic field distributions below the tip is required. The solution of the coupled electroelastic problem for piezoelectric indentation is derived and used to obtain the tip-induced electric field and strain distribution in the material. This establishes a complete continuum mechanics description of the PFM imaging mechanism. These rigorous solutions are reduced to a point charge/force behavior for large separations from contact and the applicability limits and charge/force magnitude for these models are established. Electroelastic field distributions provide a quantitative analysis of the PFM polarization switching processes and show the switching processes can be adequately described using point charge models. For high-order ferroelastoelectric, ferrobielectric and ferrobielastic switching processes the domain size is limited by the contact area, providing an approach to high-resolution ferroelectric lithography.

Supported by UT-Battelle, LLC, under U.S. Department of Energy contract DE-AC05-00OR22725.

Abstract for 2004 APS March Meeting, March 22-26, 2004, Montreal, Quebec, Canada