Probing electromechanical properties of biological systems down to the nanoscale

S.V. Kalinin,[1] A. Gruverman,[2] B.J. Rodriguez,[2] A.P. Baddorf,[1] S. Jesse,[1] J. Shin,[1,3] M. Kachanov,[4] and E. Karapetian[5]

[1]*Condensed Matter Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831*
[2]*Department of Materials Science and Engineering, North Carolina State University, Raleigh, NC 27695*
[3]*Department of Physics and Astronomy, The University of Tennessee, Knoxville, TN 37996*
[4]*Department of Mechanical Engineering, Tufts University, Medford, MA 02155*
[5]*Department of Mathematics and Computer Science, Suffolk University, Boston, MA 02114*

There is currently a paradigm shift in nanotechnology from silicon-based devices to molecular and biological systems. To design functional biomaterials and biological nanodevices, the physical properties of biological systems need to be characterized from mesoscopic to molecular levels. In this research, a combination of scanning probe microscopy (SPM) methods have been applied to study local elastic and electromechanical properties of biological systems such as abalone shell, human hair, and tooth. Electromechanical coupling, a nearly universal property of biological systems such as collagen, was studied by Piezoresponse Force Microscopy (PFM). The use of recently developed 3-dimensional PFM to obtain a vector map of electromechanical activity in various biological systems with nanoscale resolution is demonstrated. One of the examples includes electromechanical characterization of enamel and dentine layers in the human tooth with 10 nm resolution. These studies are complemented by Ultrasonic Force Microscopy (UFM) measurements, which provide information on local elastic properties of the samples. It is emphasized that the SPM techniques allow local electromechanical and elastic properties to be measured in systems that are inaccessible by macroscopic measurement techniques. As an example, 3D piezoelectric properties and local elasticity of the butterfly wing are measured with nanoscale resolution and interpreted in terms of the relative orientation of chitin molecules in the wing scales. The future prospects of SPM for electromechanical characterization of complex biological systems are discussed.

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