MRS Symposium L: Structure and Mechanical Behavior of Biological Materials - Talk

Probing electromechanical properties of biological systems down to the nanoscale

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There is currently a paradigm shift in nanotechnology from silicon-based devices to molecular and biological systems. To design functional bionanodevices and biomaterials, the physical properties of biological systems need to be characterized with the highest possible resolution. In this paper, a combination of scanning probe microscopy (SPM) methods has been applied to study nanoscale elastic and electromechanical properties of biological systems including abalone shell, hair, and human tooth. Strong electromechanical coupling is a universal property of biological systems. For example, piezoelectric properties were found in number of proteins, such as collagen and keratin. Here, we demonstrate the use of Piezoresponse Force Microscopy (PFM) to obtain a 3-dimensional map of electromechanical activity in various biological systems with nanoscale resolution. One of the examples includes electromechanical characterization of enamel and dentine layers in human tooth. These studies are complemented by Ultrasonic Force Microscopy (UFM) measurements, which provide information on local elastic properties. It is emphasized that the SPM techniques allow local electromechanical and elastic properties to be measured in systems that are inaccessible by macroscopic 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. Furthermore, the 3D electromechanical response of a bundle of collagen molecules in a human tooth has been visualized with nanoscale resolution. The future prospects of SPM for electromechanical characterization of complex biological systems are discussed.

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