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AFM probes with integrated electrostatic actuators for fast, quantitative imaging and force spectroscopy[1]

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In this talk, we summarize our efforts in developing novel AFM probes (FIRAT) with integrated sensing and actuation. These probes exploit recent advances in microscale sensor technology and open up the design space for AFM applications including fast imaging, quantitative material characterization and single molecular mechanics measurements. For fast imaging applications in air, probes with aluminum force sensing structures are surface micromachined on quartz substrates. Using 0.7-0.8μm thick, 40μm$\times$60μm clamped-clamped beams over 2.8μm of air gap, probes with resonance frequencies in the order of 1MHz and Q in the 5-15 range are obtained. These probes are actuated directly by electrostatic forces applied to the mechanical structure by rigid electrodes on the substrate shaped as optical diffraction gratings, enabling imaging bandwidths in the order of 100kHz. The integrated grating interferometer provides 10fm/$\sqrt{\text{Hz}}$ level displacement sensitivity down to 3Hz. The surface micromachining approach used for probe fabrication lets one to precisely control the probe dynamics and overcome the difficulties associated with regular AFM cantilevers for applications such as time resolved interaction force (TRIF) measurements. Using FIRAT probes with over damped dynamics, clean TRIF signals are obtained while imaging the surface at regular speeds. This enables us to use a simple model to invert quantitative mechanical properties of a variety of polymers. For measurements on single molecules, membrane type FIRAT probes suitable for in liquid operation have been developed. These probes are made of dielectric materials with embedded actuation electrodes. Used only as actuators or both actuators and force sensors, these devices are shown to enable parallel force spectroscopy measurements. We also show that the spring constant of these probes can be electrically reduced to achieve higher force sensitivity while not affecting its noise performance and discuss the effect of hydrodynamic forces in these membrane type probes as compared to cantilever type probes for fast force spectroscopy measurements.

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