Local Probing of Sub-Surface Features Buried by Transparent Layers with Megahertz Photothermal Vibrations

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Optical Heterodyne Force Microscopy (OHFM) is a novel variation of atomic force microscopy (AFM) that allows local probing in the megahertz frequency range of photothermally-induced thermal expansion vibrations of a sample surface. This method allows the imaging of subsurface buried features in nanostructures with nanometer lateral resolution using an optically-induced transient temperature distribution penetrating to the thermal diffusion depth. OHFM signals depend in general on the local optical, thermal and elastic properties not only of the sample but also of the tip. In OHFM (based on a commercial AFM) we illuminate the sample directly with a chopped laser beam at a megahertz frequency. Photothermally-induced vibrations with an amplitude ~10 pm are produced. This small megahertz frequency vibration is hard to detect directly, so it is frequency-downshifted and amplified by a heterodyne method: the cantilever is vibrated in contact with the sample at a slightly different megahertz frequency for this purpose. Because of the nonlinear nature of the tip-sample force-distance curve, a vibration of the contacting tip is induced at the difference frequency, chosen to be in the kilohertz range. The amplitude, typically ~0.1 nm, and phase of this mixing vibration is used to form OHFM images by lock-in detection of the cantilever bending with standard optical lever detection. Here we present results with this technique that demonstrate that nanoscale features buried below transparent films of various sub-micron thicknesses can be imaged. The samples are made by coating arrays of thin metal bars with silica films. We discuss the origin of the contrast in the images obtained and how it depends on the transparent film thickness.