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Abstract Details

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Abstract

TITLE: Subsurface imaging of biased structures with electrostatic force microscopy (EFM)

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ABSTRACT BODY:

Abstract Body: There is a growing need to determine the nanoscale functional and electrical properties of subsurface materials and interfaces for future computing devices and biomedical applications. Characterization and control of these interfaces is the key to improved device performance and reliability. Among a variety of electrical and optical techniques for studying subsurface physical properties, scanning probe microscopy (SPM) based techniques are very promising due to their ability to image conductive, non-conductive, and non-optically-transparent samples. SPMs use an ultra-sharp tip (~10 nm in diameter) that contacts or intermittently contacts the local area to detect electrical and topographical information from the surface as well as subsurface. While resolution decreases with depth into the sample, electric and magnetic fields can penetrate 1000s of nanometers into samples and the resulting interactions can be detected using various electrically sensitive SPM techniques.

We have applied electrostatic force microscopy (EFM) to study voltage-biased subsurface structures. We investigated both traditional EFM, which detects changes in amplitude or phase of the cantilever relative to the mechanical drive frequency of the cantilever and a new approach applying an AC+DC signal to the buried structures instead of the cantilever. An external high frequency lock-in amplifier (LIA) monitors the deflection signal of the cantilever, using the AC signal applied to the buried structure as its reference. Small changes in the phase of the cantilever oscillation can then be detected to map subtle electrostatic force variation between the subsurface metal lines and the EFM tip. To realize these goals, custom-designed 4-metalization microfabricated test structures were used. A printed circuit board (PCB) was utilized to allow external and independent electric access to the various subsurface structures in an SPM environment. The influences of the relative voltage biases on the subsurface metal lines and the substrate, the effect of the ac frequency applied to the subsurface structures, and mechanisms of subsurface contrast and contrast reversal will be presented.

In subsurface imaging applications, contrast in EFM depends on the electrostatic force between the tip and sample. In the related technique, scanning Kelvin force microscopy (SKFM) contrast arises from the force due to capacitance gradient with tip-to-sample distance (dC/dz). These measured quantities arise from variations in sample dielectric constant, any charge accumulated on subsurface structures, and subsurface variations in conductivity. Our technique allows us to independently bias the subsurface structures and thereby, separate the effect of buried charge and capacitance gradient.