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Computational Models of the Nano Probe Tip for Static Behaviors

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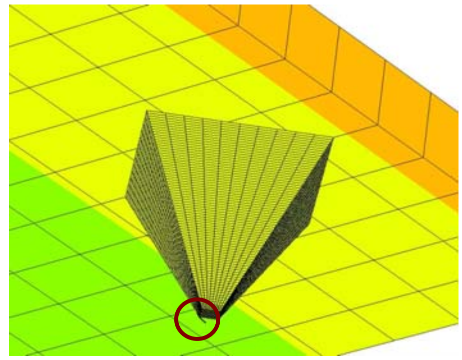
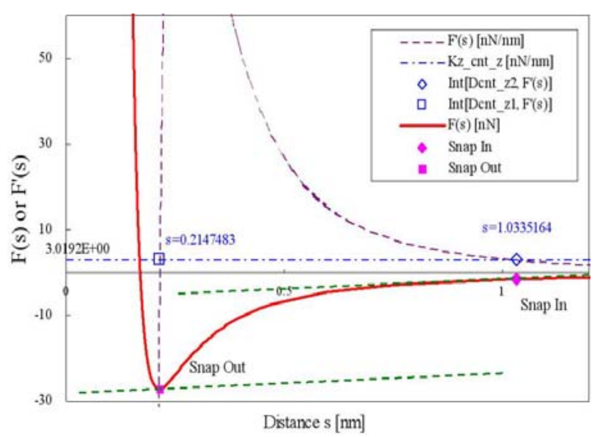
As integrated circuits become smaller and faster, the measurement of line width must have less uncertainty and more versatility. The common requirement for uncertainty is less than 10 nanometers. The industrial need for versatility is three dimensional scanning in order to measure the geometric shapes of walls and trenches. Atomic Force Microscopes (AFMs) are commonly used in laboratories for a range of critical measurements of dimensions demanded by the electronic industry. However, it is difficult to predict the measurement bias arising from the compliance of the AFM probe. The issue becomes particularly important in this situation: nanometer uncertainties need to be quantified when flexible carbon nanotubes, having diameters of 1 to 10 nm and mounted on AFM cantilevers, are used as high resolution probes. In order to estimate the probe deflections due to surface contact and the resulting dimensional biases and uncertainties, we have developed a finite element model for simulating the mechanical behavior of AFM cantilevers with carbon nanotubes attached. The finite element model was developed using the commercially available software systems, Abaqus and Ansys. They provide simulations of both the static and dynamic behavior of the cantilever/nanotube assembly through video clips and graphs. Spring constants of both the nanotube and cantilever in two directions are calculated using the finite element method with known Young’s moduli of both silicon and multi-wall nanotube as input data. Compliance of the AFM probe tip may be calculated from the set of spring constants. Both static models for contact scanning and dynamic models for tapping mode AFM are working and are being applied to estimate uncertainties in linewidth measurement using nanotubes.



Model of a Nanotube-attached Probe Tip

In particular, the interaction between a multi-wall nanotube tip and a silicon sample is modeled using the Lennard-Jones theory. Snap-in and snap-out (see figure below) of the probe tip in a scanning mode are calculated by integrating the compliance of the probe and the sample-tip interacting force model. Cantilever and probe tip deflections and points of contact are derived for both horizontal scanning of a plateau and vertically scanning of a wall. The finite element method and Lennard-Jones model provide a unique means to analyze the interaction of the probe and sample, including actual deflection and the gap between the probe tip and the measured sample surface.



Snap-in and Snap-out

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