Abstract submission
to
Scanning 2008

A Characterization of Probe Dynamic Behaviors in Critical Dimension Atomic Force Microscopy

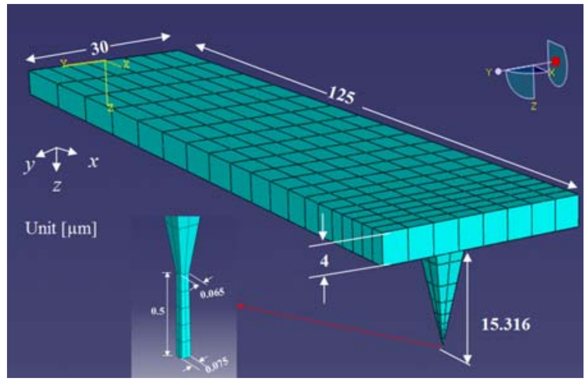
Shaw C. Feng, Che Bong Joung, and Theodore V. Vorburger

National Institute of Standards and Technology

Contact:
Shaw Feng
Manufacturing Engineering Laboratory
National Institute of Standards and Technology
100 Bureau Drive, Stop 8260
Gaithersburg, MD 20899 – 8260
Voice: (301) 975-3551
Fax: (301) 258-9749
shaw.feng@nist.gov

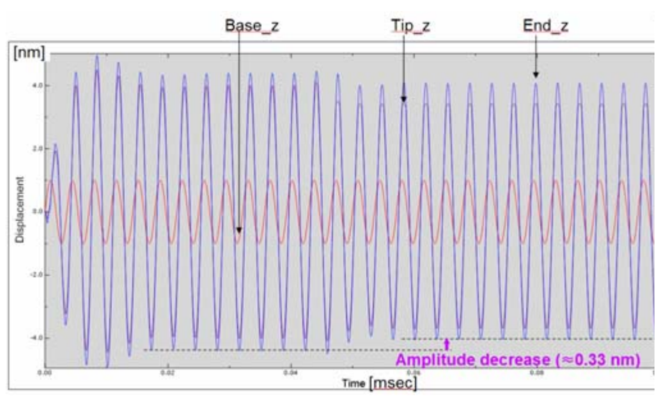
Key words: Atomic force, Cantilever, Critical Dimension, Compliance, Microscopy, Nanometrology, Probe modeling, and Scanned probe

Critical Dimension (CD) Atomic Force Microscopy (AFM) is a primary means to measure the geometric shapes of walls and trenches on the nanometer scale in laboratories supporting the electronic industry. As the widths of commercially available CD-AFM probes have become as small as 50 nm, the deformation of the probe tip during measurement may not be negligible. Although the prevailing method of CD-AFM tip width calibration includes such deformation in the "effective" tip width, the increasing contribution of tip deformation to the effective tip width raises the concern that the compliance of the probe tip may be different in scanning a side wall and a horizontal surface. If this is the case, then there may be resulting measurement biases and sources of uncertainty that are not accounted for with the conventional approach to tip calibration. To understand how the deformation might vary from one measurement configuration to another, it is necessary to develop a detailed computational model of probe-sample interaction and dynamic behaviors of the tip. In order to estimate the probe deflections due to surface intermittent contact and the resulting dimensional biases and uncertainties, we have developed finite element models for simulating dynamic behavior of AFM cantilevers with a CD tip attached. Probe tip and cantilever beam responses to intermittent contact between the probe tip and sample surface are computed using the finite element method. Using the commercially available software system, Simulia*, intermittent contacts with a wall and a horizontal surface are computed and modeled, respectively. The responses of the probe to interaction forces between the sample surface and the probe tip are shown in both time and frequency domains.



Model of a CD-75 Probe

In particular, interactions between a CD-75 nanometer tip and a wall and a horizontal surface of a silicon sample are modeled using the Lennard-Jones theory. As a case study, the probe is simultaneously vibrating sinusoidally at 280 KHz in the vertical direction and 5 KHz in the horizontal direction, harmonically. The Snap-in and snap-out of the probe tip in surface scanning are calculated and shown in the time domain. The calculation includes the compliance of the probe, the sample-tip interacting force model, and dynamic forces generated by vibration. Cantilever and probe tip deflections versus interaction forces in the time domain can be derived for both vertical contact with a plateau and horizontal contact with a side wall. Dynamic analysis using the finite element method and Lennard-Jones model provide a unique means to



Responses in Time Domain

analyze the interaction of the probe and sample, including calculation of the deflection and the gap between the probe tip and the measured sample surface.

***Disclaimer**: No approval or endorsement of any commercial products by the National Institute of Standards and Technology (NIST) is intended or implied. Certain commercial software systems are identified in this paper in order to facilitate understanding. Such identification does not imply that these systems are necessarily the best available for the purpose.