Sharp Carbon AFM Tips for Sub-nanometer Surface Roughness and Accurate Linewidth Measurements

R. Dixson, R. Köning, J. Fu,
T.V. Vorburger, J.S. Villarrubia
Precision Engineering Division, MEL

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OUTLINE

Background
- *Industrial Needs*
- *Structure of Standards*
- *Metrology Challenges*

NIST's C-AFM Project
- *Instrument Description*
- *Major Applications*

Relevant Industry Needs

Linewidth Metrology

Important to measurement of gate lengths in semiconductor industry.

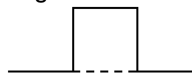
Roughness Metrology

Gate oxide roughness measurements

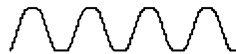
Slider roughness for magnetic disk industry

The Structure of Standards at Larger Length Scales

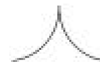
- Standards to calibrate the vertical gain of the instruments - usually step heights.



- Standards with periodic roughness profiles, which makes them amenable to surface statistical analysis and gives them a high uniformity.

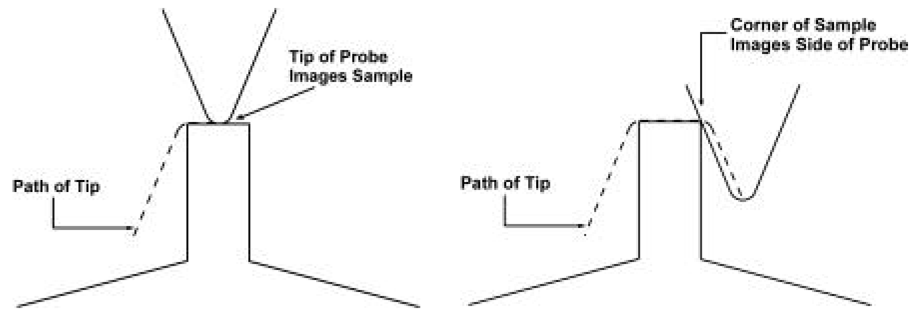


- Probe characterizers to help determine the limit of resolution of the stylus or other probe.



- Realistic engineering specimens, which test the complete instrument response operation dynamically, but which are not suitable for calibration standards.

The Basic Tip Problem



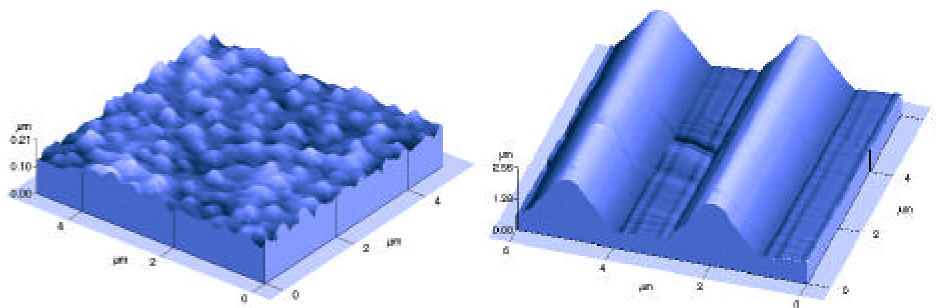
The apparent width can have a large contribution from the probe that must be subtracted out to obtain an accurate measurement.

Tip Characterization

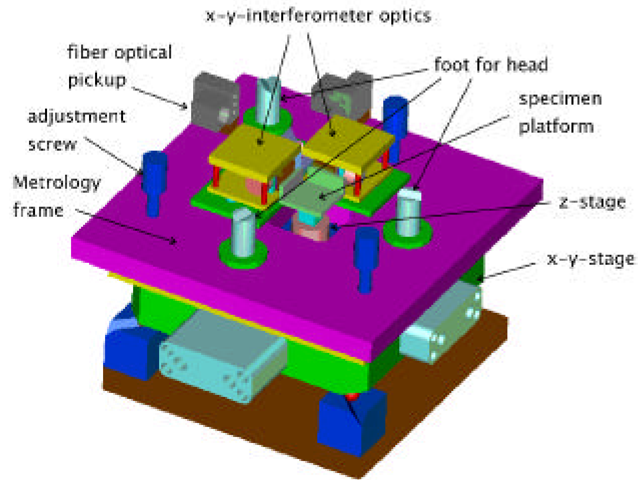
To estimate the geometry of the probe to correct the measured width of a line.

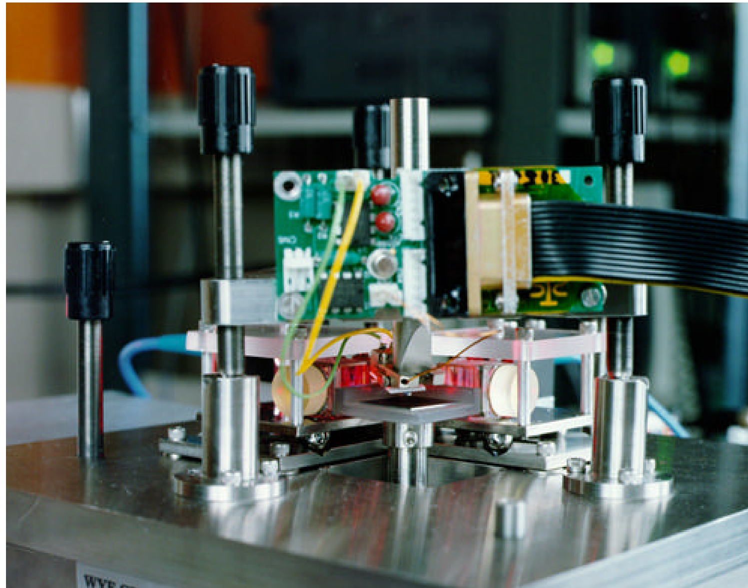
Major Methods:

- Characterizer Samples
- Modeling (reconstruction or assumed shape)



Calibrated Atomic Force Microscope Mechanical Setup





Our Objectives

C-AFM Program:

Develop AFM with traceable metrology for all three axes.

Calibrate pitch/height and linewidth standards.

Sharp Tips ATP Project:

Evaluate potential of sharp tips, including carbon nanotubes, for AFM measurements of roughness and linewidth.

Join together our experience in surface roughness measurements at larger scales with our experience in SPM tip modeling and characterization.

Linewidth Measurements with Conventional AFM Tips

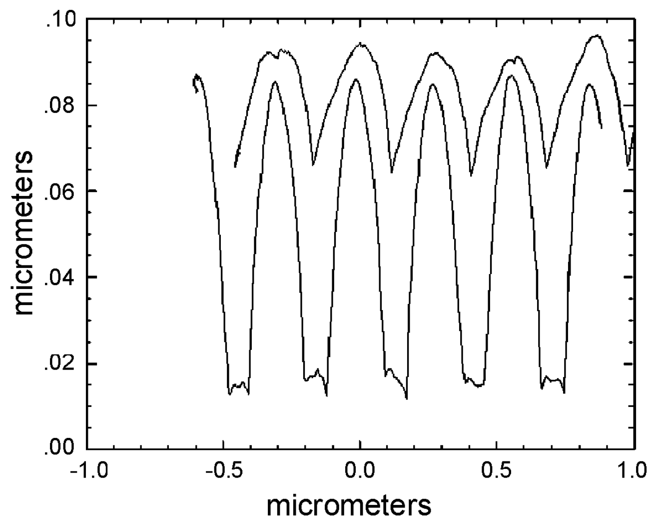
C-AFM Measured Widths:

449 ± 13 nm (k=2) - with good tip
461 ± 41 nm (k=2) - with blunt tip

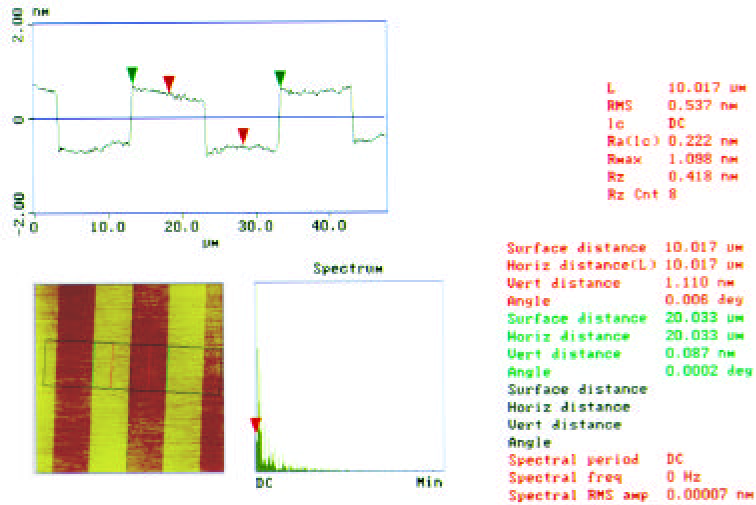
Carbon Nanotubes Mounted to Conventional Silicon Nitride AFM Tips and Imaged in an SEM

(images courtesy of S. Jones and M. Postek, PED/MEL)

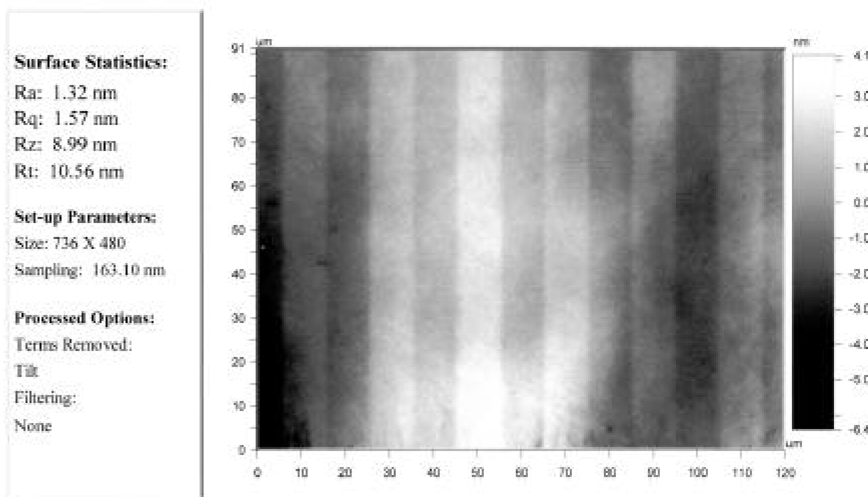
Nanotube vs. Conventional Tip:
Imaging of a 300 nm pitch holographic grating



AFM Image of Potential Roughness Standard



Interference Microscope Measurement of Roughness Sample



Future Directions

- Compare performance of tips mounted in-house to those obtained from vendors.
- Complete new linewidth inter-method comparison using sharp tips.
- Evaluate effective stiffness of tips and dependence on mounting (possibly with M. Van Landingham et al.).
- Quantify operating parameters and imaging conditions for stable performance.