Experiment 4: Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM)

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Purpose:
The purpose of this laboratory module is to provide an introduction and a hands-on demonstration of the two most common imaging techniques that have nanometer-scale resolution (much better than optical microscopy): SEM and AFM.

Theory:

Basic principles of the scanning electron microscope (SEM):

An electron beam is scanned over a specimen. An electron detector is used to record the number of electrons scattered from each point on the specimen. Measured electron intensity will be displayed on a CRT at the corresponding pixel location to reconstruct the image.

Image contrast is obtained due to the difference in electron scattering efficiency from different topology and materials.

The typical accelerating voltage of the electron beam is 1kV-30kV. A higher accelerating voltage produces more electrons, giving a better signal-to-noise ratio, but it also increases the probe area of the beam and therefore reduces the resolution.

Basic principles of the atomic force microscope (AFM):

A laser source and photodiode are used to monitor the deflection of the AFM tip. The feedback controller is used to maintain the deflection at a specific set point by moving the tip up and down corresponding to the topology of the specimen. The recording of the z-motion of the tip is used to reconstruct the image of the specimen.

The proper choice of feedback parameters and set point is crucial in obtaining an accurate image of the specimen.
Experiment:
An SEM will be used to image an AFM tip, with a tip radius of curvature of around 10-20nm. Then we will use an AFM to image the tracks of a compact disk (CD) to see the data bits recorded on it.

Equipment and materials
1) Hitachi S4800 SEM, 2) Veeco Dimension 3000 AFM, 3) Veeco Si AFM tip, 4) CD

SEM imaging procedure
1. Mount the AFM tip onto the SEM sample holder.
2. Put the sample holder into the specimen exchange chamber and evacuate the specimen exchange chamber.
3. Open the gate valve and transfer the sample holder to the specimen chamber.
4. Move the sample holder to the “HOME” position.
5. Select a 5 keV accelerating voltage and turn on the high voltage.
6. Record an image at 500 X magnification after adjusting the focus.
7. Measure the cantilever width and length.
8. Tilt the sample holder at 20 degree and record an image at 1.5 kX magnification.
9. Tilt the sample holder at 40 degree and record an image at 80 kX magnification.
10. Estimate the radius of curvature of the AFM tip.
11. Save all the images in the folder D:\Images\GEM4\sectionXX\.

AFM imaging procedure
1) Mount an AFM tip onto the AFM tip holder.
2) Put the AFM tip holder to the AFM scanner head (be careful, it costs $30K).
3) Align the laser to the AFM tip.
4) Align the detector to the reflection of the laser spot.
5) Put the CD under the AFM tip and adjust the height of the stage to bring the CD into focus.
6) Choose the scanning width to be 10µm, the height scale to be 40nm, the P-gain to be 0.6, and the I-gain to be 0.4.
7) Engage the tip and start scanning.
8) Adjust the setpoint to be around 1.2-1.4 to bring the trace and re-trace into alignment.
9) Save the image in the folder C:\capture\GEM4\sectionXX\.
10) Measure the CD track pitch from the capture image with data analysis software.