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and documents may not be taken
into the clean room.**

**MNF documents will be printed on
special clean room paper and provided
to you when you enter the lab.**



MICRO AND NANOFABRICATION MODULE

Experiment 1: Photolithography

Location: 241 Micro and Nanotechnology (MNTL) Cleanroom Lab

Instructor: Marty Harris, MNTL

Lab Assistant: Charles Choi, Electrical and Computer Engineering

Purpose and Expected Outcome:

The purpose of this laboratory module is to provide an introduction to, and hands-on experience with, standard photolithographic techniques that are used to pattern a silicon wafer. Upon completion of this module, the researcher will be able to understand and perform all the steps in a conventional optical lithography process. This will be followed by an examination of the patterned wafer under a microscope.

Overview of Photolithography:

Photolithography is a common and basic step used in the creation of bioMEMS and biosensors. This fabrication technique has been used for many years in the fabrication of integrated circuits, transistors, and MEMS devices. The underlying principal of photolithography relies on the way certain polymeric compounds called photoresists (PR) respond to exposure by ultraviolet (UV) light. Areas that have been exposed to UV will exhibit selective solubility in a developing solution. There are two main types of photoresist – positive and negative. A positive resist will result in an exact copy of what is on the master pattern, while a negative resist will result in the inverse pattern. The lithography process presented in this lab module is capable of resolving features down to approximately 0.9 microns. The method of photolithography used in this module is called contact photolithography and a generalized process flow is presented in Figure 1.

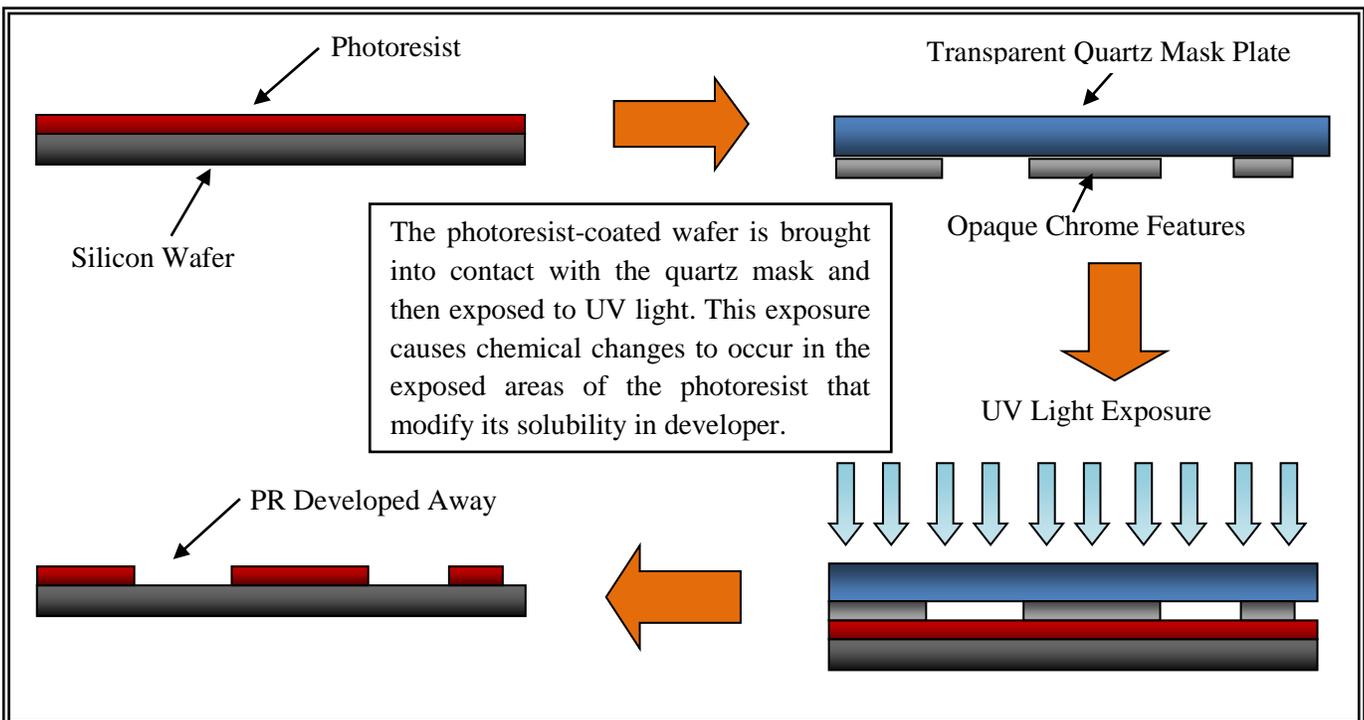


Figure 1: Generalized contact photolithography process. When the exposure is completed, the wafer is submerged in a developer to wash away the cross-linked sections of photoresist. The end result is an exact copy (or the inverse, if using a negative PR) of what is opaque on the mask plate.

Module Outline and Workflow:

In this lab module, researchers will carry out all steps of a contact photolithography process. This includes spin-coating, exposing, developing, inspection and hard-baking of a 2" Si wafer.

Procedures:

1. Spin-coating

- 1.1. Prebake a silicon wafer at 125°C for 2 minutes.
- 1.2. Pick the appropriate spinner chuck for a 2" wafer.
- 1.3. Place the baked silicon wafer on the spinner chuck, being careful to center it properly.
- 1.4. Turn on the spinner, and adjust the spin-speed to 4000 rpm. Set the timer for 30 sec.
- 1.5. With the spinner still running, place 5-6 drops of HMDS on the wafer, wait a few seconds, then turn off the spinner.
- 1.6. Pour enough AZ5214 onto the wafer to cover approximately 1/3 of the surface area.
- 1.7. Activate the spinner and wait until it automatically stops.
- 1.8. Soft bake the wafer at 125°C for 30 sec.

2. Exposure

- 2.1. Turn the Quintel aligner ON and wait for the boot screen to finish its sequence. Fill out the log sheet at this time.
- 2.2. On the right-side control panel, press the left-most LOAD button and rotate the lamp housing out of the way of the mask chuck. Press LOAD again to lock it in place.
- 2.3. Load the mask and press VACUUM. Make sure the mask is held firmly.
- 2.4. On the right-side control panel, press the left-most LOAD button and rotate the lamp housing back over the mask chuck. Press LOAD again to lock it in place.
- 2.5. Slide out the wafer tray and place the wafer on the chuck (PR facing up).
- 2.6. Press the right-most LOAD switch and slide the wafer tray in.
- 2.7. Ensure that the wafer has risen to the mask and the aligner goes in to SEPARATION mode.
- 2.8. Make any adjustments to the position of the wafer using the two joysticks for x, y, and theta.
- 2.9. Set the exposure time to 15 sec.
- 2.10. Press the EXPOSE button to start the exposure. **DO NOT LOOK AT THE UV LIGHT!**
- 2.11. When the exposure is complete, slide the wafer tray out and remove the sample.
- 2.12. On the right-side control panel, press the left-most LOAD button and rotate the lamp housing out of the way of the mask chuck. Press LOAD again to lock it in place.
- 2.13. Turn off the mask VACUUM and remove the mask.
- 2.14. On the right-side control panel, press the left-most LOAD button and rotate the lamp housing back over the mask chuck. Press LOAD again to lock it in place.
- 2.15. Turn the Quintel Aligner OFF.

3. Develop/Inspect

- 3.1. Transfer the exposed wafer to an acid hood.
- 3.2. Fill a clean Pyrex dish about ½ full with MIF 319 Developer.
- 3.3. Submerge the wafer in the developer and agitate for 30 sec.
- 3.4. Rinse the developed wafer with copious amounts of DI water.
- 3.5. Dry the developed wafer using an N₂ gun.
- 3.6. Inspect the developed wafer with optical microscope.
- 3.7. Repeat Steps 3.3 – 3.6 until the PR is fully developed.



MICRO AND NANOFABRICATION MODULE

Experiment 2: Metallization by Thermal Evaporation and Metal Liftoff

Location: 241 Micro and Nanotechnology (MNTL) Cleanroom Lab

Instructor: Hal Romans, MNTL

Lab Assistant: Adarsh Radadia, MNTL

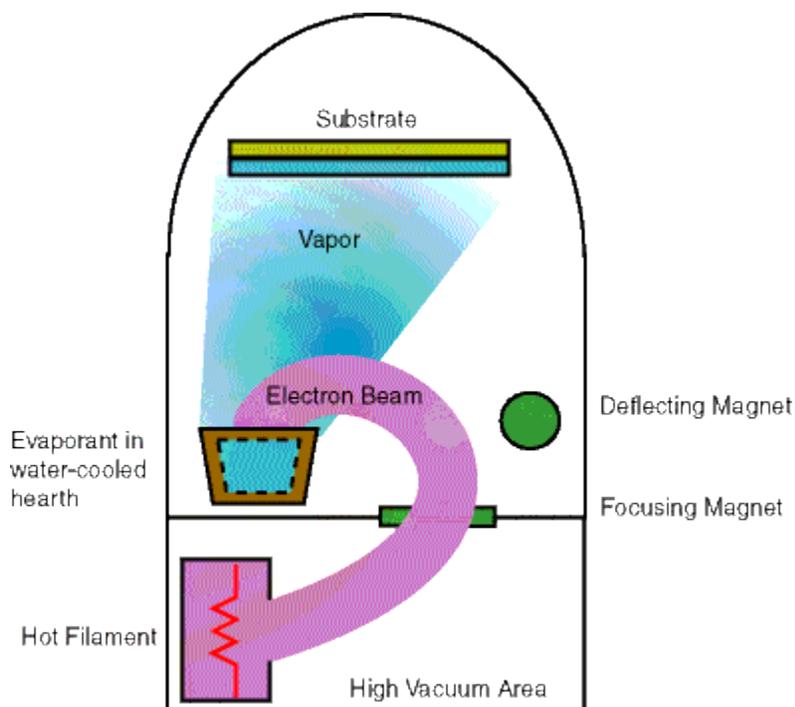
Purpose:

The purpose of this laboratory module is to provide an introduction and a hands-on demonstration of the metallization process and subsequent liftoff process.

Overview of the E-beam Evaporation Process:

In this experiment, a 2" wafer which has been previously patterned with photoresist, will be loaded into an ebeam evaporator. The vacuum chamber will be pumped down and 50 nm of Titanium will be deposited on the wafer using an e-beam source.

Principle of E-beam Evaporation:



After venting and loading samples, the deposition chamber is first pumped with a mechanical roughing pump then a cryo pump to a final vacuum of about 1×10^{-6} Torr.

An electron beam generated from a hot filament is accelerated by a 10 KV power supply and turned 270° into a water-cooled target crucible by permanent magnets. The energetic electrons impinging on the source material cause it to heat up and evaporate.

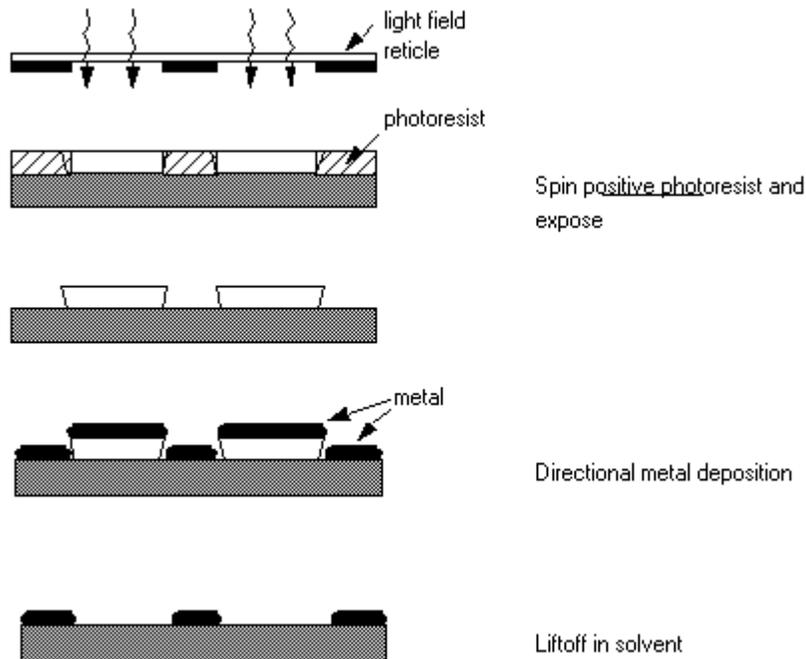
Ref: <http://www.tungsten.com/ebevap.html>

Evaporation Procedure:

1. Turn on deposition control computer.
2. Turn off ion gauges.
3. Vent the chamber.
4. Raise the chamber.
5. Load samples.
6. Load the crucible containing titanium in e-beam hearth position 3.
7. Lower chamber.
8. Open the roughing valve. When chamber pressure reaches ~150 mTorr, shut the roughing valve.
9. Open the High – Vacuum valve.
10. After several minutes, turn on ion gauge 2 to monitor chamber pressure.
11. Select titanium as the source crucible.
12. Ensure the cooling water valves are open.
13. Turn on the e-beam HV power supply breaker on the power supply enclosure to the right of the evaporator.
14. Turn on e-beam control electronics
15. Make sure the shutter is closed to protect the sample.
16. Press the start button to start the process.
17. Immediately press the “Manual” button and slowly raise power to about 29%.
18. Observe the e-beam position on the source and adjust the e-beam position as necessary.
19. Open the shutter. This will allow deposition of metal onto the sample.
20. Slowly (manually) raise the power, pausing every .2% - .4 % to observe the effects, until the thickness and deposition rate increases.
21. Adjust power until a deposition rate of about 4 Å/second is achieved.
22. When the desired thickness is reached, shut the shutter and lower power to 0% then push the stop button.
23. Allow the chamber to cool for a couple minutes.
24. Vent the chamber and remove samples.
25. Pump down the chamber, as was done in steps 7-9.

Lift Off Procedure:

26. Place the wafer in a beaker and cover with acetone.
27. Place the beaker in the ultrasonic bath and turn on the power (no heat).
28. Continue cleaning / agitating until all the unwanted metal is removed and the desired pattern is revealed.
29. Remove the wafers from the acetone and rinse with DI water.
30. Apply isopropyl alcohol and dry wafers with N₂.
31. Dispose of the acetone in the solvent waste container.



Ref: <http://www.phys.ufl.edu/~nanoscale/reports/year1/liftoff.html>



MICRO AND NANOFABRICATION MODULE

Experiment 3: Reactive Ion Etching (RIE)

Location: 241 Micro and Nanotechnology (MNTL) Cleanroom Lab

Instructor: Yaguang Lian, MNTL

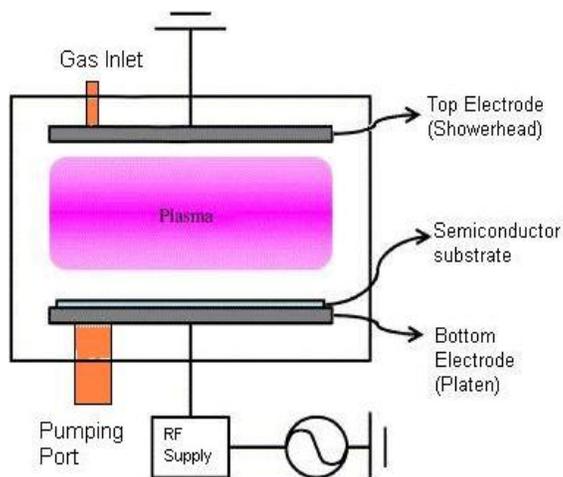
Lab Assistant: Bobby Reddy, Electrical and Computer Engineering

Purpose:

The purpose of this experiment is to provide an introduction and a hands-on demonstration of RIE technology. RIE is a “dry” etching process. It is widely used in micro-fabrication. Compared with wet etching, dry etching has two key advantages: less undercutting (allowing smaller lines to be patterned) and higher anisotropy (allowing high-aspect-ratio vertical structures).

Theory:

Typically, an RIE system has four main components: an etch-chamber, a radio frequency (RF) power supply, a pumping system, and a gas handling system. The applied RF power produces ionized gas plasma containing reactive species (atoms, radicals, and ions). Plasma dry etching incorporates a physical component (similar to glow-discharge sputtering or ion milling) and a chemical component. The etchant gas is selected to generate species that react chemically with the material to be etched, and whose reaction product is volatile, so different materials require different etchant gases. For example, halocarbon gases (CHF_3 , CF_4) can be used to etch SiO_2 and Si_3N_4 . Photoresist can be etched with O_2 .



Overview of the RIE experiment:

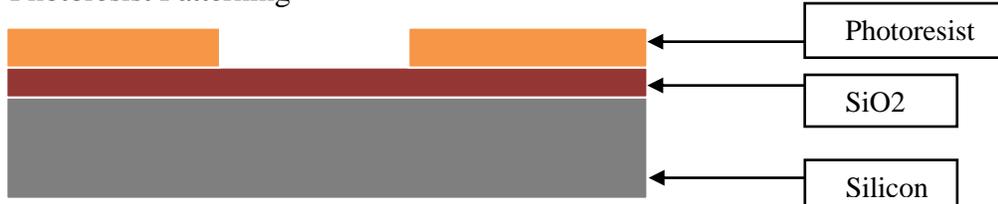
For our demonstration of an RIE process, we will be starting with a silicon wafer onto which a thermal oxide layer (SiO_2) has been grown. On top of the oxide you will see patterned photoresist on the wafer, the creation of which is detailed in Lab Module 1. The patterned wafer is inserted into the RIE chamber where the oxide layer will be etched. The photoresist acts as an etch mask to prevent etching in those areas.

The main steps of the process are shown below:

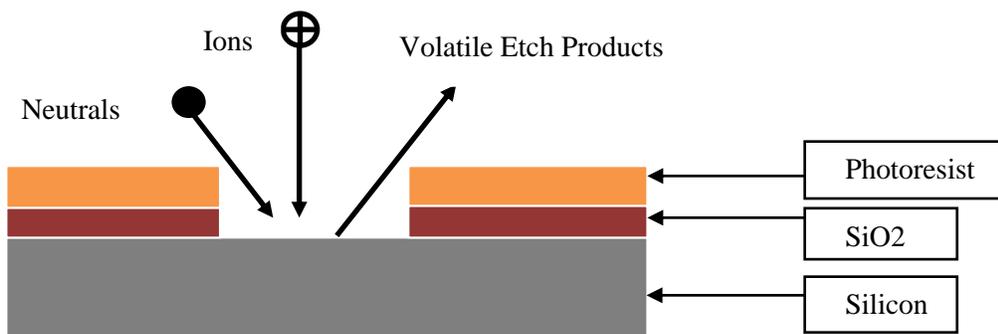
Thermal SiO₂ Layer Growth



Photoresist Patterning



Reactive Ion Etching of SiO₂



RIE procedures:

We will use a PlasmaLab® Freon RIE system in our experiment.

1. Press **Process** and **4** to select a CF₄ etch process.
2. Turn the key to the **Change Stored Parameter** position.
3. Set in the parameters for CF₄ Flow Rate, RF Power, Process Pressure, and Time.
4. Turn the key back to **Manual Operation**.
5. Press **Manual** and **Vent**.
6. Wait for the vent cycle to finish (**Vent** light will come on.)
7. Open the chamber by pushing the **Joystick** to the right and pushing down on the **Large Black Button** at the top right corner of the cabinet.
8. Put the wafer(s) into the chamber.
9. Close the chamber by pushing the **Joystick** to the left and again pushing the **Large Black Button** down.
10. Open the gas cylinder.
11. Press **Run**.
12. Wait for the process finish until **Vent** light is on.
13. Repeat the step 7; remove the wafer(s) from the chamber; repeat step 9.
14. Press **Manual** and **Rough** to pump down the chamber and close gas cylinder.



MICRO AND NANOFABRICATION MODULE

Experiment 4: Scanning Electron Microscope (SEM) & Atomic Force Microscope (AFM)

Location: 241 Micro and Nanotechnology (MNTL) Cleanroom Lab

Instructor: Edmond Chow, MNTL

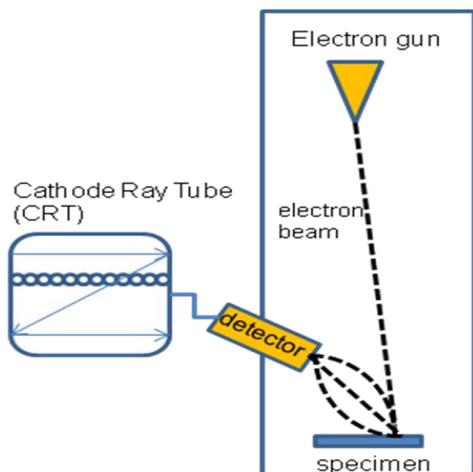
Lab Assistant: UGen Choi, Electrical and Computer Engineering

Purpose and Expected Outcome:

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):

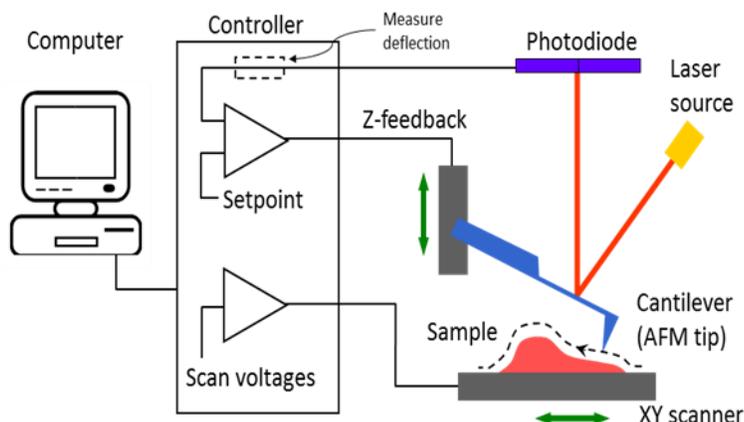


An electron beam is scanned over the specimen. An electron detector is used to record the number of electrons scattered from each point on the specimen. Measured electrons intensity will be displayed on the CRT at the corresponding pixel location to reconstruct the image.

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

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

Basic principles of the atomic force microscope (AFM):

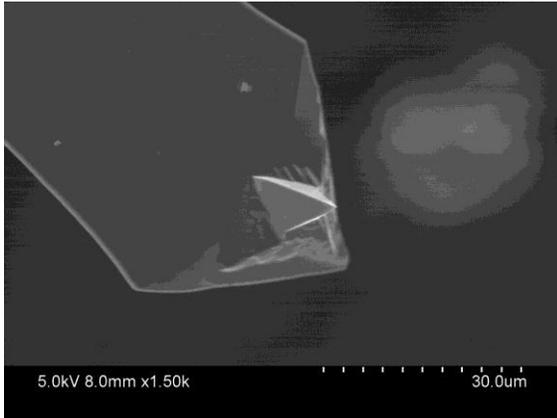


A laser source and photodiode are used to monitor the deflection of the AFM tip. The feedback controller is used to maintain the deflection at a specific set point by moving the tip up and down depends on the topology of the specimen. The recording of the z-motion of the tip is used to reconstruct the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

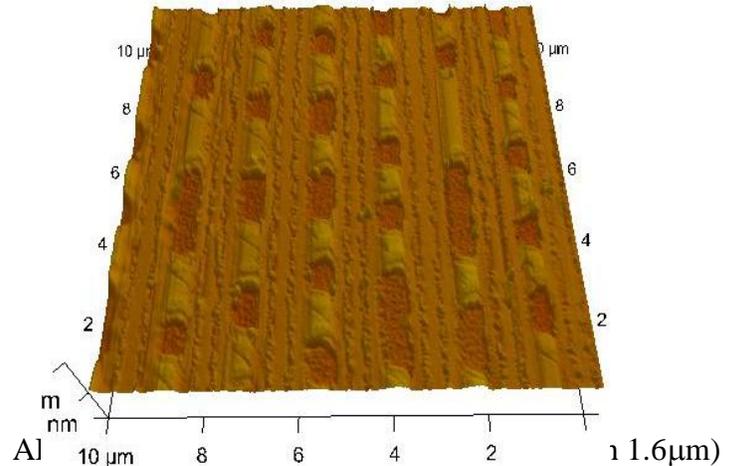
The proper choice of feedback parameters and set point is crucial in obtaining an accurate image of the specimen.

Experiment:

An SEM will be used to image an AFM tip, with tip radius of curvature around 10-20nm. Then we will use AFM to image the track of a compact disk (CD) to see the data bit recorded in it.



SEM image of an AFM tip



Equipments 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 5keV accelerating voltage and turn on the high voltage.
6. Record an image at 500 X magnification by 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 a folder D:\Images\BSBA\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 in focus.
- 6) Choose the scanning width to be 10µm, height scale to be 40nm, P-gain to be 0.6. and 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 to align together.
- 9) Save the image in a folder C:\capture\BSBA\sectionXX\
- 10) Measure the CD track pitch from the capture image with data analysis software.