Atomic Force Microscopy (AFM)

Please note that this experiment is NOT in the P. Chem lab in Mergenthaler. Students doing this experiment should go directly to NCB 228.

This experiment is designed to use an AFM to image a number of different surfaces. This experiment also incorporates a specific web-based module designed to help students come to grips with the underlying physical nature of AFM. The web-site can found by accessing my homepage at: http://www.jhu.edu/~chem/fairbr/index.html and then clicking on *Teaching* followed by *Web-Based Modules for Physical Chemistry Lab Experiments* and going to *Atomic Force Microscopy*.

Because AFM is a very modern instrumental technique that is highly visual there are a wide range of excellent websites that can help you understand the concepts behind an AFM as well as its wide ranging applications in both academic and industrial settings. For example,
http://stm2.nrl.navy.mil/how-afm/how-afm.html
is an excellent website on AFM. An animated jif showing the workings of a AFM can also be found on the bottom right of the following homepage: http://email.optics.Arizona.EDU/summaries/Richard_Workman/homepage.html
In fact by simply typing either atomic force microscopy or AFM in your favorite browser you should be able to access dozens of AFM sites that can be of assistance.

Below are listed a series of questions that together should help you to develop a working knowledge of AFM and enable you to carry out the experiment. Please note that these questions should be answered within the concept of the regular pre-lab write up. In other words ***the pre-lab is more than a list of answers to the questions below***.

Basis for Pre-Lab:

(a) How does an AFM work? Please describe the basic workings of an AFM in words (and pictures if you like). In your answer you should include the following information:
   (1) What is the role of the laser?
   (2) What is the role of the photodiode?
   (3) Why does the sample usually move and not the tip? (more common sense than science)
   (4) What is the shape of the AFM tip, (a) square, (b) circle (c) pyramidal, and why?
   (5) What does the AFM measure – (a) electron density, (b) height or (c) pressure on the surface?

(b) As the tip comes into contact with the surface atoms it experiences forces. As a function of distance form the surface are these forces (a) repulsive and then attractive or (b) attractive and then repulsive. Why? Explain your answer in terms of the force-approach curve and the nature of the forces at a molecular level?

(c) AFM imaging usually works in either contact or non-contact mode – can you explain the relative position of the tip with respect to the surface for these modes (i.e. is the tip closer to the surface in contact or non-contact mode). Which mode, contact or non-contact, would you expect to be more sensitive to the surface features and why?

The AFM lab consists of three separate imaging experiments:

(1) Imaging a diffraction grating.
(2) Imaging a superconducting quantum interference device (SQUID)
(3) Imaging a ceramic surface.

Details of experiments (2) and (3) can be found as attachments to the prelab.

To make sure that you understand these experiments please answer the following questions in the prelab.

Experiment 1: Imaging a diffraction grating.

(a) What is a diffraction grating?
(b) The diffraction grating is really used as a form of calibration for the AFM – based on the nature of a diffraction grating can you explain this?

Experiment 2: Imaging a superconducting quantum interference device (SQUID)

(a) What is a SQUID?
(b) What does a SQUID measure and how?
(c) What is a superconductor?
(d) Briefly describe the principle of superconductivity in 2-3 sentences.
(e) **Bonus Question**: Can you think of any potential uses for a superconductor?

Experiment 3: Imaging a ceramic surface

(a) Other than Al_2O_3 can you give the chemical formulae for two other ceramic materials?
(b) Why are ceramics good insulators and metals good conductors?
(c) What is a grain size? (You may need to look up a basic book on solid state or materials science or the web for this)
(d) **Bonus Question**: One of the properties of ceramic materials, piezoelectricity is actually an integral and very important part of an AFM. Can you explain how piezoelectricity is used in AFM imaging and why?

Please note that you DO NOT need to answer the questions under section 9.5 and 11.5 as part of the prelab.