PH 2510, Atomic Force Microscopy

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Abstract

Atomic force microscopes (AFMs) are instruments that allow three-dimensional imaging of surfaces with nanometer resolution and are important enabling tools for nanoscience and technology. The student who successfully completes PH 2510 will understand the functional principles of AFMs, be able to run one, and interpret the data that are collected. The course has two main parts. The first half of the term emphasizes instrumentation, the second half interpretation. Each week, there are three one-hour lectures, one one-hour computer lab, and one two-hour instrument lab. Recommended background: Introductory Mechanics and Introductory Electricity and Magnetism.

Student course objectives:

- To become competent in the use of AFMs and in the interpretation of AFM data
- To learn how physics applies to AFMs
- To gain an understanding and appreciation of scientific research
- To develop the ability to write a good lab report

The seven units of the course are:

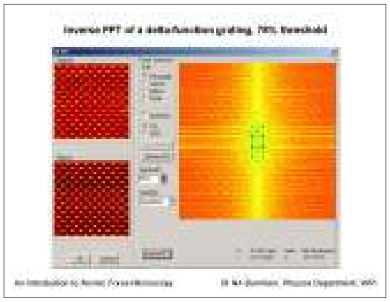
- Fundamentals of imaging
- Difficulties of imaging
- Other SPMs and operational modes
- Probe and scanner calibration
- Force-curve mechanics
- Tip-sample interactions
- A glimpse at current research

Computer labs reinforce ideas that were introduced in class. This example shows a program that demonstrates feedback gains that are too low, too high, and about right.

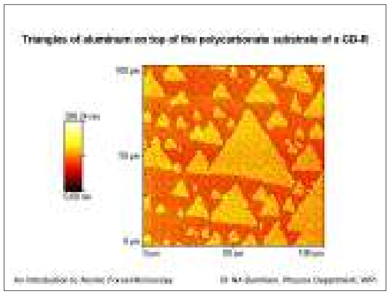
The computer labs treat:

- Image processing
- Feedback and noise
- Fourier filtering
- Potentials, forces, and stiffnesses
- The effect of compliance
- Molecular dynamics

Two types of software are used in the computer labs. The image processing program was purchased from the manufacturer of the AFM, and the educational software was written by Professor Burnham.



The students also practice image processing during the computer labs. Here, fourier threshold filtering has been used to remove streaks from an image. The green peaks are above the threshold.

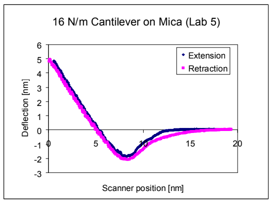


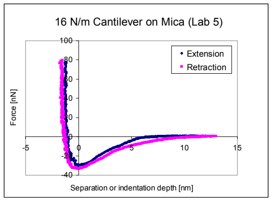
Classroom and laboratory work are well integrated. This slide, shown in class, helps prepare the students for the instrument laboratory on lateral force microscopy.

The instrument labs treat:

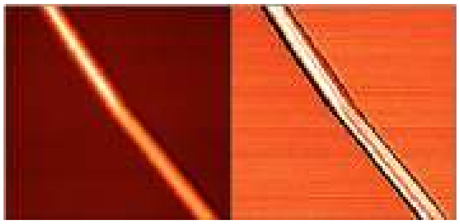
- Laboratory procedures
- Acquiring an image
- Optimizing an image and LFM
- Probe and scanner calibration
- Force-curve acquisition and processing
- Contact mechanics

The lab reports are written in the style of a manuscript to be submitted to a journal. Hints are given in the report template as to how best to write the text and abstract.





The cantilever and the tip-sample interface can be modeled as two springs in series. The consequences for force-curve data processing are shown here. Above: raw force-curve data, cantilever deflection as a function of scanner position. Below: processed force-curve data, with force as a function of separation or indentation depth.

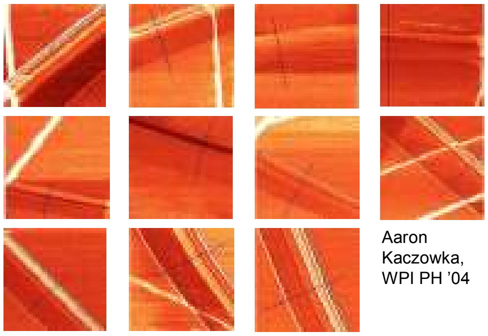


Aaron Kaczowka, WPI PH '04, did a senior thesis on the shear response of carbon nanotubes. Left image: a carbon nanotube on graphite, colorscale 15 nm, scan range 1 um. Right image: shear-amplitude image taken simultaneously. The cantilever was dithered laterally and the amplitude of the subsequent torsional twisting of the beam was collected with a lock-in amplifier.

Outcomes:

After successfully completing the course, students are well prepared for senior theses, and their applications for employment or graduate school are strengthened.

Right montage: shear-ampliitude images of a carbon nanotube rotated beneath the probe so that the shear direction ranged from roughly parallel to roughly perpendicular to the tube axis. When the shear direction was approximately parallel to the tube axis, the shear amplitudes on the tube and on the graphite were about the same (top row, right two images).



Aaron Kaczowka, WPI PH '04

Further development of PH 2510 is partially supported by the Nanotechnology Undergraduate Education program of the National Science Foundation.
The continued support of Analog Devices Incorporated is also gratefully acknowledged.