Physics
UNIVERSITY OF TORONTO

AFM
Advanced Undergraduate Laboratory

Atomic Force Microscope

Revisions

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1 Introduction

The Atomic Force Microscope (AFM) allows measurement and manipulation of atomic surfaces, and was invented by Gerd Binnig, Calvin Quate, and Christoph Gerber in 1986 [1]. The AFM is one of a family of instruments developed after the invention of the Scanning Tunnelling Microscope (STM) in 1981, for which Binnig and Heinrich Rohrer won the Nobel Prize in 1986. Unlike the STM, the AFM does not require a dry, clean, conducting surface, and so can be used to measure insulators or biological samples.

The goal of this experiment is to familiarize the student with mesoscale and nanoscale AFM measurements used in fields such condensed matter physics. As feature sizes of objects of study become smaller, optical techniques become unable to resolve these features. While electron microscopes can have the required resolution, they do not provide height information. AFM and STM technology has become the standard methods used in probing atomic, molecular and domain features, with resolutions reaching down to a few angstroms in the most advanced instruments. This experiment makes use of a research-grade Nanosurf CoreAFM.

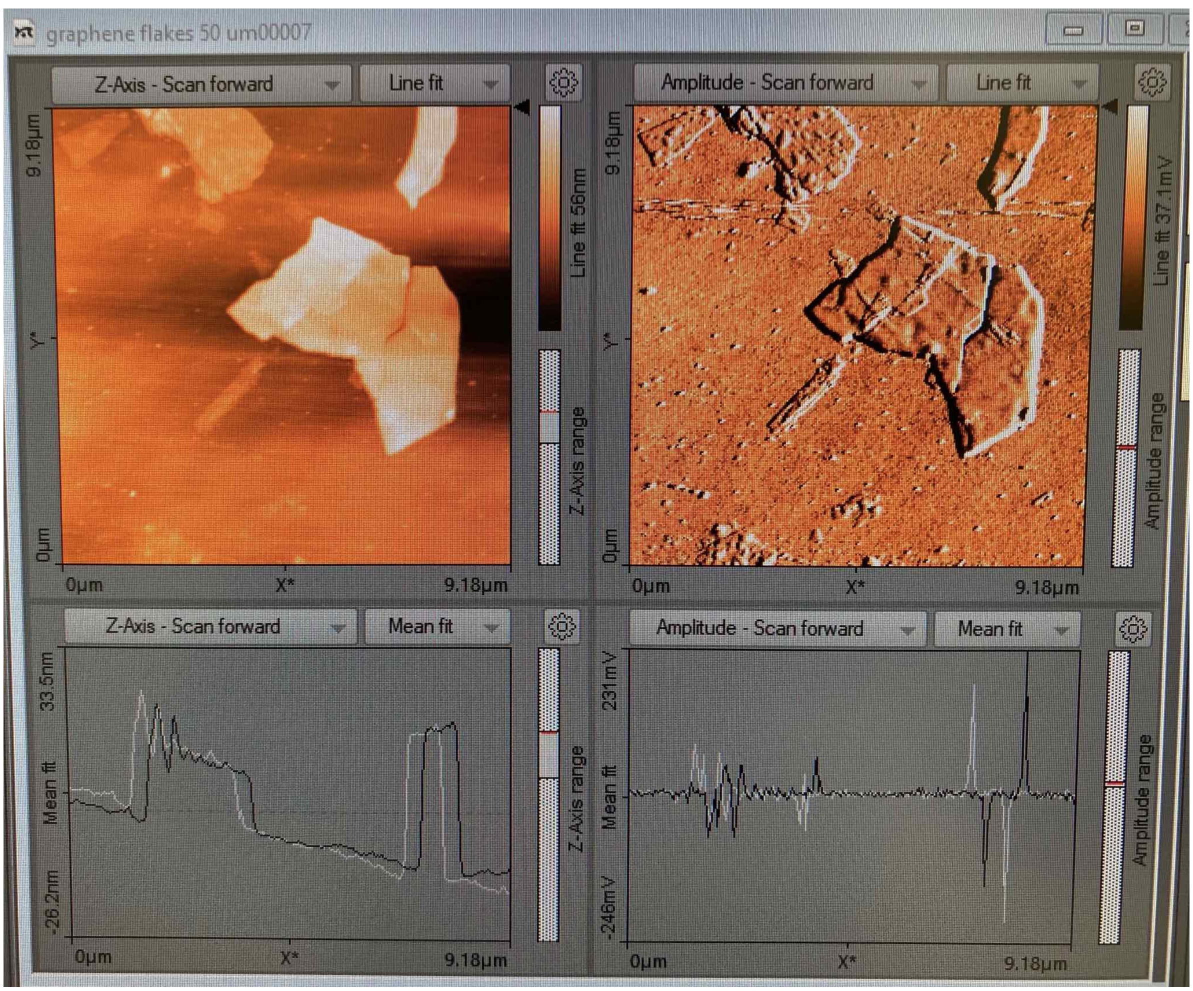

Figure 1: Image of graphene flakes made by APL student Lechun Xing.

1.1 Preparation

Before starting, look at the following Nanosurf resources.

- Atomic Force Microscope Images
- How does AFM work?
- AFM Modes Overview. You can find collection of sample images that can help you pick out what cantilever and mode to use for observation.
- CoreAFM Overview
- Mounting a cantilever
- Static mode operation

Safety Reminder

- Chemicals used in this experiment may include solvents such as acetone and ethanol, and sample materials such as graphite and polymers. It is advisable to read the Safety Data Sheet (SDS) for these materials before the experiment.
- Acetone is an irritant to the skin and eyes, and while it's not very toxic – it is a common component of nail polish remover and paint thinners – direct exposure to it should be avoided. Read the MSDS sheet.
- Eye protection and gloves must be worn when using chemicals or preparing samples.
- The tweezers are quite sharp and should be handled with care.
- The AFM has a low power built in laser that does not require eye protective equipment, but it is not recommended to look directly into the laser or any reflections from mirrors. It is safe to look at the diffuse scattered light from rough surfaces.
- Be sure to pay close attention to all Cautions in the AFM operating instructions.
- The CoreAFM system is heavy! Do not attempt to move it without first consulting with your TA, Supervisor, or Technologist.
- Do not exchange cables while power is on. This could damage the electronics.
- Powering off while the control software is running can crash your tip.
- Be very careful while handling liquid! If liquid spills inside the motorized sample stage or enters the scan head, it can seriously damage the AFM. Consult with your TA or Supervisor before attempting to make any measurements in liquids.

Let the APL Coordinator know if any of the links above are broken.

NOTE: *This is not a complete list of all hazards; we cannot warn against every possible dangerous stupidity, e.g. opening plugged-in electrical equipment, juggling cryostats, etc. Experimenters must constantly use common sense to assess and avoid risks, e.g. if you spill liquid on the floor it will become slippery, sharp edges may cut you, etc. If you are unsure whether something is safe, ask the supervising professor, the lab technologist, or the lab coordinator. If an accident or incident happens, you must let us know. More safety information is available at* `http://www.ehs.utoronto.ca/resources.htm`.

2 EXPERIMENTAL

- Instructions on using the AFM are found in the instrument's operating manual.
- Start with one of the provided samples to get comfortable with the instrument.
- Measure the measure the force-distance curve [2] for at least one sample, and it may be interesting to compare these curves for different materials.

2.1 Possibly Helpful Suggestions

Suggestions from students , TAs, and Profs.

- Practice picking up 'broken' cantilevers for a while before attempting to pick up new cantilever. This should reduce the chance that you break your first cantilever before even mounting it.
- The description of the laser alignment tool on page 18 is misleading.

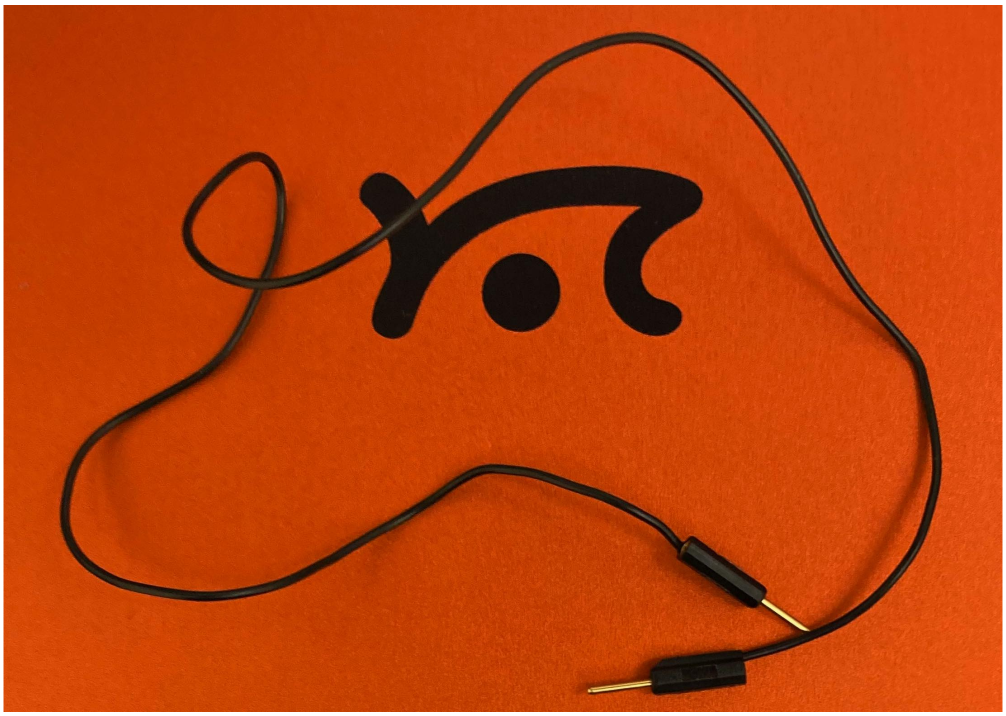

Figure 2: Correct laser alignment tool.

- Adjusting camera from top-view to side-view or vice versa distorts the scanning result, so do not touch this knob when the scanning is processing.

- When aiming the laser on the edge of the cantilever, it is better to have the cantilever close to the sample to avoid the camera focussing on the sample instead of the cantilever. Look for the intense red dot instead of blurry diffraction points to maximize the laser intensity.

- If you look at the AFM Modes Overview sub-pages, you can find wonderful collection of scanned landscapes of samples. Reading this website can help you easily pick out what cantilever and mode to use for an observation.

- A piece of a hard disk from an old computer is an interesting sample to observe.

- Samples may wander between AFM & STM, especially conducting samples (gold, graphite, silicon, Au nanodots on Si, ...) that can be measured with either apparatus, so check around the the other apparatus. If another student is doing STM, you might want to consider making collaborative measurements, e.g. measure the same (conducting) sample with both apparatus and comparing the results.

References

[1] G. Binnig, C. F. Quate, and Ch. Gerber. "Atomic Force Microscope". *Physical Review Letters*, 56(9):930–933 (1986). ISSN 0031-9007. doi:10.1103/PhysRevLett.56.930. URL https://link.aps.org/doi/10.1103/PhysRevLett.56.930.

[2] B. Cappella and G. Dietler. "Force-distance curves by atomic force microscopy". *Surface Science Reports*, 34(1-3):1–104 (1999). ISSN 01675729. doi:10.1016/S0167-5729(99)00003-5. URL https://linkinghub.elsevier.com/retrieve/pii/S0167572999000035.