Introduction to Scanning Probe Microscopy (SPM)

History

Robert A. Wilson and Heather A. Bullen,* Department of Chemistry, Northern Kentucky University, Highland Heights, KY 41099.

During the 20th century a world of atomic and subatomic particles opened new avenues. In order to study and manipulate material on an atomic scale there needed to be a development in new instrumentation. Physicist Richard Feynman said in his now famous lecture in 1959: "if you want to make atomic-level manipulations, first you must be able to *see* what's going on."[1] Until the 1980s researchers lacked any method for studying the surfaces on atomic scale. It was known that the arrangement of atoms on the surface differed from the bulk, but investigators had no way to determine how they were different. The **scanning tunneling microscope (STM)** was developed in the early 1980s by Binnig, Rohrer, and co-workers.[2]

How does the STM work?

The STM provides a 3D profile of the surface on a nanoscale, by tunneling electrons between a sharp conductive probe (etched Tungsten wire) and a conductive surface. The flow of electrons is very sensitive to the probe-sample distance (1-2 nm). As the probe moves across surface features the probe position is adjusted to keep the current flow constant. From this a topographic image of the surface can be obtained on an atomic scale.

Note: A more detailed explanation is found in SPM Basic Theory

Interesting STM Facts:

Binnig and Rohrer receive the Nobel Prize in Physics (1986) for their work on the STM. They shared this award with German scientist Ernst Ruska, designer of the first electron microscope.

The STM that Binnig and Rohrer had built was actually based upon the field ion microscope invented by Erwin Wilhelm Müller.[3]

A precursor instrument, the topografiner, was invented by Russell Young and colleagues between 1965 and 1971 at the National Bureau of Standards (NBS).[4]

This instrument was the fundamental tool in the development of nanotechnology. It opened the door for the ability to control, see, measure, and manipulate matter on the atomic scale.

* corresponding author: bullenh1@nku.edu, 859-572-5411

Drawbacks: Although the STM was considered a fundamental advancement for scientific research it has limited applications, as it only works for conducting or semi-conducting samples (needed for tunneling of electrons). In 1986, Binnig, Quate, and Gerber extended the field of application to non-conducting (biological, insulators etc.) by developing an **atomic force microscope (AFM).**[5]

How does the AFM work?
The AFM provides a 3D profile of the surface on a nanoscale, by measuring *forces* between a sharp probe (<10 nm) and surface at very short distance (0.2-10 nm probe-sample separation). The probe is supported on a flexible cantilever.

Note: A more detailed explanation is found in AFM Basic Theory

The STM and AFM may be applied to samples in very different environments: These microscopes work under vacuum conditions, air, and, in liquids (with specific modifications).

References:

1. G. Binnig, H. Rohrer, C. Gerber, Appl. Phys. Lett. 40 (1982) 178.

2. A transcript of the classic talk that Richard Feynman gave on December 29th 1959 at the annual meeting of the American Physical Society at the California Institute of Technology (Caltech) was first published in the February 1960 issue of Caltech's *Engineering and Science*, which owns the copyright. It has been made available on the web at http://www.zyvex.com/nanotech/feynman.html with their kind permission.

3. E. W. Müller, Z. Phys. 131 (1951) 136.

4. R. Young, J. Ward, and F. Scire, Rev. Sci. Instrum. **43**, 999 (1972).

5. G. Binnig, C. F. Quate, C. Gerber, Phys. Rev. Lett. 56 (1986) 930.

Acknowledgements:
This work is partially supported through NSF grant DMR-0526686. The authors would also like to acknowledge the participants at the ASDL Curriculum Development Workshop held at the University of California - Riverside, July 10-14, 2006.