

General concept and defining characteristics of AFM

Dina Kudasheva

Advisor: Prof. Mary K. Cowman

Overview

- Introduction
- History of the SPM invention
- Technical Capabilities
- Principles of operation
- Examples
- Novel Applications

Introduction

- Atomic force microscopy (AFM), invented in 1986 (Binnig et al., 1986, AFM; *Phys. Rev. Lett.* 56, 930-933) is a member of a family of powerful surface imaging techniques, known collectively as **scanned probe microscopy (SPM)**, used for studying surface properties of materials from the atomic to the micron level.

Founding Fathers of SPM



Heinrich Rohrer and Gerd Karl Binnig, scientists at IBM's Zurich Research Laboratory were awarded the 1986 Nobel Prize in physics for developing the powerful microscopy technique which allows scientists to view individual atoms on the surface of a sample.

Techniques for Surface Analysis

Chemical Analysis

X-ray Photoelectron Spectroscopy

Auger Electron Spectroscopy

Structural Analysis

Extended X-ray Absorption Fine Structure Spectroscopy

LEED and Reflection High Energy Electron Diffraction

Vibrational Spectroscopies

Reflection Absorption Infra-Red Spectroscopy

Electron Energy Loss Spectroscopy

Probing surface electronic structure

Photoelectron Spectroscopy

SPM advantages

- *'The invention of the STM by Rohrer and Binnig revolutionized surface science. This instrument enables the visualization of surfaces at the atomic scale and opened up an entirely new area of physics and technology: **nanoscience** - entirely new fields...for the study of the structure of matter.'*

committee

The

Nobel

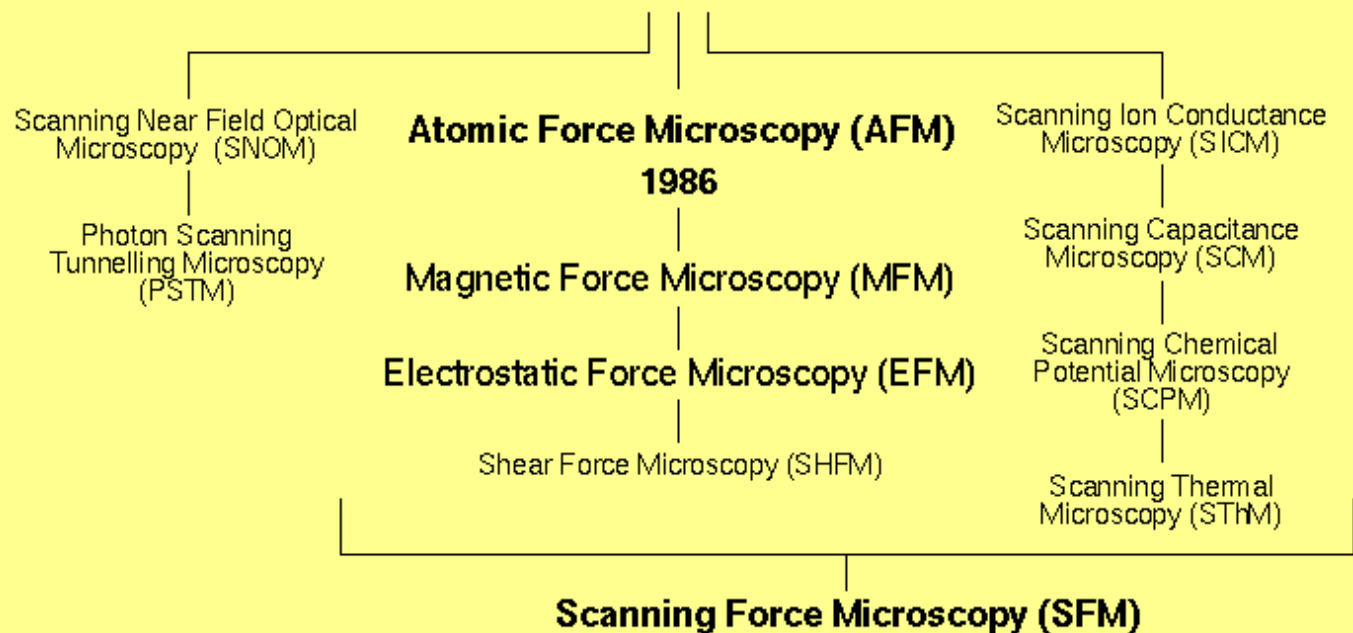
SPM advantages (con'd)

- Resolution is several orders of magnitude better than the best electron microscope;
- minimal requirements to sample preparation;
- wide range of different methods to investigate surface properties;
- can be operated in a variety of environments:
 - ambient (air)
 - liquid,
 - electrochemical,
 - ultra-high vacuum

Scanning Probe Microscopy "Family Tree" (SPM)

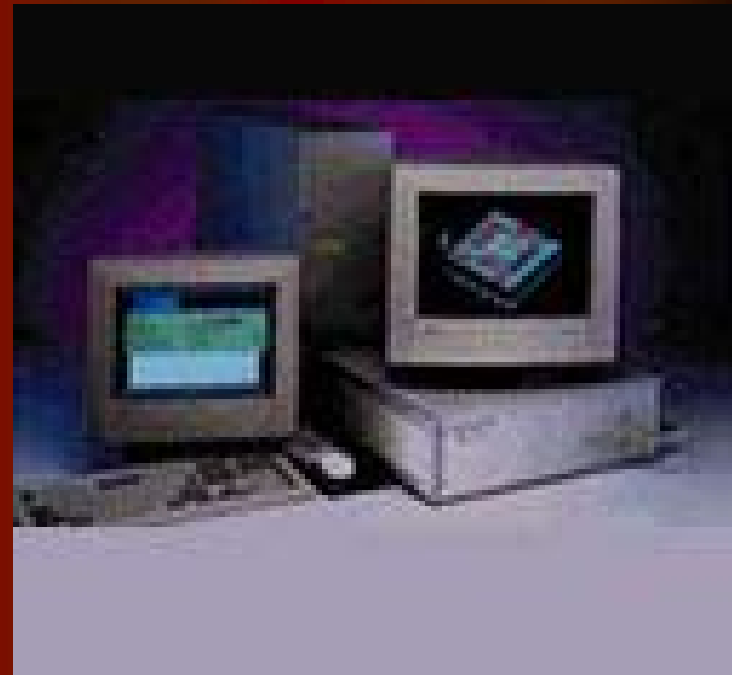
Scanning Tunnelling Microscopy (STM)

1981-2



NanoScope MultiMode Scanning Probe Microscope

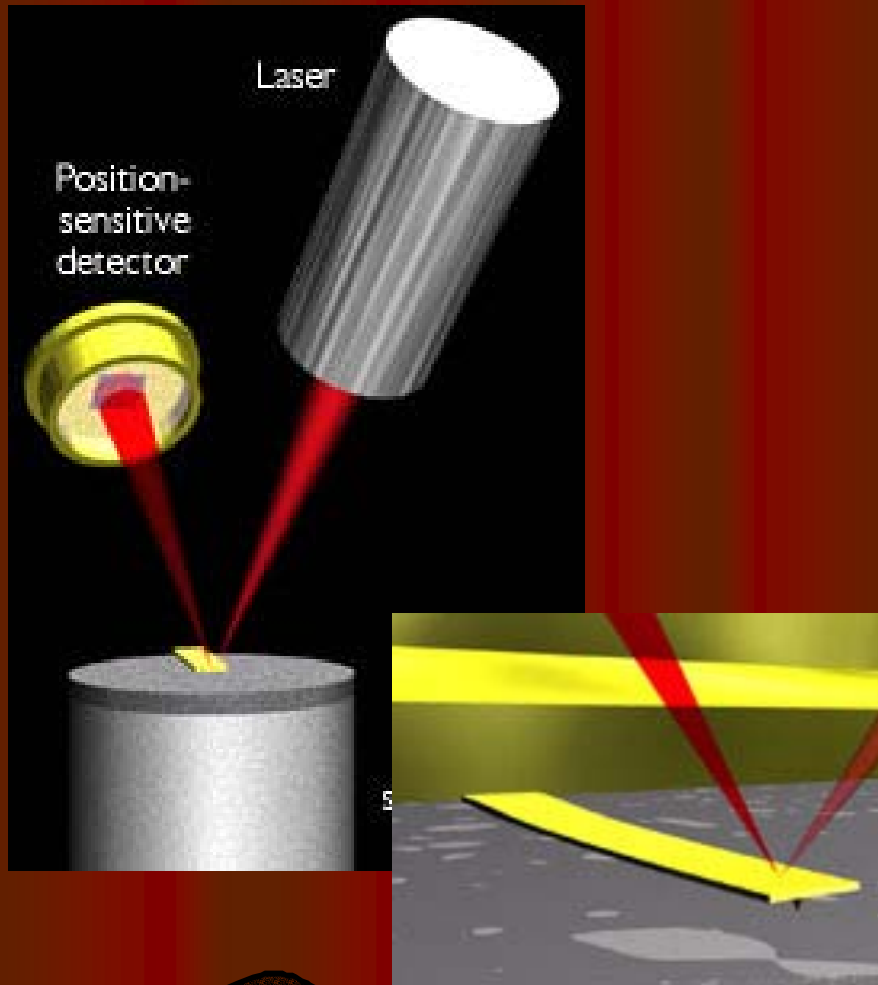
(Digital Instruments, Santa Barbara, CA)



Technical Capabilities

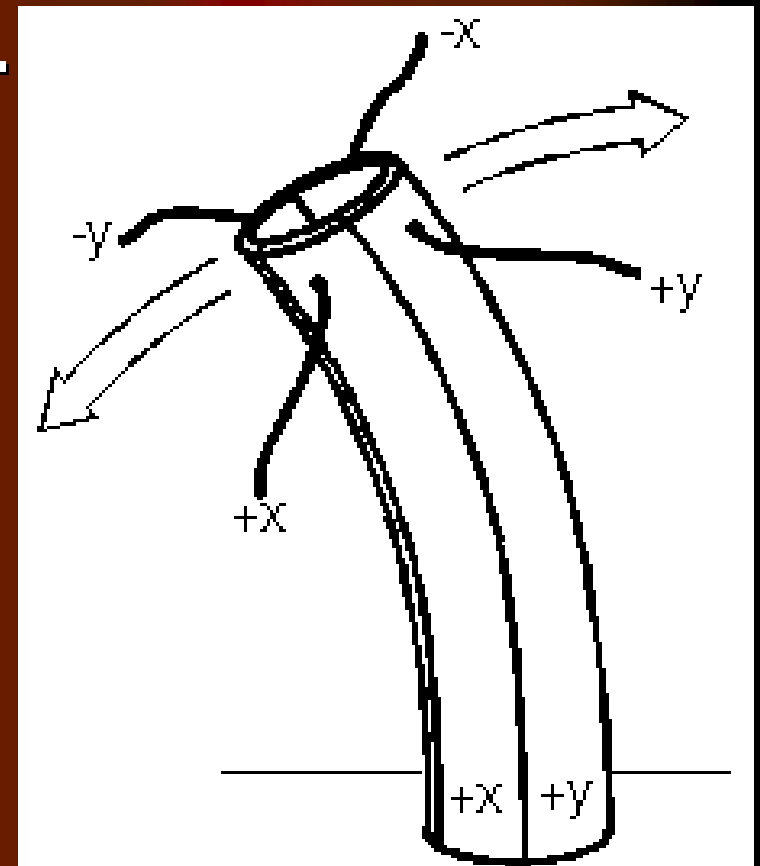
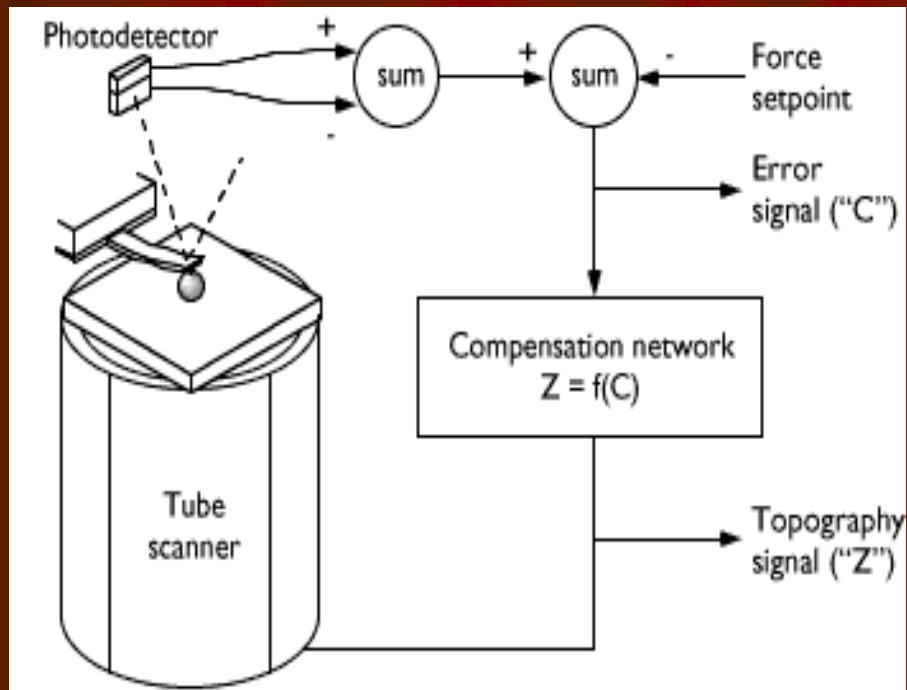
- The SPM is being applied to studies of phenomena such as adhesion, intermolecular interactions, intramolecular structural transitions, friction, abrasion, corrosion, etching, lubrication, plating and polishing;
- materials under investigation include thin and thick film coatings, ceramics, composites, proteins, synthetic and biological membranes, metals, polymers and semiconductors;
- can also examine soft biological samples (cell walls);

Laser beam deflection offers a convenient and sensitive method of measuring cantilever deflection



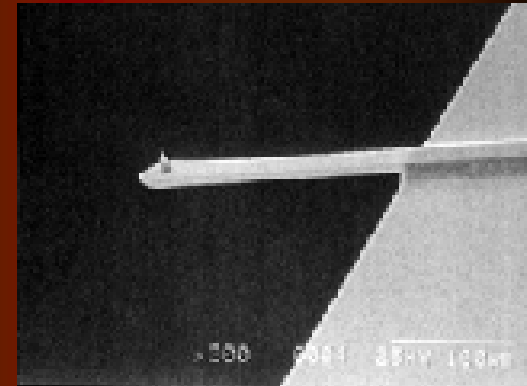
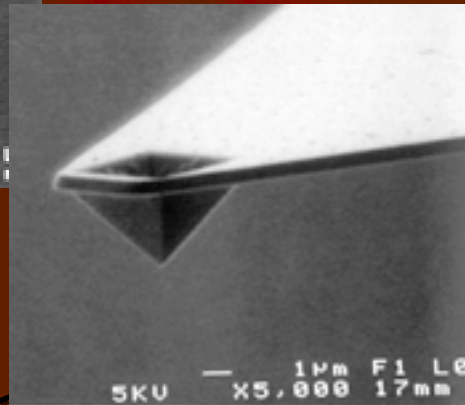
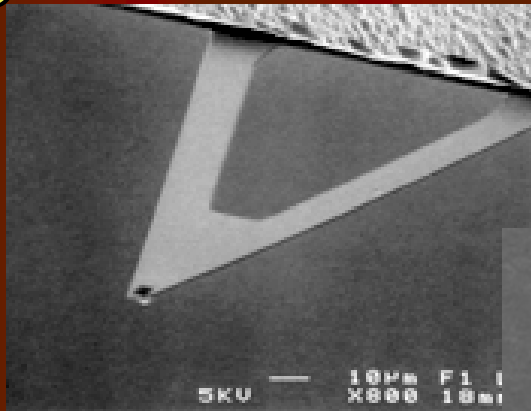
- SPM requires the sample molecules to be mounted on a flat surface;
- it relies on a very sharp probe positioned within a few nanometers above the surface of interest.

AFMs use feedback to regulate the force on the sample

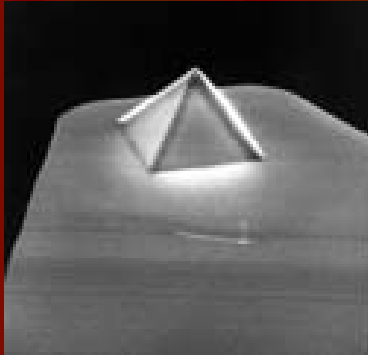


Common types of AFM tip

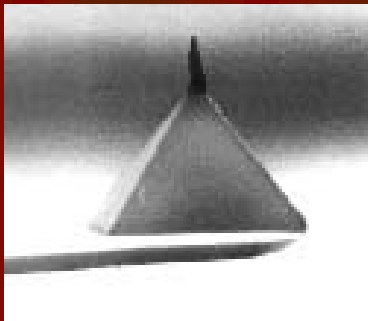
- Tips are typically made from Si_3N_4 or Si, and extended down from the end of a cantilever.



Enhanced tips



- The "normal tip" is a pyramid with 10~30 nm end radius

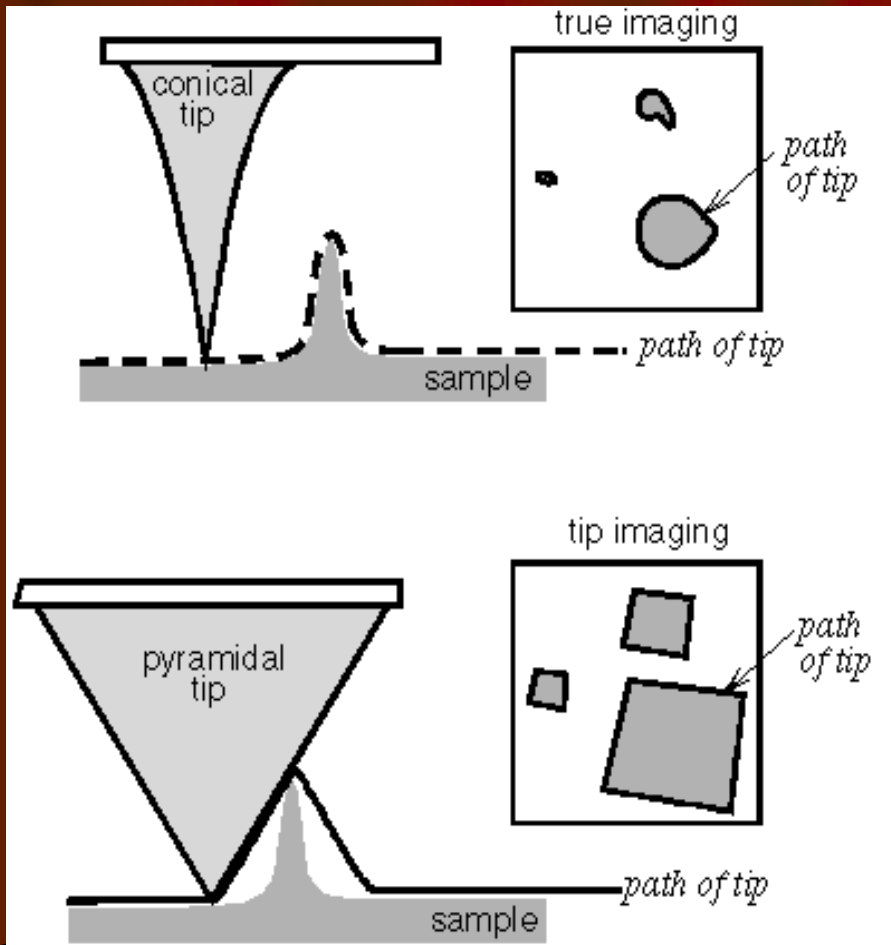


- The electron-beam-deposited (EBD) tip or "super tip": offers a higher aspect ratio (it is long and thin, good for probing pits and crevices)



- "Ultralever": conical tip, based on an improved microlithography process, offers a moderately high aspect ratio and a ~10 nm end radius

Comparison between true imaging and tip imaging.



- Pyramidal tip has a sidewall angle $\sim 35^\circ$. If such a tip is used, the edge profiles of SPM images of all features with sides steeper than 35° are dominated by the profile of the tip.
- Tips with higher aspect ratios (conical) remain limited to a sidewall angle of about 10° . Further enhancement of the sidewall angle of the tip can result in degraded durability.

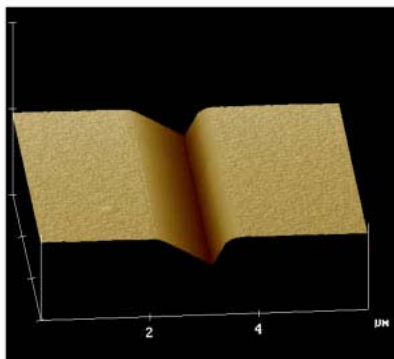
Carbon Nanotubes

ProbeMAX™ carbon nanotube Scanning Probe Microscopy tips are mounted on commercial cantilevers used in non-contact or intermittent-contact scanning probe microscopy. They are optimized for scanning in intermittent-contact mode.

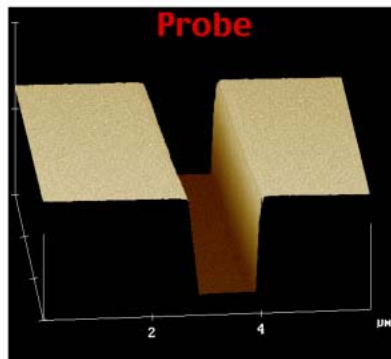


Improved Resolution of Deep Features

Etched Silicon Probe



ProbeMAX Nanotube Probe

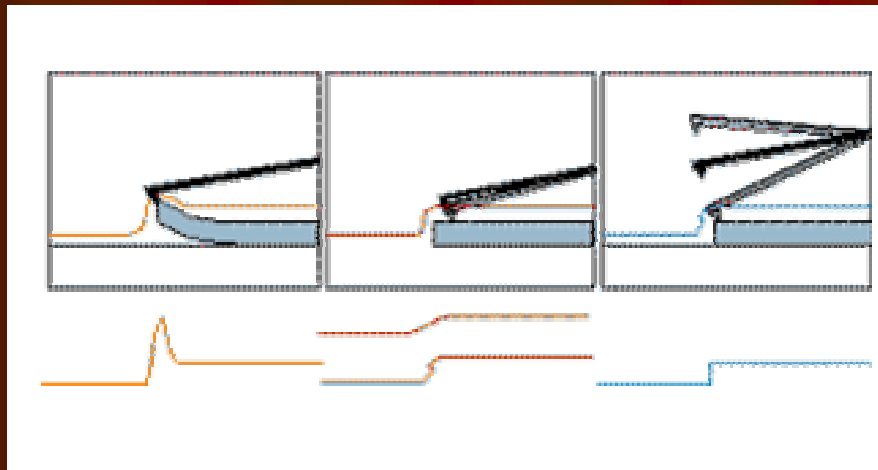


1 µm wide, 2 µm deep trench in silicon

www.piezomax.com

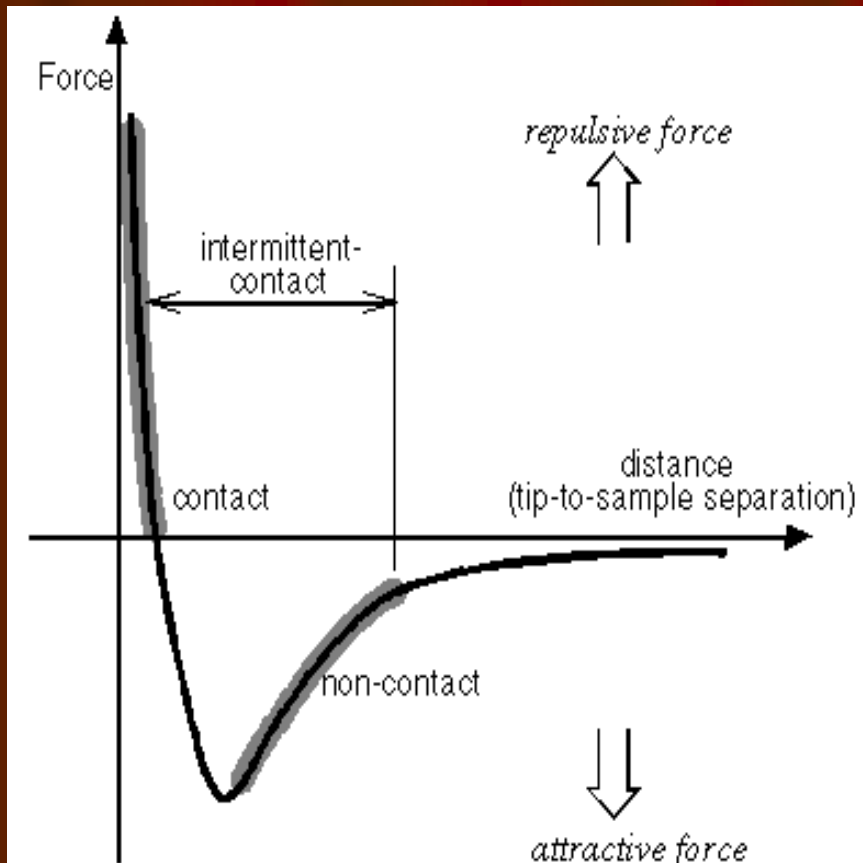
Tools for Nanotechnology
PIEZOMAX
Technologies, Inc.

The most common AFM modes



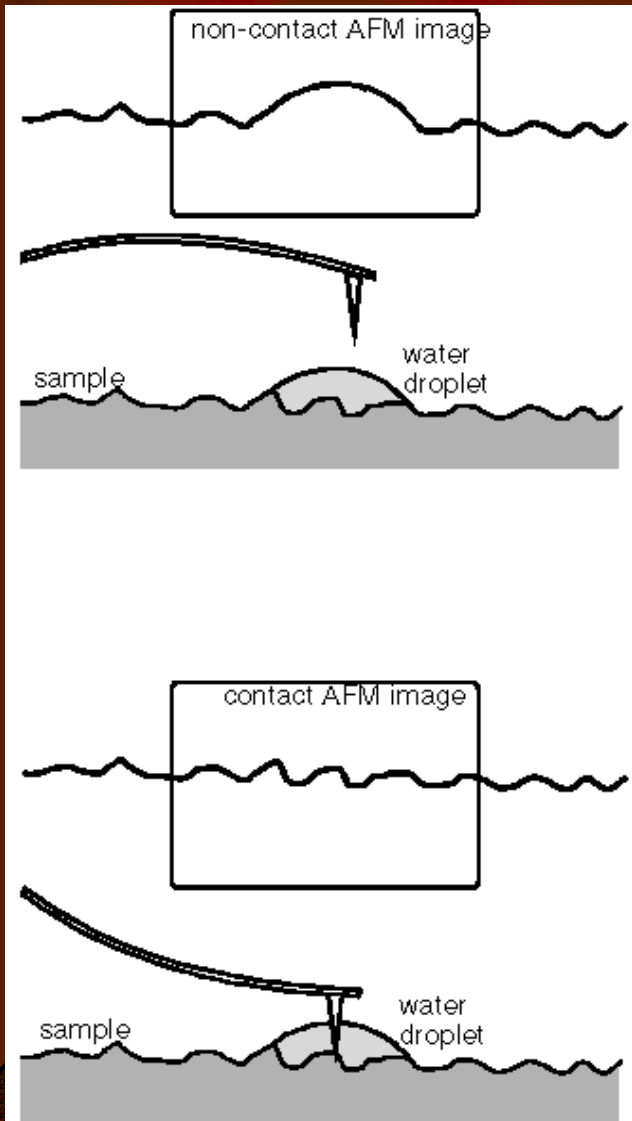
- **Contact Mode imaging (left):** measures topography by sliding probe tip across sample surface
- **Non-contact Mode imaging (center)** AFM cantilever is vibrated near the surface of a sample. The spacing between the tip and the sample is on the order of tens to hundreds of angstroms.
- **Tapping Mode imaging (right)** measures topography by lightly tapping the surface with an oscillating probe tip.

AFM modes (con'd)



- **Contact mode:** An image represents a surface of constant force, which is generally repulsive in nature and caused by Coulombic interactions (i.e. the tip is in physical contact with the surface).
- **Non-contact Mode:** Van der Waals, electrostatic, magnetic or capillary forces produce images of topography.
- **Tapping Mode:** The cantilever's oscillation amplitude changes in response to tip-to-sample spacing. An image representing surface topography is obtained by monitoring these changes.

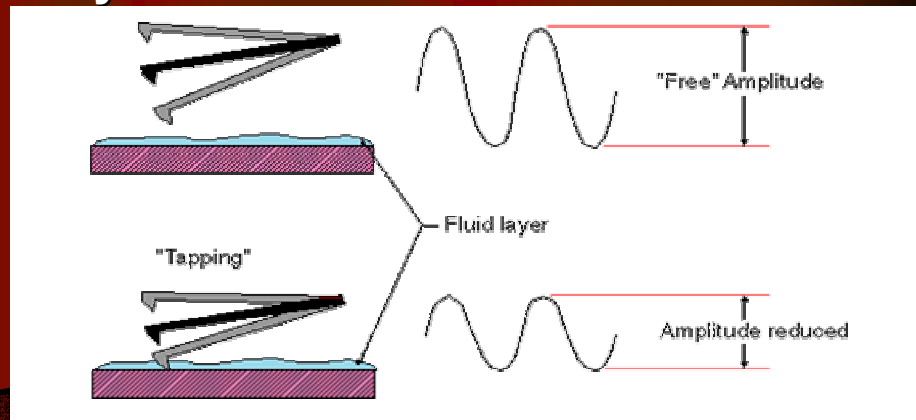
AFM modes (con'd)



Contact mode: is influenced by frictional and adhesive forces.

Non-contact: generally provides low resolution and can also be hampered by the contaminant layer.

Tapping Mode: eliminates frictional forces by intermittently touching the surface and oscillating with sufficient amplitude to prevent the tip from being trapped by adhesive forces from the contaminant layer.



Tapping Mode

- Tapping Mode is good for minimizing sample damage and movement caused by lateral forces. When imaging poorly immobilised or soft samples, tapping mode may be a far better choice than contact mode for imaging.

Evaluating Your Images

Zoom In/Out

