ATOMIC FORCE MICROSCOPE

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Contents

- What is AFM?
- History
- Basic principles and devices
- Operating modes
- Application areas
- Advantages and disadvantages

A Bit of Microscopy History

Optical Microscope
~1700

SEM: 1942

Electrons: TEM
1931

1981: STM

1986: AFM

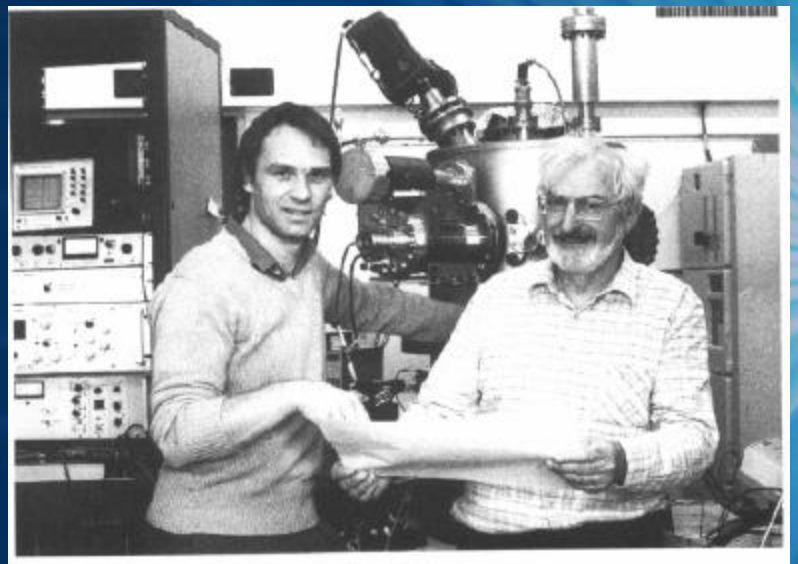
Time

Figure1: 2004 Seth Copen Goldstein

What is AFM?

- A type of Scanning Probe Microscopy
- **Atomic Force Microscopy (AFM) or Scanning Force Microscopy (SFM)** is a very high-resolution type of scanning probe microscopy, with demonstrated resolution of fractions of a nanometer, more than 1000 times better than the optical diffraction limit.
- AFM provides pictures of atoms on or in surfaces.

History of AFM

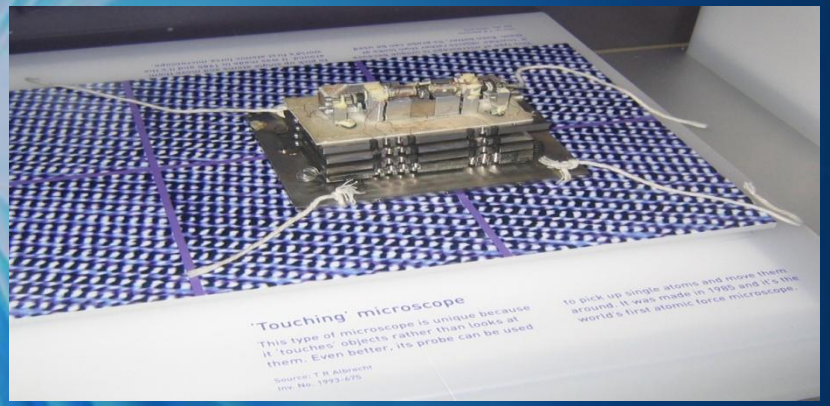


Gerd Binnig (left) and Heinrich Rohrer (right) who were awarded the Nobel Prize for their invention of the scanning tunneling microscope.

- Binnig, Quate and Gerber invented the first atomic force microscope in 1986.
- A development that earned them the Nobel Prize for Physics in 1986.

- A major advancement in 1986 is ultra-small probe tip could achieve extremely high resolutions
- In 1987 the first practical vibrating cantilever technique was made

Atomic Force Microscope



First AFM Science Museum London

Figures 2,3: www.tutorgig.com/ed/Atomic_force_microscopy

GENERAL COMPONENTS AND THEIR FUNCTIONS

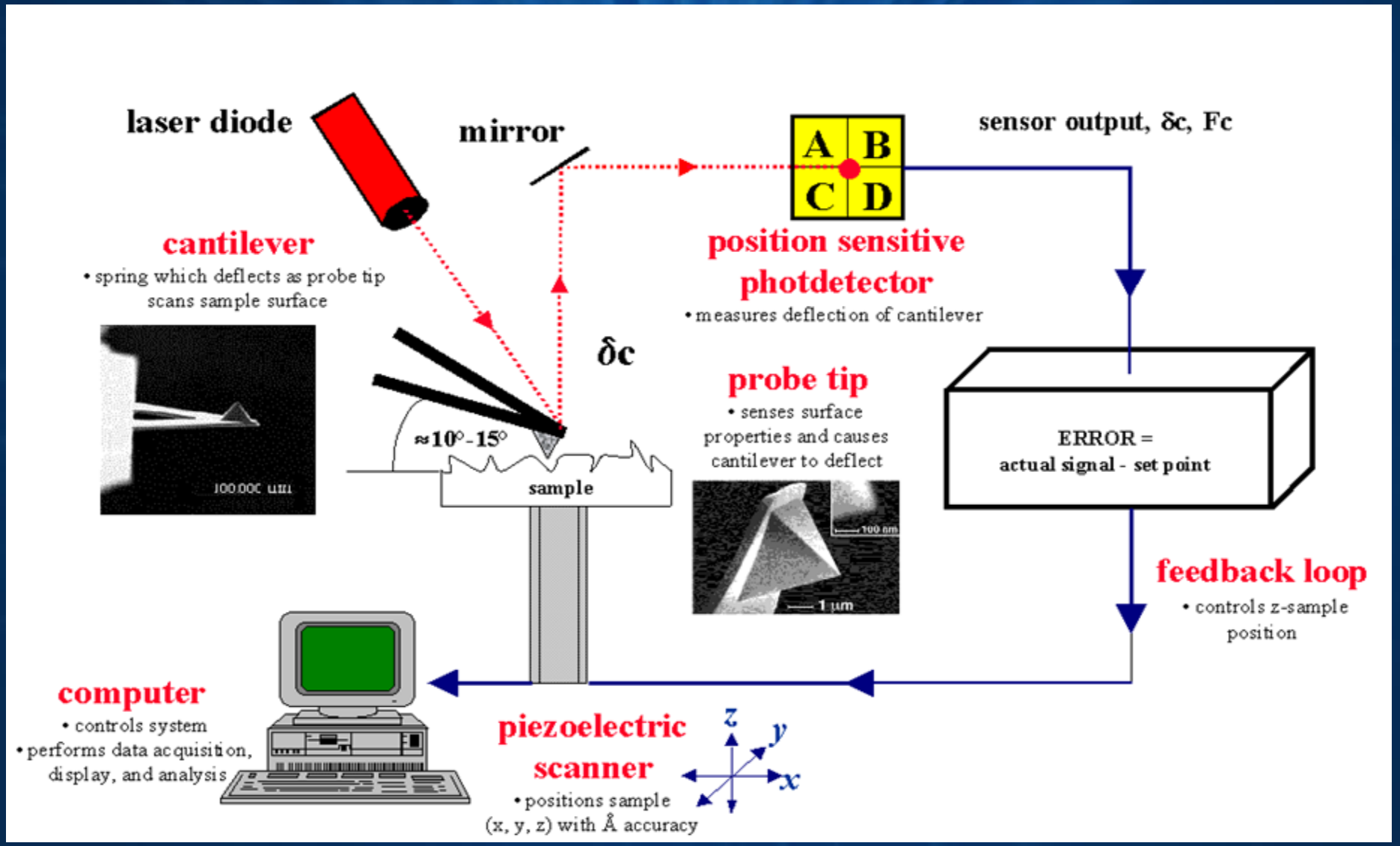
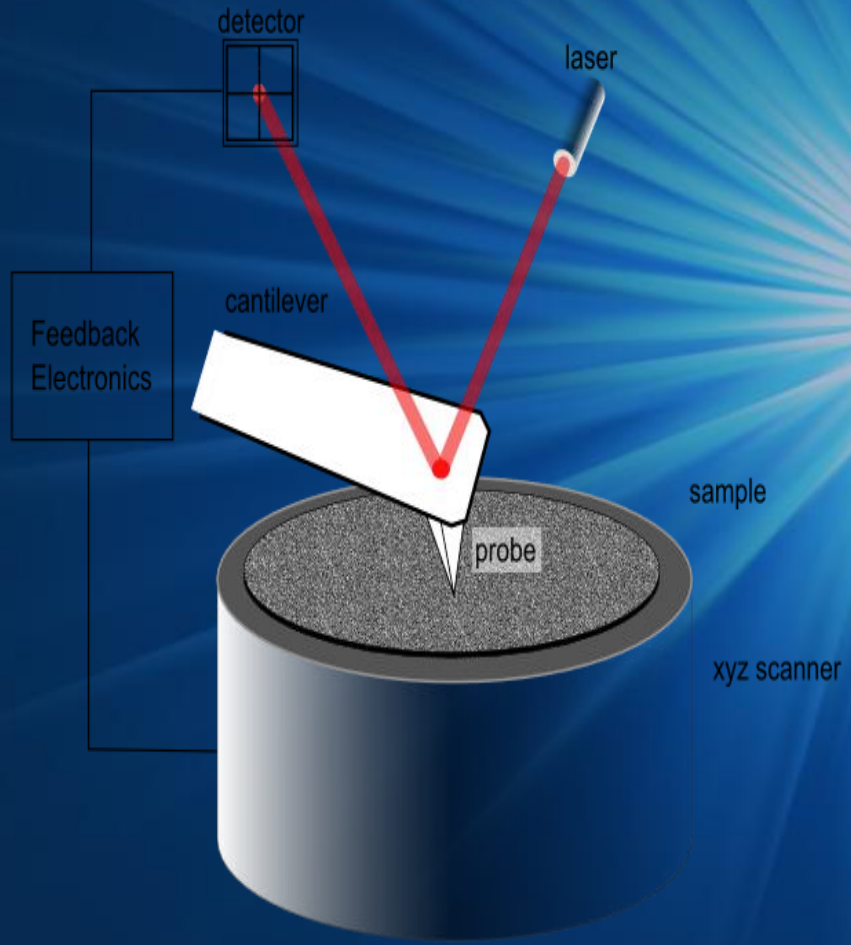


Figure4: http://web.mit.edu/cortiz/www/afm.gif

Basic principles and devices



Principle of AFM

- An atomically sharp tip is scanned over a surface.
- As the tip scans the surface of the sample, the laser beam is deflected off the attached cantilever into a dual element photodiode.
- The photodetector measures the difference in light intensities and then converts to voltage.

Figure5: knol.google.com/.../p4xu5v/afm-scheme.png

Modes of Operation

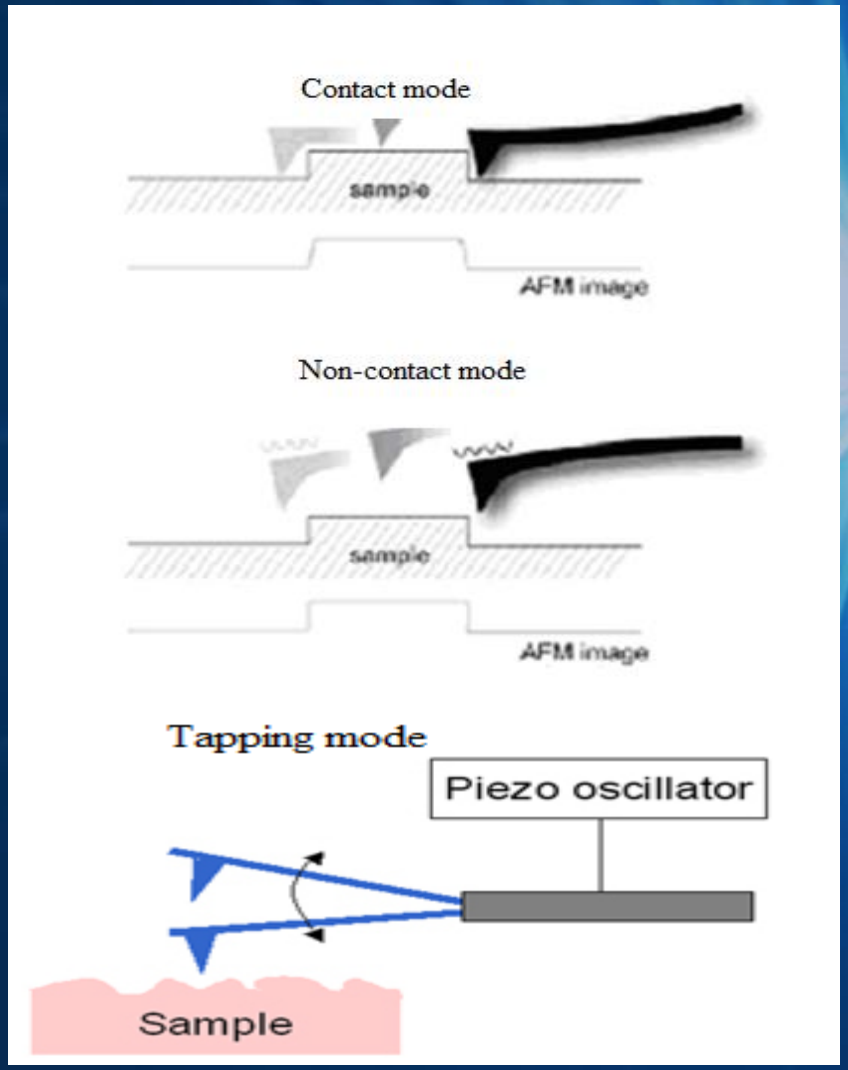


Figure6: http://www.iis.ee.ethz.ch/research/...../en.pr.html

1. **Contact Mode: The tip makes soft "physical contact" with the surface of the sample.**

2. **Non-contact Mode: the probe operates in the attractive force region and the tip-sample interaction is minimized.**

3. **Tapping mode: The most commonly used of all AFM modes, that maps topography by lightly tapping the surface with an oscillating probe tip.**

PROPERTIES OF MODES

Contact mode :

- Laser beam measures the deflection of the tip
- Feedback to a piezoelectric scanner keeps force (cantilever deflection) constant.

Non-contact mode :

- Tip oscillates with the amplitude of several nm
- Typical frequency 50 – 400 kHz
- Remains 5-10 nm from the surface
- Good for "soft" materials

Tapping mode:

- Tip oscillates with the amplitude of several nm
- Typical frequency 50 – 400 kHz
- Touches the surface at the max. amplitude

APPLICATION AREAS

- Qualitative macromolecule and polymer imaging
- Complicated or qualitative structure analysis
- Molecular interaction, molecular manipulation, surface topography, nanofood characterization

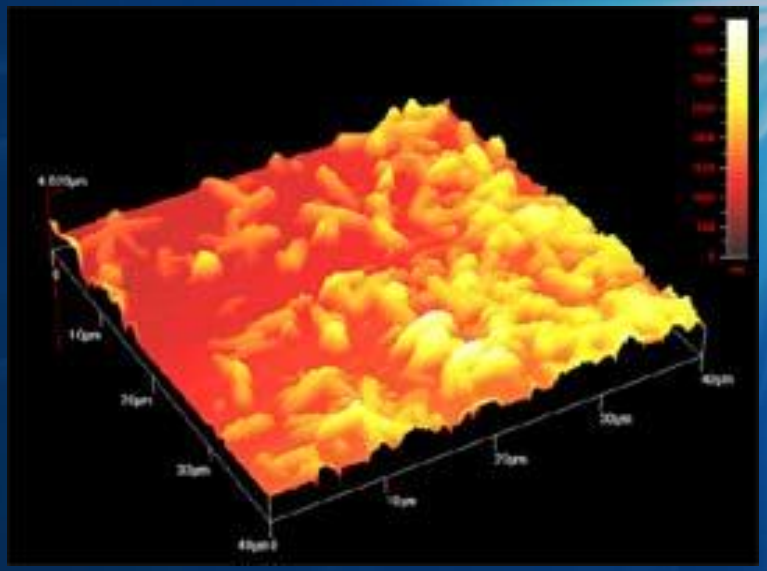
Physical Science

- The AFM will contribute new knowledge:

  - ❖Friction,
  - ❖Contact electrification,
  - ❖Elasticity
  - ❖Wetting to be studied on smaller scale than previously possible.

Biological Science

❖The AFM image individual biological molecules such as amino acid, biopolymers such as DNA, macromolecules such as proteins, and even entire cells.



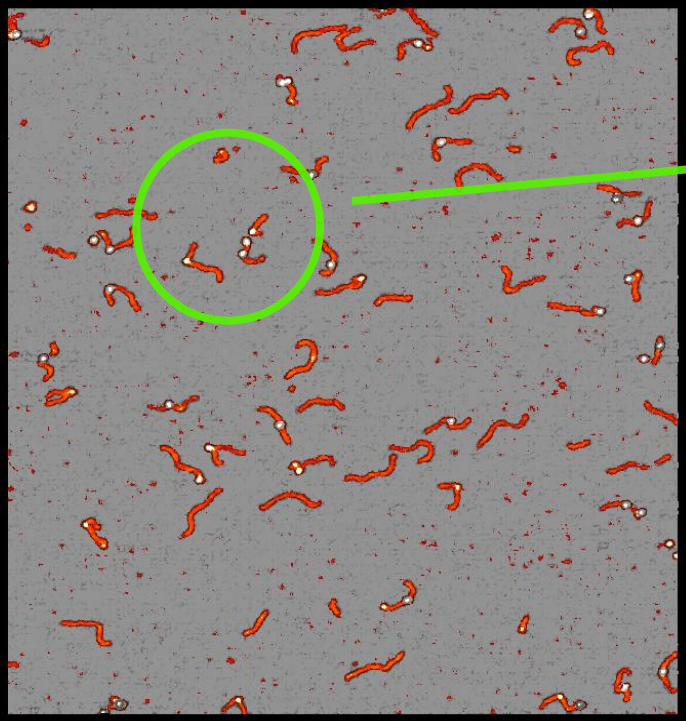
3D image of DNA crystals (Adenine)

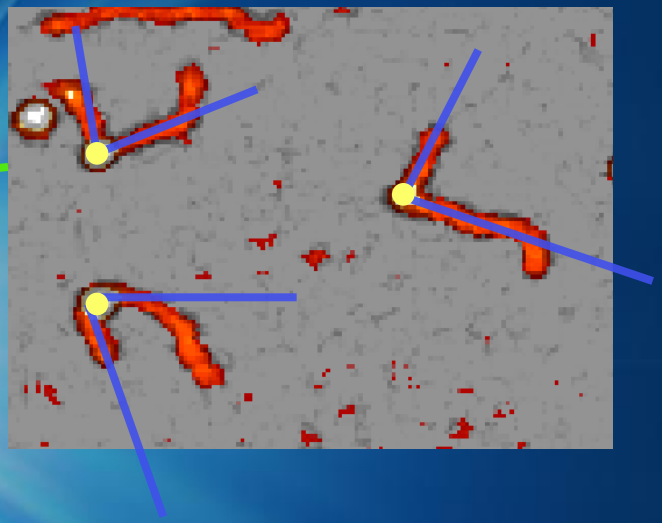
The squencing of DNA

Figure7:www.eie.gr/.../pn/pn-afmgallery-en.html

AFM image of a nucleosome on a 614 base pair DNA

2 µm x 2 µm overview scan





zoom of mononucleosome complexes

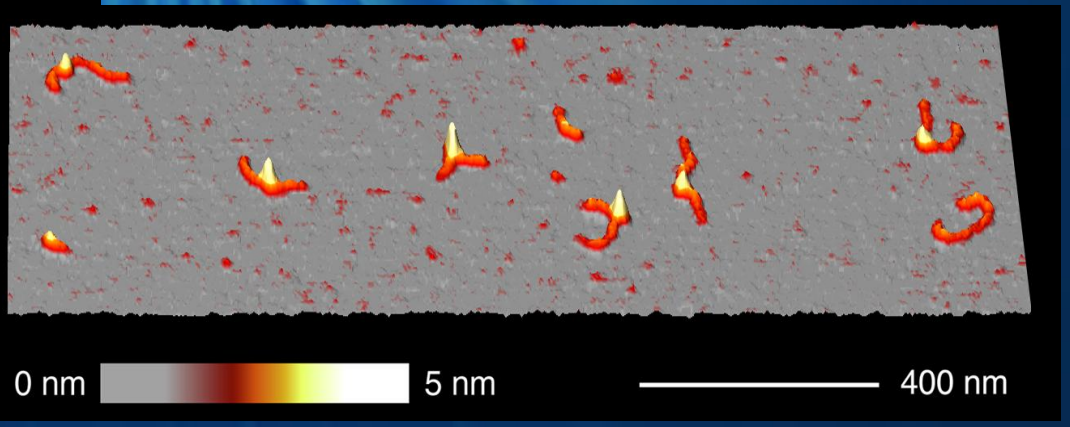
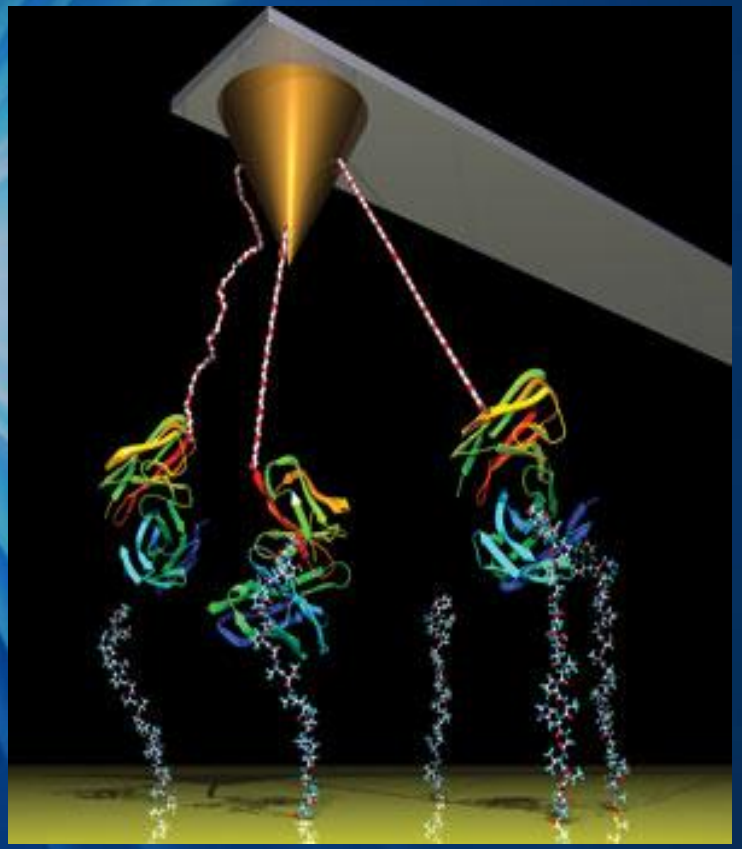


Figure8: Kepert, F., Fejes Tóth, K., Caudron, M., Mücke, N., Langowski, J. & Rippe, K., manuscript in preparation

Application Areas

Industries that AFM used;

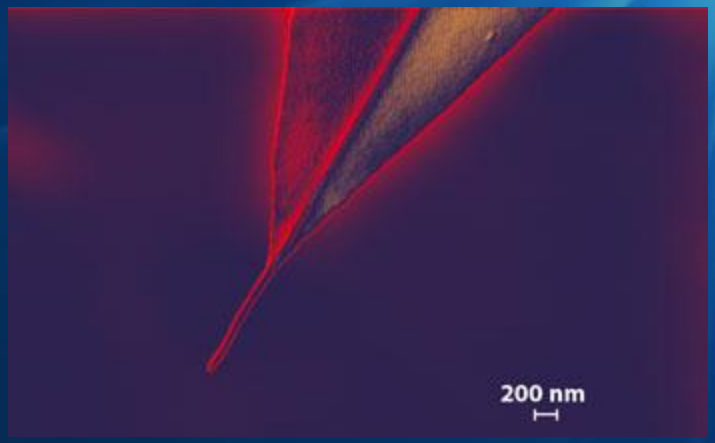
- Biology
- Chemistry
- Electronic
- Telecommunication
- Automotive
- Aerospace
- Energy



In the Future

- AFM will find numerous application in product development and quality control in the optical, semiconductor and magnetic recording industries.

- The AFM is also well suited for visualizing thin film growth morphology and grain size.

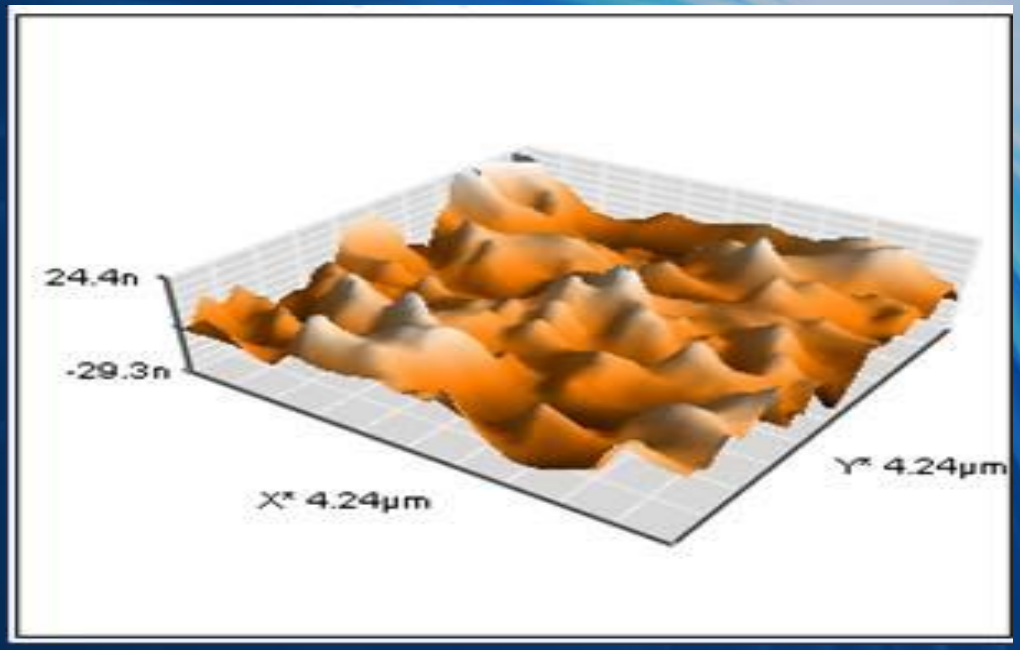


This nanowire AFM probe is made by coating a single wall carbon nanotube tip with metal

Figure9: © NEIL WILSON, WARWICK UNIVERSITY

Advantages

- **AFM provides a true three-dimensional surface profile.**



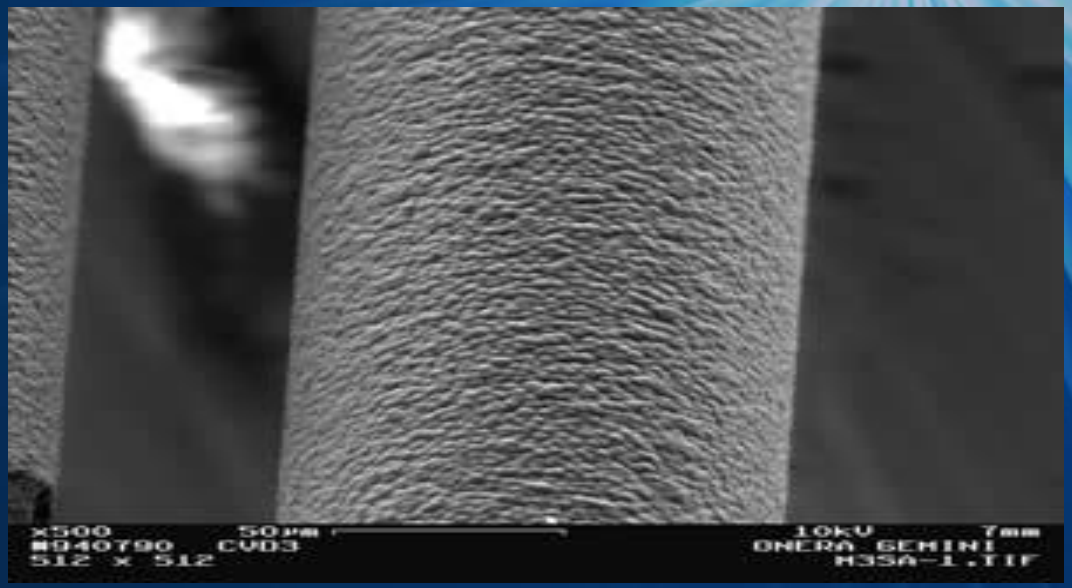
A sharp tip is scanned across a surface

Figure10: www.acsprf-ar.org/REPORTS/P9684.HTM

Advantages

- Samples do not need any special treatments because that causes irreversibly change or damage for the sample. Such as metal-carbon coatings.

- Sample preparation is easy.

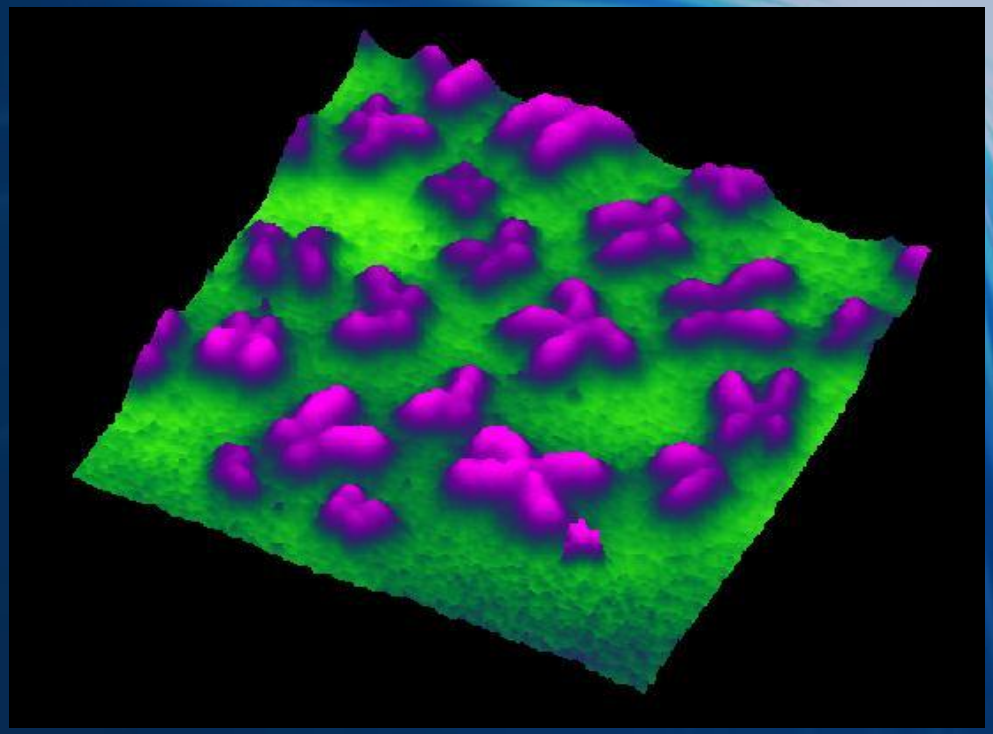


Carbon coating on the metal

Figure11: www.onera.fr/.../images/carbone-meb-02.jpg

Advantages

❖Most of AFM types can work perfectly well in ambient air or even a liquid environment. This makes it possible to study biological macromolecules and even living organisms.

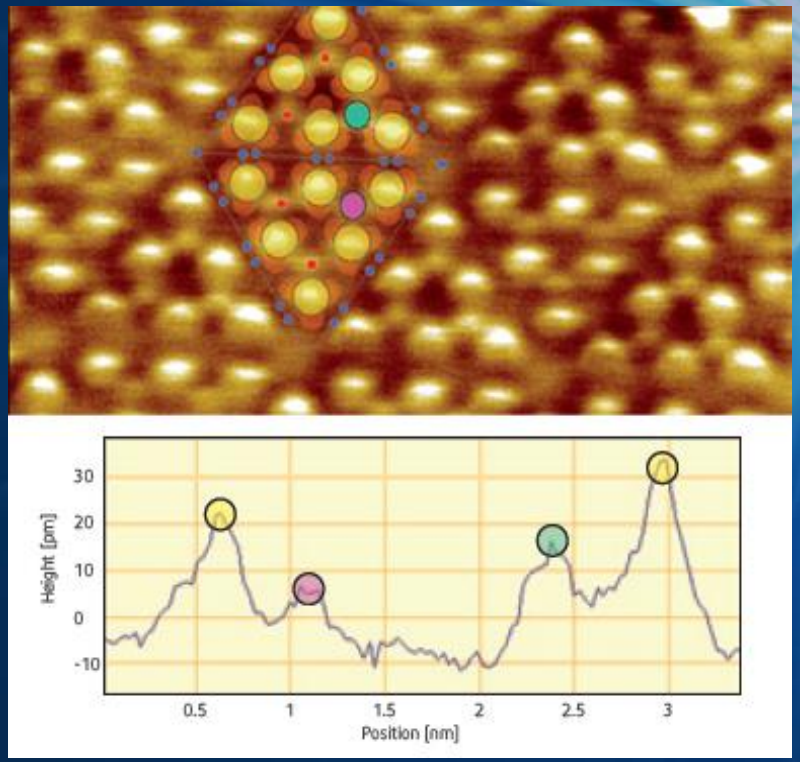


Application of atomic force microscopy

Figure12: www.nanopicoftheday.org/images/ChromosomeAFM.jpg

Advantages

❖AFM can provide higher resolution. It has been shown to give true atomic resolution in ultra-high vacuum (UHV).



Imaging of rest atoms of the Si surface with Q Plus AFM in an Omicron VT at 50 K .

Line profile showing the height difference of the rest atoms.

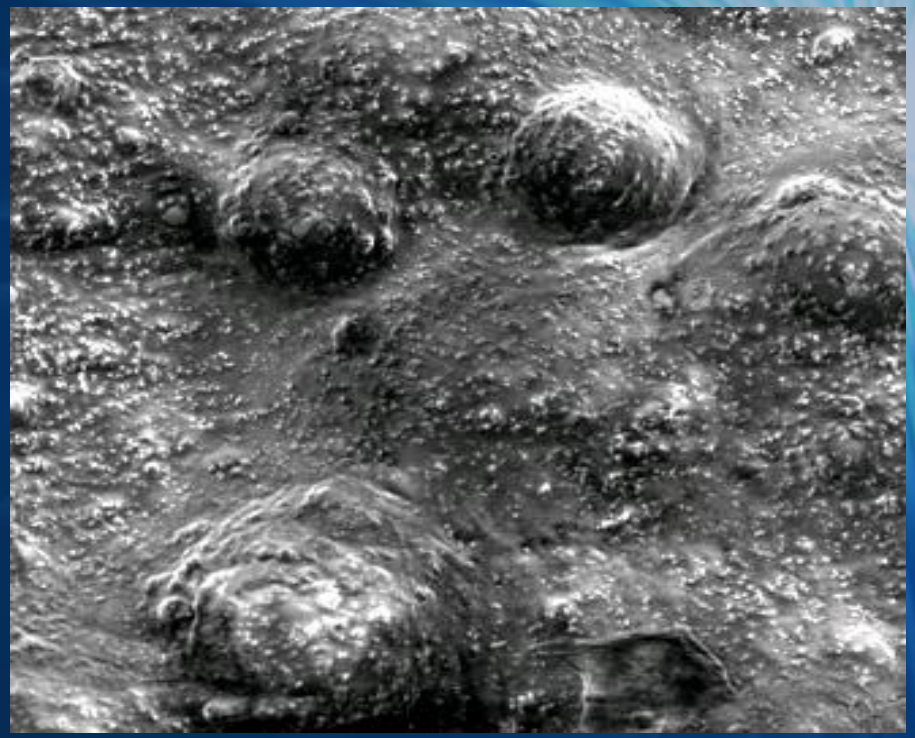
Figure13: www.omicron.de/index2.html?/results/beam_deflection_afm_qplus/index.html~Omicron

Disadvantages

- AFM has a limited vertical range
- Also it has a limited magnification range
- AFM probes cannot normally measure too high walls or overhangs.
- Datas are not independent of tip. Incorrect choice of tip for the required resolution can lead to image artifacts.
- Traditionally the AFM could not scan images as fast as the SEM.

Disadvantages

- The major disadvantages of AFM is the image size when compared with the scanning electron microscope (SEM).

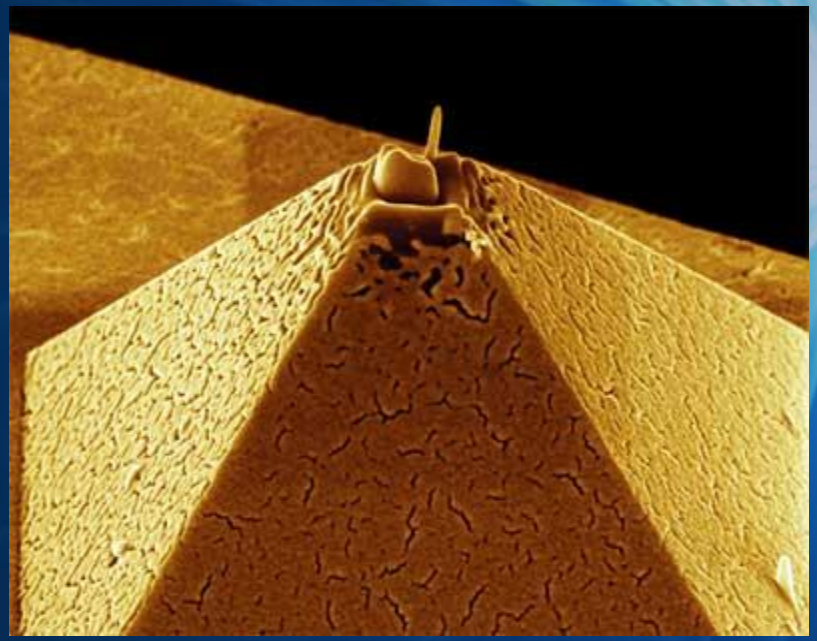


- The SEM can image an area on the order of millimeters by millimeters with a depth of field on the order of millimeters. The AFM can only image a maximum height on the order of micrometers and a maximum scanning area of around 150 by 150 micrometers.

Figure14: www.lucasict.nl/.../buiten_500x%20330%20x330.jpg

Disadvantages

- Tip or sample can be damaged



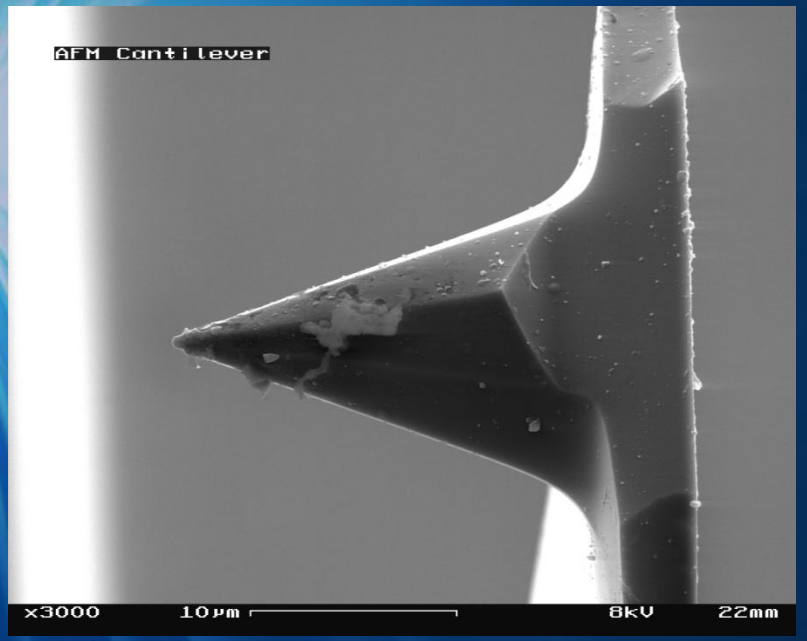


Figure15: nanobano.files.wordpress.com/.../id1456_23.jpg

Figure16:upload.wikimedia.org/wikipedia/commons/a/a6/A...

Conclusion

Atomic force microscopy (AFM) : measuring of the force on the probe

AFM was born in 1986: Gerd Binning and co-workers.

- **Versatile techniques due to the *multitude of interactions* that can be probed**
- **Operates in *most environments***
- **Can *image* various properties and *manipulate* the sample on the nano-scale**
- **High resolution *force measurements* are important in many scientific fields**

Conclusion

Atomic Force Microscopy (AFM)

- ❖Probe can touch the surface.
- ❖Maintains a constant very small force.
- ❖High resolution (x-y:2-10 nm.z:0.1 nm)
- ❖Suitable for all surfaces.

Scanning Tunneling Microscopy(STM)

- ❖Probe does not touch the surface
- ❖Maintains a constant tunnelling electrical current
- ❖Very high resolution (x-y:0.1nm,z:0.01nm)
- ❖Limiting the conducting materials.

STM: better resolution but limited to conducting materials
AFM: worse resolution but all types of surfaces

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~THANK YOU ~

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