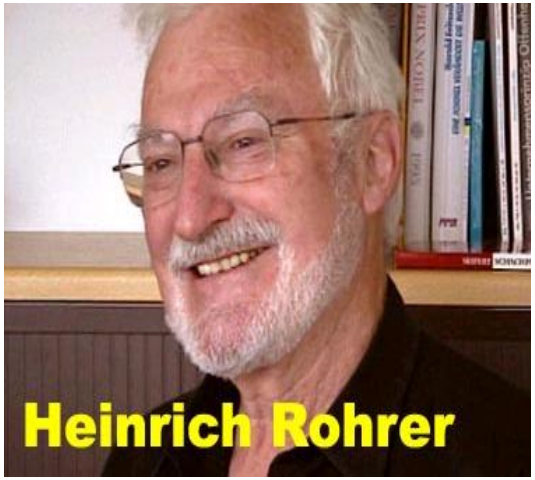
Introduction

Invented by Binnig and Rohrer at IBM in 1981 (Nobel Prize in Physics in 1986).



- Binnig also invented the Atomic Force Microscope(AFM) at Stanford University in 1986.

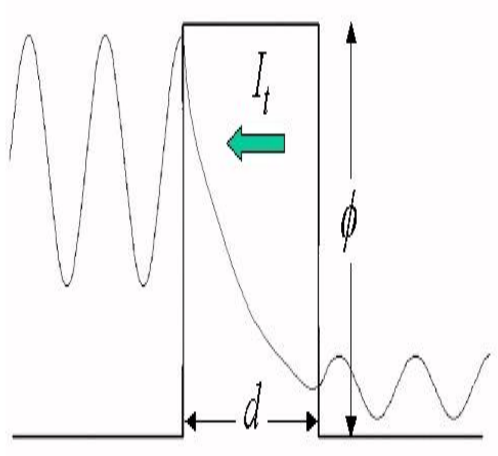
- First instrument to give 3-D images of solid surface with atomic resolution.

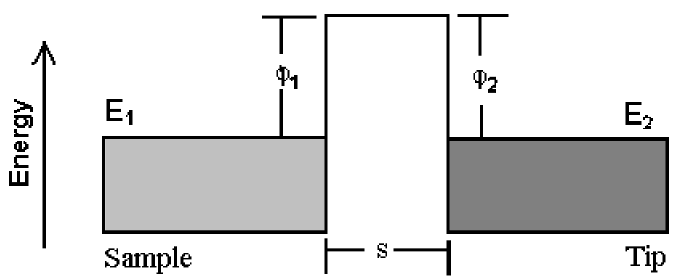
- Formation of nanofeauters by localised heating or inducing chemical reactions.

- Magnification 10^3 to 10^9 in x,y, and z directions with high resolution.

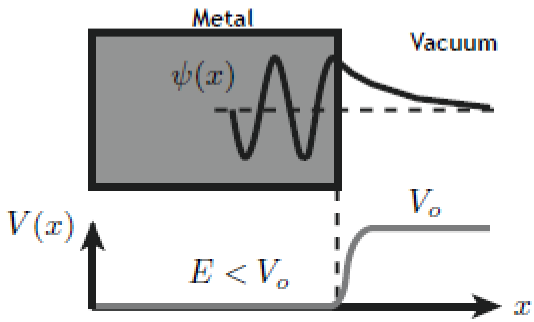
Theory and Principle

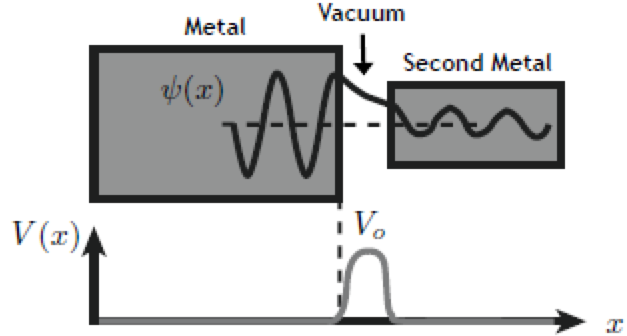
- STM employs principle of electron tunneling.
- The quantum mechanical equation assign a non zero probability for an electron to tunnel through the barrier even if its energy is less than the potential of barrier.
- Two metals must be separated by a space of not more than 10nm.
- Tunneling current decreases exponentially with separation between tip and sample.

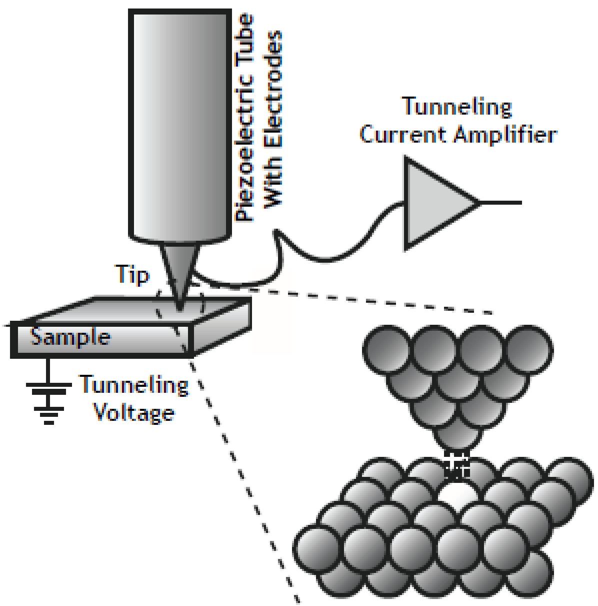




Application: Scanning Tunneling Microscopy







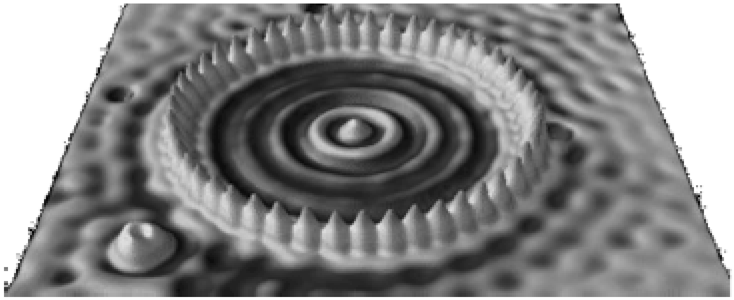
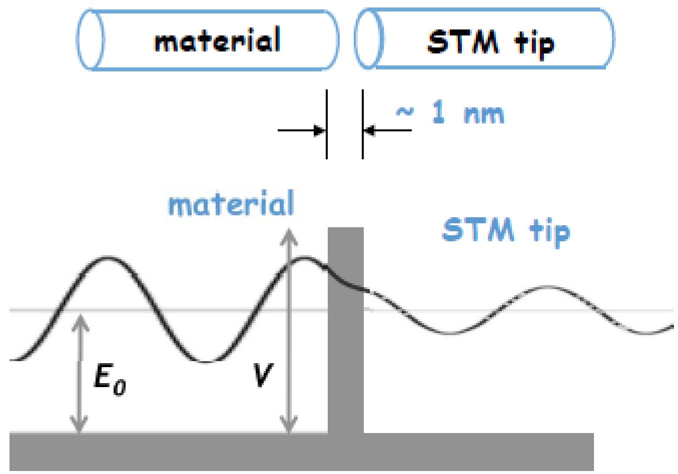


Image originally created by IBM Corporation.

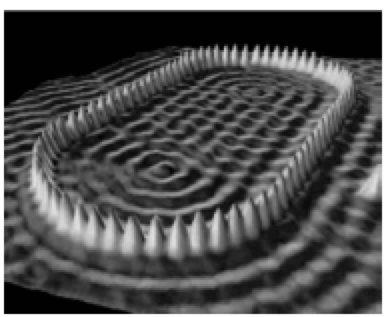
Scanning Tunneling Microscopy (STM)

Due to the quantum effect of "barrier penetration," the electron density of a material extends beyond its surface:

One can exploit this to measure the electron density on a material's surface:



Sodium atoms on metal:



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STM images

DNA Double Helix:

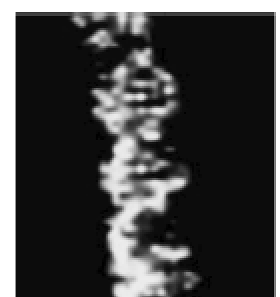
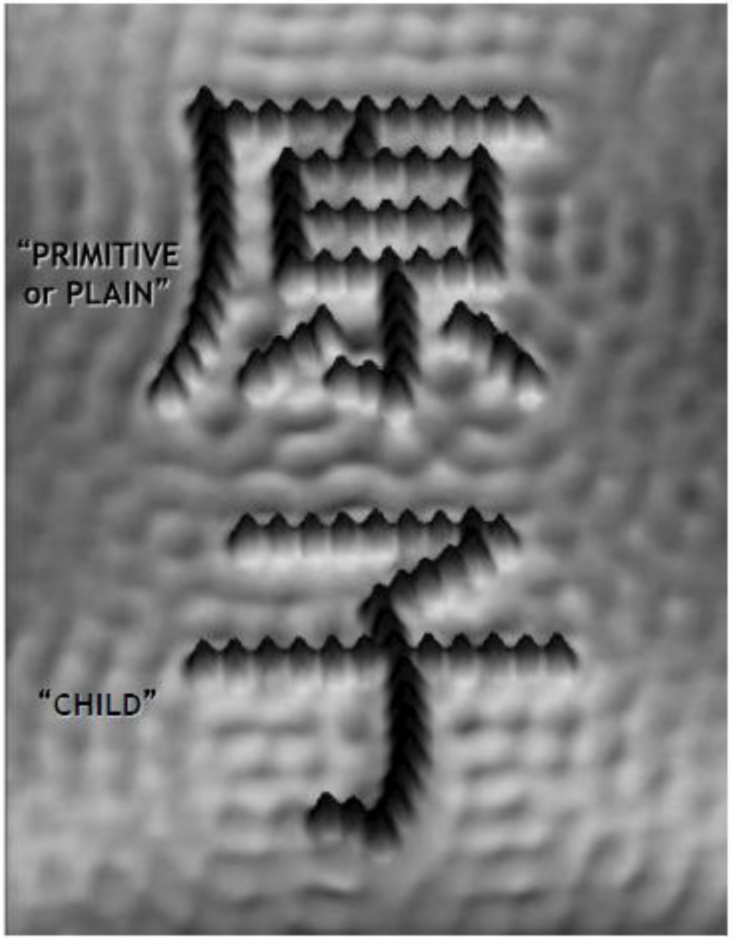
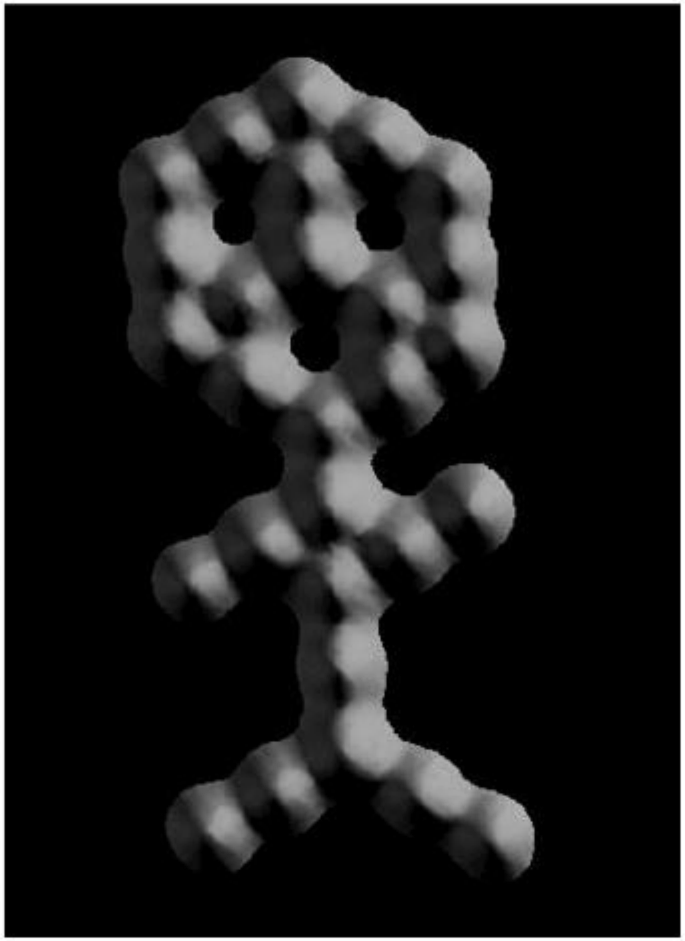


Image by Wolfgang Schonert of GSI Biophysics Research Group

Courtesy of Wolfgang Schonert, GSI. Used with permission.



= "ATOM"

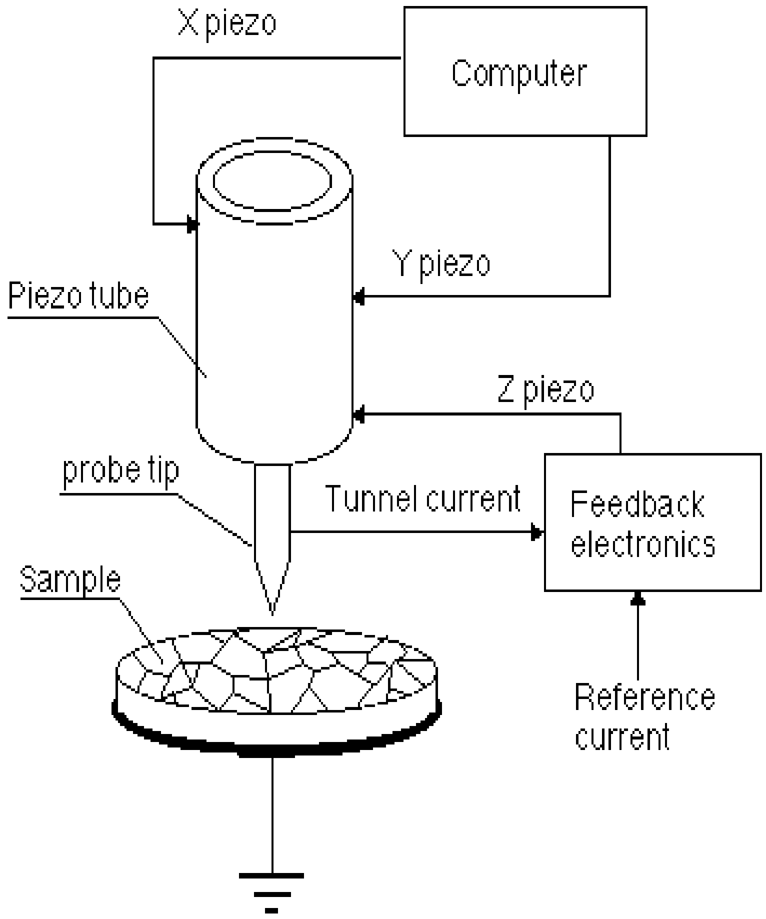


Images originally created by IBM Corporation.

Experimental methods

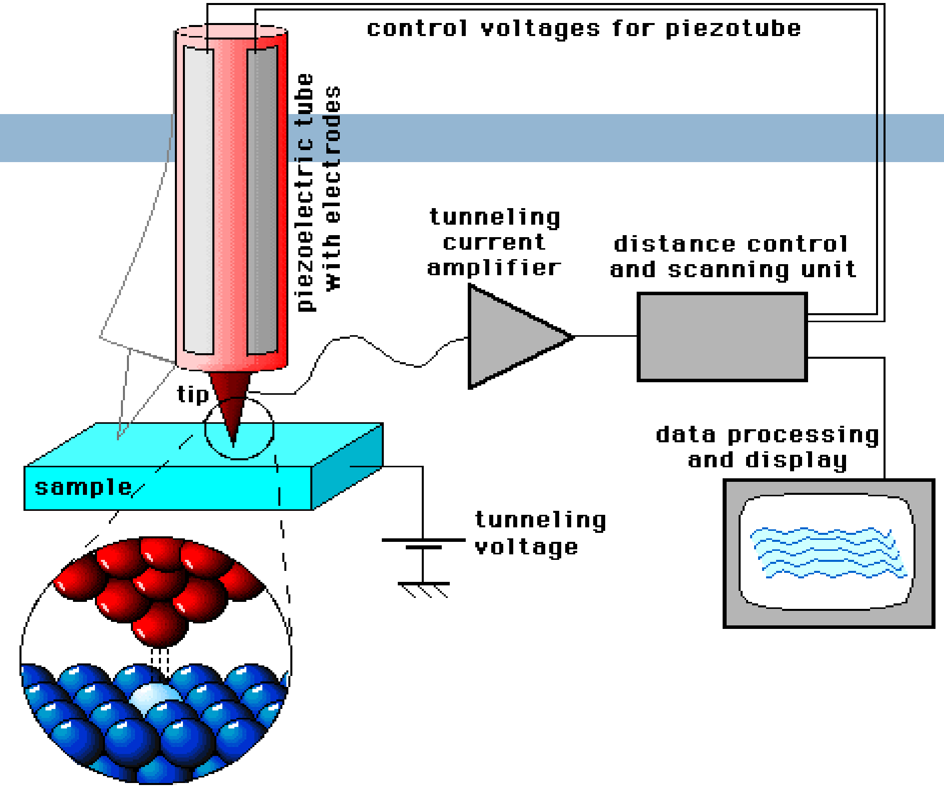
Basic Set-up

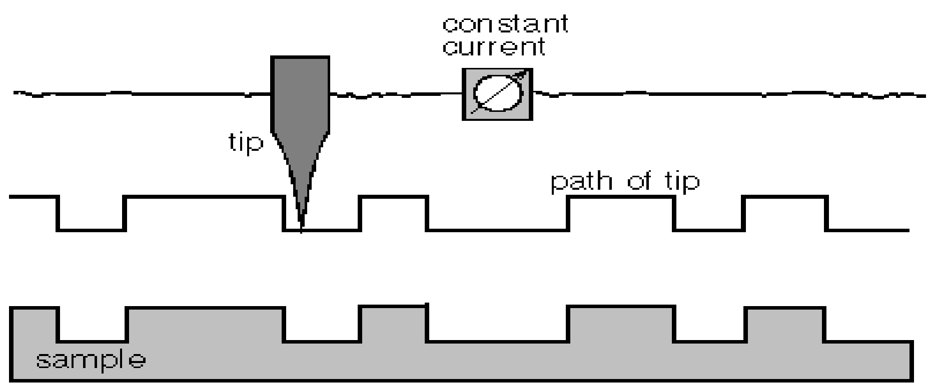
- the *sample* you want to study
- a sharp metal *tip* mounted on a piezoelectric crystal tube to be placed in very close proximity to the sample
- a mechanism to control the location of the tip in the x-y plane parallel to the sample surface
- a *feedback* loop to control the height of the tip above the sample (the z-axis)



How to operate?

- Raster the tip across the surface at a distance of 0.3-1nm. While the current between the tip and sample surface is measured. And using the current as a feedback signal.
- The tip moves over the sample with its height being adjusted continuously to keep tunneling current constant.
- Tip position is monitored to map the surface topography of the sample.





- Tip- tungsten or PtIr alloy is used.
- Tip movement in 3-D is controlled by piezoelectric arrays.
- The distance between tip and sample is between 0.2 and 0.6nm which produces a tunneling current of about 0.1-10nA.
- Spatial resolution is 0.01nm in x and y directions. And about 0.002nm in z-direction giving a true atomic resolution image in 3-D.

Modes of Operation

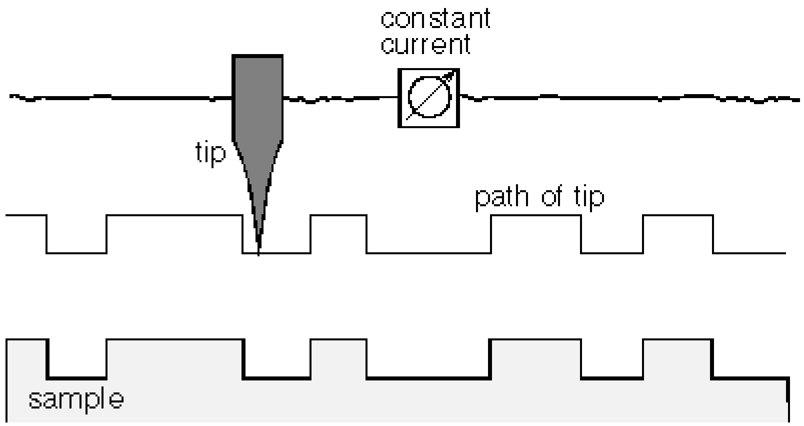
- ***Constant current***
  - Constant current is maintained between tip and sample.
  - Vertical position of the tip is changed to maintain a constant current between the two.

Advantages:

- Provides excellent surface topographic contrast of the surface atom contours.

Disadvantage:

- Slower scan rate.

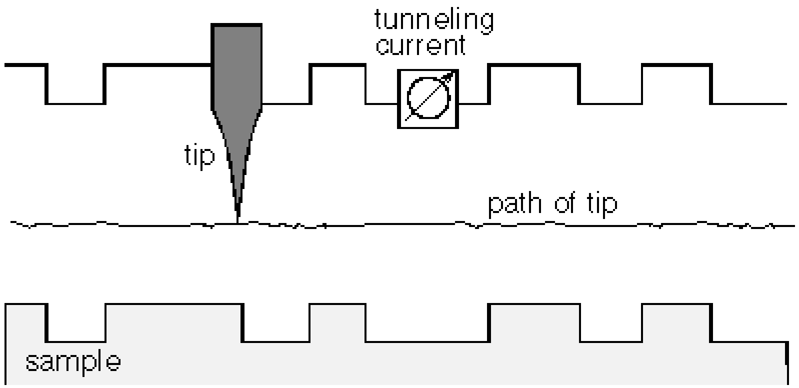


***Constant height mode*:**

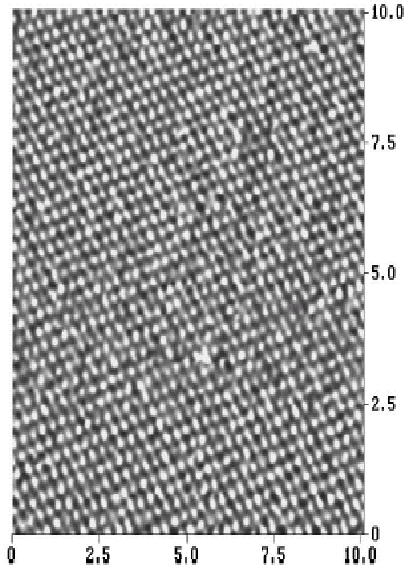
- Distance between tip and sample is kept constant.
- Constant tip position results in variations in tunneling current.

***Advantage*:**

- faster scan rate possible



Imaging the structure of electrode surface



- STM images of the Au(111) electrode surface

Concluding remarks

- STM is one the most powerful imaging tools with an unprecedented precision.

- Disadvantage of STM:

1. Making atomically sharp tips remains something of a dark art.
2. External and internal vibrations from fans, pumps, machinery, building movements, etc. are big problems.
3. UHV-STM is not easy to built and handle
4. The STM can only scan conductive surfaces or thin nonconductive films and small objects deposited on conductive substrates. It does not work with nonconductive materials, such as glass, rock, etc.
5. The spatial resolution of STM is fantastic, but the temporal resolution is typically on the order of seconds, which prevents STM from imaging fast kinetics of electrochemical process.