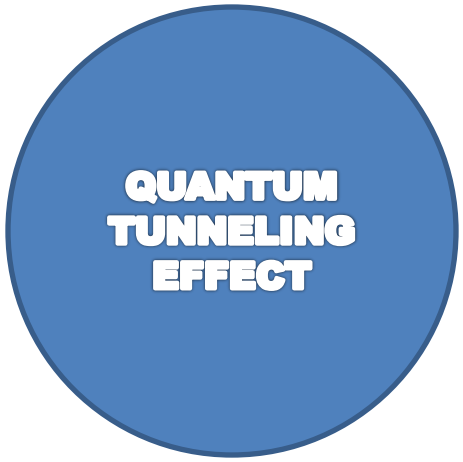
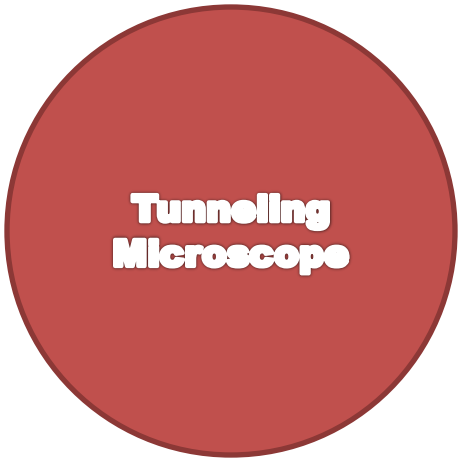
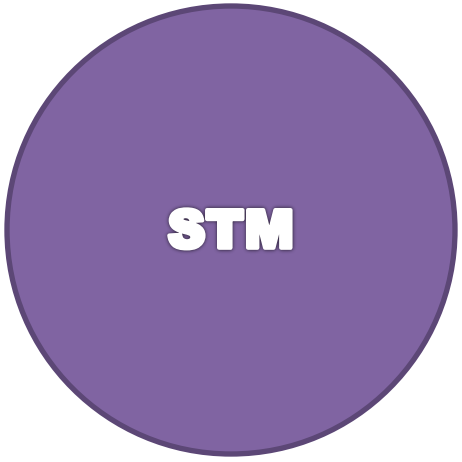
Scanning Tunneling Microscope (STM)


QUANTUM
TUNNELING
EFFECT


Tunneling
Microscope


STM

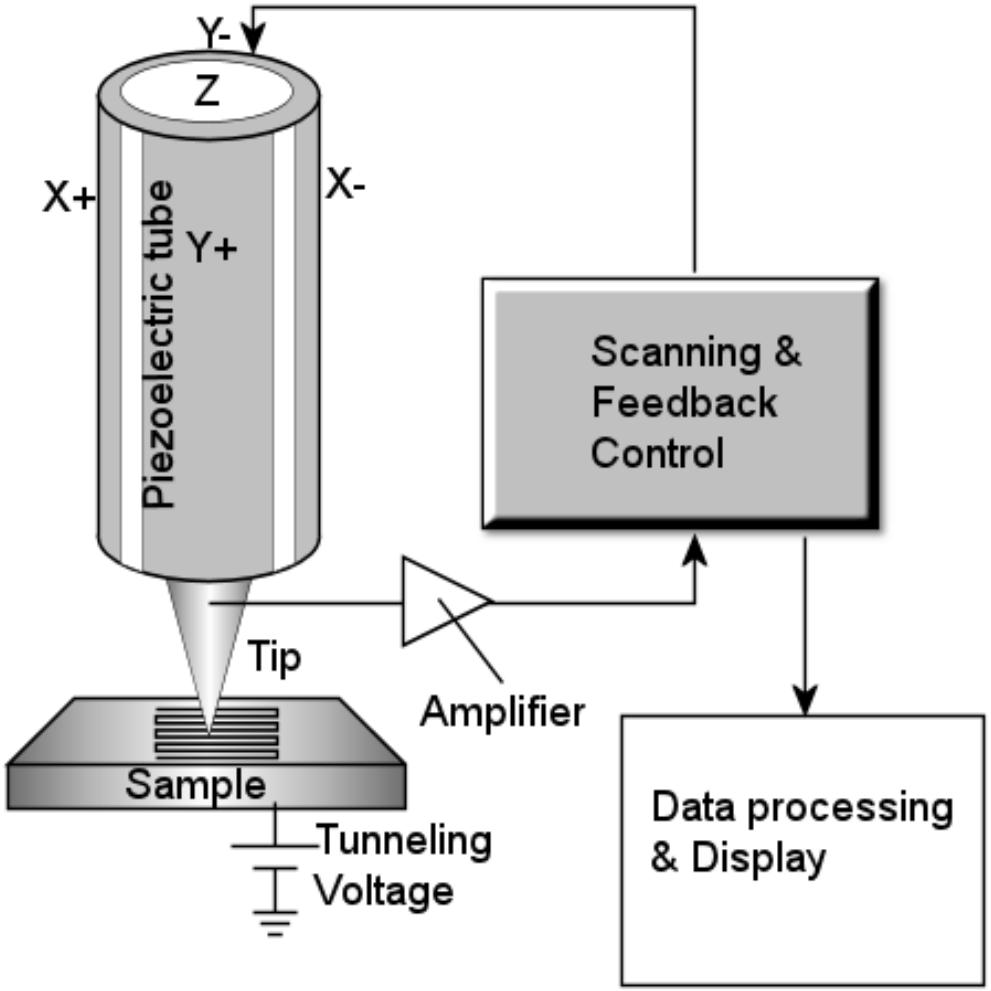
Why STM ?

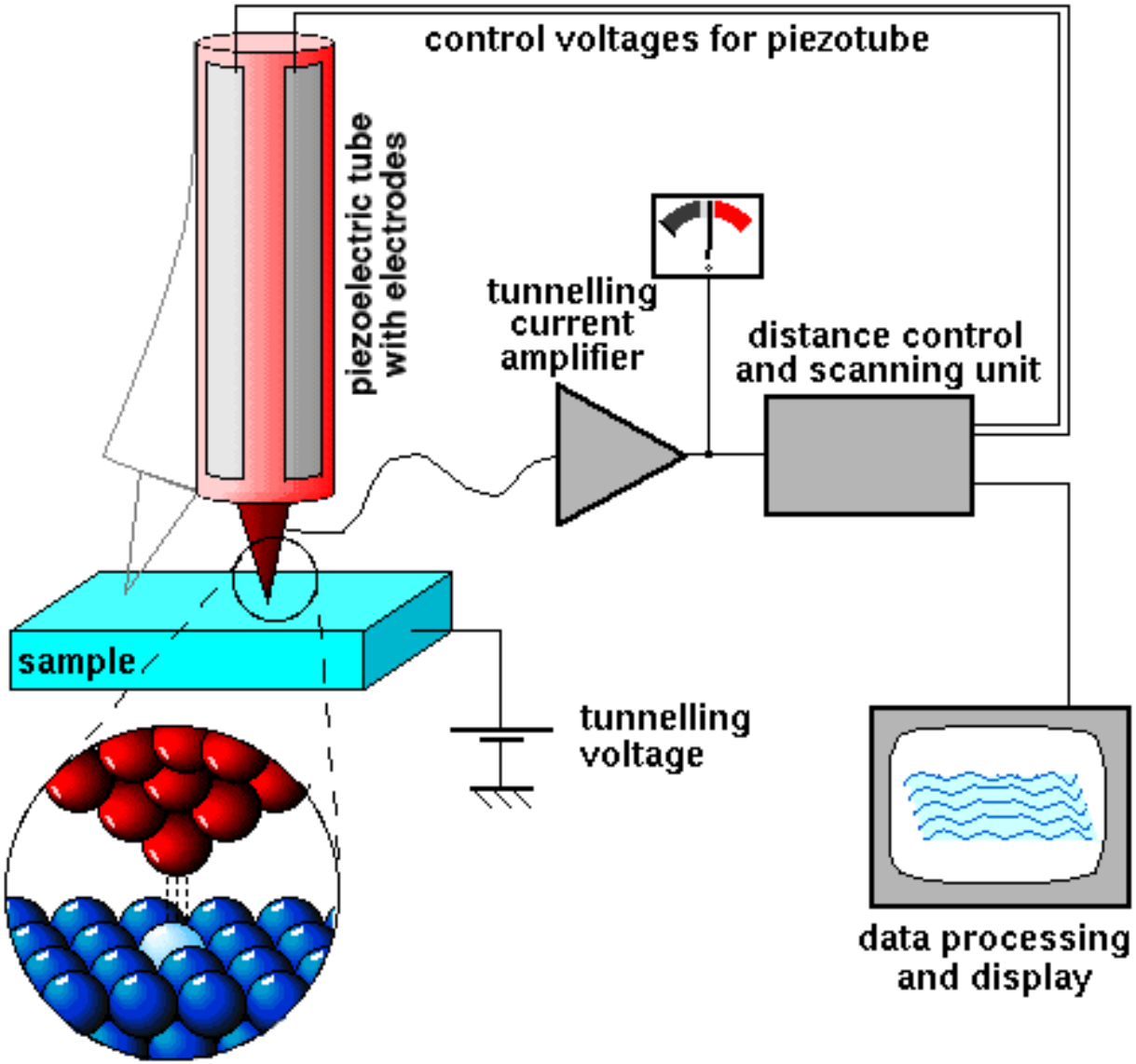
- **The electronic microscopes gives 'volume images' (penetration depth)**
- **In STM-no use of external particles**
- **Principle-Electrons tunneling between an atomically sharp tip and a surface**

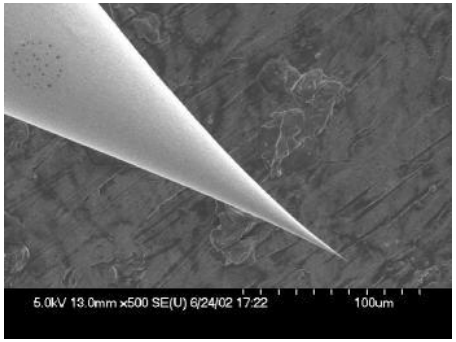
The STM combines three main concepts:

- ***Scanning***
- ***Tunneling***
- ***Tip-point probing***

STM System Components



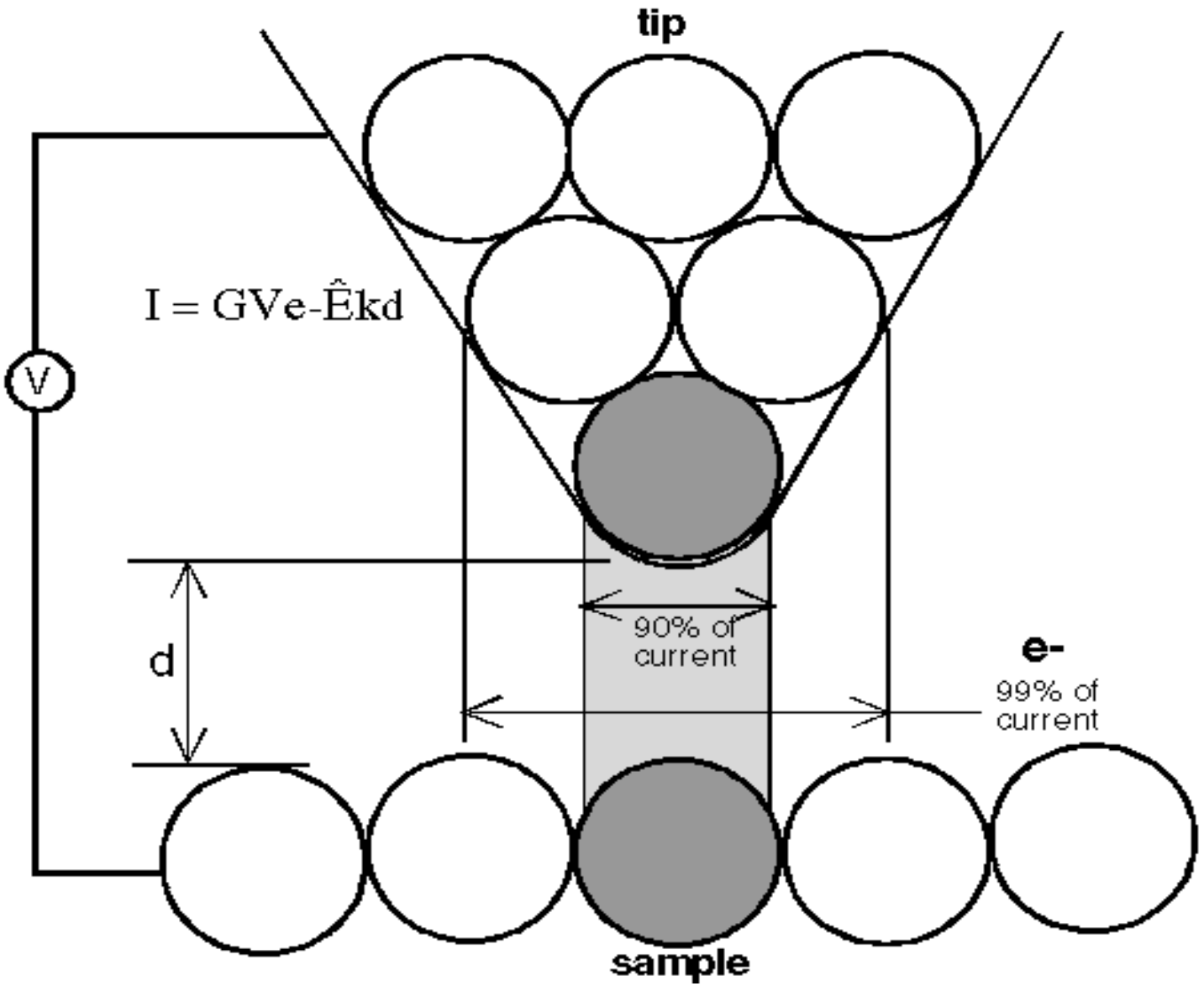

control voltages for piezotube
piezoelectric tube with electrodes
tunnelling current amplifier
distance control and scanning unit
sample
tunnelling voltage
data processing and display


5.0kV 13.0mm x500 SE(U) 6/24/02 17:22
100um

- **In STM - Bias voltage is applied between a sharp conductive tip and a conductive sample.**

- **Sample is approached to a few angstroms from the tip, tunneling current occurs, that indicates proximity of the tip to the sample with very high accuracy.**

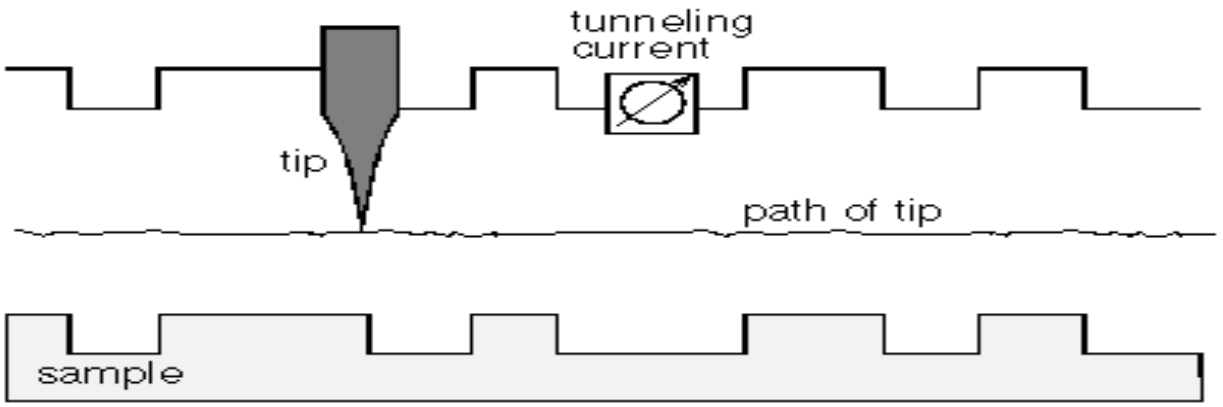
- **Scanning tunneling microscopy can be used to study conductive surfaces or thin nonconductive films and small objects deposited on conductive substrates.**


tip
I = GVe-Êkd
V
d
90% of
current
e-
99% of
current
sample

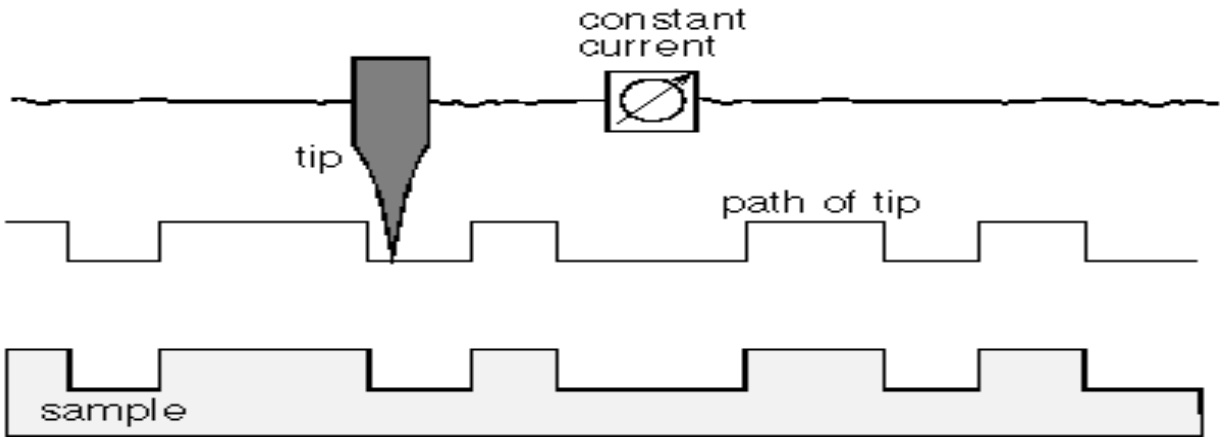
Operating modes

- Constant height mode
  - Current changes exponentially
  - Requires a smooth surface
- Constant current mode
  - Beware of insulators

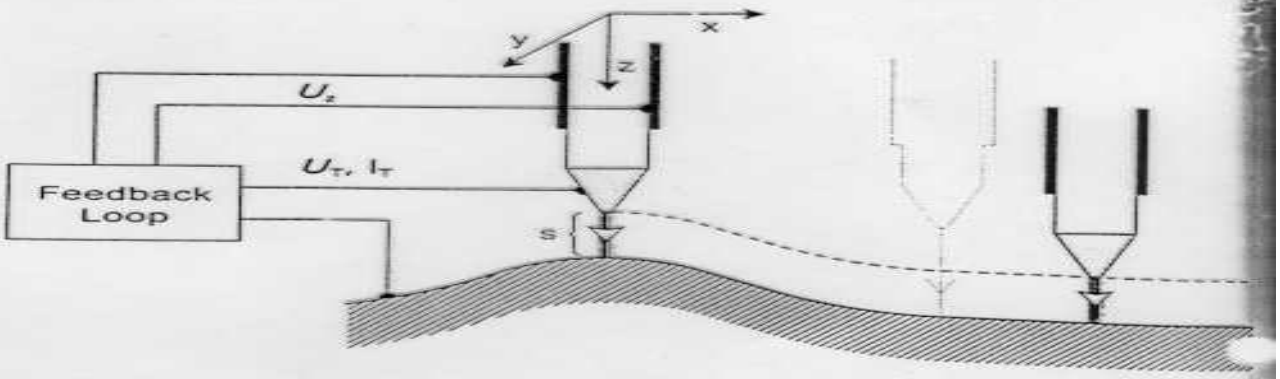
Constant height mode



Constant Current mode



(a) Constant Current Mode



(b) CONSTANT CURRENT MODE

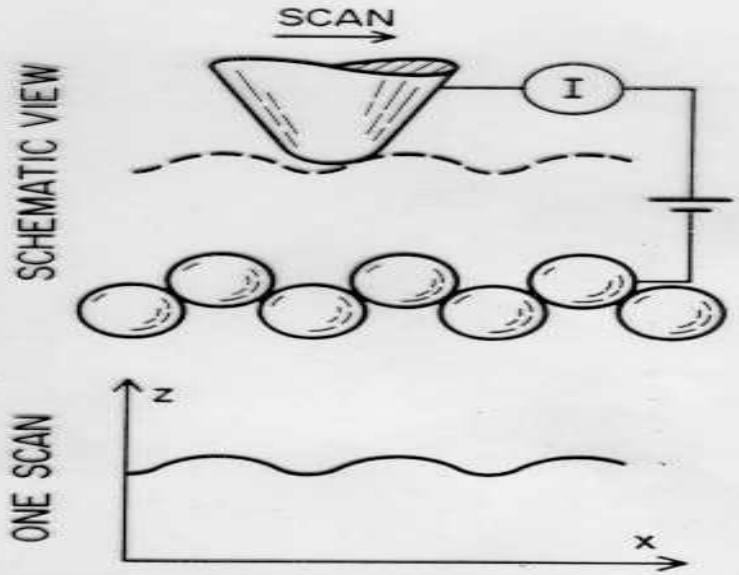


Fig. 1.60. Schematic illustration of the constant current mode of STM operation (Binnig and Rohrer, 1987; Hansma and Tersoff, 1987).

Advantages

- No damage to the sample
- Vertical resolution superior to SEM
- Spectroscopy of individual atoms
- Relatively Low Cost

Disadvantages

- Samples limited to conductors and semiconductors
- Limited Biological Applications: AFM
- Generally a difficult technique to perform

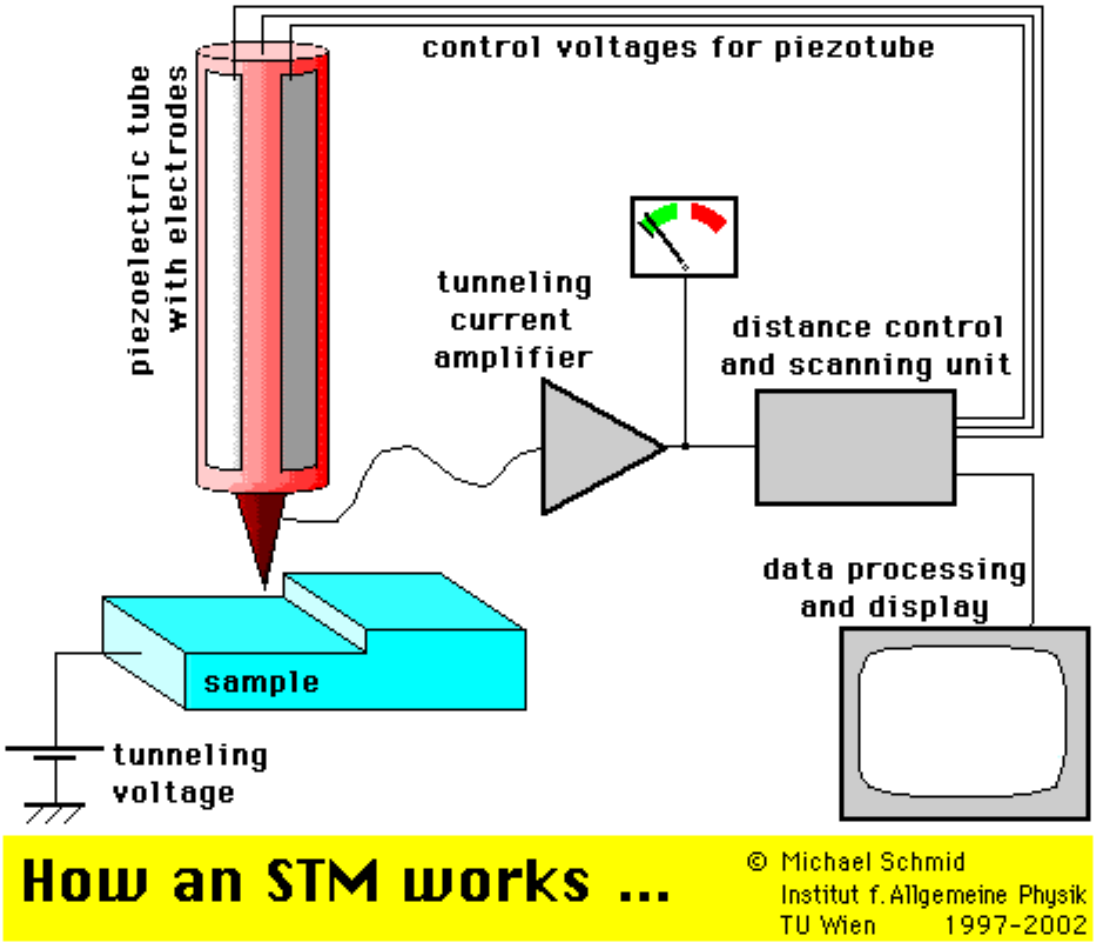
Figures of Merit

- Maximum Vertical Resolution: .1 Å
- Maximum Lateral Resolution: 1 Å
- Maximum Field of View: 100 μm

Applications of STM

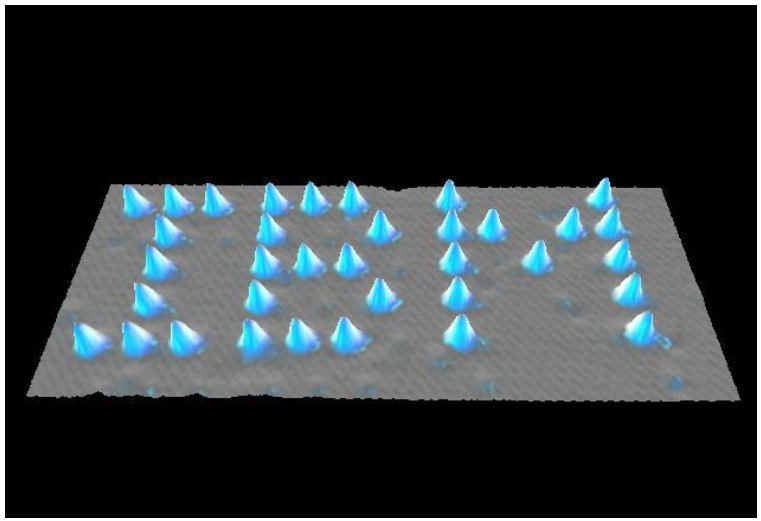
- Surface Structure: Compare to bulk structure
- Stuff Physicists Do: Semiconductor surface structure, Nanotechnology, Superconductors, etc.
- Metal-catalyzed reactions
- Spectroscopy of single atoms
- Limited biological applications: Atomic Force Microscopy
- Future Developments: Improve understanding of how electronic structure affects tunneling current, continue to develop STM offshoots

Scanning Tunneling Microscope (STM) 1981 Binnig and Rohrer

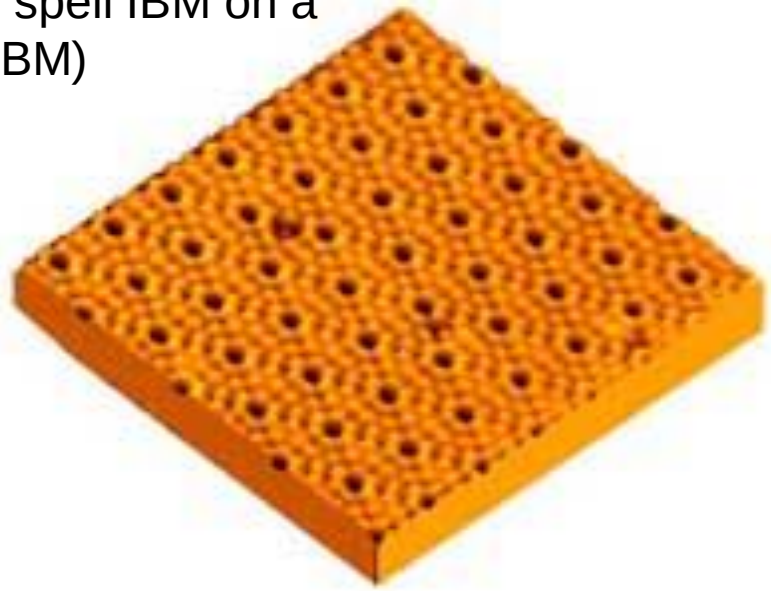


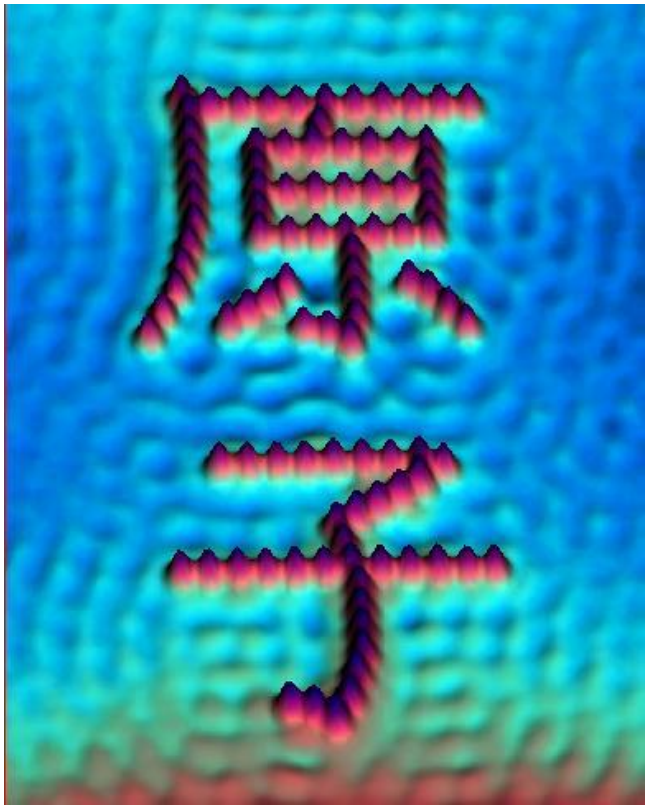
The STM can obtain images of conductive surfaces at an atomic scale of 0.2 nm, and also can be used to manipulate individual atoms, trigger chemical reactions, or reversibly produce ions by removing or adding individual electrons from atoms or molecules.

STM allows manipulation of individual atoms (1989)



Xenon atoms spell IBM on a nickel plate (IBM)





Iron atoms spell “Atom” on copper in Kanji characters. (IBM)