檢測技術 I

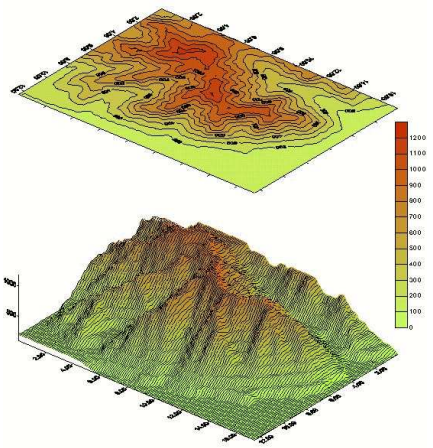
掃瞄探針顯微術

Scanning probe microscope 分類

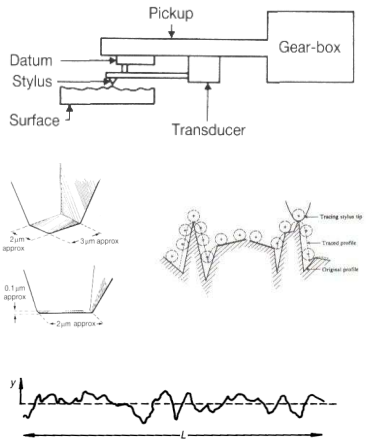
- Scanning tunneling microscope (STM, 掃瞄穿遂顯微鏡)
- Atomic force microscope (AFM, 原子力顯微鏡)
- Near-field scanning optical microscope (NSOM, 近場光學顯微鏡)

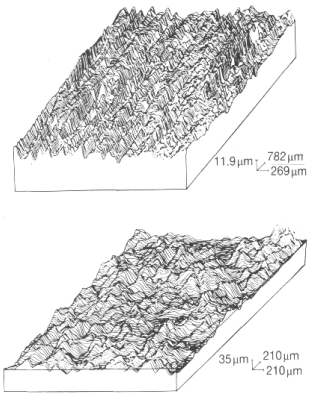
What is SPM good for?

- AFM is a tool for detecting **Surface Topography.**
- Flat, solid surfaces with small (<1um) features make suitable specimens.
- Length and height measurements are possible and relatively precise (compared to scanning electron microscopy).



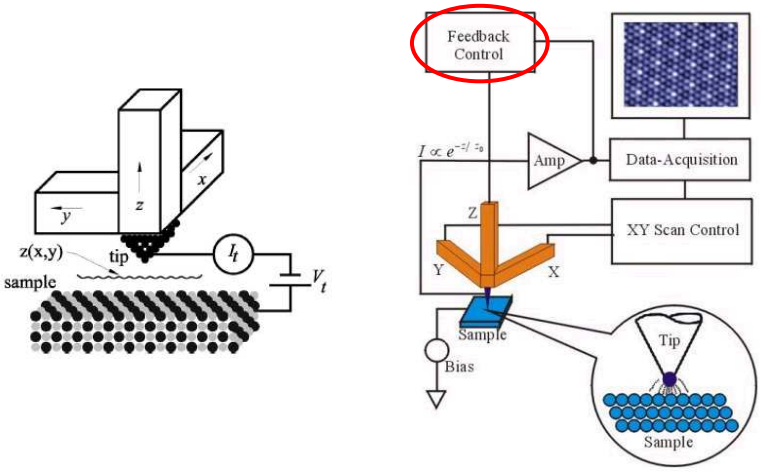
前身 surface stylus profiler





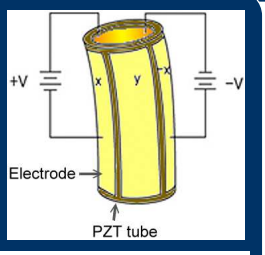
Images from Hutchings, *Tribology* (1992) and Thomas, *Rough Surfaces* (1999).

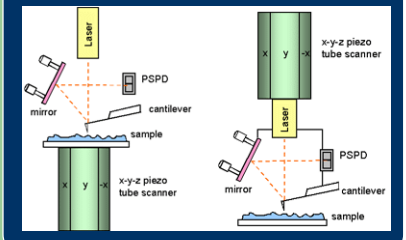
成像原理



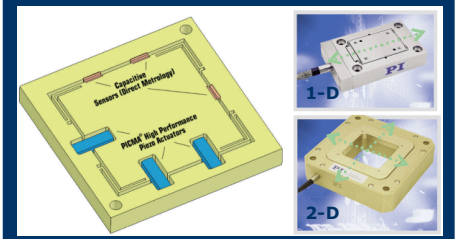
Fine positioner

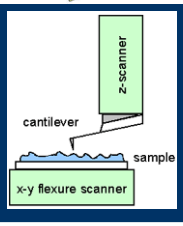
Piezo tube





Flexure Stage

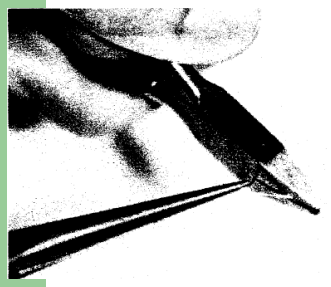


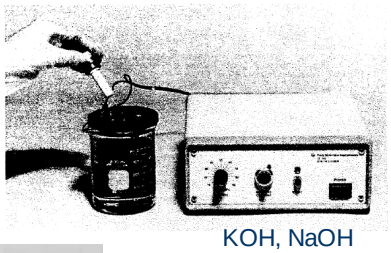


- X-Y plane and Z axis orthogonal
- Faster response
- More robust

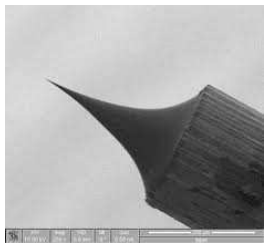
Conductive tip for STM

- Tip material: W, PtIr





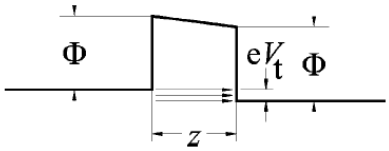
KOH, NaOH



From mse.engin.umich.edu

Tunneling effect

$$I_t(z) = I_0 e^{-2\kappa_t z}$$

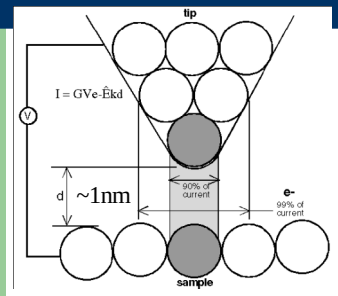


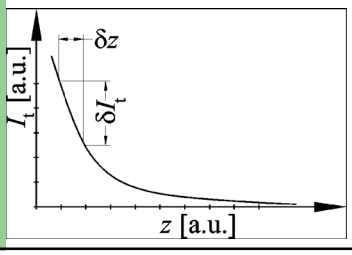
where I_0 is a function of the applied voltage and the density of states in both tip and sample and $\kappa_t = \sqrt{2m\Phi/\hbar}$

For metals, Φ= 4eV, thus κ_t~ 1Å^{-1}. When z is increased by one angstrom, the current drops by an order of magnitude.

STMs cannot image insulating materials.

Tunneling effect





I is an exponential function of z.

⬇

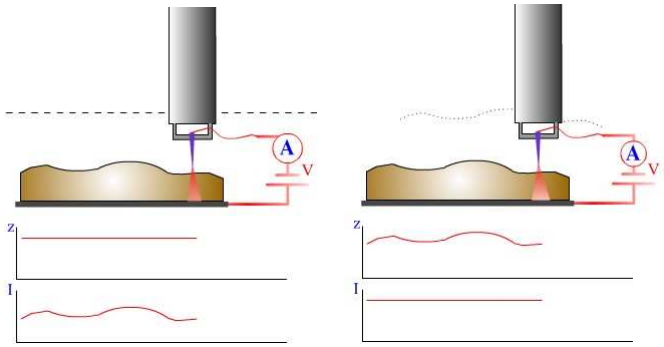
Sensitivity along z ⬆

⬇

sub-angstrom precision vertically
(atomic resolution laterally)

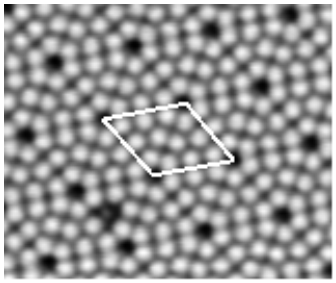
Imaging principle

- Constant height mode
- Constant current mode



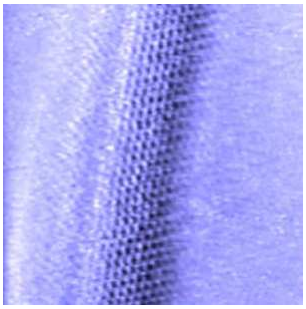
From NT-MDT

Si(111) 7x7 surface



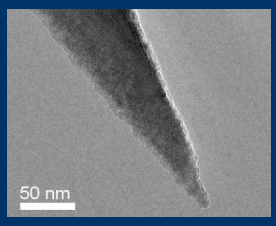
Carbon nanotube

- STM image of carbon nanotube deposited on HOPG substrate. Atomic structure of nanotube is clearly visible.

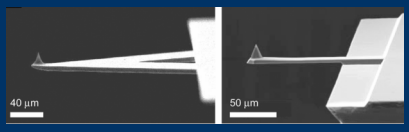


From NT-MDT

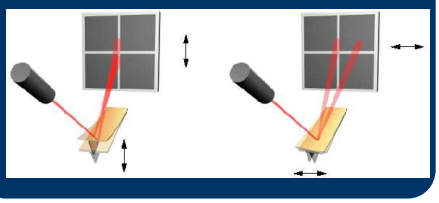
Tip and Cantilever for AFM



- Sharp tip → Small contact area
- mN/µN loads would destroy the tip, or indent the specimen
- Mechanism for pN~nN loads needed!



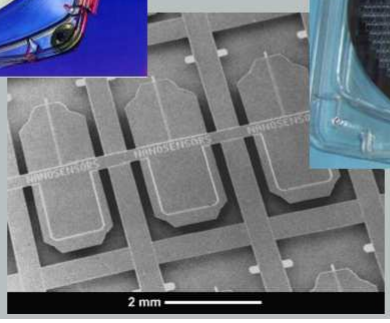
- Microfabricated Si/Si3N4 structures
- Bending can be detected by laser reflection.



General remarks - Batch Fabrication

NANO WORLD
INNOVATIVE TECHNOLOGIES

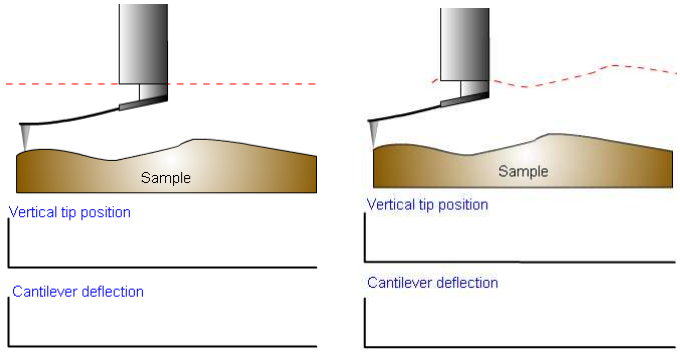
4-inch wafer
with 388 probes



6-inch wafer with more
than 1000 probes

Imaging principle

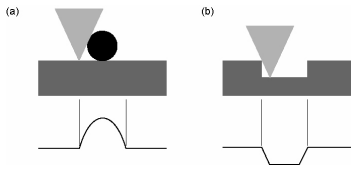
- Constant height mode (Z servo off) ➔ error signal
- Constant force mode (Z servo on) ➔ topography

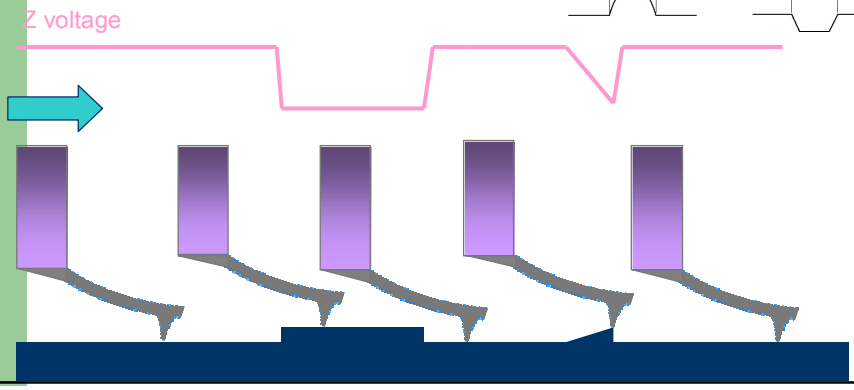


From NT-MDT

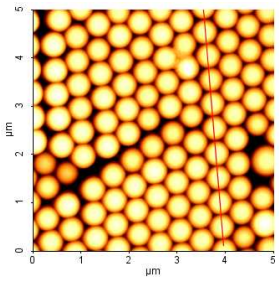
Contact AFM – constant force imaging

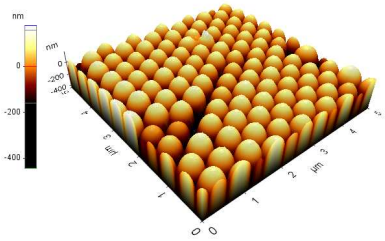
- Cantilever bending is kept constant.
- Z positioner voltage is recorded.

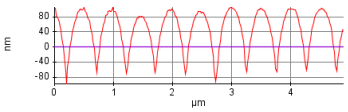




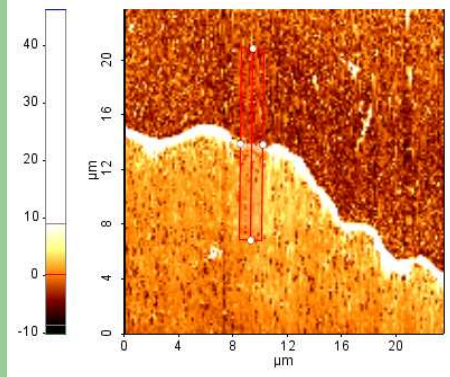
500nm nanospheres

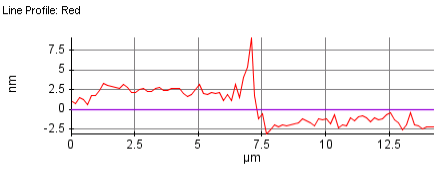


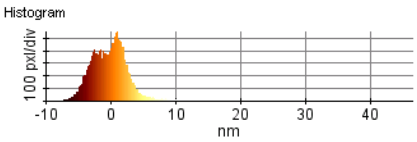




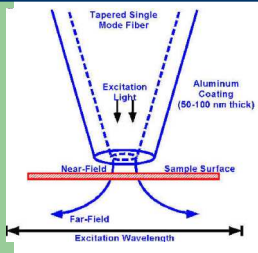
Step height

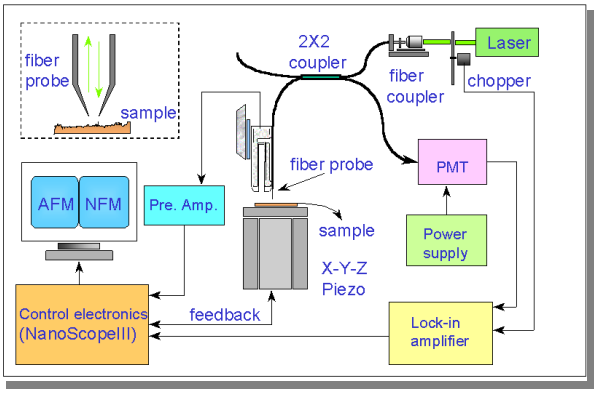






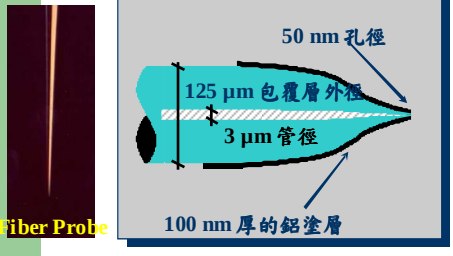
NSOM





Hollow tips for NSOM

- Fiber tip
- Nanofabricated AFM tip



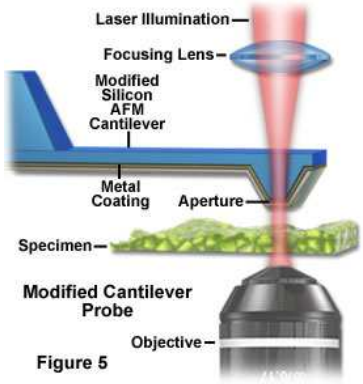
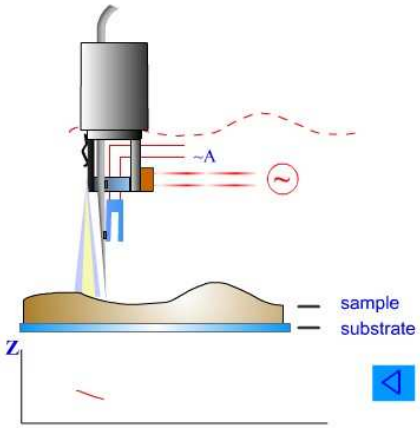


Figure 5

From Olympus

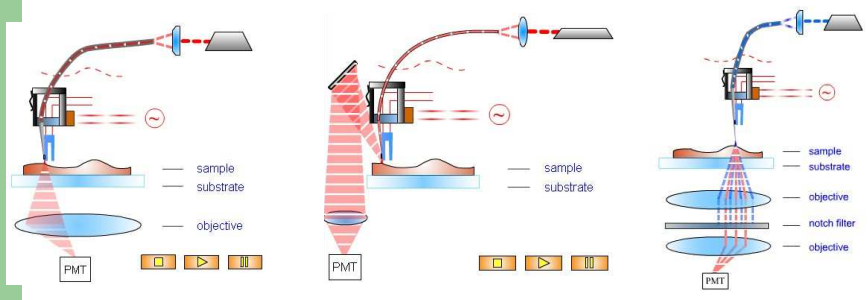
Shear force



From NT-MDT

Transmission mode

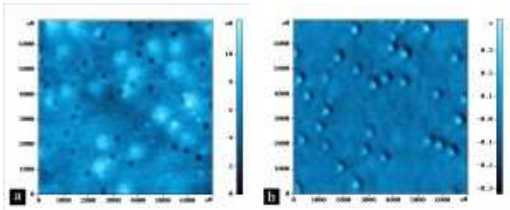
- Transmission mode
- Reflection mode
- Luminescence mode



From NT-MDT

Quantum dots

- Shear Force (topography) (a) and reflection (b) images of In-Ga quantum dots made with the use of He-Cd 442 nm laser.



From NT-MDT

延伸課程

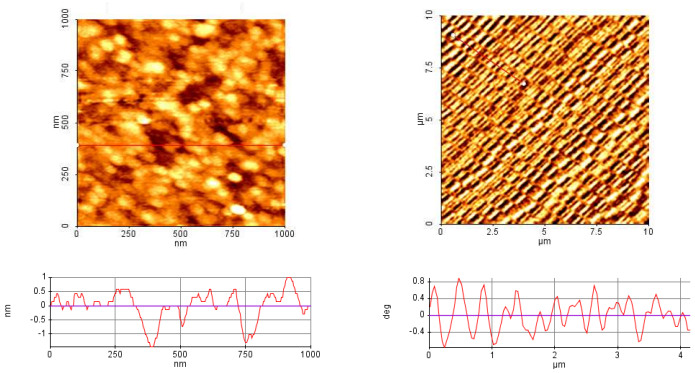
- 掃瞄探針顯微術(下學期, 大四碩一合授)
- 多功能掃瞄探針顯微鏡 (Park Systems XE-100)

contact AFM
non-contact AFM
lift-mode operation
phase detection
lateral force microscopy
force modulation microscopy
dynamic magnetic force microscopy
electrostatic force microscopy
dynamic-contact EFM
piezoresponse force microscopy
scanning Kelvin probe microscopy
high-voltage nanolithography

From Park Systems

Magnetic domains

- IBM deskstar 20GB HD



Ferroelectric domains

- $BiFeO_3$