Nanolitografías basadas en el uso del microscopio de fuerzas

Scanning Probe Lithographies

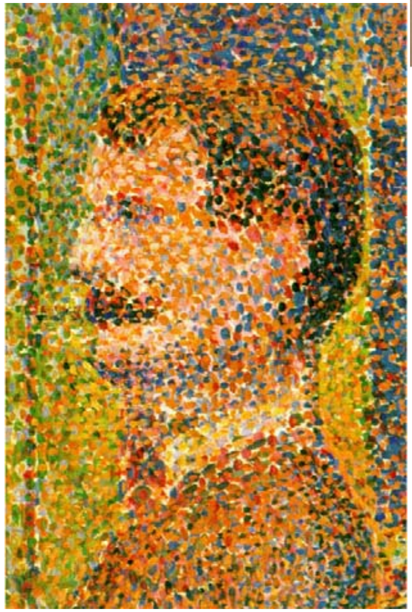
Scheme

- Introduction AFM (10 minutes)
- Overview Scanning Probe Lithographies (SPL) (40 m.)
- Applications (20 m)
- Summary (5 minutes)
- Questions (15 m.)

Top-down and Bottom-up approaches in Nanotlithography

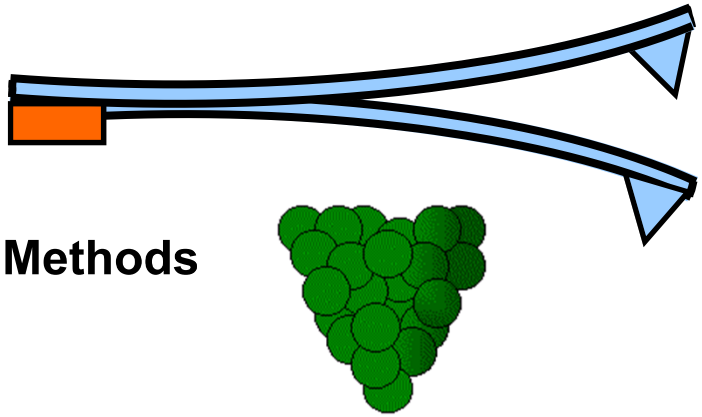
Top-down y Bottom-up en Arte

Miguel Angel Bunarroti, David (1504)



Georges Seurat, La Parade (1889)

Dynamic Atomic Force Microscopy

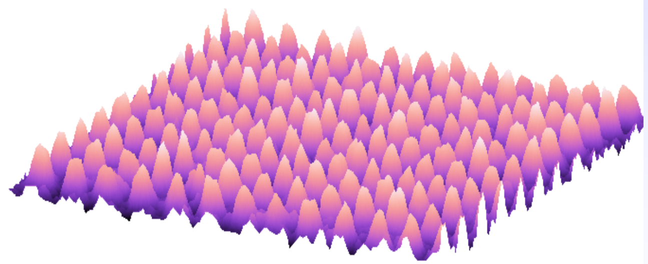


i). Introducción

Invention of Scanning Probe Methods

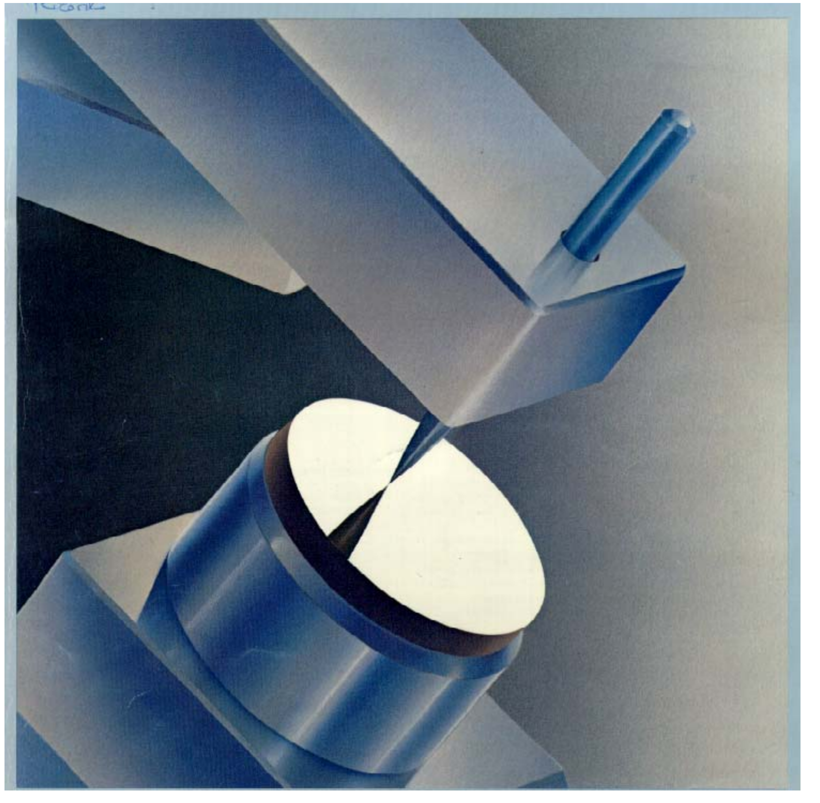
ii). Forces and Dynamics

iii). Basics of AFM



Ricardo García

Instituto de Ciencia de Materiales de Madrid



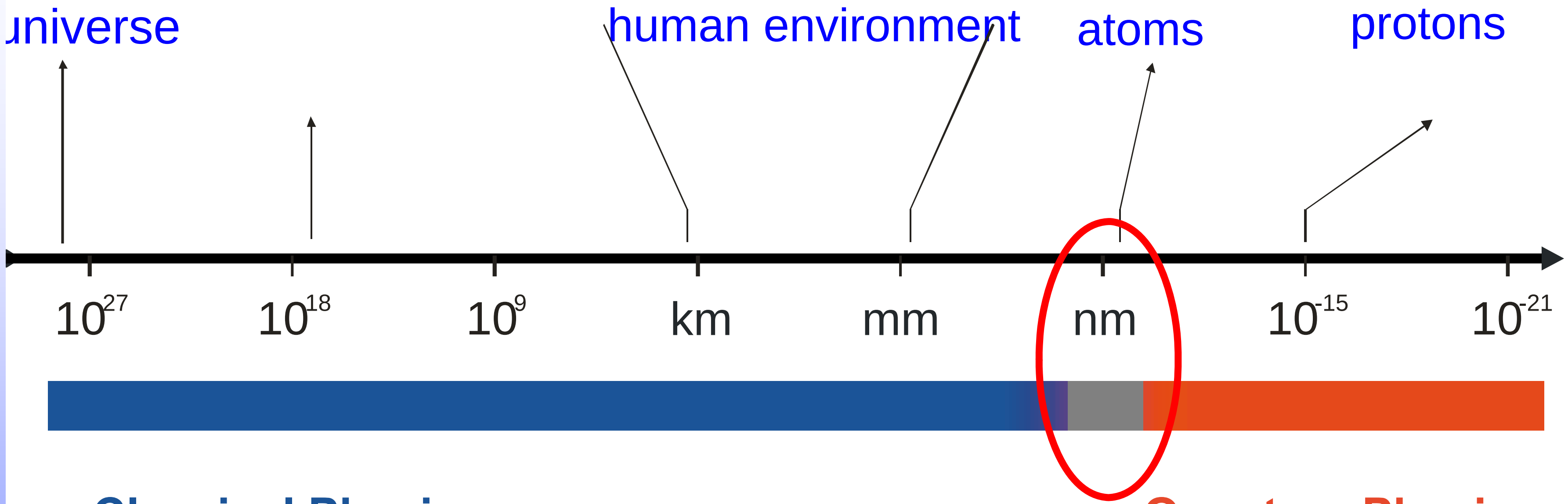
STM (scanning tunneling microscope); Binnig and Rohrer (1982). **Electron current**

AFM (atomic froce microscope). **Molecular and Adhesion forces**

SNOM (scanning near field optical microscope). **Intensity of light**

SPM (scanning probe microscope);

SXM: Kelvin Probe Microscope, Magnetic Force Microscope, Friction Force Micr



Classical Physics:

Quantum Physics

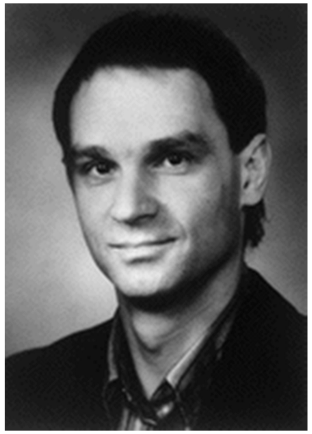
Nanoscale

⇒Systems are composed by a finite number of atoms:
statistical averages may not work

⇒Quantum effects

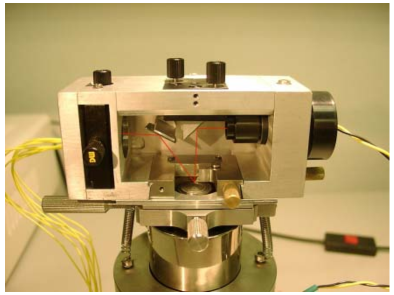
Discretization of electronic energy leves

Co-existence of classical and quantum phenomena



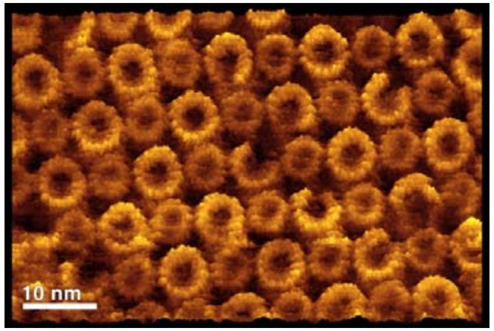
G. Binnig : Is it necessary to have either particles or waves to make a microscope ?.

AFM, Binnig, Gerber, Quate Phys. Rev. Lett. 56, 930 (1986)

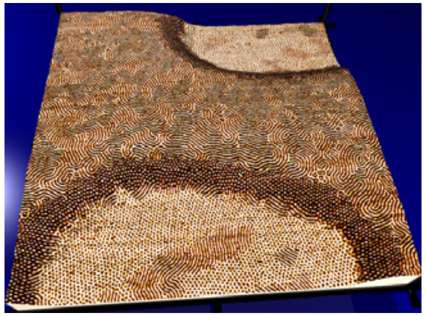


Result: AFM

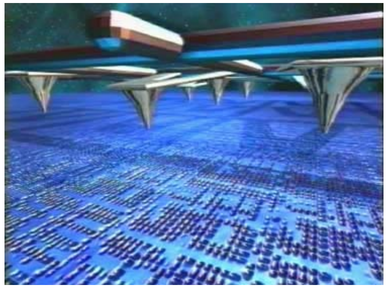
Concept: touch: Forces



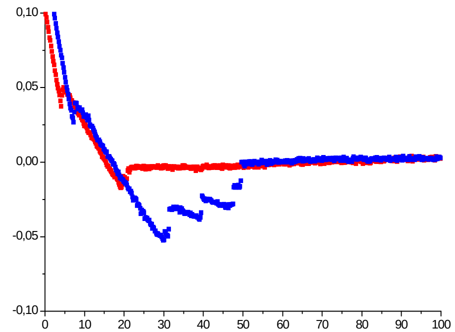
Molecular motors, H Seelertet, A. Engel, D.J. Muller (2000)



Polymers, R. Magerle (2004)

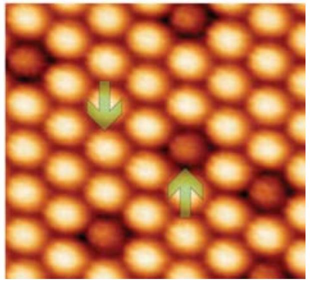


Nanopatterning, G. Binnig (1999)

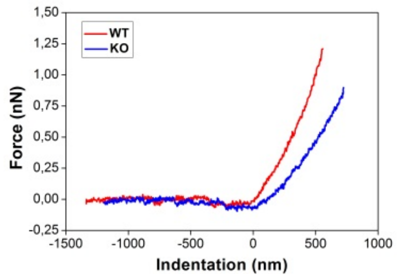


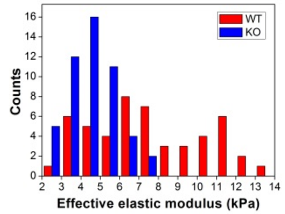
Force spectroscopy

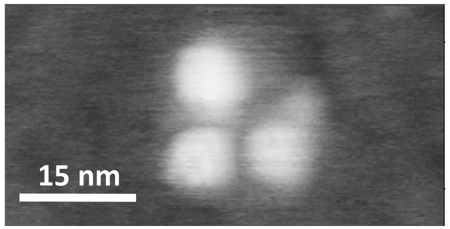
Cells, R. Acvi (2007)



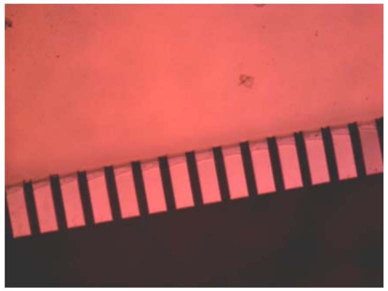
Atom identification, O. Custance, S. Morita et al. (2007)



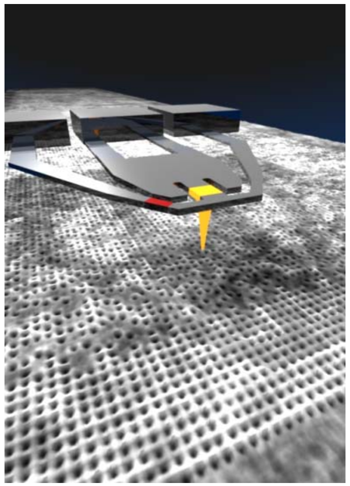




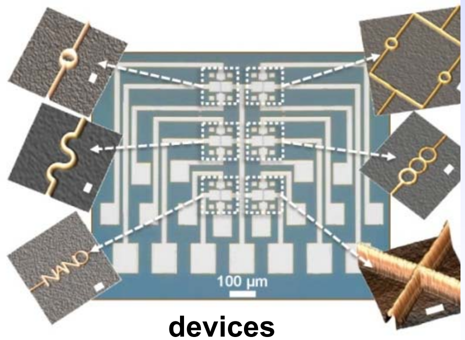
Antibodies, A.S. Paulo, R. Garcia (2000)



Nanomechanical sensors J. Tamayo (2007)



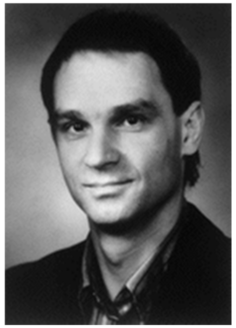
Probe lithography



devices

26 years after the invention of force microscopy

VOLUME 56, NUMBER 9 PHYSICAL REVIEW LETTERS 3 MARCH 1986



Atomic Force Microscope

G. Binnig[a] and C. F. Quate[b]
Edward L. Ginzton Laboratory, Stanford University, Stanford, California 94305
and
Ch. Gerber[c]
IBM San Jose Research Laboratory, San Jose, California 95193
(Received 5 December 1985)

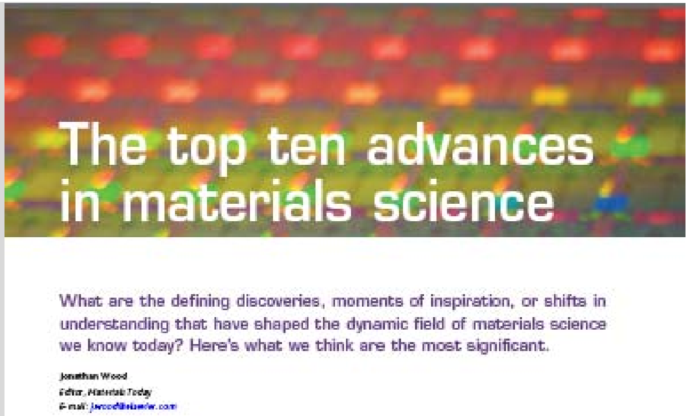
The scanning tunneling microscope is proposed as a method to measure forces as small as 10^{-18} N. As one application for this concept, we introduce a new type of microscope capable of investigating surfaces of insulators on an atomic scale. The atomic force microscope is a combination of the principles of the scanning tunneling microscope and the stylus profilometer. It incorporates a probe that does not damage the surface. Our preliminary results *in air* demonstrate a lateral resolution of 30 Å and a vertical resolution less than 1 Å.

Forces below 10^{-18} N still to be reached
Lateral resolution 3 nm improved to 0.1 nm
Vertical resolution 0.1 nm improved to 10 pm

Top 10 Advances in Materials Science since 1950

1. International Road Map Semiconductor
2. **Scanning Probe Microscopy**
3. Giant magnetoresistance effect
4. Semiconductor lasers/diodes
5. National Nanotechnology Initiative (USA)

Wood, J. The top ten advances in materials science. *Mater. Today* **11**, 40 (2008).
Ball, P. Material witness: Greatest hits. *Nature Mater.* **7**, 102 (2008).

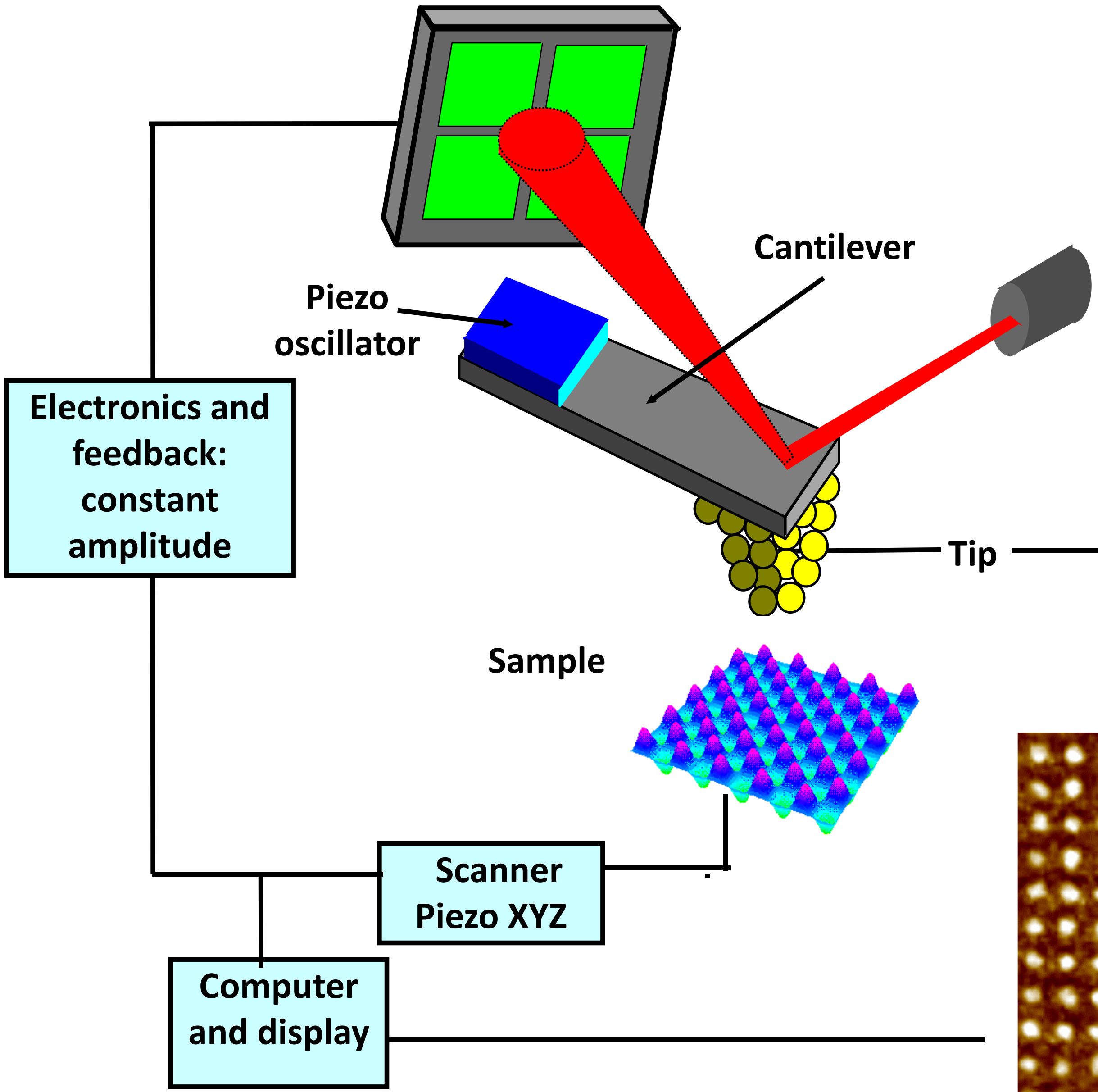

The top ten advances in materials science

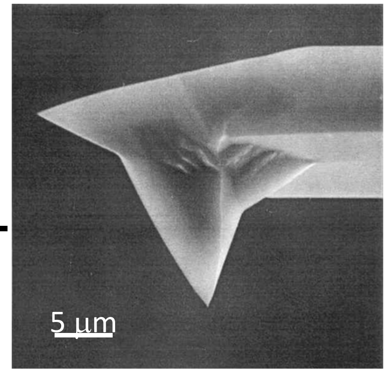
What are the defining discoveries, moments of inspiration, or shifts in understanding that have shaped the dynamic field of materials science we know today? Here's what we think are the most significant.

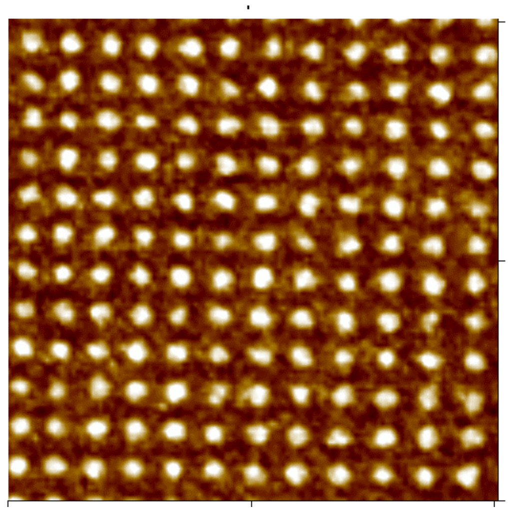
AM-AFM

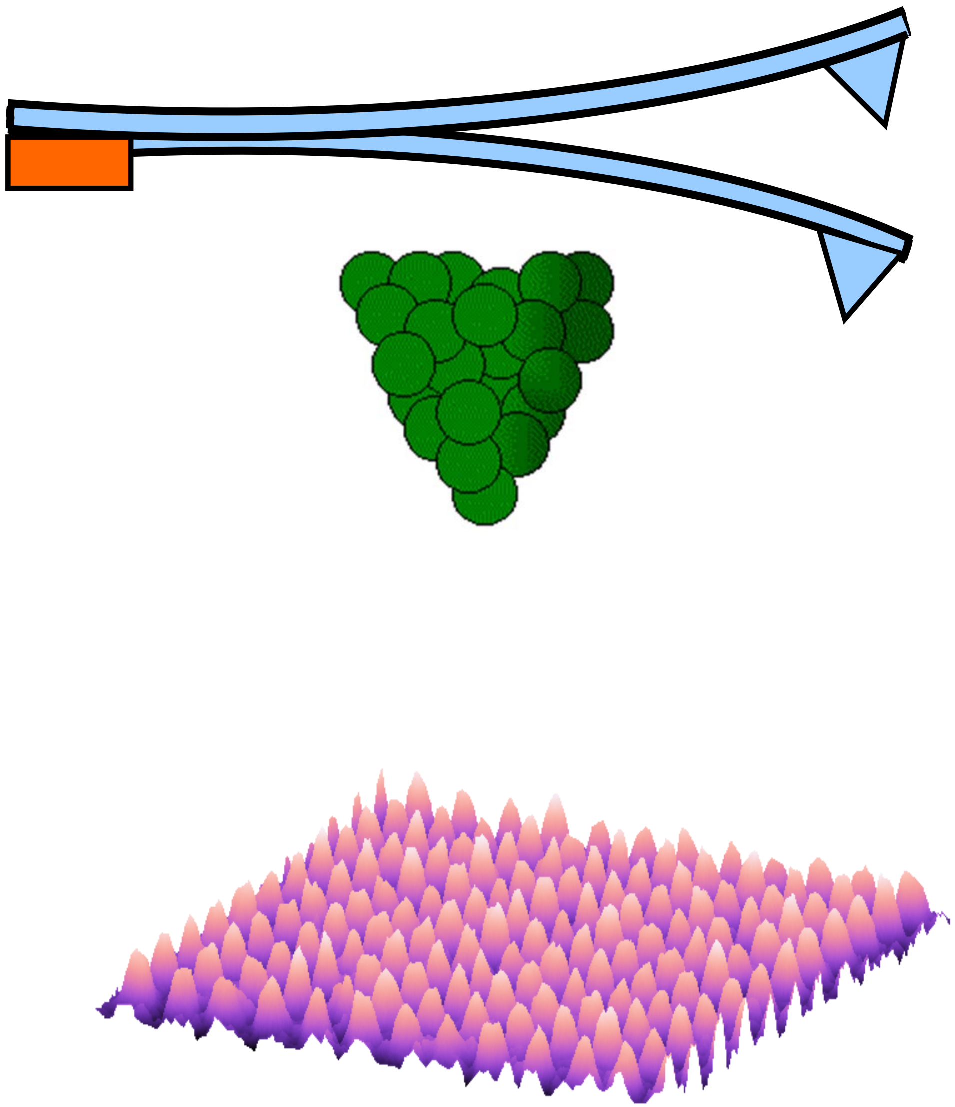
Fixed excitation frequency

constant oscillation amplitude





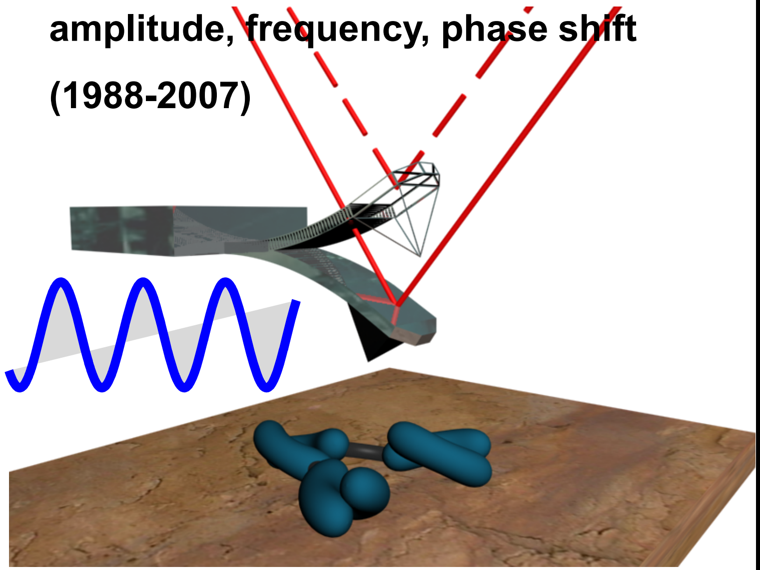




Dynamic AFM:

amplitude, frequency, phase shift

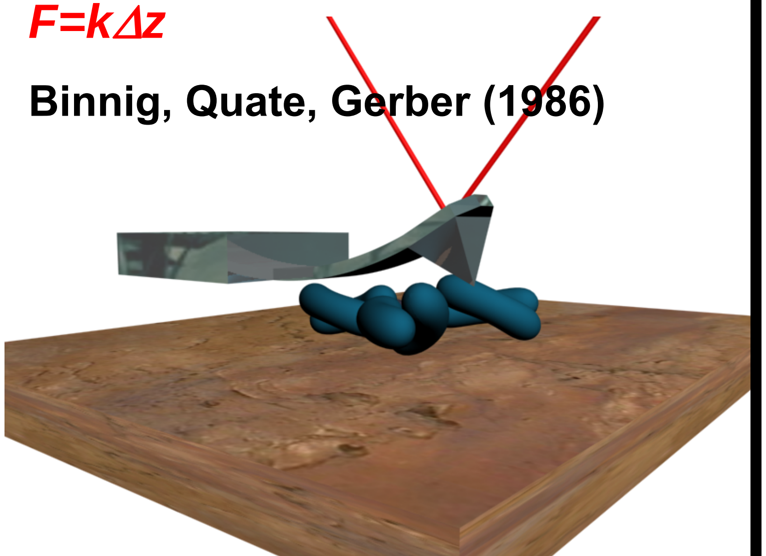
(1988-2007)



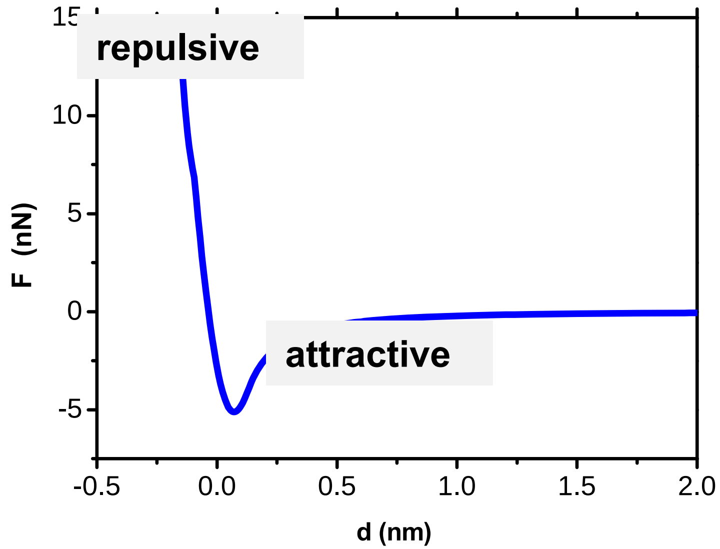
Contact : static deflection,

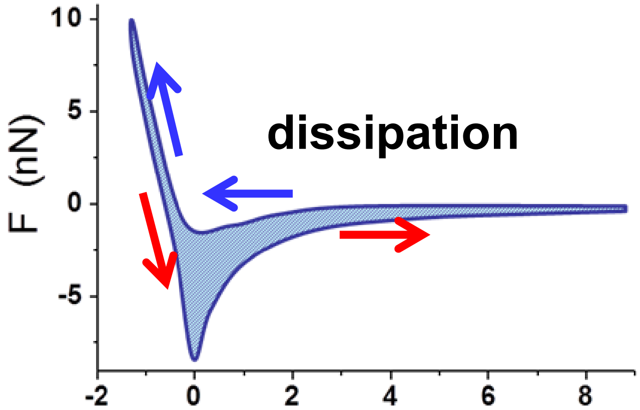
F=k∆z

Binnig, Quate, Gerber (1986)

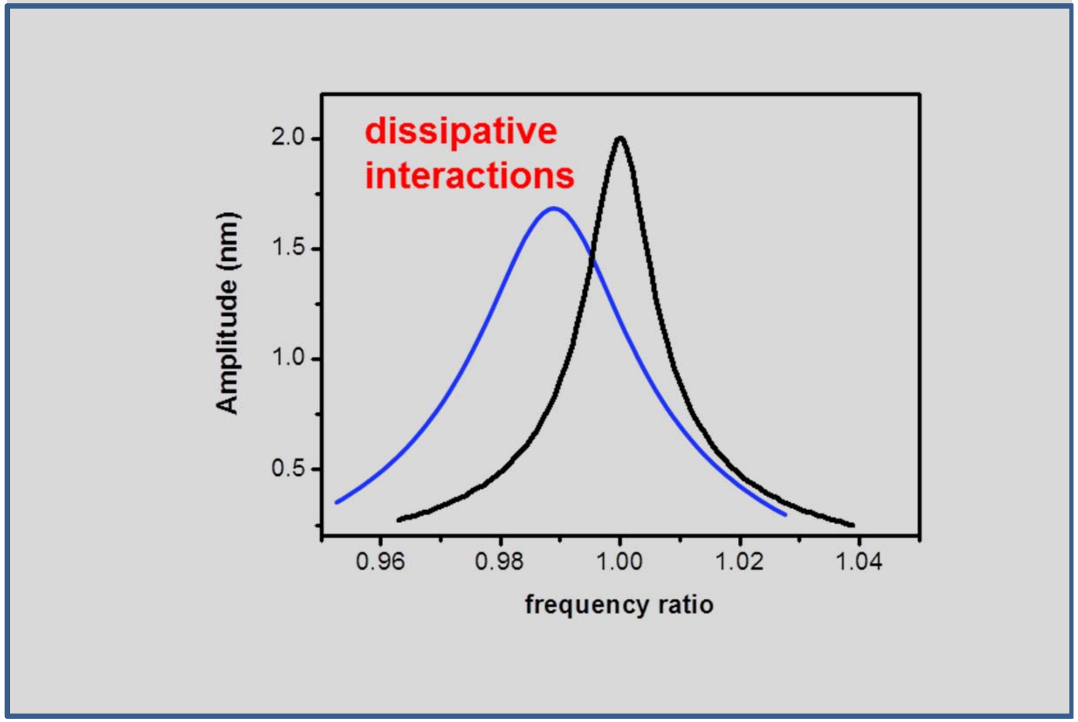


Forces:
Short and Long range
Conservative and dissipative





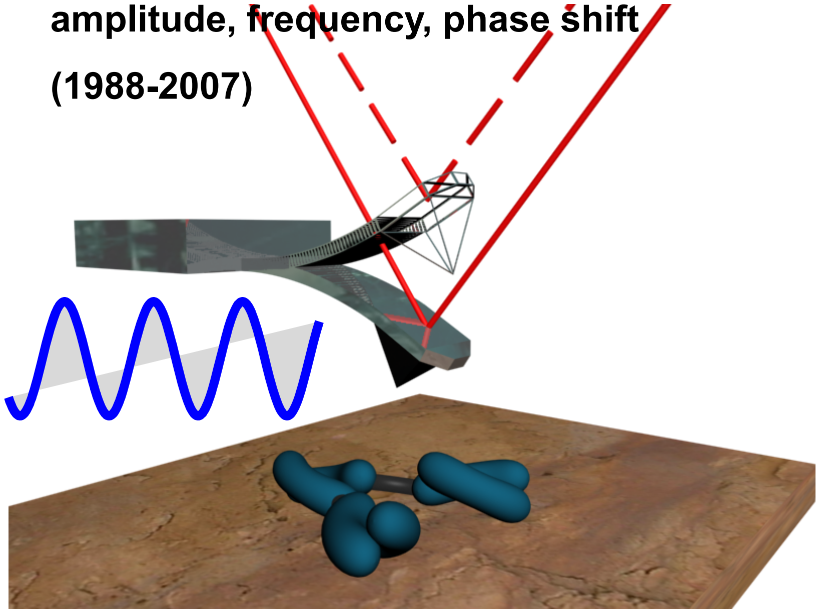
A force acting on a vibrating cantilever changes its **resonant frequence** and **reduces its amplitude**



Dynamic AFM:

amplitude, frequency, phase shift

(1988-2007)



Two main dynamic AFM modes

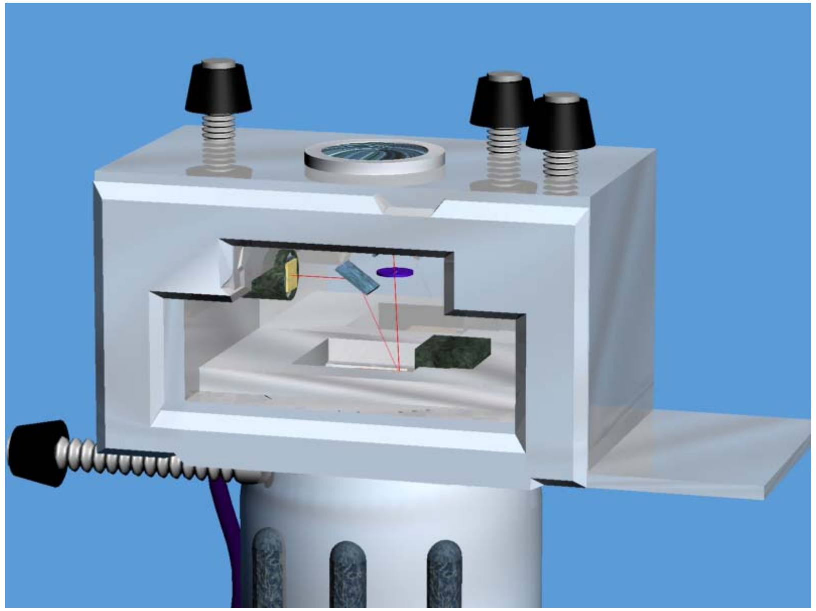
Frequency Modulation AFM **feedback on the frequency**

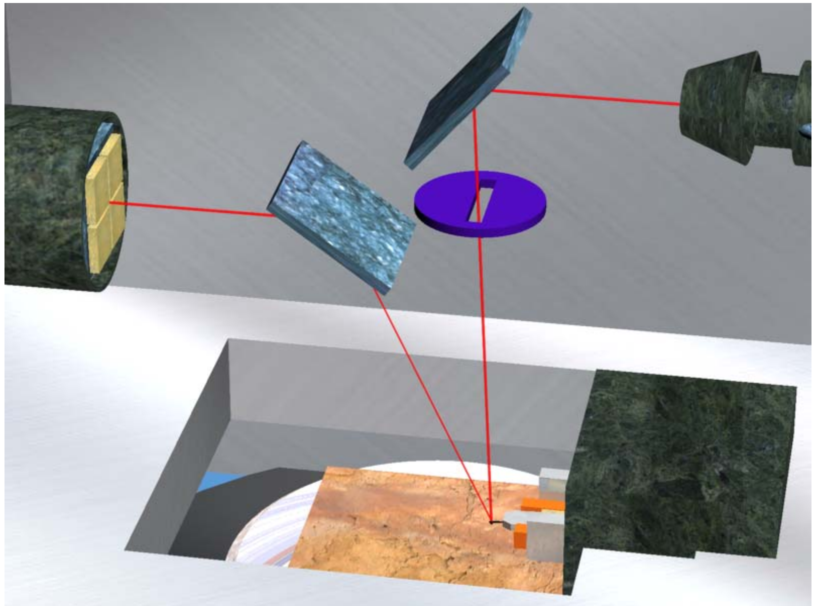
T.R. Albrecht, P. Grütter, D. Rugar, JAP 69, 668 (1991)

Amplitude Modulation AFM **feedback on the amplitude**

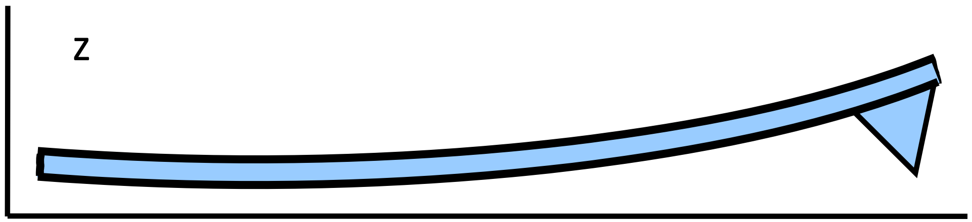
Martin, Williams, Wickramasinghe JAP 61, 4723 (1987)

El sistema de detección óptico mide cambios de pendiente





$$z(L) = \frac{2L}{3}\frac{dz(L)}{dx}$$



Microcantilevers

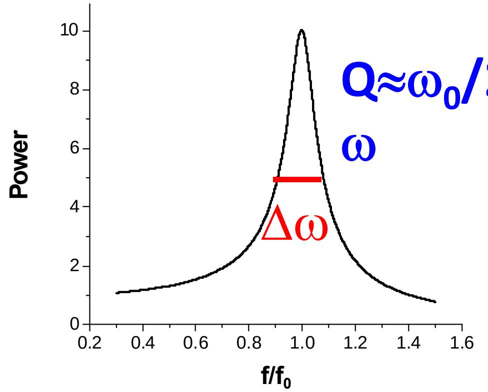
Mechanical device to detect and amplify tip-surface interactions

Si or Si_3N_4

The dynamic response of the μcantilever is characterized by three quantities: force constant k_n , resonance frequency f_n and quality factor Q_n

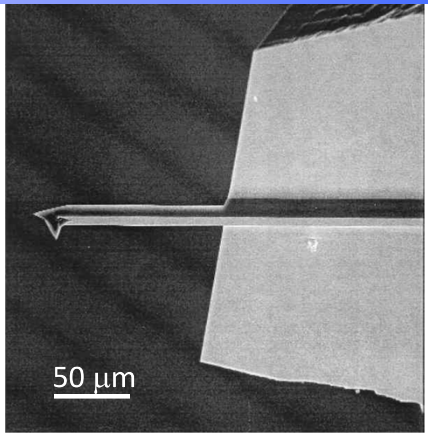
$$k = \frac{3\,EI}{L^3} = \frac{Ebt^3}{4\,L^3}$$

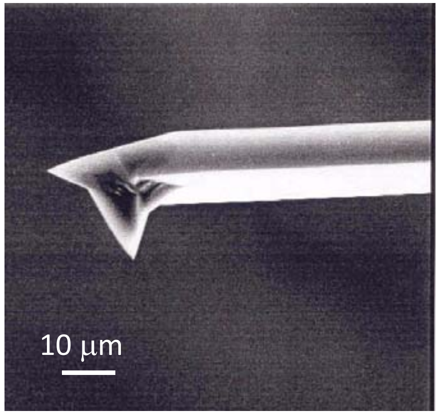
$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m_n}} = \frac{C_n^2}{2\pi}\frac{t}{L^2}\sqrt{\frac{E}{\rho}}$$

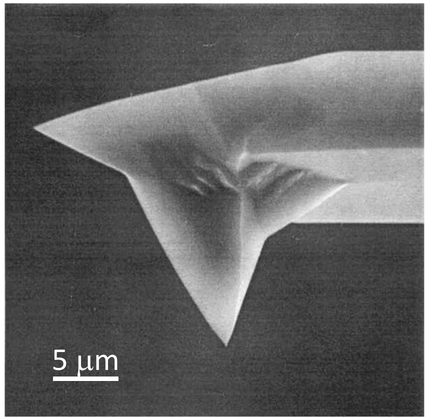


$Q \approx \omega_0 / 2\Delta\omega$

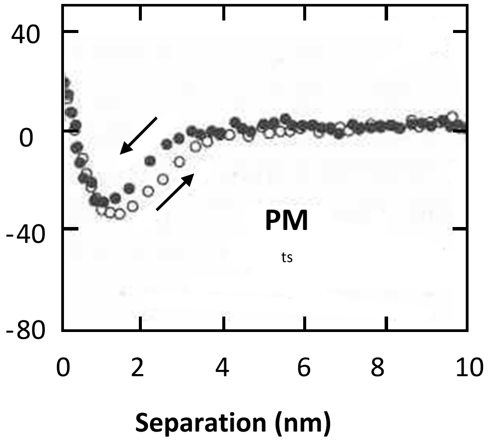
Resonace frequency	Force constant	Q-factor
10^4-4x 10^5 Hz	0.01-50 N/m	1-10^5

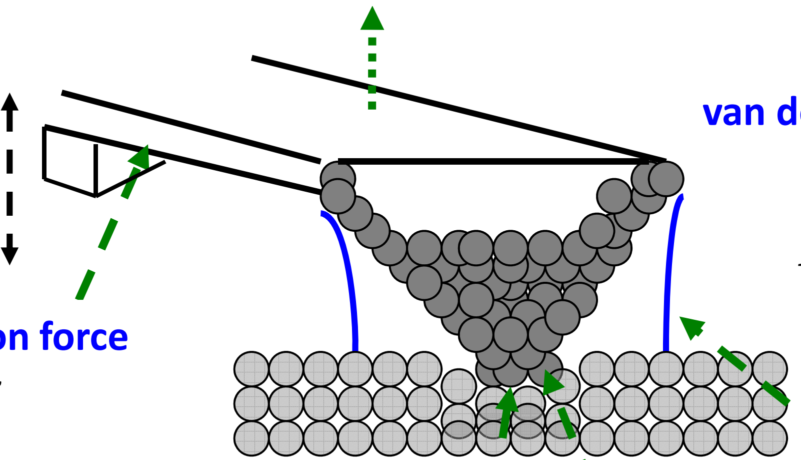






Forces in AFM





Restoring force cantilever

$F_c = -kz$

van der Waals forces

$$F_{vdw} = \frac{HR}{6d^2}$$

Excitation force

$F_0 \cos \omega t$

Capillary forces

Hidrodynamic forces

$$F_h = \frac{m\omega_0}{Q}\frac{dz}{dt}$$

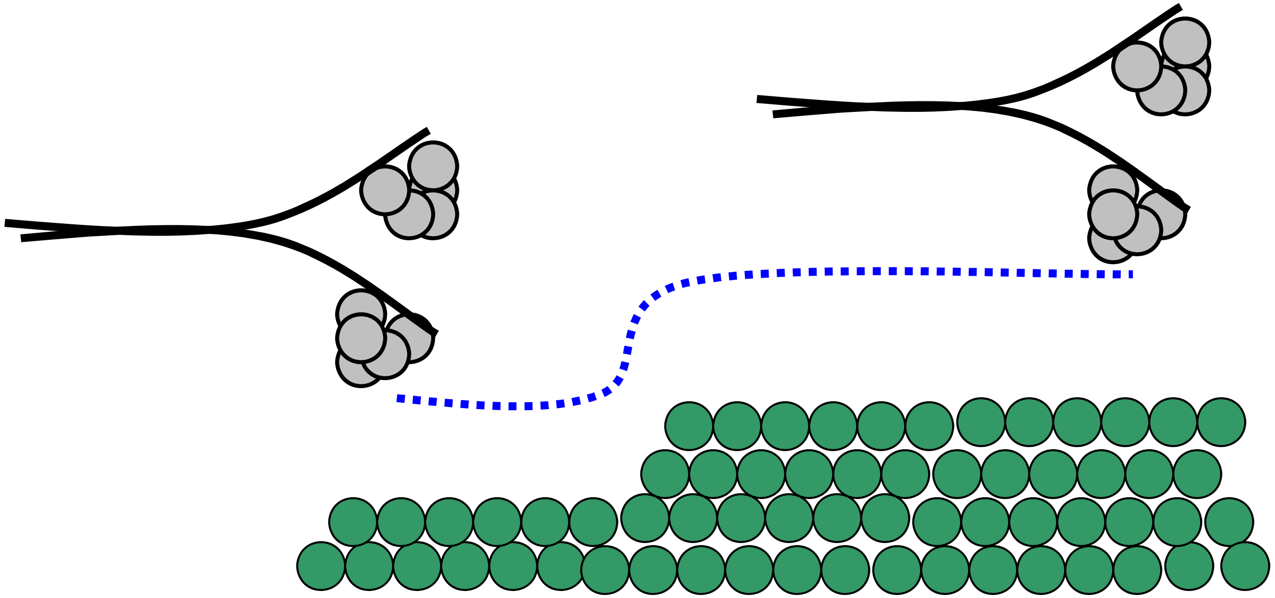
Adhesion forces

$F_a = 4\pi\gamma R$

Short range repulsive forces (DMT)

$$F_{DMT} = E^* \sqrt{R}\delta^{3/2}$$

Amplitude modulation AFM (tapping mode AFM):
an image is formed by scanning the tip across the surface at a fixed oscillation amplitude.



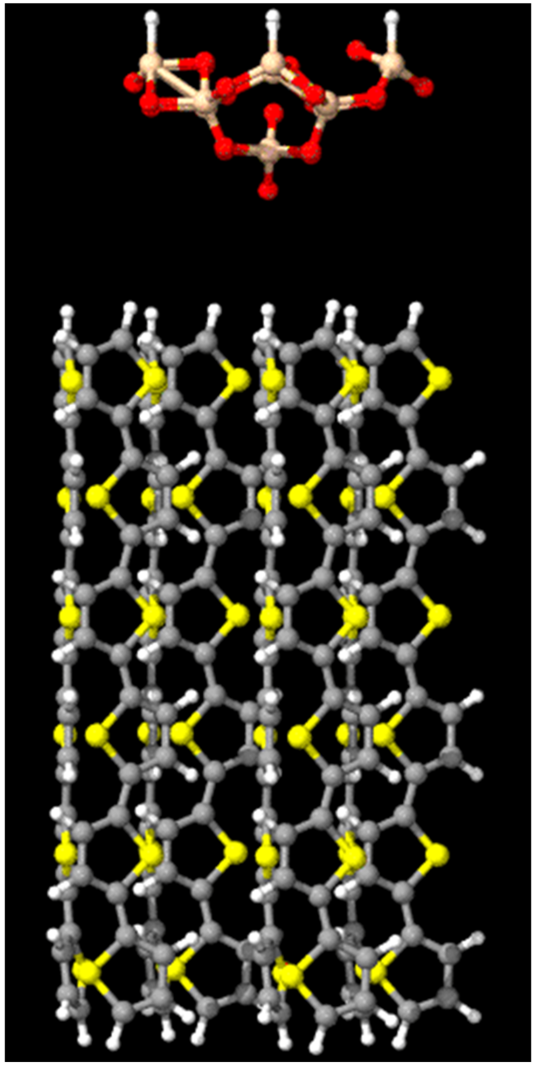
Zhong et al. Surf. Sci. 290, L688 (1993);
Anselmetti et al. Nanotechnology 5, 87 (1994);
García, Pérez, Surf. Sci. Rep. 47, 197 (2002).

collaboration with Wojciech Kaminski, Rubén Pérez, UAM

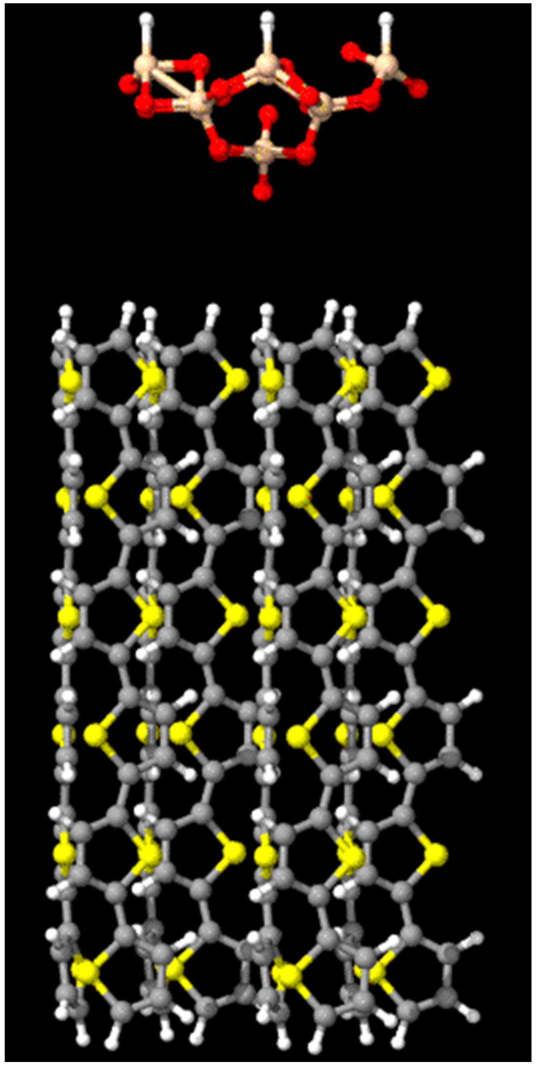
Silica tip on oligothiphene monolayer

• C position

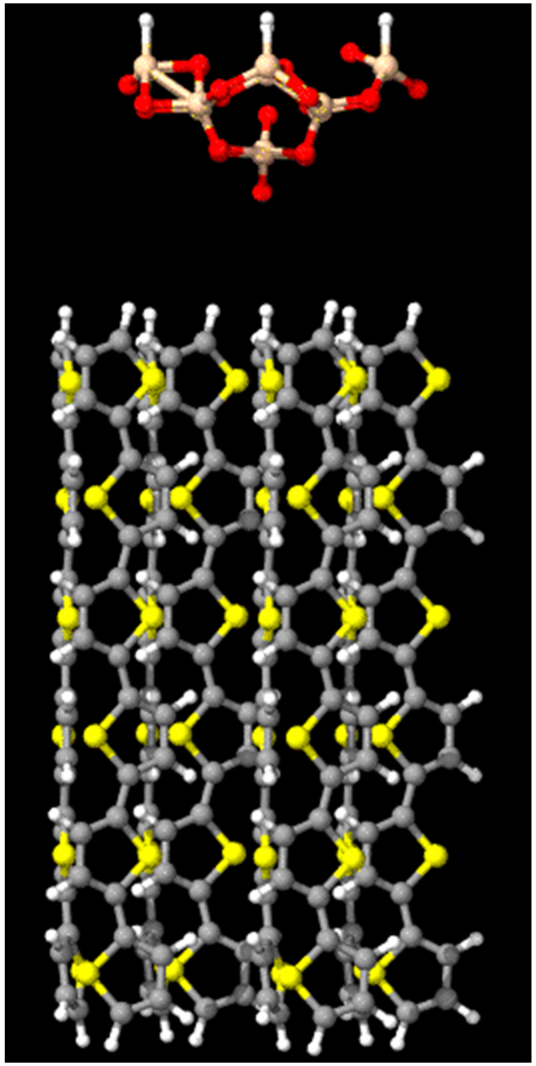
short: 5 Å → 2 Å → 5 Å



middle: 5 Å → 0 Å → 5 Å



long: 5 Å → -1 Å → 5 Å



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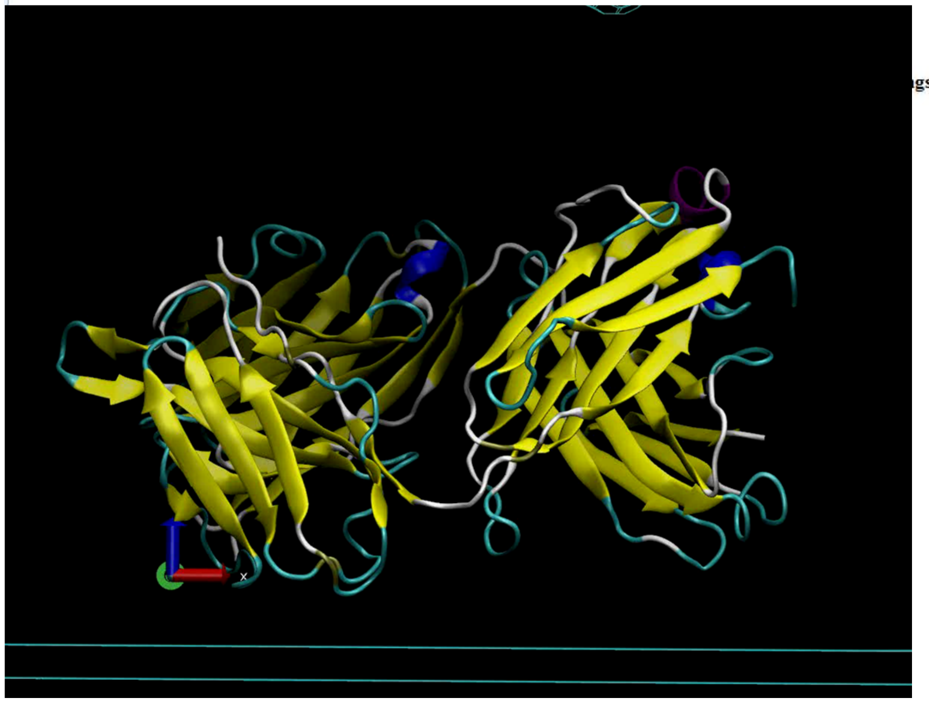
Force for Future

Consolider

FORCE FOR FUTURE

Advanced force technology for future nanomechanics and nanomedicine

Force-For-Future



...gs to the CONSOLIDER program. The project aims to implement multifrequency concepts to develop a new