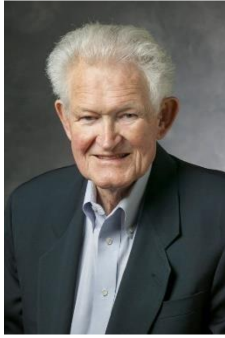
AFM

ANDERSON CAIRES

TEM

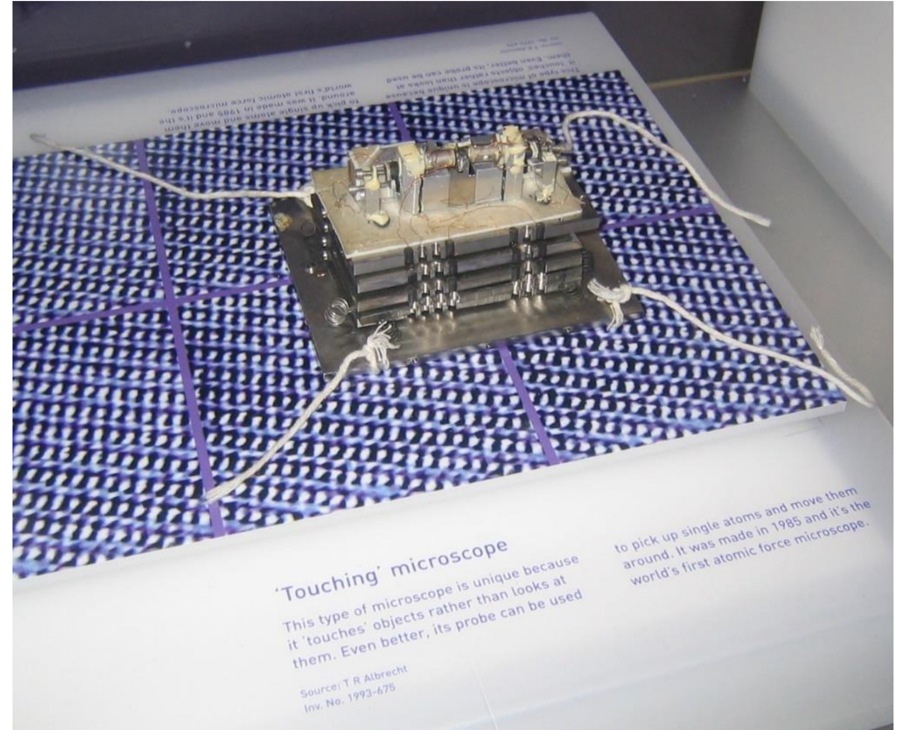
AFM

The First Atomic Force Microscopy (AFM)



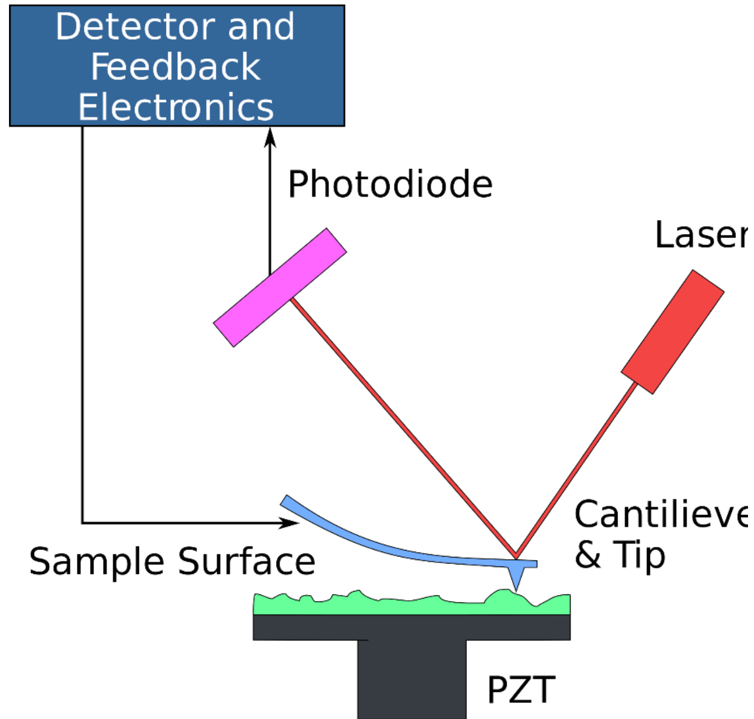
Binnig, Calvin Quate and Christoph Gerber
1986

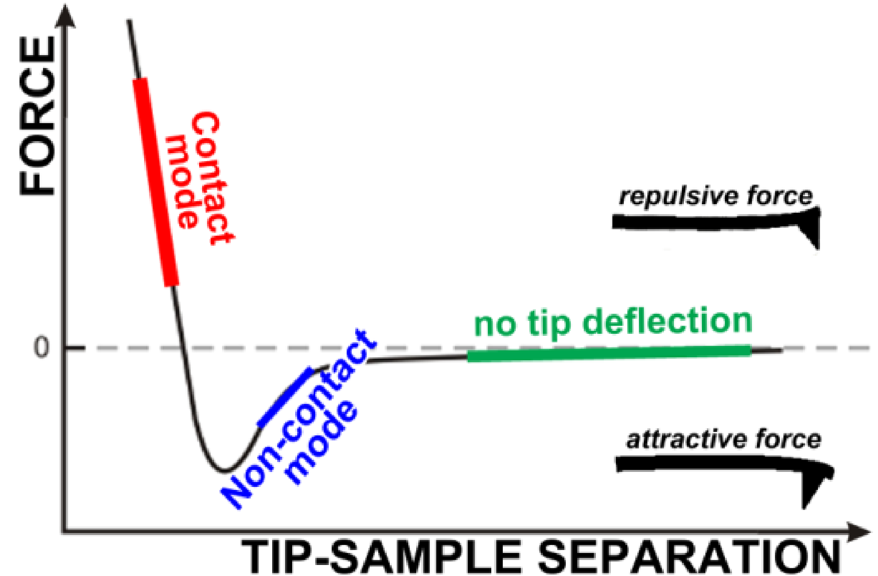
"In order to measure smaller forces 1µN between the surface of the tip and the sample surface"



https://pt.wikipedia.org/wiki/Microsc%C3%B3pio_de_for%C3%A7a_at%C3%B4mica#cite_note-1

Atomic Force Microscopy (AFM): Basic principles





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http://www.intechopen.com/source/html/42103/media/image2.png

Atomic Force Microscopy (AFM): Basic principles

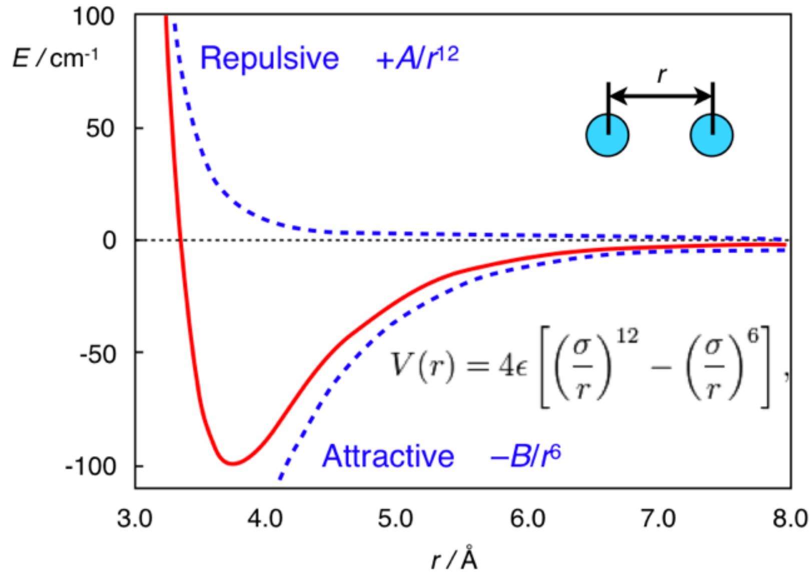
LENNARD-JONES potential

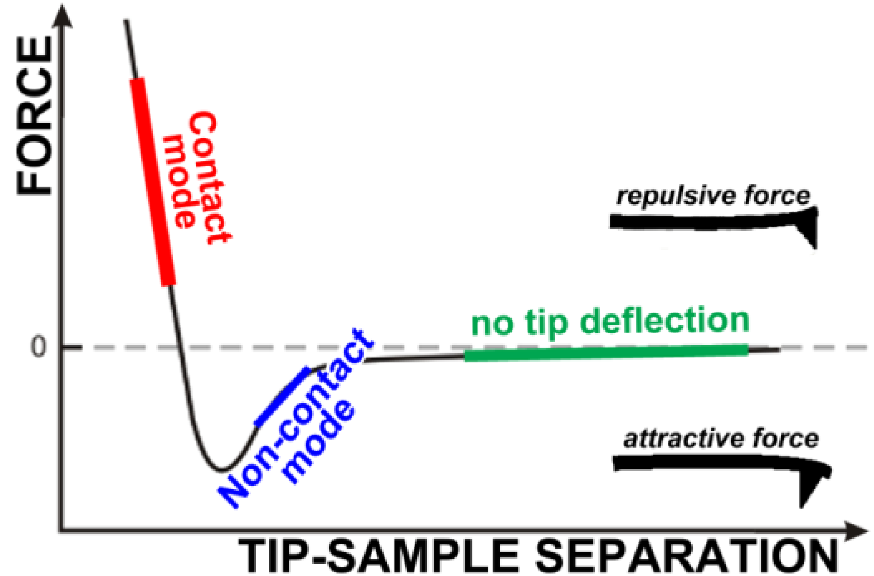
$$V(d) = 4\varepsilon\left(\underbrace{\left(\frac{\sigma}{d}\right)^{12}}_{\text{repulsion (short range)}} - \underbrace{\left(\frac{\sigma}{d}\right)^{6}}_{\text{attraction (long range)}}\right)$$

$\varepsilon, \sigma = \text{const}$

Em grandes distâncias, as interações são predominantemente atrativas, devido às forças de Van der Waals. Se aproximarmos ainda mais a ponta com a superfície, as interações são repulsivas devido a repulsão entre os orbitais eletrônicos dos átomos da superfície da amostra e os da ponta do microscópio de força atômica.

Atomic Force Microscopy (AFM): Basic principles





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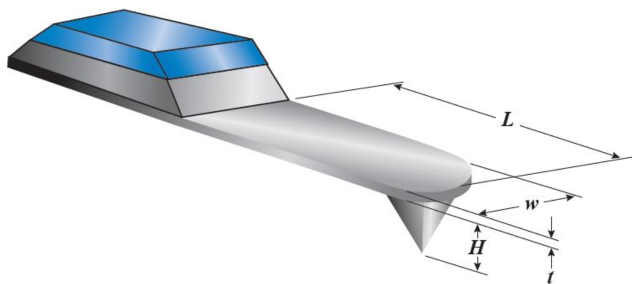
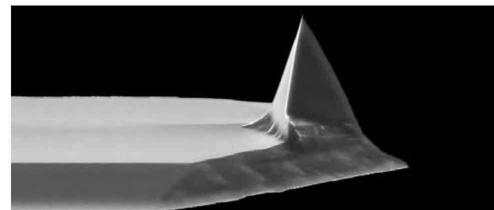
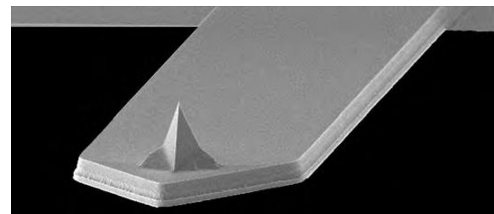
The Modern AFM

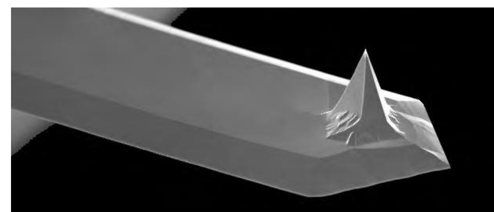
The Modern AFM

Cantilever









Contact

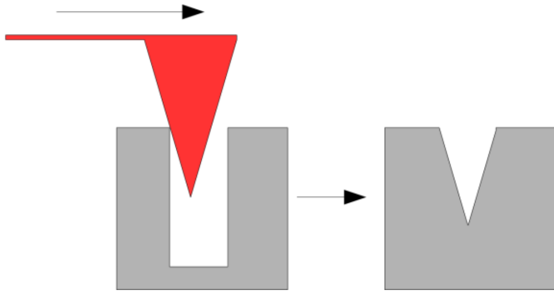
Non-contact

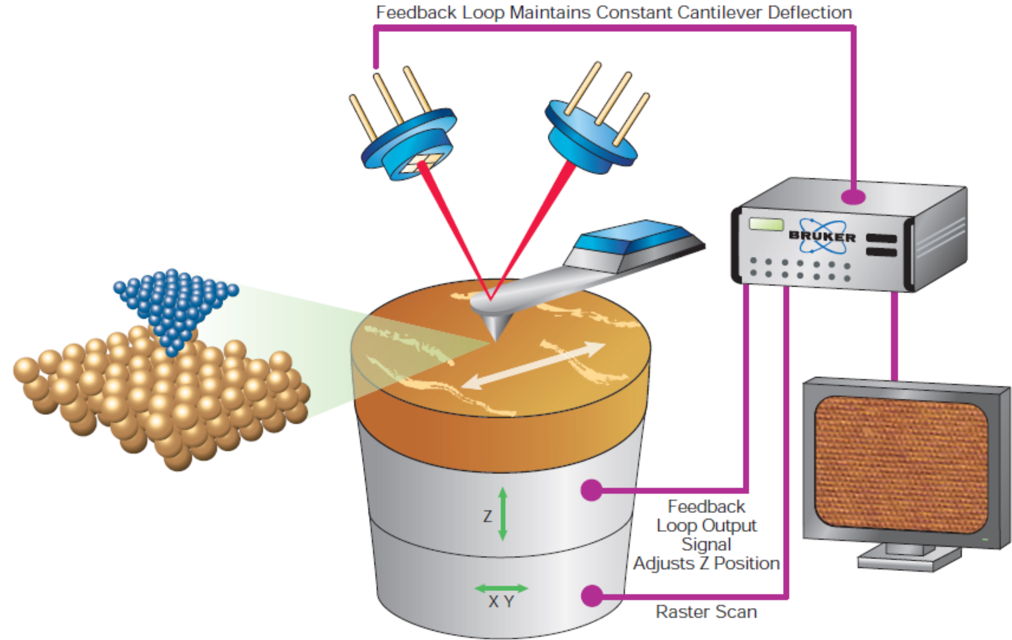
Tapping

Contact Mode

Este método é especialmente indicado para amostras rígidas. A compressão e as forças geradas pelo modo contato podem causar danos nas amostras.

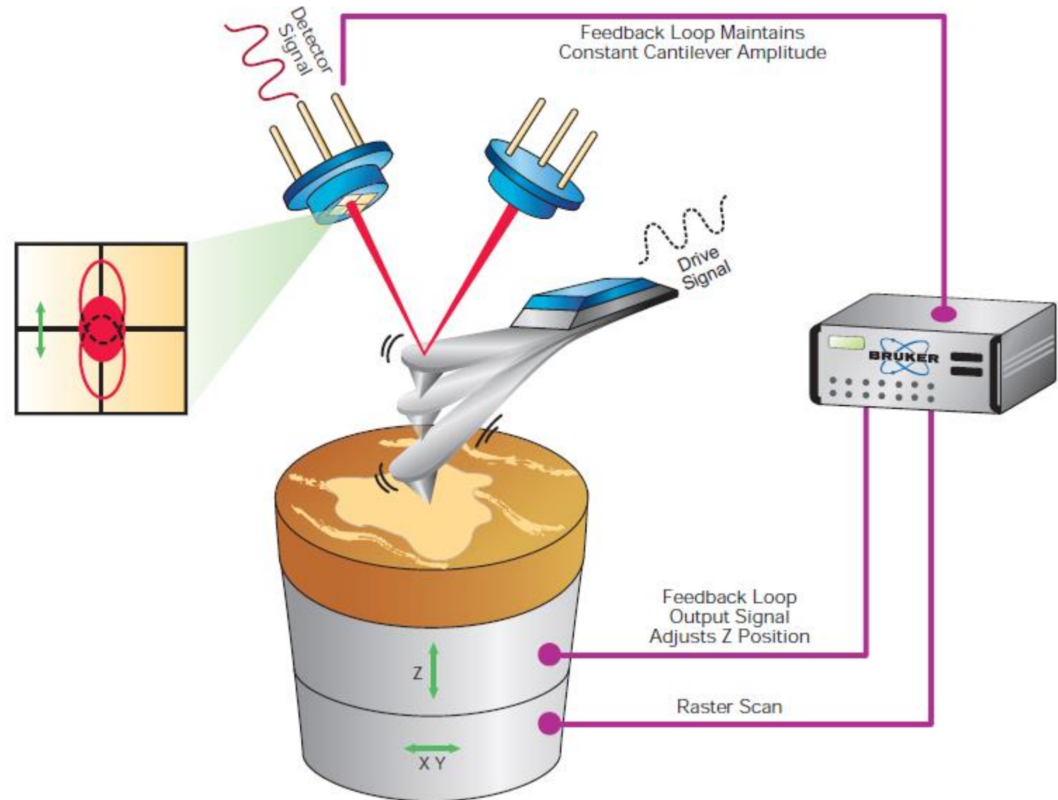
Amostras rugosas – Muitos artefatos





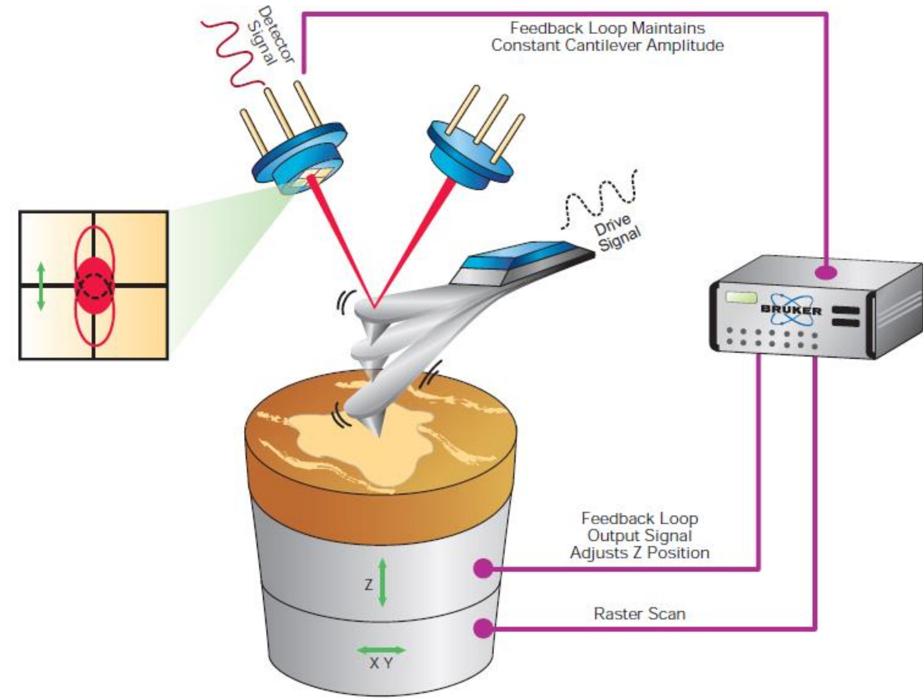
Non Contact mode

O método de não contato é usado preferencialmente em amostra moles. Porém a grande distância entre a ponta e a amostra traz uma limitação na resolução da imagem.

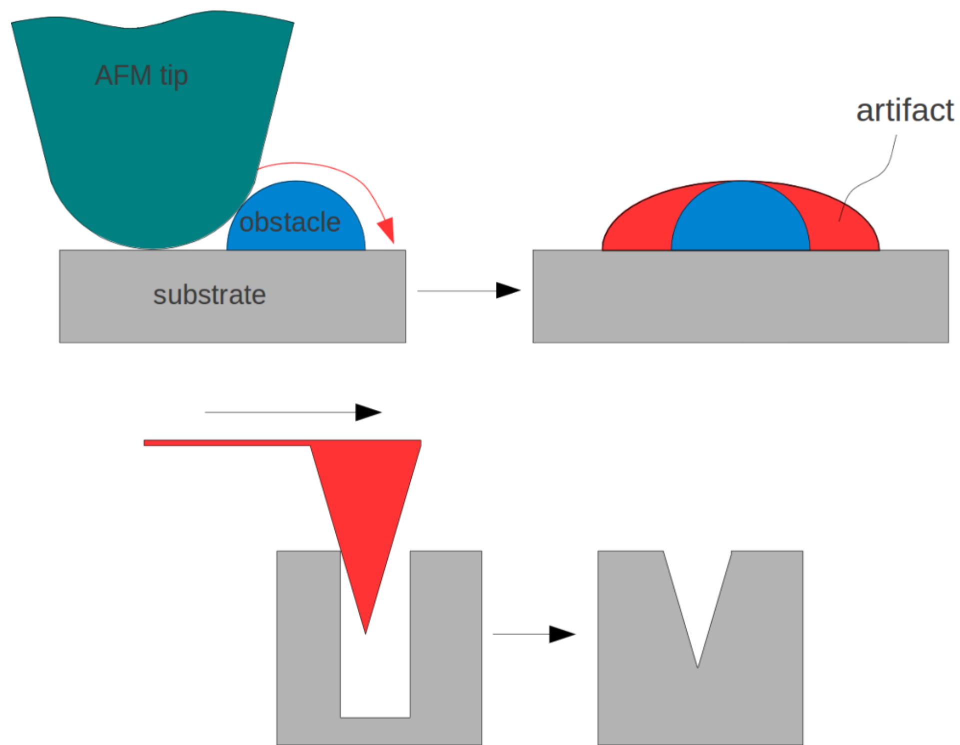


Tapping Mode

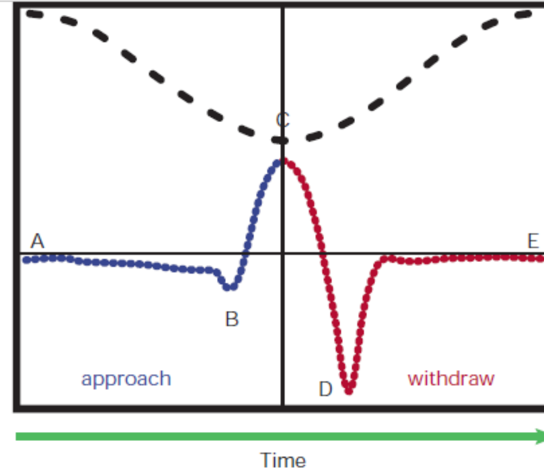
O método de tapping ou contato intermitente é utilizado para contornar as restrições presentes nos modos de contato e de não-contato. **O modo de contato intermitente é utilizada em materias biológicos, polímeros e amostras demasiadamente rugosas, pois estes são maleáveis e deformáveis pela ponta.**

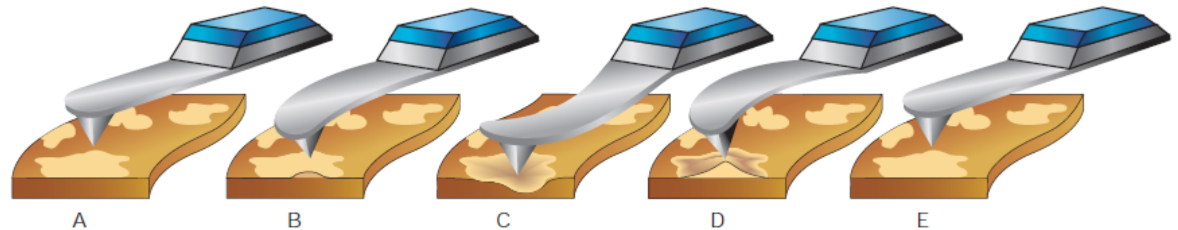


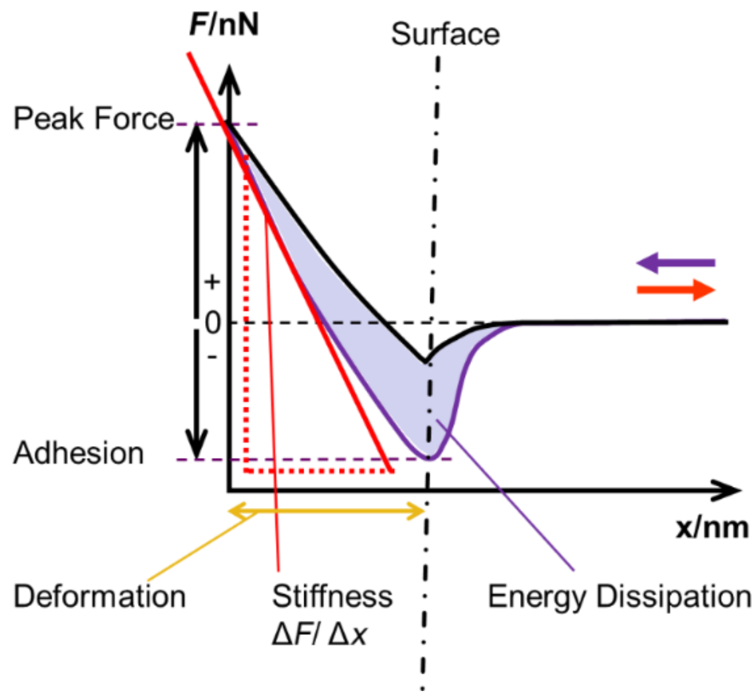
AFM Artifacts



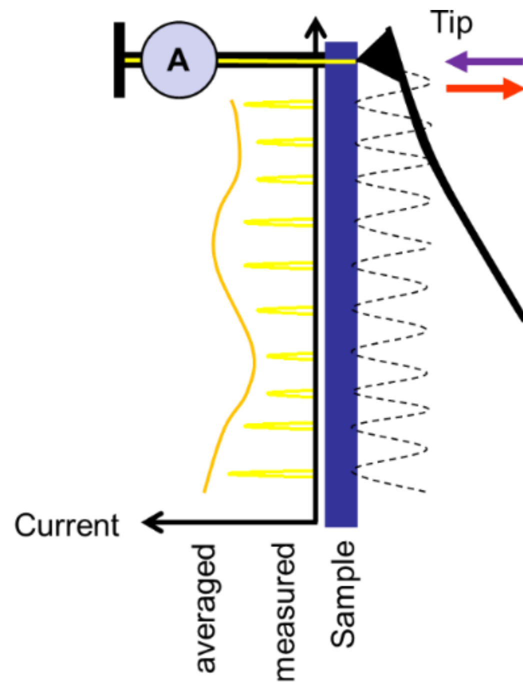
PeakForce Tapping







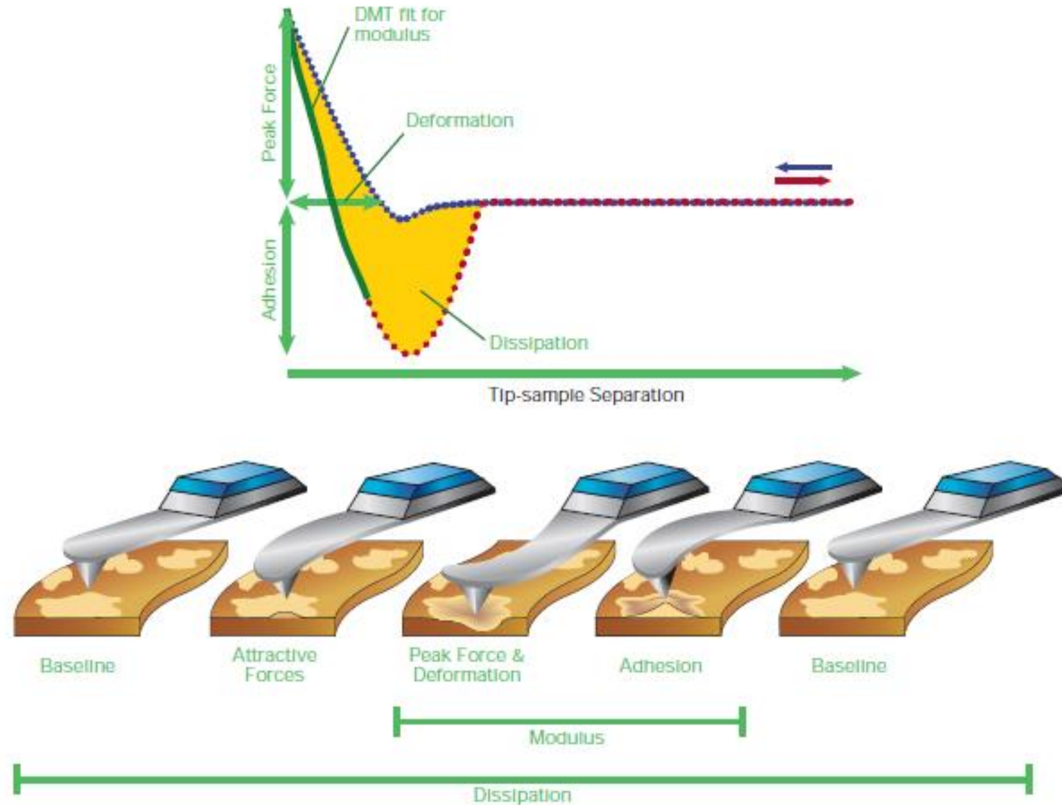
F/nN
Surface
Peak Force
+
0
-
Adhesion
x/nm
Deformation
Stiffness
ΔF/ Δx
Energy Dissipation



A
Tip
Current
averaged
measured
Sample

QNM

Quantitative Nanomechanical Mapping



Quantitative Nanomechanical Mapping

Adhesion: The peak force below the baseline

Deformation: The maximum deformation of the sample (defined as the distance from the base of the **Deformation Fit Region** position to the peak interaction force position) caused by the probe.

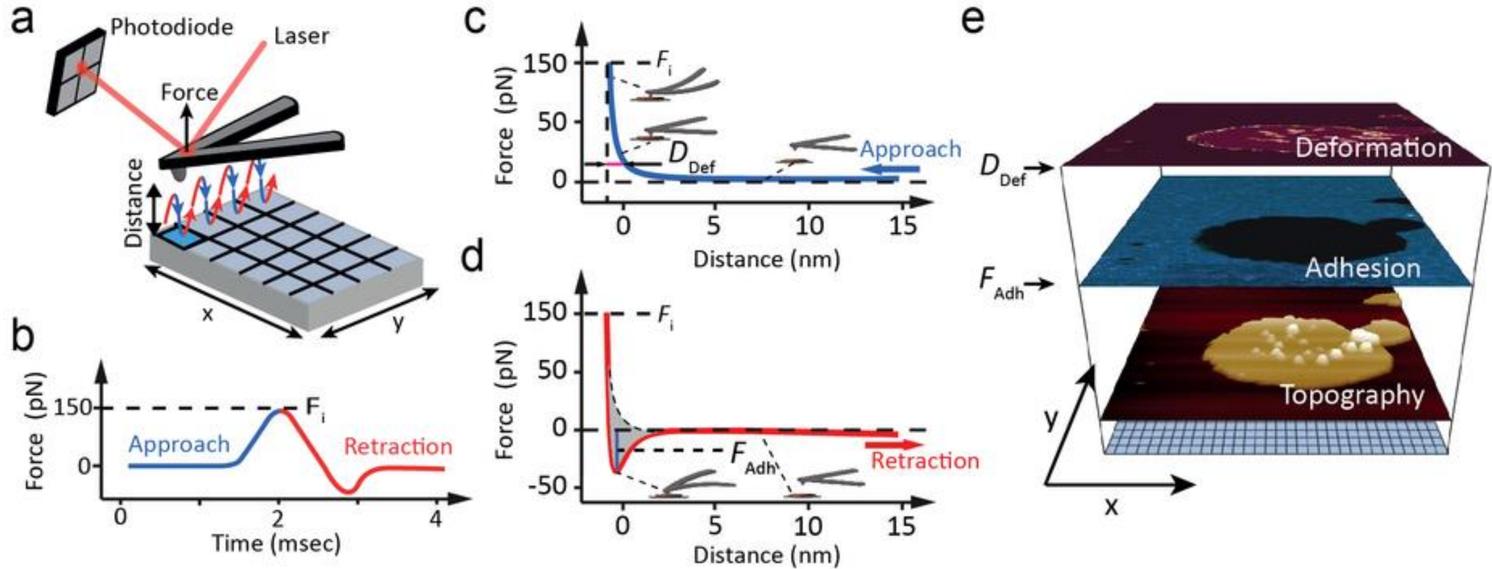
DMT Modulus:

$$F_{tip} = \frac{4}{3}E^{*}\sqrt{Rd^{3}} + F_{adh}$$

Dissipation:

$$W = \int_{0}^{T} \bar{F} \bullet \bar{v}dt = \int \bar{F} \bullet d\bar{Z}$$

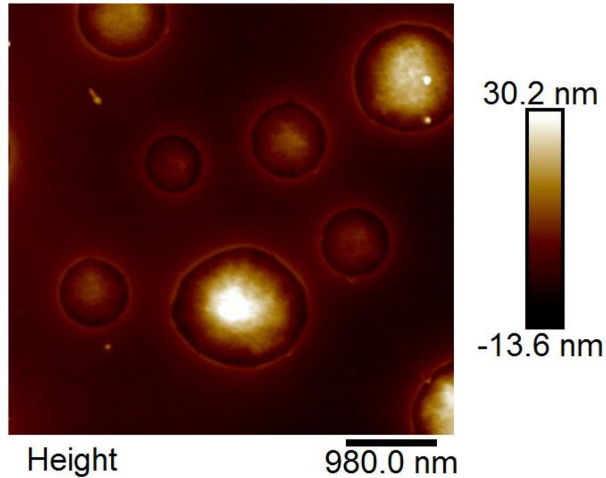
Quantitative Nanomechanical Mapping

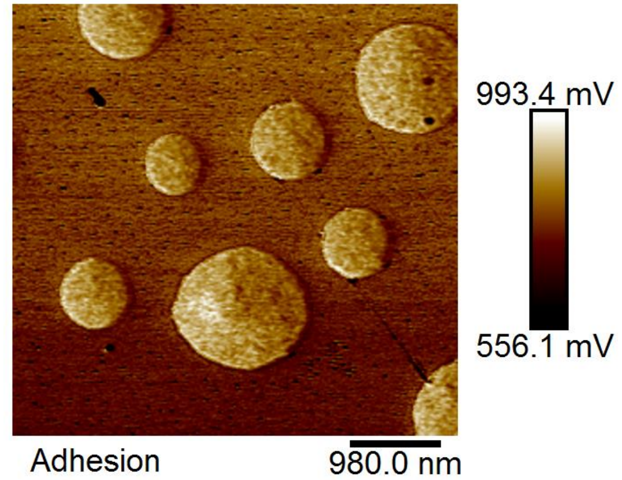


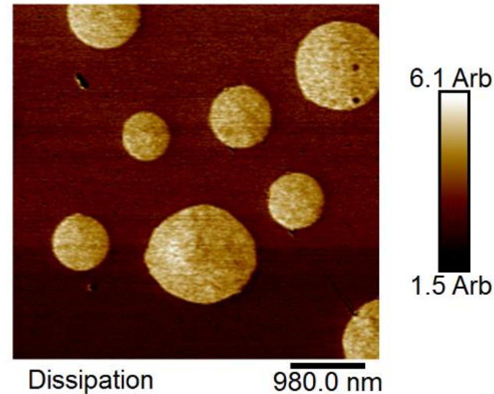
Nature Methods 12, 2015, 845–851

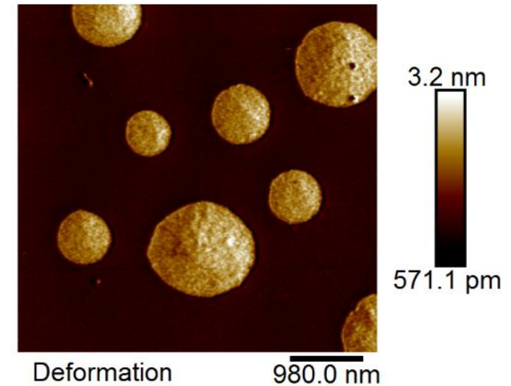
Quantitative Nanomechanical Mapping

PS+LDPE blend









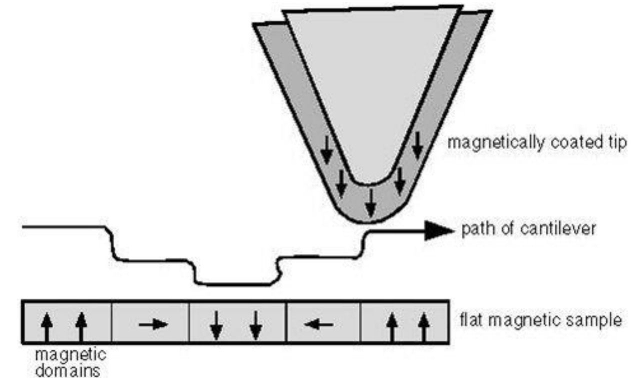
LasMat

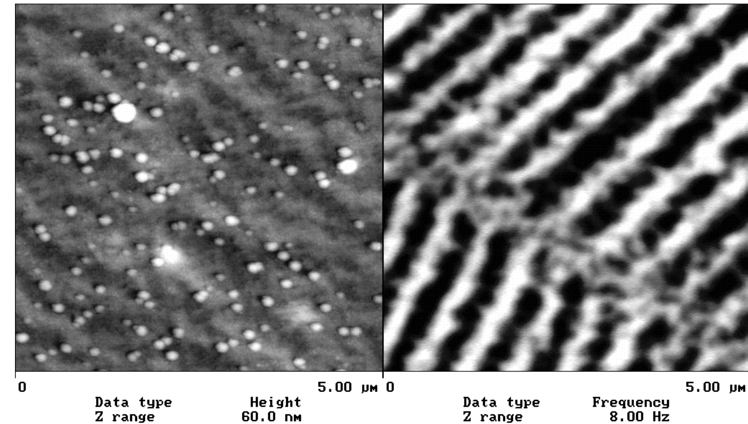
CeNano²I

MFM

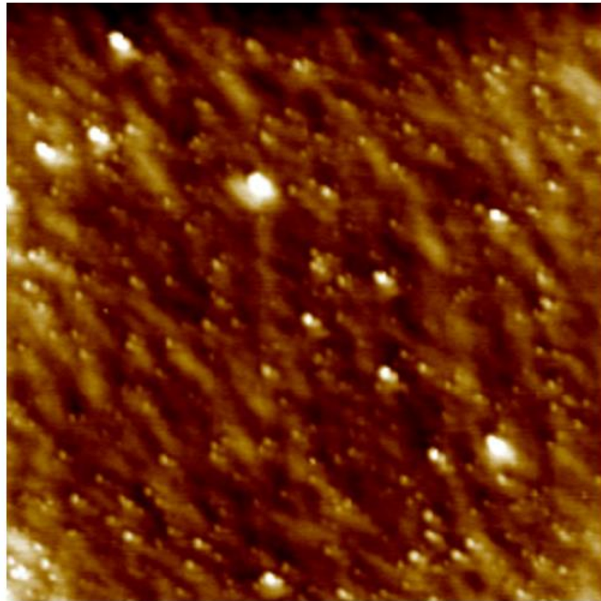
Magnetic Force Microscopy

In the absence of magnetic forces, the cantilever has a resonant frequency *f0*. This frequency is shifted by an amount Δf proportional to vertical gradients in the magnetic forces on the tip

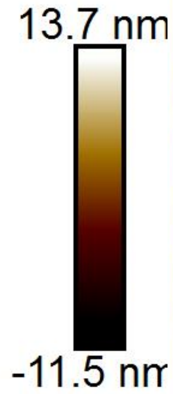


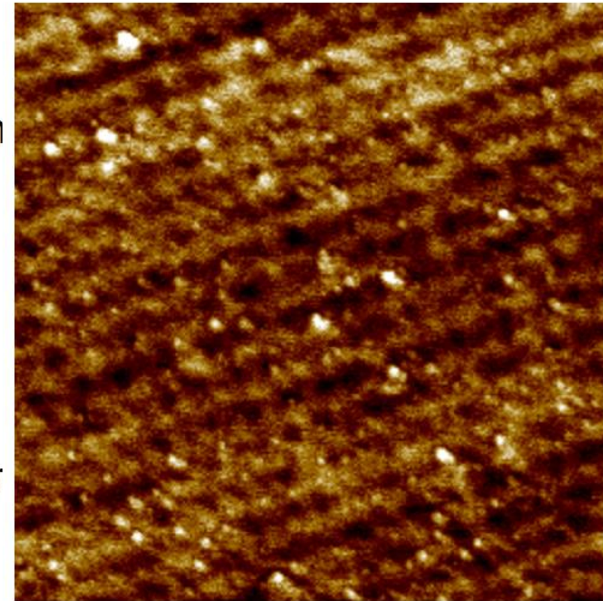


Magnetic Force Microscopy

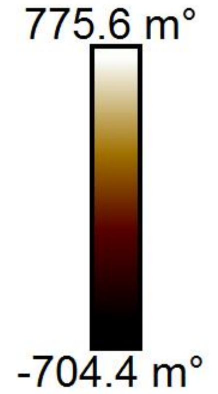


Height 2.0 µm





Phase 2.0 µm



Magnetic Force Microscopy

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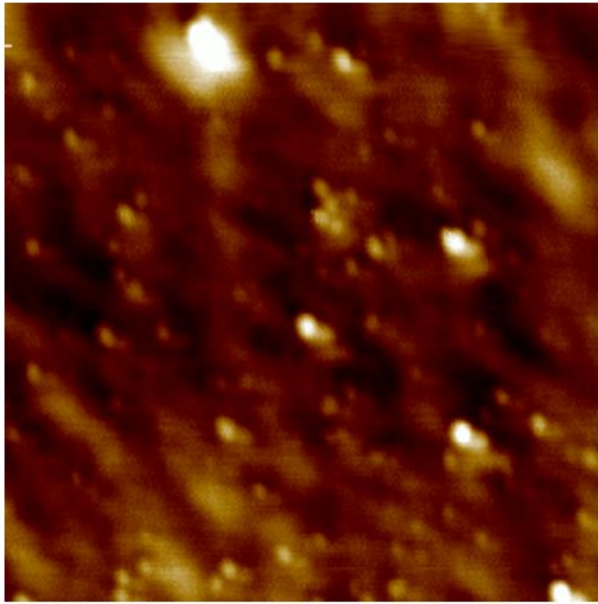
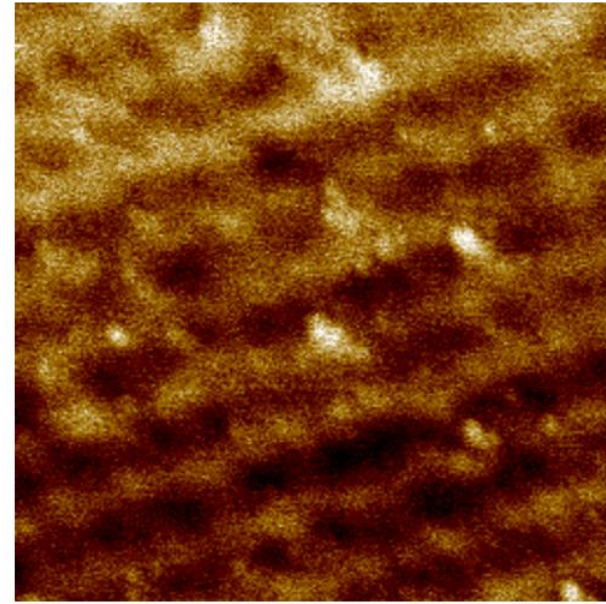
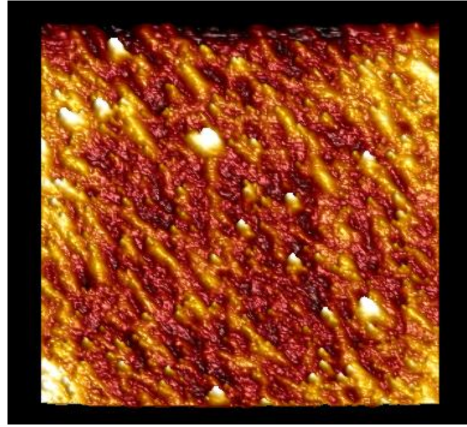
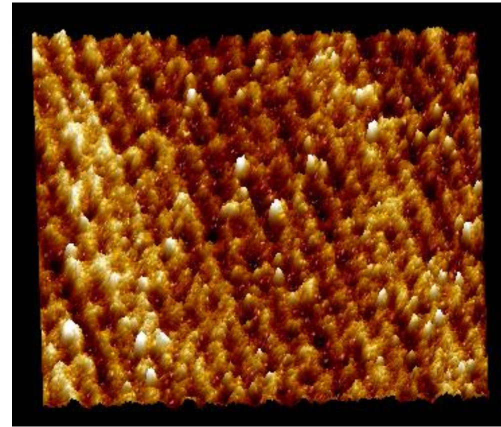
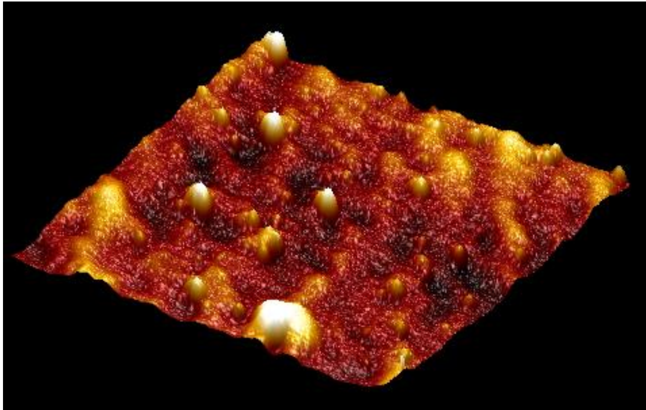


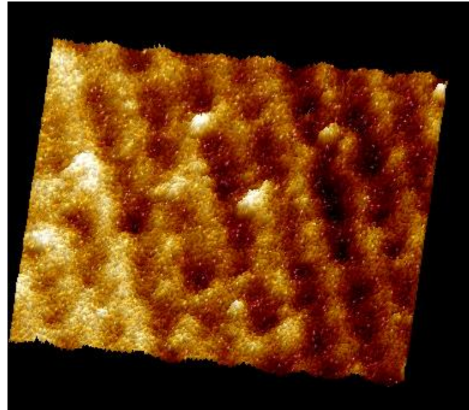


Magnetic Force Microscopy









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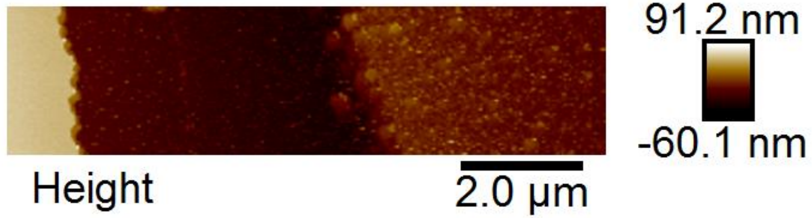
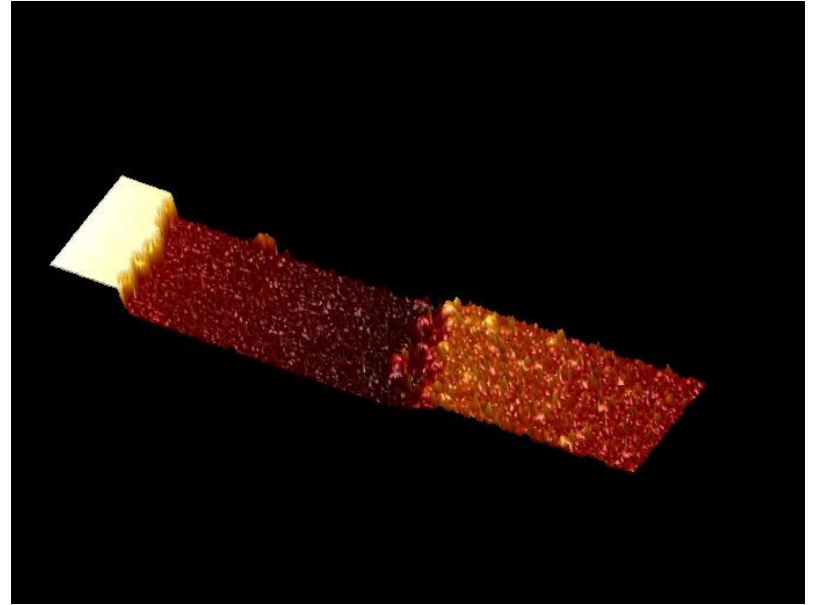
EFM

Electric Force Microscopy

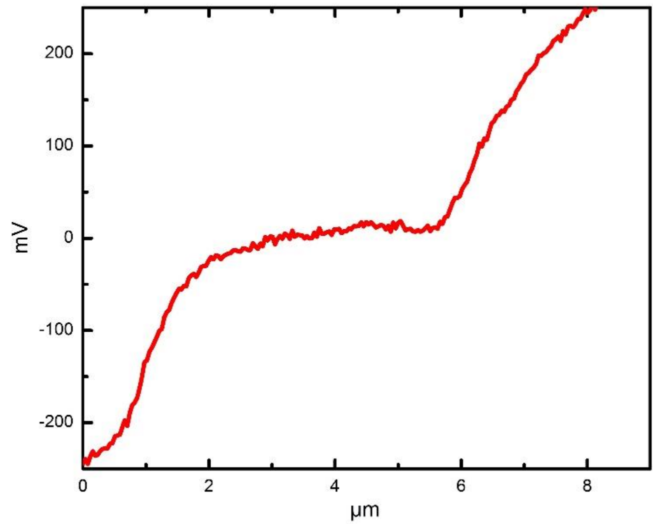


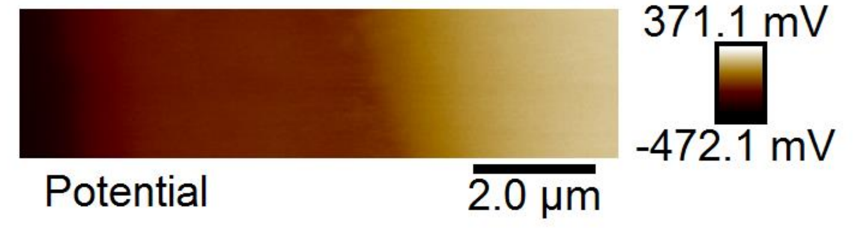


LasMat

CeNano²I

Electric Force Microscopy



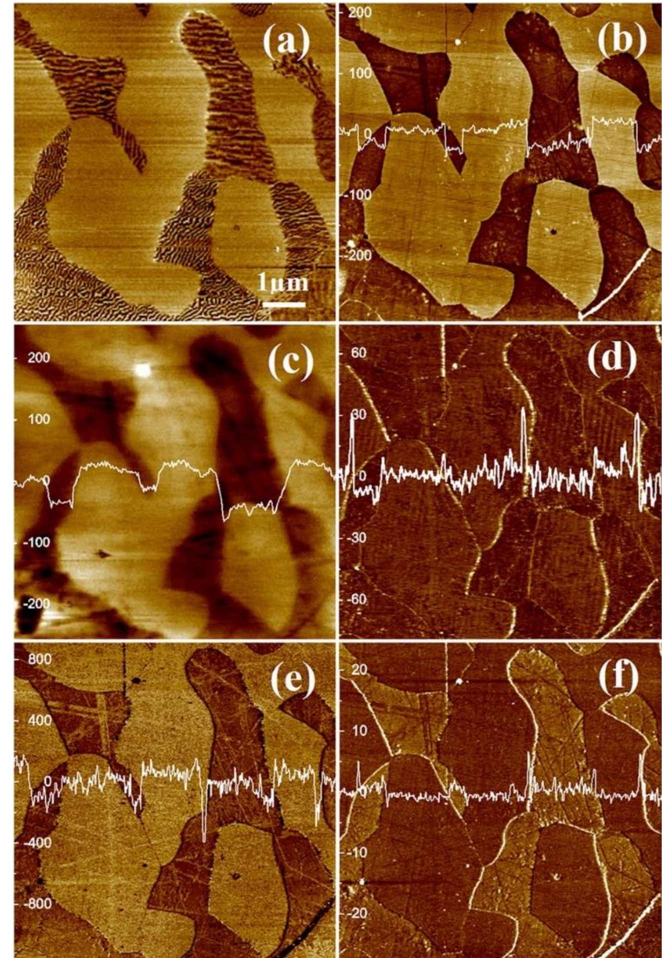


Characterization of steel: AFM

Ferrite and austenite phases in a duplex stainless

(a) A MFM image of the duplex stainless steel; (b) An AFM topography image (c) EFM potential mapping; (d) Adhesion mapping (nN); (e) Modulus (GPa) mapping; and (f) Deformation mapping (nm).

Nature Scientific Reports 6, 20660 (2016)

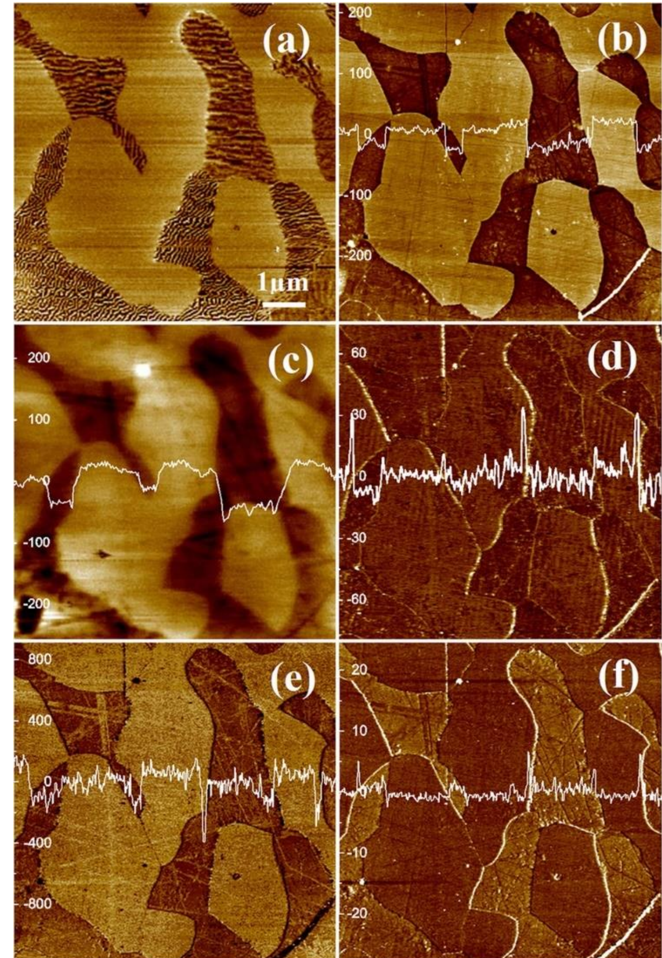


Characterization of steel: AFM

The ferrite phase has a striped appearance due to its ferromagnetic behavior, while the paramagnetic austenite phase shows a uniform appearance.

Topography (Fig. 2(b)) of the same area reveals that austenite (lighter) is higher than ferrite (darker). The difference in height is caused by the electrochemical polishing during which the ferrite phase dissolved faster than austenite due to its relatively lower corrosion resistance.

Nature Scientific Reports 6, 20660 (2016)

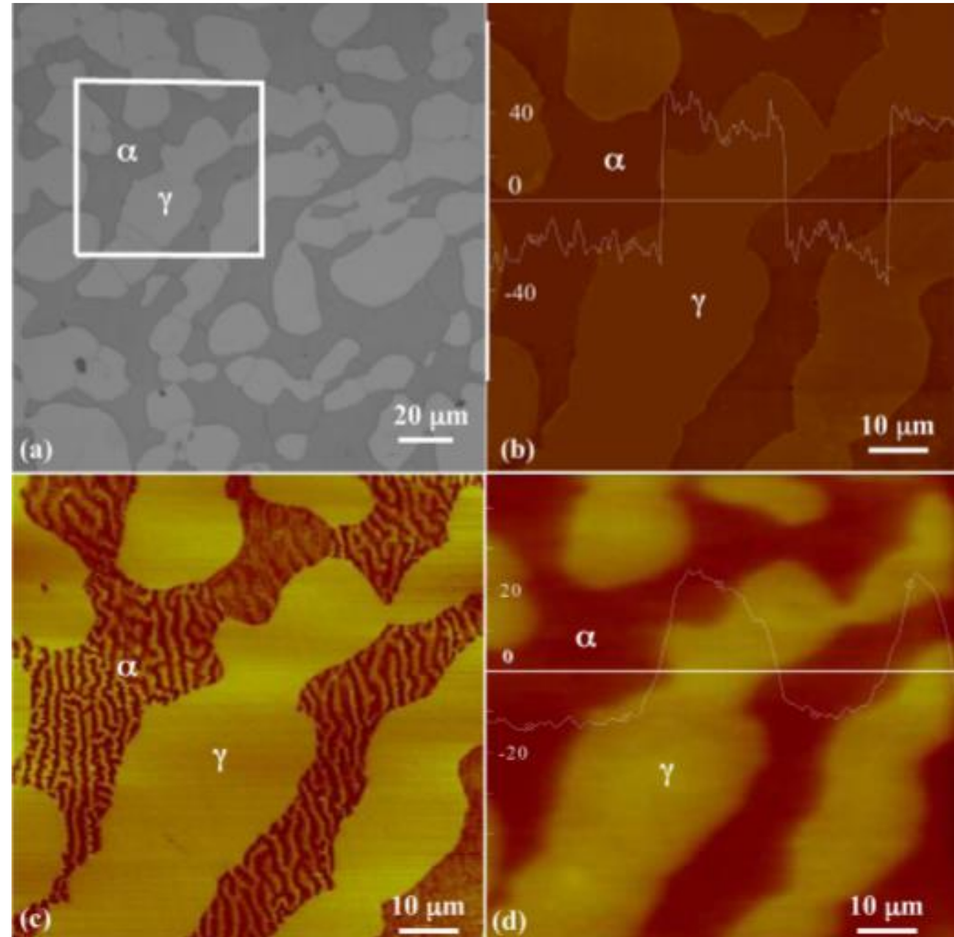


Characterization of steel: AFM

Ferrite and austenite phase identification in duplex stainless steel

Ferrite (α) - Austenite (γ) phases

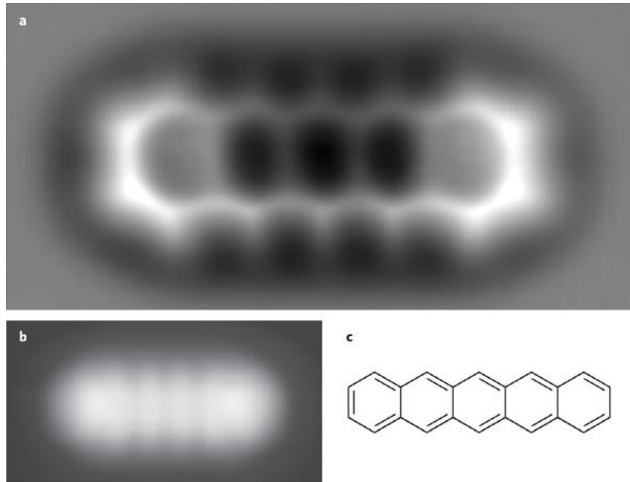
(a) Optical image duplex stainless steel surface; (b) AFM topography (c) MFM image; (d) EFM potential map.

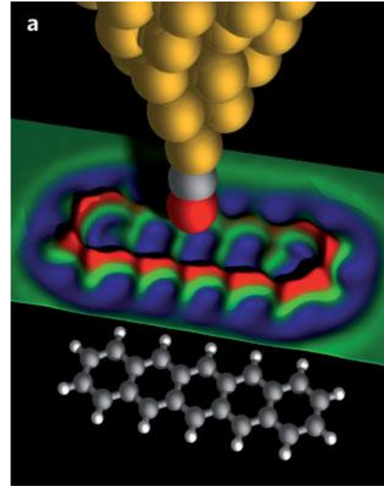


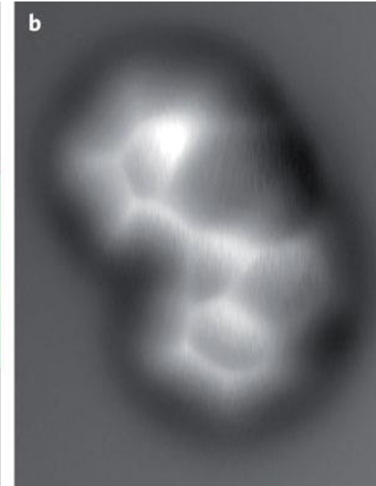
L.Q. Guo et al. /Applied Surface Science 287 (2013) 499– 501

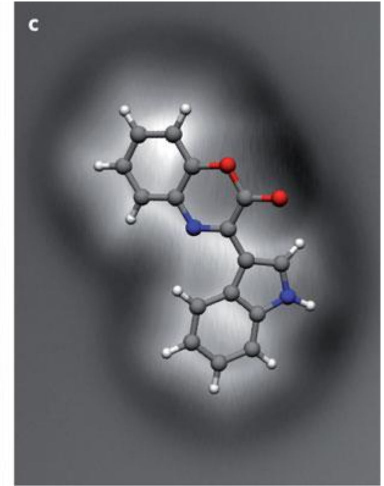
Molecular imaging

Molecular imaging: The tip of what can be seen



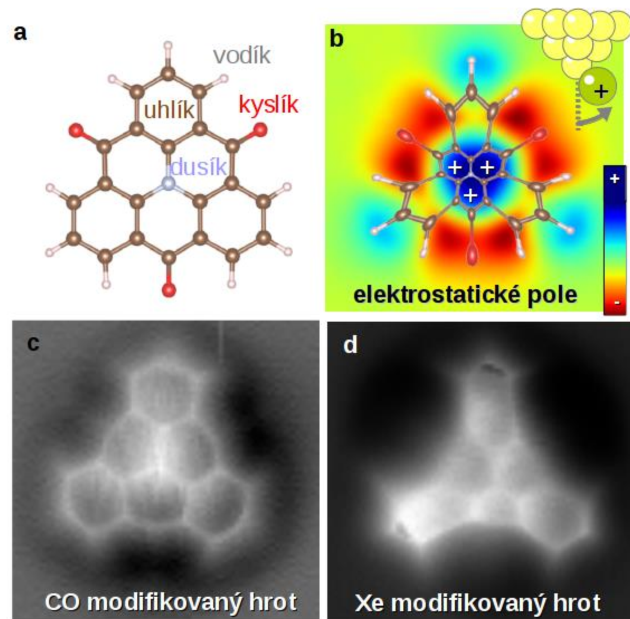


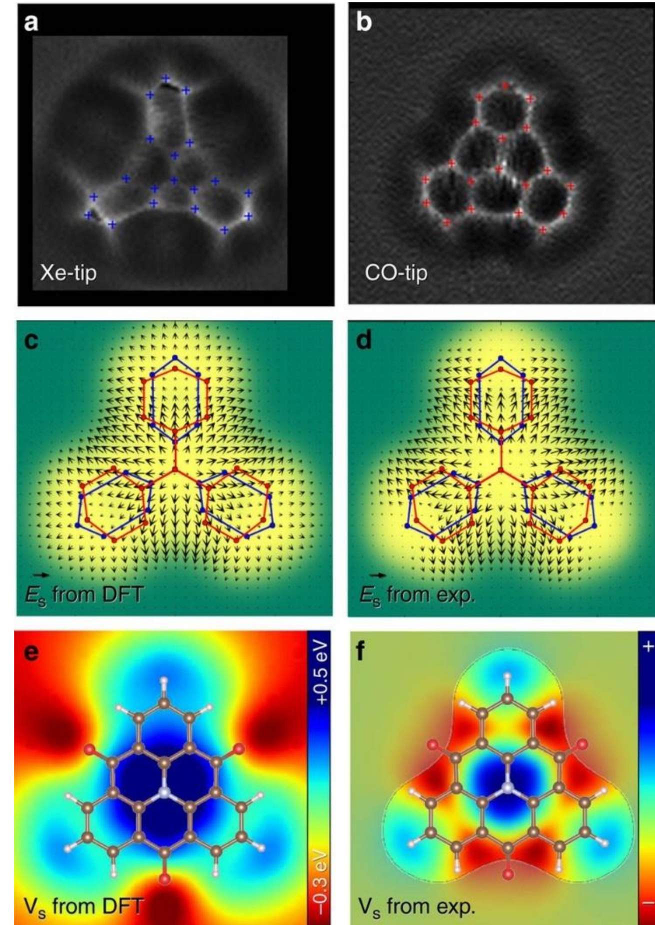




Nature Chemistry 3, 2011, 273–278

Molecular imaging





Nature Communications 7, 11560 (2016)

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