Nanotehnologije

Mikroskopija primenom skenirajuće sonde

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SPM tehnike

- **General Purpose Modes for Atomic Force Microscopes**
- **Other Modes for Atomic Force Microscopes**
- **Force Spectroscopy Modes for Atomic Force Microscopes**
- **Electrical Characterization Modes for Atomic Force Microscopes**

SPM tehnike

General Purpose Modes for Atomic Force Microscopes

- Contact Mode
- PeakForce™ QNM™ (Quantitative Nanomechanical Property Mapping)
- PhaseImaging™
- ScanAsyst™
- TappingMode™

SPM tehnike

◎**Other Modes for Atomic Force Microscopes**

- Force Modulation Microscopy (FMM)
- Lateral Force Microscopy (LFM)
- Magnetic Force Microscopy (MFM)
- Nanoindenting and Nanoscratching
- Scanning Electrochemical Potential Microscopy (SECPM)
- Scanning Thermal Microscopy (SThM VITA)
- Scanning Tunneling Microscopy (STM)
- Torsion Resonance Mode (TRmode)

SPM tehnike

Electrical Characterization Modes for Atomic Force Microscopes

- Conductive AFM Option (C-AFM)
- Electrostatic Force Microscopy (EFM)
- PeakForce TUNA™
- Scanning Capacitance Microscopy (SCM)
- Scanning Spreading Resistance Microscopy (SSRM)
- Surface Potential (SP)
- Torsional Resonance Tunneling AFM (TR TUNA)
- Tunneling AFM (TUNA)

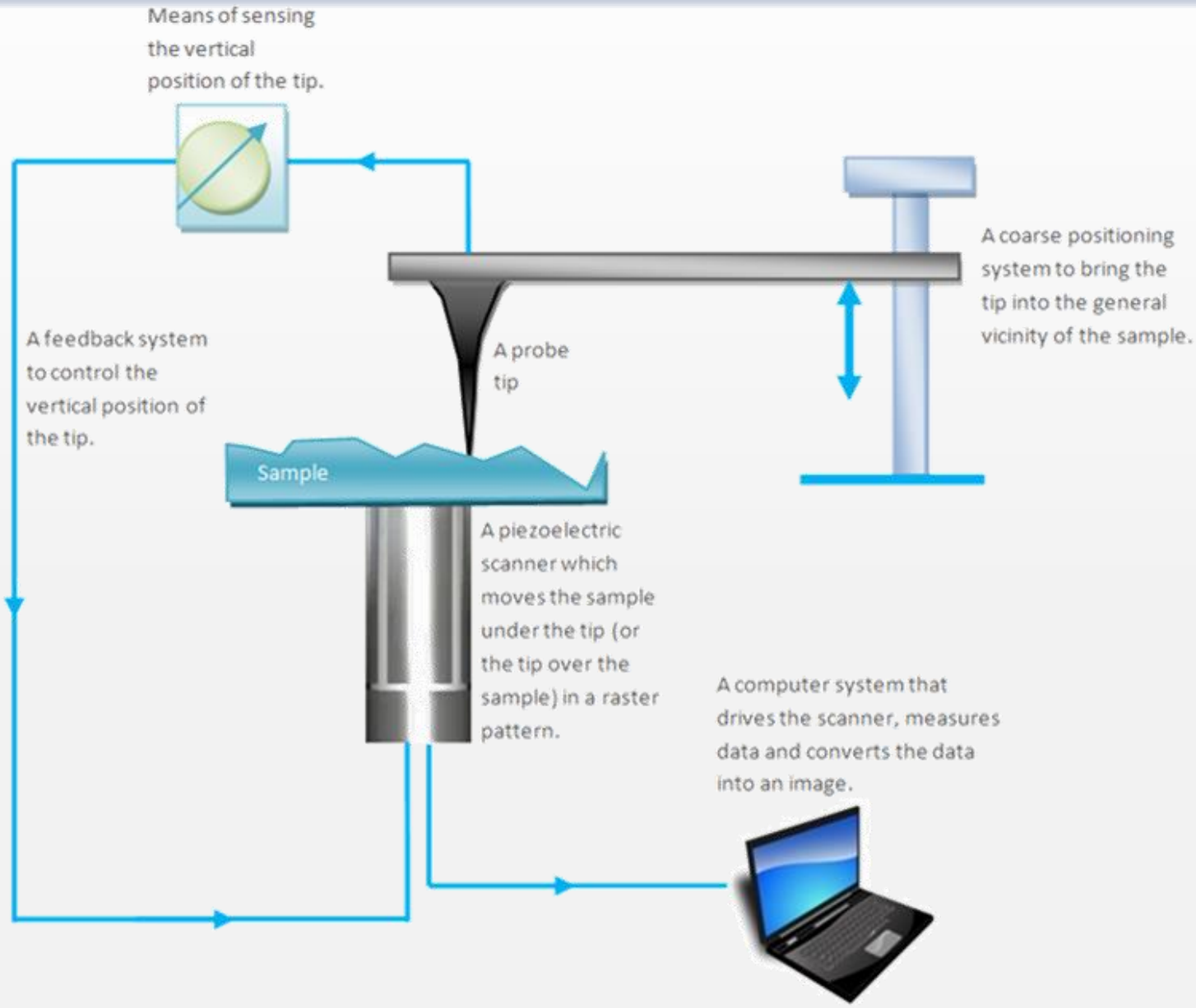
SPM tehnike

Abbrev.	Technique	Interaction type	Usage
STM	Scanning Tunneling Microscopy	Tunneling current	3-D topography: size, shape and periodicity of features, surface roughness. Electronic structure, and possible elemental identity
AFM	Atomic Force Microscopy	Interatomic and intermolecular forces	3-D topography: size and shape and periodicity of features, surface roughness.
FMM	Force modulation microscopy	Interatomic and intermolecular forces	Hardness and surface elasticity at various locations
LFM	Lateral Force Microscopy	Frictional forces	Differences of adhesiveness and friction at various locations.
MFM	Magnetic Force Microscopy	Magnetic forces	Size and shape of magnetic features. Strength and polarity of magnetic fields at different locations.
SThM	Scanning Thermal Microscopy	Heat transfer	Thermal conductivity differences between surface features.
EFM	Electrostatic force microscopy	Electrostatic forces	Electrostatic field gradients on the sample surface.
NSOM	Near-field Scanning Optical Microscopy	Reflection, absorption and Fluorescence of light	Optical properties of surface features

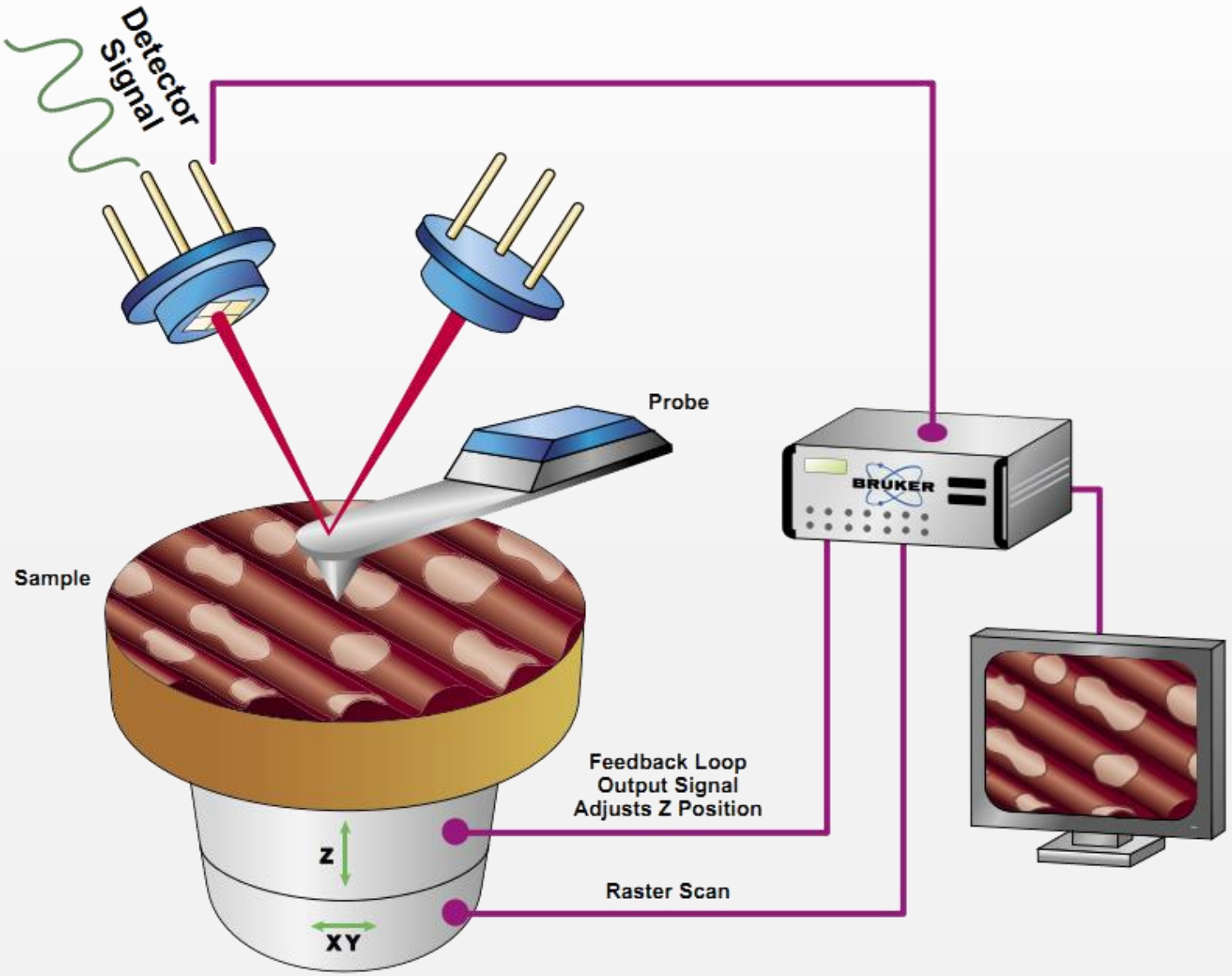
SPM tehnike

	AFM	TEM	SEM	Optical
Max resolution	Atomic	Atomic	1's nm	100's nm
Typical cost (x $1,000)	100 - 200	500 or higher	200 - 400	10 - 50
Imaging Environment	air, fluid, vacuum, special gas	vacuum	vacuum	air, fluid
In-situ	Yes	No	No	Yes
In fluid	Yes	No	No	Yes

SPM tehnike


Means of sensing the vertical position of the tip.
A coarse positioning system to bring the tip into the general vicinity of the sample.
A feedback system to control the vertical position of the tip.
A probe tip
Sample
A piezoelectric scanner which moves the sample under the tip (or the tip over the sample) in a raster pattern.
A computer system that drives the scanner, measures data and converts the data into an image.

SPM tehnike


Detector Signal
Probe
Sample
BRUKER
Feedback Loop
Output Signal
Adjusts Z Position
Z
XY
Raster Scan

SPM tehnike

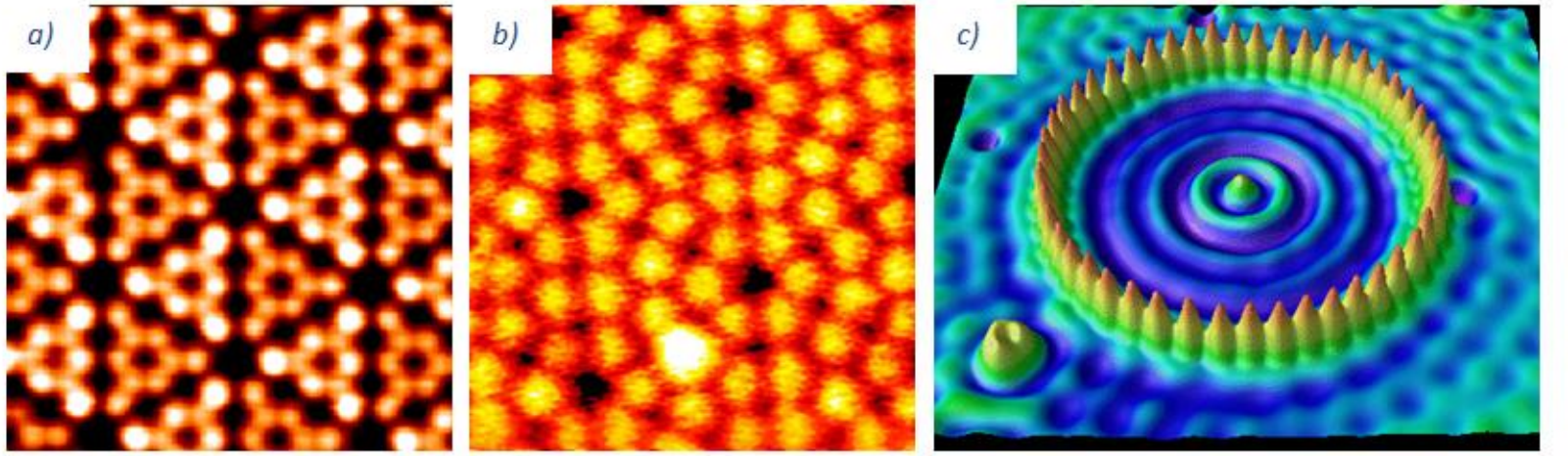
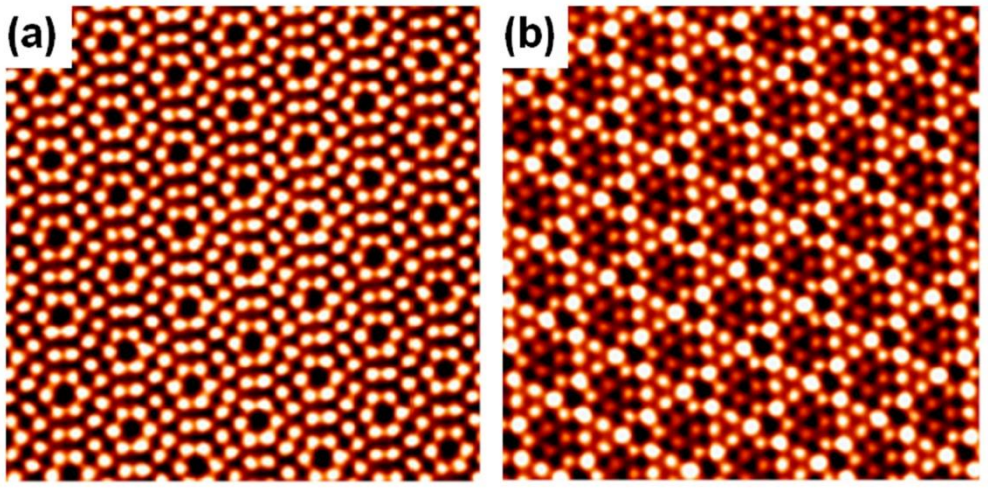


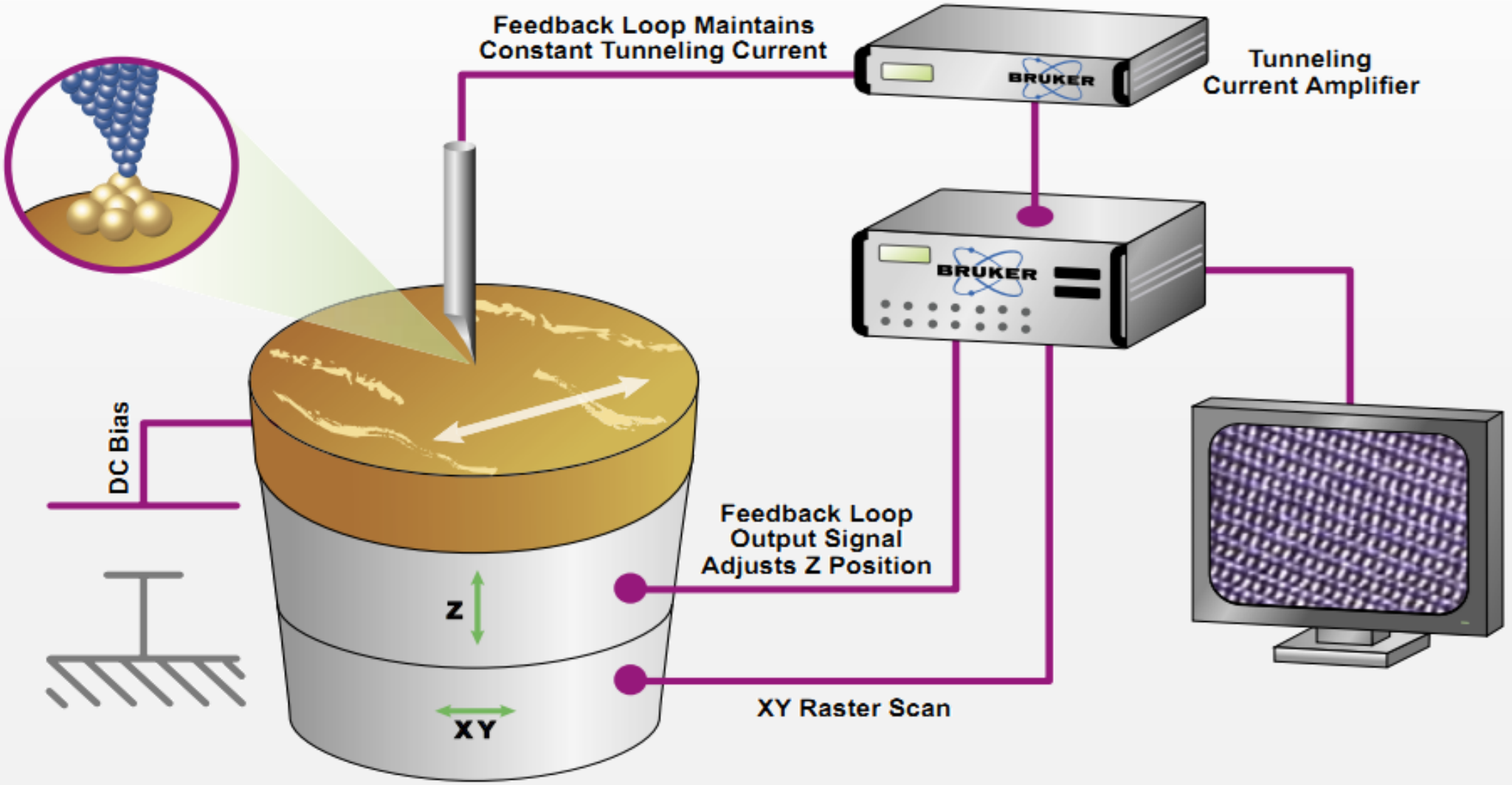
Figure 1: a) Highest resolution experimental result for Si (111)-7x7 [4]*; b) Atomic Resolution on Si (111) (7x7) in NC AFM* [5]*; c) "Quantum corral" - a ring of 48 iron atoms on a copper surface* [6]



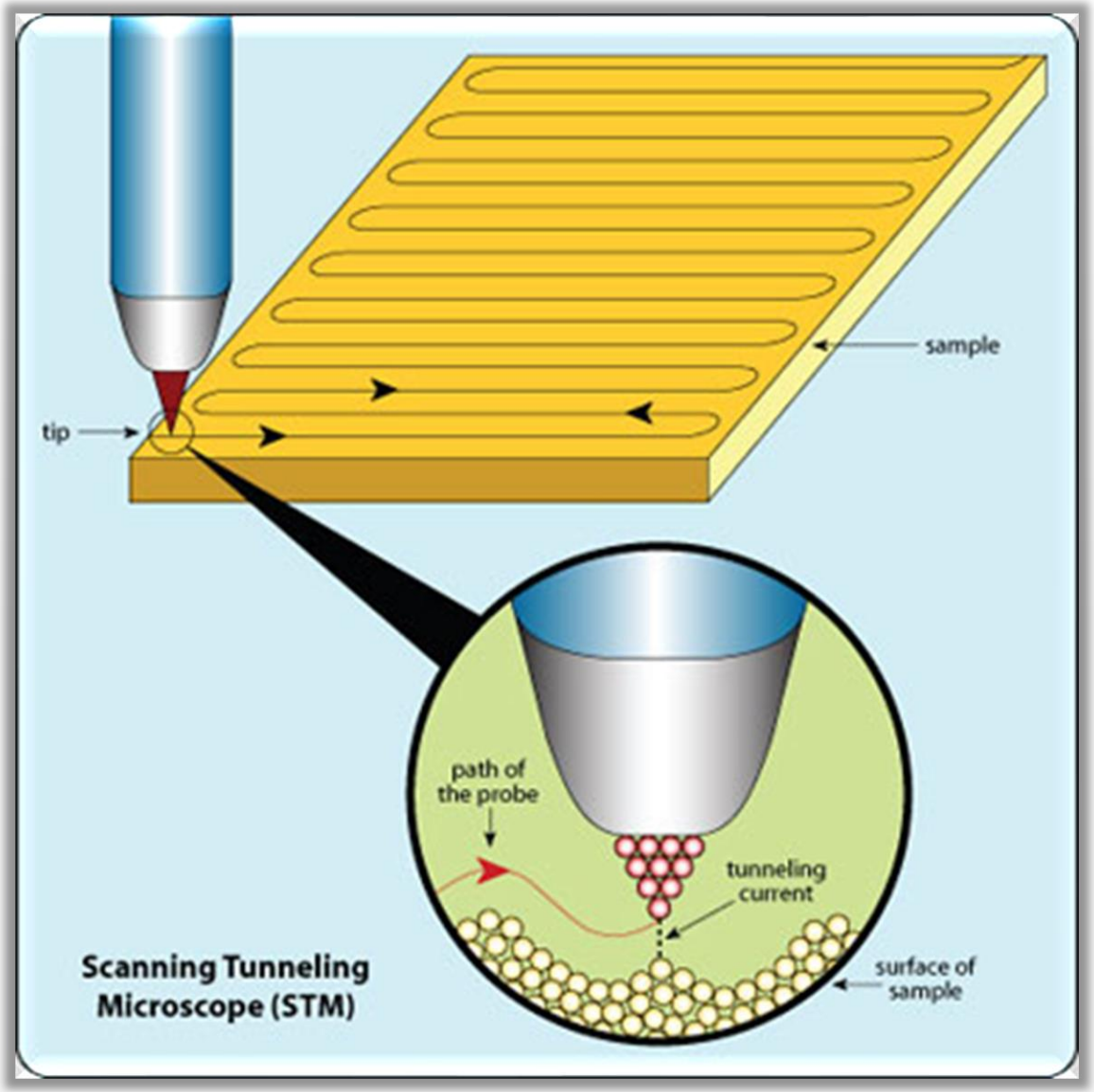
Typical atomic resolution STM images of Si(111)-7×7 surface. The bright spots mark only the 'dangling bonds' of adatoms. (a) Empty states. (b) Occupied states. The adatoms on the faulted half are brighter than that on the unfaulted half.

Haiming Guo et al 2014 J. Phys.: Condens. Matter 26 394001

Scanning Tunneling Microscope

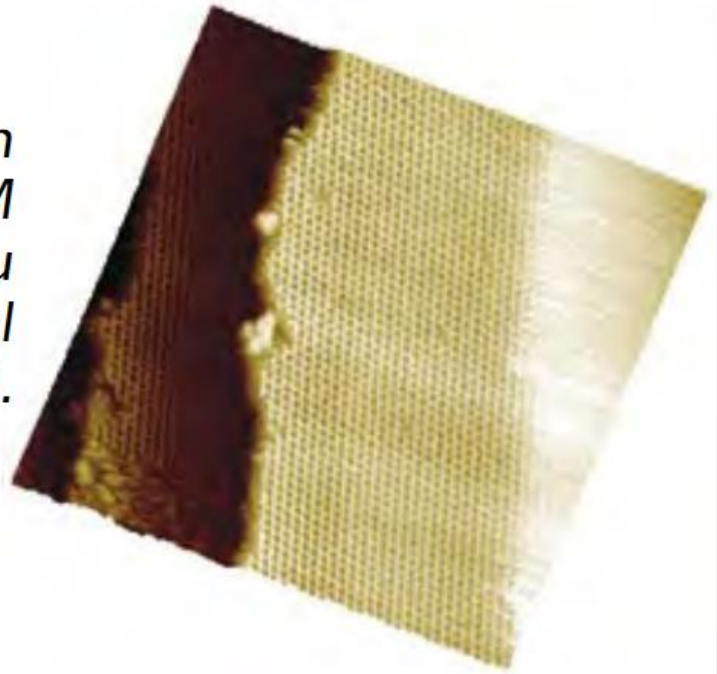


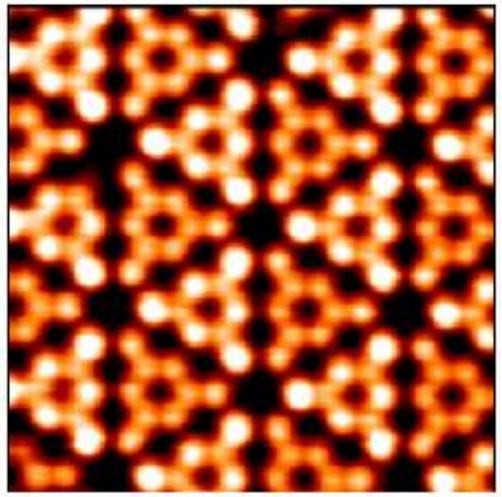
Scanning Tunneling Microscope



Scanning Tunneling Microscope – primeri

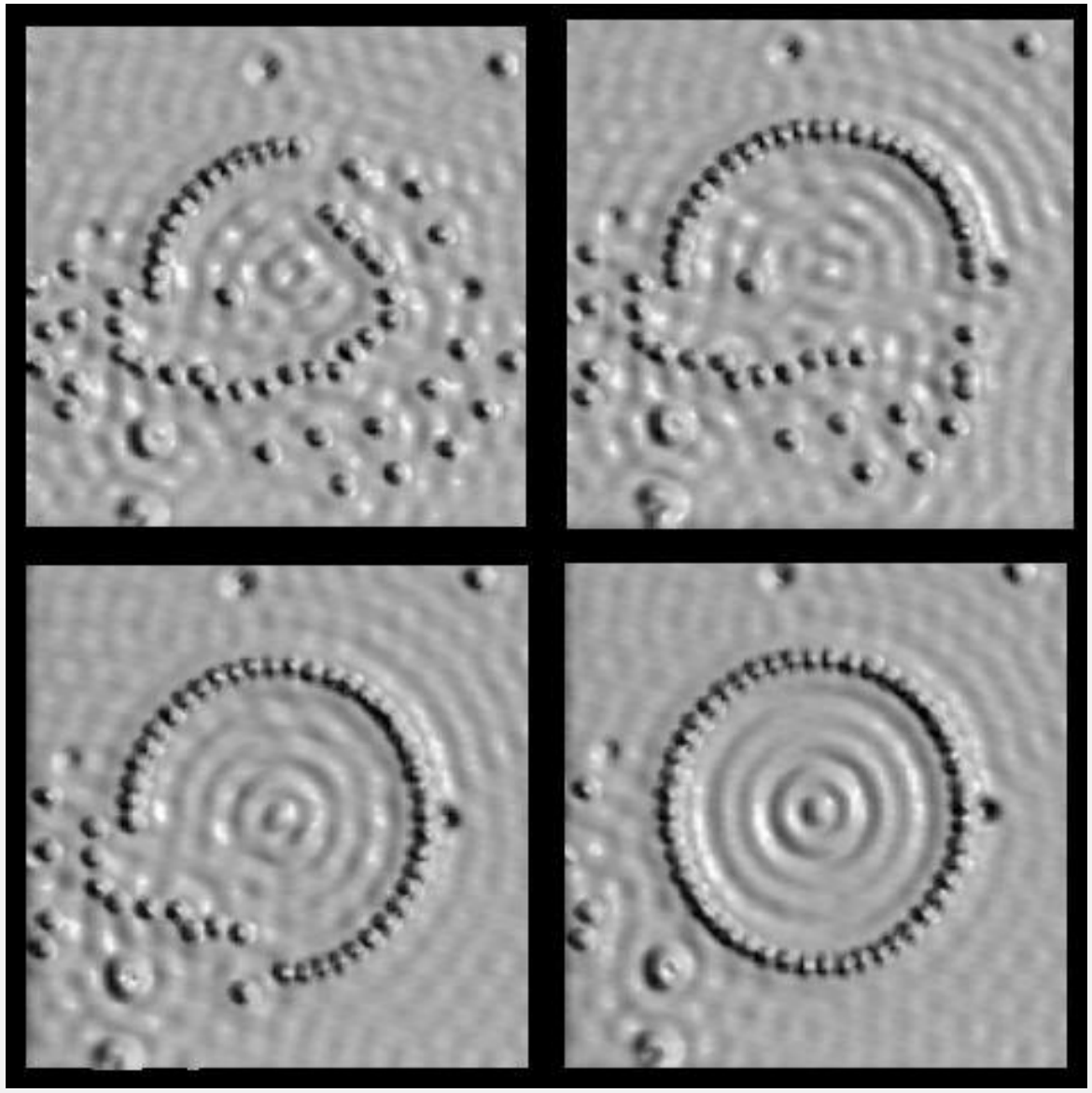
In-situ atom resolution electrochemical STM image of Cu underpotential deposition on Au(111).

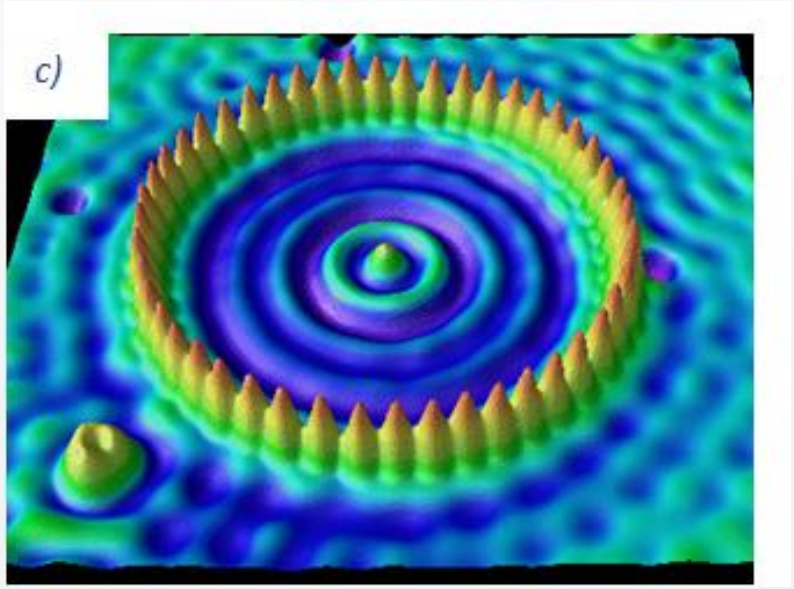




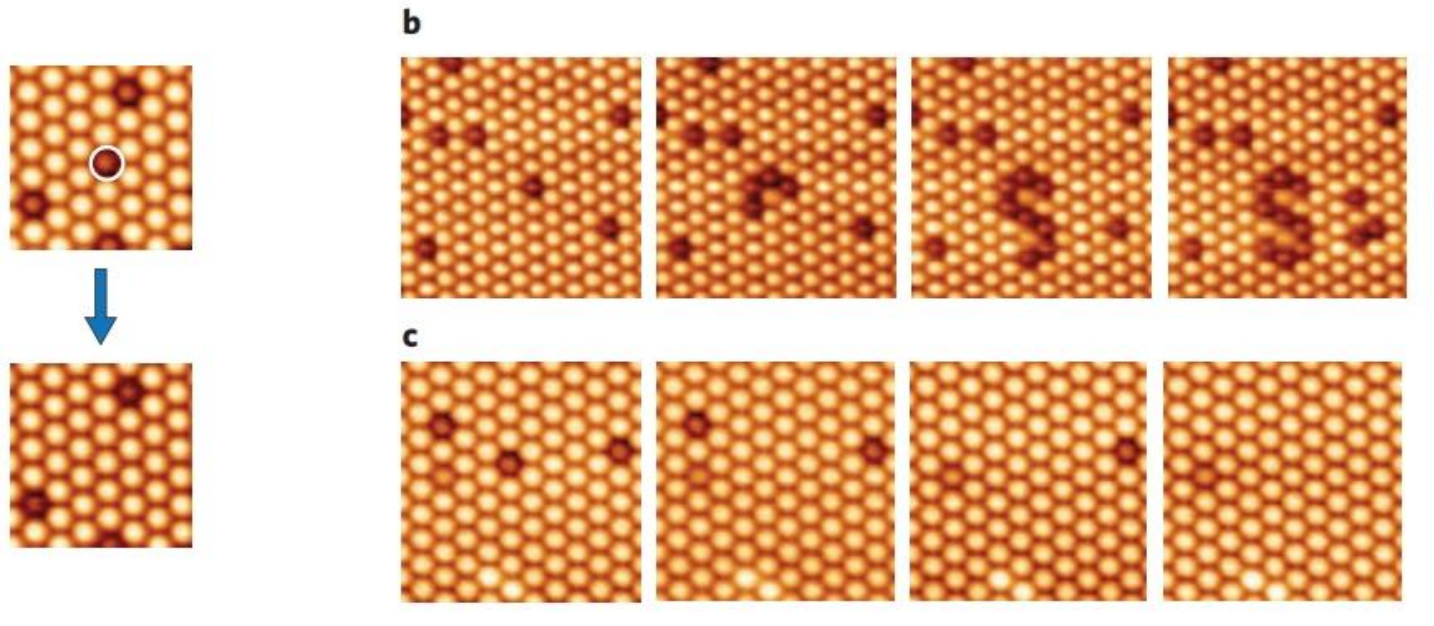
Highest resolution experimental result for Si(111)-7x7 with bias voltage -1.5 V and tunneling current 0.41 nA.

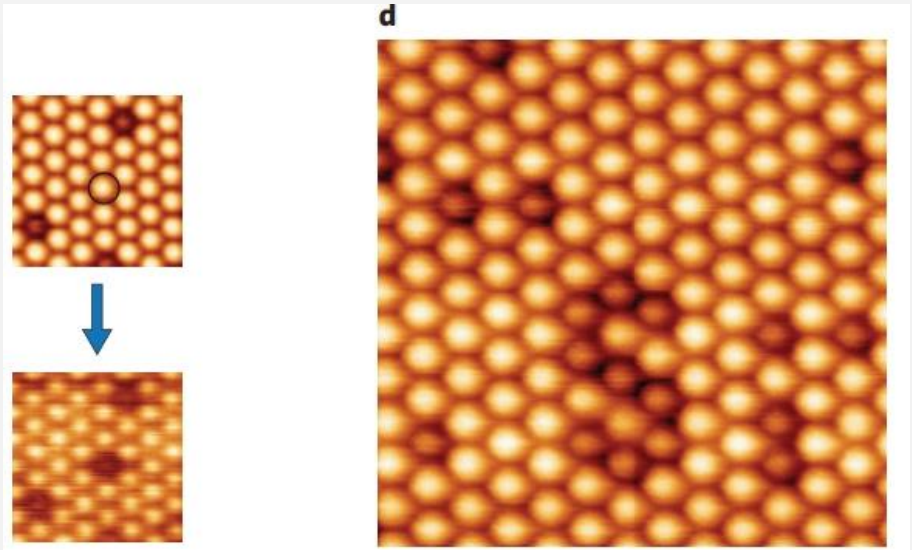
SPM tehnike – manipulacija atoma - primeri





SPM tehnike – manipulacija atoma-primeri

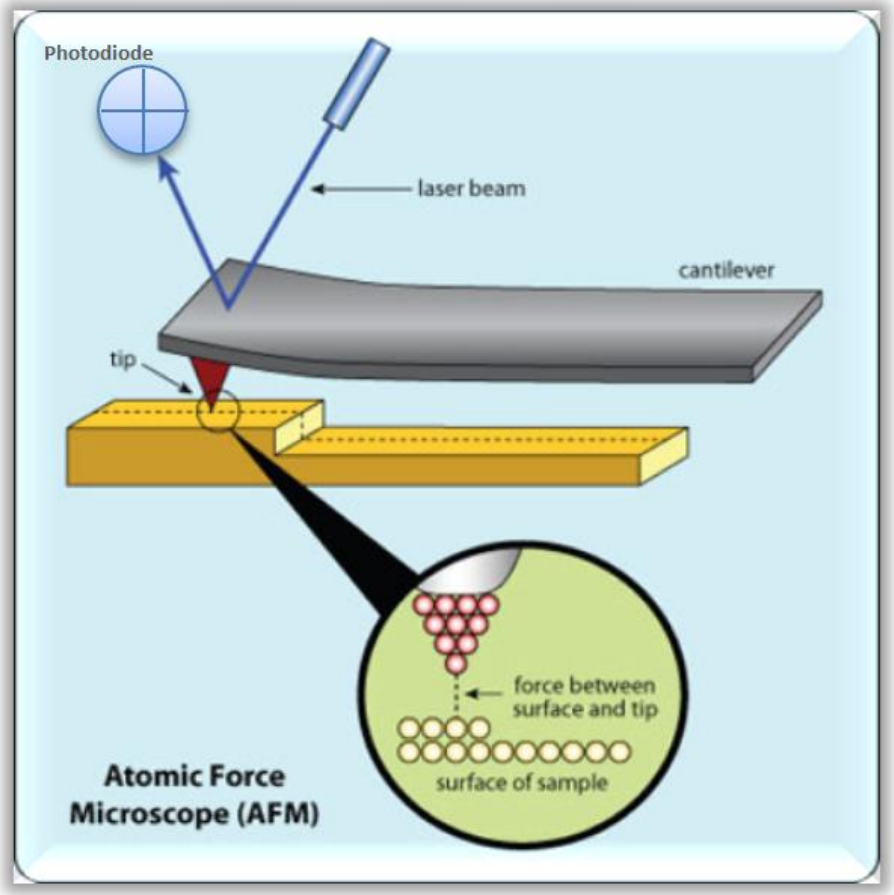


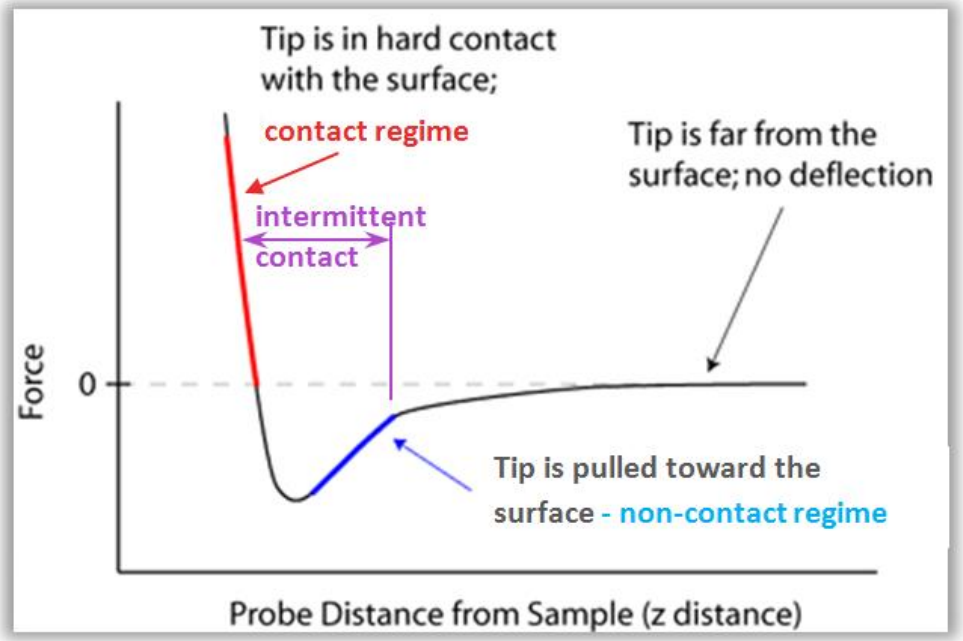


Scanning Probe Lithography

Atomic Force Microscope

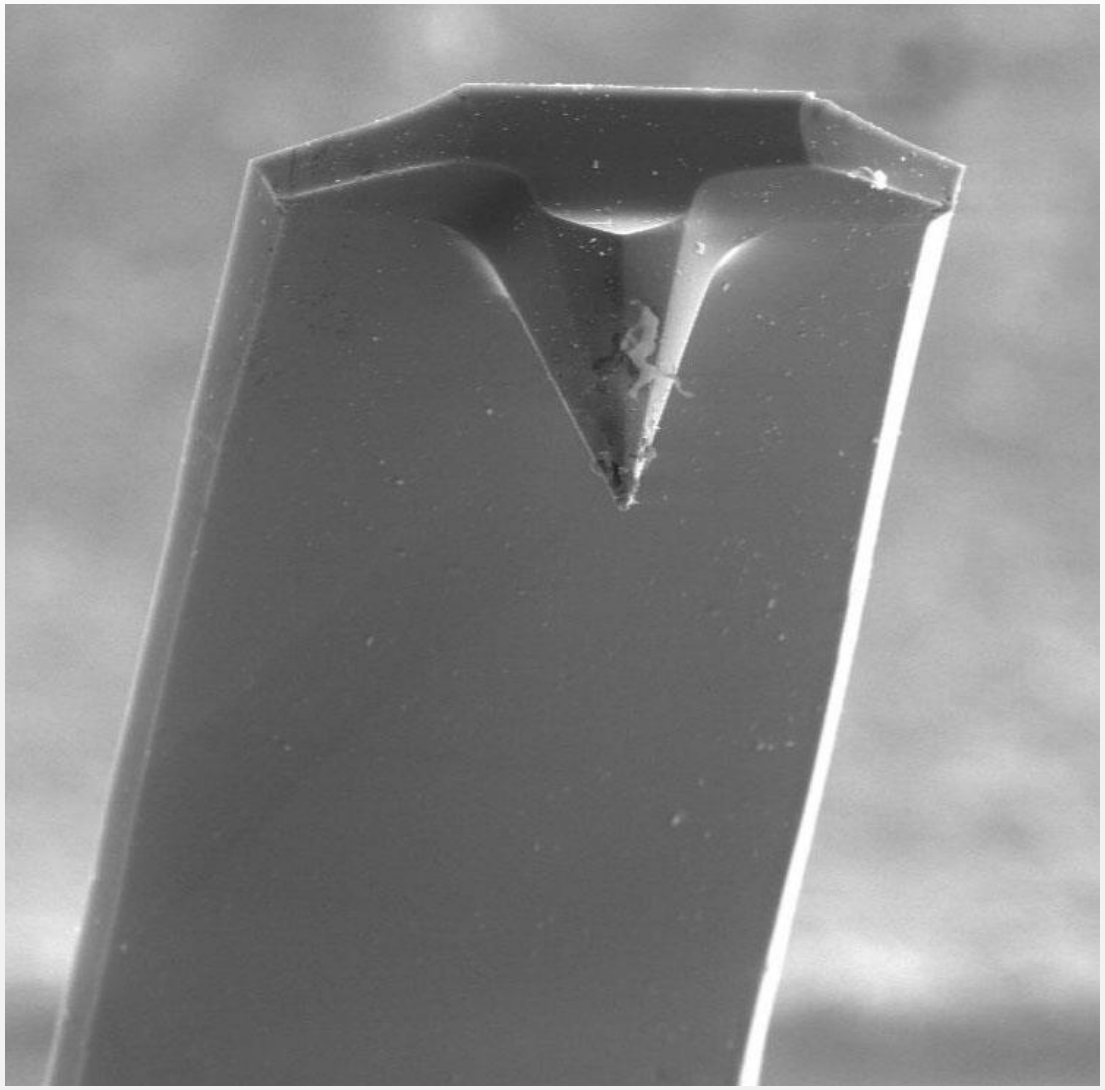
- **Contact AFM**
- **Non-contact AFM**
- **Intermittent-contact AFM (tapping mode)**



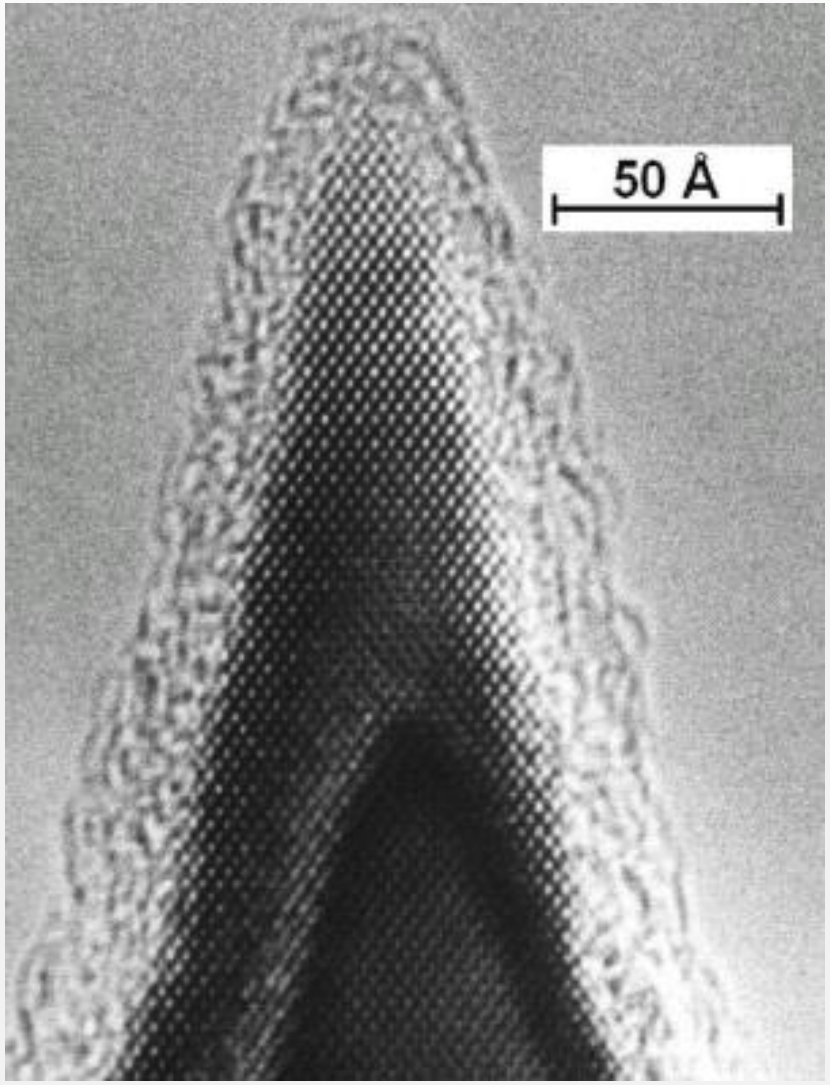


Atomic Force Microscope

Izgled sonde za kontantni način rada



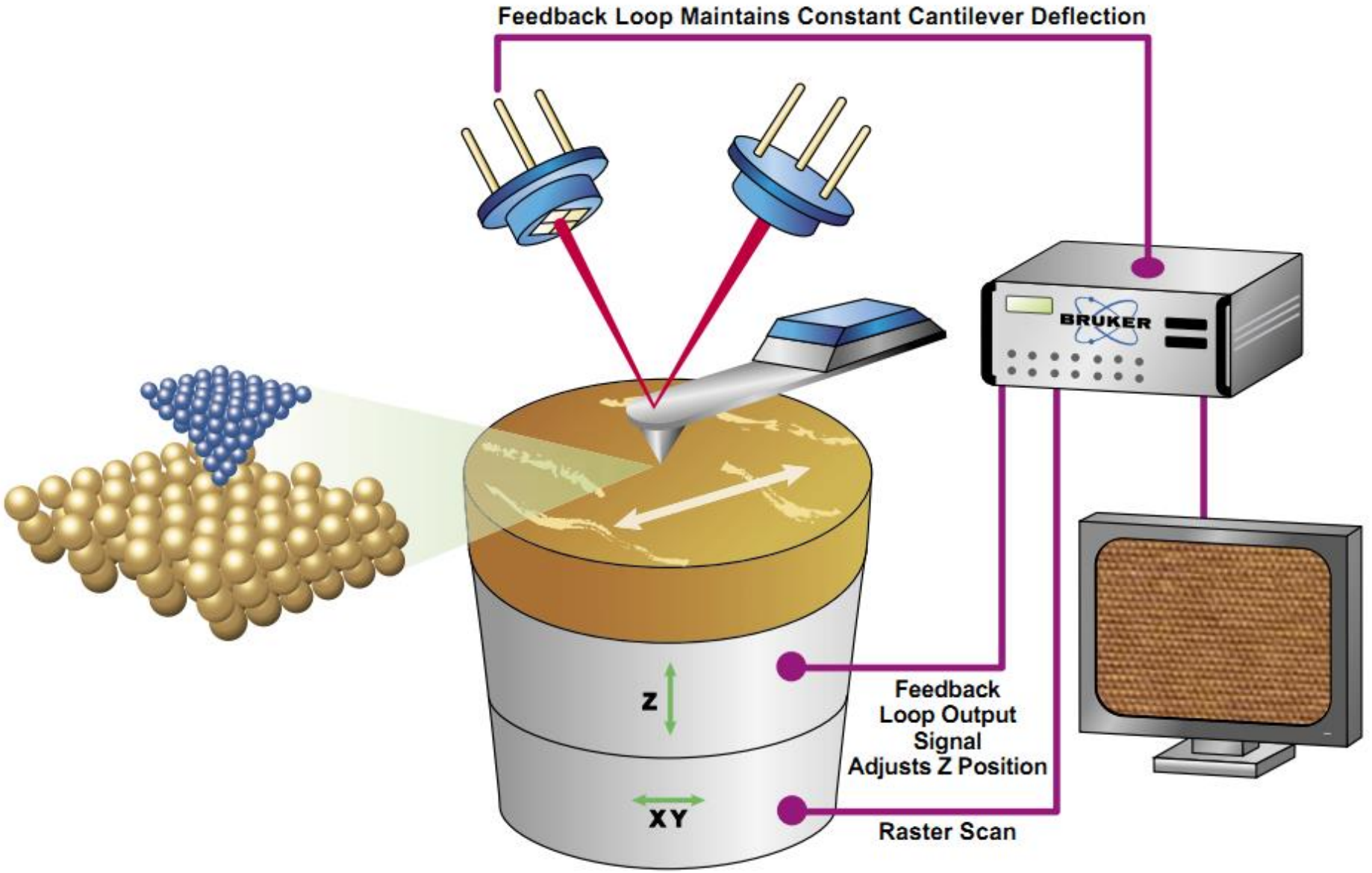
Poprečni presek vrha sonde, slika na TEM-u atomske rezolucije



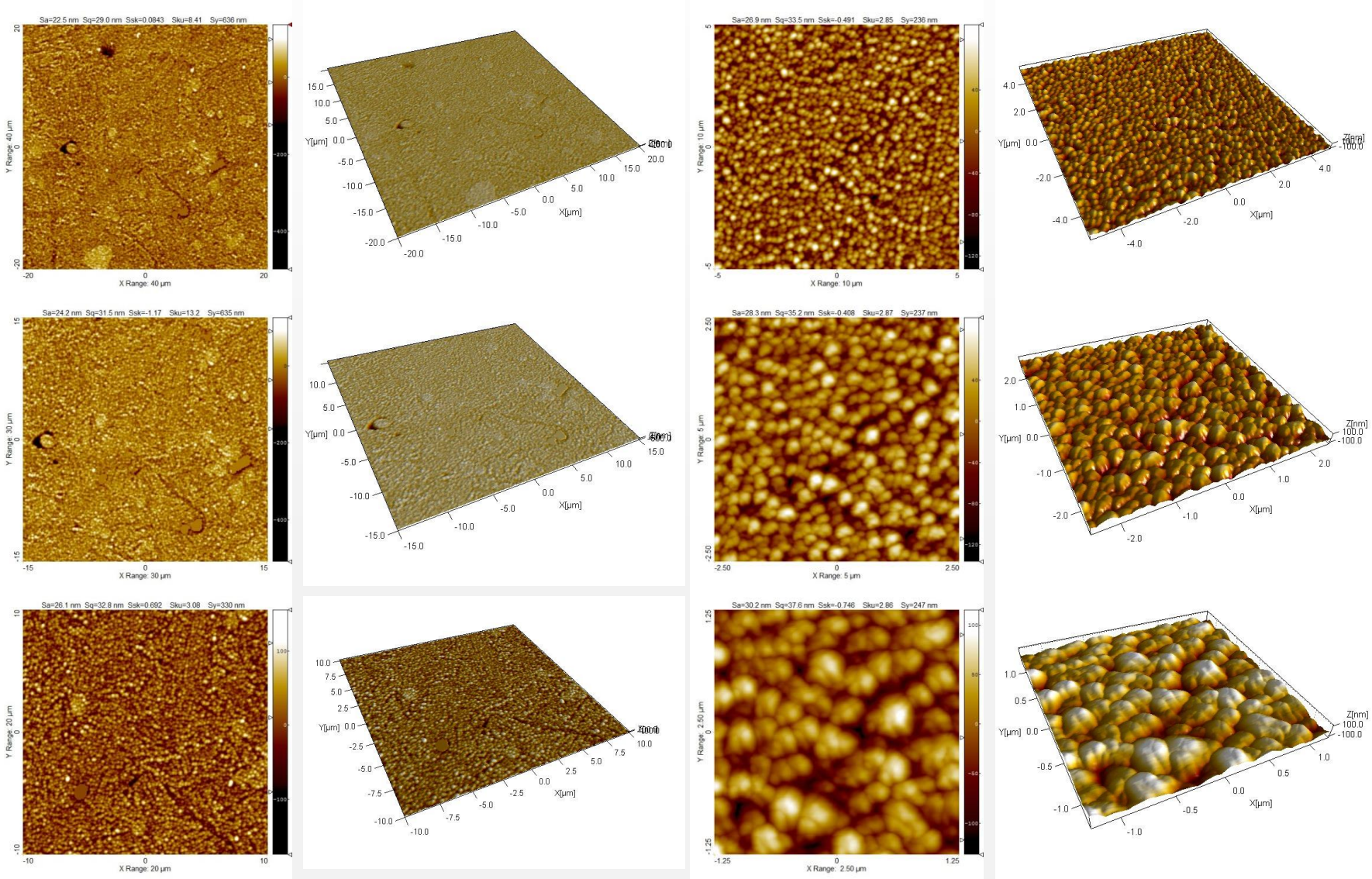
Atomic Force Microscope

- **Contact AFM**
- **Non-contact AFM**
- **Intermittent-contact AFM (tapping mode)**

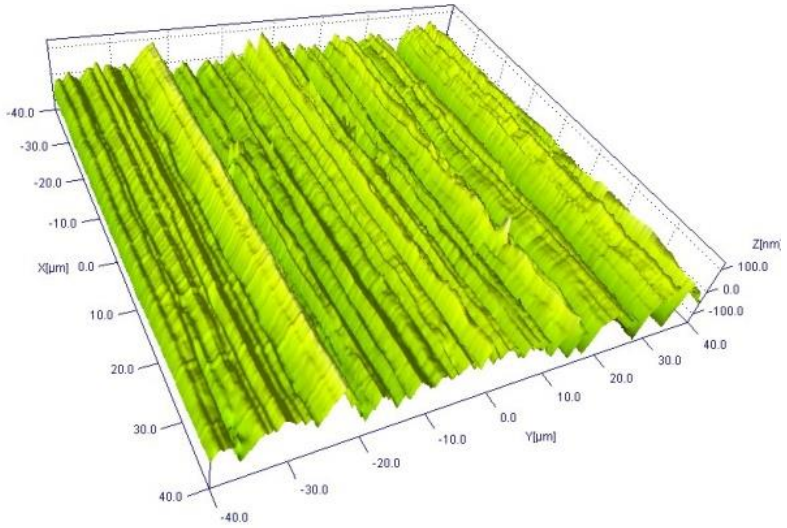
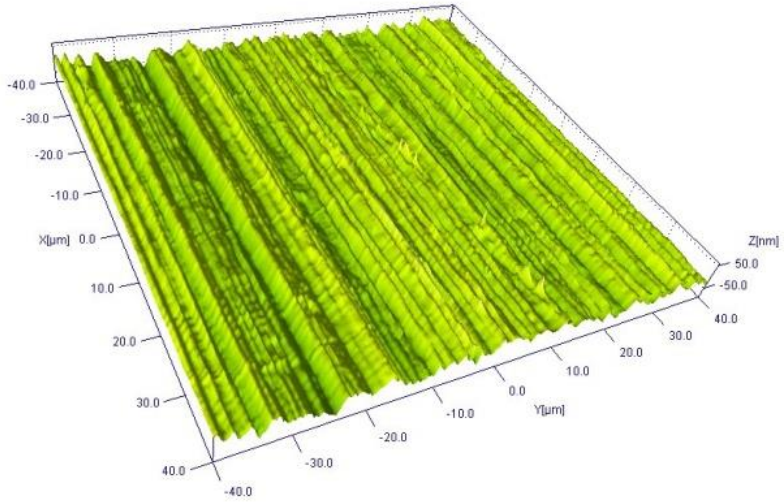
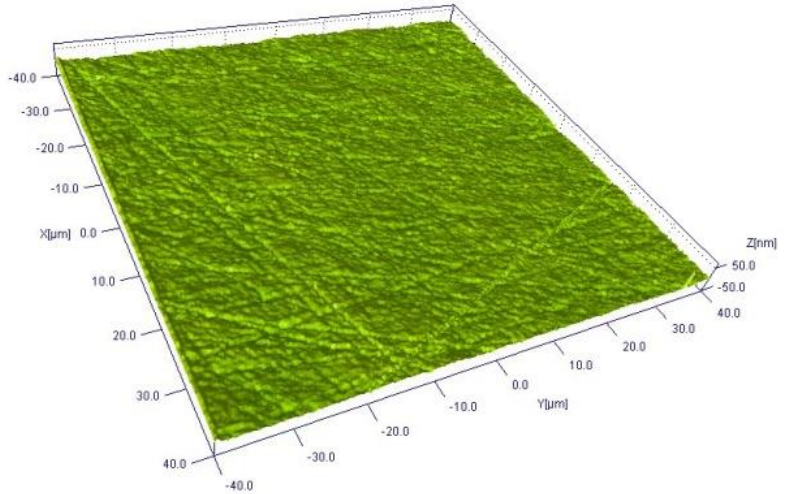
Contact AFM


Feedback Loop Maintains Constant Cantilever Deflection
BRUKER
Z
XY
Feedback
Loop Output
Signal
Adjusts Z Position
Raster Scan

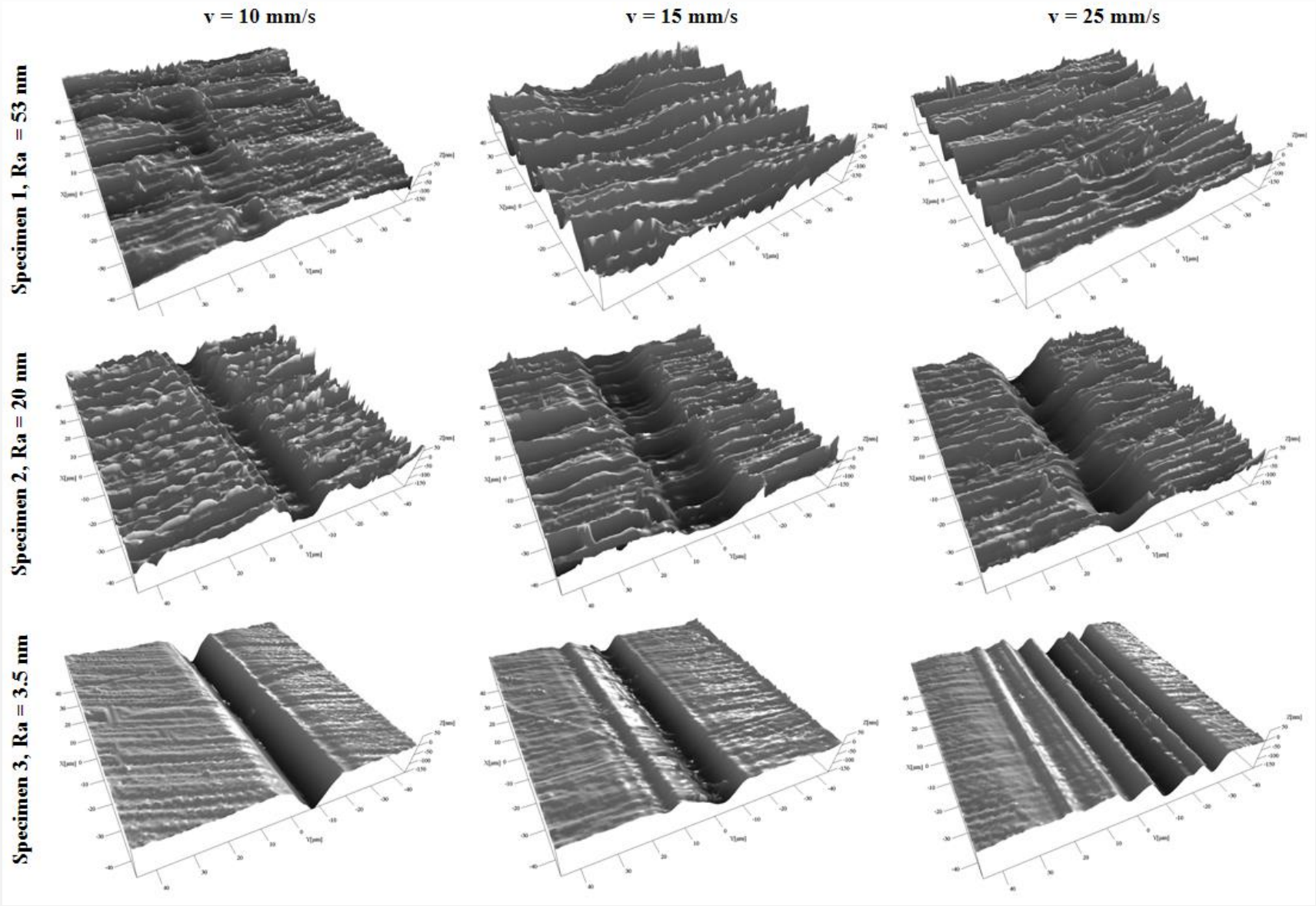
Contact AFM - primeri



Contact AFM - primeri

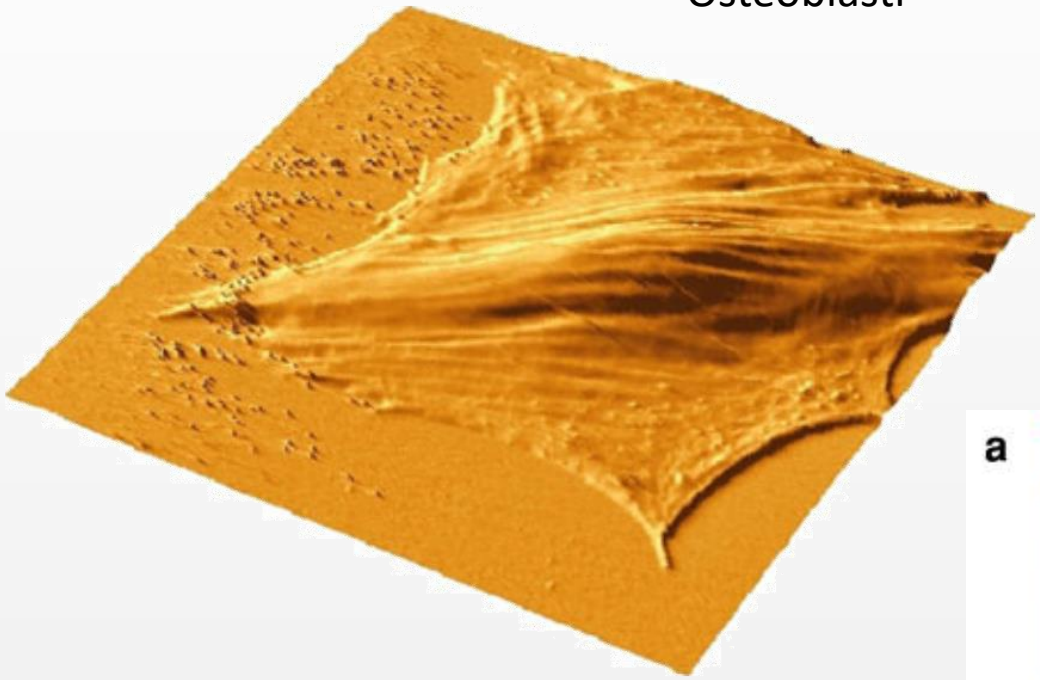
Sample 1	Sample 2	Sample 3
400 grit paper	1500 grit paper	2000 grit paper + polished
Ra 39 nm	Ra 14 nm	Ra 4 nm
		

Contact AFM - primeri



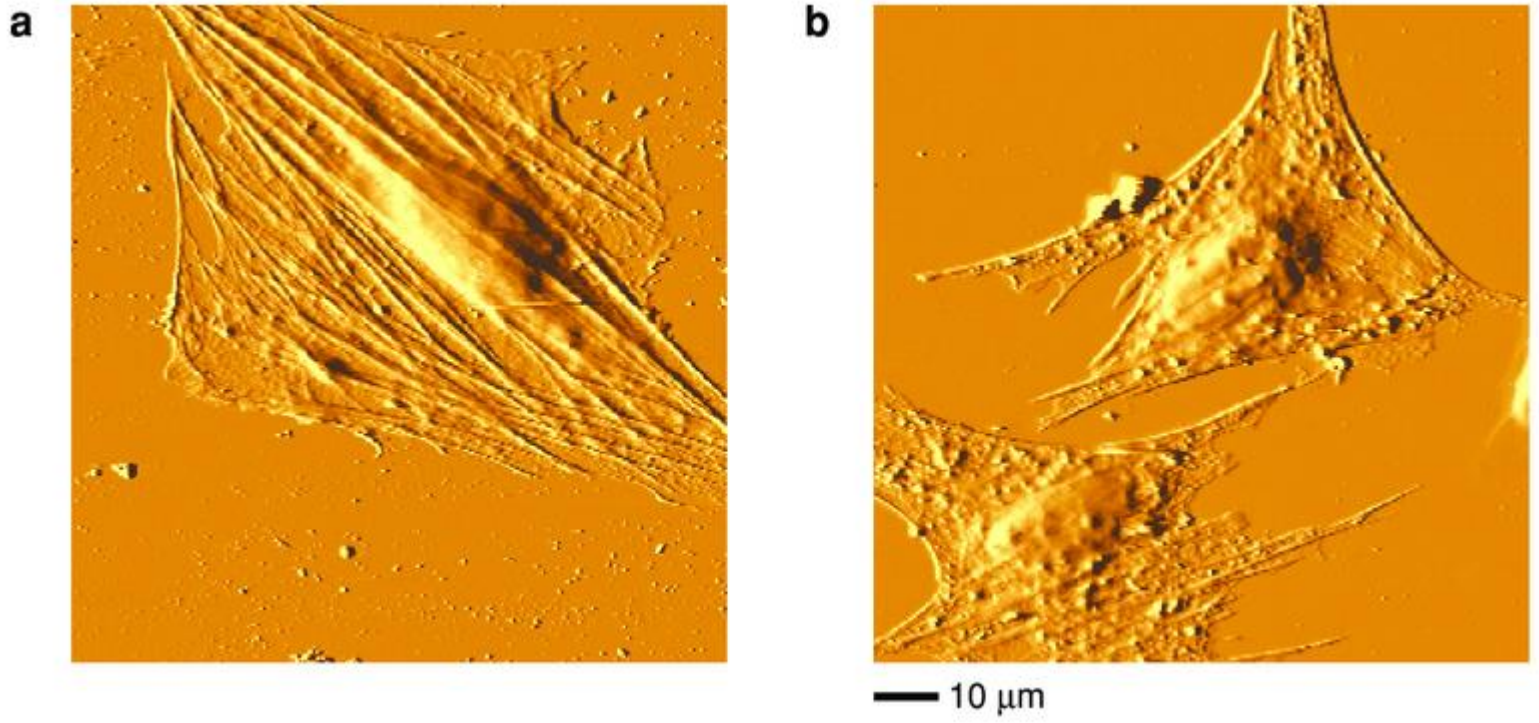
Contact AFM - primeri

Osteoblasti



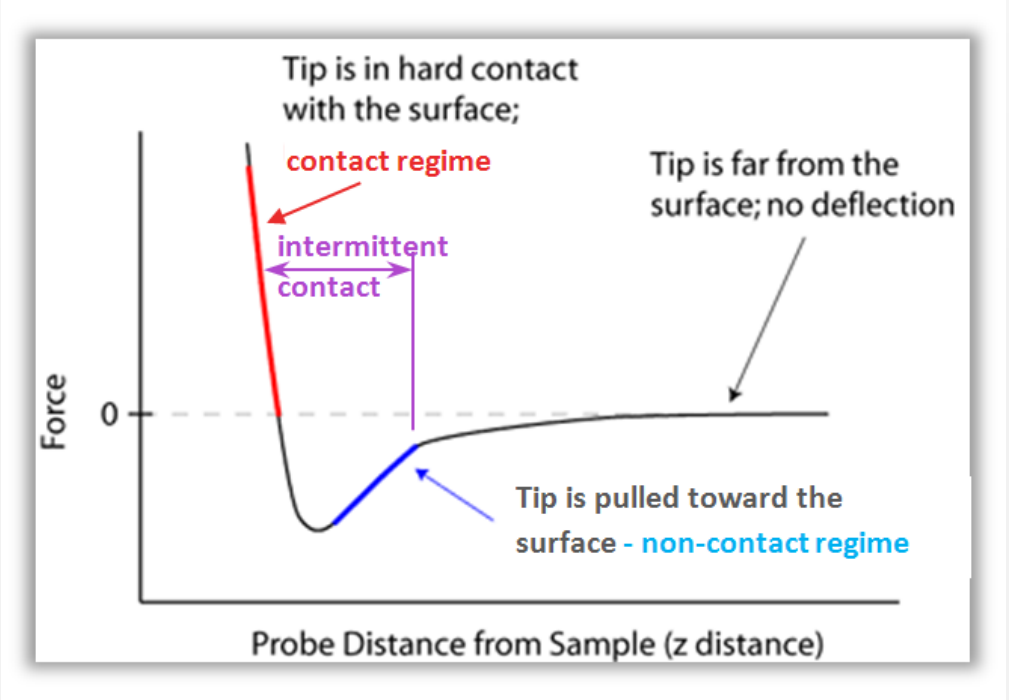
Žive ćelije

Hemijski fiksirane

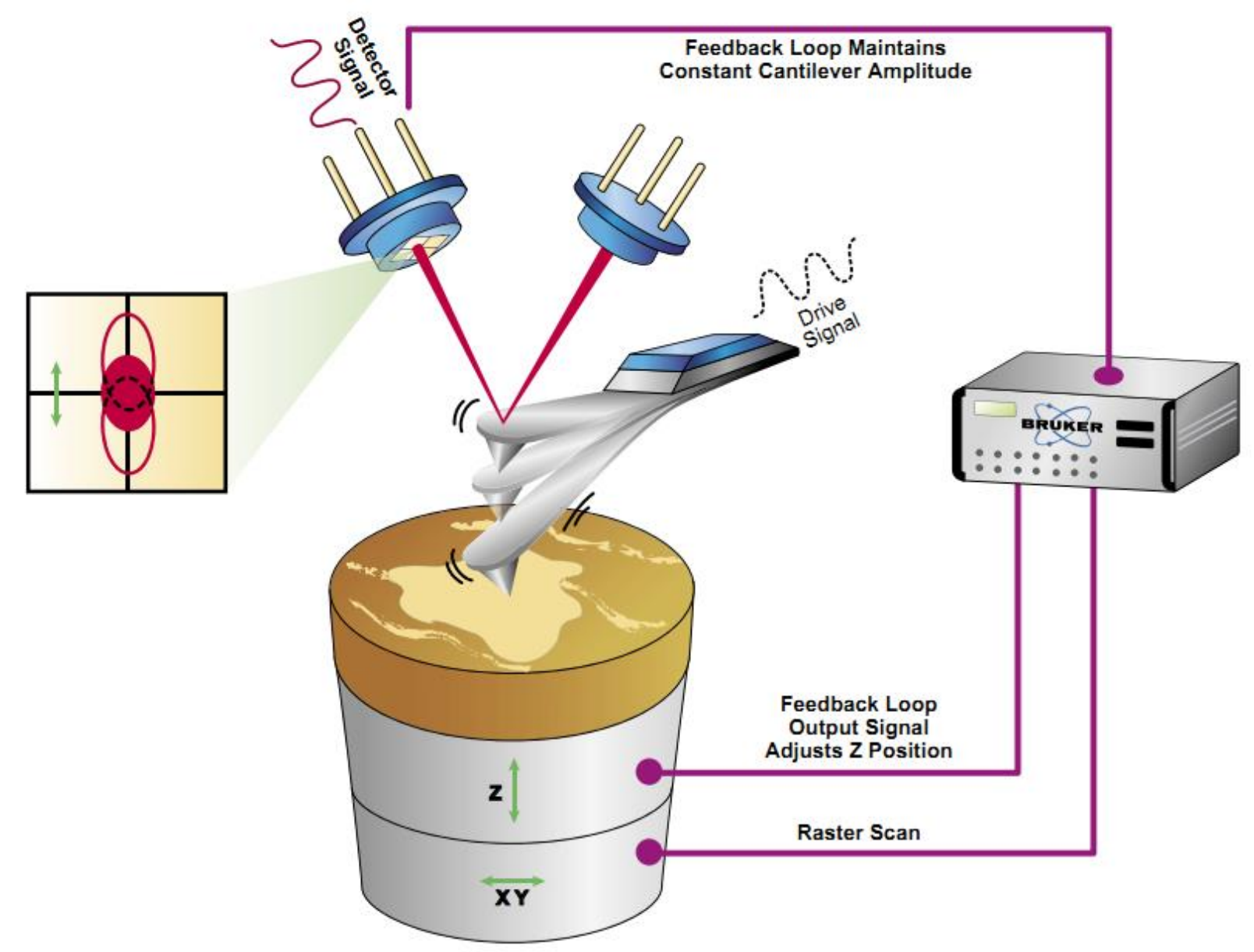


Non-contact AFM

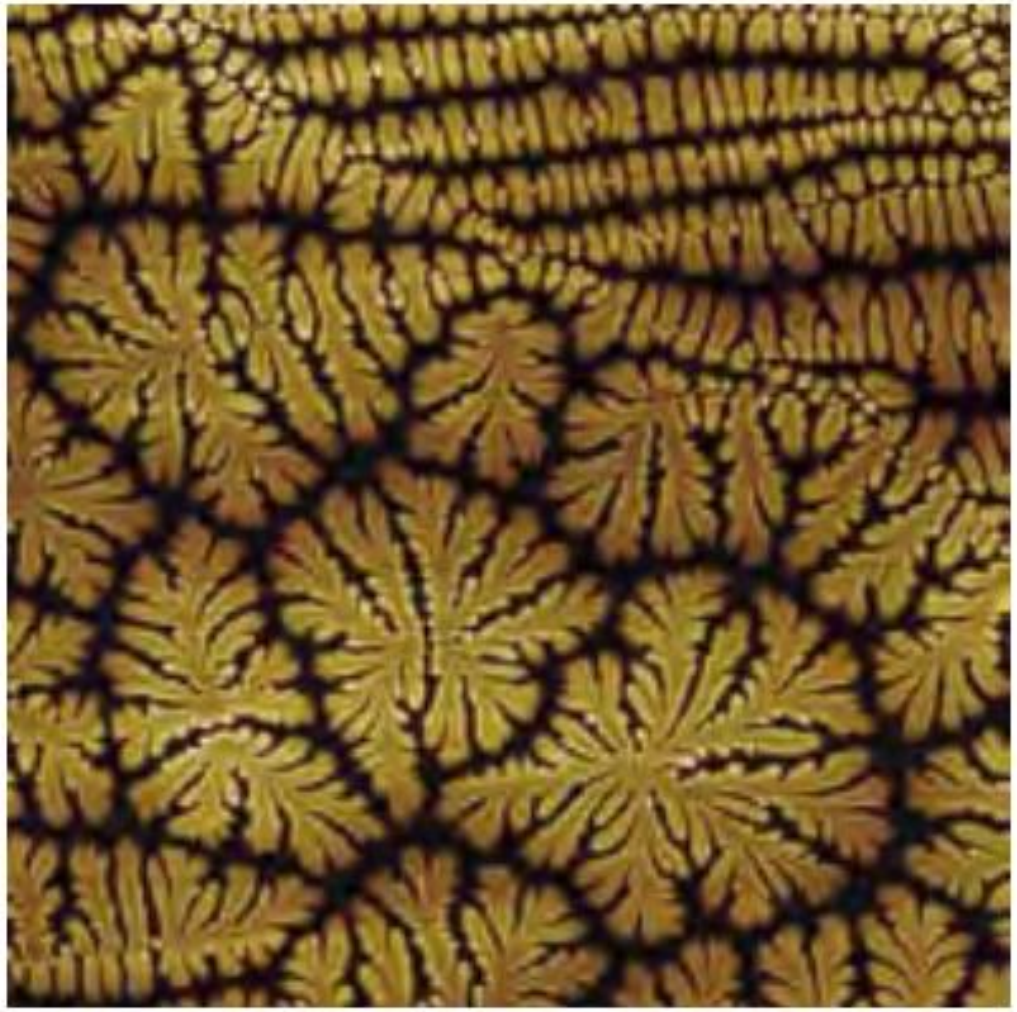
- Vrši se vibriranje sonde
- Usled približavanja površini dolazi do promene frekvencije ili amplitude vibracija <<parametar za upravljanje



Intermittent-contact AFM (tapping mode)

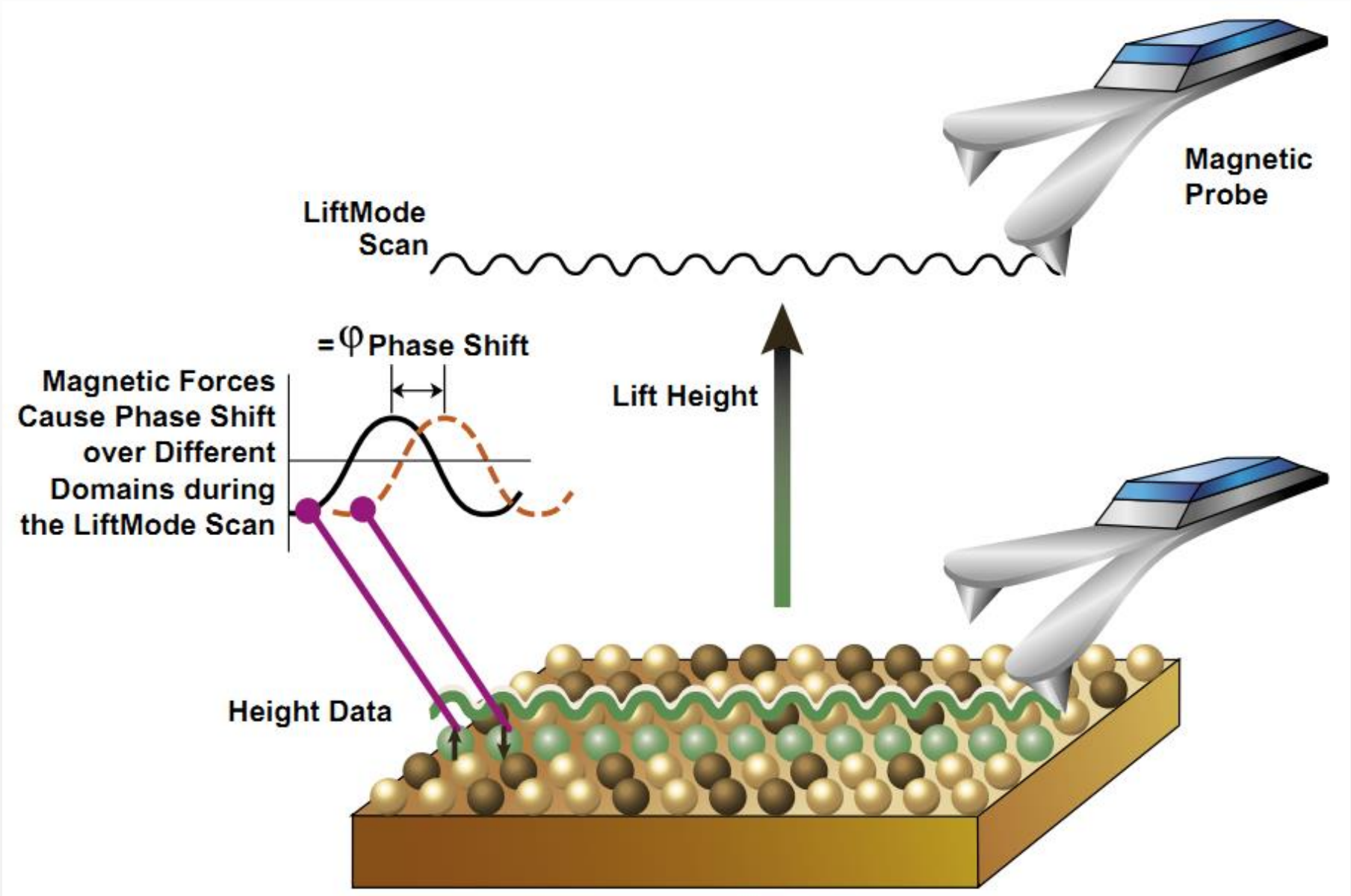


Intermittent-contact AFM (tapping mode)

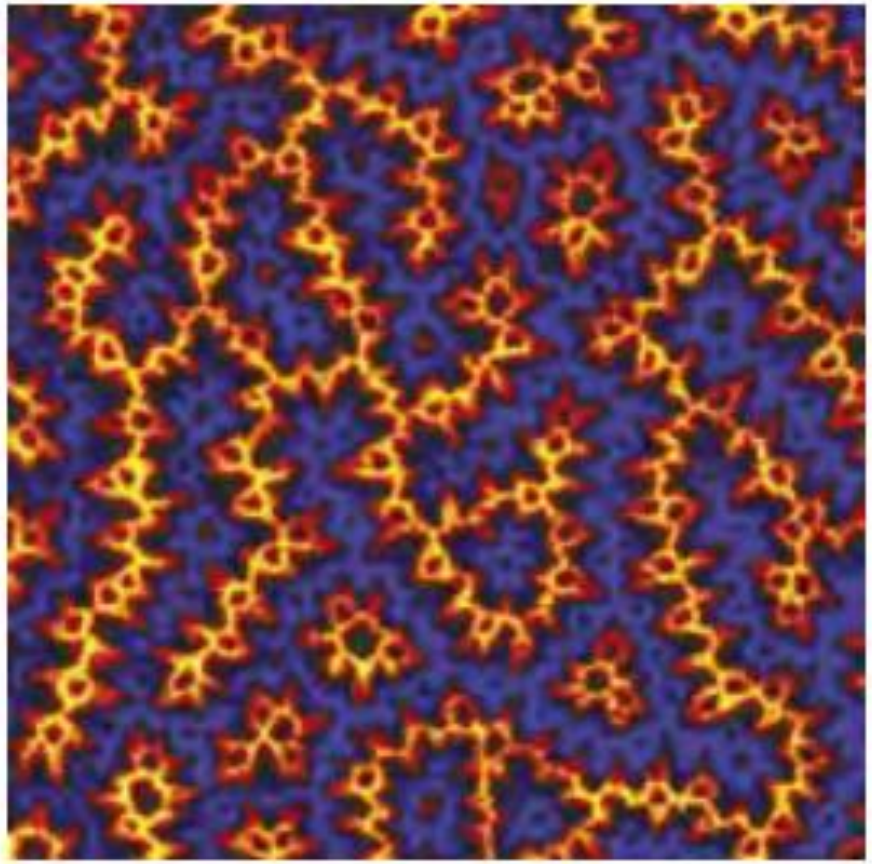


Topography of antimony dendrites on graphite.

Magnetic Force Microscopy (MFM)



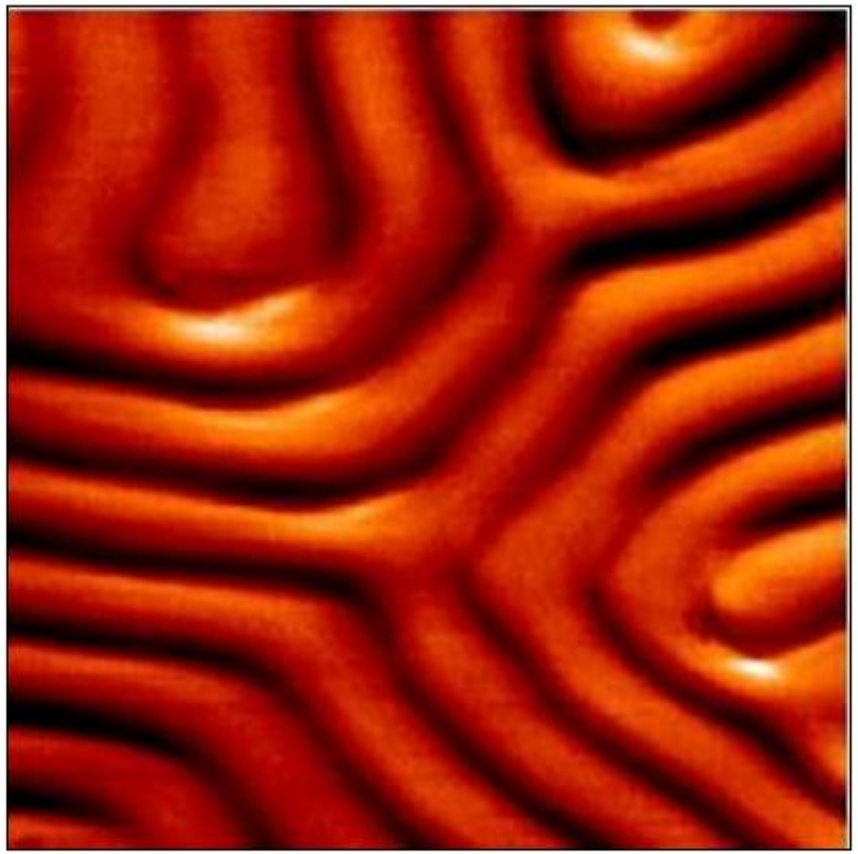
Magnetic Force Microscopy (MFM)



Magnetic domains in a steel sample.

Magnetic Force Microscopy (MFM)

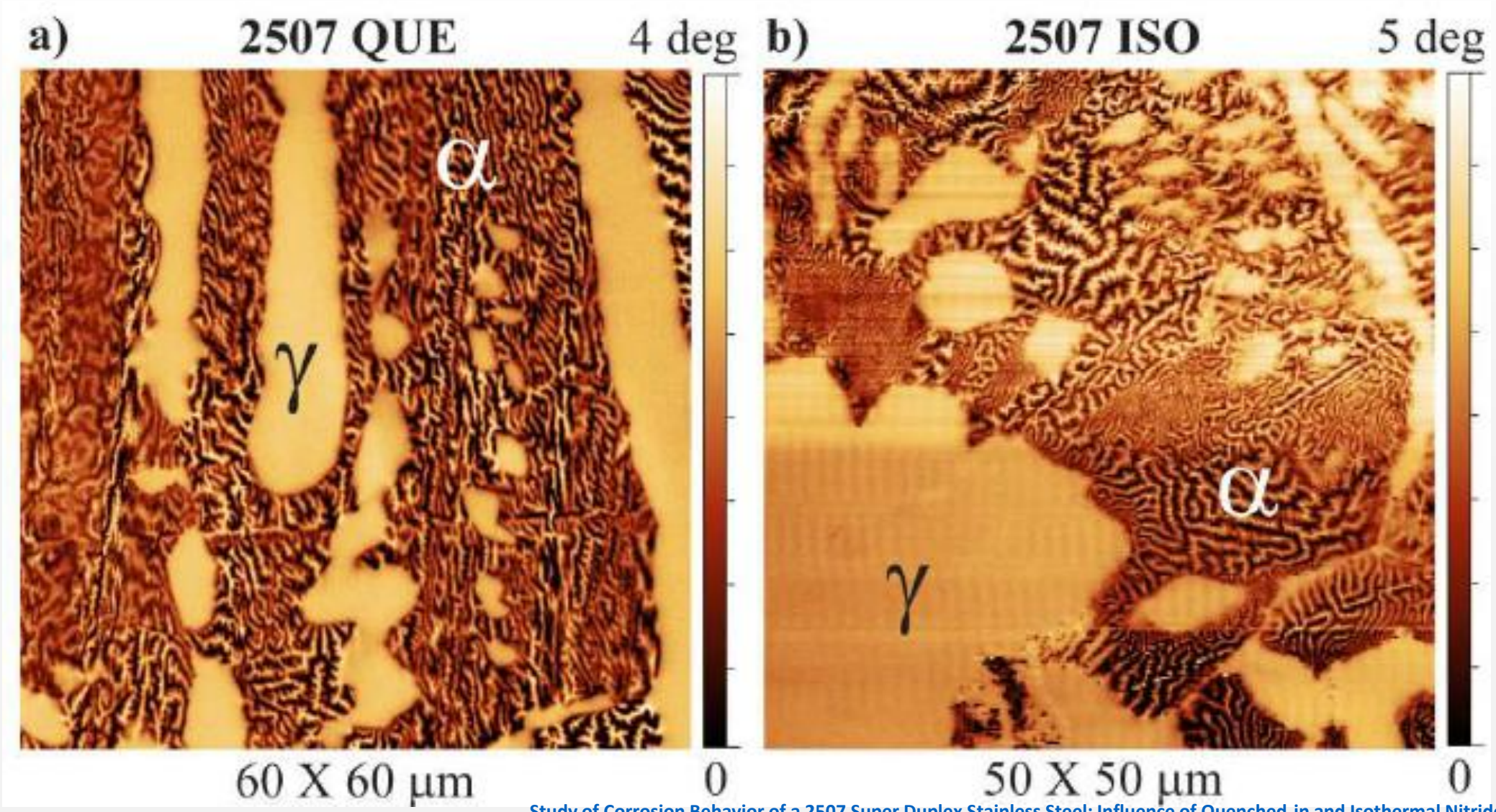
Magnetic domain walls



MFM-mode : Magnetic domain walls on a $BaFe_{12}O_{19}$ single crystal; the cantilever was coated with a magnetic iron film.

Data courtesy of: A. Wadas et al. of the group of Prof. R. Wiesendanger, University of Hamburg, Germany.

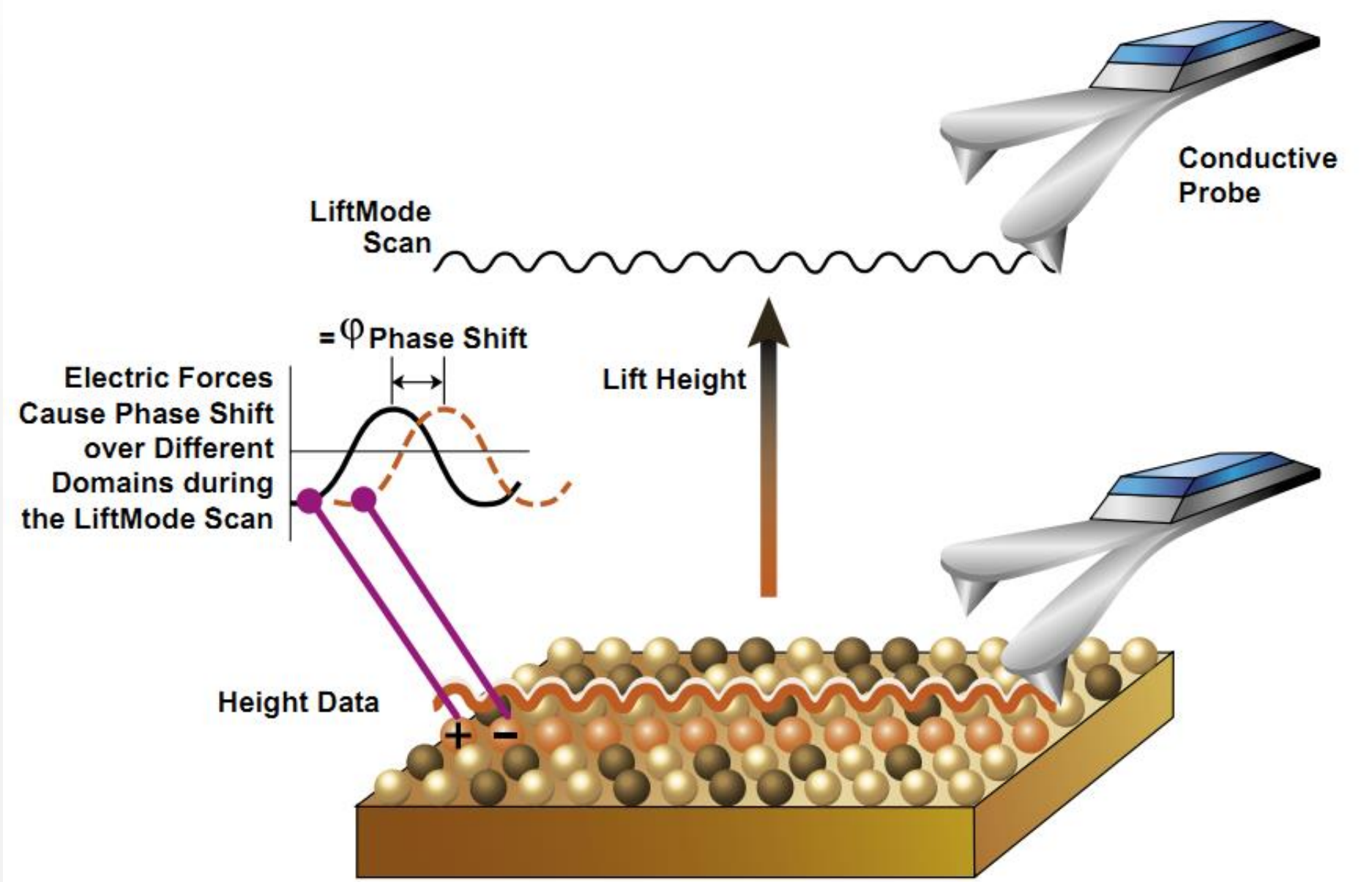
Magnetic Force Microscopy (MFM)



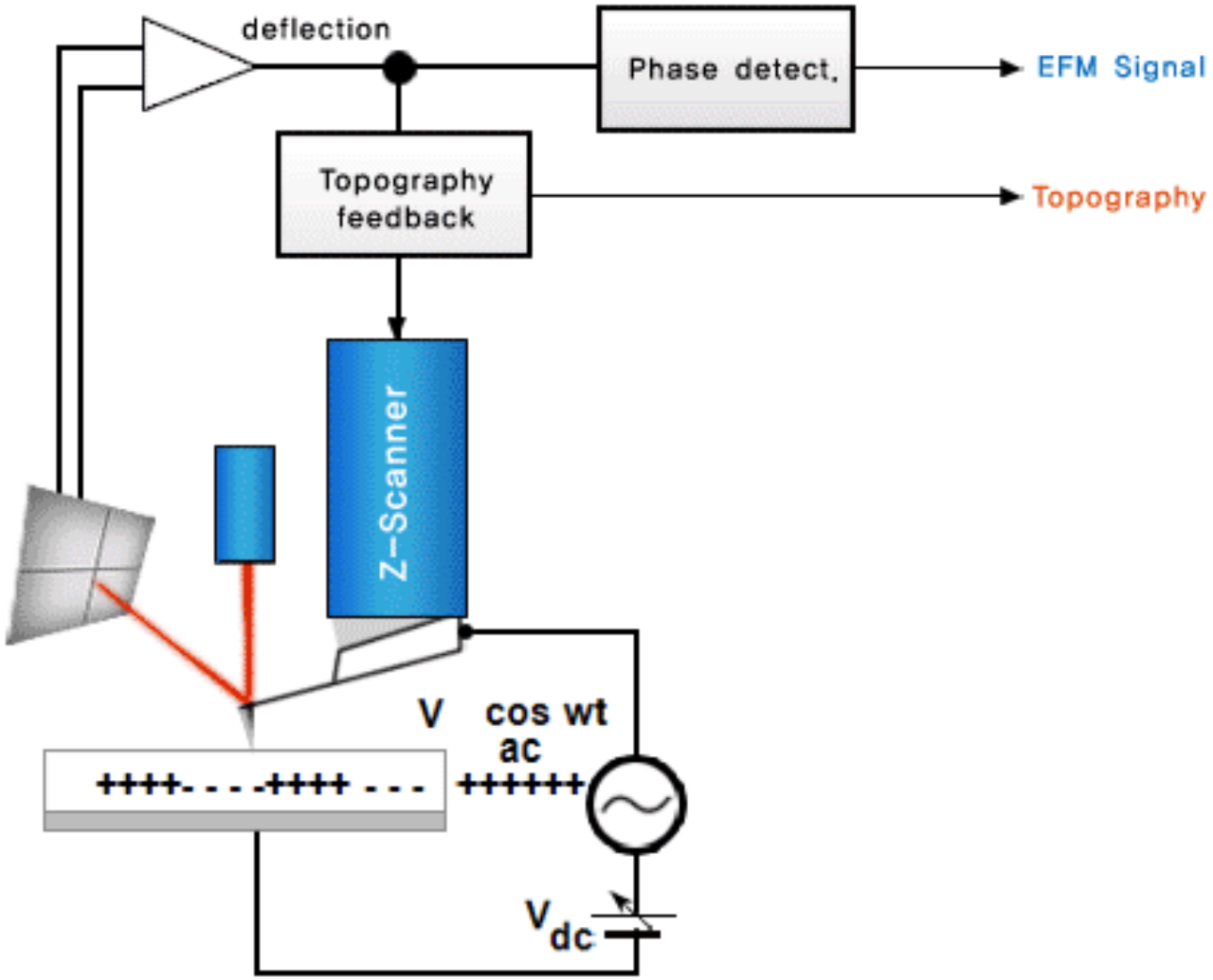
Study of Corrosion Behavior of a 2507 Super Duplex Stainless Steel: Influence of Quenched-in and Isothermal Nitrides

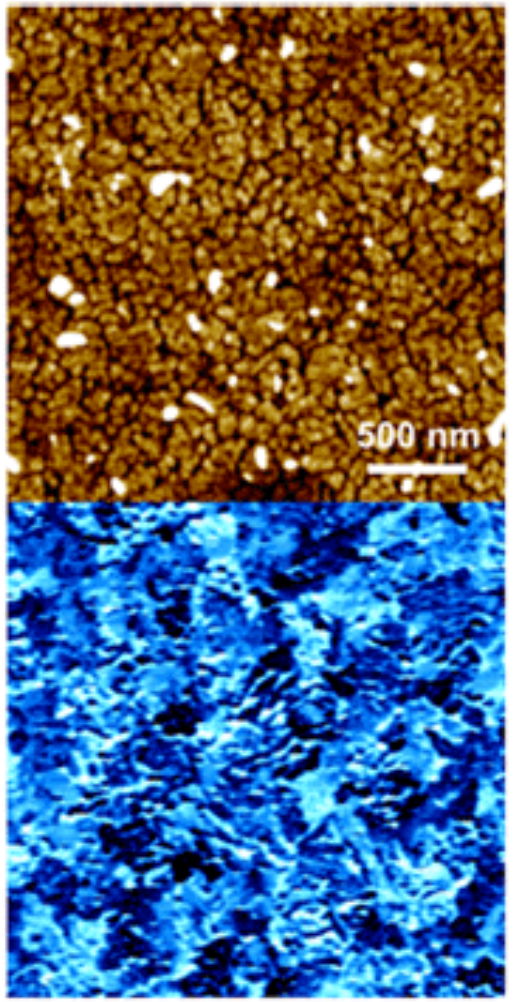
Article · Jan 2014 · International journal of electrochemical science

Electrostatic Force Microscopy (EFM)



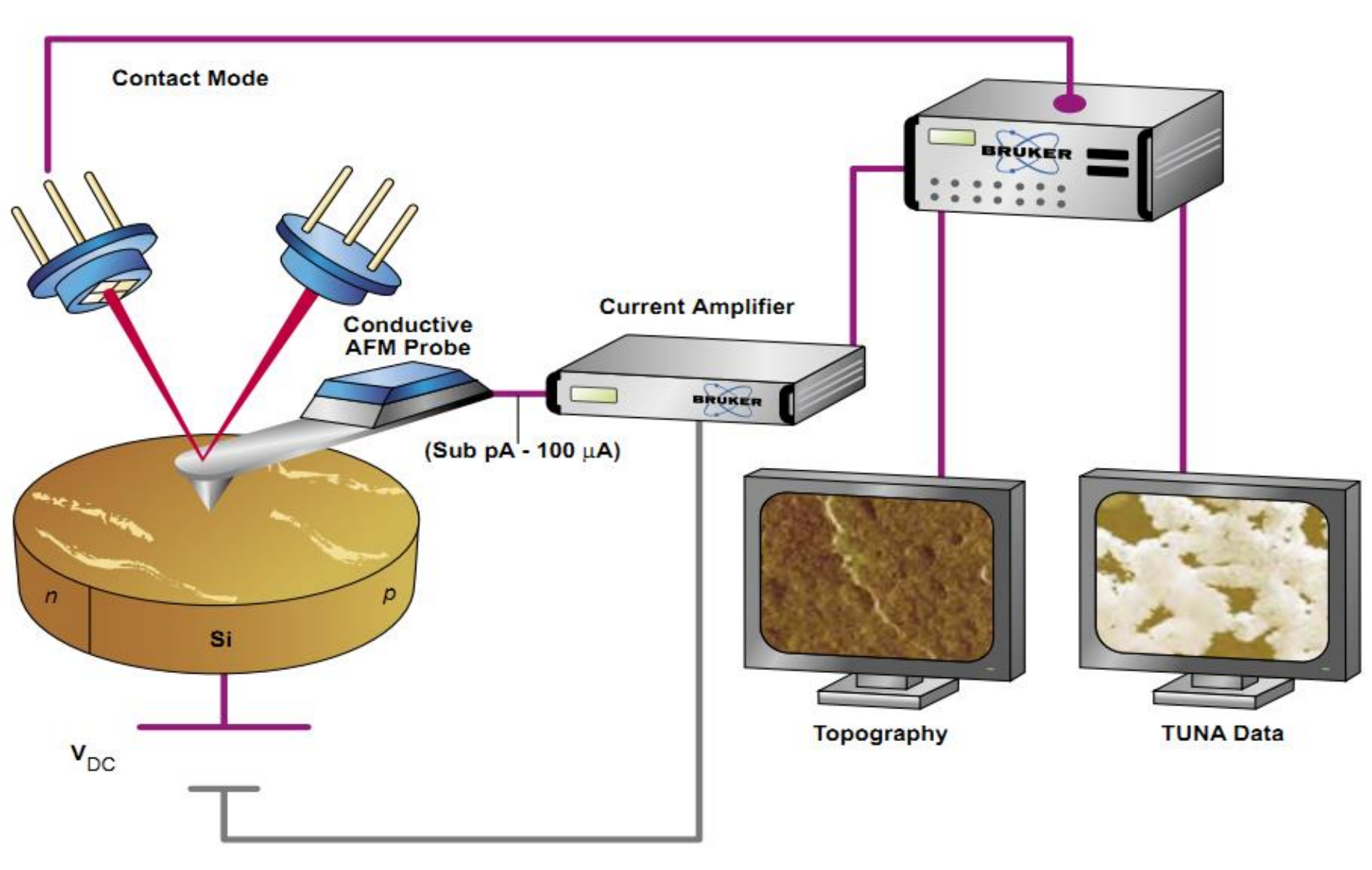
Electrostatic Force Microscopy (EFM)



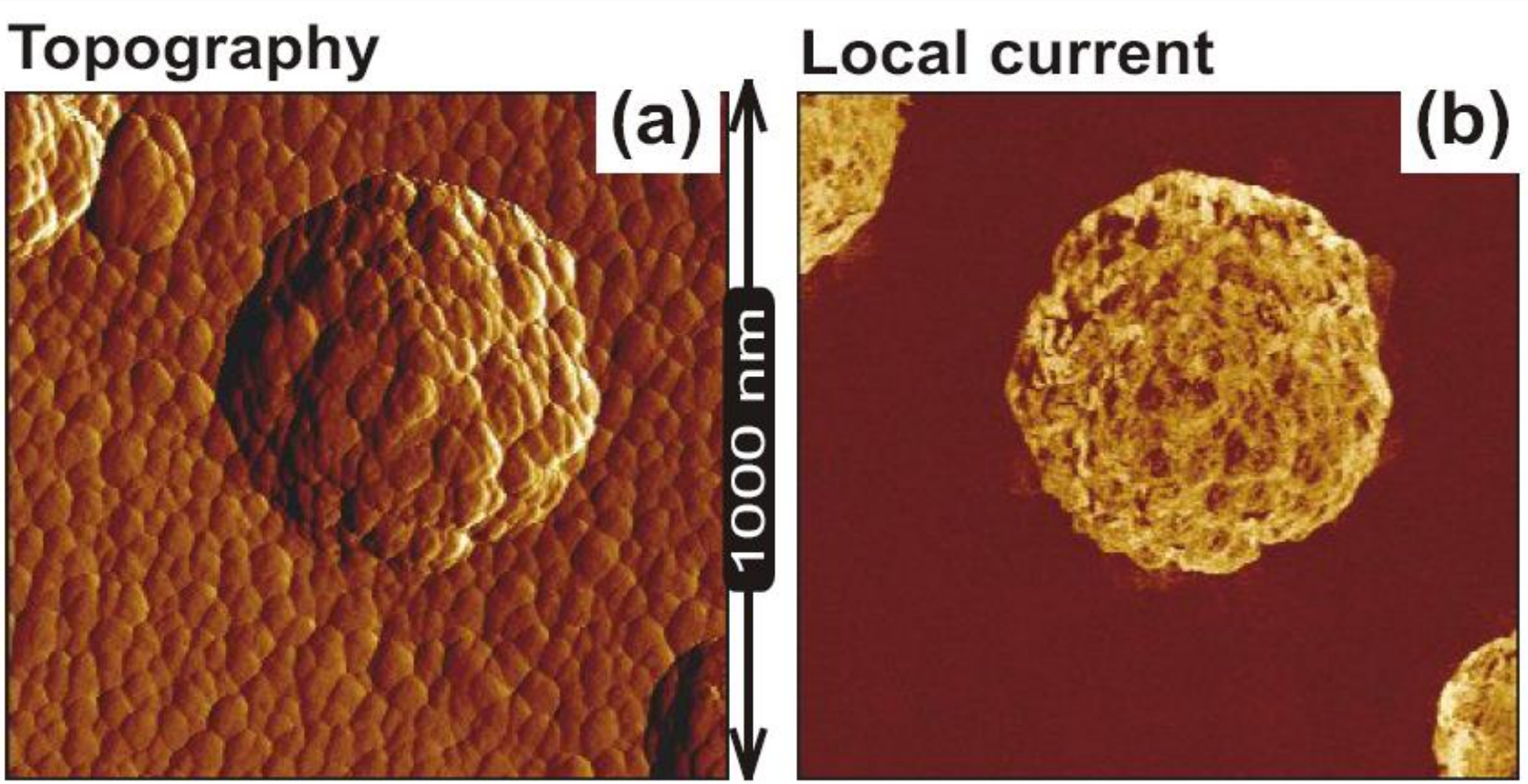


Topography (top) and EFM Phase (bottom) of PZT thin film

Conductive Atomic Force Microscopy Mode (C-AFM)



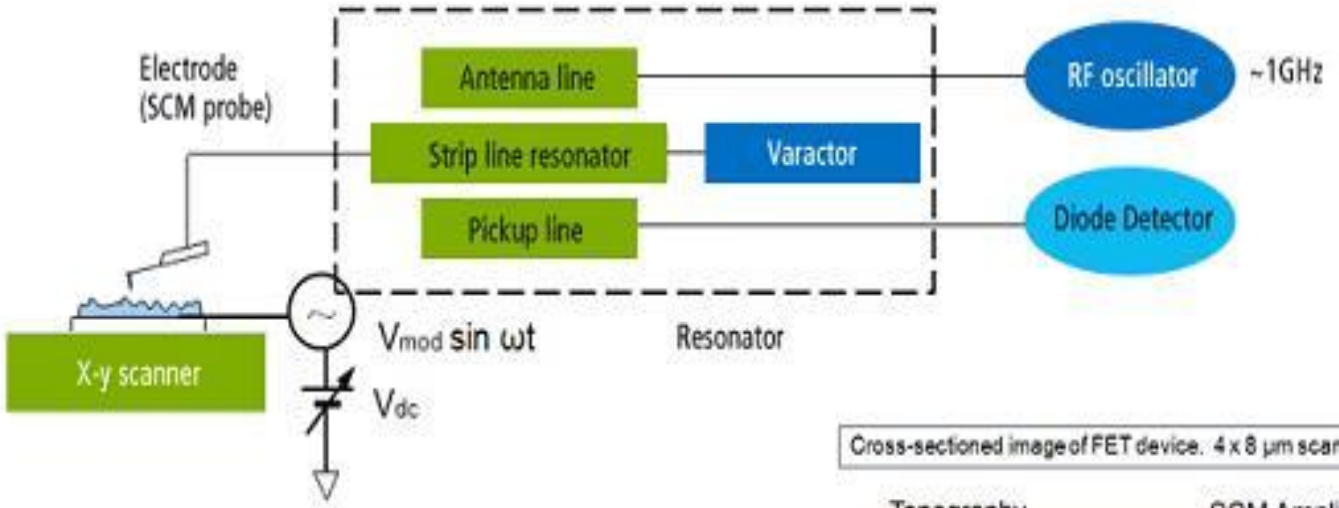
Conductive Atomic Force Microscopy Mode (C-AFM)

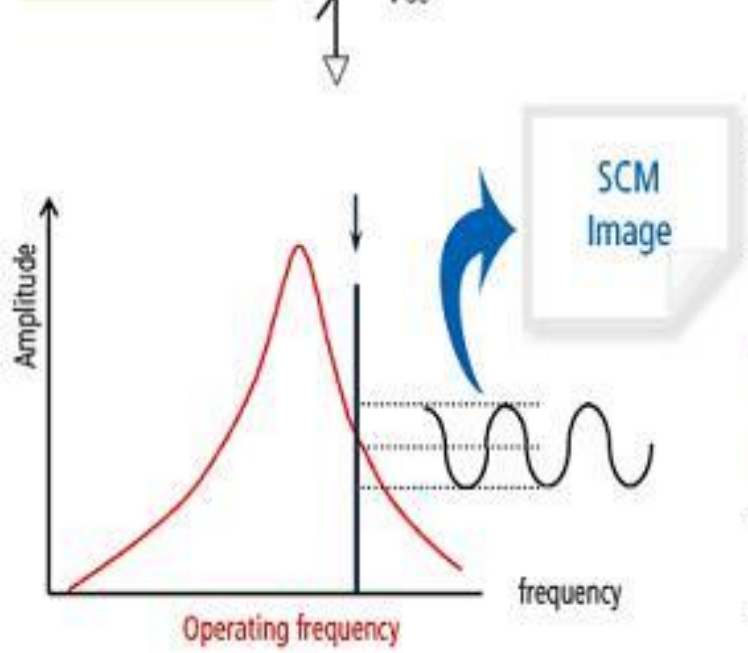


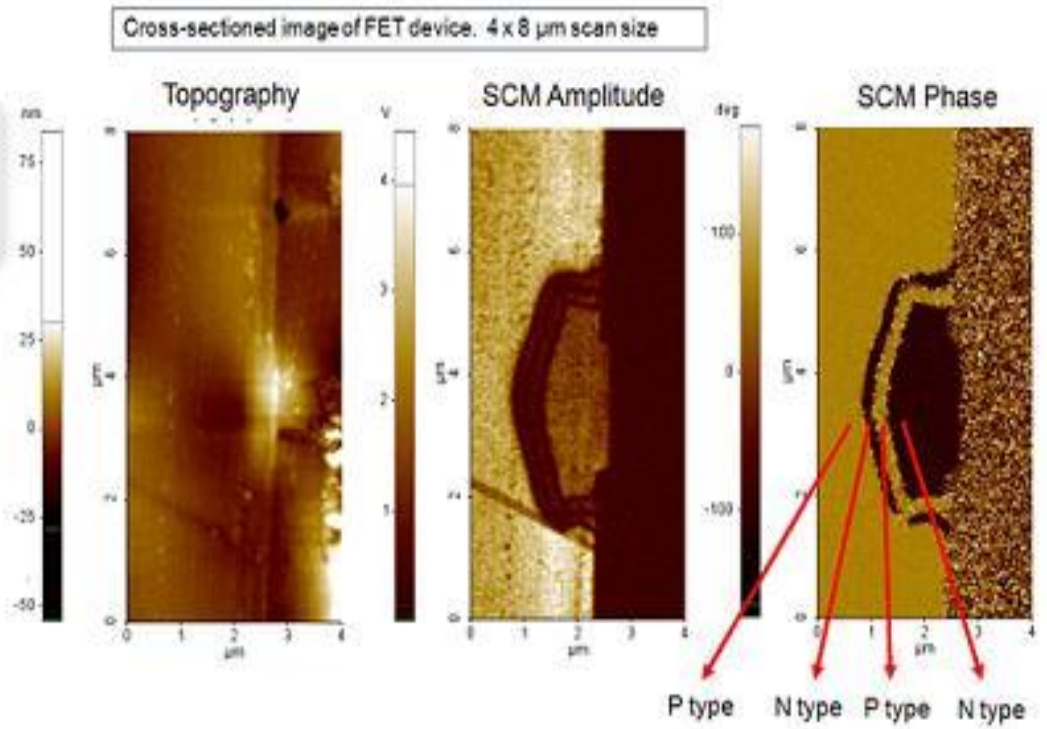
U_{bias}=2V, I range=0.2pA

T. Mates et al., **J. Non-Crystalline Solids, 352 (2006) 1011.**

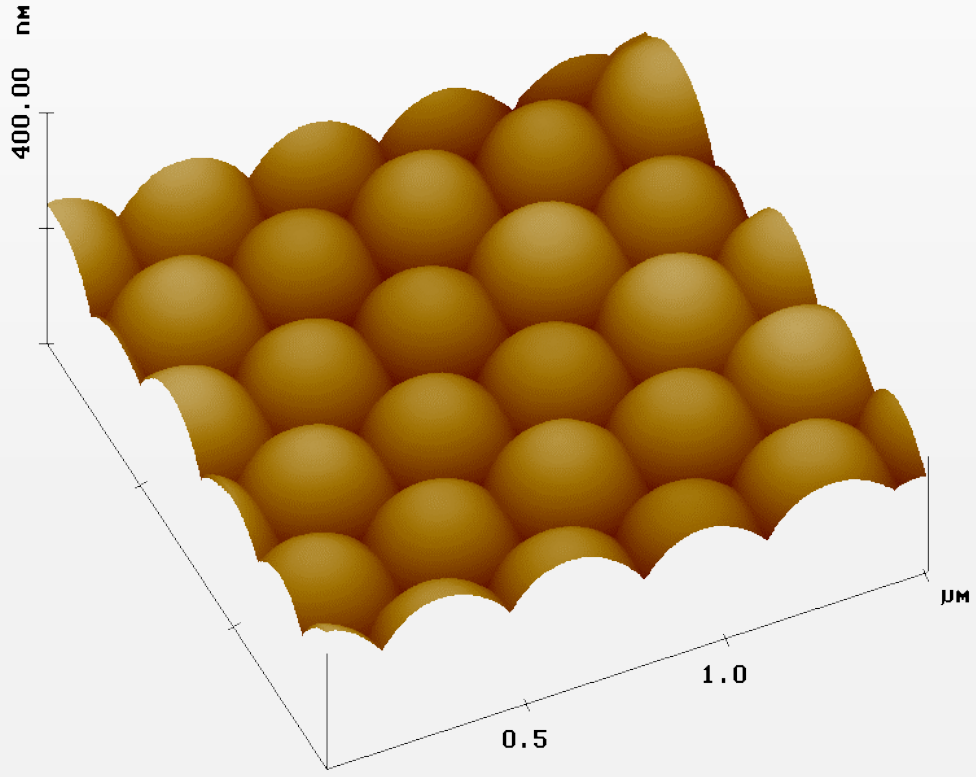
Capacitive Atomic Force Microscopy Mode (C-AFM)







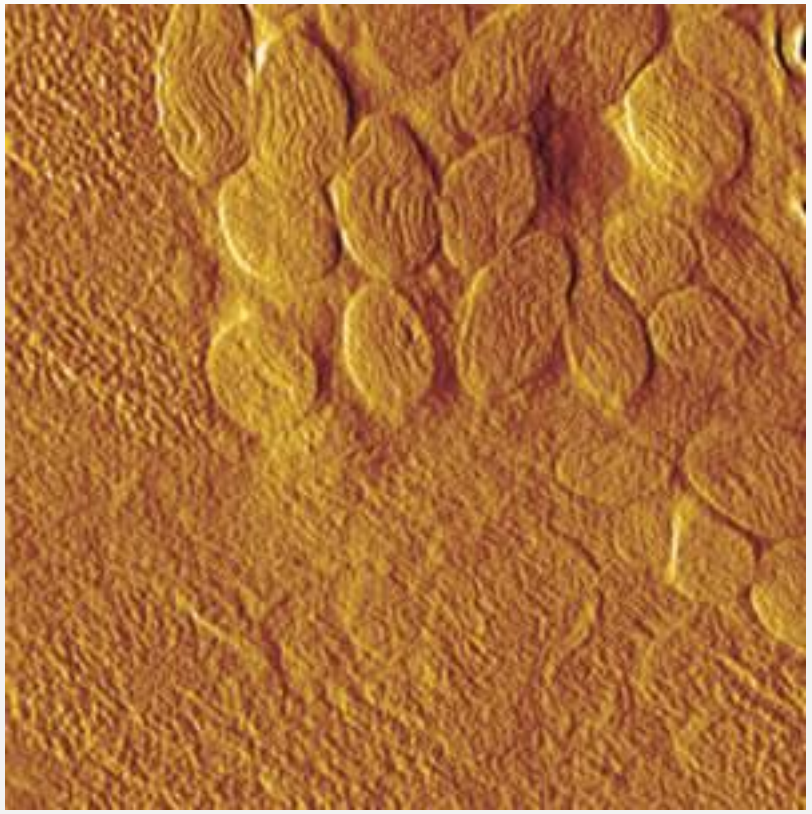
AFM primeri



Artificial opal

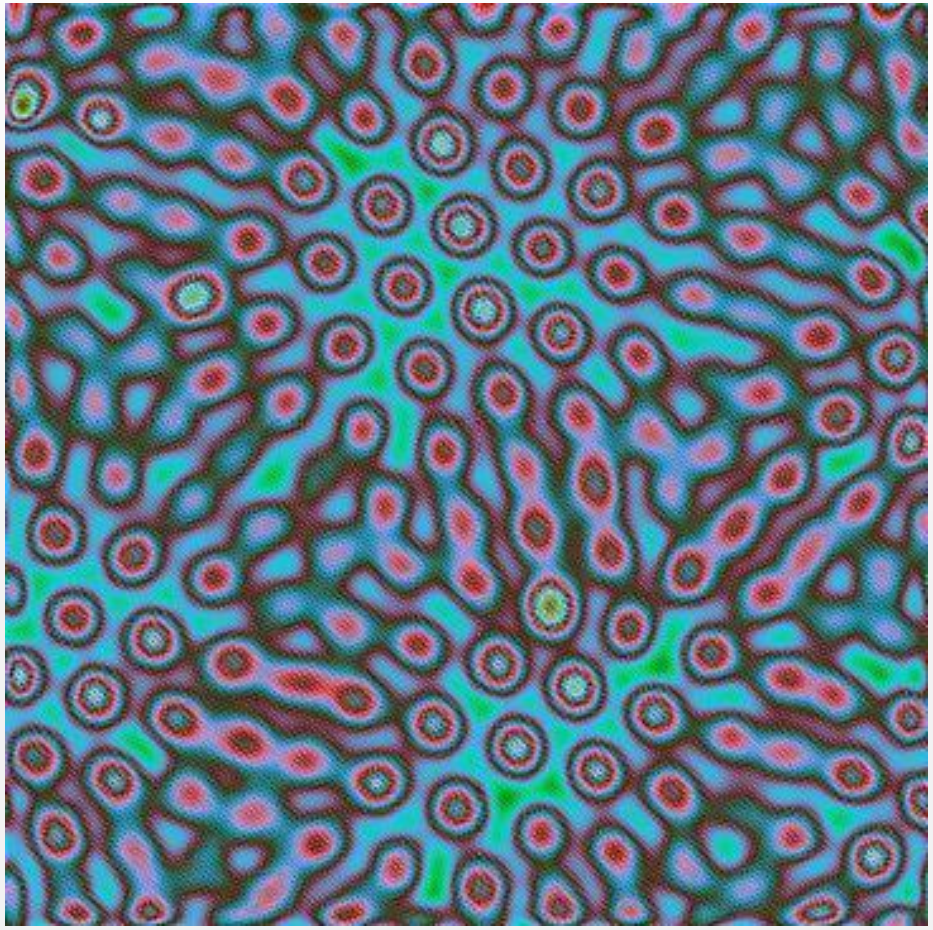
Si close-packed

AFM primeri



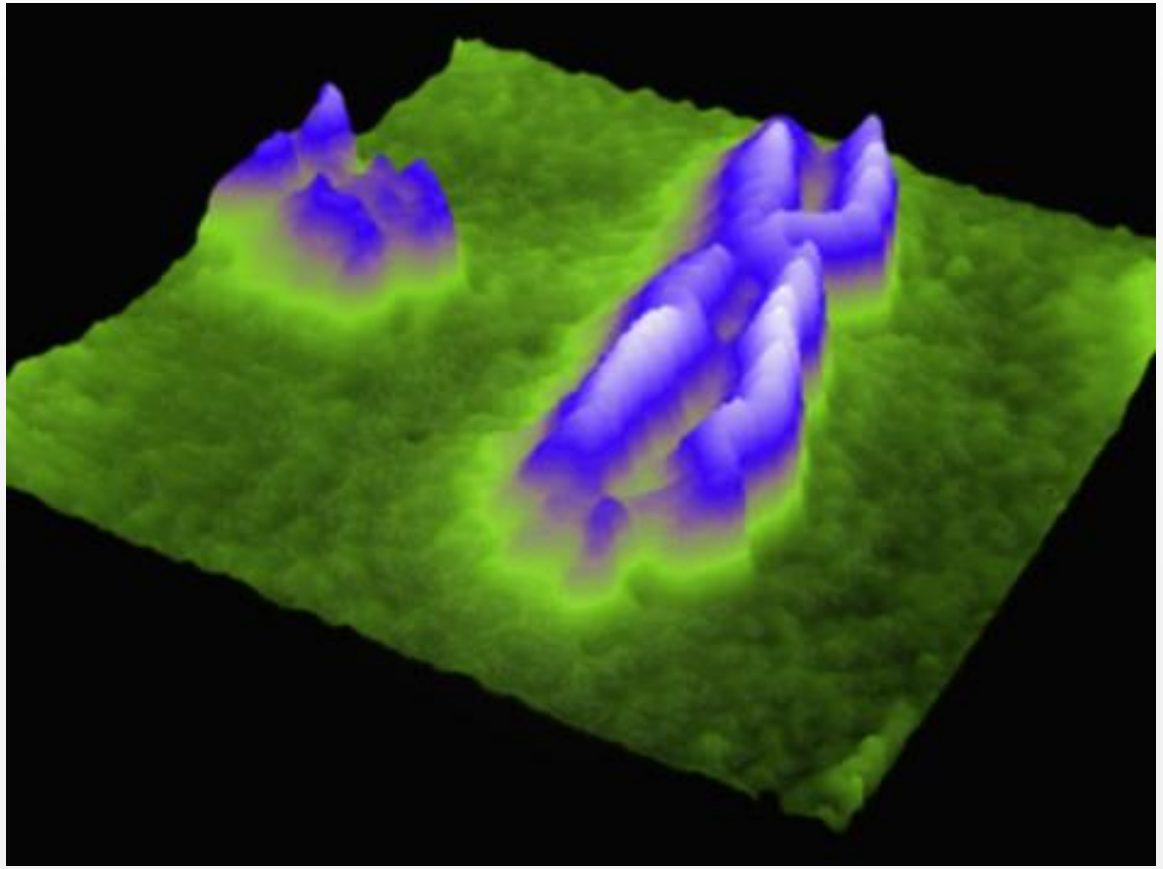
Cat mite muscle

AFM primeri



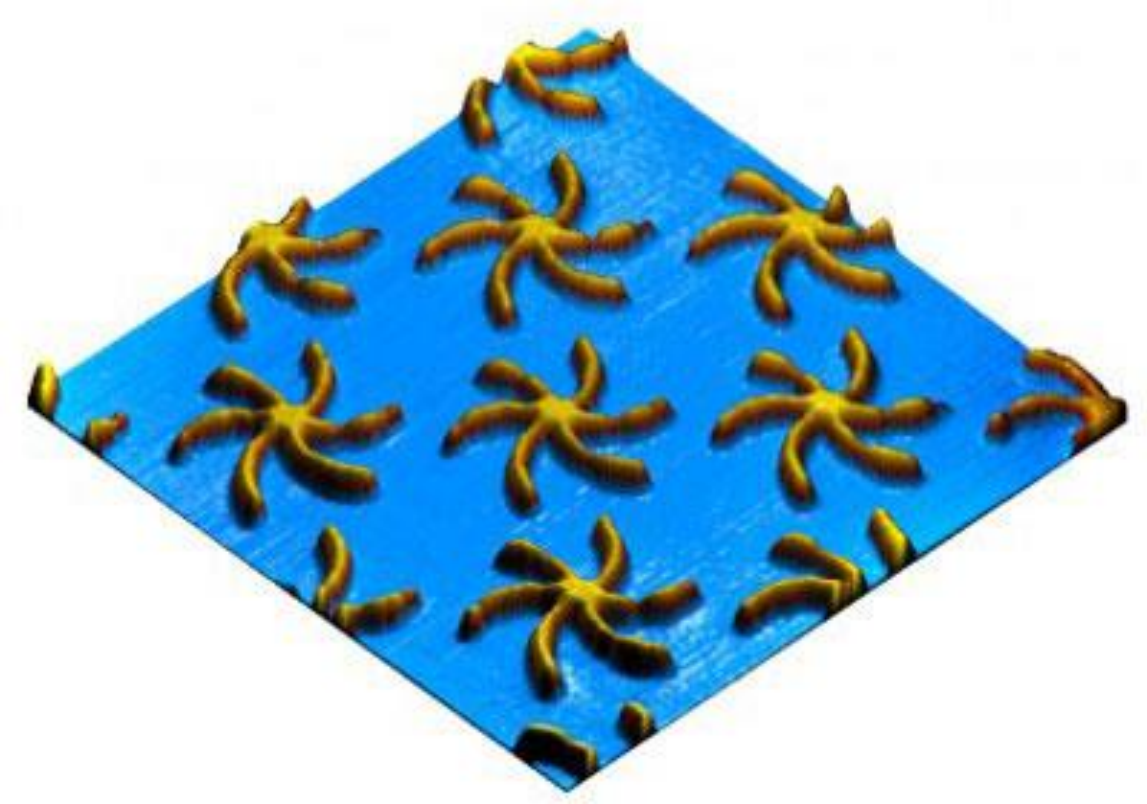
Graphene

AFM primeri



X hromozom

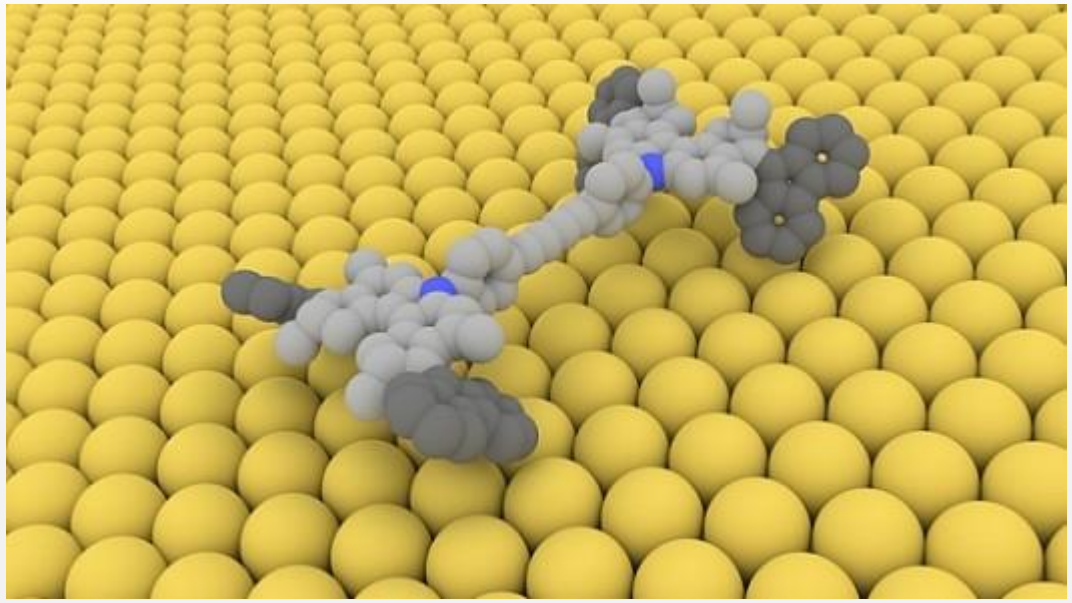
AFM primeri



Copper particles
on Si substrate

SEM litography
and ion etching

AFM primeri



Nanoautomobil

Jedan molekul – pokreće ga elektricitet iz STM igle
Svaki točak se ponaša kao poseban motor

Hvala na pažnji