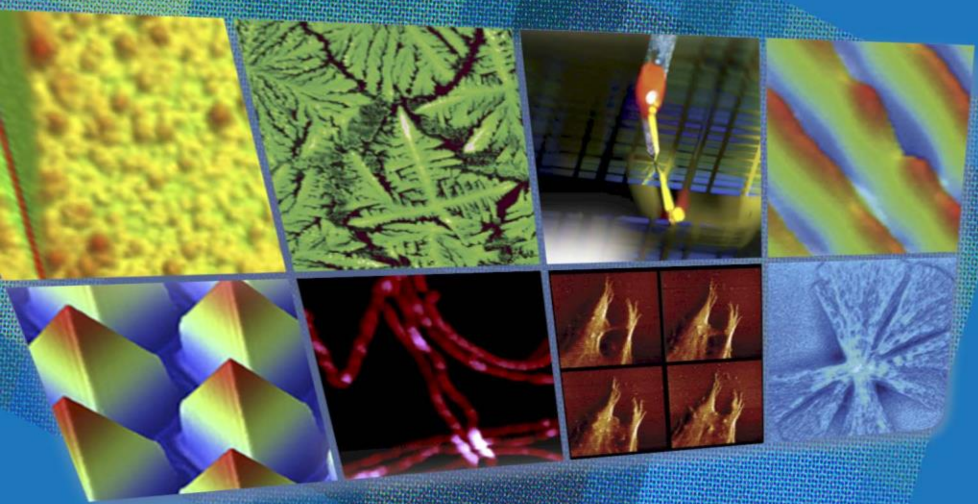
Scanning Probe Microscope Training

Wenhui Pang



Atomic Force Microscopy
3D Optical Microscopy
Tribology
Automated AFM
Stylus Profilometry
Mechanical Testing, Nano Indentation

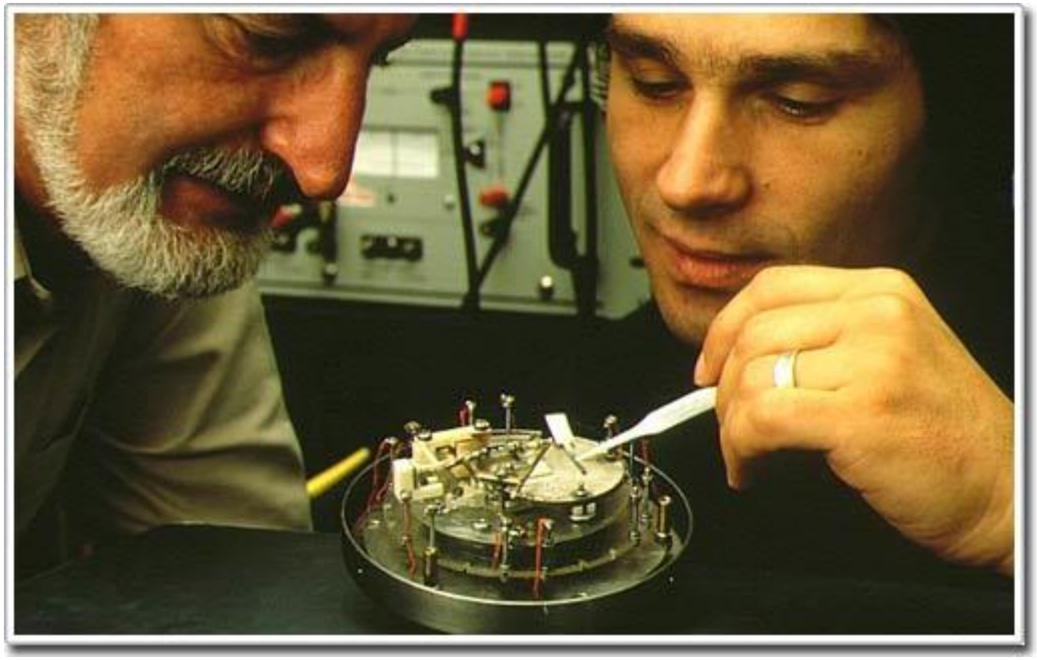
Innovation with Integrity

Bruker Nano Surfaces Division

Background - Comparison of AFM with Other Imaging Modalities

		Optical Microscopy	SEM	TEM	AFM
Resolution	**XY**	200 nm	2 nm	0.1 nm	1 nm
	Z	500 nm	N/A	N/A	0.1 nm
Sample Preparation		Simple	Moderate	Skilled	Simple
Sample Types		Living or non living	Non living	Non living	Living or non living
Ambient Atmosphere		Air, Fluid, Vacuum	Vacuum	Vacuum	Air, Fluid, Vacuum
Field of View		Large	Large enough	Limited	Moderate
Functionality		Simple	Moderate	Moderate	Advanced
Speed		Fast	Moderate	Slow	Slow
Skill Required		Low	Moderate	Advanced	Advanced
Data Interpretation		Easy	Moderate	Moderate	Complex

The First SPM in the World

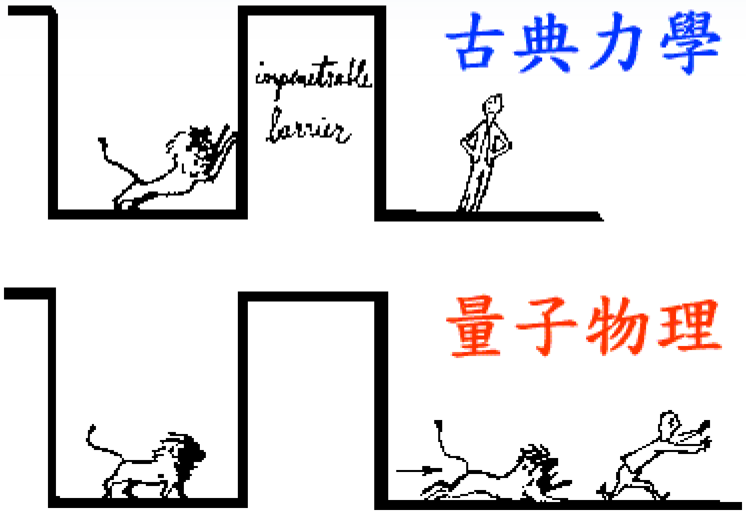


G． Binning and H． Rohrer invented the first Scanning Tunneling Microscope in 1981.

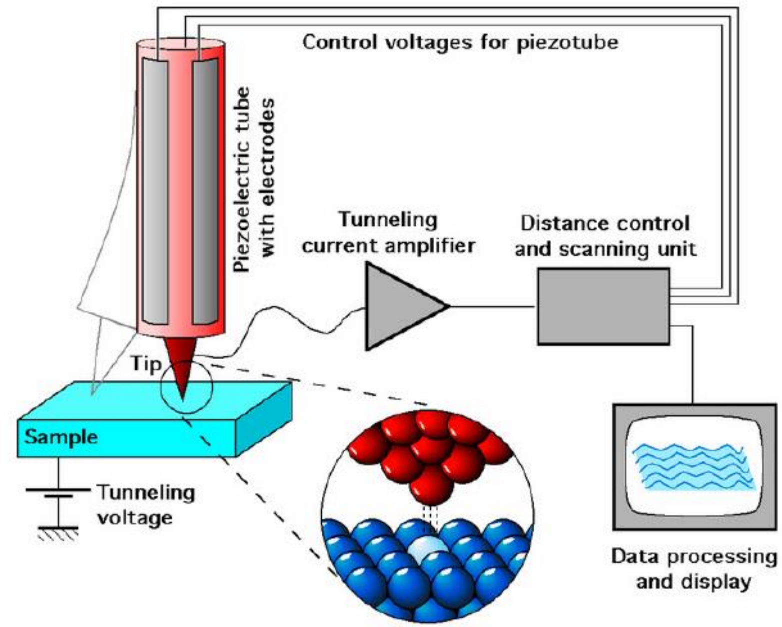
1986 Nobel Prize

STM is the first instrument that can reflect information of material surface in atomic scale.

Scanning Tunneling Microscope



The difference between classical theory and quantum theory, illustrating tunneling through potential barrier. This illustration was used by Van Vleck in his last publication, the Julian E. Mack Lecture at his Alma Mater, the University of Wisconsin, in 1979. (After B. Bleaney, Contemp. Phys. 25 (1984) 320.)

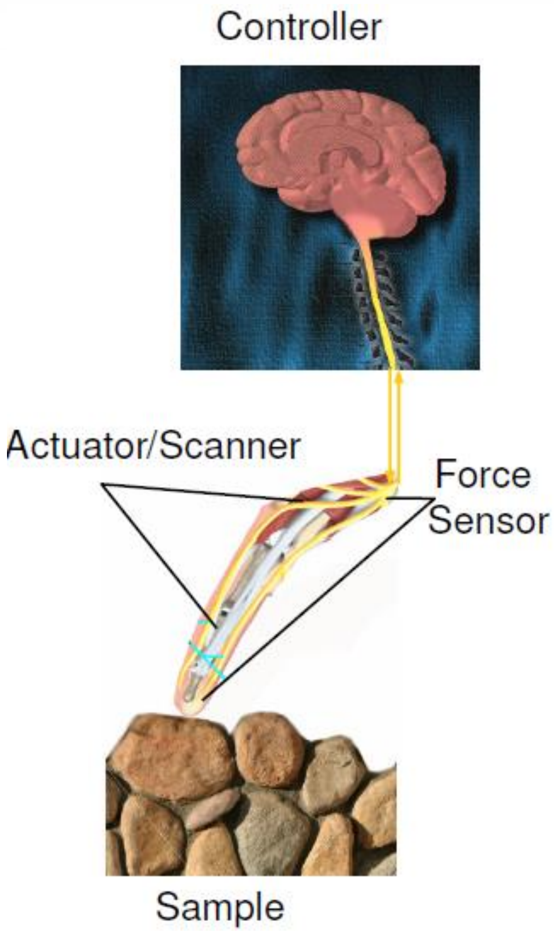


STM is based on the fact that the tunneling current between a conductive tip and sample is exponentially dependent on their separation.

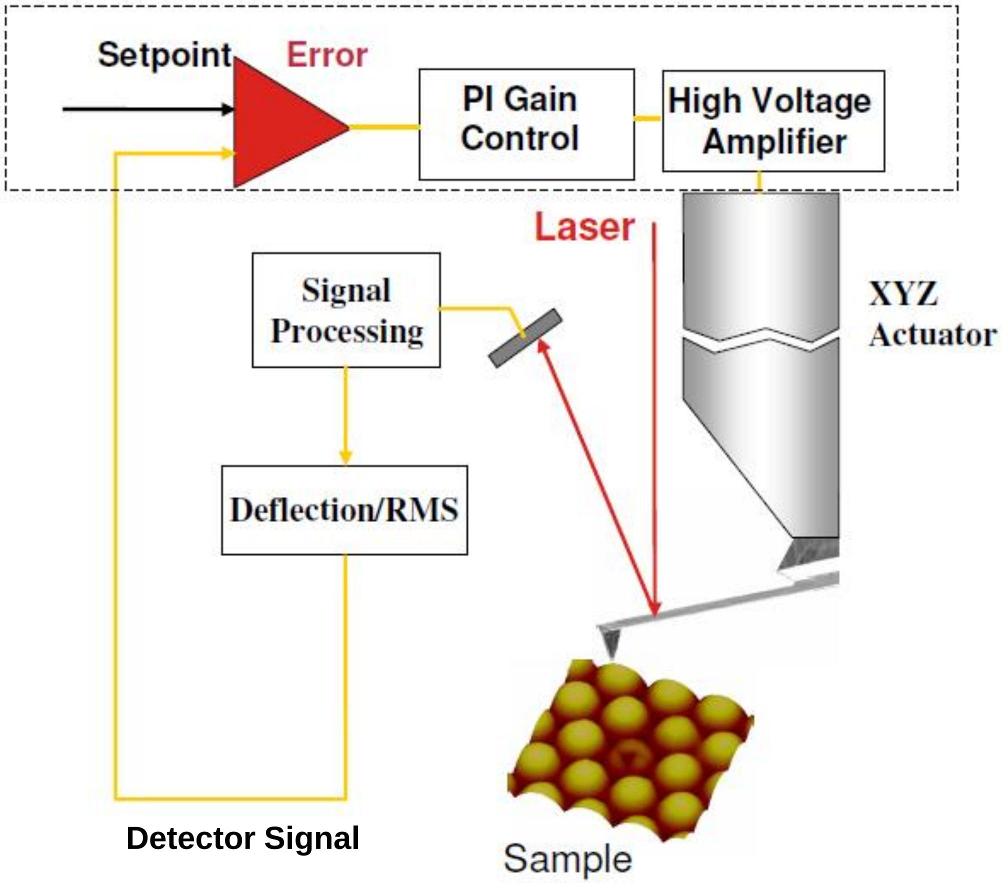
This can be represented by the equation: $I \sim Ve^{-cd}$

This technique is typically **limited to conductive and semiconducting surfaces**

AFM System



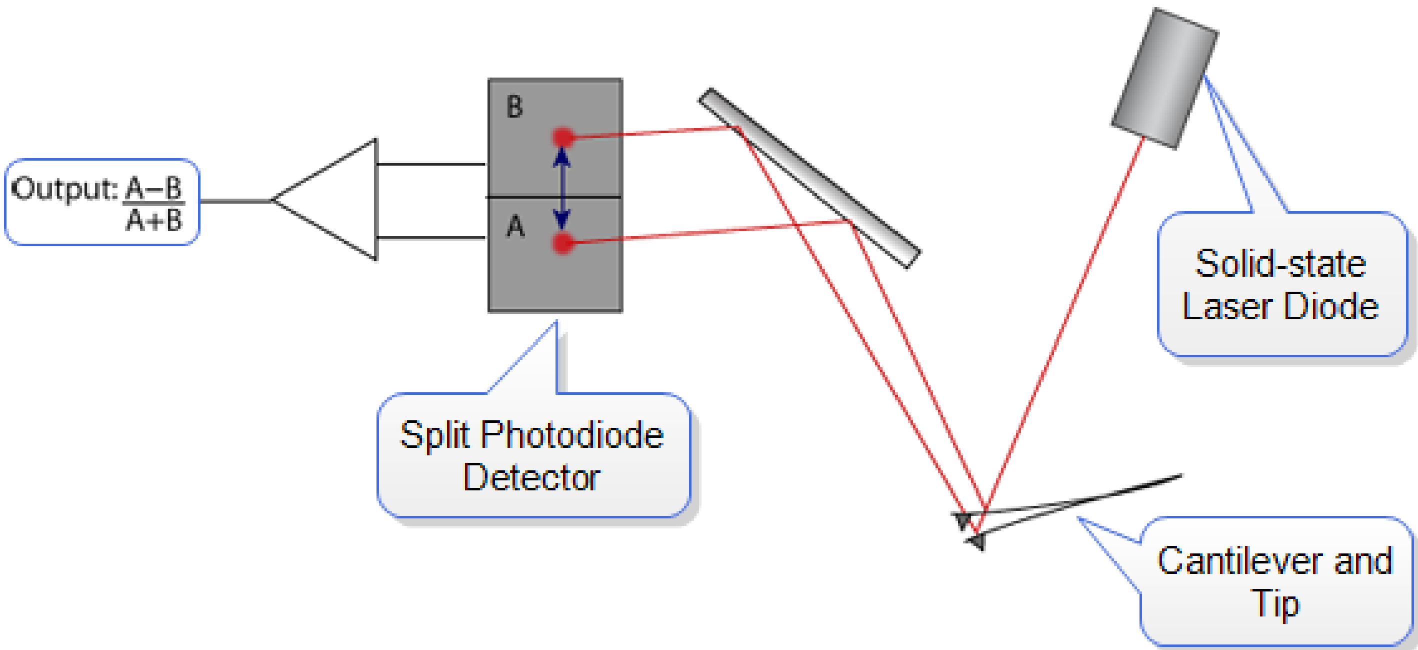
Controller
Actuator/Scanner
Force
Sensor
Sample



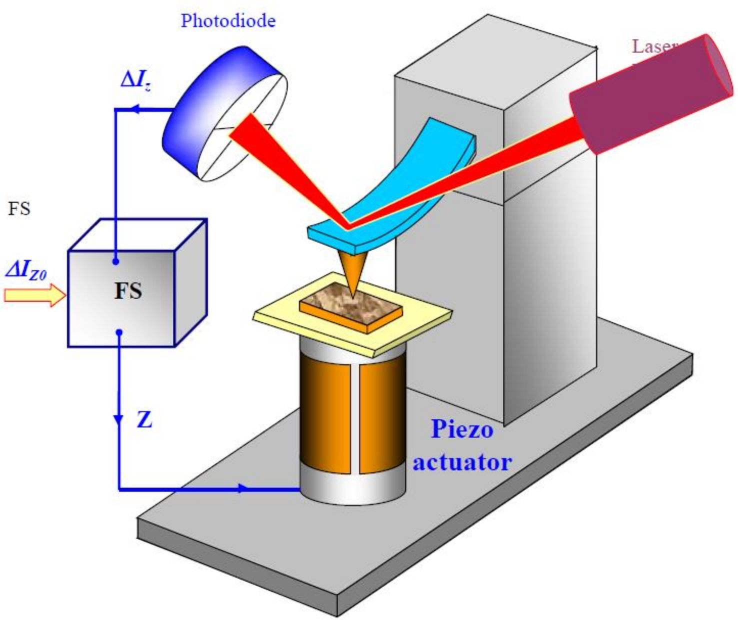
Setpoint
Error
PI Gain
Control
High Voltage
Amplifier
Laser
Signal
Processing
XYZ
Actuator
Deflection/RMS
Detector Signal
Sample

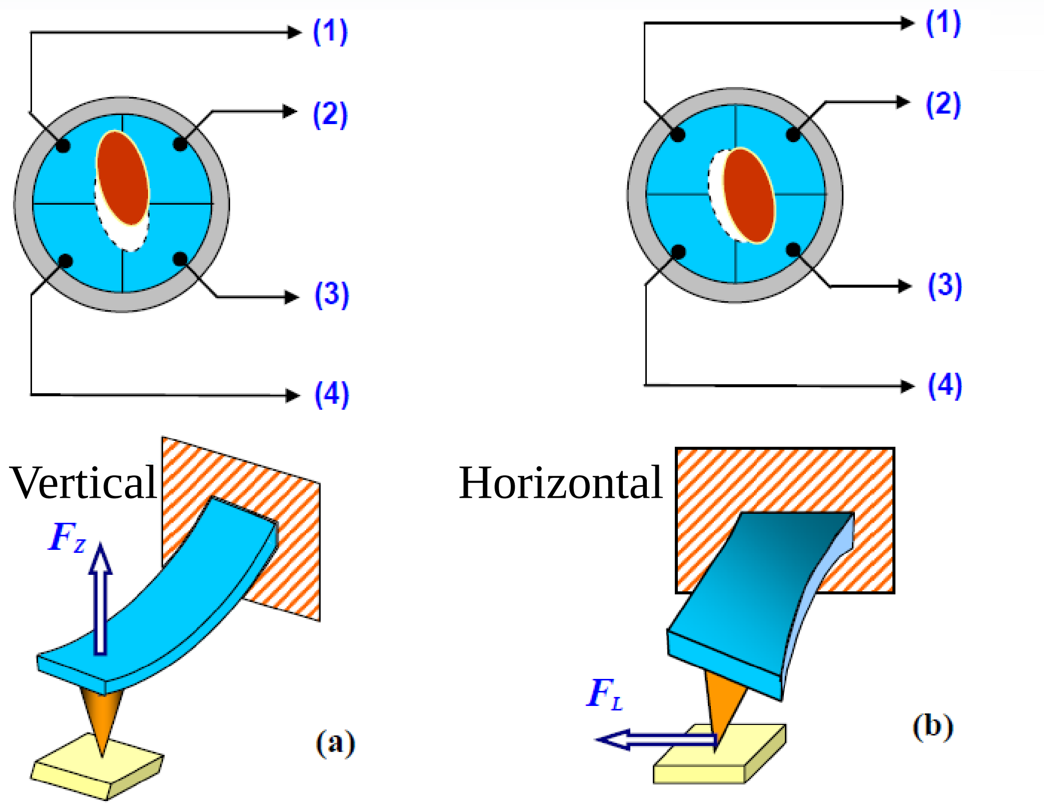
Position-Sensitive Photodetectors

The optical system is aligned so that the beam emitted by a diode-laser is focused on the cantilever, and the reflected beam hits the center of a photodetector. Four-section split photodiodes are used as position-sensitive photodetectors (PSPD).



Sum, Vertical and Horizontal





The ΔI_Z value is used as an input parameter in a feedback loop of the atomic force microscope.

$$\Delta I_z = (\Delta I_1 + \Delta I_2) - (\Delta I_3 + \Delta I_4) \qquad \Delta I_L = (\Delta I_1 + \Delta I_4) - (\Delta I_2 + \Delta I_3)$$

$$\text{Sum} = \Delta I_1 + \Delta I_2 + \Delta I_3 + \Delta I_4$$

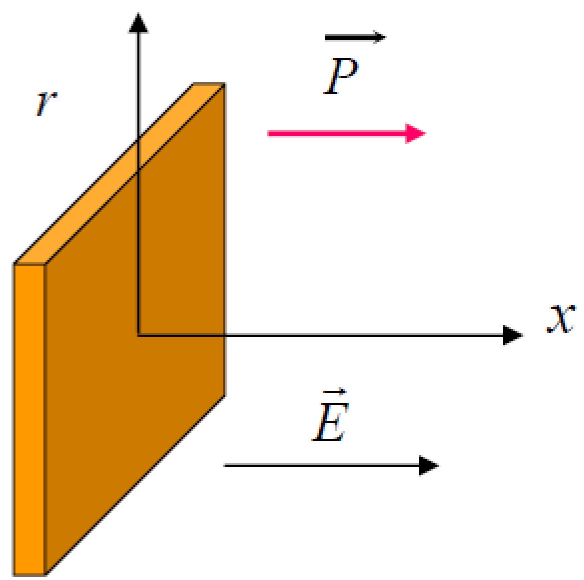
Piezoceramic Plate in an External Electric Field

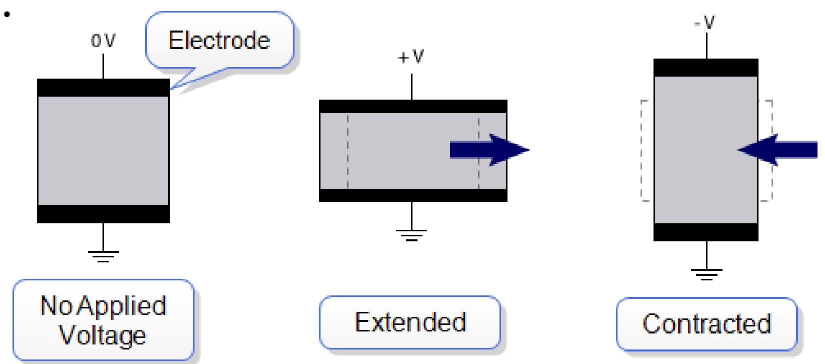
The probe microscope scanners are made of **piezoelectric materials**. Piezoelectric materials change their sizes in an external electric field.

$$u_{ij} = d_{ijk} E_k$$

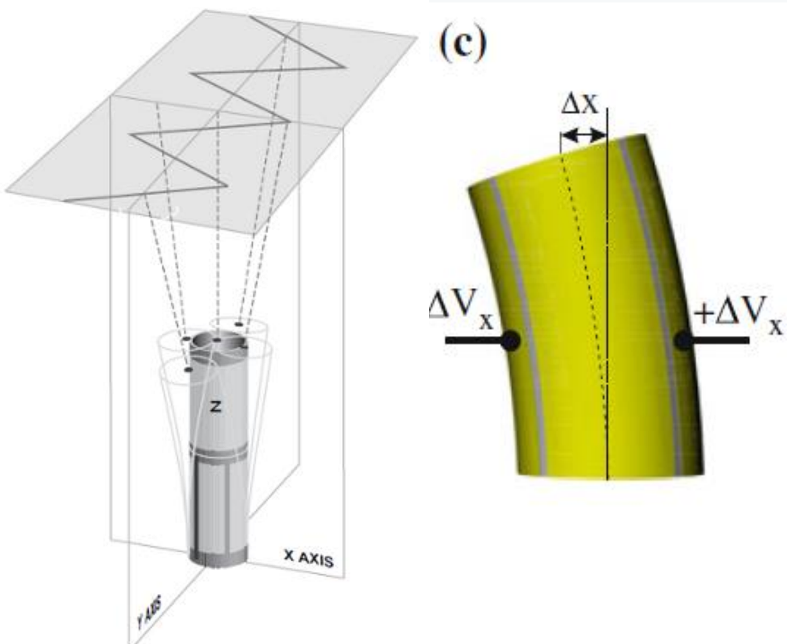
$$u_{xx} = d_{\parallel} E_x \qquad u_{rr} = d_{\perp} E_x$$

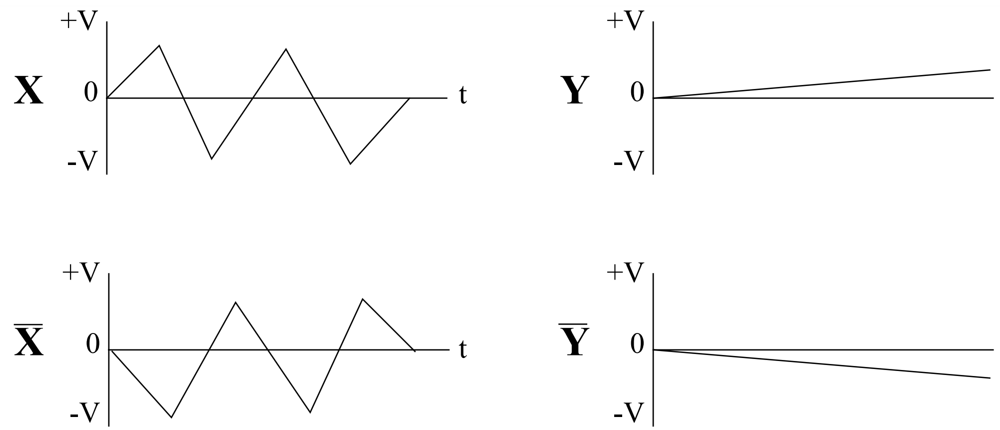
The piezoceramics is polarized polycrystalline material obtained by **powder sintering from crystal ferroelectrics**.





Tubular Piezo-scanner





Z Direction: Change of the internal electrode potential with respect to all external sections results in **lengthening or reduction** of the tube along Z axis.

X, Y Directions: When differential-mode voltage is applied on opposite sections of the external electrode (with respect to the internal electrode) part of the tube reduces in length and increases (where field and polarization directions are opposite). This leads to a **bend** of the tube.

Piezoceramics Nonlinearity

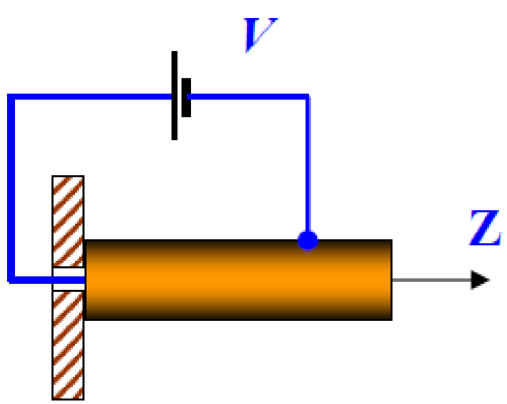
Generally (especially at large control fields) the piezoceramics are characterized by **nonlinear dependence** of the deformation on the field. Thus, deformation of piezoceramics is a complex function of the applied electric field:

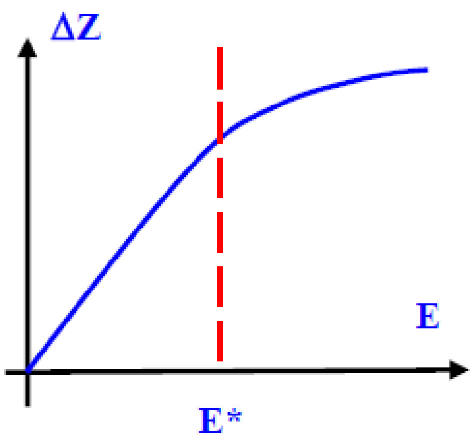
$$u_{ij} = u_{ij}(\vec{E})$$

For small control fields the given dependence can be represented in the following way:

$$u_{ij} = d_{ijk}E_k + \alpha_{ijkl}E_kE_l + \ldots$$

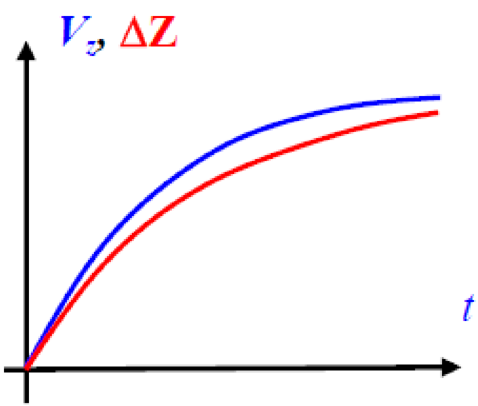
Typical values of fields E*, at which nonlinear effects cannot be neglected, are about **100 V/mm**.

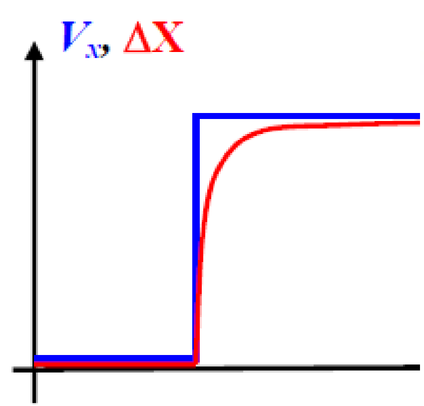


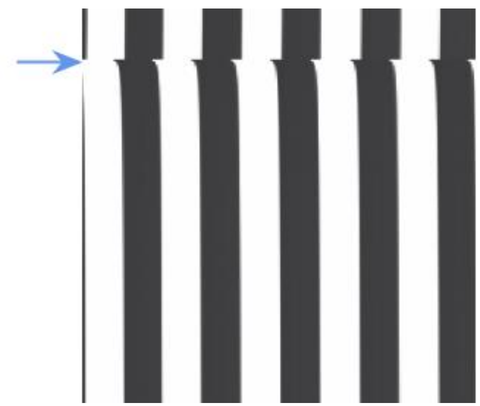


Piezoceramics Creep

Piezoceramics creep is a **delay** in the response to **sudden change** of the control electric field value.



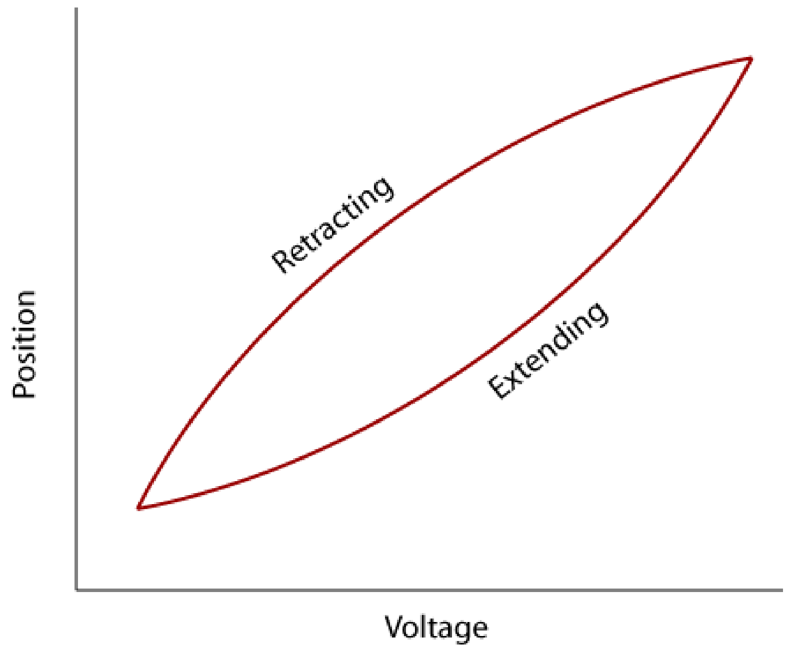




The creep results in **appearance of geometrical distortions** in SPM images. Specifically strong influence of the creep occurs, **on initial stages of the scanning process**, or **after a large displacement of the starting point of the scanned area**.

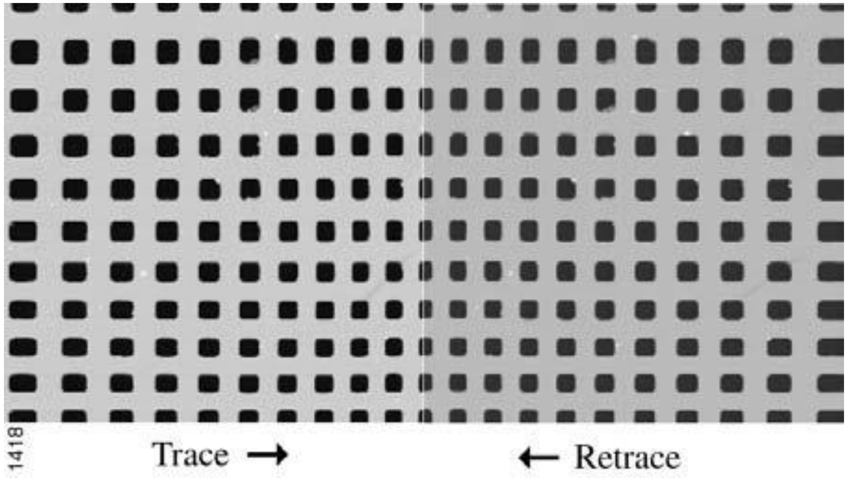
Piezoceramics Hysteresis

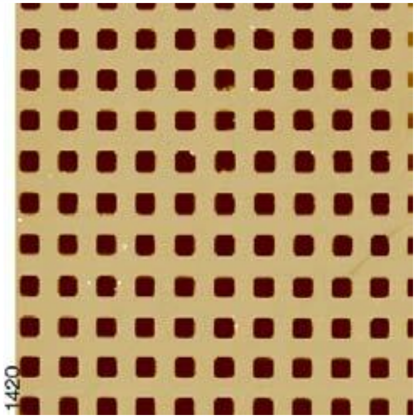
Piezoceramics hysteresis is that the piezoceramic deformation depends on the sign of previously applied electric field.

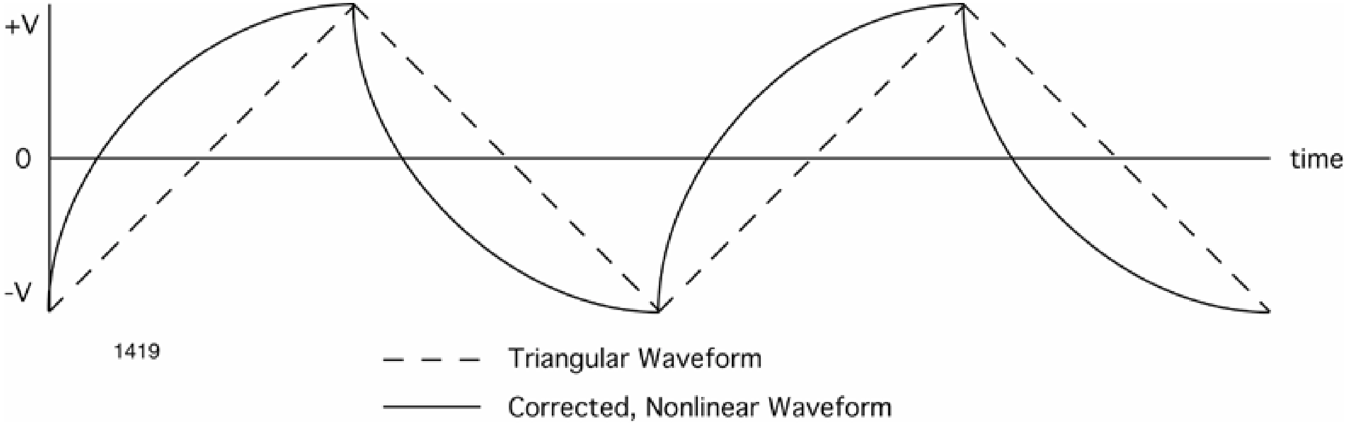


To avoid distortions in the SPM images caused by piezoceramics hysteresis, information is stored, in a sample scanning, only while **tracing one of the loop branches $\Delta Z = f(V)$**.

Piezoceramics Hysteresis

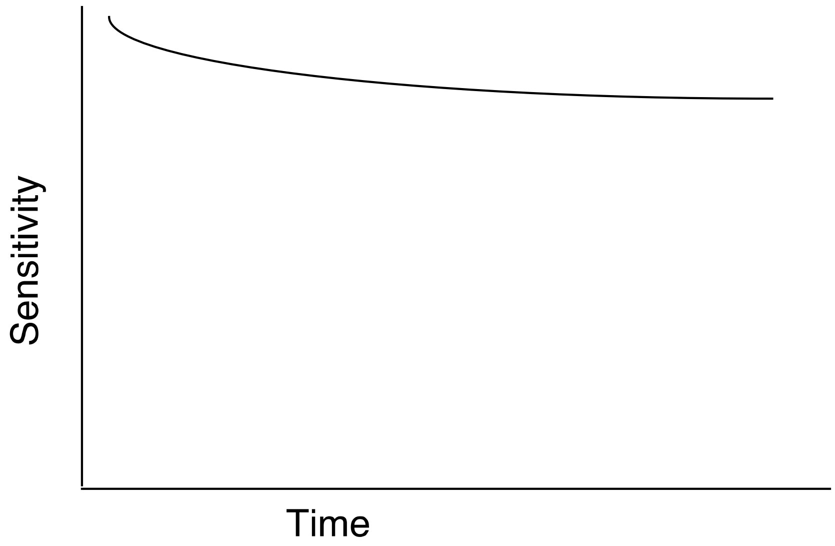






Piezoceramics Aging

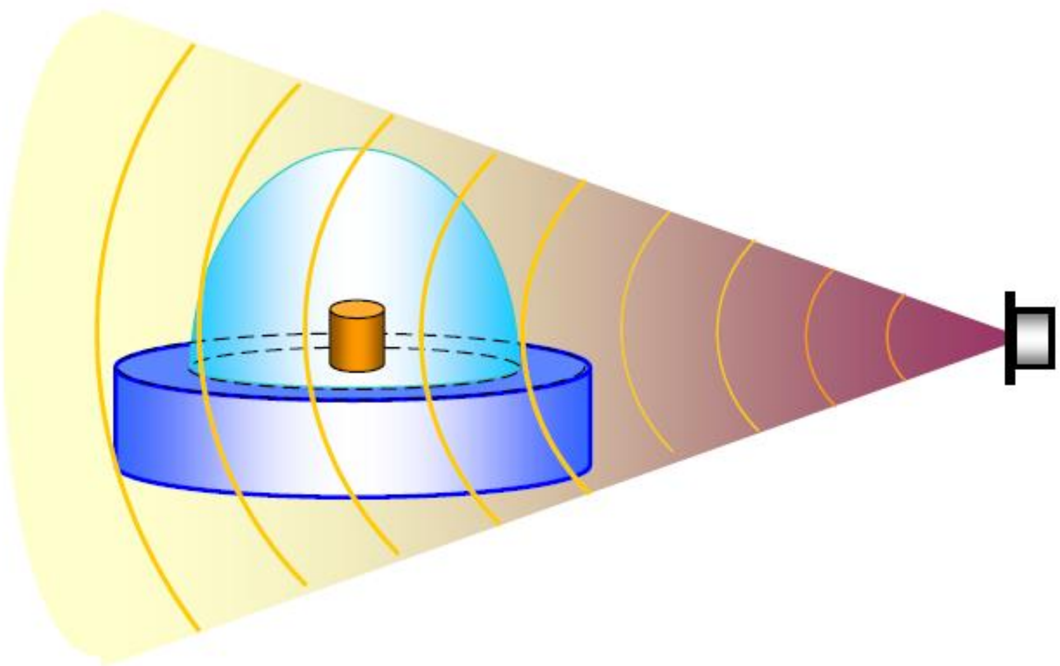
The sensitivity of piezoelectric materials **decreases exponentially with operation time**. This causes most of the change in the sensitivity to occur **at the beginning of a scanner's life**. Scanners are run approximately 48 hours before they are shipped from the factory to get the scanner past the point where the sensitivity changes dramatically over short periods of time. As the scanner ages, the sensitivity will change less with time, and will eventually get to the point where it very seldom needs recalibrating.



First Year- Every 3 months

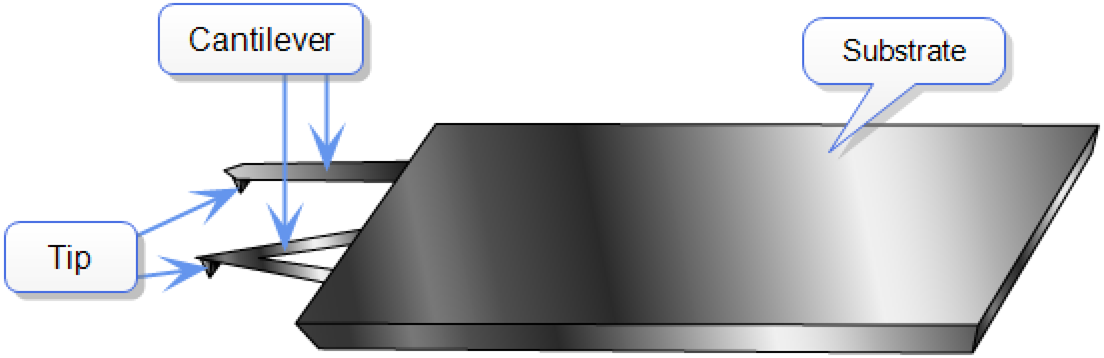
Subsequent Years -Every 6 months

Protection against Acoustic Noise



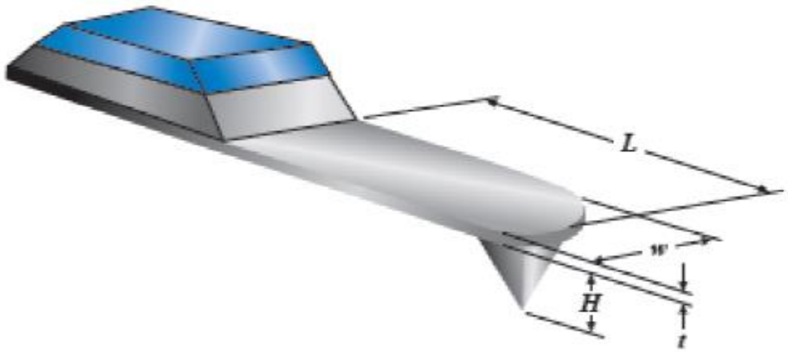
Acoustic waves directly affect elements of SPM heads, resulting in oscillations of the tip with respect to the sample surface. Various protective enclosures, allowing a sensible reduction of the level of acoustic noise are used to protect the SPM. The most effective protection against acoustic noise is to place the measuring head into a vacuum chamber.

AFM Probes



- An AFM probe has three components: tip, cantilever, and substrate
- There are two different shapes of cantilever: rectangular and triangular
- Key probe parameters: spring constant (k), resonance frequency (f_0), and tip radius (R)
- For more information, please visit http://www.brukerafmprobes.com

Cantilever Parameters



w – width of cantilever

H – tip height

p – cantilever mass per unit-length

$\rho_{air} = 1.18 kg / m^3$

$\eta_{air} = 1.86 \text{x} 10^{-5} kg / m \cdot s$

t – thickness of cantilever

f_0 – resonance frequency of cantilever (in Hz)

ρ – density of cantilever (silicon) = 2.33gm/cm^3 = 2330kg/m^3

L – length of cantilever

P – mass of tip

E – elastic modulus of cantilever = $1.39 \text{x} 10^{11} \text{N/m}^2$ (in the <110> direction)

Spring Constant :

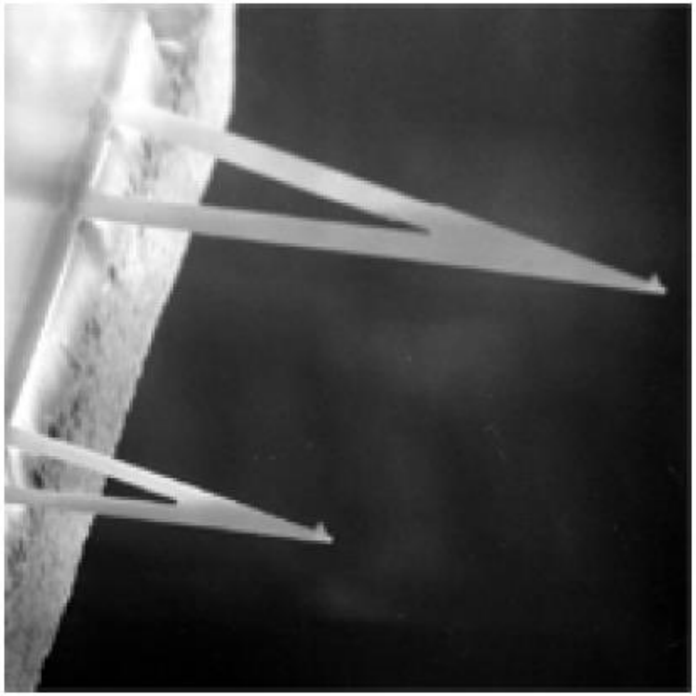
$$k = \frac{F}{Z} = \frac{Ewt^3}{4L^3}$$

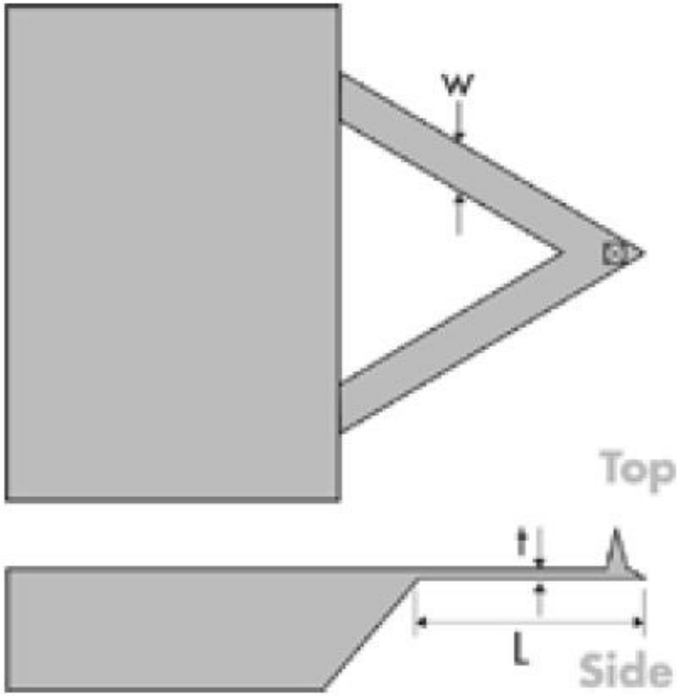
Resonance Frequency (without tip mass):

$$f_0 = 0.162 \cdot \sqrt{\frac{E}{\rho}} \cdot \frac{t}{L^2} \approx \frac{1}{2\pi} \sqrt{\frac{E}{\rho}} \cdot \frac{t}{L^2}$$

$$f_0 = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

Nitride Probes

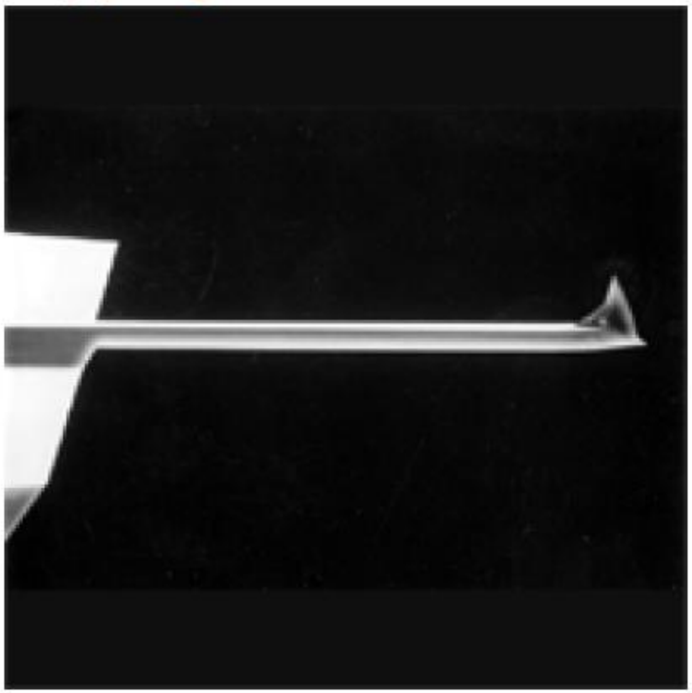


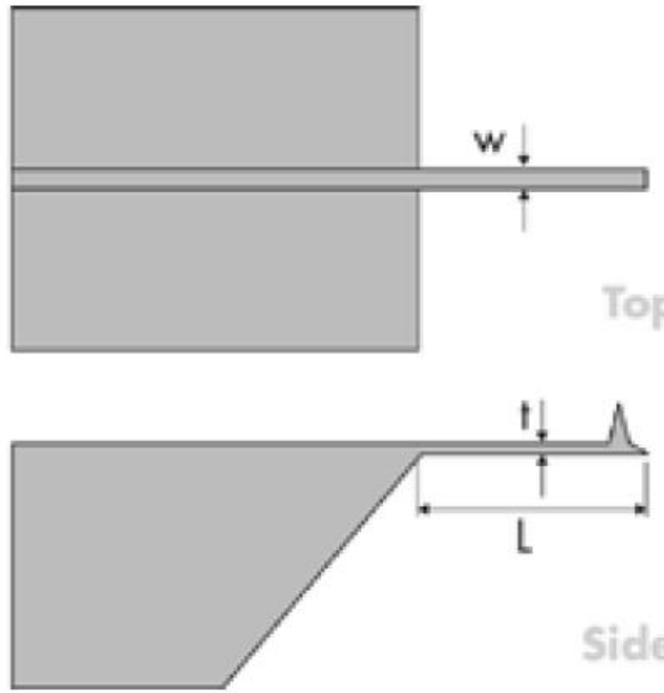


A wafer of silicon nitride probes for contact and fluid tapping mode imaging and force measurement.

DNP, DNP-S, SNL, DNP-O, ScanAsyst-Air, ScanAsyst-Fluid, ScanAsyst-Fluid+

Silicon Probes





(R)TESP(A), (O)TESPA, OLTESPA, (R)FESP(A)
SCM-PIT, SCM-PIC, MESP, DDESP

Factors to Be Considered

1

Sample Properties to be Measured

Topography
Viscoelasticity
Electric Properties
Magnetic Properties

2

Environment

Air
Liquid

3

Imaging Mode

Contact Mode
Tapping Topography
Tapping Phase
TRmode

Probe Selection Guide — Life Science

Sample Type		Imaging Environment: Liquid	Imaging Environment: Air	Probe Family / Model		Nominal Specifications: Force Constant (N/m)	Resonant Frequency (kHz)	Radius of Curvature (nm)	Coatings: Backside	Coatings: Tip Side
Life Sciences	Biomolecules (nucleic acids, proteins, lipids, carbohydrates, etc.)	-	✓	Silicon	TESPA	42	320	8	Al	None
		-	✓		RTESPA	40	300	8	Al	None
		-	✓		NCHV-A	42	320	10	Al	None
		✓	✓	Silicon Nitride	DNP-S	0.06-0.58	18-57	10	Au	None
		✓	✓		MSCT	0.01-0.5	7-120	10	Au	None
		✓	✓		SNL	0.06-0.58	18-57	2	Au	None
		✓	✓		MSNL	0.01-0.5	7-120	2	Au	None
		✓	✓		ScanAsyst-Air	0.2-0.8	45-95	2	Al	None
		✓	-		ScanAsyst-Fluid	0.35-1.4	100-200	20	Au	None
		✓	-		ScanAsyst-Fluid+	0.35-1.4	100-200	2	Au	None
	Cells	✓	-	Silicon Nitride	DNP	0.06-0.58	18-57	20	Au	None
		✓	-		MLCT	0.01-0.5	7-120	20	Au	None
	Tissues	-	✓	Silicon	TESPA	42	320	8	Al	None
		-	✓		RTESPA	40	300	8	Al	None
		-	✓		NCHV-A	42	320	10	Al	None
		✓	-	Silicon Nitride	DNP	0.06-0.58	18-57	20	Au	None
		✓	-		DNP-S	0.06-0.58	18-57	10	Au	None
		✓	-		MLCT	0.01-0.5	7-120	20	Au	None
		✓	-		MSCT	0.01-0.5	7-120	10	Au	None
		✓	-		SNL	0.06-0.58	18-57	2	Au	None
		✓	-		MSNL	0.01-0.5	7-120	2	Au	None
		✓	✓		ScanAsyst-Air	0.2-0.8	45-95	2	Al	None
		✓	-		ScanAsyst-Fluid	0.35-1.4	100-200	20	Au	None
		✓	-		ScanAsyst-Fluid+	0.35-1.4	100-200	2	Au	None

Probe Attributes	AFM Mode: Peak Force/ Scan Asyst	Tapping	Contact	Force Curves	Electrical	Magnetic
Highest Resolution, Asymmetric Tip		✓	-	-	-	-
Highest Resolution, Symmetric Tip		✓	-	-	-	-
High Resolution, Asymmetric Tip		✓	-	-	-	-
High Resolution, Low Force, Symmetric Tip (sharpened)		✓	✓	✓	-	-
High Resolution, Lowest Force, Symmetric Tip (sharpened)		✓	✓	✓	-	-
Ultra-High Resolution, Low Force, Symmetric Tip (extremely sharp)		✓	✓	✓	-	-
Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)		✓	✓	✓	-	-
Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
High Resolution, Lowest Force, Symmetric Tip (sharpened)	✓	-	-	-	-	-
Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
Low Force, Symmetric Tip		✓	✓	✓	-	-
Lowest Force, Symmetric Tip		✓	✓	✓	-	-
Highest Resolution, Asymmetric Tip		✓	-	-	-	-
Highest Resolution, Symmetric Tip		✓	-	-	-	-
High Resolution, Asymmetric Tip		✓	-	-	-	-
Low Force, Symmetric Tip		✓	✓	✓	-	-
High Resolution, Low Force, Symmetric Tip (sharpened)		✓	✓	✓	-	-
Lowest Force, Symmetric Tip		✓	✓	✓	-	-
High Resolution, Lowest Force, Symmetric Tip (sharpened)		✓	✓	✓	-	-
Ultra-High Resolution, Low Force, Symmetric Tip (extremely sharp)		✓	✓	✓	-	-
Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)		✓	✓	✓	-	-
Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
High Resolution, Lowest Force, Symmetric Tip (sharpened)	✓	-	-	-	-	-
Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-

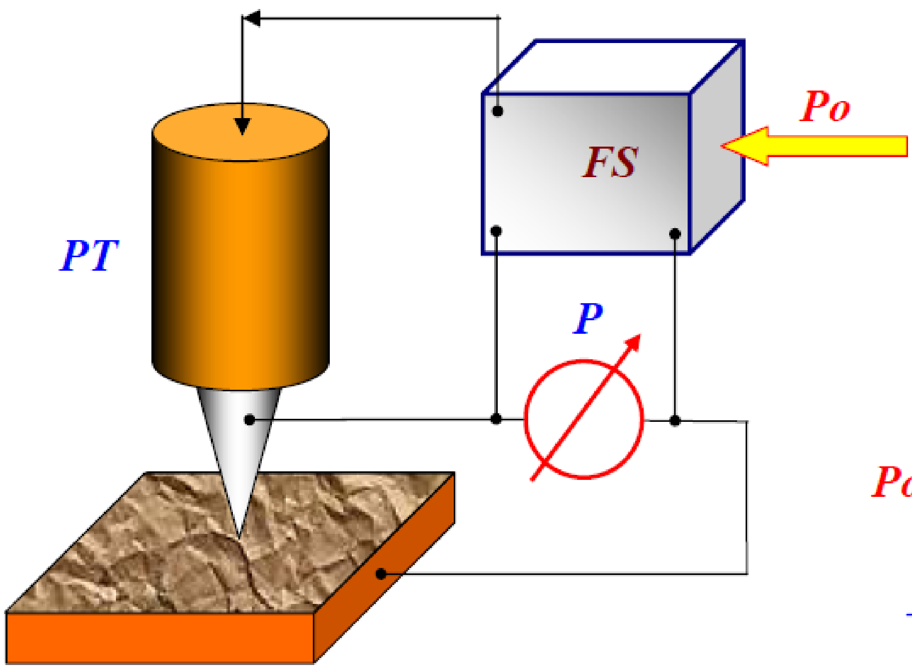
Probe Selection Guide — Material

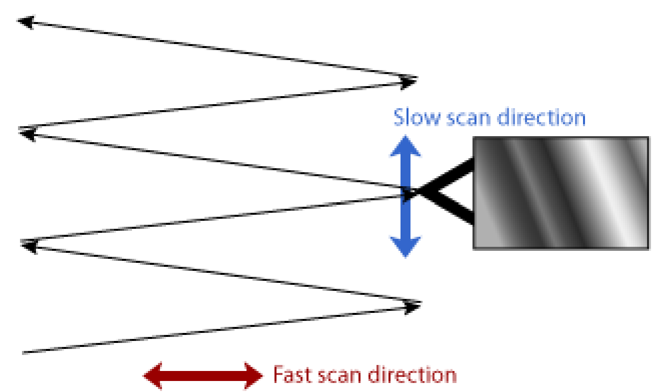
Sample Type		Imaging Environment: Liquid	Imaging Environment: Air	Probe Family / Model		Nominal Specifications: Force Constant (N/m)	Resonant Frequency (kHz)	Radius of Curvature (nm)	Coatings: Backside	Coatings: Tip Side
Materials	Polymers / Soft Samples	-	✓	Silicon	FESP	2.8	75	<10	None	None
Materials	Polymers / Soft Samples	-	✓	Silicon	TESPA	42	320	8	Al	None
Materials	Polymers / Soft Samples	-	✓	Silicon	LTESP	48	190	<10	None	None
Materials	Polymers / Soft Samples	-	✓	Silicon	NCHV-A	42	320	10	Al	None
Materials	Polymers / Soft Samples	✓	✓	Silicon Nitride	DNP	0.06-0.58	18-57	20	Au	None
Materials	Polymers / Soft Samples	✓	✓	Silicon Nitride	SNL	0.06-0.58	18-57	2	Au	None
Materials	Polymers / Soft Samples	-	✓	Silicon Nitride	MLCT	0.01-0.5	7-120	20	Au	None
Materials	Polymers / Soft Samples	✓	✓	Silicon Nitride	ScanAsyst-Air	0.2-0.8	45-95	2	Al	None
Materials	Polymers / Soft Samples	✓		Silicon Nitride	ScanAsyst-Fluid	0.35-1.4	100-200	20	Au	None
Materials	Polymers / Soft Samples	✓		Silicon Nitride	ScanAsyst-Fluid+	0.35-1.4	100-200	2	Au	None
Materials	Hard Samples	-	✓	Silicon	TESPA	42	320	8	Al	None
Materials	Hard Samples	-	✓	Silicon	NCHV-A	42	320	10	Al	None
Materials	Hard Samples	-	✓	Silicon	RTESPA	40	300	8	Al	None
Materials	Hard Samples	-	✓	Modified Silicon	MESP-RC	2.8	75	25	Co/Cr	Co/Cr
Materials	Hard Samples	-	✓	Modified Silicon	SCM-PIC	0.2	13	20	Pt-Ir	Pt-Ir
Materials	Hard Samples	-	✓	Modified Silicon	SCM-PIT	2.8	75	20	Pt-Ir	Pt-Ir
Materials	Hard Samples	-	✓	Modified Silicon	DDESP	42	320	35	Doped Diamond	Al
Materials	Hard Samples	✓	✓	Silicon Nitride	DNP	0.06-0.58	18-57	20	Au	None
Materials	Hard Samples	✓	✓	Silicon Nitride	SNL	0.06-0.58	18-57	2	Au	None
Materials	Hard Samples	✓	✓	Silicon Nitride	ScanAsyst-Air	0.2-0.8	45-95	2	Al	None
Materials	Hard Samples	✓		Silicon Nitride	ScanAsyst-Fluid	0.35-1.4	100-200	20	Au	None
Materials	Hard Samples	✓		Silicon Nitride	ScanAsyst-Fluid+	0.35-1.4	100-200	2	Au	None

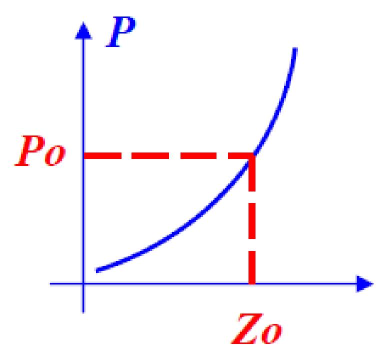
Probe Attributes	AFM Mode: Peak Force/ Scan Asyst	Tapping	Contact	Force Curves	Electrical	Magnetic
High Resolution, Lower Force, Asymmetric Tip		✓	-	✓	-	-
Highest Resolution, Asymmetric Tip		✓	-	✓	-	-
High Resolution, Long-Lever, Asymmetric Tip		✓	-	✓	-	-
High Resolution, Asymmetric Tip		✓	-	✓	-	-
Low Force, Symmetric Tip		✓	✓	✓	-	-
Ultra-High Resolution, Low Force, Symmetric Tip (extremely sharp)		✓	✓	✓	-	-
Lowest Force, Symmetric Tip		-	✓	✓	-	-
Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
High Resolution, Lowest Force, Symmetric Tip (sharpened)	✓	-	-	-	-	-
Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
Highest Resolution, Asymmetric Tip		✓	-	-	-	-
High Resolution, Asymmetric Tip		✓	-	-	-	-
Highest Resolution, Symmetric Tip		✓	-	-	-	-
High Performance, Magnetic Characterization, Asymmetric Tip		✓	-	-	✓	✓
High Performance, Electrical Characterization, Asymmetric Tip		-	✓	-	✓	-
High Performance, Electrical Characterization, Asymmetric Tip		✓	-	-	✓	-
Conductive, with Increased Wear Resistance		-	✓	-	✓	-
Low Force, Symmetric Tip		✓	✓	-	-	-
Ultra-High Resolution, Low Force, Symmetric Tip (extremely sharp)		✓	✓	-	-	-
Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-
High Resolution, Lowest Force, Symmetric Tip (sharpened)	✓	-	-	-	-	-
Ultra-High Resolution, Lowest Force, Symmetric Tip (extremely sharp)	✓	-	-	-	-	-

Basic Working Principle

If there is a **sharp enough** and **unique (single valued)** dependence *P = P (z)* of that parameter on the tip-sample distance, then *P* can be used in the feedback system (FS) that control the distance between the tip and the sample.





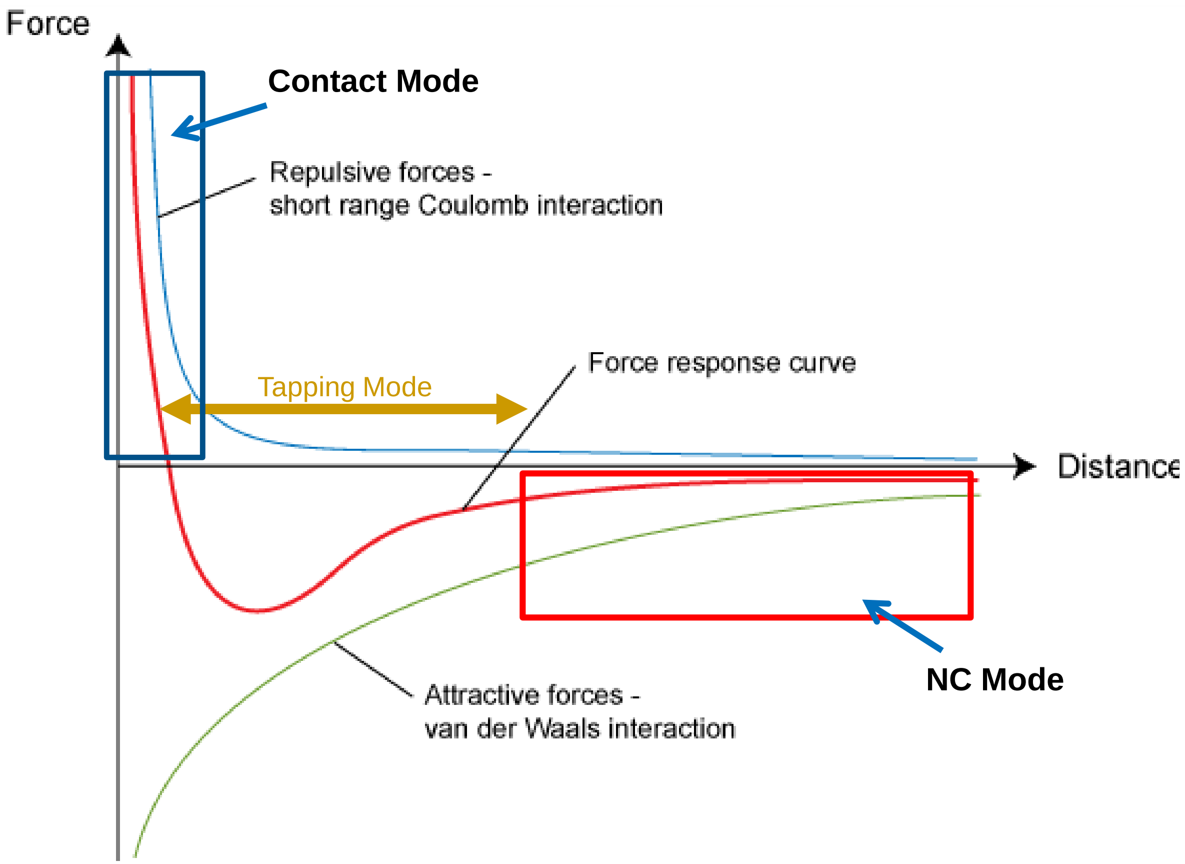


STM
SFM

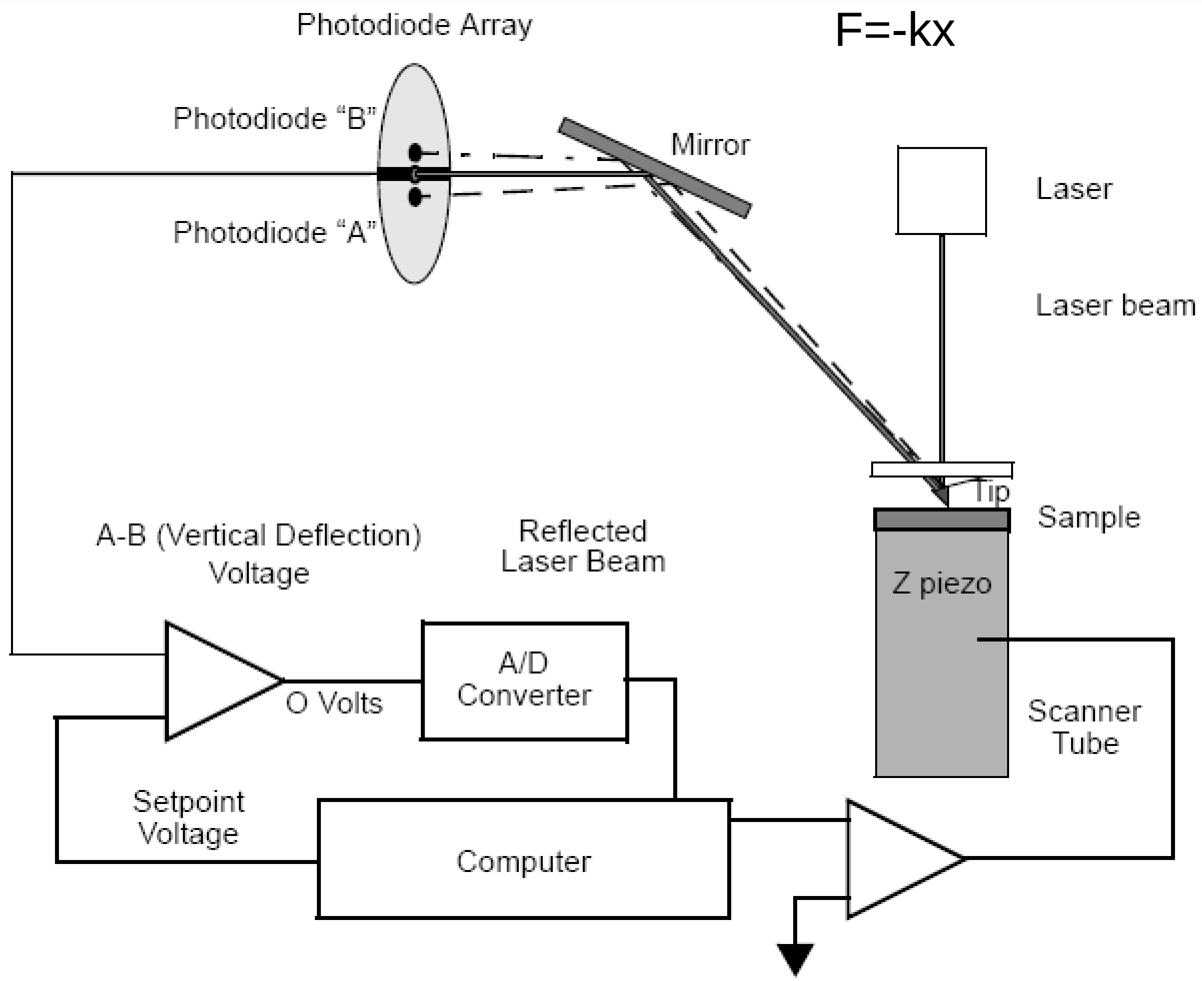
SPM Primary Imaging Modes

P = P(z)	Working Mode
Tunneling Current *i*	Scanning Tunneling Microscope (STM)
Cantilever Amplitude A	Tapping Mode AFM™
Cantilever Deflection D	Contact Mode AFM
Cantilever TR Amplitude A_t	Torsional Resonance Mode (TRmode) AFM™
Tip-Sample Force F	PeakForce Tapping AFM™

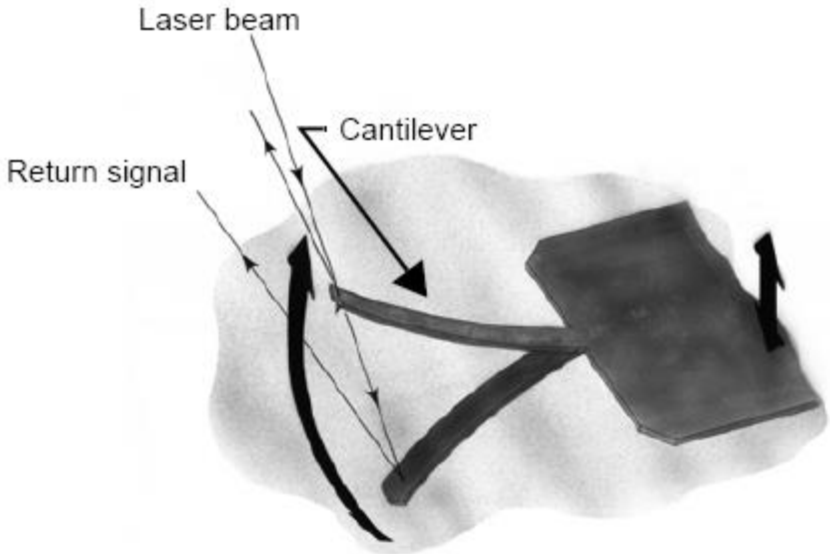
The Lennard-Jones Potential



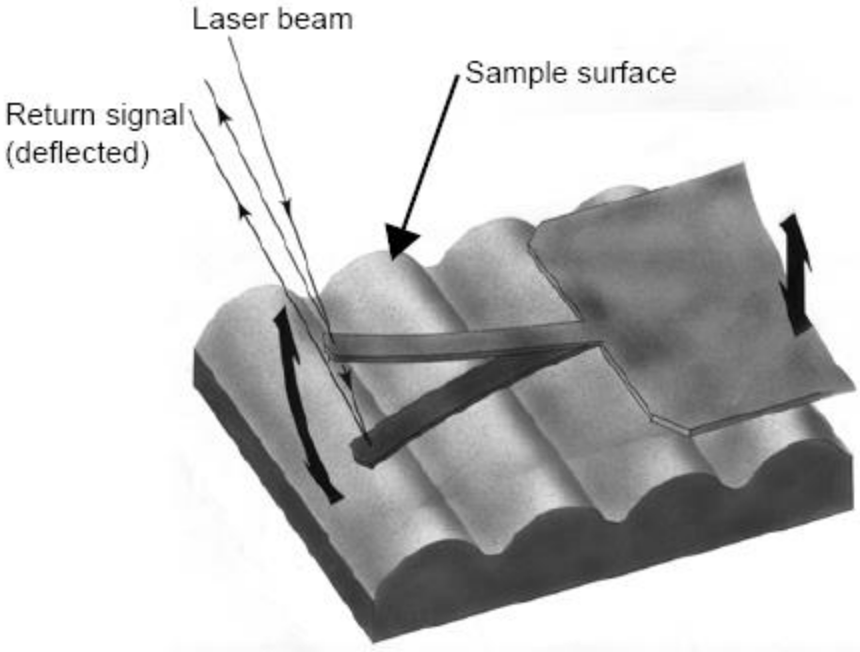
Simplified Block Diagram of Contact Mode AFM



Tapping Mode AFM



Tapping Cantilever in Free Air.



Tapping cantilever on sample surface. Note deflection of cantilever and return signal.

Advantages and Disadvantages - Contact

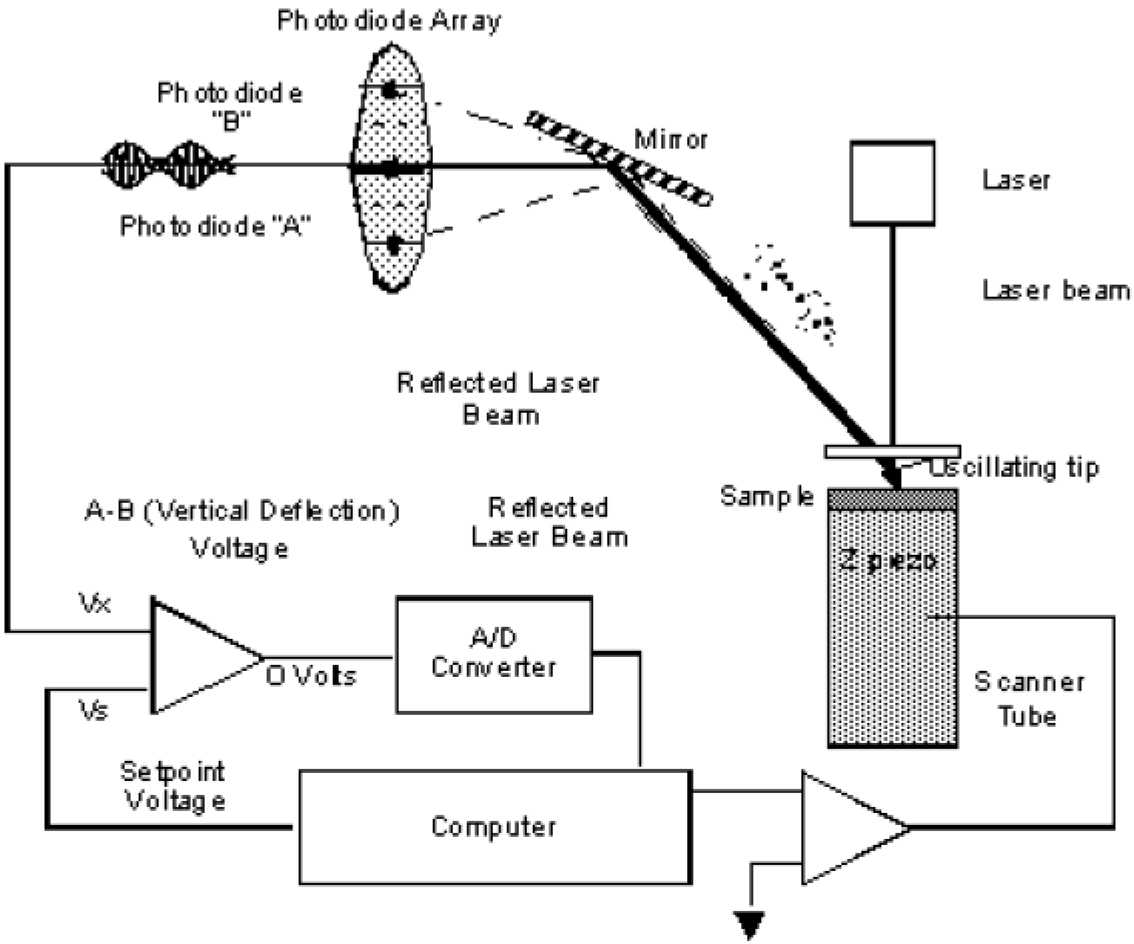
Advantages

- Compared with tapping mode under same experimental conditions, the contact mode has higher scan speeds (throughput)
- Rough samples with extreme changes in vertical topography can sometimes be scanned more easily
- Some special applications, such as lithography, SCM, scratch, must be done under contact mode
- Compared with tapping mode, contact mode is a “static” mode, no need to deal with dynamics of cantilever (no tuning needed), feedback control is easier

Disadvantages

- Lateral (shear) forces can distort features in the image
- Forces normal to the tip-sample interaction can be high in air due to capillary forces from the adsorbed fluid layer on the sample surface
- Combination of lateral forces and high normal forces can result in reduced spatial resolution and may damage soft samples (i.e., biological samples, polymers, silicon) due to scraping between the tip and sample

Simplified Block Diagram of Tapping Mode AFM



Advantages and Disadvantages- Tapping

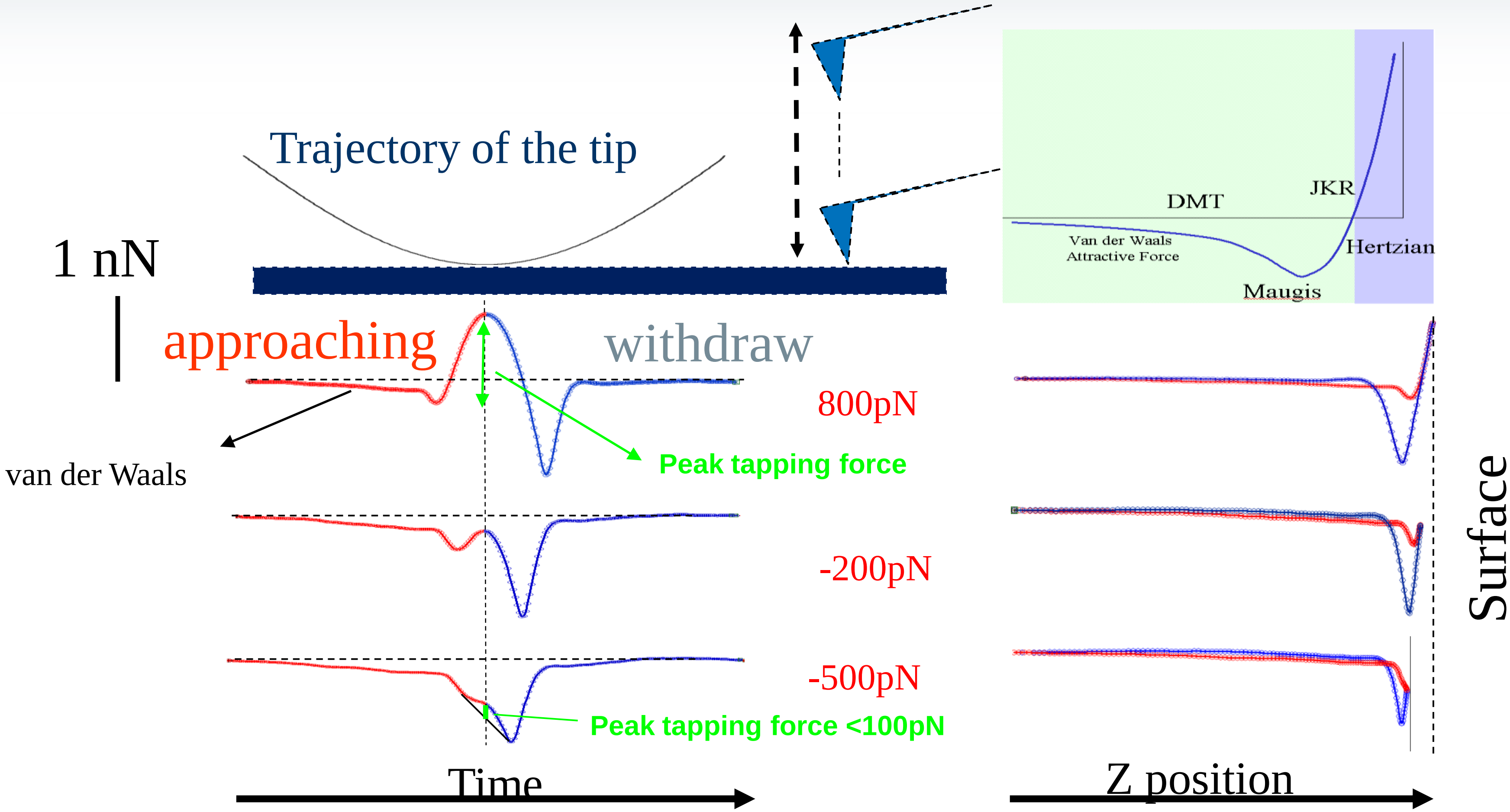
Advantages

• Compared with contact mode in air, can achieve higher lateral resolution on most samples (1nm to 5nm)
• Compared with contact mode, tapping mode has lower forces and less damage to soft samples imaged in air
• Lateral forces are virtually eliminated, so there is no scratching

Disadvantages

• Slightly slower scan speed than contact mode AFM
• Need to deal with dynamics of cantilever, feedback loop is harder to adjust
• Cannot be easily operated in vacuum environment
• Fluid operation is difficult
• Tip-sample interaction force is not directly controlled

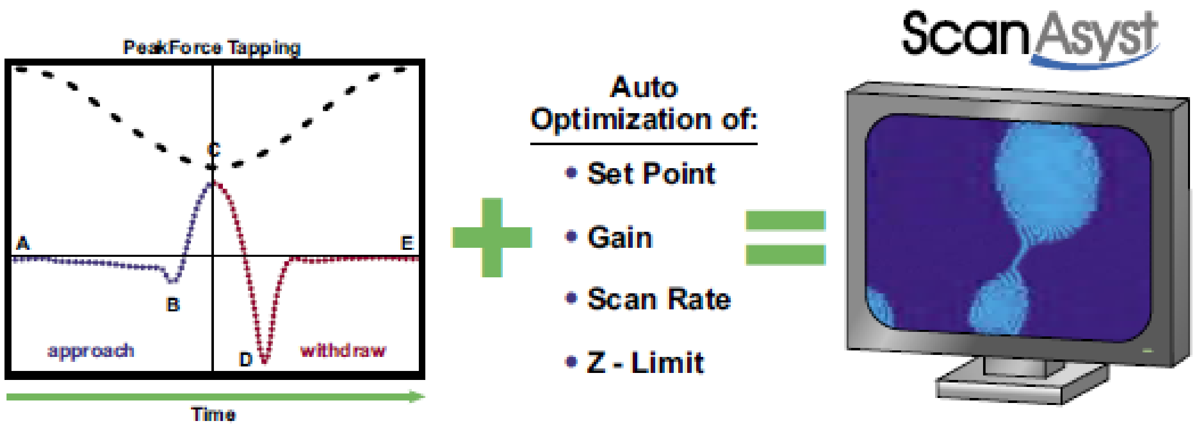
Peak Force Tapping Control



TESP (42 N/m) on Si, MM8

ScanAsyst Advantages

- Automatic image optimization results in faster, more consistent results, regardless of user skill level
- Direct force control at ultra-low forces helps protect delicate samples and tips from damage
- Elimination of cantilever tuning, setpoint adjustment, and gain optimization makes even fluid imaging simple



Secondary Imaging Modes

Derivation of Contact Mode

LFM
cAFM
TUNA
PFM
SCM
SSRM
SThM

Derivation of TRmode™

TR cAFM
TR TUNA

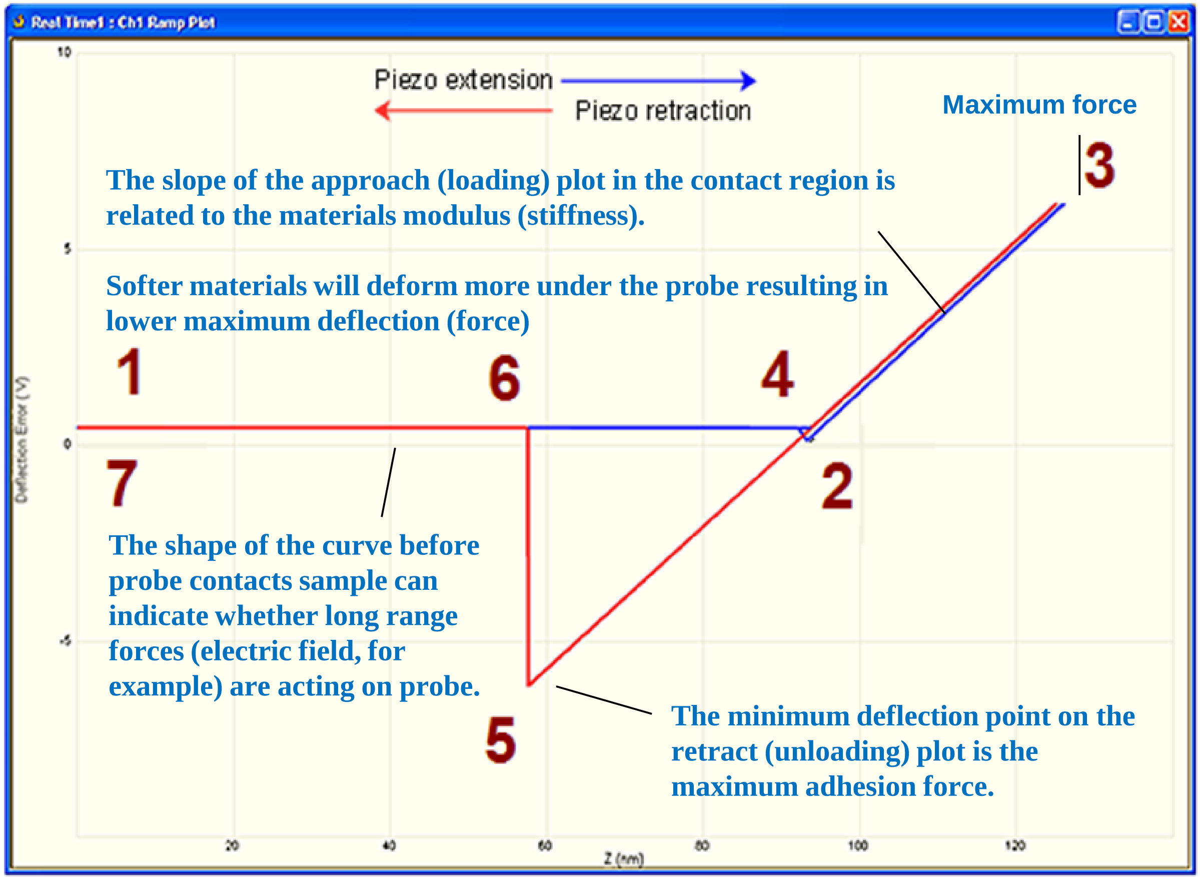
Derivation of Tapping Mode™

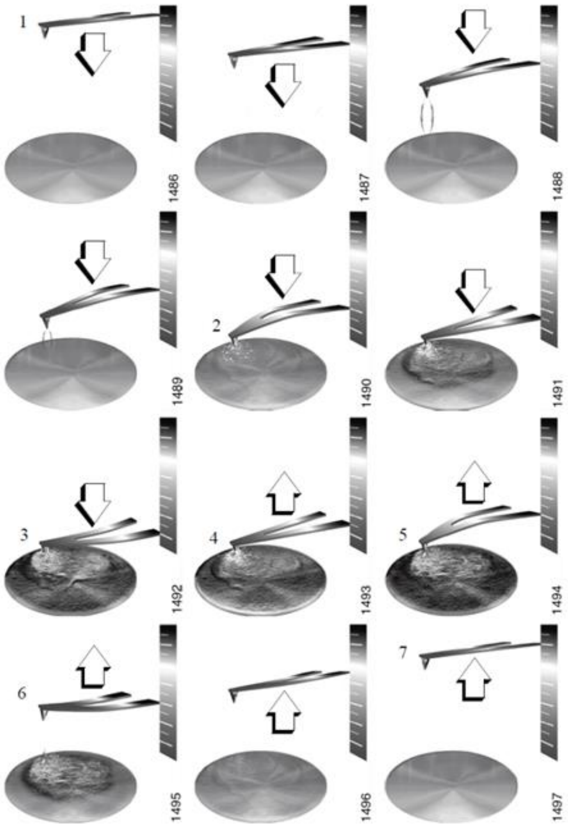
Phase Imaging™
EFM
MFM
TP-KPFM

Derivation of PeakForce Tapping

ScanAsyst™
PeakForce QNM™
PeakForce TUNA™
PeakForce SSRM
PeakForce KPFM

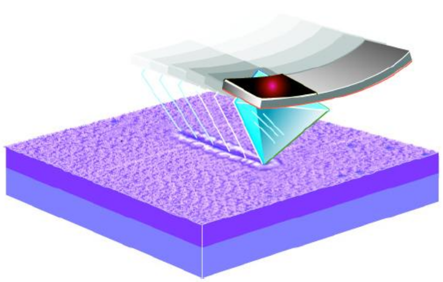
Non-Imaging Modes – Force Curve

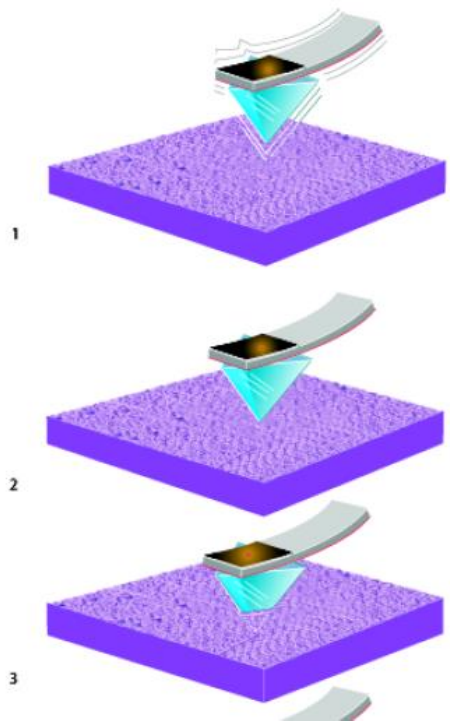


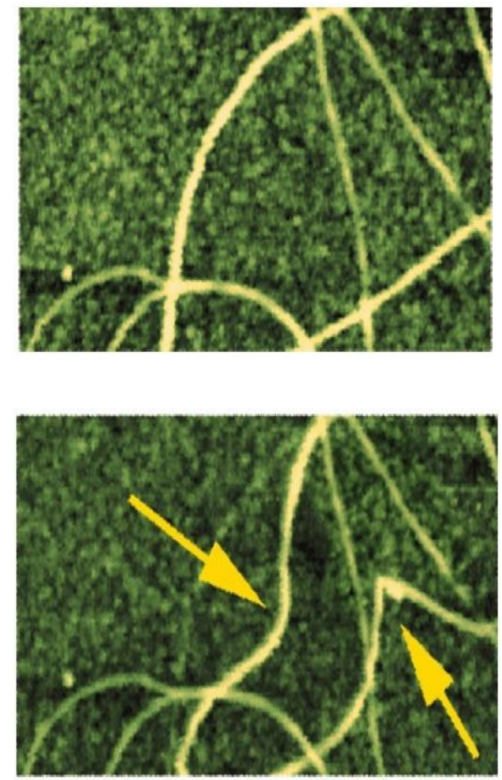


Surface Modification

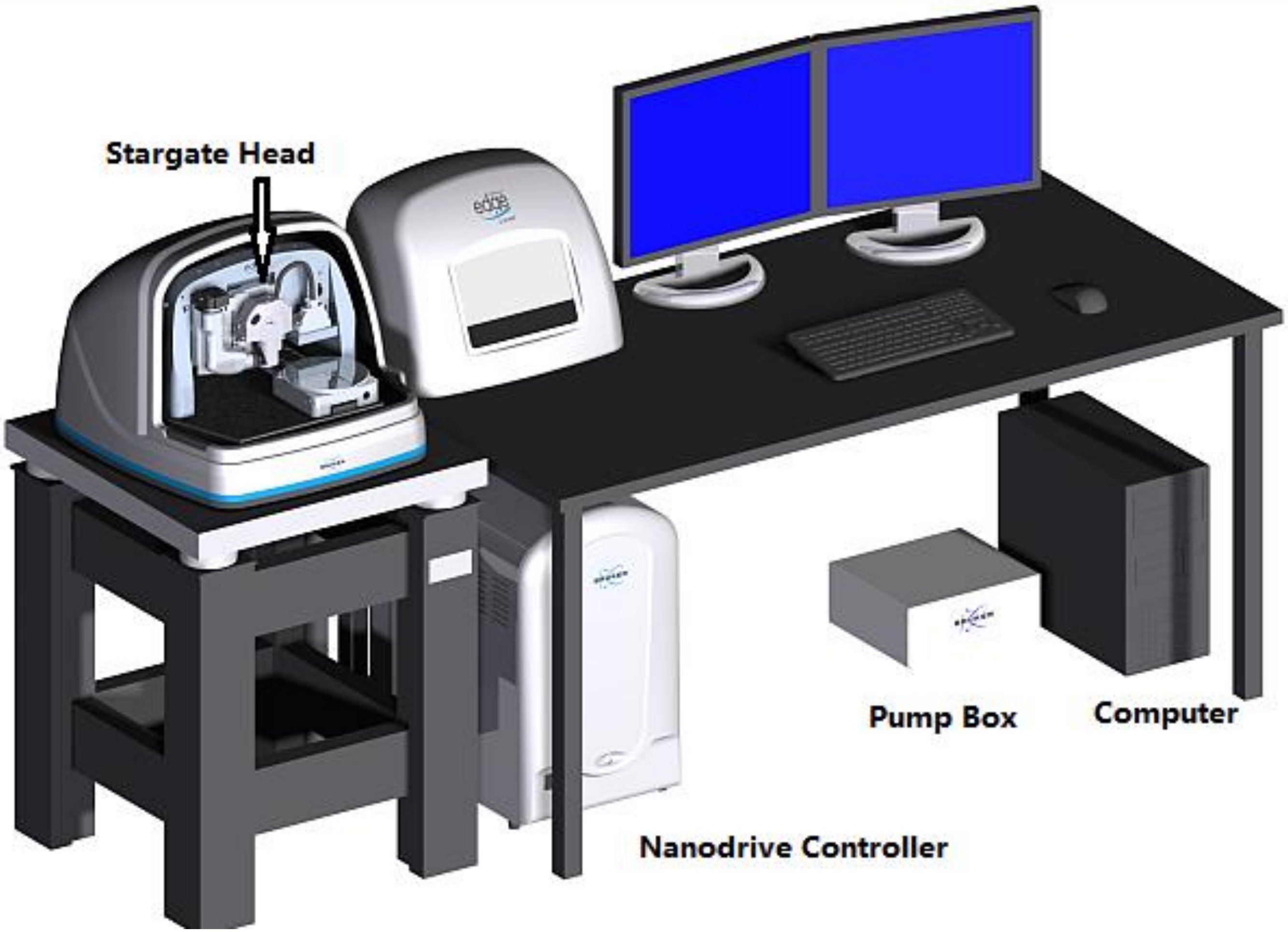
- **Surface Modification Techniques**: Nanolithography, Nanoindentation, Nanoscratching, Nanomanipulation



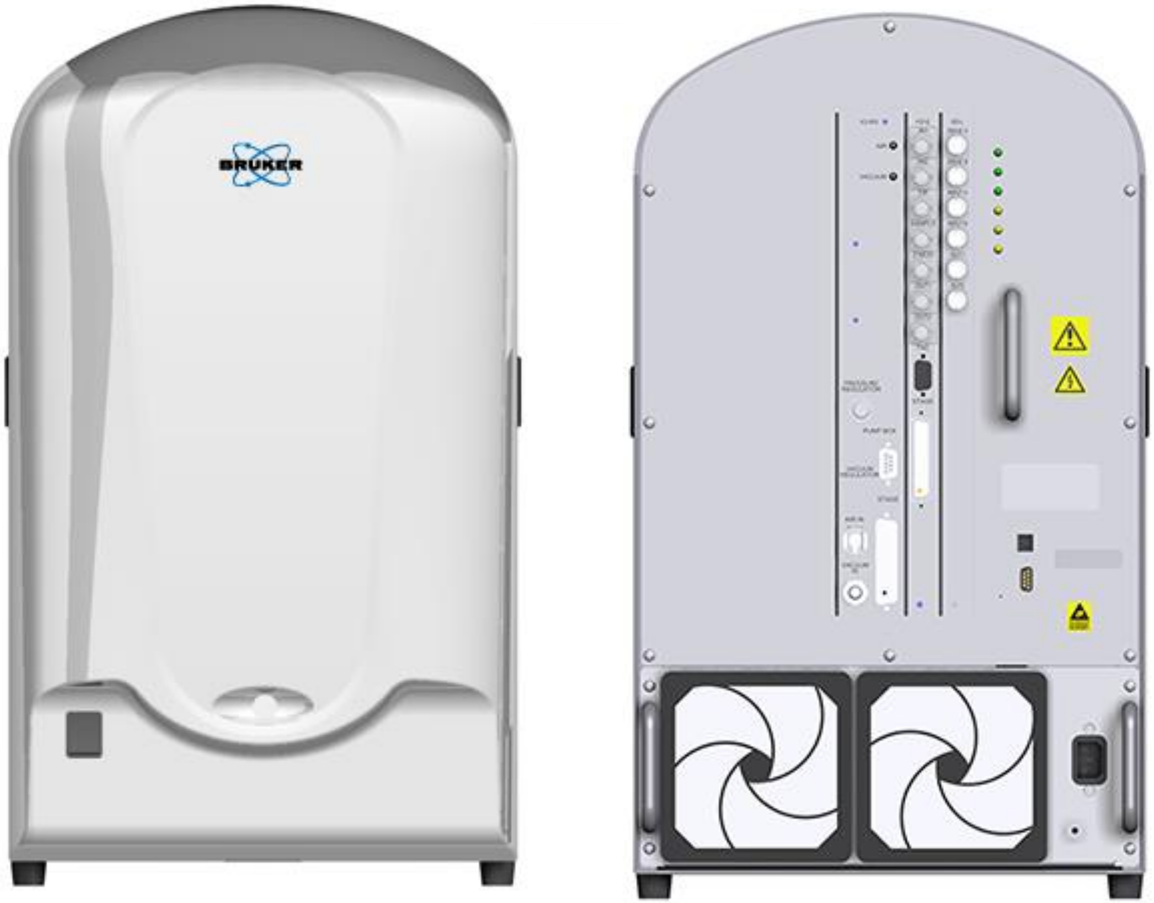




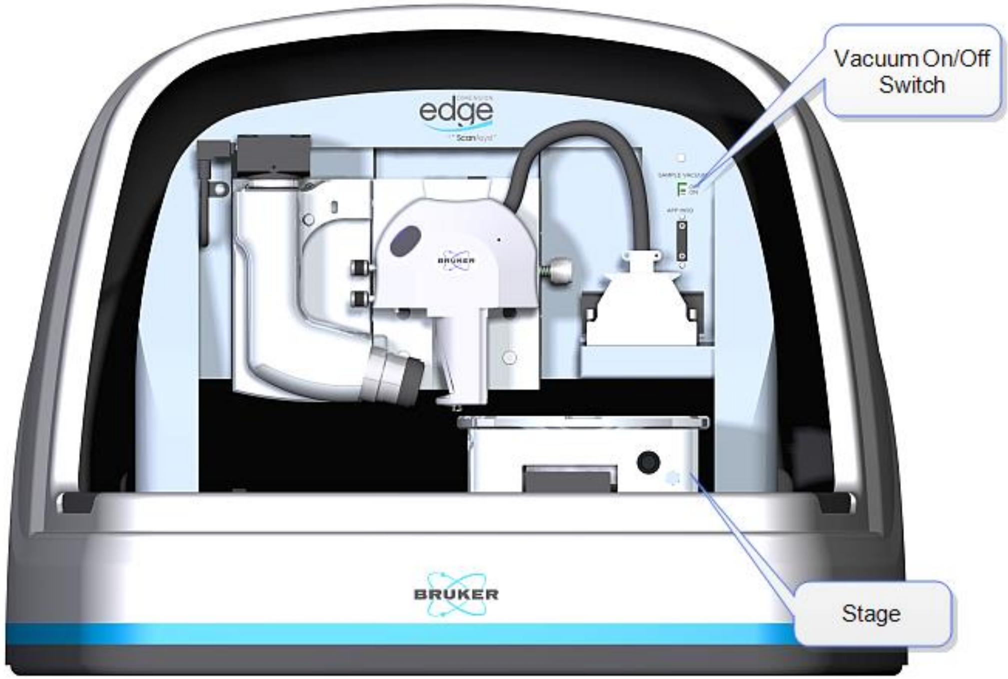
Basic Components of SPM - Dimension Edge

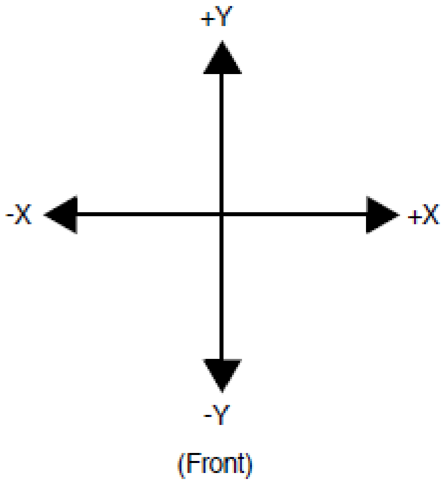


Nanodrive Controller

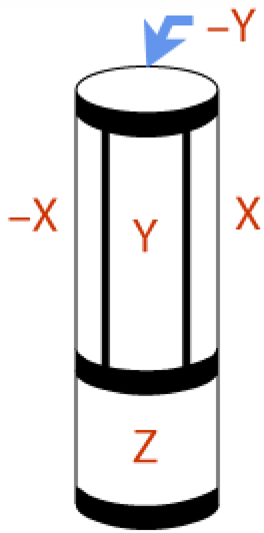


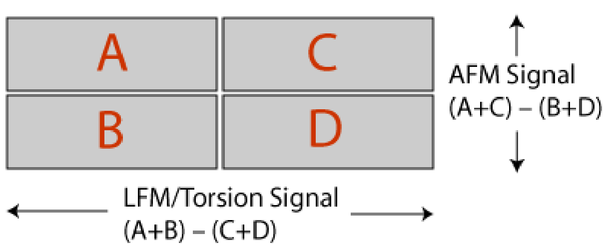
Stage System

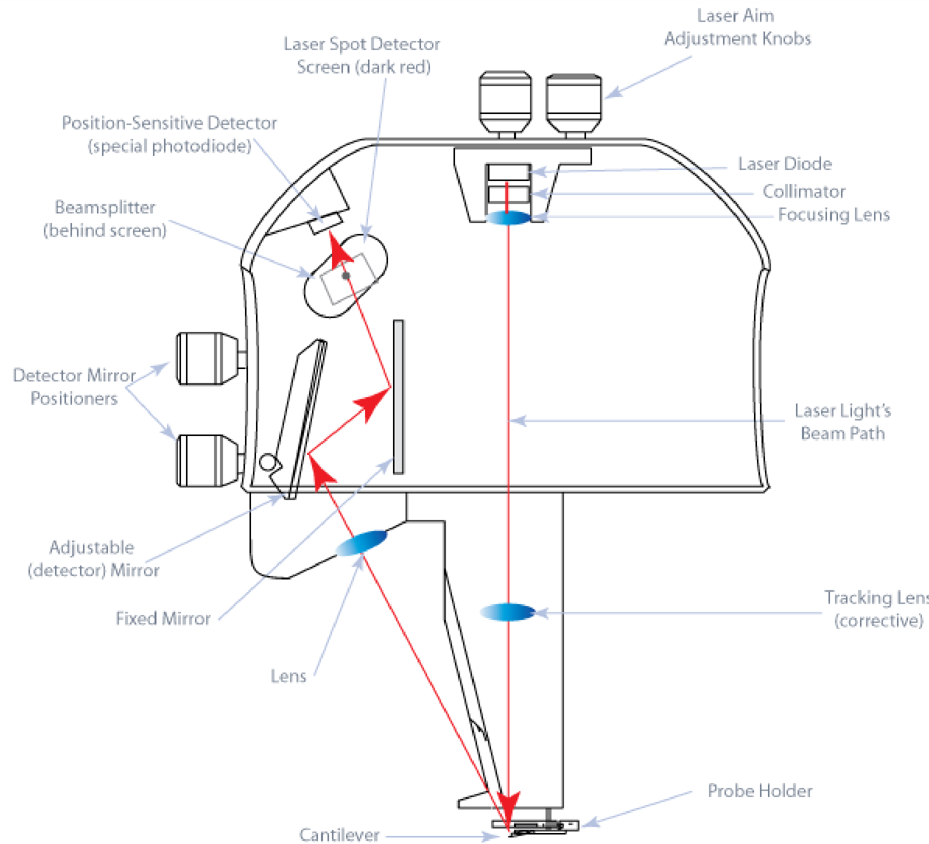




Dimension Stargate Head







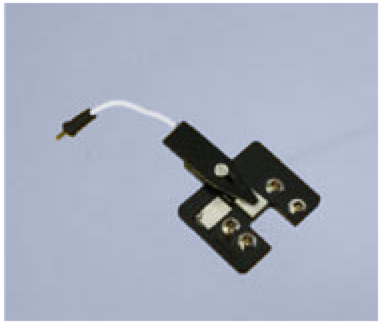
Dimension SPM Probe Holder

Standard

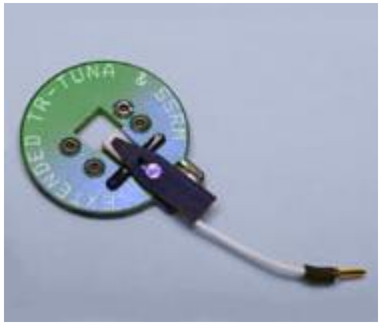
Non-Magnetic

STM

Fluid



SCM



CAFM, TUNA

Resolution Issues

Lateral Resolution

***Tip Shape*:**
The radius of curvature of the end of the tip will determine the highest lateral resolution obtainable with a specific tip. The sidewall angles of the tip will also determine its ability to probe high aspect ratio features.

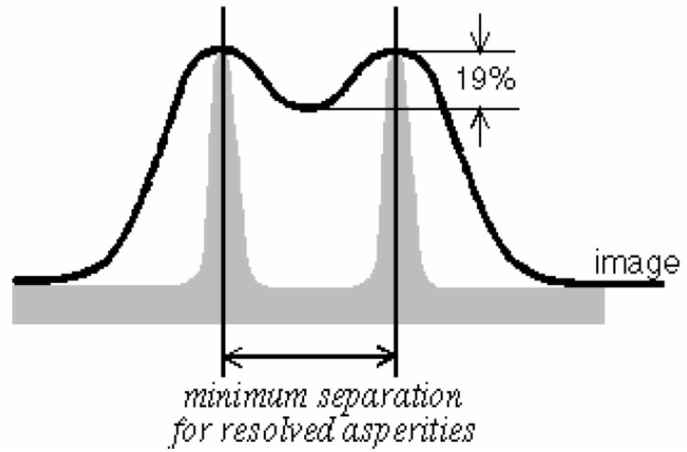
Pixelization

Vertical Resolution

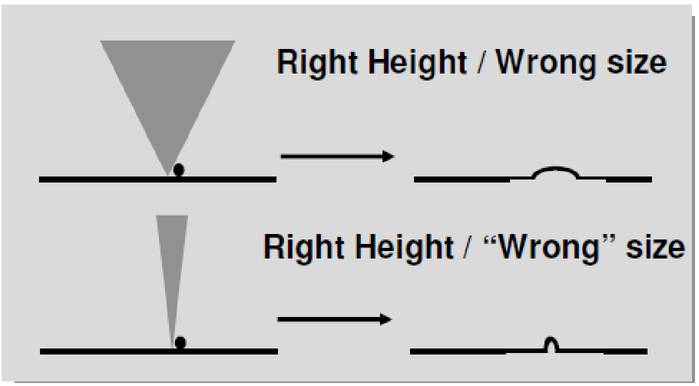
Scanner

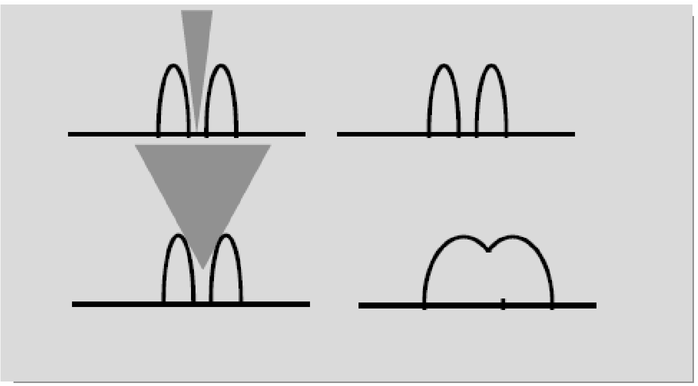
Z Limit

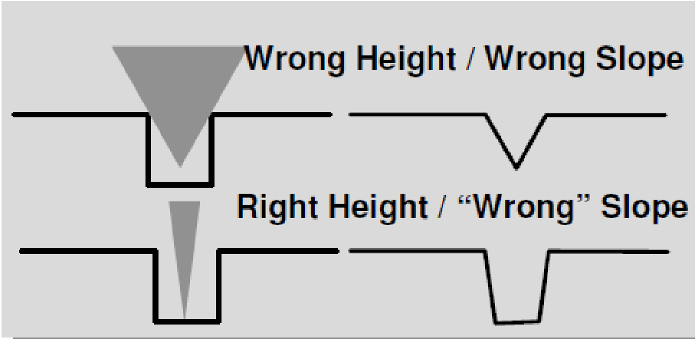
Noise

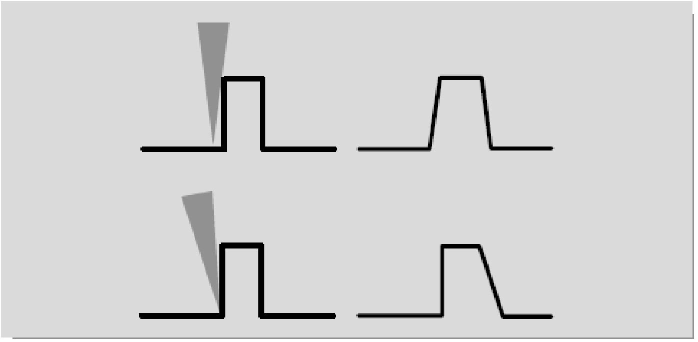


Tip-Sample Convolution



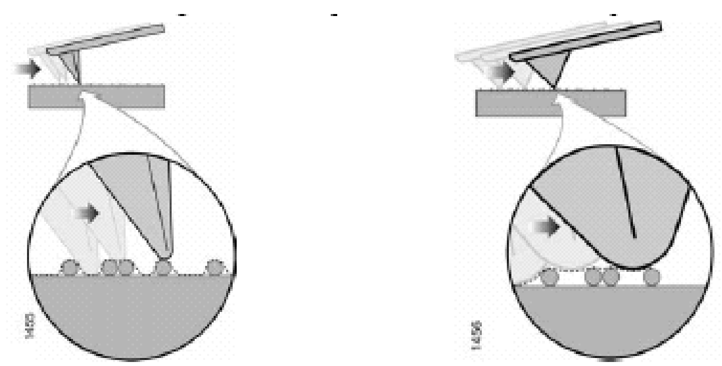




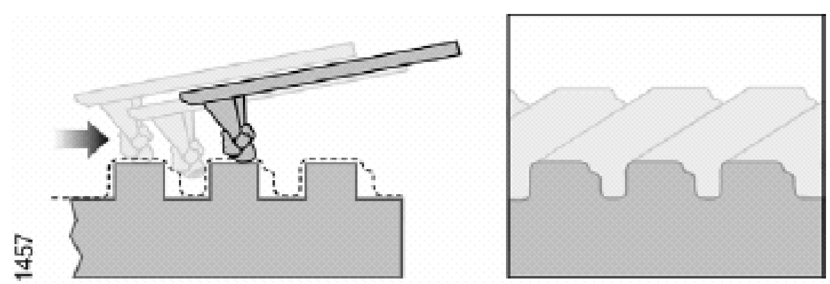


Tip Shape Issues

The smaller the radius of curvature, the smaller the feature that can be resolved. A sharper tip will be able to laterally resolve smaller features than a dull tip with a larger radius of curvature. The accumulation of debris on the end of the tip can also dull the tip and result in image distortion.



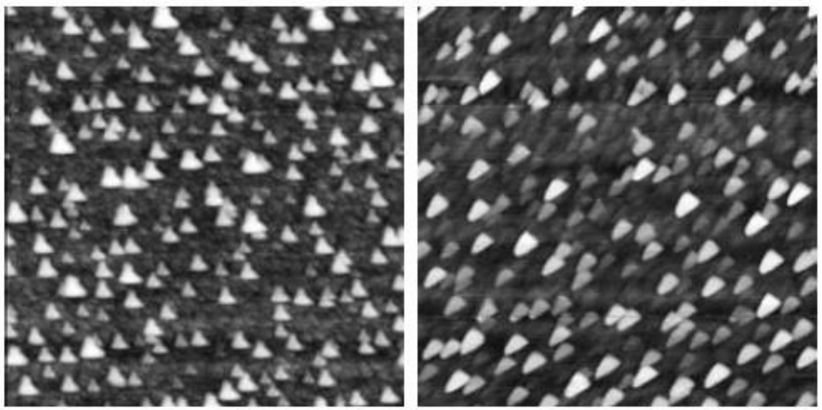
Probe Limited Resolution



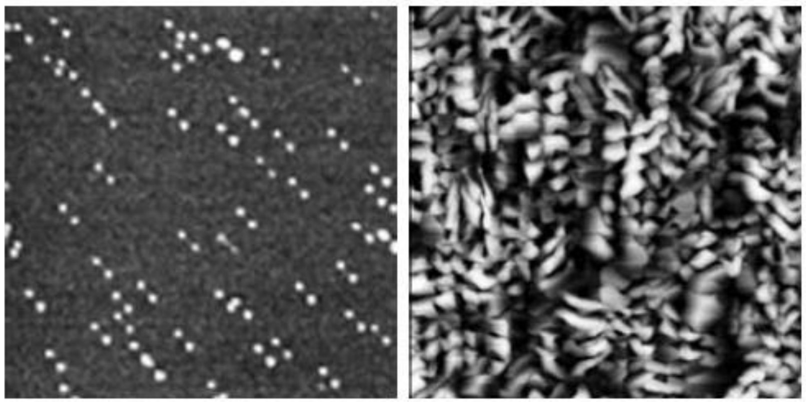
Dirty Probe

Note: A dull or dirty tip **may not affect** the measurement of the **vertical dimensions** of these samples.

Typical Image Artifacts Caused by Tip



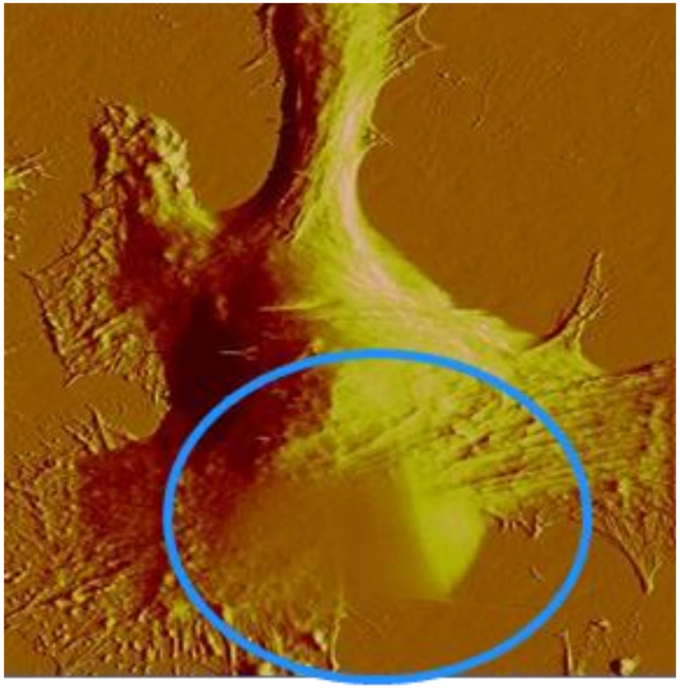
Dull or dirty tip



Double or multiple tips

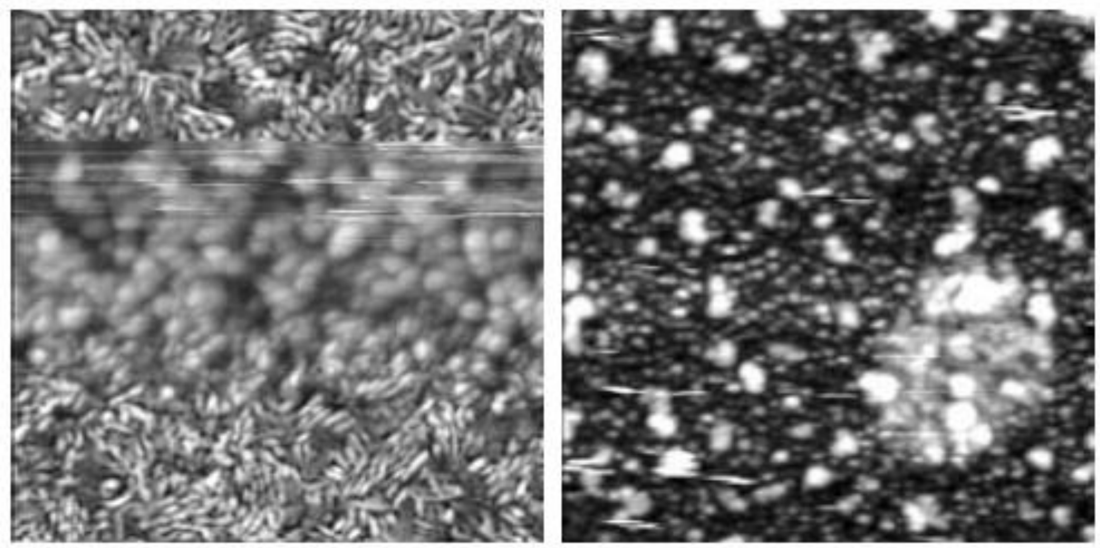
Tip Sidewall Image

Another tip artifact occurs on very tall samples or samples where the slope of the features is greater than the slope of the tip. This causes the tip sidewall to interact with the sample instead of the tip apex. The typical appearance is that of an almost linear ramp-like artifact around the feature, as shown below:



Tip/Sample Contamination

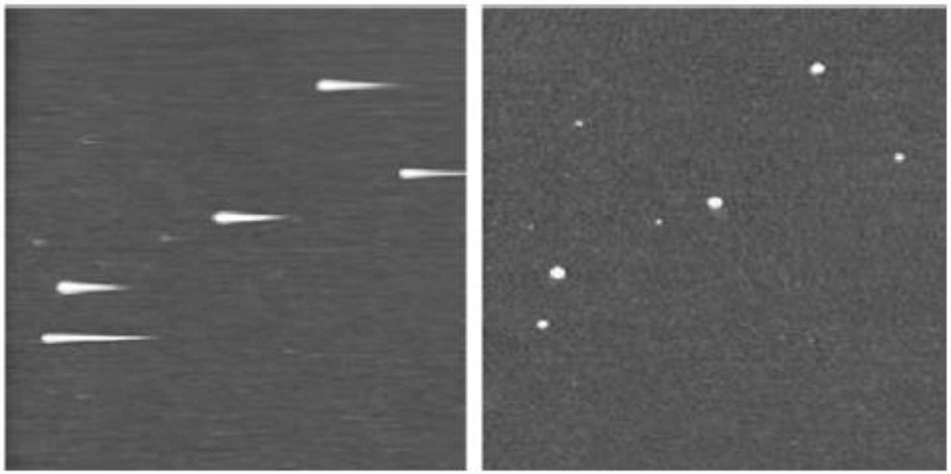
Check is there any dust or debris on the sample top surface or backside. If yes, clean it as needed. If the sample is hydrophilic and exposed in ambient air for long time, if there is any soft or loose residue remain on the sample after sample preparation, which can easily contaminate the tip. If the sample is not in good condition, and hard to recover, get a fresh clean sample.



Contamination from tip or sample surface

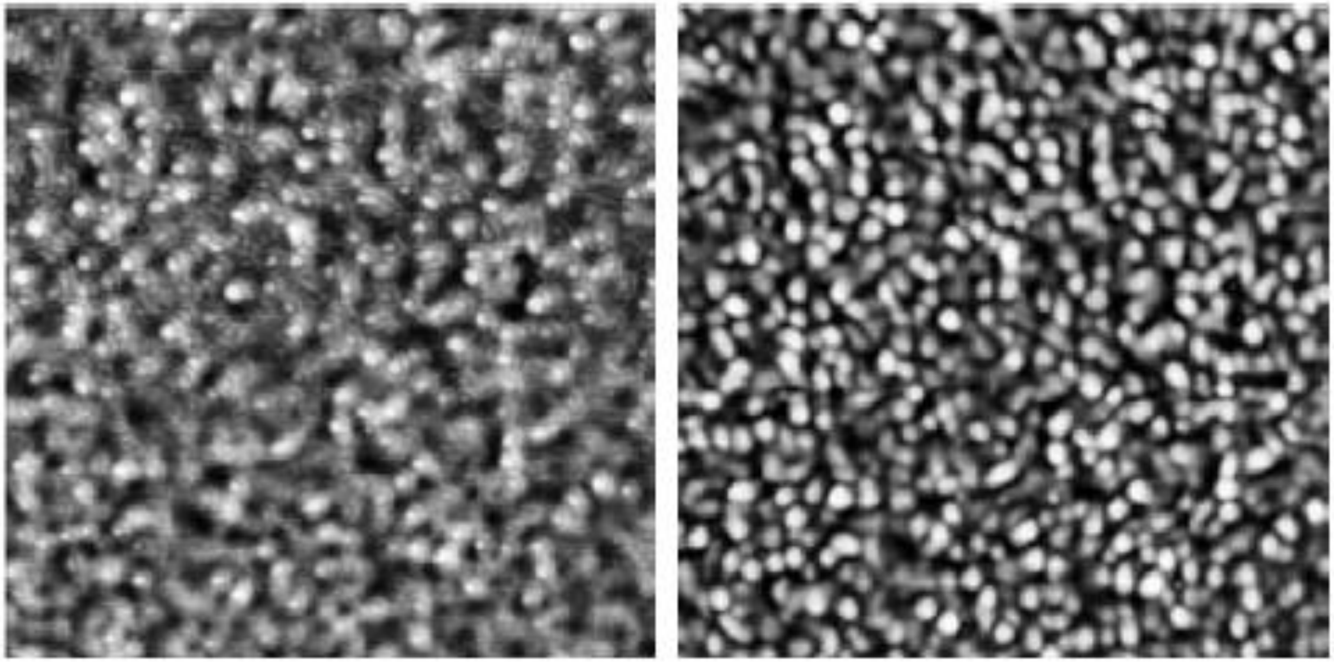
Tapping Mode Artifacts: Not Tracking

In tapping mode, if cannot track surface, **decrease the Amplitude setpoint, decrease the scan rate or increase the I gain and P gain.**



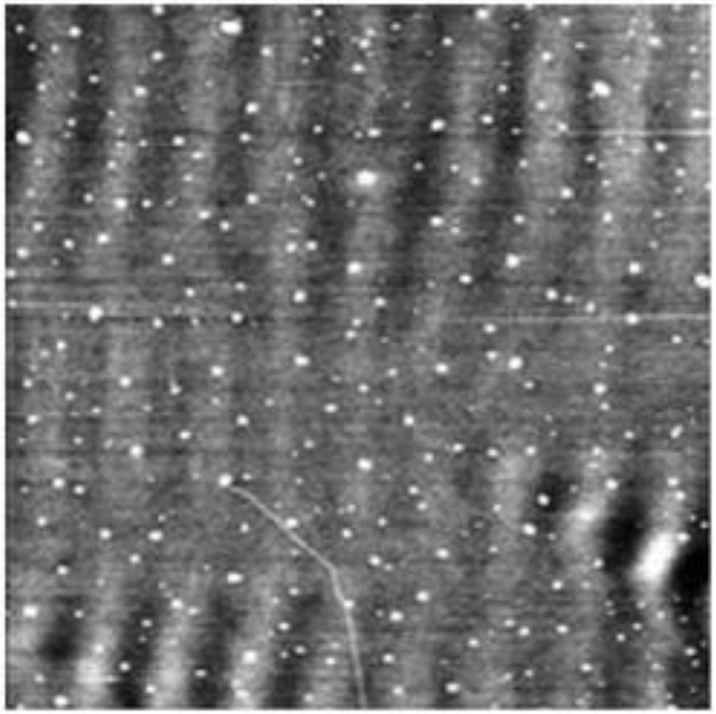
Insufficient tapping force
An excessively fast scan rate
Gain values set too low

Tapping Mode Artifacts: High Frequency Operation



In tapping mode, **decrease the Drive Frequency.**

Optical Interference

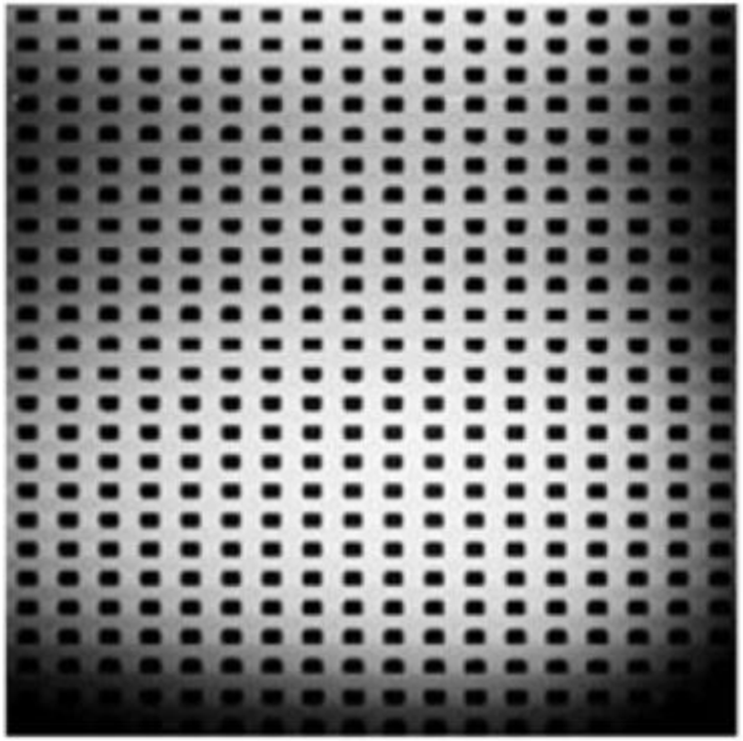


Interference between the incident and reflected light from the sample surface can produce a sinusoidal pattern on the image with a period typically ranging between 1.5 –2.5 μm.

It can usually be reduced or eliminated by adjusting the laser alignment so that more light reflects off the back of the cantilever and less light reflects off the sample surface, or by using a cantilever with a more reflective coating (MESP, TESPA).

Bow

Second order bow:
the arch-shaped bow



Third order bow:
the arch-shaped bow

Technical and Application Support

➢ **Customer Care Center Support**

✓400 Telephone Support: 400-890-5666

✓Team Viewer Remote Control

✓Email Support: support.bns.cn@bruker.com

✓Free Test/Repair service for warranty/service contract customers

✓Free Training service for warranty/service contract customers

✓6 big basic training classes every year (2 in Beijing, 3 in Shanghai, 1 in Guangzhou)

✓6 big advanced training classes every year in Beijing

➢ **Field Support**

✓Free Field Service for warranty/service contract customers

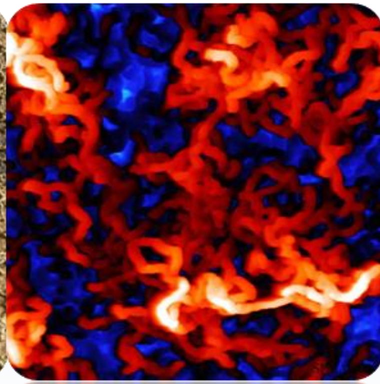
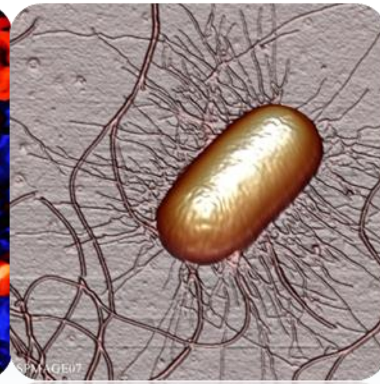
✓Billable Support for out of warranty customers

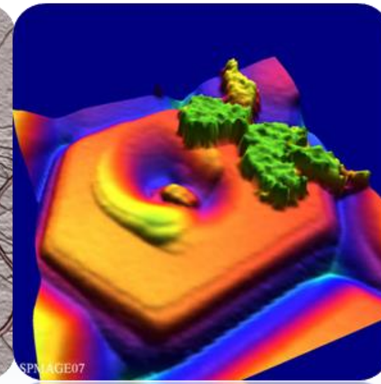
✓Return Visit

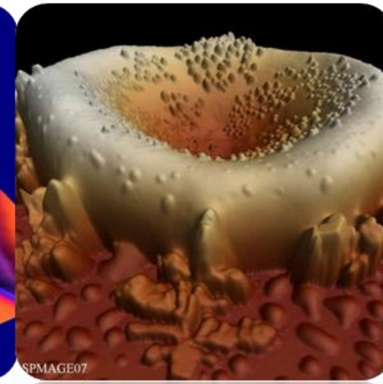
➢ **Web Support**

✓http://nanoscaleworld.bruker-axs.com, http://www.brukersupport.com

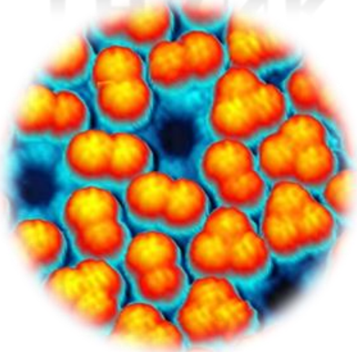
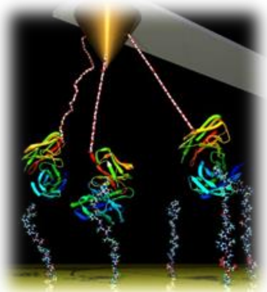
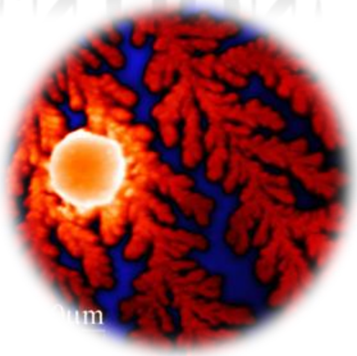
✓Training Webinars





THANK YOU FOR YOUR ATTENTION!

Small Tip Big Science