What is Scanning Probe Microscopy?

Scanning Probe Microscope (SPM) was invented in 1981 by G.Binning and H.Rohrer and in the early 1980's it dazzled the world with the first real-space images of the surface of silicon. Now, SPMs are used in a wide variety of disciplines, including fundamental surface science, routine surface roughness analysis, and spectacular three-dimensional imaging-from atoms of silicon to micron-sized protrusions on the surface of a living cell.

So, scanning probe microscope (SPM) is a device that enables investigation of various surfaces with high resolution from micrometers down to atomic scale.

Three basic SPM techniques are classified by the type of probe used:

- scanning tunneling microscopy (STM),
- scanning force microscopy (SFM),
- scanning near field optical microscopy (SNOM).

Scanning probe microscopes ***Solver P47-SPM-MDT of NT-MDT*** allow the use of various techniques in STM, SFM and SNOM modes. What methods are suitable for the specific sample depends on its properties and features to be resolved

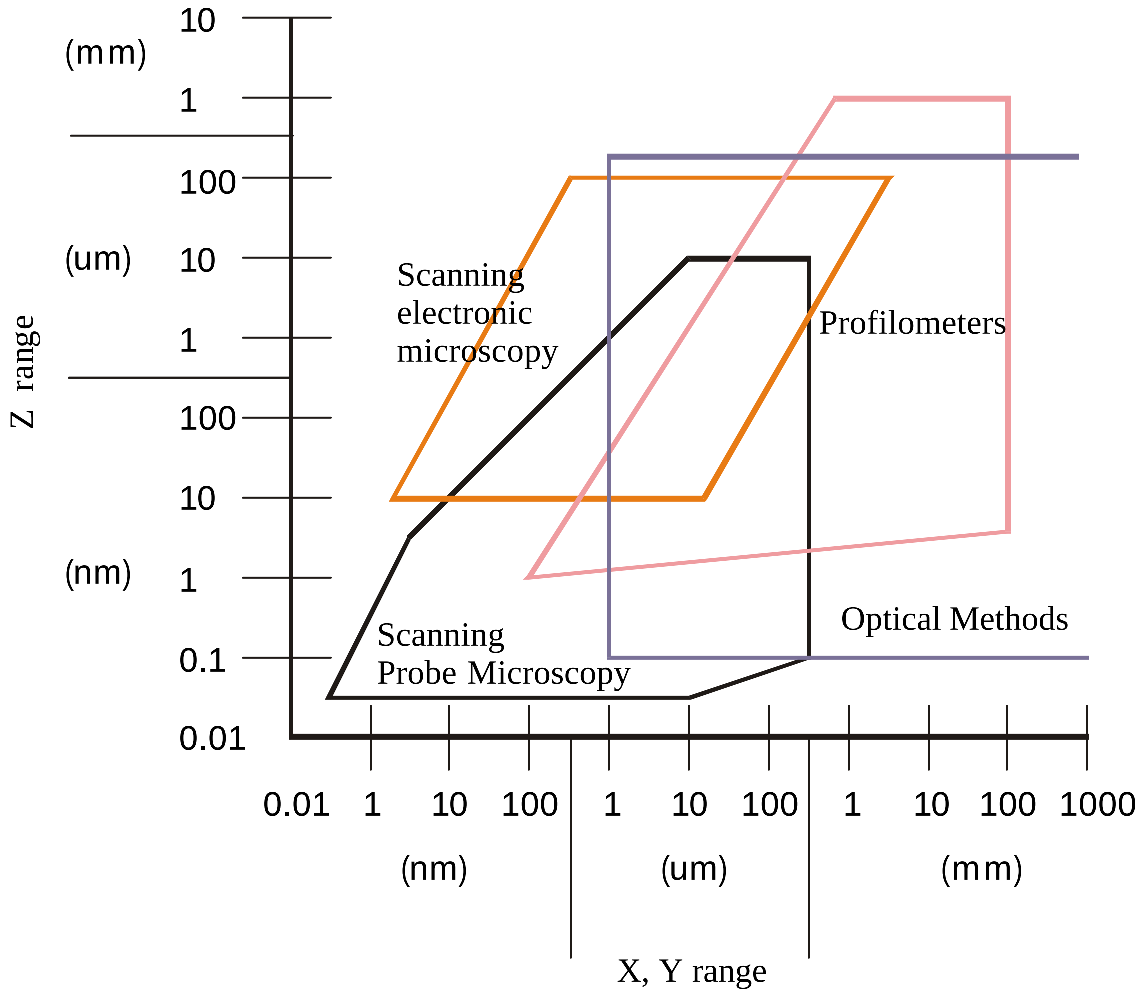
NT-MDT, at present, is an independent company that was established 8 years ago in Zelenograd - the Silicon Valley of the former USSR. NT-MDT is the only producer of Scanning Probe Microscopes world wide that also designs and produces both cantilevers and calibration gratings themselves. Thus having «All-Technology in-house», it enables them to tune all parameters needed to reach the ultimate scan results. Besides all available SPM modes can be incorporated in one single head! Scanning Probe Microscope ***Solver P47-SPM-MDT*** is a reliable and easy to assimilate device that provides a user with a wide range of tools for investigation and modification of various objects on solid surface with micrometer or atomic resolution.

You can look into the short description of our devise ***Solver P47-SPM-MDT*** (Multimode Scanning Probe Microscope), measuring modes available in *Solver P47-SPM-MDT* (SNOM/AFM/LFM/Resonant Mode/Phase Imaging/MFM/EFM/SCM/Adhesion Force Microscopy/Lithography and others), our UltraSharp cantilevers and calibration gratings below. You can also look into our two another Solvers: ***Solver P7LS -SPM -MDT*** and ***Solver P7 UHV -SPM--MDT***.

Characteristics of Common Techniques for Imaging and Measuring Surface Morphology

	Profilometer	Optical Microscope	Confocal Microscope	SEM	AFM
Resolution X, Y	1µm	0.5µm	170 nm	2 nm	(0,1-3) nm
Resolution Z	1 nm	N/A	500 nm	N/A	0,01 nm
Circumstance (sample oreration environment)	air	air, vacuum, liquid	air	vacuum	air, liquid, gas, vacuum
Sample preparation required	little	little	little	hard:freeze drying, coating	none
Sample damage	10^{-6}nN			distroyed sample, caused by spetial preparation of sample surface	10^{-9} nN
Magnification		10^{3}	10^{4}	10^{7}	10^{9}

Common Techniques for Imaging and Measuring Surface Morphology



A generic scanning probe microscope consists of the following components:

- ♦ probe
- ♦ cantilever deflection monitoring system
- ♦ scanning system
- ♦ electronics
- ♦ computer

So, the base elements of SPM are:

Probes (cantilevers)

We (NT-MDT) offer a wide range of silicon cantilevers to you. You can find different types of cantilevers for contact and non-contact SPM modes. We can cover tips by various special hard and conductive coatings according with your requirements.

General Ultrasharp silicon cantilever characteristics

(Products of NT-MDT)

All Ultrasharp silicon cantilevers:

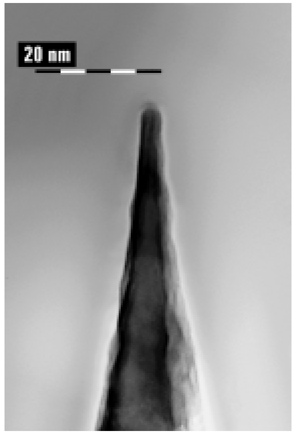
- are compatible with most of SPM devices;
- have standard sizes and thickness (0.45 mm) of cantilever chip;
- have Al high reflectivity coating (reflective property is increased by 2,5 times in comparison with uncoated cantilevers). You can choose cantilever without this coating;

All cantilever series are devided into *two types*: CONTACT and NONCONTACT. The thickness of CONTACT cantilever spring is 1.0 µm and for NONCONTACT cantilever spring is 2.0 µm.

All Ultrasharp silicon cantilever tips have standard characteristics:

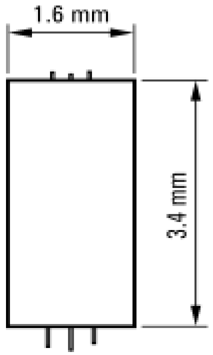
- high aspect ratio conical tips (cone angle is less than 20O);
- curvature radius of tip is less than 10 nm (for uncoated tips);
- tip height 10÷15 µm;
- conductive lever and tip (resistivity less than 0.002 W.cm).

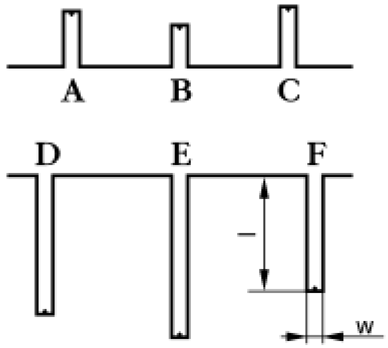
SEM image of Ultrasharp silicon tip



SC12 series of Ultrasharp silicon cantilevers

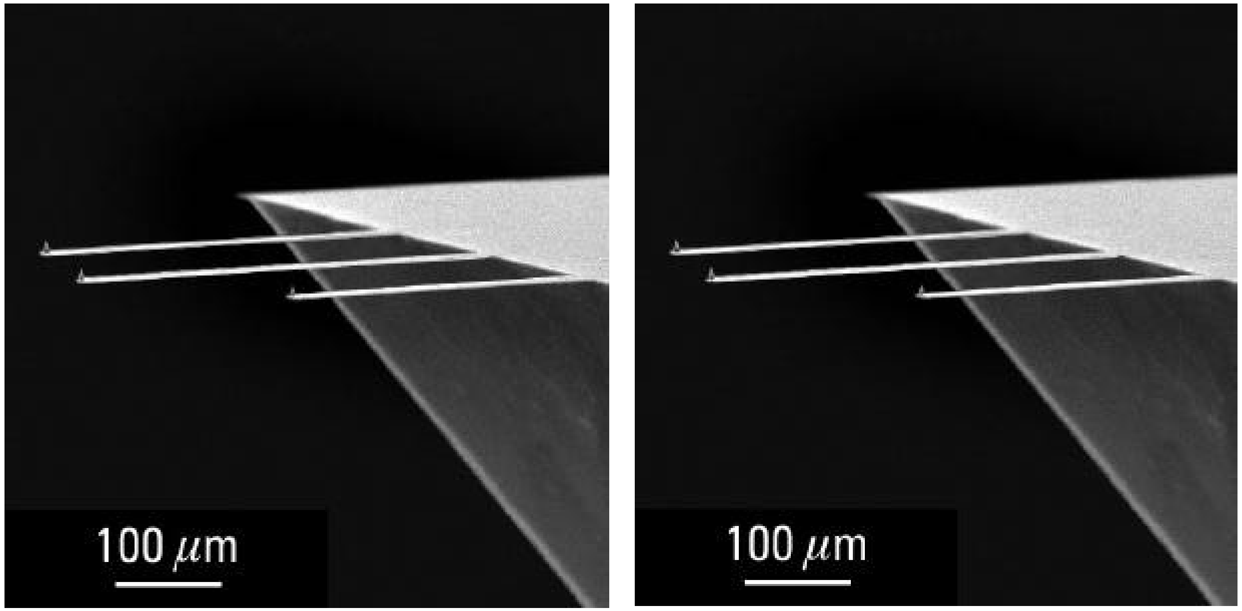
The main feature of SC12 series of Ultrasharp silicon cantilevers is a tip's position on the spring. The tip is located very close to the edge of the spring. It is very convenient for deep trench scanning. SC12 series cantilever chip has six straight springs with different characteristics that allows to choose easily the spring you need.





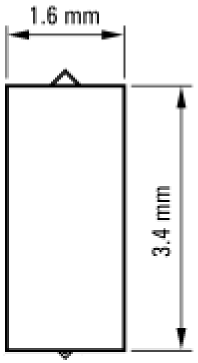
Ultrasharp silicon cantilever chip of SC12 series includes 6 straight springs. Thickness of the chip is 0.45 mm

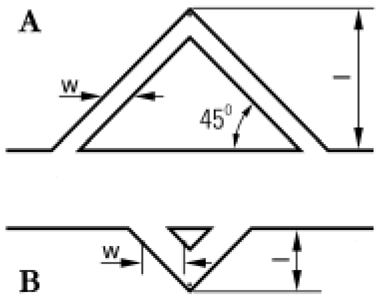
SEM images of Ultrasharp silicon cantilever tip (SC12 series)



SC11 and SC21 series of Ultrasharp silicon cantilevers

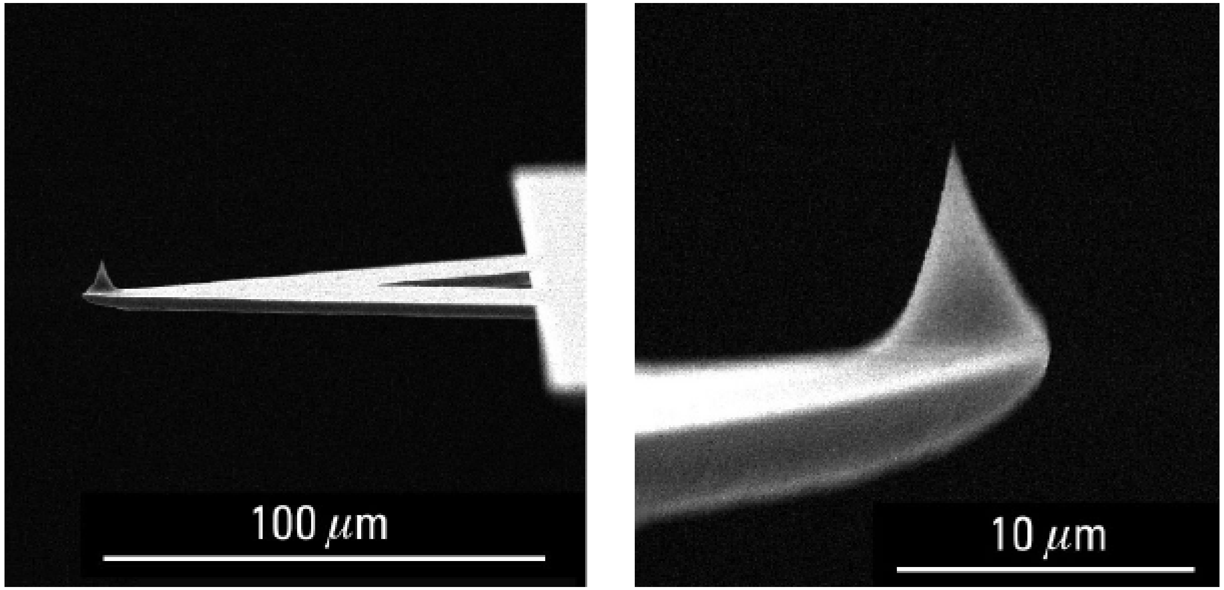
Ultrasharp silicon cantilevers of SC11 and SC21 series have the same design. Each chip includes the big triangular spring and the small one. The main speciality of triangular springs is low sensibility to lateral forces. Ultrasharp silicon cantilevers of SC11 and SC21 series are intended for probing of widest sample range with highest resolution.





Ultrasharp silicon cantilever chip of SC11 series and SC21 series includes 2 triangular springs. Thickness of the chip is 0.45 mm

SEM images of Ultrasharp silicon cantilever tip (SC11 series)



- *Ultrasharp silicon cantilevers with special coatings*

We offer special types of cantilevers with conductive and wear-resistance coatings.

CONDUCTIVE CANTILEVERS

Conductive Ultrasharp silicon cantilevers with hard conductive coatings are intended for:

- STM
- nano-spreading resistance profiling
- electric field mapping
- Kelvin probe microscopy
- Scanning Capacitance Microscopy

Conductive coatings provide:

- high mechanical stability
- good ohmic contact to sample surface
- minimum oxidation of tip surface
- high chemical stability

We offer some different materials for this coating. The conductive coatings of W_2C, TiN, TiO, W, Cr are available for you at the moment. The typical value of conductive coating thickness is about 10÷20 nm. The resistivity is from 5 to 50 µW.cm for different coatings. The curvature radius of tip with such conductive coating is less than 30 nm. We can form any thickness of conductive coating in accordance with your requirements.

In addition we offer special type of CONTACT Ultrasharp silicon cantilevers coated with highly mechanically and chemically stable Si_3N_4 film. The Si_3N_4 film is a high quality dielectric coating formed by CVD process. These cantilevers are more useful for long-term, durable contact measurements. The typical value of Si_3N_4 coating thickness is about 10 nm.

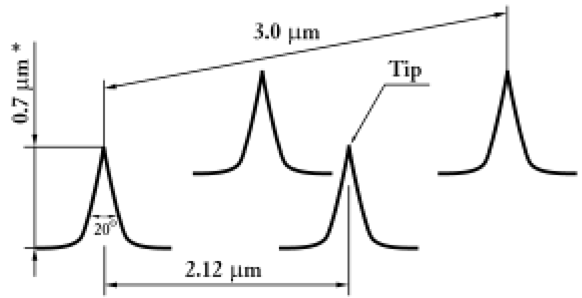
Calibration gratings

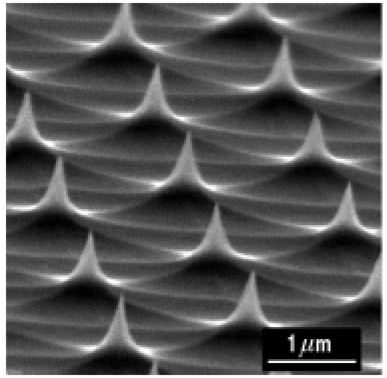
(Products of NT-MDT)

We also offer a different tipes of calibration gratings to you. All of our gratings passed metrological certification at Gosstandart.

Silicon grating TGT01

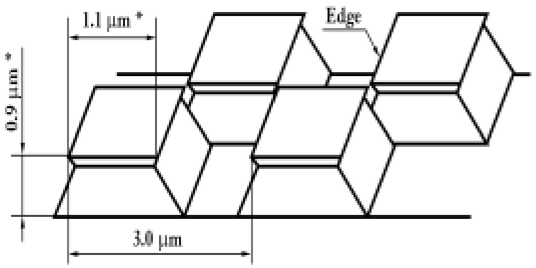
Silicon calibration gratings of TGT series are characterised by strict symmetry of tip sides, small cone angle (less than 20 degrees), small curvature radius of tips (less than 10 nm) over the whole sample area. They are intended to get 3-D image of the cantilever tip for detection of cantilever tip angle and its curvature radius.

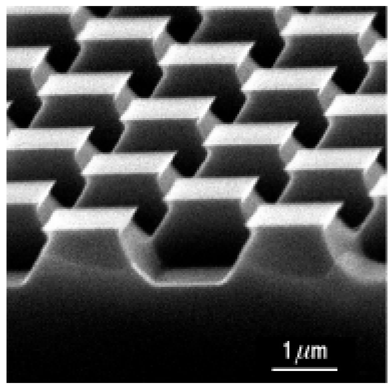




Silicon grating TGX01

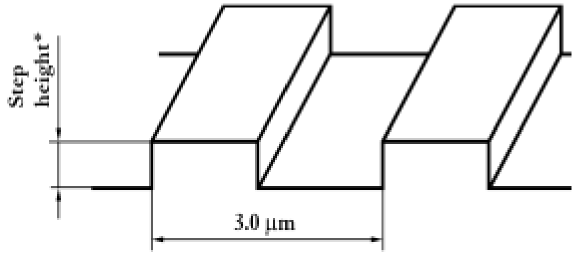
Silicon calibration gratings of TGX series provide 3 µm pitch pillars with good linear edges, formed by <110> silicon crystallographic directions. The accuracy of pitch is 5 nm. Radius of curvature of a pillar edges is less than 5 nm. These gratings are applied as test structures for lateral calibration of SPM scanners, assessment of lateral nonlinearity, hysteresys and piezoceramics creep-effect.

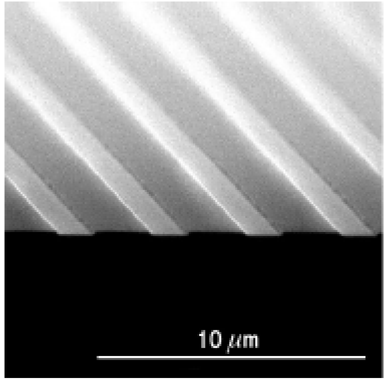




Silicon gratings TGZ

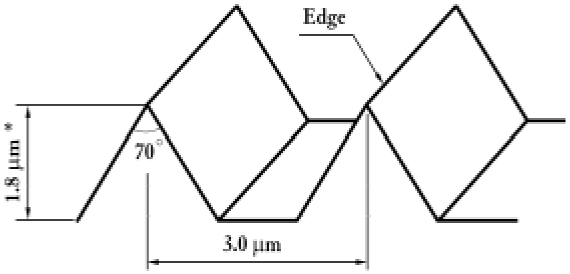
Silicon calibration gratings of TGZ series provide the calibration value of the step height on the whole sample area. The accuracy of step height for heights up to 30 nm is 1.0 nm, for step heights more than 30 nm - 1.5 nm. It is intended for Z-axis calibration and nonlinearity measurements.

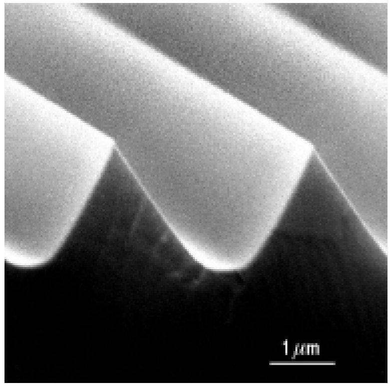




Silicon grating TGG01

Silicon calibration gratings of TGG series provide exact linear and angular stripe sizes, formed by (111) silicon crystallographic planes. It characterises small curvature radius of edge at top of sides (less than 10 nm) on the whole sample area. The accuracy of pitch is 5 nm. These gratings are applied as test structures for lateral calibration of SPM scanners, detection of nonlinearity of the scanner in lateral and normal directions; assessment of angular distortion, detection of curvature radius of cantilever tip.

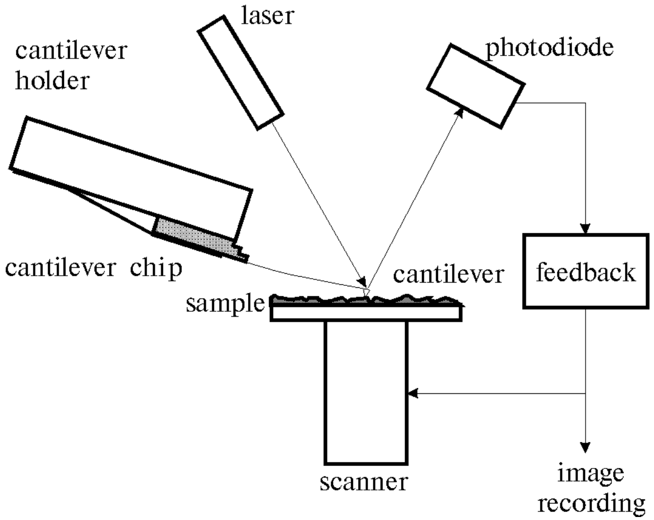




Cantilever deflection monitoring system

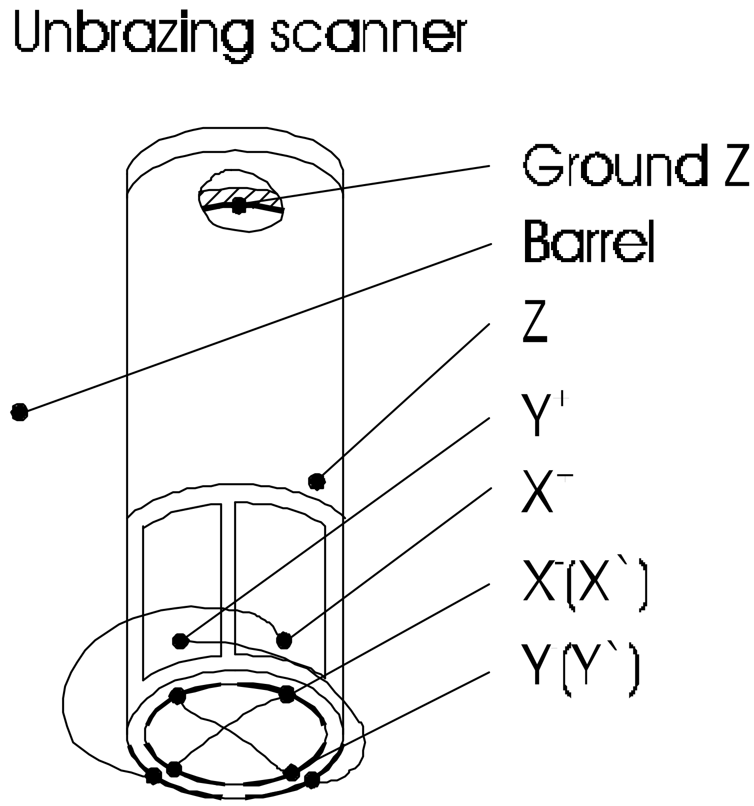
The SFM head uses a beam deflection scheme to monitor the cantilever displacement. This scheme is quite simple and permits registration of both normal deflection of the cantilever with sub-angstrom resolution and its twisting angle, so normal and lateral force can be measured simultaneously.

A semiconductor laser is used as a light source with wavelength 670nm and optical power 0.9mW. A laser beam is focused onto the back surface of cantilever close to tip position, and reflected beam falls onto the quadrant photodiode. Cantilever deflection causes displacement of the reflected beam over sections of the photodiode. An amplified differential signal from the quadrant photodiode permits measurement of angular deviation with the accuracy of less than 0.1″, that corresponds to normal cantilever deflection of the order of 0.05 nm.



Piezoelectric scanner of SPM

The cantilever moves over the sample surface (or the sample under the probe) by means a piezoelectric scanner. It is a piezoelectric material tube with three couple of separated electrodes on the surface. Piezoelectric materials are ceramics that change dimensions in response to an applied voltage. So, a piezotube bends by means applying voltages Ux, Uy and this process causes the cantilever moving over the sample surface (or the sample under the probe) in X, Y axes. By means applying voltage Uz the piezotube shrinks and extends, so the tip-sample distance is changed.



Titanium construction of our scanner allows to start measurements immediately after power-on due to negligible thermal drift. Moreover low weight and low thermal extension coefficient together with good corrosion properties makes titanium very good material for use it in SPM.

SPM applications

Powders: Carbon Black, Copier Toner, Clays; Air Pollution Particles, Fly Ash; FiIters: Nucleopore, Millipore; Asbestos, Collagen, Lithium Niobate Chromatography Column Packing; Latex Spheres; Biological Materials, Chromosomes, Antigen/Antibody Testing, DNA, Liposomes, Virus, Fish Cells and Parts; Liquid Crystals; Buckyballs, Ferrofluid; Conductive Polymers: Beads. Rolled, Crazed; Membranes, Pores, Polymer, Glass, Metal, Corrosion Metals, Electrochemical Reactions; Electrode Surfaces, Polymers, Battery; Hair; Contact Lenses; Paper; Bearings; Polished Surfaces; Optics; Thin Films and Coatings, CVD Diamonds, Ozide Films, AISiCu, Gold; Optical Materials, Laser Windows, Magnetic Domains, Mirrors; Semiconductors, Silicon Wafers, Unprocessed, Processed, Resists, Photo Resists; Masks; Lithography Traces, Test Patterns; Devices; Ion Milling; Ion Implanting; Etch Pits; Laser Pits, Grains, Metal. Aluminum, Copper, Steel, Superalloys, Splat Cooled Metals, Amorphous Metals; Atomic Steps, Gold, Metals, Diamond, Minerals, Cement Powder; Crystal Structure, Calcite, Mica, Quartz, Graphite, Minerals in General; Recording Media Disk Drive Heads, Disks, Magnetic Tape, CD's, Optical Disks, Magnetic Optical Disks, Read-Write Heads; Body Parts, Prosthetic Joints, Bones, Heart Valves, Teeth, Artificial Veins/Arteries; Electron/Ion Beam Created Features; Ion Exchange Resins; Tubing; Adhesion; Bio Sensors.

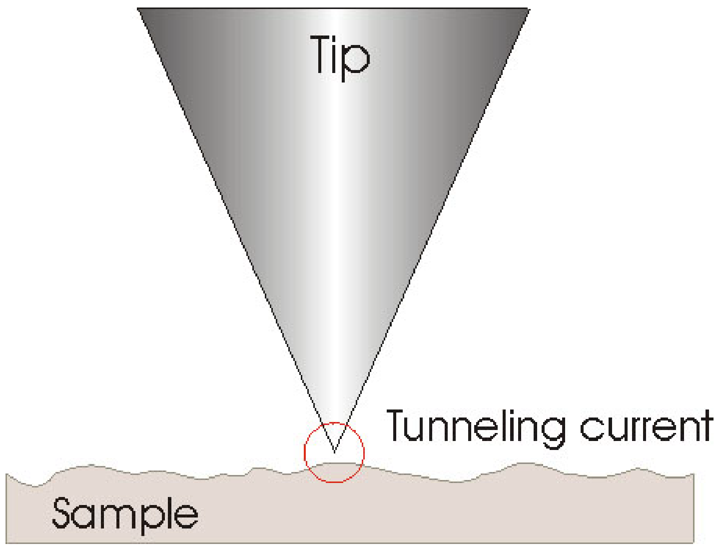
List of SPM modes:

- **Scanning Tunnelling Microscopy**
  - **STM Imaging**
  - **ST Spectroscopy (modulation technique)**
  - **STM Lithography**
- **Contact mode**
  - **Topography**
  - **Force Imaging**
  - **Force Curve Imaging**
  - **Lateral Force Microscopy (LFM)**
  - **Adhesion Force Microscopy**
  - **Spreading Resistance Imaging**
- **SPM in liquid environment**
  - **Liquid cell**
  - **Electrochemical SPM**
- **Nano Lithography**
  - **Contact AFM Lithography**
  - **Resonant Mode Lithography**
  - **STM Electrical Lithography**
  - **AFM Electrical Lithography**
- **Force modulation technique**
  - **Local Viscoelasticity Imaging**
- **Resonant Mode**
  - **Topography**
    - **Semicontact Mode**
    - **Non-contact mode**
  - **Phase Imaging**
  - **Two-pass technique**
    - **Magnetic Force Microscope (MFM)**
    - **Electrostatic Force Microscope (EFM)**
  - **Scanning Capacitance Microscope (SCM)**
  - **Scanning Kelvin Microscope (SKM)**
- **SNOM**
- **Heating performance with temperature control of the sample**

Scanning Tunneling Microscopy

In STM bias voltage is applied between a sharp conductive tip and a conductive sample, so when the sample is approached to a few angstroms from the tip, tunneling current occurs, that indicates proximity of the tip to the sample with very high accuracy. STM gives true atomic resolution on some samples even at ambient conditions.

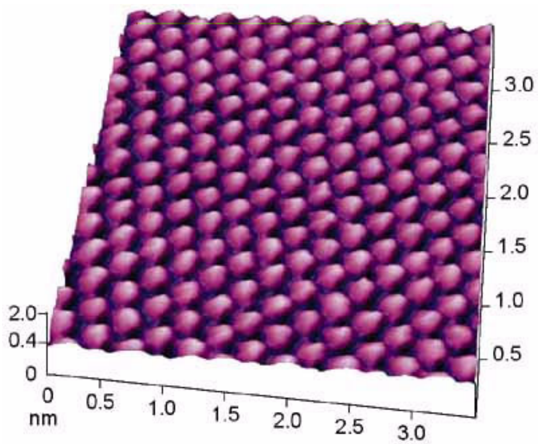
Scanning tunneling microscopy can be applied to study conductive surfaces or thin nonconductive films and small objects deposited on conductive substrates. Some commonly used substrates are highly oriented pyrolytic graphite (HOPG), gold or platinum layers on mica, on quartz, on polished silicon.



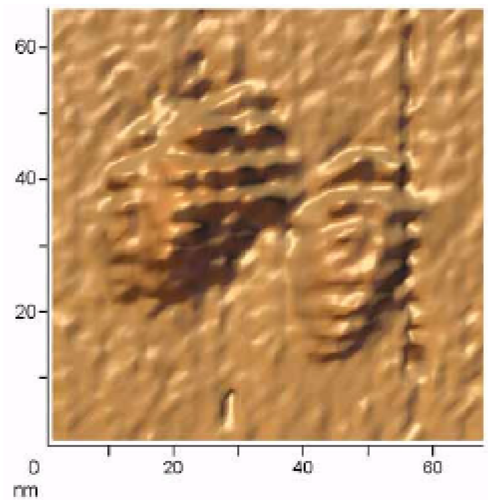
STM Imaging

1. *STM Topography* (I=const)
The most usual mode for STM imaging. Measures topography of surfase electronic states using the tunneling current which is dependent on the separation between the probe tip and a conductive sample surface.

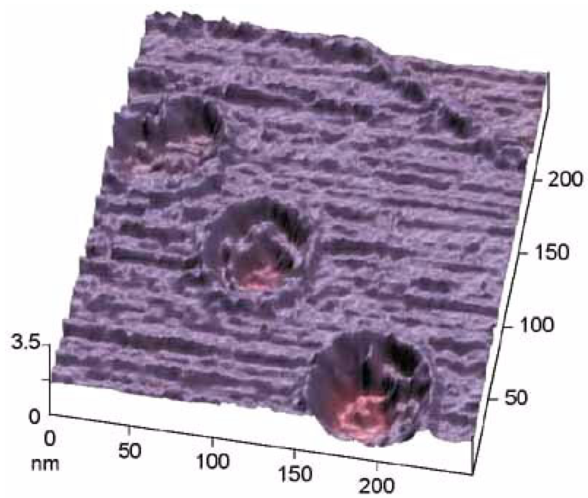
2. *STM Current Imaging* (Z=const)
Can be used for scanning relatively flat surfaces, since it can be done more fast and precise without any feedback control.



STM image of Highly Oriented Pyrolitic Graphite (HOPG) surface



STM image of Parvo Virus on HOPG



STM image of conducting LB film after local exposure to three electric pulses. (LB film was formed by MDT-LB5)

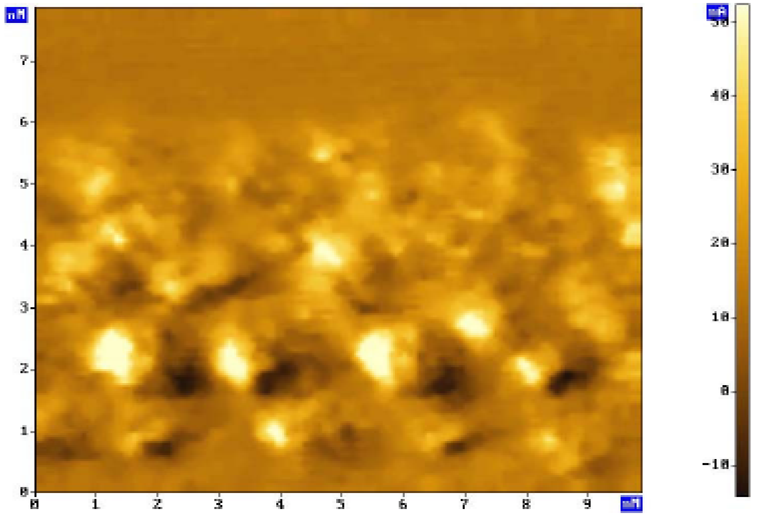
ST Spectroscopy (modulation techniques):

1. *Local Barrier Height Imaging (dI/dZ)*

A sample (or tip) vibration lead to tunneling current oscillations to receive a signal dI/dZ (by means of modulating of tunnelling gap and registering the amplitude of current response). This provides information on local height of potential barrier for electrons (local work function). This mode enables to distinguish parts of surface of different chemical nature to detect presence of adsorbed layers and so on.

2. *Imaging of Local Spectral Density (dI/dU)*

Bias voltage modulation allows to register the signal dI/dU, determined by local spectral density of states of tunneling electrons.



STS image of fullerene C60 in surfactait matrix on the surface of graphite

STM Lithography

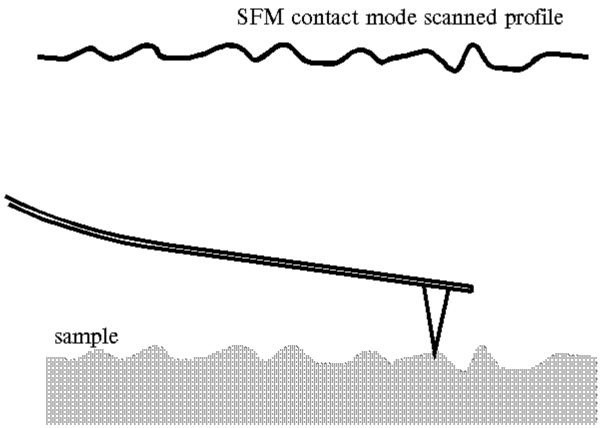
Using this mode you can modify the sample surface by applying the electric pulse. Above you could see the effect of STM Electrical Lithography on the LB film surface (Right picture : STM image of conducting LB film after local exposure to three electric pulses(LB film was formed by MDT-LB5))

Contact mode SPM

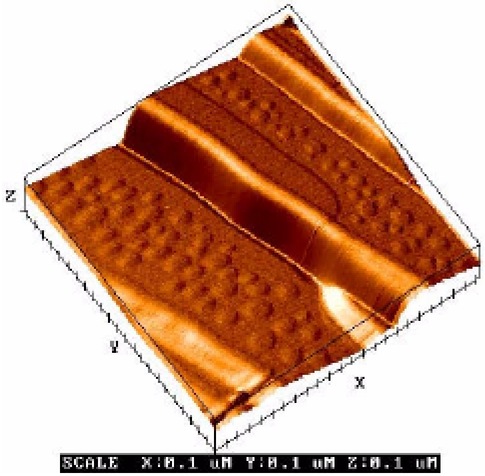
- **Topography**
- **Force Imaging**
- **Force Curve Imaging**
- **Lateral Force Microscopy**
- **Adhesion Force Microscopy**
- **Spreading Resistance Imaging**

Contact mode

In this mode cantilevers touches the surface while scanning in repulsive mode (like a needle of gramophone).



Imaging of polar plane of threeglizinsulfate (TGS) crystal split obtained in Contact Mode of AFM ▸



Topography

The most usual mode for SFM imaging. Measures topography by means of the probe tip sliding across the sample surface. (F=const)

Force Imaging

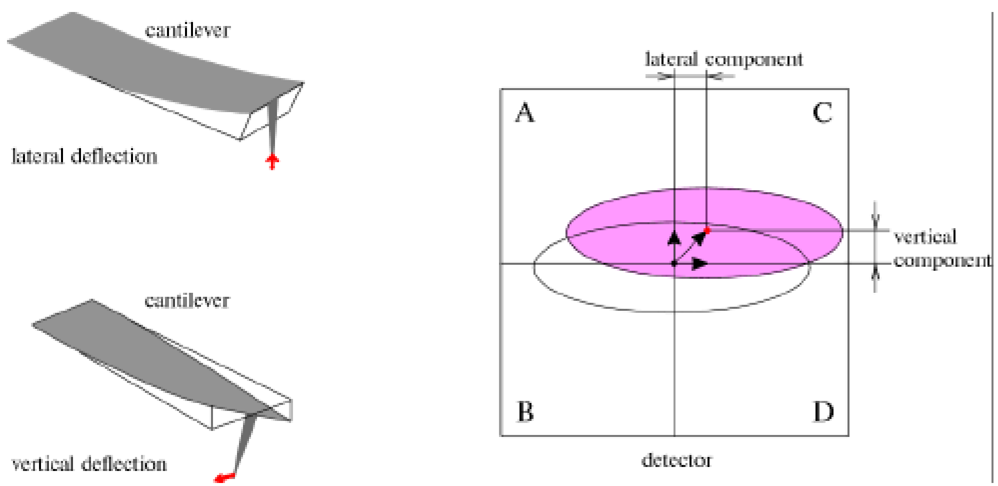
Can be used for scanning relatively flat surfaces, since it can be done more fast and precise without any feedback control. (Z=const)

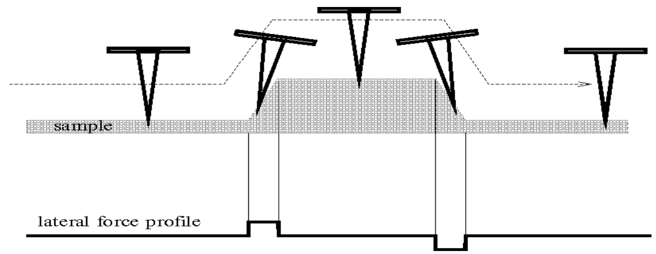
Force Curve Imaging

Force vs. distance curves are used to measure the vertical force that the tip applies to the surface while a contact-AFM image is being taken. It is a duty of measuring F(z). This technique can also be used to analyse surface contaminants, viscosity, lubrication thickness, and local variations in the elastic properties of the surface.

Lateral Force Imaging

Allows to distinguish areas with different friction and also to obtain edge-enhanced images of any surface. This capability may be used in conjunction with topographical images during one scan to characterise your samples more completely. LFM has important uses for semiconductors, polymers, deposited films, data storage devices, investigative studies of surface contamination, chemical speciation and frictional characteristics, and a growing list of new applications.

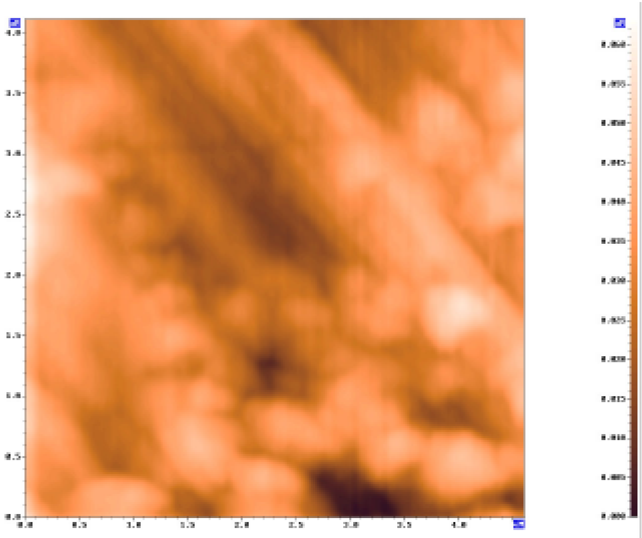




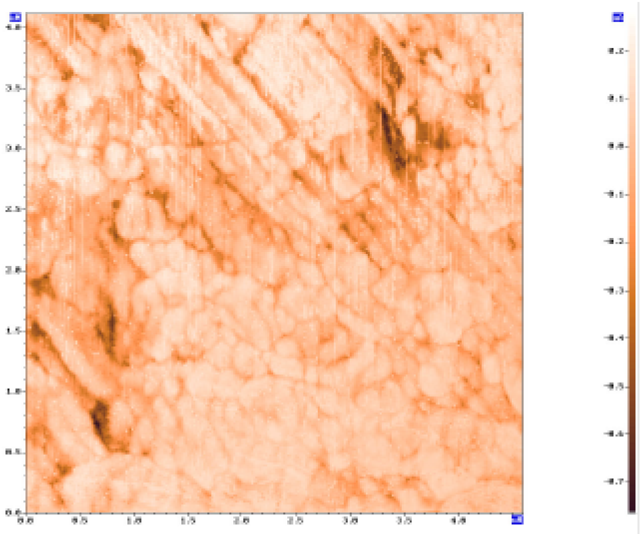
Lateral Force Imaging of Mica ▸

Adhesion Force Microscopy

Adhesion Force Microscopy permits to get an information about adhesion propertiesof the sample. While scanning the Force-Distance Curves are being measured and the Force Value at the moment of jump off (Snap Back) is being imaged. In each point of scan the Force Distance Curves can be imaged in the oscilloscope.



Contact mode AFM
(Mix of epoxy and Al boring)

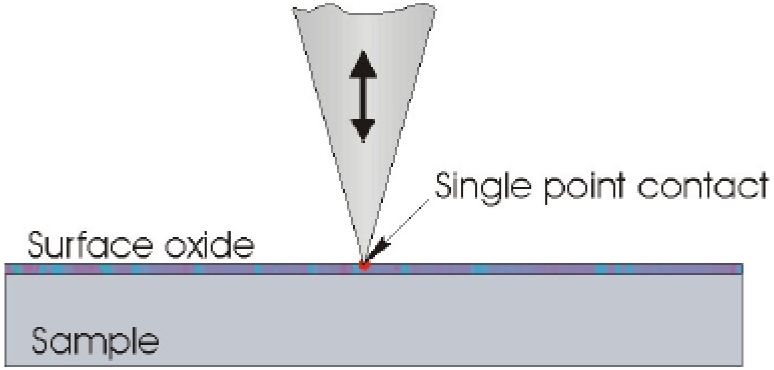


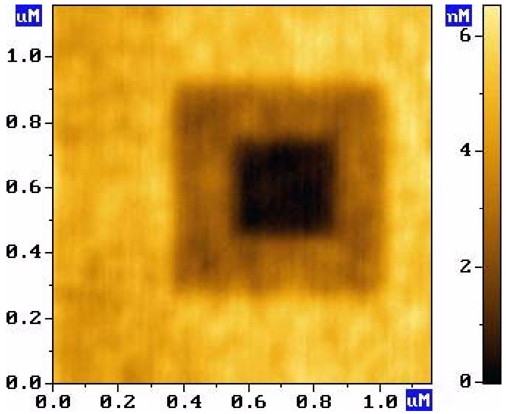
Adhesion Force Imaging
(Mix of epoxy and Al boring)

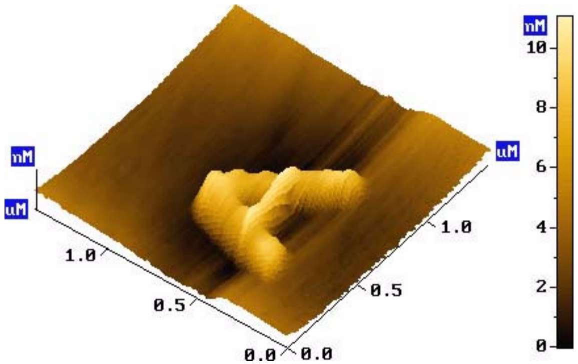
Spreading Resistance Imaging

For obtain SRI a sharp conducting probe is used to contact a low-angle beveled surface to expose the distribution of dopants in a silicon sample. Contact is made with considerable force in order to punch through the native surface oxide.

By using our UltraSharp silicon cantilevers with conductive coating you can simultaneously obtain two images - AFM and STM, or you can measure the local conductivity of your sample. This mode is usually done simultaneously with conventional AFM topographic imaging.



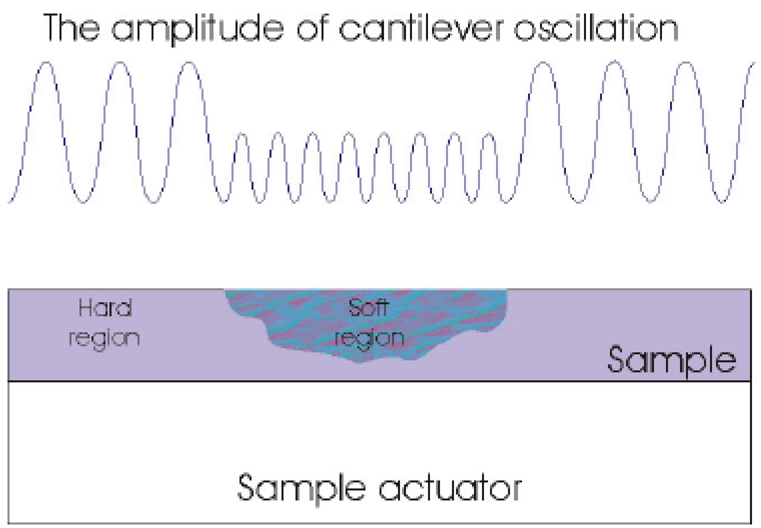




Two Spreading Resistance imaging of film tungsten coated of SiC after applying different lithography.

Force modulation technique

Vibrating piezotube of a scanner which is holding the sample and measuring the amplitude response of cantilever permits identify and maps differences in surface stiffness or elasticity. This mode is usually done simultaneously with conventional AFM topographic imaging. Force modulation technique is particularly useful for detecting soft and stiff areas on substrates which exhibit overall uniform topography. It has important applications where surface features must be differentiated, and in investigative studies of relative surface elasticity. It has numerous users in polymers, semiconductors, composite materials and other applications.



Resonant Mode

- Topography
  - Semicontact Mode
  - Non-contact Mode
- Phase Imaging
- Two-Pass Technique
  - Magnetic Force Microscopy (MFM)
  - Electrostatic Force Microscopy (EFM)
- Scanning Capacitance Microscopy (SCM)
- Scanning Kelvin Microscopy (SKM)

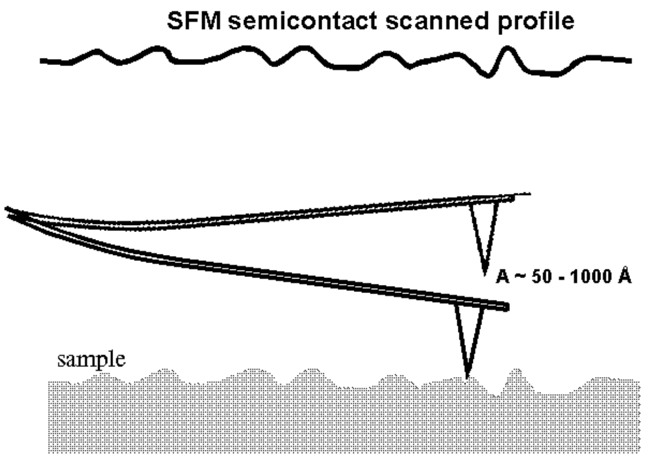
Semicontact Mode

The semicontact mode - is a special modulation technique for non-destructive imaging of soft samples as well as of hard. It measures topography by tapping the surface with an oscillating probe tip.

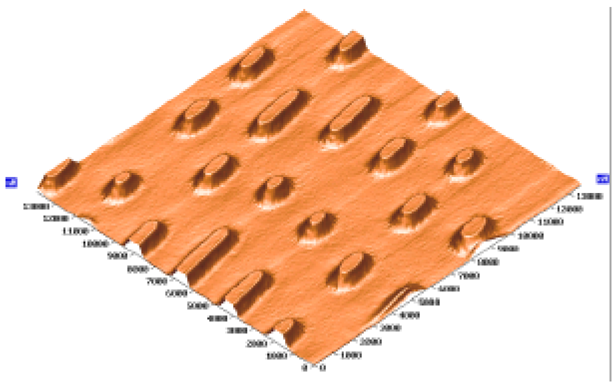
The semicontact mode of the Atomic Force Microscopy can be characterized by some advantages in comparison with contact mode AFM. First of all, in this mode the force of pressure of the cantilever onto the surface is less, that allows to work with softer and easy to damage materials such as polymers and bioorganics. The semicontact mode is also more sensitive to the interaction with the surface that gives a possibility to investigate some characteristics of the surface - distribution of magnetic and electric domains, elasticity and viscosity of the surface.

Topography

Usual SFM objects can be measured in this mode as well as a soft samples.

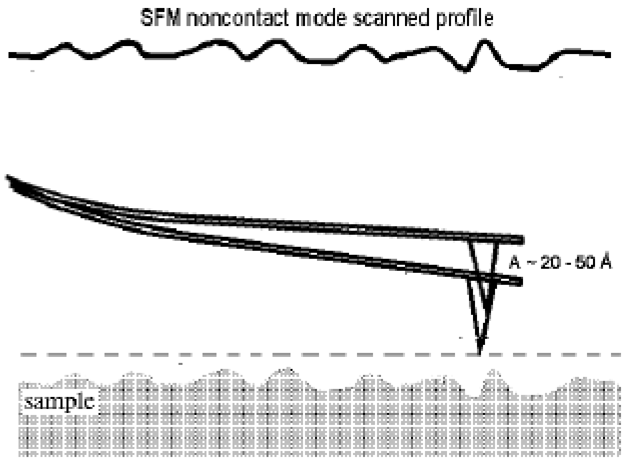


Imaging of CD stamper in Semicontact mode

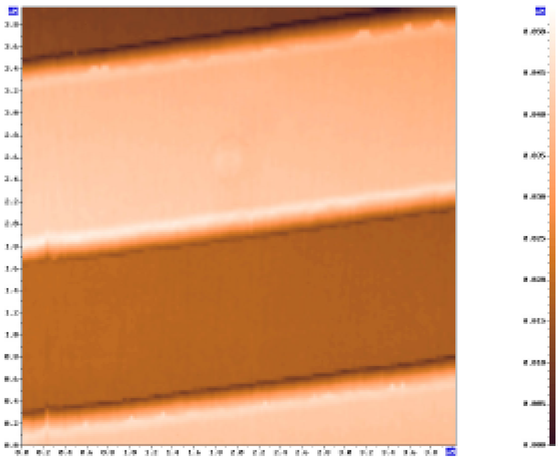


Non-contact mode

In non-contact mode cantilever, vibrating with a small amplitude, experiences an influence of a non-uniform force field near the sample surface. Therefore this method provides measurement of Van der Waals, electrostatic, magnetic forces near the surface. Interaction force can be very small (about 10^{-12} N) that allows investigation of very sensitive objects or those loosely coupled to a substrate surface, without any destruction or displacement.



Silicon Grating TGZ.
Non-contact Mode



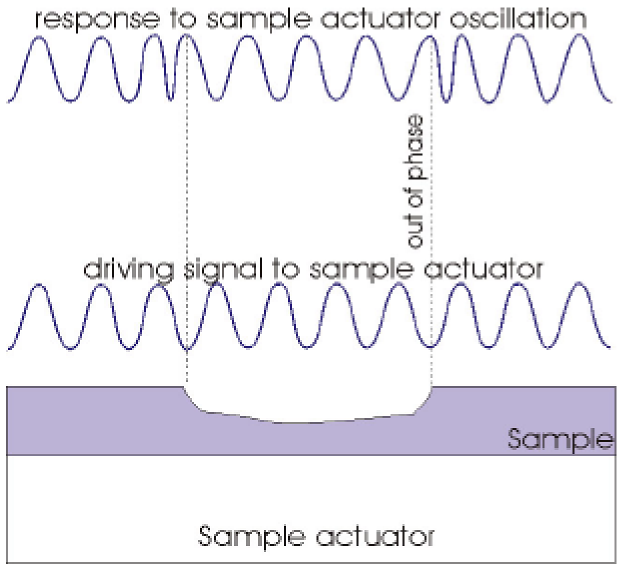
As a non-contact mode we can define two types of measurements:

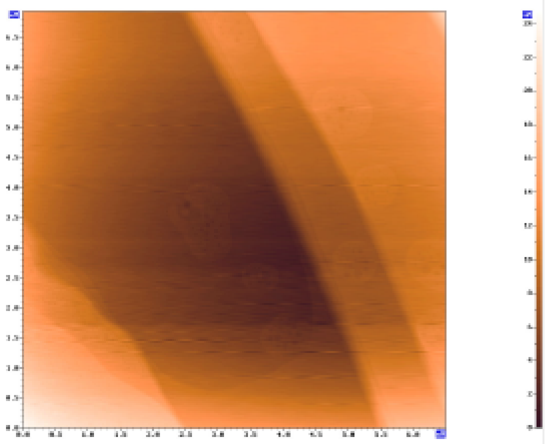
- Measurement of far-field forces (magnetic, electrostatic etc.) on a distance from a surface (the appropriate techniques are described in the section about two-passed techniques.)
- Measurement of topography without contact to a surface is applied for researching of very gentle, easy-destroyed objects.

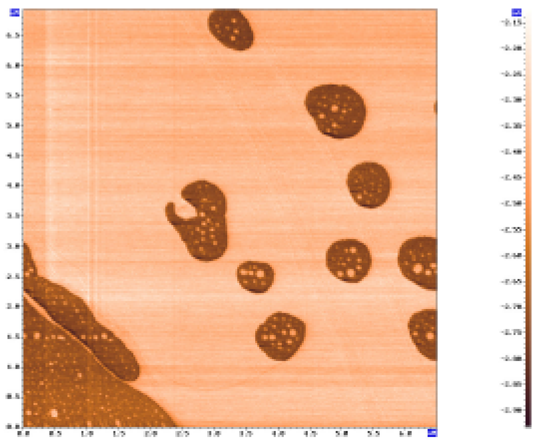
The second mode is applied only in the case when even during scanning in the semicontact mode the sample is exposed to destruction, i.e. this mode is more complicated and less stable than semicontact and resolution received in this mode usually is less than in semicontact.

Phase Imaging

This mode is usually done simultaneously with conventional AFM topographic imaging to map variations in surface properties such as composition, adhesion, friction, viscoelasticity, and perhaps other properties in comparison with surface topography. That is in this mode you can obtain a visual information about variations of surface properties by mapping the phase of the cantilever oscillation during the Semicontact Mode Scan. Phase Imaging gives valuable information for a wide range of applications, in some cases giving contrast where none was anticipated from the material properties. This mode is used, for example, for biological objects, specimens with magnetic and electric properties and for a lot of other samples.







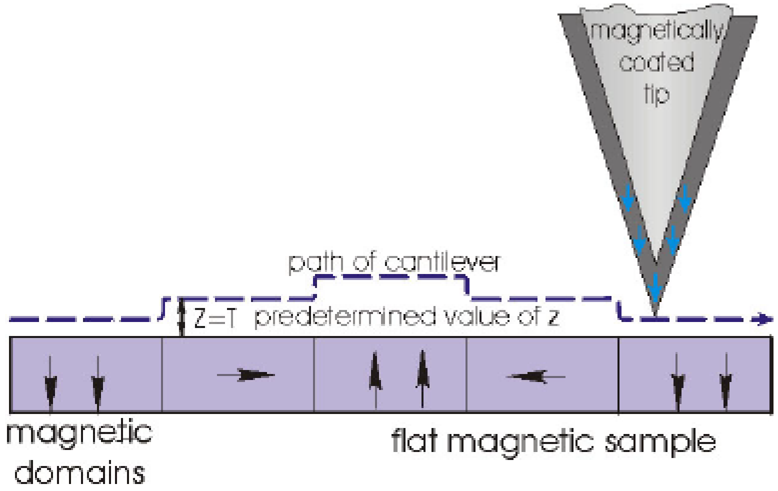
From left to the right:

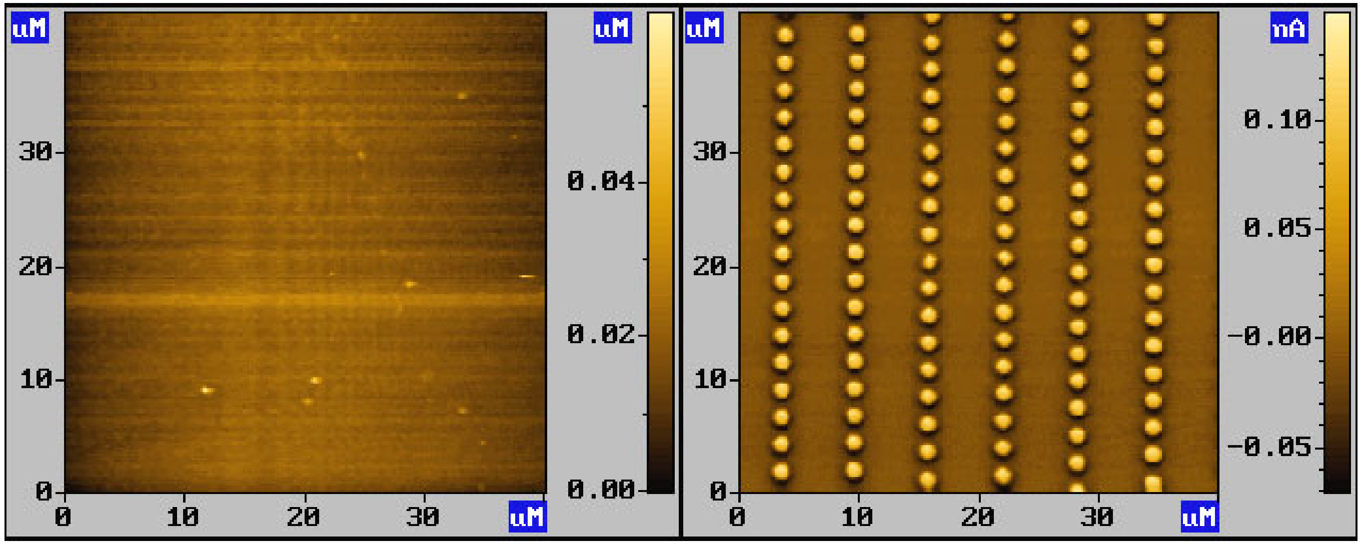
Topography of TGS
Phase imaging of TGS

Magnetic Force Microscopy (MFM)

MFM images the spatial variation of magnetic forces on sample surface. By using cantilevers coated with ferromagnetic film you can simultaneously obtain two images - topography and MFM. That is MFM measures magnetic field intensity and distribution above the sample surface using amplitude, phase or frequency shifts. MFM can image naturally occurring and deliberately written domain structure in magnetic materials.

So, MFM is useful for measuring magnetic information for storage media (disks, tape), magnets, and "soft" magnetic materials such as Permalloy and garnet films.



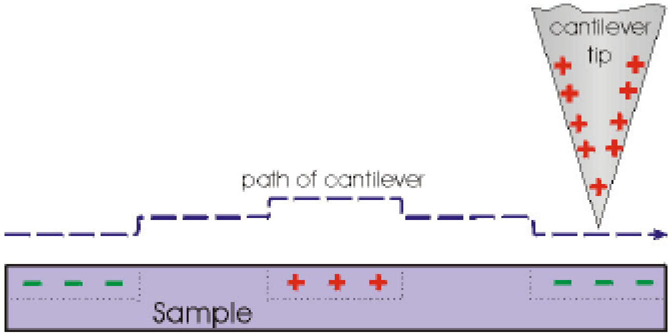


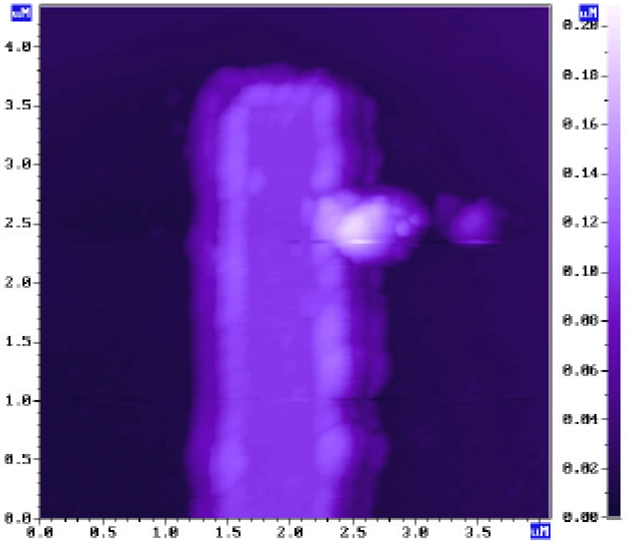
Magneto - Optical disk.

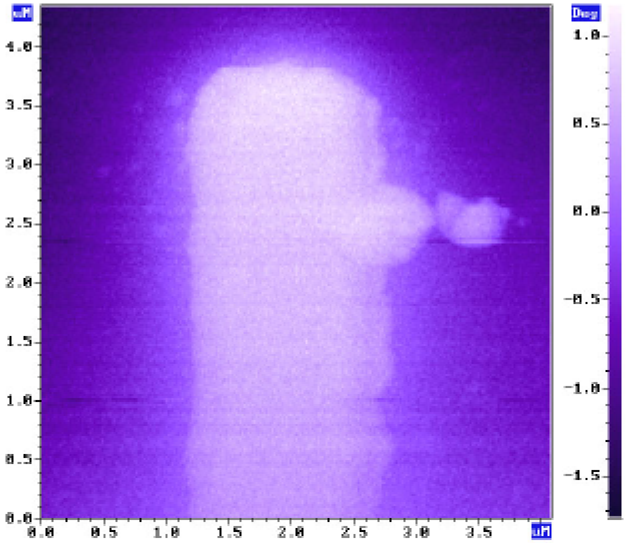
From left to right:
Topography
MFM imaging

Electrostatic Force Microscopy (EFM)

By using our UltraSharp silicon cantilevers with conductive coating you can simultaneously obtain two images - AFM topography and the distribution of electric forces (EFM). In EFM the voltage between the tip and the sample is applied during scanning and the cantilevers hovers at a constant height above the surface eliminating the topography influence. So, the cantilever deflection will be caused just by the electrostatic field. EFM measures electric field gradient and distribution above the sample surface. EFM is used to monitor continuity and electric field patterns on samples such as semiconductor devices and composite conductors, as well as for basic research on electric fields on the microscopic scale.







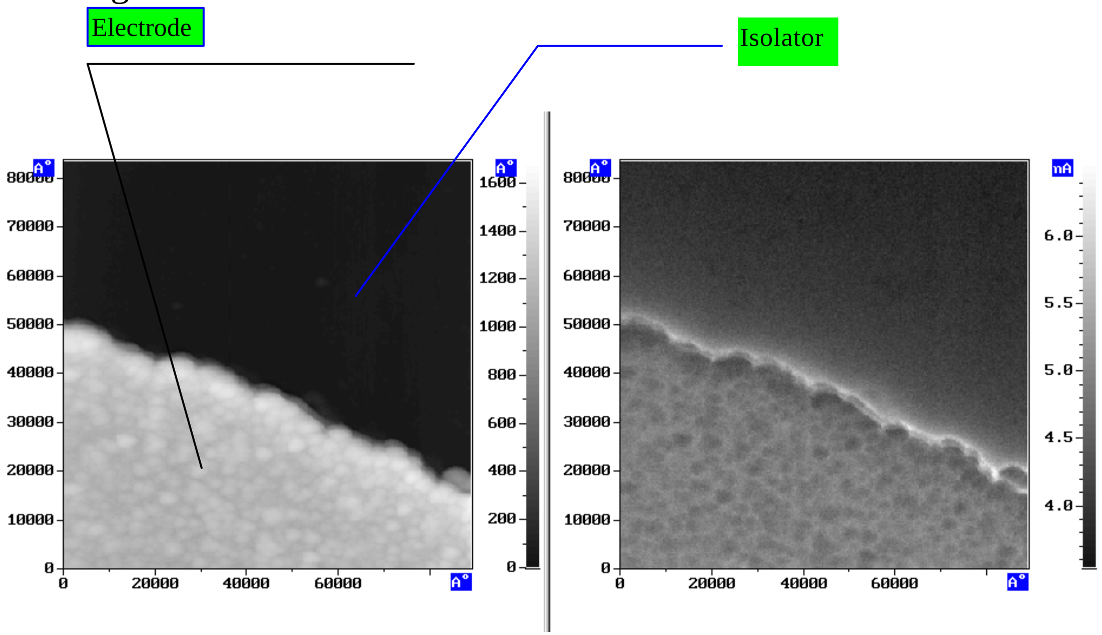
Metallic electrode under the voltage

From left to right:
Topography
EFM imaging

Scanning Capacitance Microscopy

Scanning capacitance microscopy (SCM) images spatial variations in sample capacitance. Like in EFM, the voltage between the tip and the sample is applied during scanning. The cantilever operates in non-contact, constant-height mode. The base of electrical measurement is electrostatic driving of a cantilever. If there is a voltage between the sample and the cantilever and force between them is proportional to $(dC/dz)*U^2$ (C is a capacitance, z is a distance between the surface and the cantilever), consequently there are vibrations on the first and the second harmonics of a driving signal. To measure a capacitance you use the second harmonic.

SCM studies can image variations in the thickness of a dielectric material on a semiconductor substrate. It also used to visualize sub-surface charge- carrier distributions.

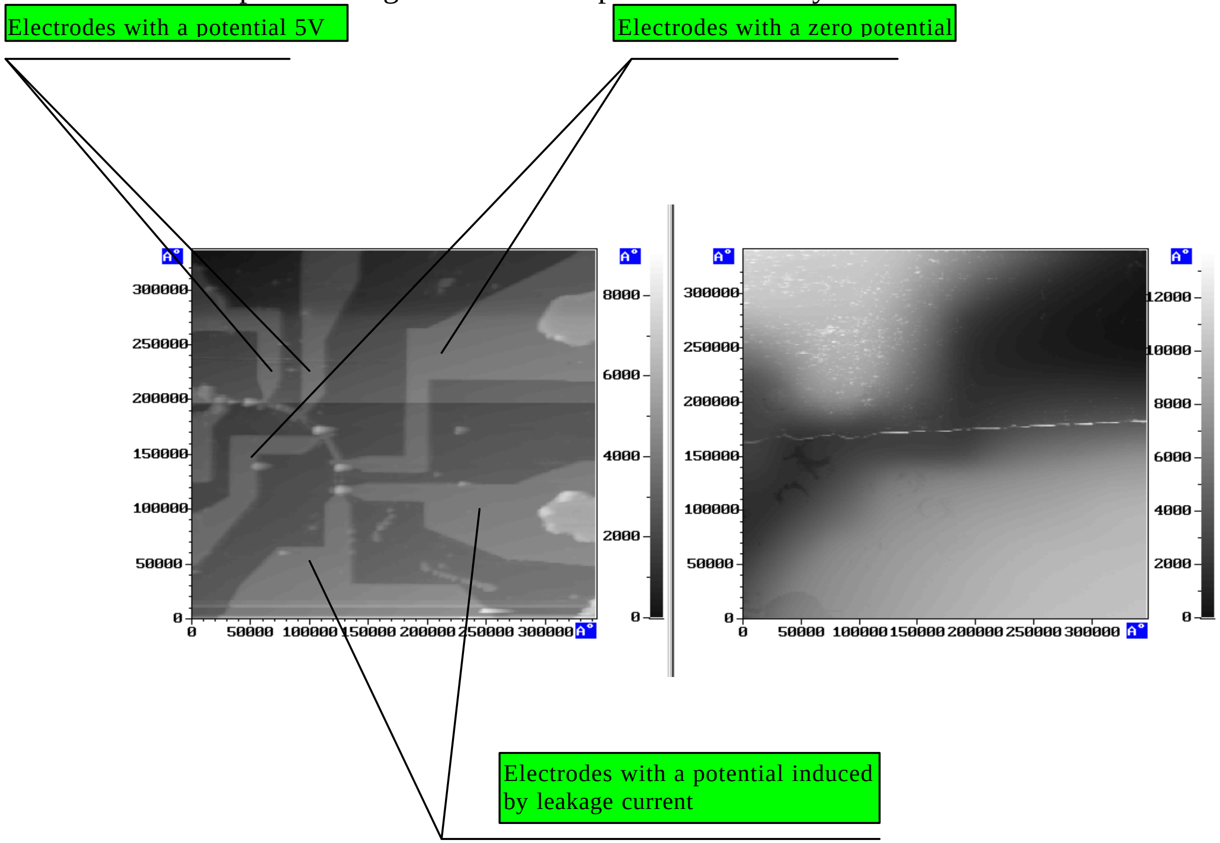


Topography. SCM imaging

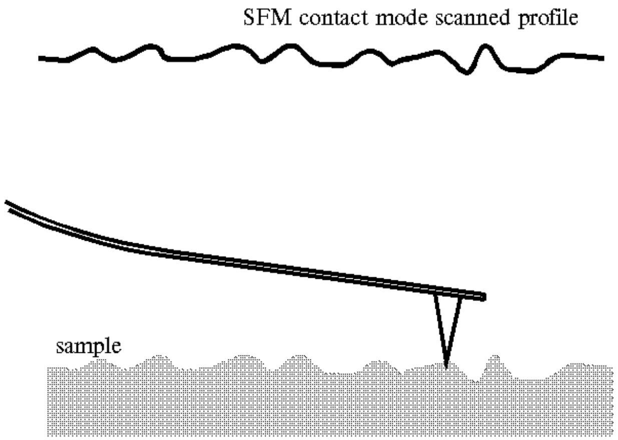
Scanning Kelvin Microscopy (SKM)

SKM is same with SCM. Like SCM, SKM induces a voltage between the sample and the tip, but in this case we can obtain an information about surface potential distribution. It is impossible because to measure a surface potential we use the first harmonic of the signal as a detector (when the voltage between cantilever and sample is equal to zero you don't have the first harmonic of the signal).

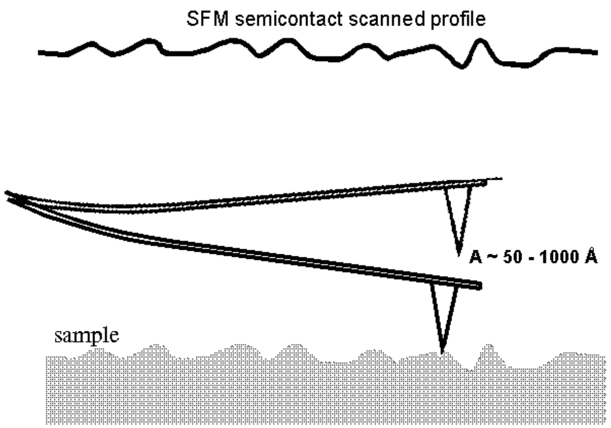
This method can locate and identify the cause of device failure in multilevel, multimaterial device structures. It is possible to use this technique for correlating abnormal device behavior with specific changes in the surface potential caused by surface or sub-surface defects.



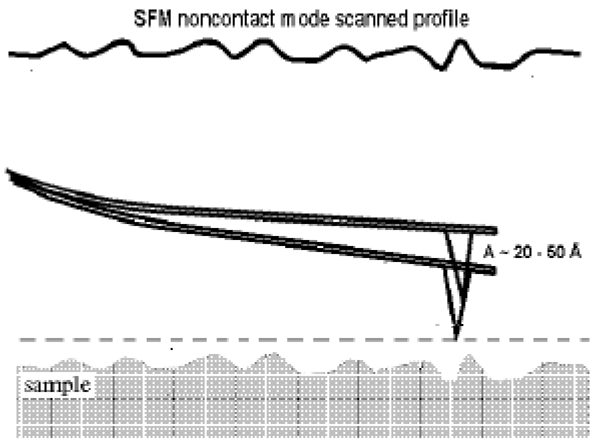
Comparison of AFM Contact, Semicontact and Non-contact SPM Modes.



Contact
Mode AFM



Semicontact
Mode AFM



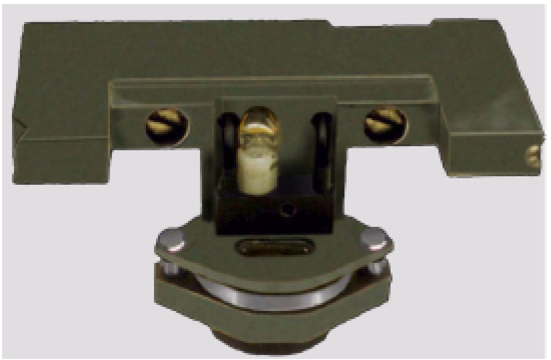
Non-contact
Mode AFM

Liquid cell

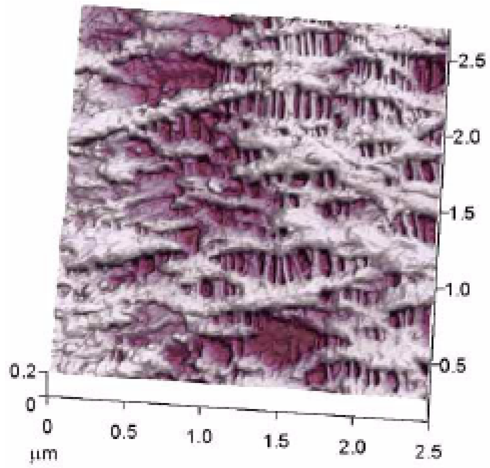
Liquid cell provides possibility to investigate solid-liquid interface in AFM modes. The mode of functioning AFM in the liquid environment is the same with the contact mode AFM on air.

Liquid cell is useful for AFM studies of hydrophilic surfaces to avoid large capillary forces by total dipping the cantilever inside liquid and it becomes indispensable in the case of some objects like living cell which will be damaged in air environment (for example, the surface of eye lens) or simply perishes on air.

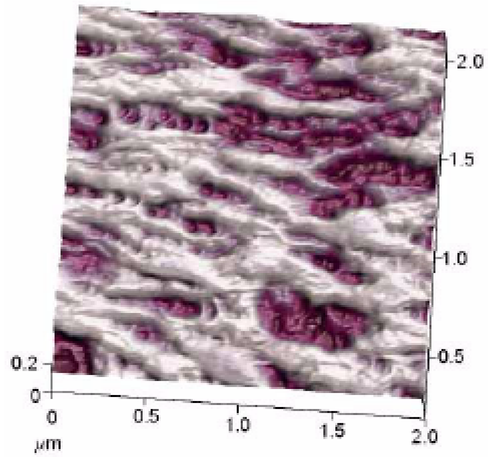
The design of our liquid cell eliminates the usual liquid cell problems due to bubble entrapment and fluid leakage. Our liquid cell has the cylindrical form made from fluoroplastic and titanium. This admit wide range of liquids from water and organic solvents to some acids and alkalis. It is possible to supply the liquid cell with heating and liquid temperature control feature. The diode detector located in 2 mm from the measuring point to guarantee the low temperature gradient and high accuracy of liquid temperature control.



Appearance of a liquid cell



Film of polymer measured in contact mode on air



Film of polymer measured in contact mode in liquid environment

Electrochemical SPM (ECSPM)

Electrochemical SPM measures topographical changes as induced by electrochemical reactions in electrolyte solutions. For functioning of Electrochemical SPM use counter electrode (Pt electrode), reference electrode (AgCl) and working electrode (sample surface).

The main criterion in the study of electrode kinetics is the nature of the electrical value given or in other words imposed to the system (external influence). These values can be voltage or current. The amount of another electrical value, current or potential, which is usually registered as a function of time, is determined by the electrode process (response to external influence). In stationary electrochemical measurements electrical values are closely interrelated and for this reason it is not important which of the electrical values is used as an independent variable.

The electrochemical cell can operate in below modes:

- **Galvanostat**
- **Potentiostat**
- **Bipotentiostat mode (STM mode)**

- **Galvanostat**

When using the electrochemical cell in the galvanostat mode it is possible to record the time- potential relation. In this mode electrolysis take place at direct current.

- **Potentiostat**

In our case a potentiostat is used for measuring stationary polarization curves, for measuring the electrode potential. The strength of current flowing through the system is controlled at the external power source (at the external "Extension" socket).

The operation of the electrochemical cell in the galvanostat/potentiostat mode makes it possible to implement:

1) electrolytic deposition of metal from electrolytic solution at an electrode made of the same metal;
2) electrolytic deposition of metal from electrolytic solution at an electrode made of different metal or electrically conductive material (for example, graphite);
3) anodic oxidation of metals up to ions forming an insoluble compound with solution components resulting in a film-coated electrode covering;
4) anodic oxidation of metals with formation of solvable ions;

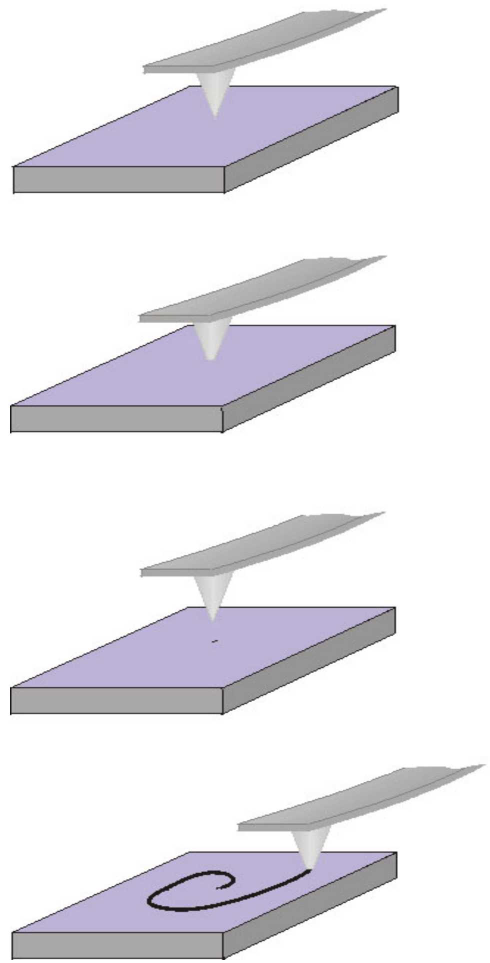
- **Bipotentiostat mode (STM mode)**

The scanning tunneling microscopy mode is designed for studying conductive surfaces in chemically active medium (in electrolyte) or in air with an accuracy up to atomic resolution. For operation in electrochemical medium the tip shall be well electrically insulated. An ideal tip for electrical tests must be coated with a layer of chemically or electrochemically inert insulation. In such a way that only the endpoint remains open.

For this mode usually used PtIr tips coated by the following isolators:

1) Glass
2) Poly-α-methylstyrene
3) Silicon dioxide (SiO_2) (relatively good coating)
4) The so-called “apiezon” mastic (can be a promising insulating coating (material) for tips)
5) Paraffin coated tips (show relatively good results)

Nanolithography



Lithographic operations are designed to change the topography or properties of the surface at scales comparable with the probe dimensions.

Depending upon the microscope operating mode lithography can be done in two different ways: by applying a short voltage pulse or a series of voltage pulses up to 10 V between the probe and the sample when working in the STM mode or with conductive cantilevers in SFM mode; or by "scratching" the surface with the probe when working in the SFM mode. In the SFM mode the surface is subjected to mechanical influence from the cantilever’s probe when non-conductive cantilevers are used.

So, lithography can be implemented by:

1. Mechanical Influence

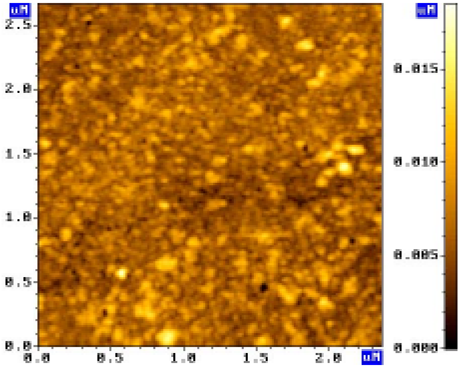
- Contact AFM Lithography. This mode allows to scratch the sample using cantilever tip.
- Resonant Mode Lithography

2. Electric Influence

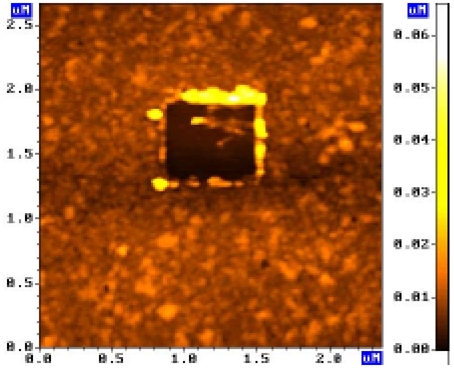
- STM Electric Lithography
- AFM Electric Lithography

Mechanical Influence Lithography

- **Contact AFM Lithography**

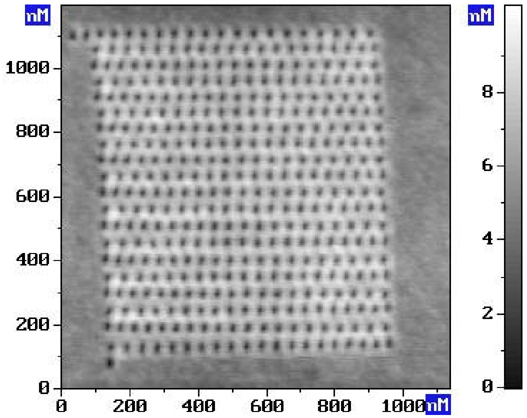


AFM imaging of immunoglubuline on the surface of mica befor Contact AFM Lithography



AFM imaging of immunoglubuline on the surface of mica after applying of Contact AFM Lithography

- **Resonant Mode Lithography**



The polycarbonate film on silicon surface after Resonant Mode Lithography

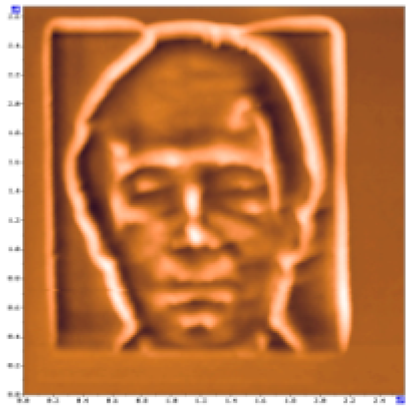
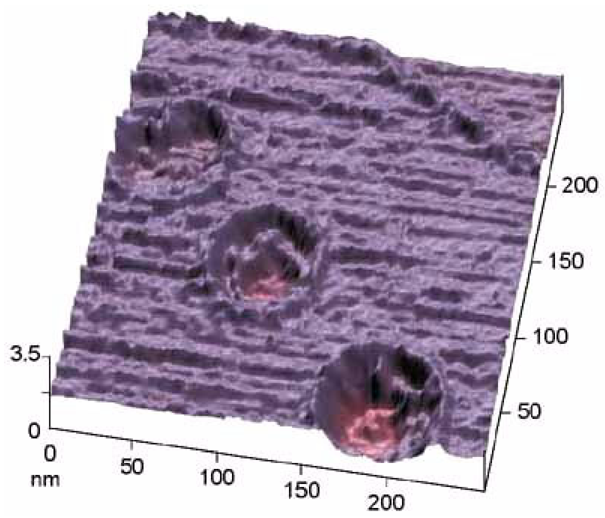


Image of polycarbonate film on silicon surface after Resonant Mode Lithography

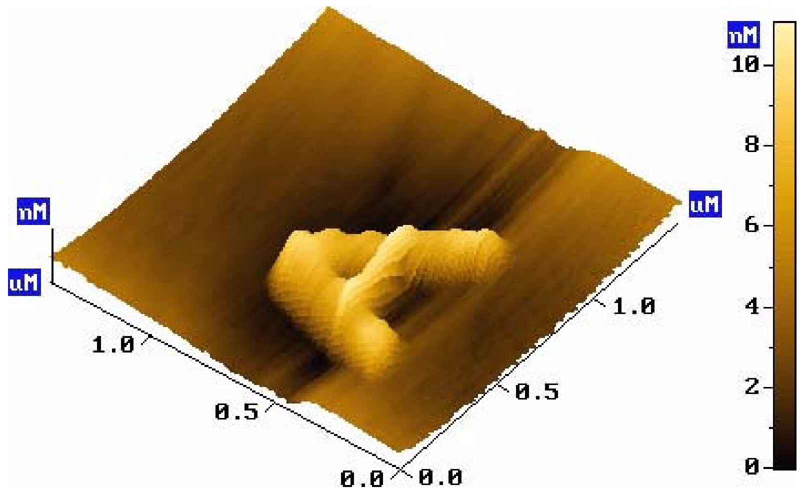
Electrical Influence Lithography

- **STM Electrical Lithography**



The conducting LB film after
STM Electric Lithography

- **AFM Electrical Lithography**



The film tungsten coated of SiC after
AFM Electric Lithography

Scanning Near Field Optical Microscopy (SNOM)

Near-field scanning optical microscopy (SNOM) uses a special type of scanning probe microscope that operates using visible light. Traditionally, the resolution of optical microscopes has been limited by the wavelength of light to about half a micron. SNOM improves the resolution of an optical microscope by an order of magnitude.

In SNOM a specially prepared sharpened optical fiber is set close to the sample and collects light from luminescent objects on the surface or collects an evanescent light wave from the surface of a transparent sample illuminated from inside. Here amplitude of lateral vibrations of the optical fiber is usually used as a proximity gauge and collected light intensity gives information about optical properties of the sample.

So, SNOM consists of:

I. Shear Force Mode - Topography Imaging
II. Optical input/output

The SNOM system can be supplied in two configurations:

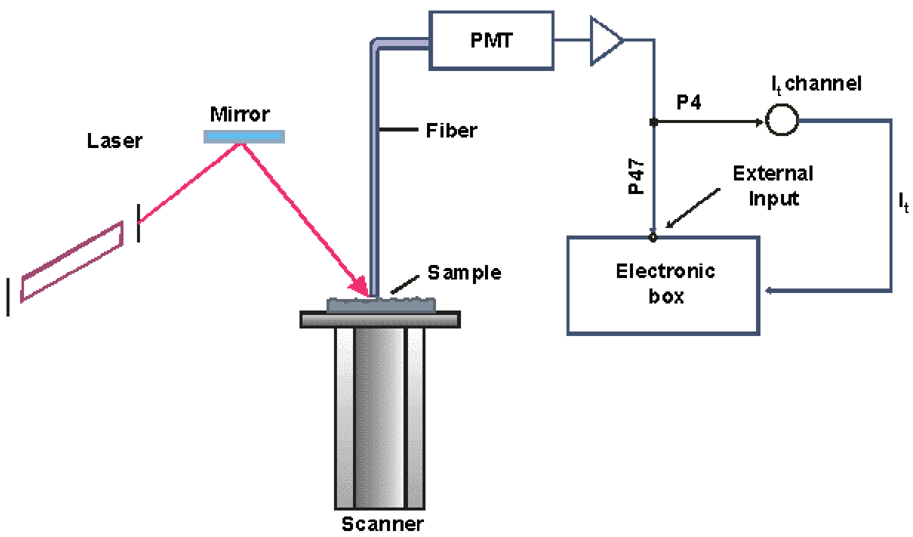
a) scanning by the sample
b) scanning by the optical fiber

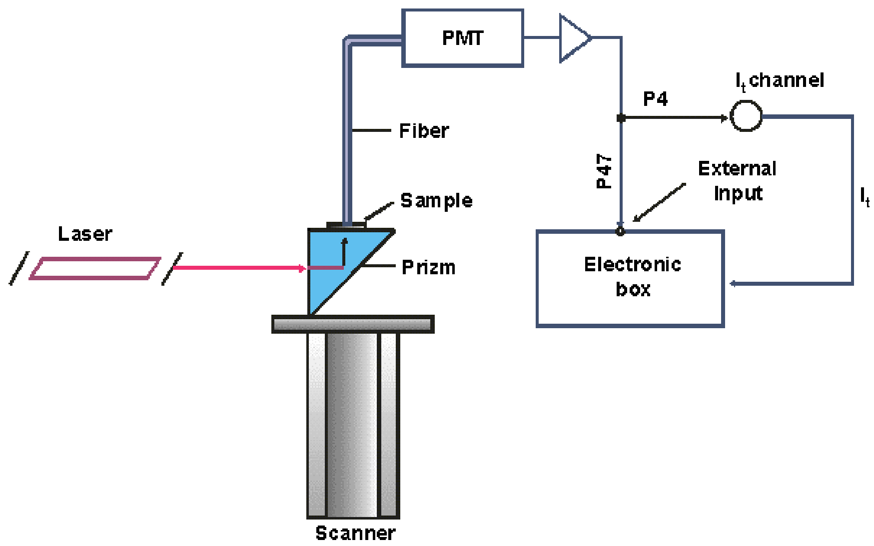
In the scanning by the optical fiber system it is possible to measure the samples up to 70x70x20mm (100x100x20 mm) with the possibility of micro positioning at the area of 5mm (15mm) on the sample surface. The positioning can be done with the resolution of 3um and could be observed through optical system with CCD camera.

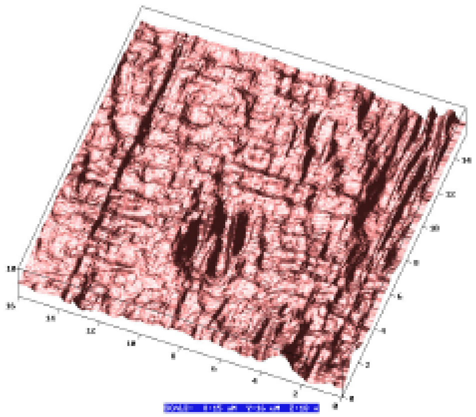
Two registration schemes of Scanning Near-field Optical Microscope

Reflected mode SNOM
SNOM

Transmitted mode







The topography image of polarizer film obtained in Shear `Force mode

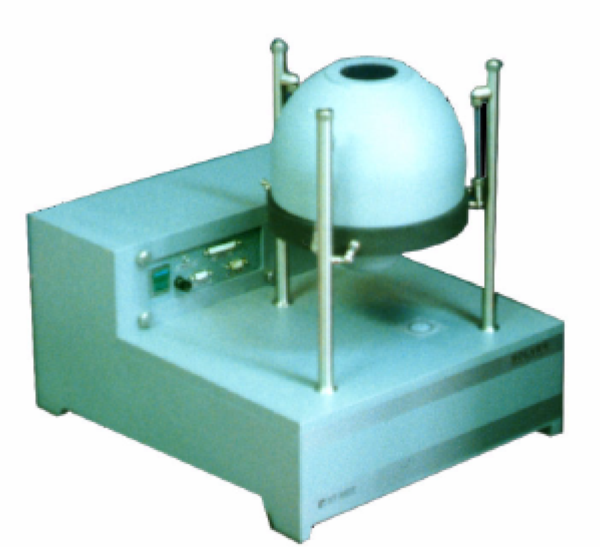
Heating performance with temperature control of the sample

Using our special device, called **"hot bench"** we can heat the sample and effect the temperature control of the sample **up to 130°C** (160°C) with accuracy 0.1°C. This duty is used for research phase transfer in same agents (for example, liquid crystals) or for delete adhesion barrier from the sample surface (for example, for research drying films)

"Hot bench"

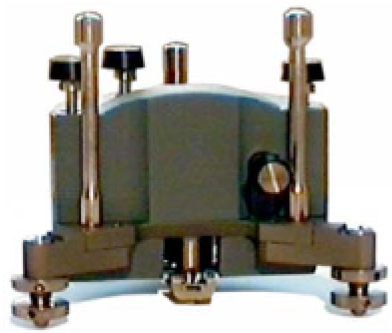
The head for scanning
by the sample

The head for scanning
by the cantilever



Solver P47/P47H-SPM-MDT

Shear Force head
for SNOM



Stand Alone head

Solver P47-SPM/EC-MDT
(Electrochemical SPM)

Highlights of Solver P47-SPM-MDT:

- All in one: STM/STS; Contact AFM/LFM/Spreading resistance Imaging/Adhesion Force Imaging; Force Modulation Techniques; Resonant Mode: Non-contact AFM , Semicontact AFM/MFM/EFM/SCM/SKM/Phase Imaging; AFM Lithography/STM Lithography. The range of measuring techniques is very wide. Most of them are standard low cost configuration.
- The measuring head allows switching between imaging techniques of STM/AFM/LFM/Resonant mode by a click of the mouse in the control program.
- The topography of the same area can be shown simultaneously with LFM, MFM/EFM or STM images for comparison purposes.
- Advanced electronics High-Q: 22 bits X,Y resolution
  Resonant frequency setting with the ultimate accuracy 0.01Hz

For SNOM it is highly important due to highest Q factor, for Resonant Mode Lithography this is very important, and this is the reason why this mode is absent in all systems.

- Antivibration system is not required. Atomic resolution is obtainable within usual laboratory environment, without special anti-vibration tables.
- Residual nonlinearity in horizontal (X, Y) dimension is less then 1%.
- Temperature control of the sample up to 130°C with accuracy 0.1°C
- High precision Adhesion Force Microscopy

We can image exactly the SNAB back point, so measuring not just cross section but the value of force when the snap back happened.

- Resonant Mode Lithography performed by mask.

Using this mode you can download, for example, your photo in control program and print it in micron size visualizing after that in semicontact AFM mode.

- Titanium construction allows to start measurements immediately after power-on due to negligible thermal drift.

Low weight and low thermal extension coefficient together with good corrosion properties makes titanium very good material but very expensive for all producers except Russian. Russia has 90% of World titanium.

- Low weight (90kg) and compact construction fitting on the single table.
- Wide range of voltage operation 100-200V, 50-60Hz allow do not care about voltage stabilisation.
- Low power consumption - 100 W.

Solver P7LS-SPM-MDT

P7LS-SPM-MDT

Main technical specifications:

- ***Measuring modes:*** Contact AFM/LFM/Adhesion Force Microscopy; Force Modulation Technique/Local Viscoelasticity; Resonant Mode: Non-contact Mode, Semicontact Mode/Phase Imaging/ MFM/EFM, Spreading Resistance Imaging or SCM/SKM.
- ***Noise level:*** **<** 1A RMS in vertical (Z).
- ***SPM configuration:***
    - 30x30x1.5μm or up to 100x100x1.5μm scanner.
    - Residual lateral nonlinearity (in XY - direction) less than 1%.
    - Advanced electronics High Q (22 bits XY resolution) allows to set the resonance frequency with an accuracy 0.01 Hz.
- ***Sample size:***
    - Up to 250mm (300mm optional) in diameter.
    - Up to 15mm thick.
- ***Sample holder:***
    - Vacuum chuck for CD stampers, replicas and glass master discs.
    - Vacuum chuck for hard discs (48mm, 65mm, 95mm, and 130mm) and other samples.
    - Semiconductor wafer vacuum chuck for 50mm, 100mm, 125mm, 150mm, 200mm, and 250mm wafers.
- ***Motorized Positioner:***
    - Inspectable area up to 250mm in diameter with linear and rotary stage.
    - Linear resolution - 2μm.
    - Bidirectional repeatability - 1μm.
    - Angular Resolution 0.002 degree.
    - Angular Repeatability 0.0014 degree
- ***Optical Microscope:***
    - Resolution 5μm (with optional objective - up to 1.5μm).
    - Field of view With 14X eyepieces: 2.4mm to 28mm.
    - Magnification With 14X eyepieces: 8.4X to 100X; With color CCD: 43X to 470X
- ***Tip Viewing:*** Scanning cantilever can be viewed on the monitor screen during scanning procedure

Highlights of Solver P7LS-SPM-MDT

- All in one: Contact AFM/LFM/Adhesion Force Microscopy; Force Modulation Technique/Local Viscoelasticity; Resonant Mode: Non-contact Mode, Semicontact Mode/Phase Imaging/ MFM/EFM, Spreading Resistance Imaging or SCM/SKM.
  The range of measuring techniques is very wide. Most of them are standard low cost configuration
- The topography of the same area can be shown simultaneously with LFM, MFM/EFM or STM images for comparison purposes.
- Antivibration system is not required. Atomic resolution is obtainable within usual laboratory environment, without special anti-vibration tables.
- Advanced electronics High-Q:
  - 22 bits X,Y resolution
  - Resonant frequency setting with the ultimate accuracy 0.01Hz
- Sample sizes up to 300 mm in diameter could be investigated as well as Glass Master discs (CD/DVD production feature).
- High precision Adhesion Force Microscopy

We can image exactly the SNAP back point, so measuring not just cross section but the value of force when the snap back happened.

- Resonant Mode Lithography performed by mask
- Repeated approach and automatic scanning of 20 predefined areas.

This feature allows operator just predefine areas for scanning and set the approach parameters for the first one after that he may go away and return to collect the results.

- Titanium construction allows to start measurements immediately after power-on due to negligible thermal drift.

Low weight and low thermal extension coefficient together with good corrosion.
properties makes titanium very good material.

- Low power consumption - 100 Watt.
- Low weight (90kg) and compact construction fitting on the single table.
- Wide range of voltage operation 100-200V, 50-60Hz

The new Large Sample SPM ***Solver SPM LS/M-300*** has been specially designed to fit in-line in the quality control process of the CD and DVD production. Ones tuned, the stampers and replica's are automatically loaded and scanned according a predefined scanning scheme allowing unattended operation. The resulting scans are automatically evaluated on critical parameters giving the operator an immediate impression of all quality aspects. Ones an out-range parameter is detected, the operator can directly zoom-in to the spot of interest and visualize any of the appearing defects. By a large amount of very powerful analysis tools, any values of interest of any cross-section can be obtained. With the integrated optical microscope with CCD camera, the probe and the spot of interest can be optically inspected, before and during scanning, with a resolution of up to 1,5 um.

Wide range of applications of Solver SPM LS/M-300:

Semiconductors

Roughness control of silicon wafers. Topography defects control and characterization. Conductivity control of contact plates. Cleaning process control. Resist residuals identification.

Data storage media

Morphology control of magnetic films. Roughness control of starting materials. Visualization of magnetic bits and their orientation. Controlled surface modification using the Lithography modes.

Optical components

Surface quality control. Visualization and 3D measurements of polishing residuals such as stretches, wells, grooves etc. Final control of surface roughness.

Solver P7UHV-SPM-MDT

P7UHV-SPM-MDT

Highlights:

- Vacuum 10^{-11} torr.
- Sample size up to ∅ 25.4mm thickness up to 10mm
- Large scan area up to 100x100x5μm (minimum 3x3x0.5μm)
- Measuring modes: STM, Low current STM, AFM, LFM, MFM, EFM, SCM, Resonant Mode, Measuring Spreading Resistance, Phase Imaging.
- Lithography
- Low vacuum chamber for measuring heads provides customer with:
    - easy and fast adjustment of the laser as the adjustment is carried out in a low vacuum
    - the potential to work in an aggressive environment since the laser, and all electronics chips are located in low vacuum
- Use of an antivibration table is not required
- Feasible to process and modify the surface using standard UHV techniques (ion etching, heating, etc) just before measurements, and then to return the same area of the sample for further review
- Optical registration of cantilever deflection (with the possibility to use piezocantilevers)
- CCD cameras to observe the sample and the tip
- Advanced electronics High-Q-22 bit resolution on a full scan size
- The full sample motion along Z axis is 30mm being made by UHV stepper motor
- Temperature range for sample thermal treatment: 300K - 500K, 100K - 700K
- Bakeout

Comparative table of Solvers: P47-SPM-MDT, P47H-SPM-MDT and P7LS-SPM-MDT

Items for comparison	P47-SPM-MDT	P47H-SPM-MDT	P7LS-SPM-MDT
Measuring Modes	STM, Contact AFM, LFM, Adhesion Force Microscope, Spreading Resistance Imaging, Resonant Mode: Non-contact Mode, Semicontact Mode AFM/ MFM/EFM/SCM/ SKM/ Phase Imaging/ Force Modulation/ Lithography.	The same as in P47	Contact AFM, LFM, Adhesion Force Microscope, Resonant Mode: Non-contact, Semicontact Mode/Phase Imaging/ Force modulation/ MFM/ EFM, Spreading Resistance Imaging or SCM/SKM
Environment	Ambient and controlled gas, liquids	Ambient ,controlled gas	Ambient environment
Maximum sample size	40 x 40mm x 20mm thick	100 x 100mm x 20mm thick and UNLIMITED sample size in Stand Alone configuration	250mm in diameter - standard (300 mm in diameter - optional), up to 15mm thick with the possibility to test glass Master Disks.
Scan ranges	7 x 7 x 4 um 14 x 14 x 4 um 30 x 30 x 1.6 um 35 x 35 x 4 um 100 x 100 x 4 um	14 x 14 x 1.5 um 35 x 35 x 1.5 um 55 x 55 x 3 um 100 x 100 x 5 um	30 x 30 x 1.6 um 60 x 60 x 4 um 100 x 100 x 5 um
Min scanning step	0.015 nm	0.015 nm	0.015 nm
Integrated vibration isolation system	2Hz	2Hz	7Hz

Noise level in vertical Z direction	<0.25A RMS	<0.5A RMS	<1A RMS
Translation Range	Manual X, Y positioning stage, range of positioning 5 mm, +/- 2.5 mm, positioning accuracy 5 um.	Manual 5mm x 5mm sample translation stage or Manual 15mm x 15mm sample translation stage Positioning resolution - 5um.	R, X motorised (PC controlled) translation stage, angle of rotation from 0 to 360 degrees, X range 200mm.
Critical dimensions	Atomic resolution in contact AFM (mica, HOPG), in STM (HOPG)	The same as for P47	Atomic steps in contact and semicontact AFM modes (HOPG)
Rough approach	The manual sample-to-tip approach up to 1mm is also possible to reduce the approach time. Automatic approach.	The manual tip-to-sample approach up to 1mm is also possible to reduce the approach time. Automatic approach.	Automatic tip to sample approach with one stepper motor with automatically adjustable approach parameters.
Sample heating with temperature control	The possibility of heating the sample from home temperature to 150C with thermostabilization of a sample with the accuracy 0.1C degree.	The possibility of heating the sample from home temperature to 150C with thermostabilization of a sample with the accuracy 0.1C degree.	unavailable
Optional accessories	SNOM, Low current STM, Hermetic cell (for liquid operation)	SNOM, Low current STM, Hermetic cell (for liquid operation)	