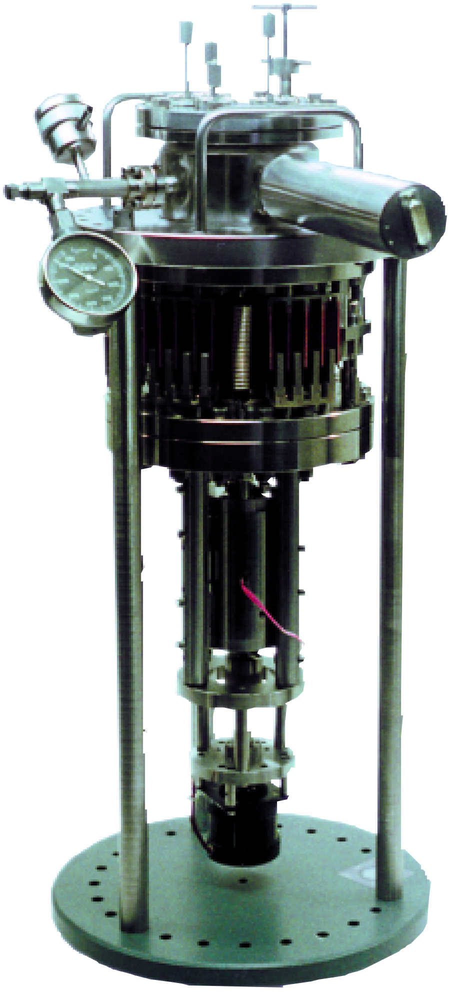
Solver P7UHV

Universal Ultra-High Vacuum SPM Solver P7UHV

Advanced multimode Ultra-High Vacuum Scanning Probe Microscope (scanning by the sample system configuration).

Measuring modes:
STM/ low current STM/ AFM/ LFM/ ResonantMode/ Phase Imaging/ Spreading Resistance Imaging/ MFM/ EFM/ SCM/ SKM



Flange module of Ultra-High Vacuum probe microscope Solver-P7UHV

Ultra-High Vacuum Scanning Probe Microscope Solver P7UHV

Universal Ultra-High Vacuum SPM Solver P7UHV

Technical Specification	
Vacuum	10^{-11} torr
Sample size	up to 25.4 mm thickness up to 10 mm
Scan ranges	maximum 100x100x5 µm minimum 3x3x0.5 µm
Temperature range for sample thermal treatment	300 K — 500 K; 100 K — 700 K
Advanced electronics High-Q — 22 bit resolution on a full scan size	
The full sample motion along Z axis is 30 mm being made by UHV stepper motor	
A vacuum compatible manipulator provides sample movement within the vacuum chamber	
Bakeout	

UHV complex (P=10^{-11} torr) which includes the technological module MBE, standard analytical chamber, sample preparation chamber, sluice loading chamber and two chambers with scanning probe microscopes. In the first chamber is mounted microscope allows to work in AFM/ STM modes (including all modulation techniques). Chamber consists of 2 sections: low vacuum (P=10^{-3}torr), where optical registration system of cantilever deflection is located and high vacuum with a sample and probe mounting system. This design allows to increase greatly the reliability and makes easier the process of system adjustment without evacuation of UHV module. System of registration cantilever deflection: electrical (piezo cantilevers) or optical (four sectional photo diode).

Temperature control of the sample in the range of 100 - 700K. Ultimate vibro isolation based on the spring system and magnetic damper.

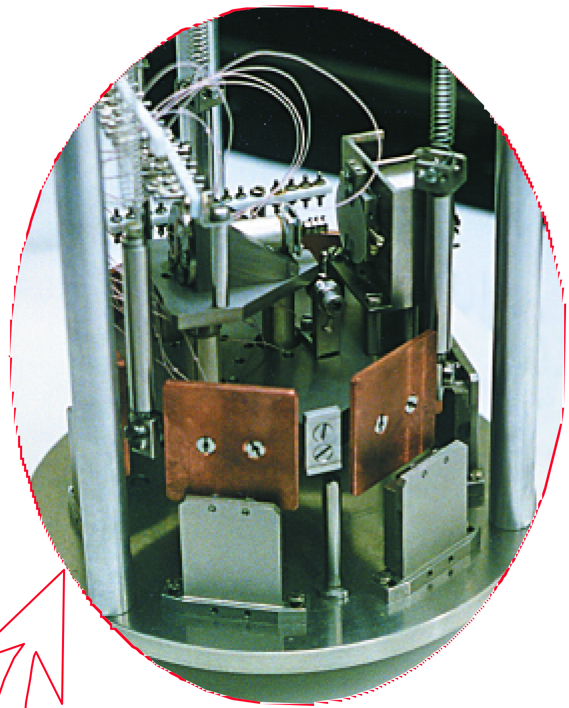
Low-temperature Ultra-High Vacuum SPM Solver P7UHVHe

Low temperature UHV SPM (scanning by the tip).

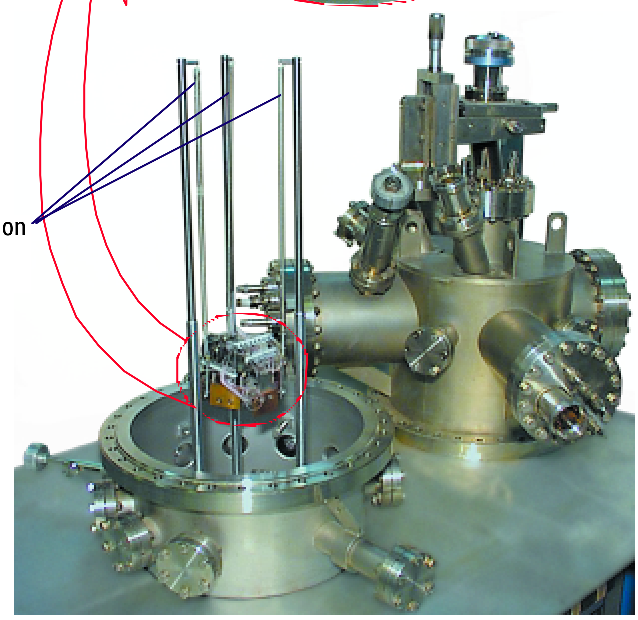
Measuring modes:
STM/ Shear Force / Phase Imaging/
AFM (with peizo cantilever)

Low-temperature UHV SPM inside ultra high vacuum helium cryo-pump

Measuring head for low-temperature Ultra High-Vacuum scanning STM



spriugs for antivibration protection



Measuring head of low-temperature SPM, installes into the analytic chamber

Low-temperature Ultra-High Vacuum SPM Solver P7UHV

Technical specification	
Minimum sample temperature	< 5 K
Maximum sample temperature	~1300 K
Starting cooling time	till to5 K < 6 hours
95% helium evaporation time	> 50 hours
Scanning area	10*10*1 µm3 under T=300 K
Scanning area	1,8*1,8*0,2 µm3 under T=5 K
Resolution	along Z < 0,01 nm
Range of tunneling voltage	± (0,5 mV to 10 V)
Range of tunneling current maintenance	$5x10^{-11}$ A , $5x10^{-8}$ A
Resonant frequency of vibroprotective springs	<1 Hz
Annealing temperature	till 170°C
Final vacuum in the analytic chamber	10^{-11} torr
Possibility to work in the tunneling current mode and also in atomic force mode and in standard modes in the presence of tenzocantilevers	
Adaptation possibility of analytic chamber and transport unit to other ultra high-vacuum analytic units	

The system consists of two or three high-vacuum chambers with handling possibility of samples and probes set in the standard holders. Realization of a two- or three-chambers variant matches with customer inquires.
Basic chamber is analytic. It is intended for making researches in the temperature field up to helium temperature. Another two chambers are auxiliary, one for quick loading of samples and probes, another one for preliminary processing of samples and probes (thermal heating, ion etching, chip etc.).
Nitrogenous helium cryostat in the analytic camera is made of two copper bowls. On the polished surfaces of the bowls an ultra-thin aluminum covering is formed. This covering decreases atoms diffusion from the volume on the surface and increases reflection factor that decreases demand of liquid helium and nitrogen.
Depending on conditions of device exploitation two variants of vibroprotective systems are suggested. The first variant includes special rubber beds in the system. The probe microscope is hung on the special springs in the analytic chamber that provides effective vibration elimination. The second variant suggests setting of the special vibroprotective springs on the table. Resonant frequency of the system in the second variant is less than 1 Hz. Such system allows to effectively eliminate power external noise vibration.
This analytic process system can be used for making researches in the field of fundamental and applied science: molecular biology, surface physics and chemistry, nanotechnology of modern microelectronic devices etc.

Comparative table of Solver line SPMs

Environment	P47	P47H	P47EC	P47BIO	P7LS	SMENA	P7UHV
UHV							YES
ambient	YES	YES	YES	YES	YES	YES	YES
controlled air	YES	YES	YES				YES
liquids	YES		YES	YES			
electrochemistry			YES				
Heating							
Up to 150C	YES	YES	YES	YES			
Up to 300C		YES	YES				
Up to 700K							YES
Sample size							
up to 40 mm	YES	YES	YES	YES	YES	YES	YES
up to 100 mm		YES		YES	YES	YES	
up to 300 mm					YES	YES	
unlimited						YES	
Scanner X,Y,Z							
14x14x1,4um	YES		YES				YES
30x30x1,4um		YES		YES	YES	YES	YES
60x60x4um	YES	YES	YES	YES	YES	YES	YES
100x100x5um		YES		YES	YES	YES	YES
Positioning							
manual X,Y	YES	YES		YES		YES	YES
motorized R, j					YES		
Optical system	**YES**	**YES**		**YES**	**YES**	**YES**	**YES**
Applications							
Material science	YES	YES	YES		YES	YES	YES
Semiconductors	YES	YES	YES		YES	YES	YES
CD/DVD					YES		
Biology			YES	YES			
Electrochemistry			YES				
Critical resolution							
Atomic	YES						YES
Atomic steps		YES	YES	YES	YES	YES	

ELECTRONICS

SPM processor

System controller Solver P7

Solver-P7 controller has:

- Controller is realized in a standard frame "Vertical Tower Diplomat Case" (produced by VERO Co.) with the size 445x160x500 mm^3, weight 14,5 kg. Demand power 60 W, alternating supply voltage 50 - 60 Hz, from 80 to 250 W.

- *Analog-digital converter.* Two 16ty rate ADC allow to register two different signals at the same time which are independently selected from the set of all entering, transformed and external signals. A filter of lower frequencies of the second form tunable in the range of 100 Hz-20 kHz is situated before each ADC. Before the one of ADC 16 rate displacement digital-to-analog converter and resonant amplifier is situated. It allows to compensate the constant component of the measurable signal and controlled amplifier with an amplifier coefficient 1, 10, 100, 1000. This allows to increase ADC resolution up to the level specified by an input noise in the measuring region.

- *Amplifiers of X and Y* piezoscanner deviation are identical. It is a compound DAC and a high voltage amplifier with a paraphase outlet. It increases the full voltage brandish on the scanner up to +320V/-320V with a unidirectional feed 350V. The zone of X and Y amplifiers is 2,5 kHz. A compound DAC consists of two precision 16 rate DACs, precise supporting source and two deglitchers (for peak suppression during DACs switching). The use different amplifier coefficients for DAC allows to reach effective precision compound DAC - 22 bits that gives a minimum step about 0,025 nm on the area of 100x100 mkm. The problem of the precise DAC amplifier co-ordination can be solved by means scanning just by one of them - by «older» or by «junior» in depending on chosen scan area size.

- *Z amplifier* of the piezoscanner deviation contains the same scheme of the compound DAC, but the highvoltage amplifier has just one outlet (0-320V), wider band - 15kHz and can work with the load up to 100 nF. It has an input of external modulation and a possibility to apply an internal modulation signal. Resistor devisor and buffer amplifier are used for Z value measuring in the mode when a feedback Z is switched on.

- *Feedback circuit* consists of scaling amplifier, polarity control, integrator with controlled time constant and reset and keeping modes, error amplifier, multiplying 16 precision DAC which determines the level of signal maintenance by means a feedback. The signal proportional to the full photodetector precip can be used like a reference voltage of the DAC. It decreases a device sensitivity to instability and laser noise.

- *Multiplexers.* For the signals commutation three group of multiplexers are used. Multipexers - amplifiers of external signals which allow to choose between input signals (low frequency and band-pass STM, low frequency and high frequency SFM and external) subjected to the transformation signals. Multiplexers selecting two independent signals for simultaneous measuring by two ADC. Multiplexers selecting outlet signal to use it in the feedback circuit while working in the mode of maintenance the input current value, modulation amplitude and etc.

- *DSP.* For the digital control of the device there is a digital signaling processor ADSP 2181.

- *Input amplifiers* are situated on the measuring heads. In the STM mode two types of input amplifiers are used: for the range of input currents 10pA - 10nA and 1pA - 1nA in the Z-constant mode. They are current transformers - voltage with the trance-impedance 20 MoHm and 200 MoHm accordingly. The value of measuring input current is limited by 50 and 5 nA, the frequencies band - 15 and 6 kHz accordingly. In the SFM mode the input amplifier is a quad-converter photocurrent - voltage (by one for the each photodetector section) with the band 1 MHz. On integrating - subtracting amplifiers there is a scheme translating 4 input signals into the voltage proportional to the normal cantilever deflection, leteral turn and the full photodetector precip. The last is used at the constant relative cantilever deflection maintenance. It allows to compensate instubility and laser noises even while working with nonzero differented signal.

- *Signals filters.* In the STM mode the filter of the lowest frequencies of the 3rd form is used with the band 10 kHz which allows to keep up the constant middle current while working with dI/dZ or dI/dU measurement with modulation Z or U at the frequency above 18 kHz. For work in modulation modes the filter of lowest frequencies of the 3rd form is used with the band 10 kHz which allows to keep up the constant middle current while dI/dZ or dI/dU measurement with the modulation of Z or U at the frequency about 18 kHz. For modulated signal detachment a band-pass filter of 5th form at the frequency 18 - 25 kHz is used. In SFM mode two connecting filters of 3rd form at the lowest and highest frequencies with the critical frequencies 50 kHz are used. As an input a signal feeding to the external input connector of the device can be used. The parameters of its filters are the same with SFM channel filter.

- *Signals converters* allow to receive simultaneously and independently the signal proportional to the logarithm of input current and the signal proportional to the amplitude of the input signal while working in the modulation mode (with synchronic detection using), to the rootmeansquare value of the input, to the phase shift between input and initiating signals. All signals pass controlled filters lowest frequencies of the 2nd form with the range of reconstruction 200 Hz - 20 kHz. The range of frequencies while work in modulation methods in the STM mode - 18-25 kHz, in SFM mode - 1kHz-1,8MHz when the cantilevers properties are studied and 50kHz -1,2MHz when the sample surface is studied. Synchronic detection can be used at frequencies divisible to the initiating frequency. There is a mode with the maintenance of constant phase shift between initiating and input signals by means cantilever oscillation frequencies changing by the feedback circuit. In the case a conducting cantilever is used there is a possibility to maintain one its oscillation parameters (the phase, amplitude etc.) by means applying to the cantilever potential changing.

- *The block of frequency synthesis* consists of 32 rate independent synthesizer of sin(w t), cos(w t) signals - for the synchronic detection and cos(w t+j) - for the modulation impacts. The frequency, amplitude and the phase switch over independently. The step of the reconstruction by frequency - 0,01 Hz, by the phase - 0,1 degree. The amplitude of modulation impact can change in the range 1mV - 10V with the step 1mV. As a controller of strong frequency can be used both quartz generator (40 MHz) and controlled by a voltage generator (9-11 MHz) in the mode with feedback maintenance by the phase and frequency control.

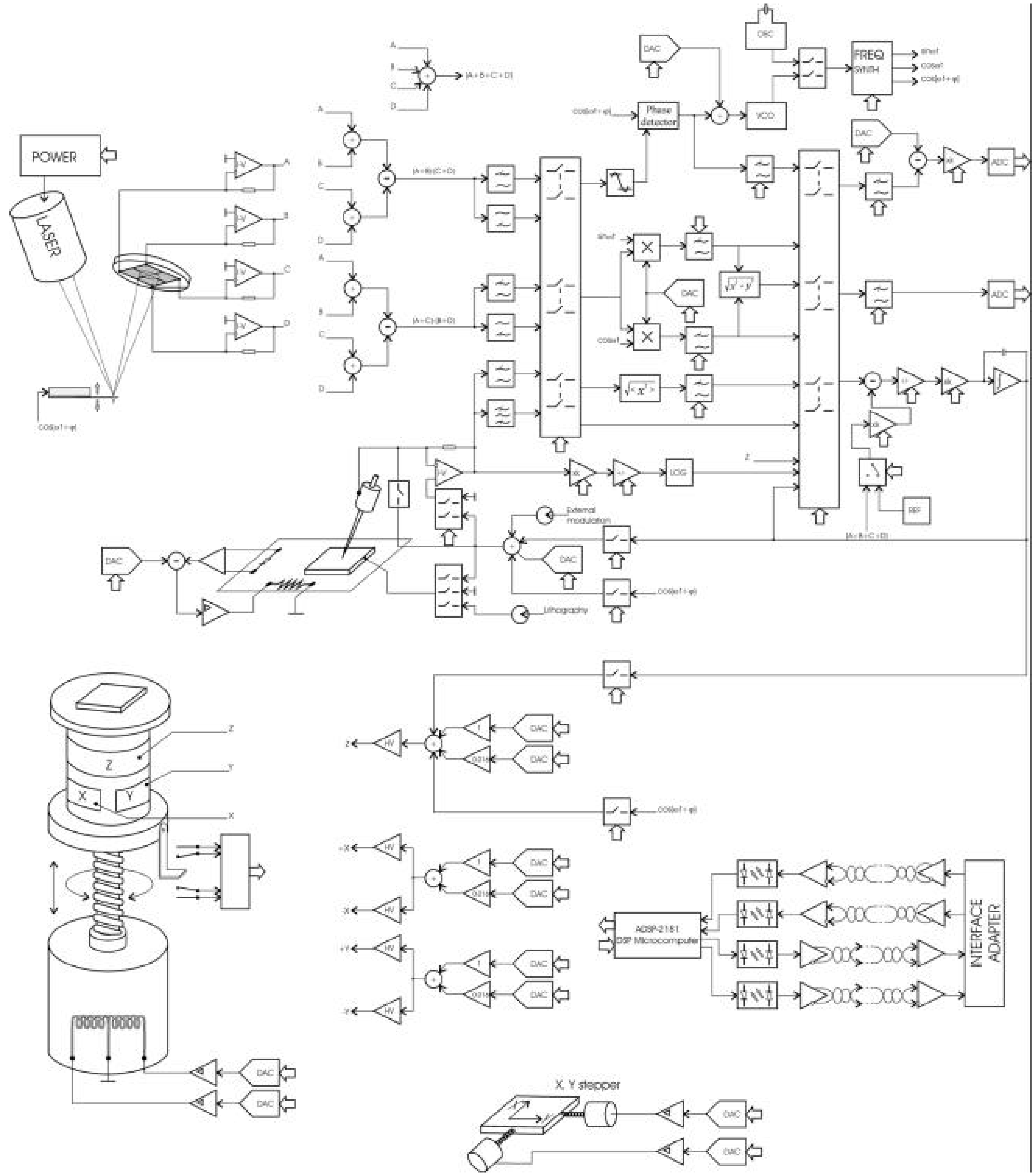
- *The block of approach control* consists of 12ty rate DAC. The software produces two displaced for 90 degree sinusoidal voltage applying to two power amplifiers which control by the current through stepper motor winding.

- *Motorized Positioner driving.* There is a possibility of two additional five-phase stepper motor (type RDM 545/100A)control.

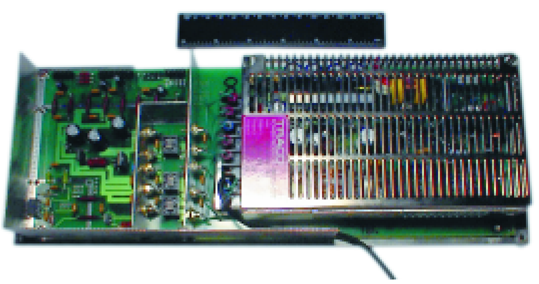
- *Temperature stabilizato*r allows to maintain a constant temperature of the substrate with a sample in the range 30 - 150 C with the accuracy 0,05 degree.

System controller Solver P7

Block scheme of the system controller Solver P7 with connection to measuring systems of microscopes.

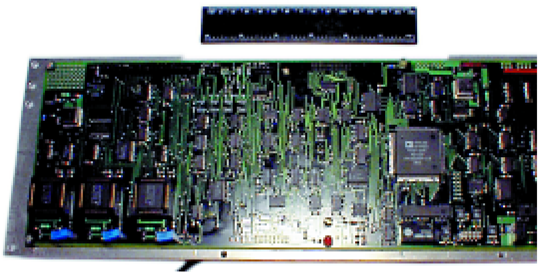


Block of the power source



Contains:	
System source	50W, ±15V, +5V, filter barrier, control circuit.
Passive elements	72
Active elements	7 (TRACO, MURATA, OXLEY)

Electronic block interface

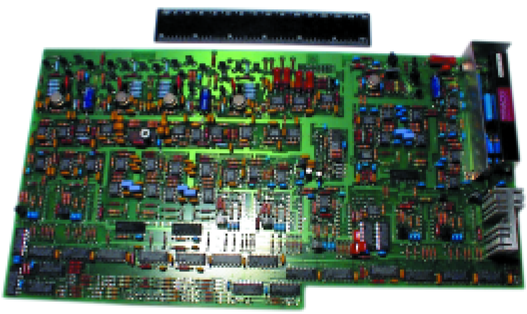


Contains:	
DSP Microcomputer	ADSP-2181(Analog Devices), three DDS Modulator AD7008 (schemes Analog Devices) and schemes of encoding- decoding.
Passive elements	76
Active elements	82 (Analog Devices - 4, Burr-Brown - 2, Other76 (IQD, Philips))

Board control for the Large Sample stepper motor X, Y

Contains:	
Two channels of impulse former of the sinusoidal current for two five-phases Step Motors.	
Passive elements	130
Active elements	26 (Analog Devices - 3, Other - 23 (SGS Thomson, Philips))

High-voltage scanning control board

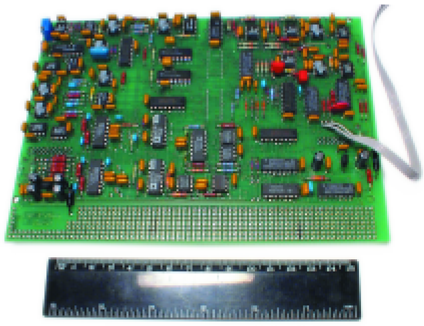


Contains:	
Seven 16ty precision ADC AD7849 (Analog Devices), transformer DC-DC from 12V in 350V deglitcher scheme and three high-voltage amplifier X, Y, Z.	
Passive elements	93
Active elements	56 (Analog Devices - 56, Other - 93 (TRACO, ZETEX, Philips))

Analog-digital converter board

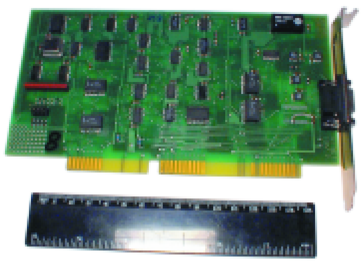
Contains:	
Two 16ty precision ADC - ADS7809 (Burr-Brown), two controlled filters, scheme of compensation of the constant level and controlled amplifier.	
Passive elements	110
Active elements	29 (Analog Devices - 16, Burr-Brown - 6, Other - 7 (Philips))

The phase detector board with the scheme of frequency control



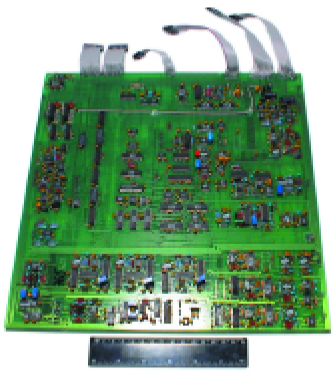
Contains:	
Passive elements	250
Active elements	60 (Analog Devices - 33, Burr-Brown - 1, Other - 26 (Philips, Harris))

Interface board



Contains:	
Electronic block	slot ISA (of the computer through four twisted couple)
Passive elements	60
Active elements	34 (Analog Devices - 4, Other - 30 (Philips, IQD, NEWPORT))

The basic motherboard



Contains:	
The most analog functional assembly (entering amplifier, synchronous detector, Feed Back channel, BIAS VOLTEG channel, signals multiplexer, T° and Step motor approach control)	
Passive elements	680
Active elements	179 (Analog Devices - 110, Burr-Brown - 13, Other - 56 (Philips, ZETEX etc.))

Controller Solver P10 (in developing)

Electronics block Solver P10

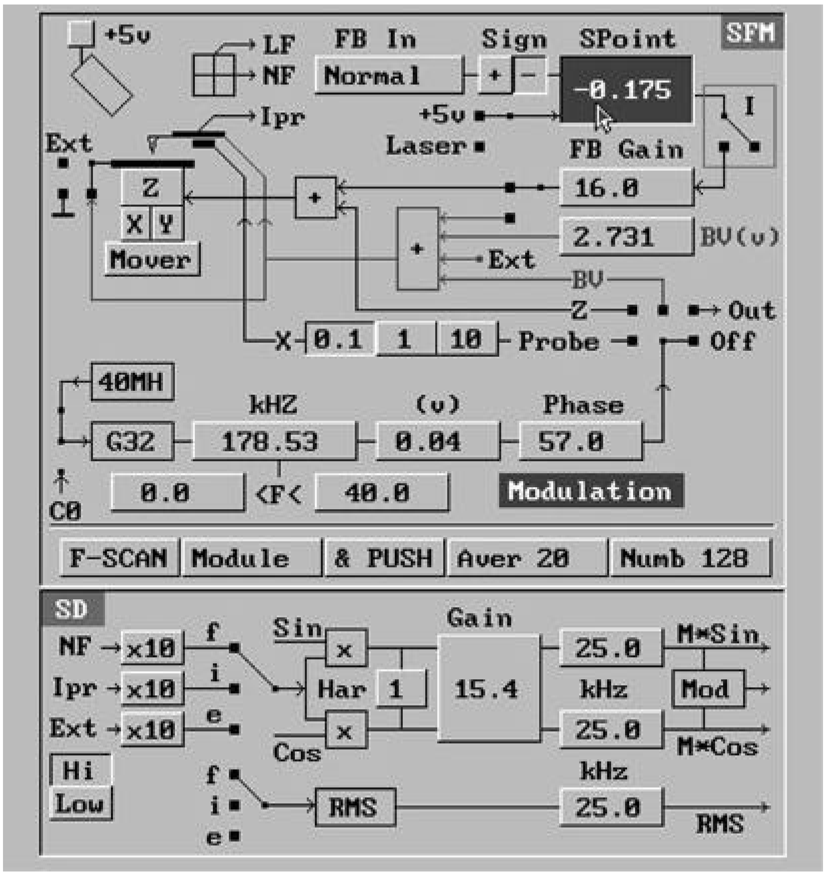
- Controller is performed in a standard body "Vertical Tower Diplomat Case" (produced by VERO Co.) with size 445x160x500 mm3. Power consumption is 75 watt, supply voltage alternating 50-60 Hz, from 80 to 250V with connection possibility to the airborne net with voltage 12V.
- Flexible, program redesigned structure realized on microcircuits ANALOG CROSSPOINT SMITCH ARRAY`S and analog multiplexes.
- Digital controlling using DSP and CPLD allowing incircuit reprogramming.
- Availability of expansion slots that makes possible access to the input analog and digital signals and simple expansion of set of available functional possibilities by special units connection.
- Output on the external connector through inserting into the expansion slots transition plates that allows to create new modifications without base electronics change.
- Realization of high-voltage amplifiers on the separate plate connected to the expansion slot allows to easily modify it or to use external high-voltage module with demanded characteristics (power, speed of response etc.)
- Scanner control using three DAC in each of the channels X, Y, Z of quasi-bipolar amplifiers that essentially decreases power consumption.
- Availability of fourth DDS Modulator`s and four-channels lock-in-amplifier allows to realize multiple-frequency detection.
- Setting possibility of simultaneously launched 4 and 16 -digital ADC having 3 measuring channels each of them with high switching speed.
- Availability of self-testing, self-calibration and self-configuration connectors.
- Compactness as a result of controller electronic circuits realization in bodies SOIC, PLCC etc..

Software

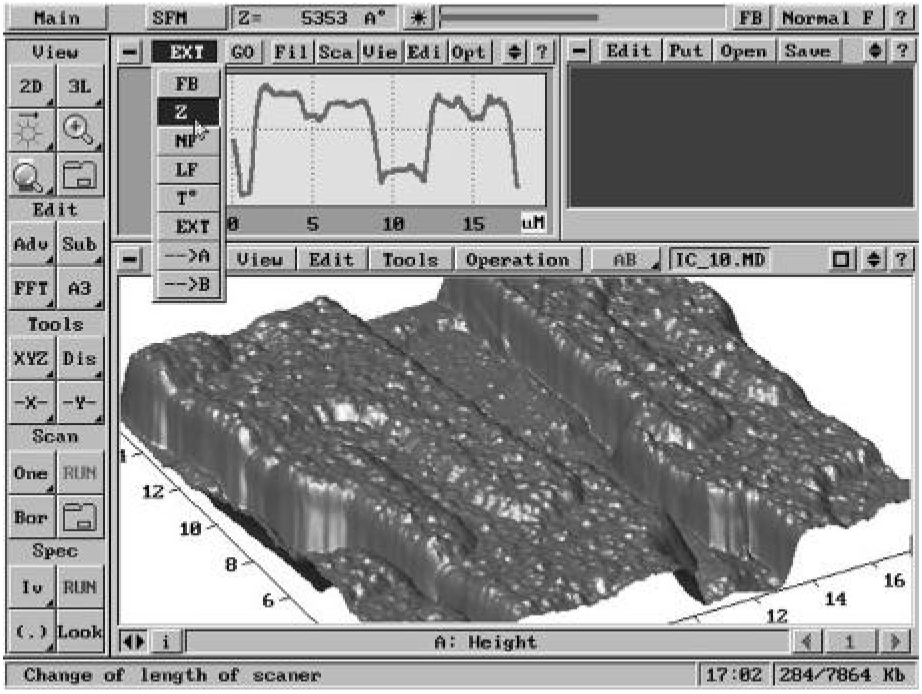
For the device of SOLVER line has the strongest between known possibilities. The control of the device and image adaptation are realized by one of the program and there is no need to exit the control program and to start a working program.

There are high- performance, simple in tuning the algorithm of piezoceramics (of the microscope scanner) imperfection correction. Non-linearity scanner correction at X, Y directions is implemented with the accuracy better than 1%.

There are also possibilities for image processing in the program: distance and angles measurement in the image plane and space, length of determined curve, estimation of the statistic parameters of the roughness in a determined imaging area with frequency function obtaining. There are different types of image introduction: in two-dimensional form with scale change, in three-dimensional form with scale change in X, Y, Z directions, section in any direction with profile introduction in a graphic form in a special window of two-dimensional graphic - «oscillograph».



The graphic interface for the program control SPM complex.



The graphic interface for SPM complex image introduction and processing.

For small defects stressing introduction with a «backlighting» is used. There is a possibility to choose the direction of «backlighting» in the case of two- and three-dimensional graphic, selection of a color palette with the possibility to edit a palettes, selection of the palette scale in determined image area.

There are possibilities of image editing in the program: cutting of determined image area , «clearing» and «flattening» determined image area, fast Fourier direct and inverse transformation with the possibility to edit in inverse space, weight filtration by average with selection of the dimensionality of the matrix odd rank transformer from 3x3 to 29x29, weight median filtration with selection of matrix dimensionality of the odd ranks transformer up to 29x29. There is also a possibility to differentiate the image, to cut picks and holes in image automatically, to subtract from the image surfaces of low (1st and 2nd) form with the possibility to choose the basic image place that allows to correct the slope and curvature of the sample, automatic subtraction of the averaged by matrix chosen image form from the initial that allows to visualize small parts and negligible changes on the surfaces with a significant relief, to subtract images from each other. During the work with files there is a possibility to load data files for future processing as well as text files, to copy files to any directory on the disk, to delete files from the disk, to sort files by the names, time of creation and size, to create new directories on the disk, to save in *.pcx, *.bmp formats the whole screen or any its part, for example, just image. The program reads files with the possibility of subsequent processing of other microscope producers: DI (Nanoscope II, Nanoscope III), PSI, Omicron, RHK, Topometrix.

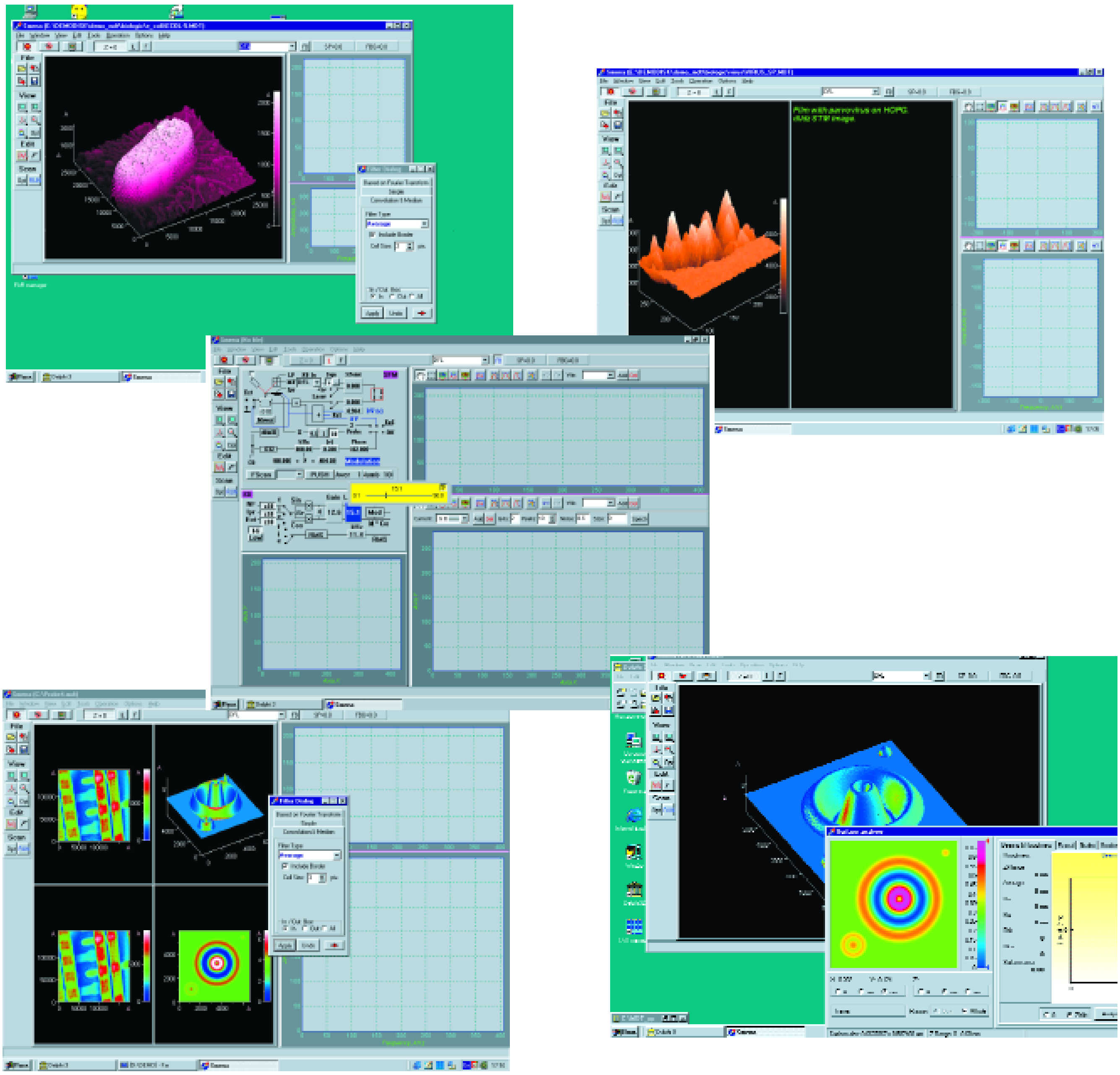
There is a possibility to load and process by the program 3 dimensional images in *.pcx and *.bmp formats.

Together with 2 dimensional graphic with a built graphic editor there is a text editor in the program that allows to comment results. Comment, which automatically including a time and a supervision conditions, is kept in the file format, so, there is no possibility to «lose» the file.

New windows control software for SOLVER - SOLVER PROGRAM

The most important advantage of this program is its compatibility with Windows 95,Windows 98. So now you can obtain data and browse files with MDT extension and work with them in the most convinient operation system, printing and date inyer-change with Windows graphic pack.

This program has all performance capabilities that had old version of the DOS version Viewer. But in addition it has a new, user-friendly HELP organization and realization of surface analysis. Detailed information about program capabilities you can find looking at the SOLVER PROGRAM HELP. File SOLVER PROGRAM is a new version of the final program which you can now able to use for microscope controlling.



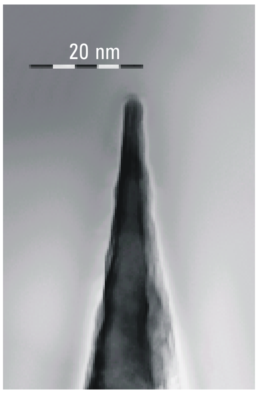
ULTRASHARP SILICON CANTILEVERS

General Ultrasharp silicon cantilever characteristics

All Ultrasharp silicon cantilevers:

- are compatible with 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 divided 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.

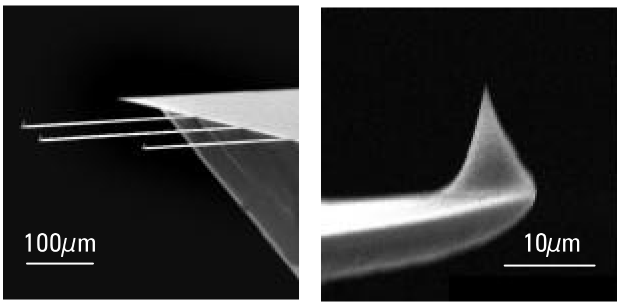


All Ultrasharp silicon cantilever tips have standard characteristics:

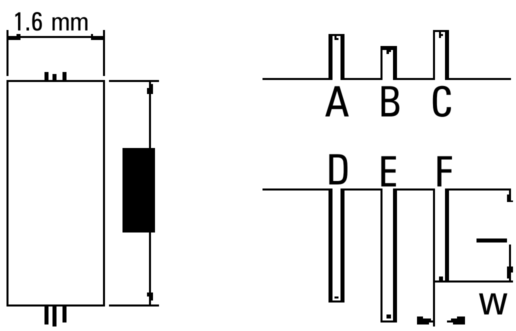
- high aspect ratio conical tips (cone angle is less than 20°);
- curvature radius of tip is less than 10 nm (for uncoated tips);
- tip height 10-15 µm;
- conductive lever and tip (resistivity less than 0.002 Om•cm).

SEM image of Ultrasharp silicon tip

SC12 series of Ultrasharp silicon cantilevers specifications



SEM images of CONTACT Ultrasharp silicon cantilever tip (SC12 series).



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

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.

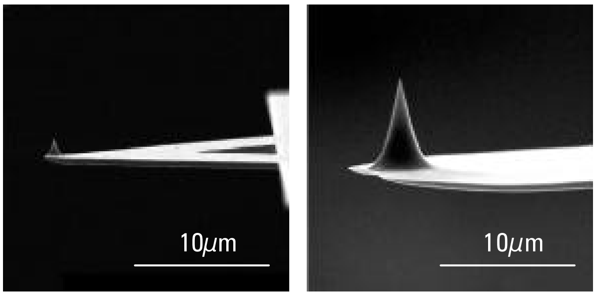
ULTRASHARP SILICON CANTILEVERS

SC12 series of Ultrasharp silicon cantilevers specifications

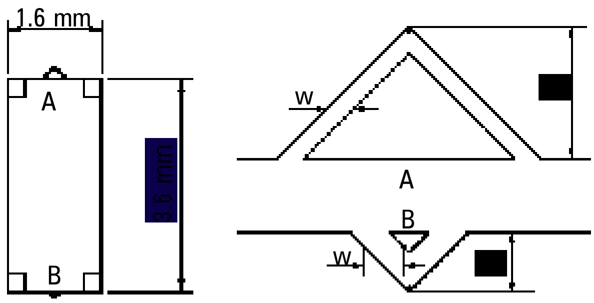
	type	length, μm	width, μm	thickness, μm min	thickness, μm typical	thickness, μm max	resonant frequency N/m min	resonant frequency N/m typical	resonant frequency N/m max	force constsnt, N/m min	force constsnt, N/m typical	force constsnt, N/m max
CONTACT	A	110	35	0.9	1.0	1.1	70	90	110	0.5	0.7	1.0
	B	90	35	0.9	1.0	1.1	130	160	190	1.2	1.7	2.3
	C	130	35	0.9	1.0	1.1	60	75	90	0.4	0.6	0.8
	D	300	35	0.9	1.0	1.1	12	15	18	0.03	0.05	0.07
	E	350	35	0.9	1.0	1.1	8	10	12	0.02	0.03	0.04
	F	250	35	0.9	1.0	1.1	16	20	24	0.06	0.08	0.10
NONCONTACT	A	110	35	1.9	2.0	2.1	140	180	220	5	6	7
	B	90	35	1.9	2.0	2.1	260	320	380	12	14	16
	C	130	35	1.9	2.0	2.1	120	150	180	4.0	4.5	5.5
	D	300	35	1.9	2.0	2.1	25	30	35	0.30	0.35	0.45
	E	350	35	1.9	2.0	2.1	16	20	24	0.20	0.25	0.30
	F	250	35	1.9	2.0	2.1	32	40	48	0.55	0.65	0.75

SC11 and SC21 series of Ultrasharp silicon cantilevers with triangular springs

Ultrasharp silicon cantilevers of SC11 and SC21 series have the same design. Each chip includes the triangular spring and the small one. The main specialty 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.



SEM images of UltraSharp silicon cantilever tip (SC11 series)



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

SC11 and SC21 series of Ultrasharp silicon cantilevers specifications

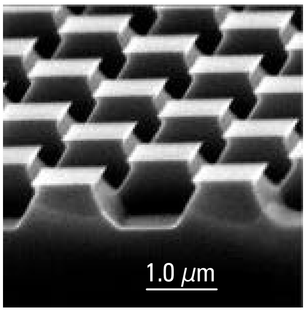
		type	length, μm	width, μm	thickness, μm min	thickness, μm typical	thickness, μm max	resonant frequency, N/m min	resonant frequency, N/m typical	resonant frequency, N/m max	force constsnt, N/m min	force constsnt, N/m typical	force constsnt, N/m max
SC11	contact	A	200	40	0.9	1.0	1.1	16	20	24	0.25	0.35	0.50
		B	90	60	0.9	1.0	1.1	140	180	220	4.5	6.0	8.0
	noncontact	A	200	40	1.9	2.0	2.1	32	40	48	2.5	3.0	3.5
		B	90	60	1.9	2.0	2.1	300	360	420	41	48	55
SC21	contact	A	290	40	0.9	1.0	1.1	7	10	13	0.09	0.12	0.16
		B	110	40	0.9	1.0	1.1	80	110	140	1.5	2.0	3.0
	noncontact	A	290	40	1.9	2.0	2.1	16	20	24	0.8	0.9	1.1
		B	110	40	1.9	2.0	2.1	180	260	280	15	17	20

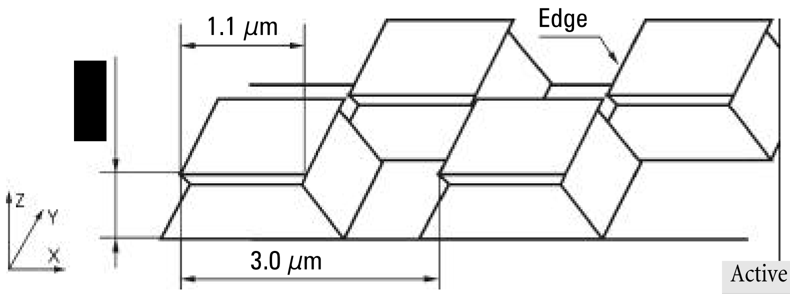
ULTRASHARP CALIBRATION GRATINGS

This test structures is intended for scanning probe microscopes.
It will help you:

- *to calibrate your scanner in normal directions;*
- *to calibrate your scanner in lateral directions;*
- *to determine normal and lateral nonlinearity, degree of angular distortion;*
- *to determine piezoceramics hysteresis value of your device;*
- *to determine degree of creep-effect influence on the image;*
- *to obtain full 3-D image of the cantilever tip, to measure its curvature radius.*

Silicon square grating with negative angles TGX01



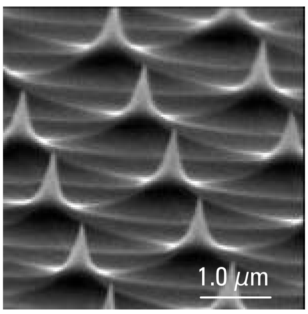


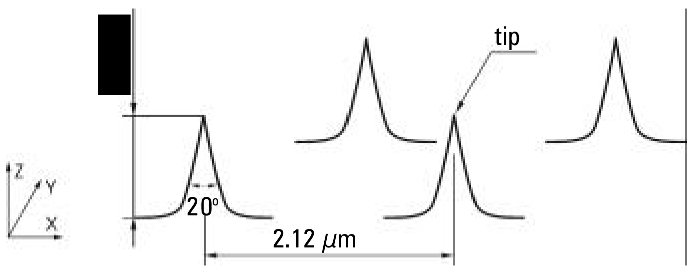
Active area	2x2 mm array
Edge radii	less than 5 nm
Pitch	3,0 μm

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 grating TGT01



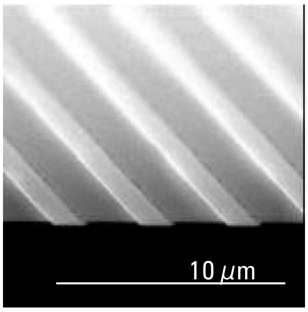


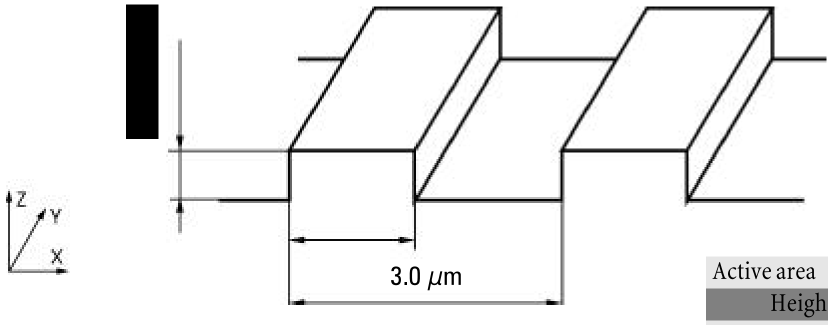
Active area	1x1 mm array
Edge radii	10 nm
Pitch	2.2 μm
Diagonal pitch	3.0 μm

Silicon calibration gratings of TGT series are characterized by strict symmetry of tip sides, small cone angle (less than 20 degrees), small curvative 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.

ULTRASHARP CALIBRATION GRATINGS

Silicon Gratings TGZ

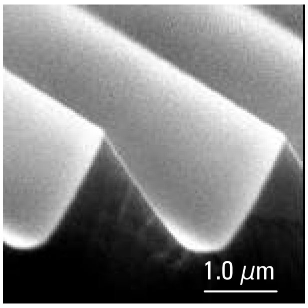


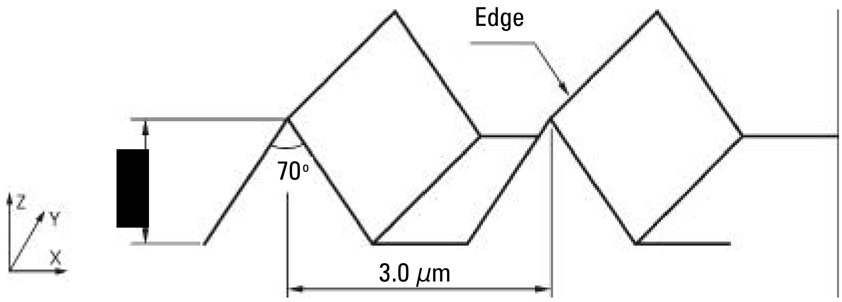


Active area	3x3 mm array
Height of step:	
TGZ 01	20 ± 1 nm
TGZ 02	100 ± 1,5 nm
TGZ 03	500 ± 1,5 nm

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 Gratings TGG01





Active area	3x3 mm array
Edge radii	less than 10 nm
Pitch	3,0 µm

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.

Highly Oriented Pyrolytic Graphite

HOPG (Highly Oriented Pyrolytic Graphite) consists of plains of carbon atoms, which (plains) are highly oriented between each other. This property enables to use HOPG like a substrate for different samples.

The HOPG is manufactured at temperature of 3273 Kelvin. The surface of HOPG does not outgase at temperature range up to 600 C and remains stable at temperature up to 2000 C (in inert environment).

HOPG consists of plains of carbon atoms, which (plains) are "highly oriented" between each other, i.e. in ideal variant they are parallel to each other.

This parallelness is characterized by "mosaic spread angle". The less this angle is the higher is the quality of the HOPG.

HOPG is used for many applications, including using it as very smooth substrates for investigation of samples under microscopes.

Technical specification		
Quality - ZYA	**Quality - ZYB**	**Quality - ZYH**
Mosaic spreads less than 0.4° ±0.1°	Mosaic spreads less than 0.8° ±0.2°	Mosaic spreads less than 3.5° ±1.5°
Available standard sizes up to 30x40x2 mm	Available standard sizes up to 50x50x2 mm	Available standard sizes up to 50x50x6 mm

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

STM Topography (I=cost)

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.

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 Spectroscopy (modulation techniques)

Local Barrier Height Imaging (dI/dZ)

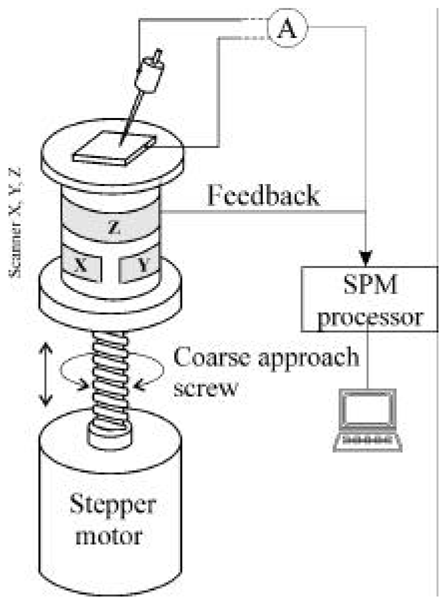
A sample (or tip) vibration lead to tunneling current oscillations to receive a signal dI/dZ (by means of modulating of tunnelling gap and registering the amplitude of current response). This provides information on local height of potential barrier for electrons (local work function). This mode enables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

Imaging of Local Spectral Density (dI/dU)

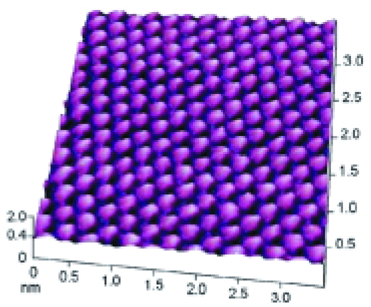
Bias voltage modulation allows to register the signal dI/dU, determined by local spectral density of states of tunneling electrons.

STM Lithography

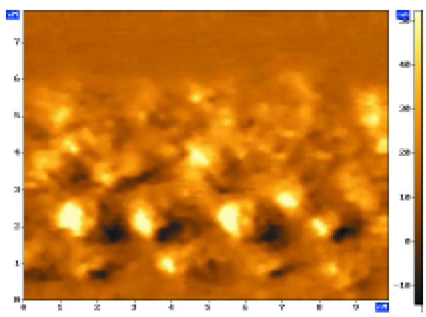
Using this mode you can modify the sample surface by applying the electric pulse.



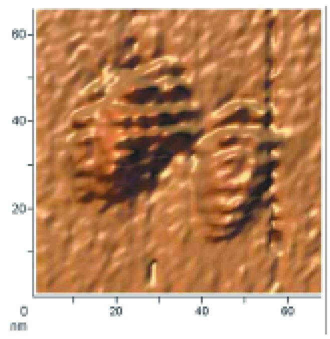
Scheme of Scanning Tunneling Microscope realization



STM image of (HOPG) surface



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



STM image of Parvo Virus on HOPG

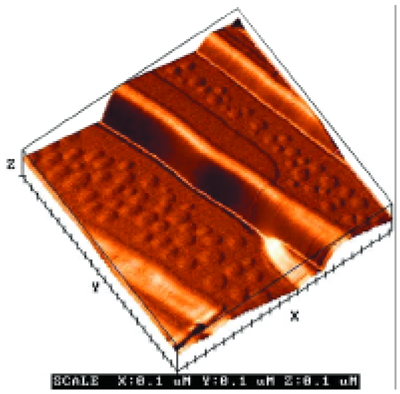
Atomic Force Microscopy

Contact mode

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

Topographic Imaging

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



Imaging of polar plane of threeglizinsulfate (TGS) crystal split obtained in Contact mode

Force Imaging

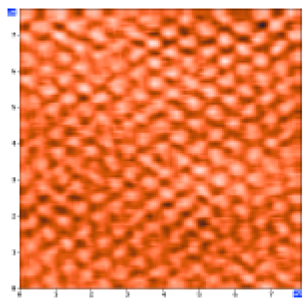
Can be used for scanning relatively flat surfaces, since it can be done more fast and precise without any feedback control. (Z=const)

Force Curve

Force 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 analyze 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 characterize 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.

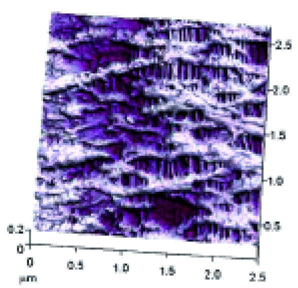


Lateral Force Imaging of Mica

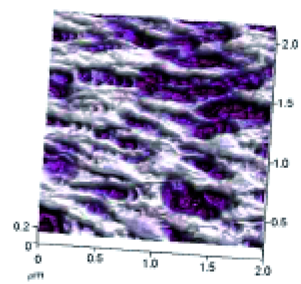
SPM in liquid environment

SPM mode in liquid environment 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 AFM mode 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.



Film of polymer measured in contact mode on air

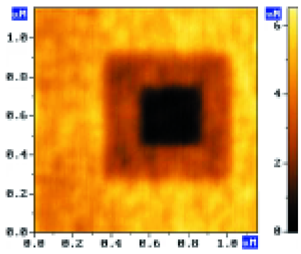


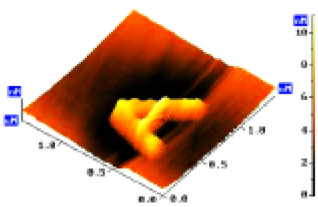
Film of polymer measured in contact mode in liquid environment

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.

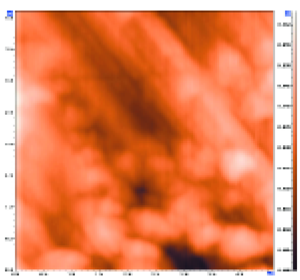




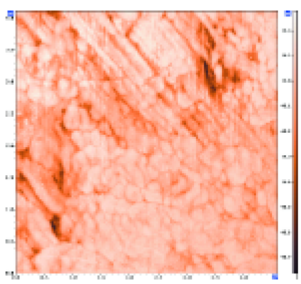
Two Spreading Resistance imaging of film tungsten coated of SiC after applying different lithographies

Adhesion Force Microscope

AdhFM permits to get an information about adhesion ability of the sample. While scanning the Force-Distance Curves are being measured and the Force Value at the moment of jump off 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)

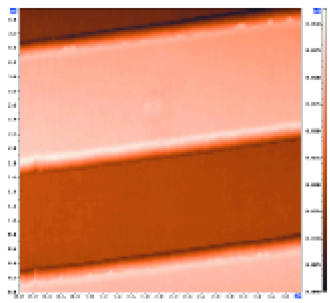


Adhesion Force Imaging (Mix of epoxy and Al boring)

Non-contact mode

In noncontact 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. As a noncontact 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 a surface is used for researching very gentle, easy-destroyed objects. The second mode is applied only in the case when during the scanning even in a 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.



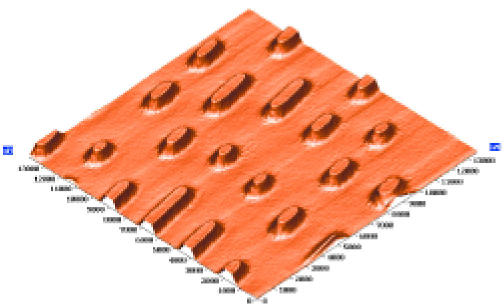
Silicon Grating TGZ. Non-contact Mode

Semicontact Mode (Resonant 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 soft samples.



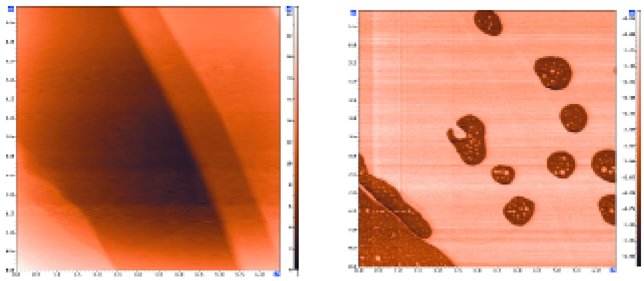
Imaging of CD stamper in Semicontact mode

Force modulation technique

Vibrating piezotube of a scanner which holds the sample and measures the amplitude response of cantilever permits identify and maps differences in surface stiffness or elasticity. This mode is usually done simultaneously with conventional SFM 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.

Phase Imaging

This mode is usually done simultaneously with conventional SFM 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

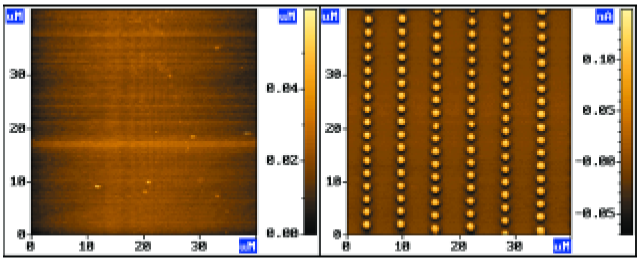
Two-pass Techniques:

In two-pass technique each line is scanned twice. So, in these modes you can simultaneously obtain two images - topography imaging (measured during the first pass) and electrostatic/magnetic/capacitance/potential imaging (measured during the second pass).

The second pass is realized by already known relief in noncontact mode when the tip of the cantilever moves on a determined distance from the sample surface.

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.

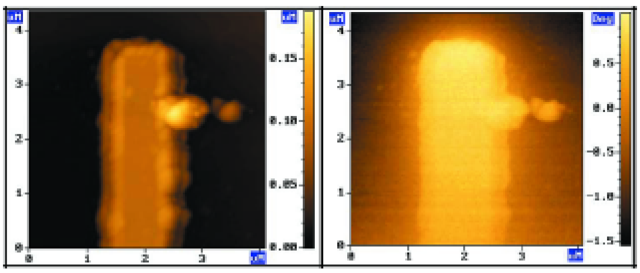


Magneto - Optical disk. From left to right: Topography. MFM imaging

Electrostatic Force Microscopy (EFM)

By using our UltraSharp silicon cantilevers with conductive coating you can simultaneously obtain two images - topography and the distribution of electric forces (EFM). In EFM the voltage between the tip and the sample is applied during scanning and the cantilever 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.



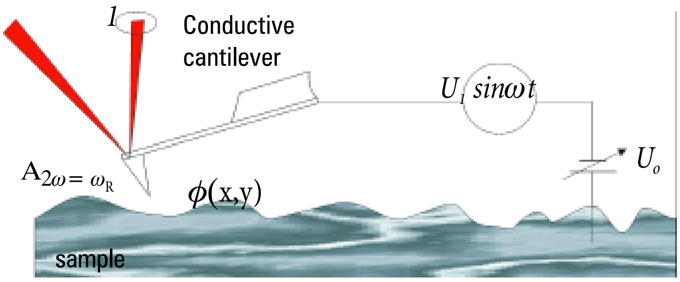
Metallic electrode under the voltage. From left to right:Topography and EFM imaging

Electrodynamic forces.

If the cantilever and the sample are made from conductive materials (surface conductivity is not required) they can be enclosed in electric circuit. Applying constant U_0 and alternating $U_1 sin\omega t$ voltage it is possible to initiate an attraction and to register the force of this attraction. If the electric capacity of cantilever-sample system is equal to C then electric energy which is accumulated in capacitor will be equal to $E = \frac{CU^2}{2}$. The force of cantilever attraction to the sample surface is equal to

$$F = \frac{\partial E}{\partial Z} = -\frac{1}{2} U^2 \frac{\partial C}{\partial Z}$$

The full voltage between the sample and the cantilever is equal to $U = (U_o - \phi(x,y)) + sin(\omega t)$, - the value of surface potential in the measuring point.



The scheme of measuring in Kelvin and non-contact capacitance mode. The amplitude of the cantilever oscillation A is registered by an optico-position system in which the intensity of reflected laser ray in-focused to the reflecting cantilever surface is registered by the four quadrant photodiode (1).The cantilever deviations are activated by electric field of the cantilever-sample gap.

The force between the sample and the cantilever is equal to:

$$F_z = \frac{1}{2}[(U_o - \phi(x,y))^2 + (U_o - \phi(x,y))^2 U_1 sin\omega t - \frac{1}{4} U_1^2 cos(2\omega t)]\frac{\partial C}{\partial Z} \quad (1)$$

So, the cantilever will be influenced by the force at the zero frequency which is equal to:

$$F_z(\phi = 0) = -[\frac{1}{2}(U_o^2 - \phi(x,y))^2 + \frac{1}{2}(U_1^2)]\frac{\partial E}{\partial Z} \quad (2)$$

the first harmonic of the activate signal:

$$F_z(\phi) = -[(U_o - \phi(x,y))U_1 sin\omega t]\frac{\partial C}{\partial Z} \quad (3)$$

the second harmonic of the activate signal:

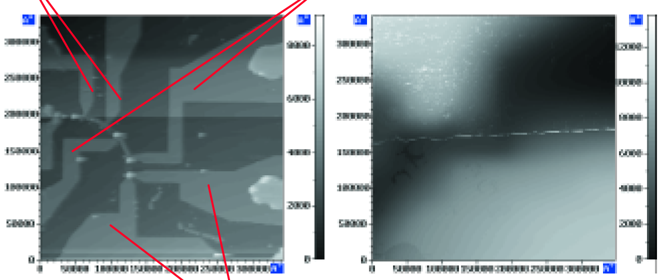
$$F_z(2\phi) = [\frac{1}{4} U_1^2 cos(2\omega t)]\frac{\partial C}{\partial Z} \quad (4)$$

Constant force change(2) is caused by both capacity change and the surface potential that makes difficulties for result assignment.

Scanning Kelvin Microscope (SKM)

The force registration on the first harmonic (3) allows to obtain a map of surface potential distribution $\phi(x,y)$ in the case when during the scanning this force is kept up equal to zero by constant voltage U_o change. In accordance with (3) $F_Z(2\phi)=0$ in the case when $U_o=\phi(x,y)$ with any value of activate potential U_1 and with any value of surface capacity derivative.

U_1 should be maximum in Kelvin mode, the frequency of alternating electric field should be equal to the resonant frequency of the cantilever. During the second pass the amplitude of the cantilever oscillation is kept equal to zero by means of constant voltage value U_o change with a feedback circuit using. Thus the map of voltage change is interpreted in accordance with (3) like distribution of surface potential or work function.



Topography SKM mode imaging

Scanning Capacitance Microscopy

The force on the second harmonic according to the frequency of activate voltage (4) changes just by the change of $\frac{\partial C}{\partial Z}$ value.

The capacity of the cantilever-sample system C is summed up from two capacities included consecutively - the gap capacity which depends on the distance cantilever-sample C_Z and surface capacity $C_{X,Y}$ and is equal to

$$C=\frac{C_z C_{x,y}}{C_z+C_{x,y}} \qquad (5)$$

In approximation of the plain capacitor:

$$C_Z \sim Z^{-1} \qquad (6)$$

Expression (4) can be approximated like:

$$F_Z(X,Y)=\frac{U_1^2}{4}\sin(2\omega t)\frac{\partial C}{\partial Z}(X,Y)\approx\frac{U_1^2}{4}\sin(2\omega t)\frac{C_{X,Y}^2}{ZC_z+\left(1+\frac{C_{X,Y}}{C_z}\right)^2} \qquad (7)$$

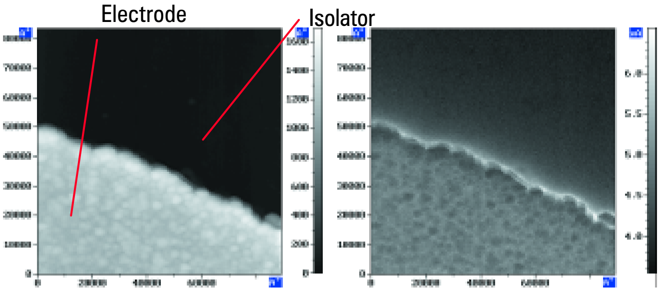
This force can be registered with the maximum sensitivity in the case when the frequency of its change is equal to the resonant frequency of the cantilever

$2\omega=\omega_R$

$C_z Z\approx const$ in the case of C_Z is about or more than $C_{x,y}$, change of the force in the process of scanning (7) will be determined by surface capacity change $C^2_{x,y}(x,y)$.

Change of the force (7) during non-contact scanning causes the change of the cantilever oscillation amplitude. It is caused by both change of the force and change of the resonant frequency of the cantilever that causes displacement of the phase of the registered signal. Therefore both amplitude and phase of the cantilever oscillations should be registered for right results interpretation.

Lithography



Topography SCM mode imaging

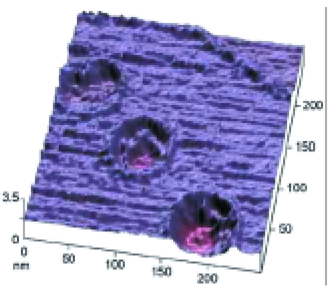
Lithographic operations are designed to change the topography or properties of the surface at scales comparable with the probe dimensions.

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 exists like:

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



STM image of conducting LB film after STM Electric Lithography

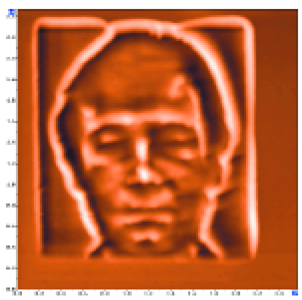


Image of polycarbonate film on silicon surface after Resonant Mode Lithography

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) or up to 300°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).

SNOM

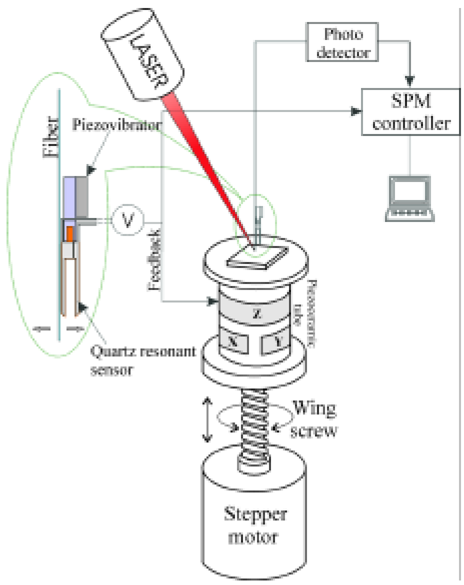
Near-field scanning optical microscopy (SNOM) uses a special type of scanning probe microscope that operates using visible light. Traditionally, the resolution of optical microscopes has been limited by the wavelength of light to about half a micron. SNOM improves the resolution of an optical microscope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

Shear Force Mode - Topography Imaging

Optical input/output

The SNOM system can be supplied in two configurations:
- scanning by the sample
- scanning by the optical fiber



Scheme of Scanning Near Field Optical Microscope realization

ECSPM

Electrochemical SPM measures topographical changes as induced by electrochemical reactions in electrolyte solutions. For functioning of Electrochemical SPM use counter electrode (liquor of electrolyte), 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 the follow modes:

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:

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

- PtIr wire -the most suitable for STM tests
- Glass coated tips
- Poly-a-methylstyrene
- Silicon dioxide (SiO_2) (relatively good coating)
- The so-called "apiezon" mastic (can be a promising insulating coating (material) for tips)
- Paraffin coated tips (show relatively good results).