Closed-loop scanner control.

To improve the scanning performance and to expand the instrument functionality, closed-loop control with the use of the equivalent scanner technique was added.

The equivalent scanner is an external twin of the working scanner, which has capacitance sensors to register actual movement of the scanner in the X, Y and Z dimensions. The working and equivalent scanners are connected parallel to the auxiliary control unit and then to the SPM controller in order to provide movement synchronism and closed-loop control of scanning.

This way the equivalent scanner improves the scanner linearity (non-linearity in vertical (Z) dimension is less than 3%) and compensates the creep effect allowing one-step zoom as accurate as 2% from the whole scanning range in any part of the range.

Now you can zoom in on a feature of interest at once (one step zoom) from any position within the scan range in order to characterize this feature at higher resolution. Moreover, the equivalent scanner improves the accuracy/linearity of the vector nanolithography operation and allows experiments where manipulation of nanoparticles is required.

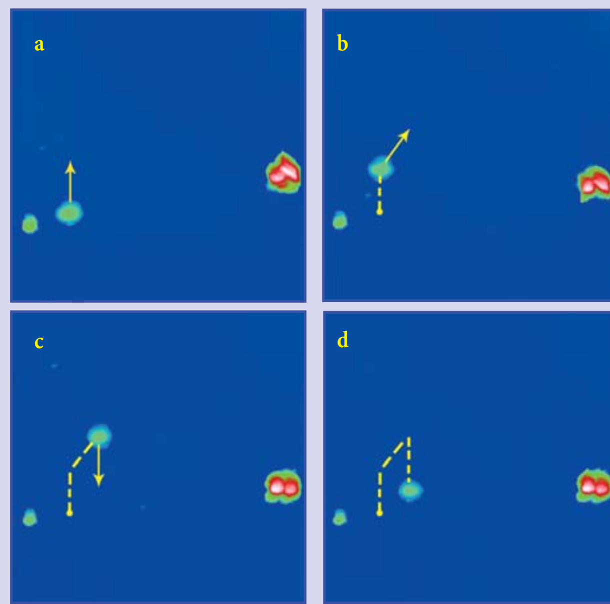
In addition, our implementation of the equivalent scanner technique provides the Solver PRO with a number of new functional capabilities.

The scanning range in a vertical dimension is increased two times. For example, the maximum Z range of 100x100x5 µm scanner will be increased up to about 10 µm, which could be very important for the investigation of biological cells, tissues, MEMS and other samples with high relief.

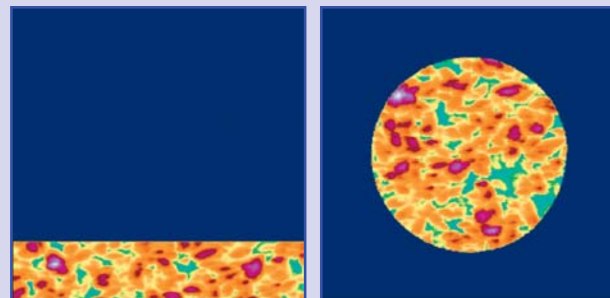
Using the equivalent scanner you may increase the scanning speed by 3-3.5 times (up to 6 Hz) and substantially reduce the time of the experiment. It becomes possible due to the SpiralScan™ technique, which allows scanning not line-by-line, but along a spiral to avoid the back tracing and scanner re-oscillation at extreme points. One more advantage of the SpiralScan™ is that you can start imaging a selected feature on your sample surface, immediately, because the technique allows you to start scanning from the center point. Whilst in line-by-line scanning the image is created from a border side of the square scanning area and you need to wait for some time until the probe reaches the selected feature on the sample surface.

Atomic Force Acoustic Microscopy.

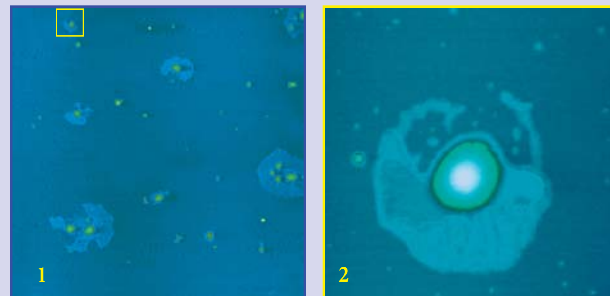
The optional module of Atomic Force Acoustic Microscopy (AFAM) provides you with the unique possibility to perform contrast imaging of the local hardness distribution on soft as well as on hard samples that is hardly possible using other techniques, such as Phase Imaging or Force Modulation. What is even more valuable, AFAM allows Young's modulus to be quantitatively determined at each point of the scan.



Carbon nanoparticles (C^{60}) on HOPG. Nanomanipulation of a nanoparticle using the Contact AFM Vector Nanolithography technique in the specified direction (see the yellow arrow). Image size: 1.3x1.3 µm.
Reference point: red point (nanoparticle) on the right.
b) Relocation 102 nm; c) Relocation 113 nm; d) Relocation 138 nm.
Images are obtained in Semicontact AFM mode.



Nanocrystallin Ti film. Topography image in semicontact mode. Line-by-line scanning (left) and SpiralScan™ (right). Scan time: 20 s. Selected scan area: 5x5 µm.



Polyethylene crystals on mica substrate. Zooming from the full scan range to the small feature at one step. 1. Scan size: 47x47x0.065 µm. 2. Scan size: 4x4x0.03 µm.

HIGHLIGHTS

- Open design, modularity and upgradeability. The instrument can be configured according to a certain application in order to optimize the measurement conditions.
- Small, and large samples with unlimited size can be examined.
- A big scanning range in all three dimensions XYZ (up to 150x150x15 µm) available in some system configurations.
- Fast SpiralScan™ up to ~6 Hz reducing the time per measurement ratio.
- Atomic and molecular resolution in air and liquid in contact AFM, semicontact AFM and STM (non-conductive fluids) modes.
- High resolution nanolithography - 10 nm.
- Manipulation of nanoparticles down to 50 nm in diameter.
- 16 SPM techniques in one measuring head: AFM (contact + semicontact + non-contact)/ LFM/ Phase Imaging mode/ Force Modulation mode/ Adhesion Force Imaging/ dc & ac MFM/ dc & ac EFM/ SRI/ AFM Lithography (Force & Current)/ SCM/ SKM).
- Full software system control allows operation in a big number of modes with one probe without any hardware readjustment.
- Integrated, easy-to-use optical viewing system delivers optical resolution of 3 µm.
- The best contrast imaging of local hardness distribution on soft and hard samples in AFAM mode.
- Quantitative determination of Young's modulus in every point of the scan image in the mode of AFAM spectroscopy.
- Compatibility with one of the best nanoindentation system (Triboscope, Hysitron Inc., USA) for mechanical properties investigation.
- Cantilever tip quality and tip-induced image distortion estimation capability by means of the Deconvolution software.
- Powerful and user-friendly data acquisition and image analysis software.
- "Smart Software" - built-in software wizard for quick start of measurement.
- "SPM Techniques Educator" - educational software package for quick learning of different types of SPM techniques.
- Universal probe holder makes it possible to use almost any commercially available cantilever probes as well as your own home-made probes required for a certain application.

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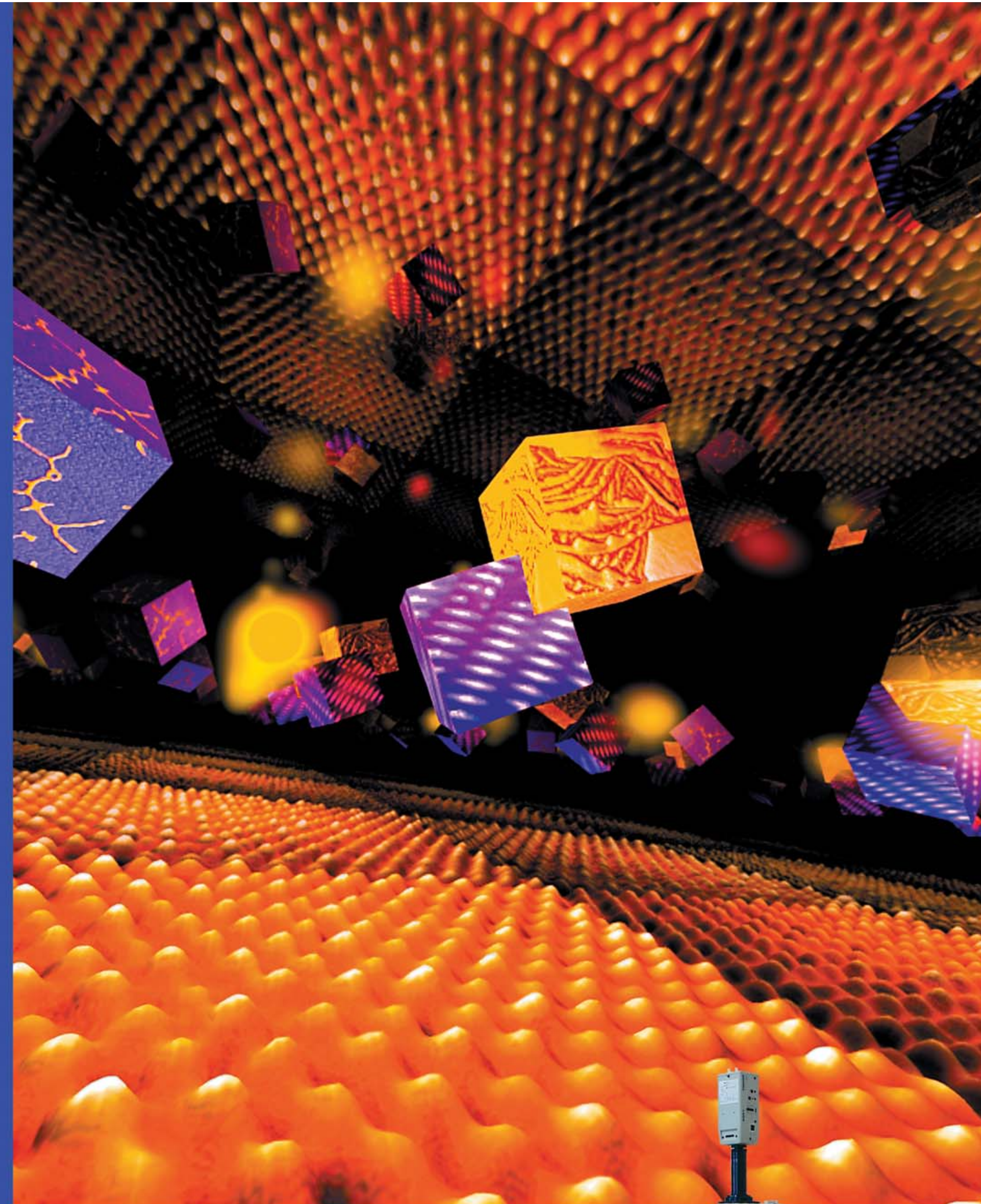


SOLVER PRO

SCANNING PROBE MICROSCOPE

SOLVER PRO

Solver PRO is a powerful instrument for

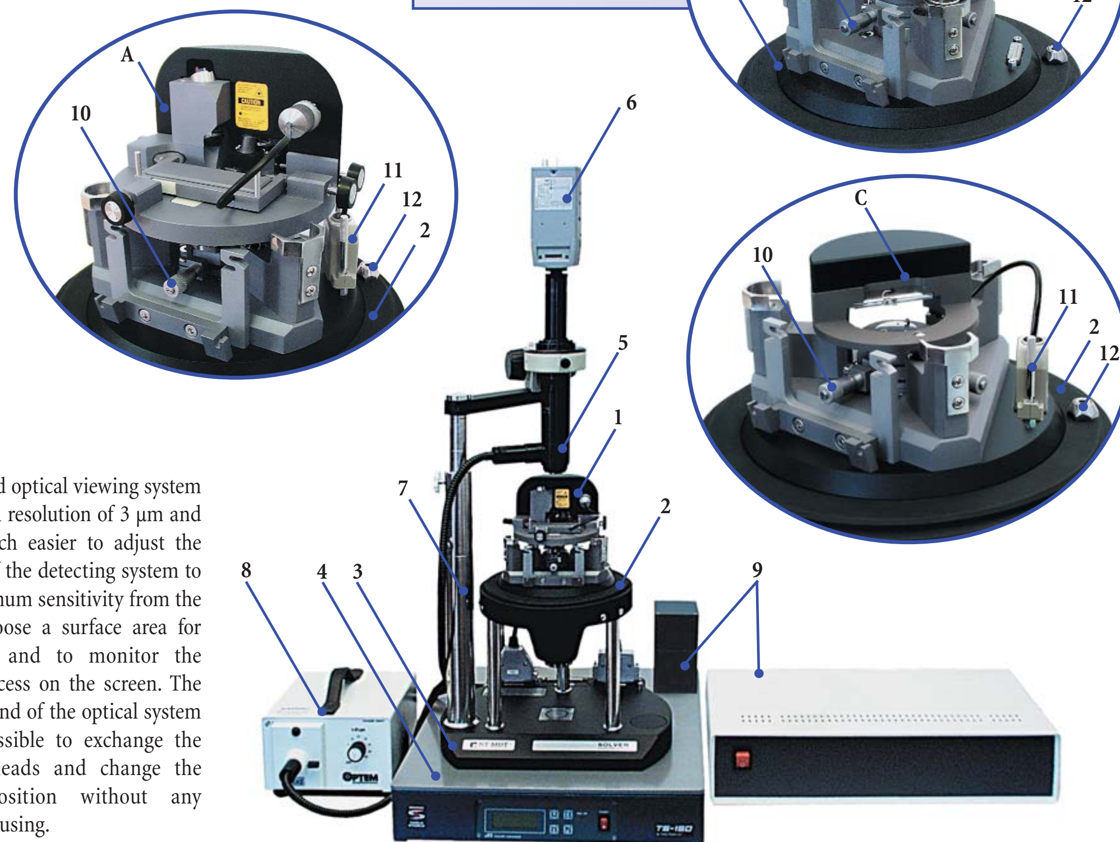
the investigation of new materials, thin films, polymers, semiconductors, biological samples and for any other applications which require atomic or molecular resolution in air, gas or fluid environments, as well as in-situ examination of structural changing on the sample surface during heating.

Solver PRO configuration.

1. Measuring head;
   A. AFM measuring head (scanning by sample);
   B. AFM measuring head (scanning by probe);
   C. STM measuring head (scanning by sample);
2. Base unit with automatic approach and positioning stage;
3. Support base;
4. Active vibration isolation;
5. Optical microscope;
6. CCD camera;
7. Adjustable stand for optical viewing system;
8. Light source;
9. Closed-loop scanner equivalent (CLE);
10. Positioning screws;
11. Replaceable scanner connection;
12. Air/ gas inlet.

The Solver PRO Scanning Probe Microscope is NT-MDT's newest development in the field of instrument-making, incorporating the latest technological know-how in scanning probe microscopy. Solver PRO is absolutely versatile due to its functionality and measuring capabilities, but at the same time it is very easy to use. This unique instrument will open up new horizons for the thorough investigation of different kinds of samples, delivering resolutions on the atomic/molecular scale in air, gas and liquid environments as well as the opportunity to use almost any known scanning probe microscopy technique. Moreover, you may heat the sample up to 150°C (heating up to 300°C is possible in a different system configuration) and observe structural changes on the sample surface.

The modular system design is unique too, because it allows you to configure the instrument for your own application. For instance, the original construction of the Solver PRO base unit provides a simple procedure of scanners replacement, set up of the sample holder, AFAM module, heating stages and so on depending on the experimental requirements. The tip to sample approach procedure is automated, but doesn't exclude manual operation to speed up the preparation for the experiment. Furthermore, due to the base unit construction it's possible to mount any type of atomic force (AFM), scanning tunneling (STM) and shear force measuring heads. The scanning range may vary from 1.3 to 15 microns along Z direction, and from 3 to 150 microns along XY.



The integrated optical viewing system has an optical resolution of 3 μm and makes it much easier to adjust the laser beam of the detecting system to get the maximum sensitivity from the probe, to choose a surface area for examination and to monitor the scanning process on the screen. The adjustable stand of the optical system makes it possible to exchange the measuring heads and change the scanning position without any additional focusing.

The instrument allows scanning either by probe or by sample. In the scanning-by-probe configuration a measuring head with the built-in scanner traces the probe across your sample. The advantage of this scan type is the availability of a wide scanning range (up to 100x100x5 μm) that allows the investigation of large and heavy samples (up to 100 mm in diameter). In addition, the measuring head can be used for stand alone operation allowing samples with unlimited size to be studied.

In the scanning-by-sample configuration a replaceable scanner installed into the SPM base unit traces the sample under the probe. The highest resolution from molecular down to atomic scales in STM or contact AFM modes can be achieved using the scanners 3x3x1.3 μm or 10x10x2 μm due to their low noise level (0.24 A RMS in vertical (Z) dimension with acoustic/vibration isolation) and extremely small scanning steps (22 bit compound DAC is used in the SPM controller).

The unique feature of the Solver PRO is that you may increase the scan range in the horizontal dimension (XY) up to 150 μm and/ or in the vertical dimension (Z) up to 7.5 μm using simultaneously the scanning-by-sample and scanning-by-probe configurations (DualScan™ mode). Moreover, it's even possible to increase the scan range in the vertical dimension (Z) up to 15 μm using both scanning configurations and CLE.

The unique probe holder design allows almost any commercially available cantilever probes to be used as well as the set up of different probes types, including your own home-made probes.

Hence, the Solver PRO brings together the whole series of scanning probe microscopes in a single platform, providing all of the major SPM techniques. Its state-of-the-art design and powerful software, which can be easily set up for any measuring technique, will substantially reduce the time required to thoroughly examine the sample and obtain full and accurate information about the sample properties, i.e. surface topography, magnetic and electric field distribution, local hardness and elasticity (including Young's modulus calculation), friction forces, adhesion etc.

Software.

The Solver PRO software is a full-featured, user-friendly package compatible with Windows 95/98/XP that enables quick data acquisition and the most comprehensive image processing and analysis. The special built-in "Smart Software" wizard will step-by-step guide you through all settings required for the scanning operation (e.g. laser and photodiode adjustment, cantilever resonance frequency adjustment, setting up parameters for operation in all available SPM modes), making it so easy to start your experiment right away.

To quickly learn how to use the instrument in different measuring modes, the special educational program - "SPM Techniques Educator" can be supplied with the Solver PRO. This program consists of a number of Flash animations together with brief descriptions of each technique available with the instrument.

Solver PRO Technical Specification.

	Scanning by sample	Scanning by probe
Sample size	Up to ∅40x10 mm Up to 12x12x2 mm with the liquid cell use	Up to ∅100x20 mm and unlimited for measuring head used for stand alone operation
Scanners*	3x3x1.3 μm (±10%); optional: 10x10x2 μm (±10%), 50x50x2.5 μm (±10%)	100x100x5 μm (±10%); optional: 50x50x2.5 μm (±10%); 80x80x3.5 μm (±10%) (only for Shear Force)
Min. scanning step (DAC)	0.0004 nm; 0.0011 nm; 0.006 nm	0.012 nm; 0.006 nm; 0.009 nm
SPM heads	AFM STM: 30 pA-50 nA, RMS noise 4 pA (standard pre-amplifier); 10 pA-5 nA, RMS noise 1.5 pA (low current preamplifier)- optional Shear Force - optional	AFM Shear Force - optional
Optical viewing system	Resolution 3 μm Numerical aperture 0.1 Magnification with CCD 58x to 578x Horizontal field of view 5.1 (2) to 0.5 mm	
XY sample positioning	5x5 mm	
Positioning resolution	5 μm	
Heating	130°C	
Temperature stability	0.1°C	
Voltage supply	90-240 V, 50-60 Hz	
Power	60 W	
Vibration isolation	Active vibration isolation system: Active damping (0,6-100 Hz), >100 Hz - passive damping. Table top 400x400 mm (Halcyonics, Germany). Electric shielding and acoustic isolation is provided by the special cast metal hood.	
Fully software controlled device		
* - scan range in Z direction is increased two times when CLE - Closed-loop equivalent scanner is used		

Microscopy modes:

in air: STM/ Atomic Force Microscopy (AFM) (contact + semicontact + non-contact)/ Lateral Force Microscopy (LFM)/ Phase Imaging mode/ Force Modulation mode/ Adhesion Force Imaging/dc & ac Magnetic Force Microscopy (MFM) / dc & ac Electrostatic Force Microscopy (EFM)/ Scanning Capacitance Microscopy (SCM)/ Kelvin Probe Microscopy (KPM)/ Spreading Resistance Imaging (SRI)/ Atomic Force Acoustic Microscopy (AFAM) - optional;

in liquid: Atomic Force Microscopy (AFM) (contact + semicontact)/ Lateral Force Microscopy (LFM)/ Phase Imaging mode/ Force Modulation mode/ Adhesion Force Imaging.

Spectroscopies: AFM (force-volume imaging, amplitude-distance, phase-distance curves), STM (I(z), I(V), Local Barrier Height (LBH), Local Density of States (LDOS).

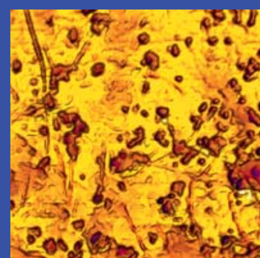
Lithographies:

in air: AFM (Force (scratching + semicontact) and Current (dc + ac))/ STM;

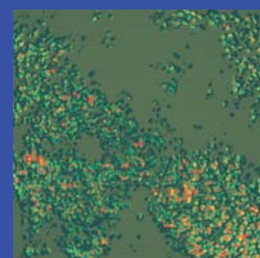
in liquid: AFM (scratching + semicontact).

Nano-manipulations: Contact Force.

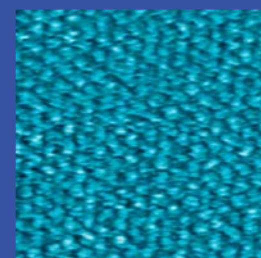
SOLVER PRO



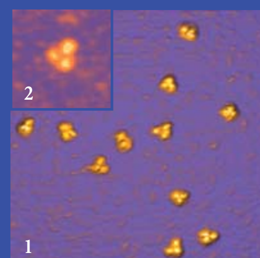
Carbon nanotubes embedded in polymer matrix. Phase imaging mode. Scan size 3.2x3.2 μm.
Sample courtesy of Dr. J. Loos, Technical University of Eindhoven, the Netherlands.



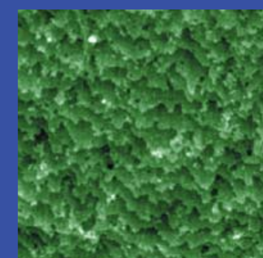
Cu-CrN composite. Spreading resistance imaging. Scan size 1.6x1.6 μm.



Atomic resolution on mica in liquid. Contact AFM image. Scan size 12x12 nm.

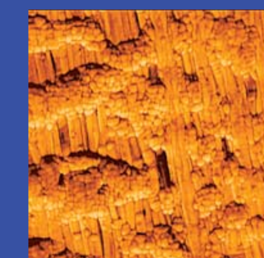


Monoclonal antibodies 1RK2 to A-chain of ricin (IgGl). Topography imaging in semicontact mode.
1. Scan size: 270x270x3nm.
2. Scan size: 60x60x3nm.

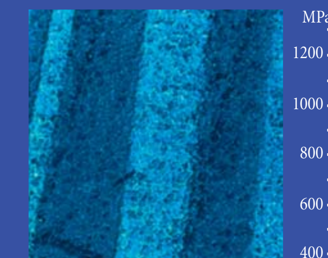


Monoatomic steps on $SrTiO_3$. Topography imaging in semicontact mode. Scan size: 1x1 μm.
Sample courtesy of Dr. Ch. Gerber, IBM Zurich Research Laboratory, Switzerland.

Ultrathin titanium film. AFM nanolithography image obtained by electrical local probe oxidation technique. Scan size 1.9x1.9 μm.



Polypropylene membrane. Phase Imaging mode. Scan size: 1.75x1.75 μm.
Sample courtesy of I. Volegova, Karpov Institute for Physical Chemistry, Moscow, Russia.



Stripes of low and high density polyethylene with different elasticity. Young Modulus map derived from Atomic Force Acoustic Microscopy (AFAM). Scan size: 47x47 μm.