SmartSPM™

Simplifying surface characterization at the nanoscale

AIST-NT at MRS 2007 exhibit, Boston, USA

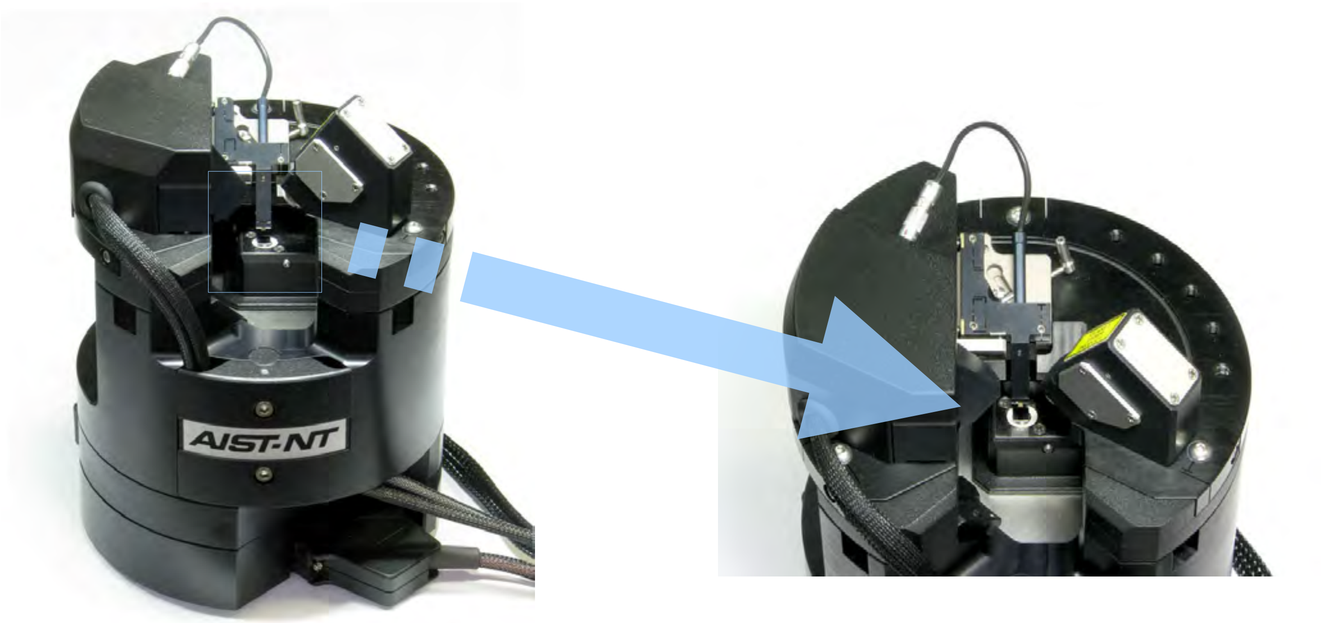
AIST-NT Inc.

is a young dynamic company founded by a team of researchers and design engineers in 2007 as a spin-off from NT-MDT. Our main focus is innovative research and development of advanced integrated scanning systems for nanotechnology.

- Scanning Probe Microscopy
- Custom design, integration and OEM
- Advanced scientific research and development

SmartSPM™

Simplifying surface characterization at the nanoscale



Fully automated

SmartSPM can be automatically adjusted before starting measurements

High speed 100 µm scanner

(scanner resonant frequencies higher than 7kHz XY & 15kHz Z), capacitive sensors for high linearity & accurate positioning

1300 nm AFM laser

eliminates interference with VIS light-sensitive biological and semiconductor samples. It also makes it possible to perform simultaneous AFM and fluorescence or Raman scattering measurements without any crosstalk for most popular UV-VIS-NIR (364-830 nm) excitation lasers

Advanced closed-loop control

with active removal of XY phase lag, overshooting & ringing for high speed scanning

True non-contact scanning

and extra safe landing procedure

Digital modular controller

with fast DSP, USB interface and expandable architecture

Automation

- The automated laser-to-tip alignment sets researchers free from this routine operation. This feature also provides a high level of the system adjustment reproducibility that doesn't depend on operator's experience;
- SmartSPM is capable of testing cantilever's reflective coating before starting measurements by mapping the distribution of cantilever's oscillation amplitude. In addition, after the mapping is done, the operator can manually choose the most appropriate position of the laser spot on the cantilever based on his specific measurement requirements;
- The motorized sample positioning in the horizontal plane allows researchers to easily find the surface area where the further scanning is to be done;
- In the automatic mode the operator should only specify the main probe parameters and scan area to let SmartSPM perform the full system adjustment, engage the probe with the sample surface and start scanning;
- The minimal learning period as well as the very quick start of measurements (less than 5 minutes!) makes SmartSPM the perfect solution for any multi-user facilities;
- Both the embedded scripting language (Lua) and DSP programming macro language let the user personalize his SPM experience by extending the SmartSPM software with his custom program extensions in such categories as scanning, force curves, nanolithography, high-throughput screening (HTS) and more.

Optical access

- The SmartSPM design provides open access to the sample enabling using the upright optics with 100x objective (NA = 0.7) and side optics with 20x objective (NA = 0.42). This allows the easy integration with Raman spectrometers;
- The possibility to have not only the top optical access, but also the side one enables the laser exposure with some given polarization and light collection reflected from the sample surface, which is extremely important for TERS (Tip Enhanced Raman Scattering) and scattering SNOM experiments.

Fast scanning

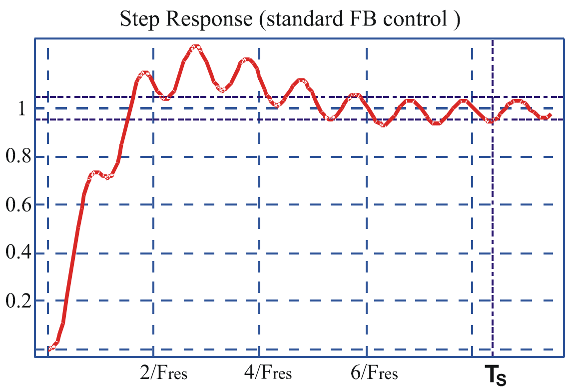
- The SmartSPM fast scanner has the very high resonance frequencies (resonant frequencies are 7kHz in XY & 15kHz in Z), which makes it possible to significantly increase the scanning speed without sacrificing the image quality while using standard cantilevers;
- The innovative scanning system of SmartSPM based on flexure guides made of high quality solid piezoceramic stacks offers the metrological performance;
- The outstanding mechanical stability of SmartSPM plus the high frequency 100 µm scanner allow attaining the atomic resolution on HOPG;
- The thermal compensation of the scanner provides a very low level of thermal drift.

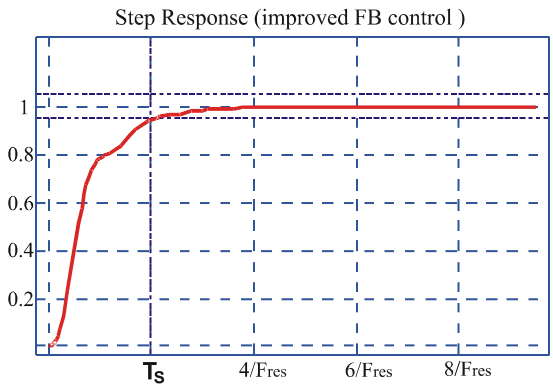
XYZ flexure AFM scanner

- Scanning range: 100µm x 100µm x 15µm;
- High resonance frequency: XY – 7 kHz, Z – 15 kHz);
- 10 times faster scanning than with most of commercially available scanners;
- High linearity for metrological applications;
- Extremely low noise closed loop sensors to provide the monoatomic step resolution.

Improved feedback (FB) control algorithm

substantially reduces settling time for any step response along X, Y and Z directions. This feature allows much faster scanning without any target overshooting and scanner ringing problems. (Ts – settling time, Fres – resonant frequency of scanner oscillations along the given axis)

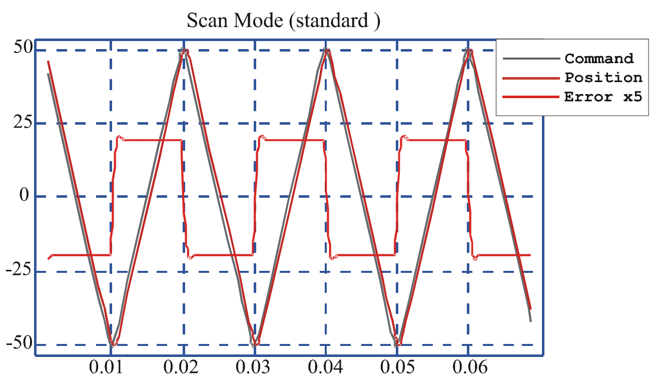


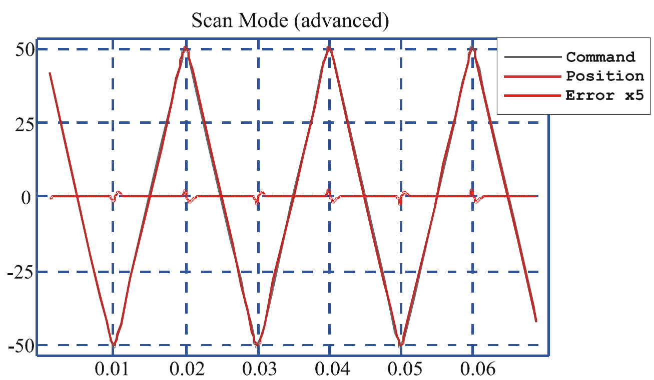


Advanced scanning motion control

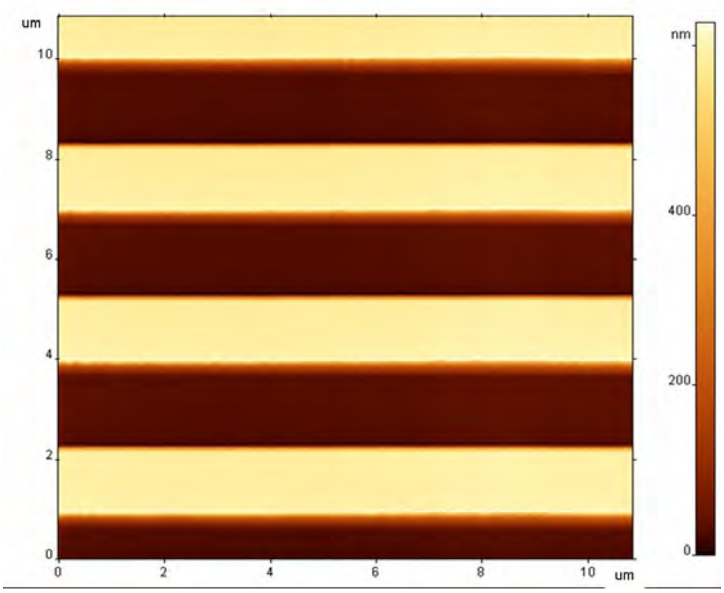
along X and Y directions diminishes phase lag error by several tens or even hundreds of times. Without such control the actual probe position differs from the desired one depending on scanning speed and direction, which causes image distortion and zooming errors.

50 Hz scan along X-axis is shown in the figure below (X-axis - scanner position, Y-axis - time).



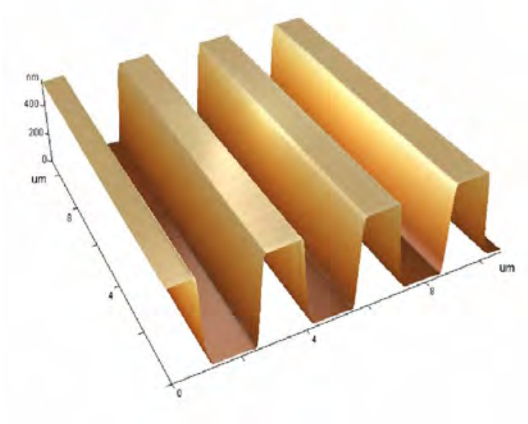


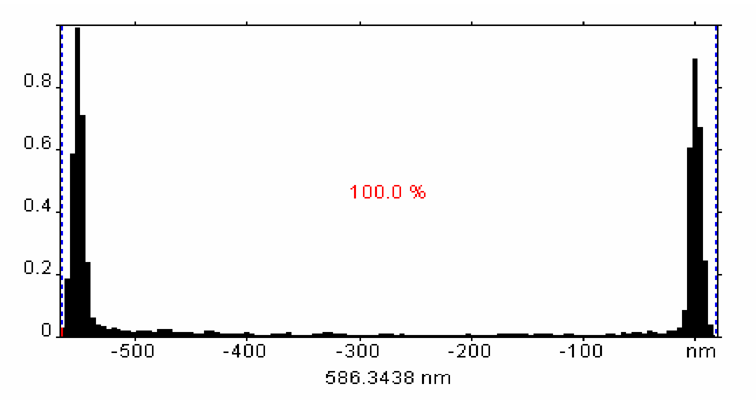
High speed, multi-axis, precise scanning



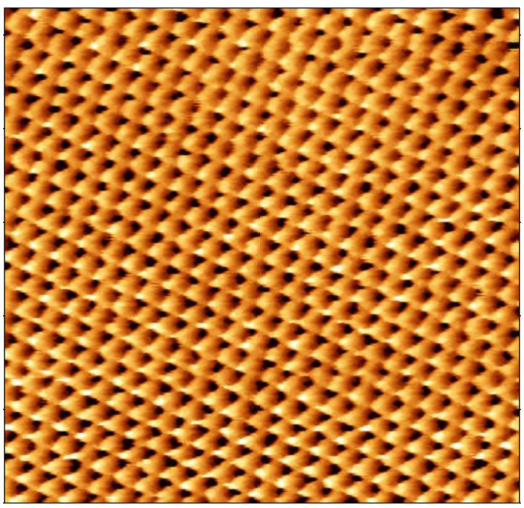
Calibration grating

- Grating period: 3µm;
- Height: 540 nm;
- Contact AFM mode;
- **Scan rate 10 Hz;**
- Scan field: 11x11 um





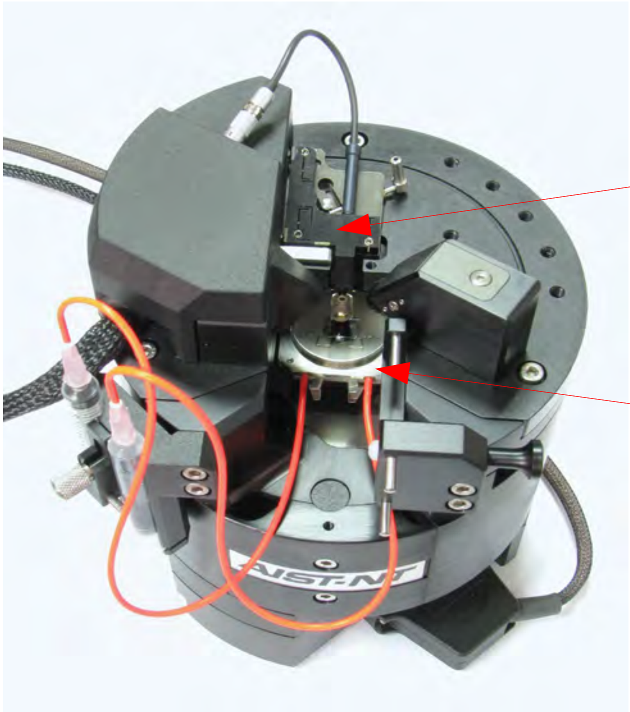
Height distribution hystogram

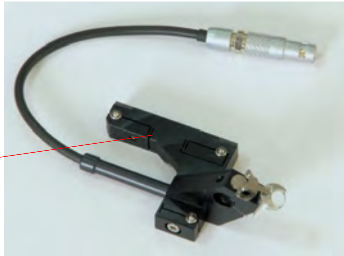


Highly oriented pyrolytic graphite

Atomic resolution of highly oriented pyrolytic graphite (HOPG) obtained with the 100 microns scanner. AFM contact mode, 32 angstroms scan.

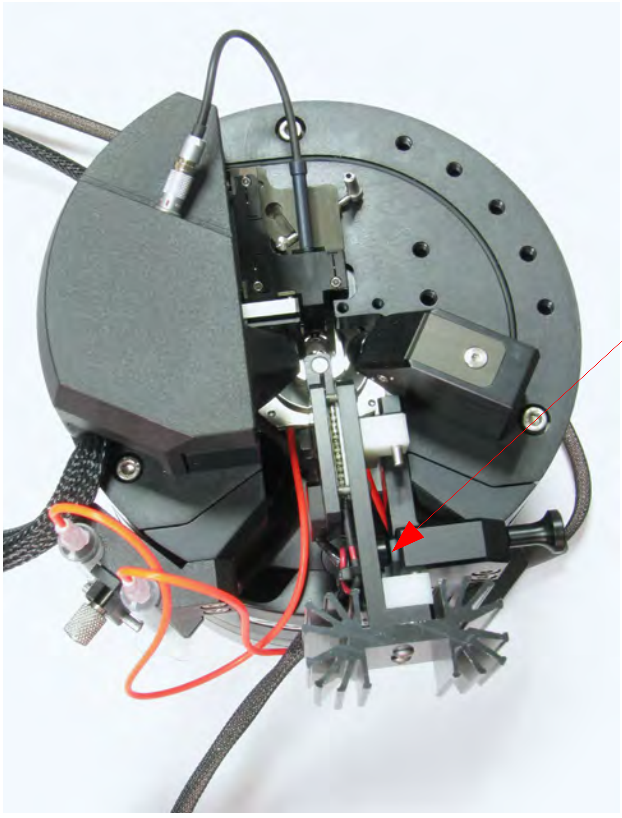
Operation in liquids





Cantilever holder

Liquid cell



Cooler / Heater

- Sample size: 2mm thickness, 25mm diameter;
- Heating: up to 60°C;
- Cooling: below room temperature down to 5°C;
- Sample positioning range: 5x5mm;
- Positioning resolution: 1um;
- Cell size: 40x40x12mm;
- Volume of liquid: 3ml;
- Capability of liquid exchange;
- Autoclave and ultrasonic cleaning of cell parts.

Environmental control

Humidity control

- Relative humidity range 10% - 90%
- Relative humidity stability ±1%
- Humidity sensor inside environmental chamber

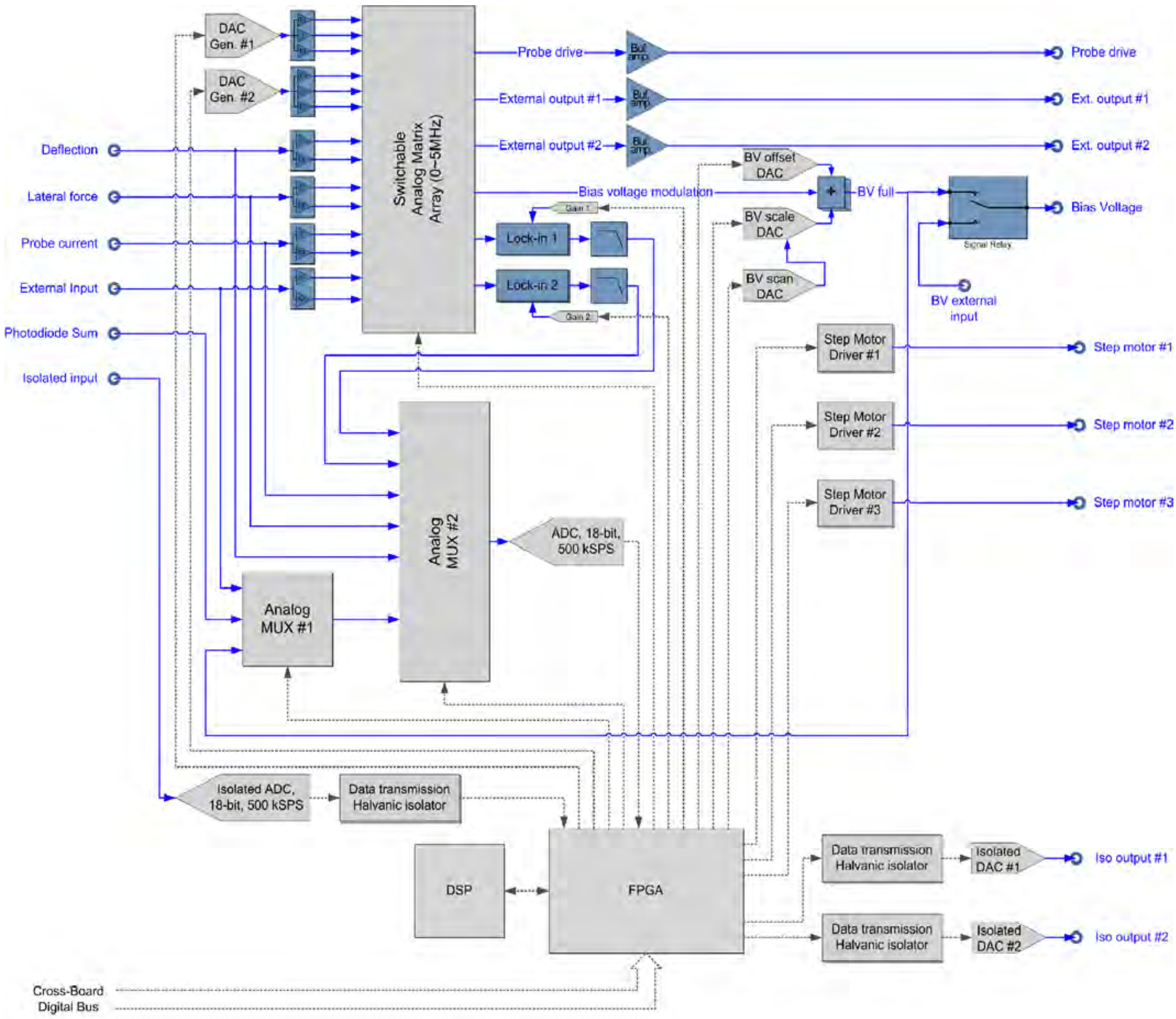
Vacuum control

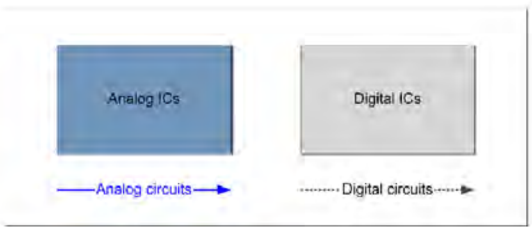
- Vacuum chamber, turbo-molecular pump, scroll pump, vacuum gauge
- Vacuum level 10-2 Pa
- Vacuum chamber can be used to create controlled environment with different gases (air, carbon dioxide, nitrogen, argon, helium) under required humidity.

AI-110 digital controller

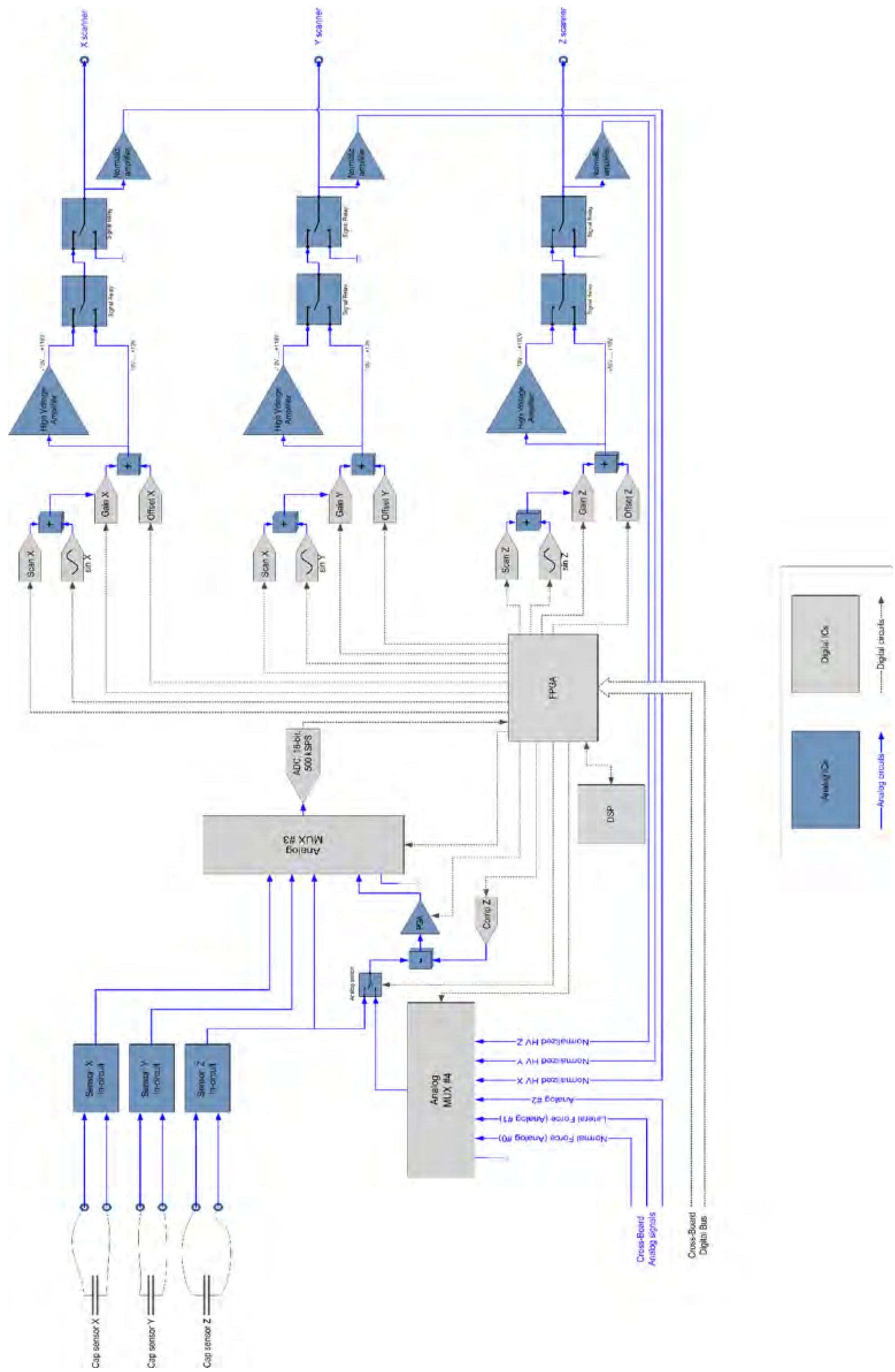
- The modular controller design allows researchers to expand or optimize the AI-110 controller to meet their specific needs as well as easily upgrade it with new boards;
- The high speed DSP makes it possible to synthesize the fully digital PID feedback in three dimensions with the option of extending it up to 9 control channels allowing the integration with other measuring techniques (e.g. Tip Enhanced Raman Scattering (TERS));
- 2 synchronous detectors and 6 digital 32-bit generators with the range up to 5MHz provide simultaneous signal registration at different frequencies (multiple frequencies tracking);
- The AI-110 digital controller offers the control of 7 stepper motors and possibility to extend their number.

AI-110 Digital Controller block diagram (AFM controller board)





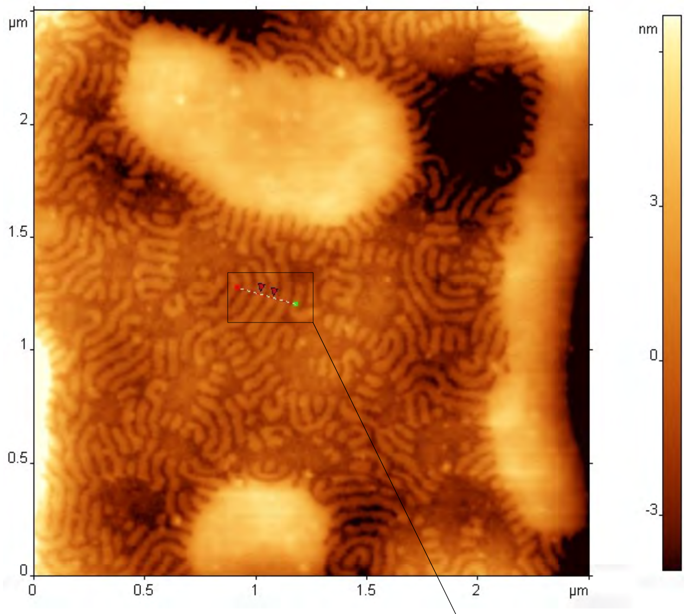
AI-110 Digital Controller block diagram (Scanner controller board)



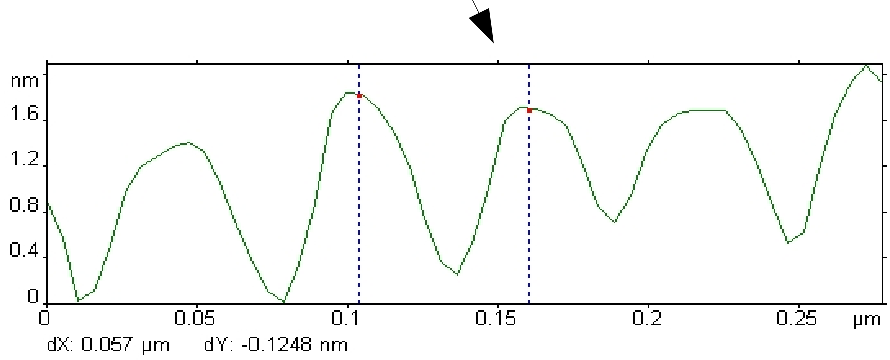
Polymer research

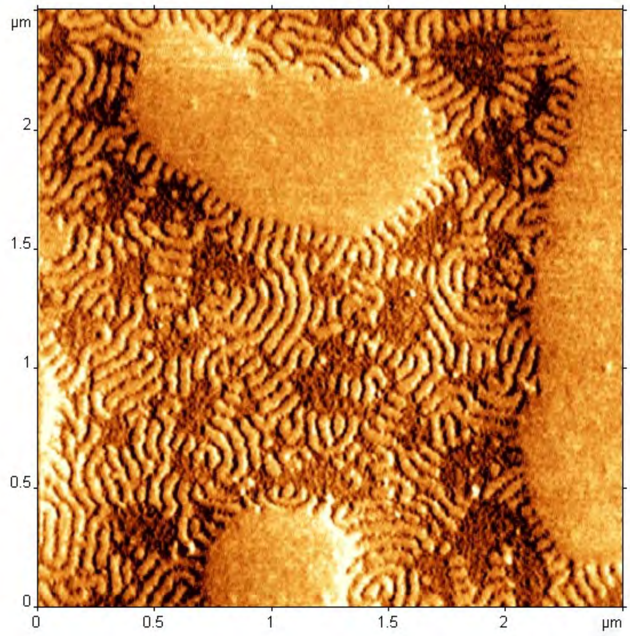
Thin film of PS-PMMA block copolymer

- Scan field: 2.5x2.5µm;
- True noncontact AFM mode;
- Sample courtesy of Dr. Easan Sivaniah (Texas Tech).



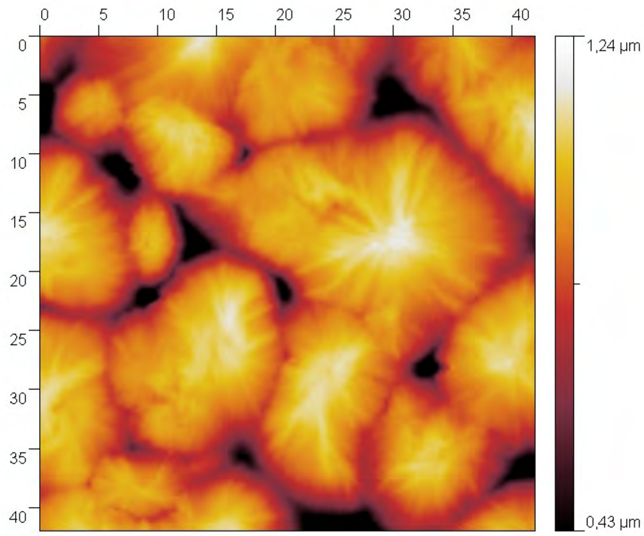
Topography

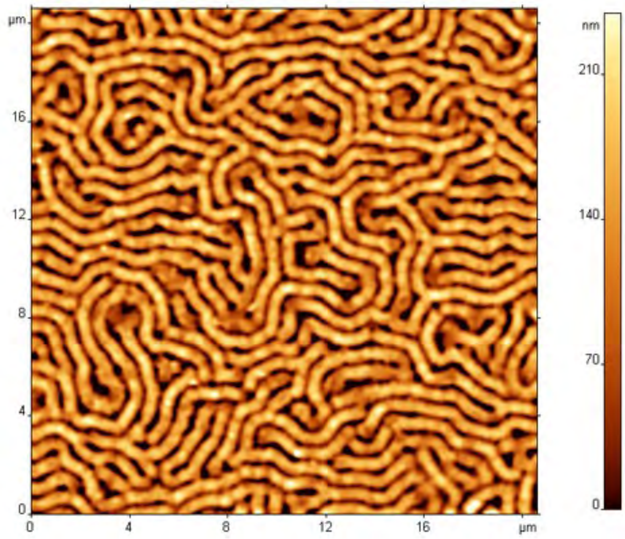




Phase contrast

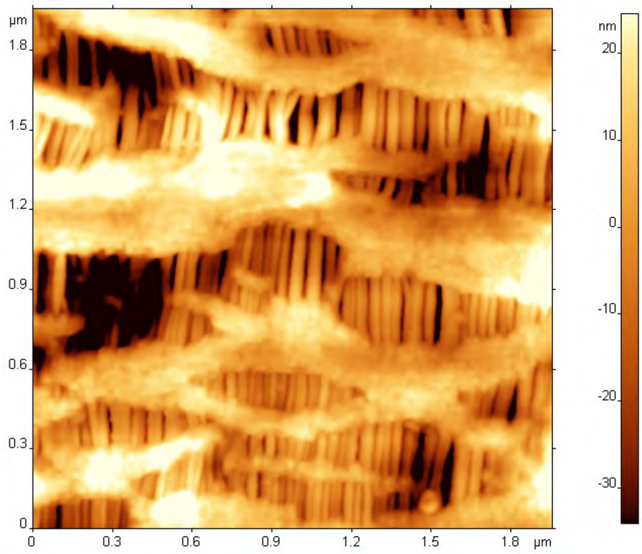
Polymer research

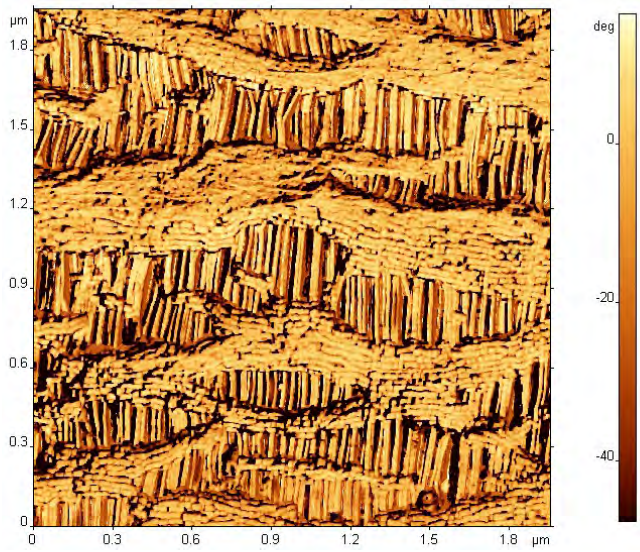




Spherulites of isotactic polypropylene
Sample courtesy of Dr. V. Prokhorov, Institute of Bioorganic Chemistry, RAS.Topography image, 42 µm scan, closed loop active.

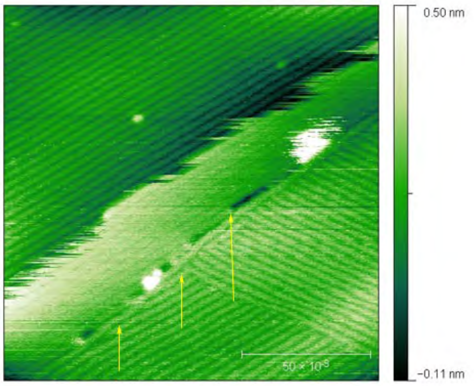
Hydro-2 (Filofocon A) polymer irradiated with an excimer laser. Topography image, 20 µm scan, closed loop active. Sample courtesy of Jan Siegel, PhD, Laser Processing Group, Instituto de Optica - CSIC, Madrid, SPAIN.



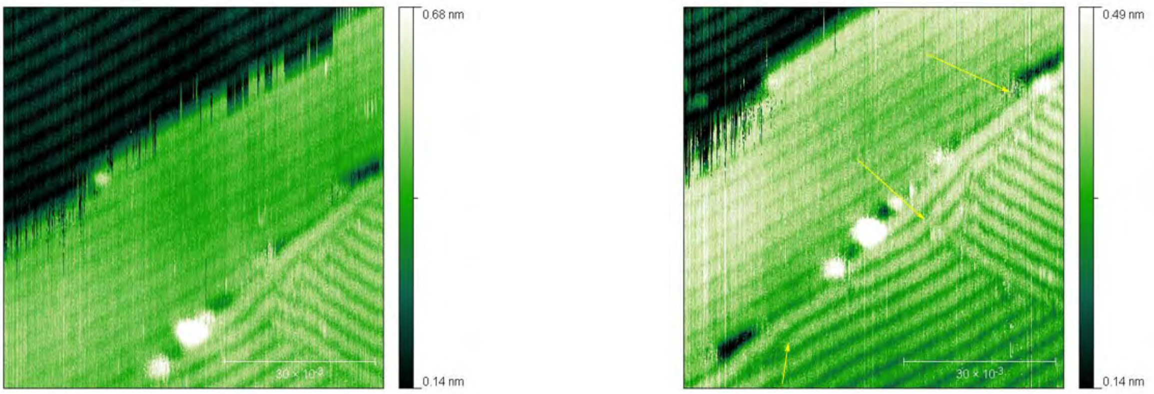


Celgard 2400 polypropylene membrane
Topography (left) and phase(right) images, 2 µm scan, closed loop active.
Sample courtesy of Celgard LLC.

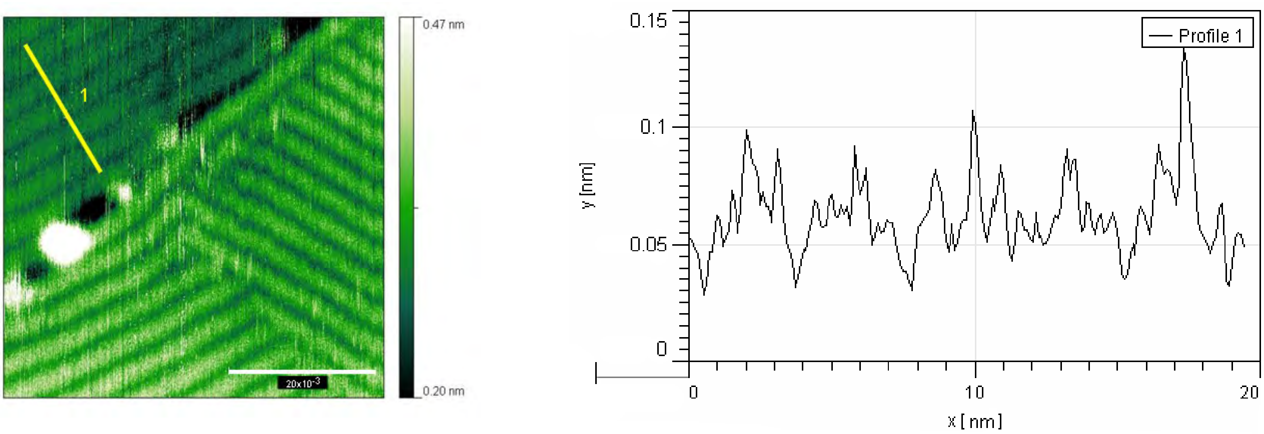
Polymer research ($C_{32}H_{66}$ lamellar stripes)



145×145nm topography scan of C32H66 lamellar stripes taken with fpN01-DLC cantilever. Several interesting defects at the intersection of the islands with different orientation are clearly seen in the image.

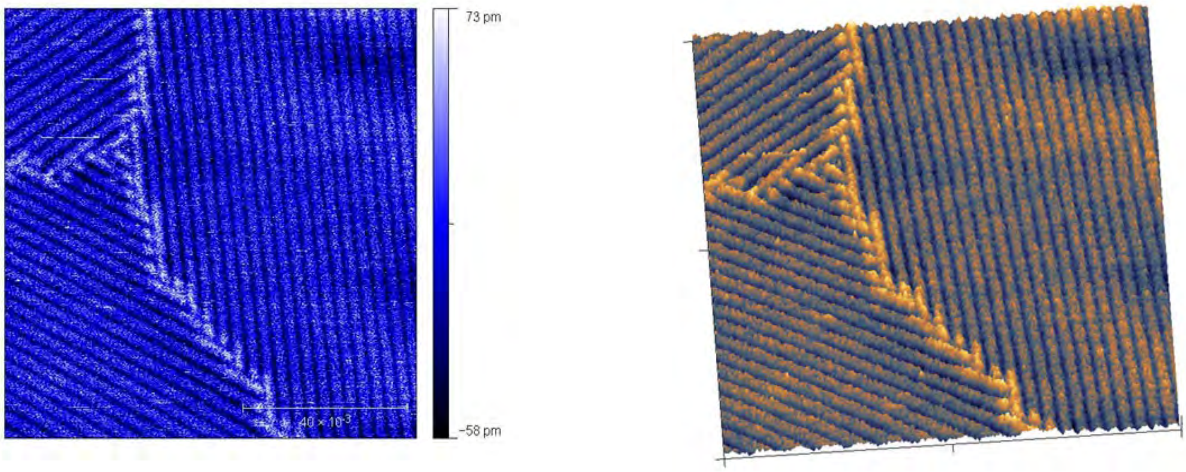


Two consecutive 75×75nm topography scans of the same area. Defects of lamellar packing is much better seen in these images.

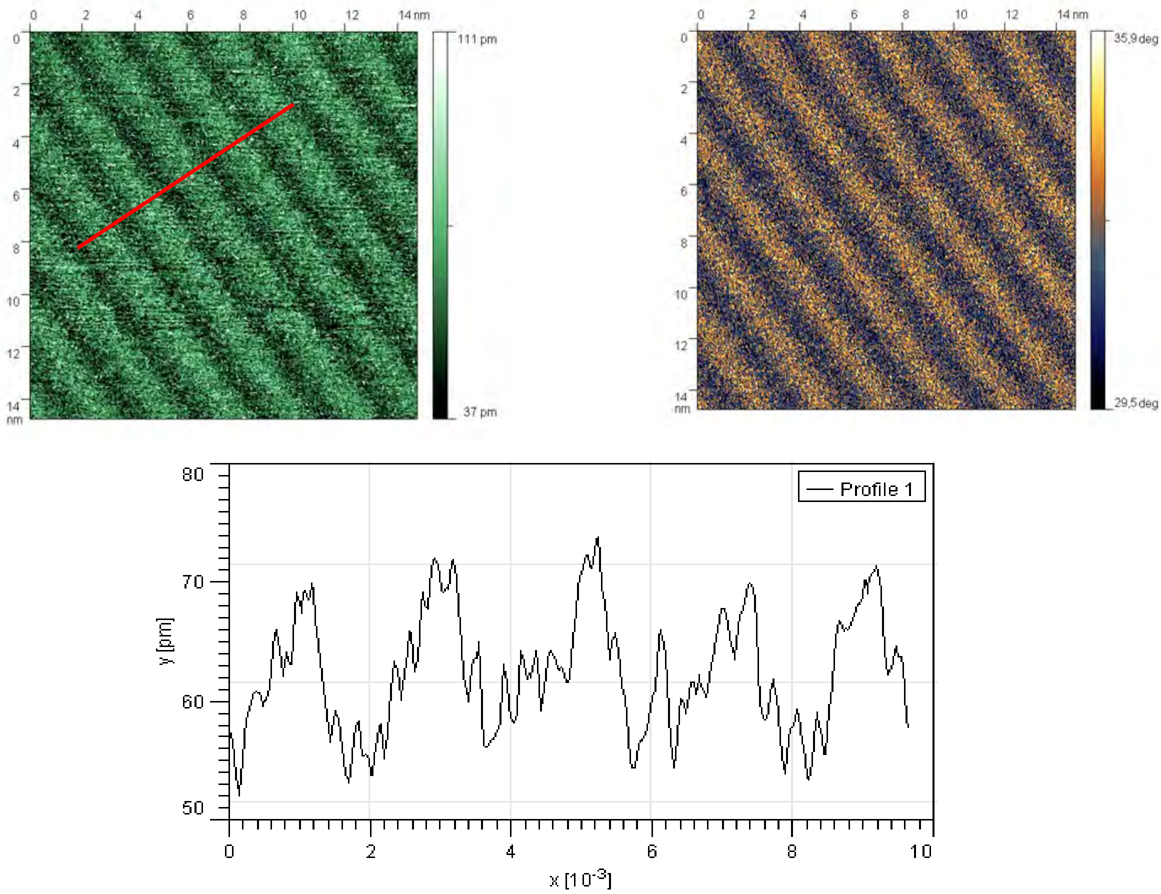


50×50nm topography scan of C32H66 lamellar stripes taken with fpN01-DLC cantilever. The width of lamellar stripes is about 4nm.

Polymer research ($C_{28}H_{58}$ and $C_{18}H_{38}$ on HOPG)

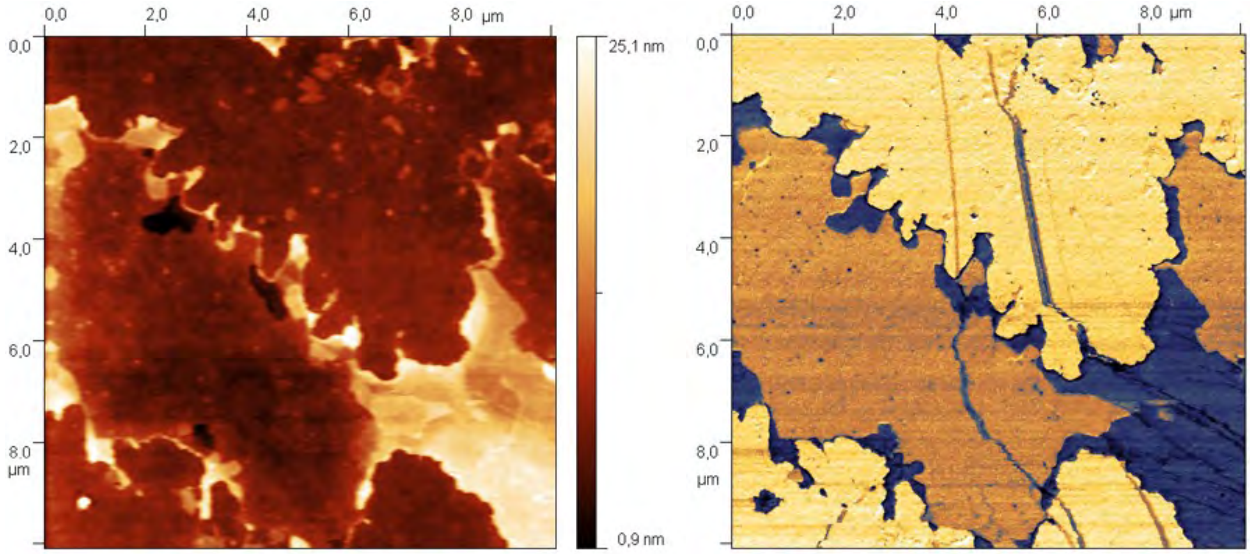


100×100nm Topography scan of C28H58 lamellae on HOPG. Z range is 1.3Å.

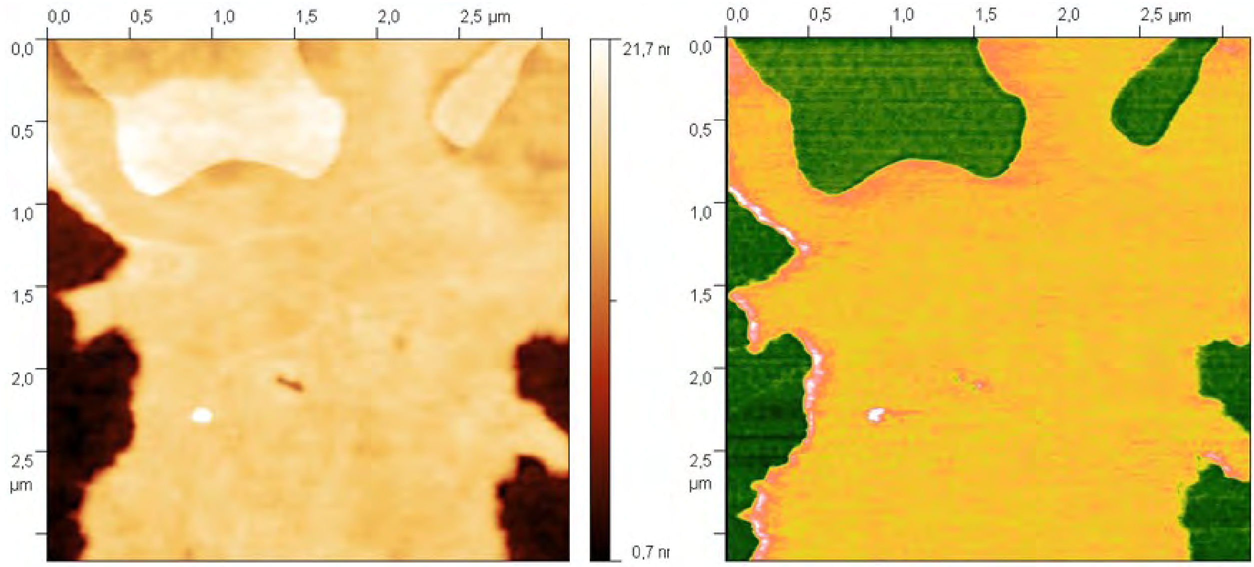


14.5×14.5 nm topography scan of the lamellar stripes of C18H38 linear alkane. The width of the lamellae is about 2nm. Z range – 0.6 Å.

Polymer-fullerene blend

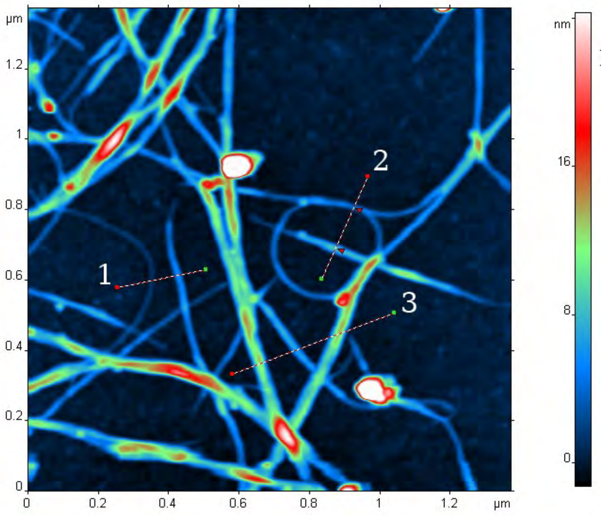


Topography (left) and force modulation (right)
images of polymer-fullerene blend (such as P3HT:PCBM).10 microns scan.

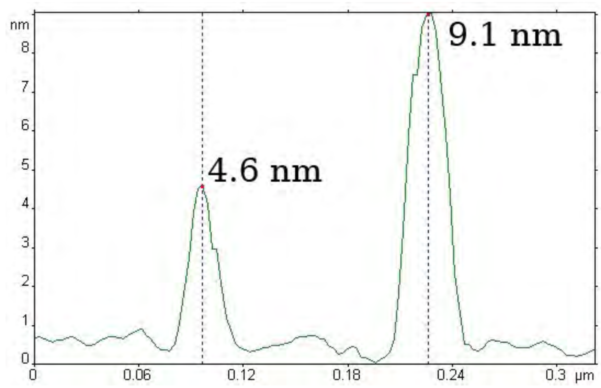


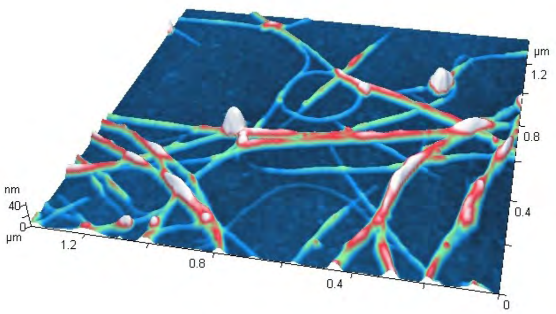
Topography (left) and lateral force (right)
images of polymer-fullerene blend (such as P3HT:PCBM). 3,6 microns scan.

Investigation of carbon nanotubes

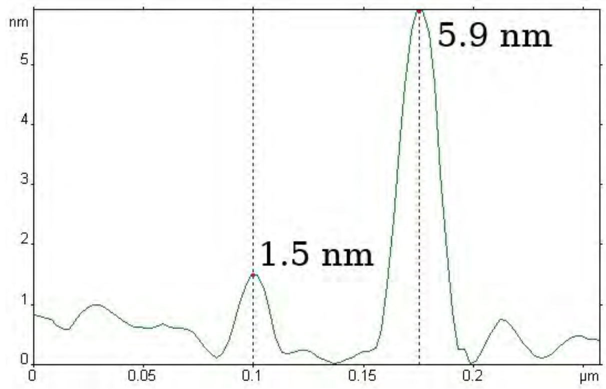


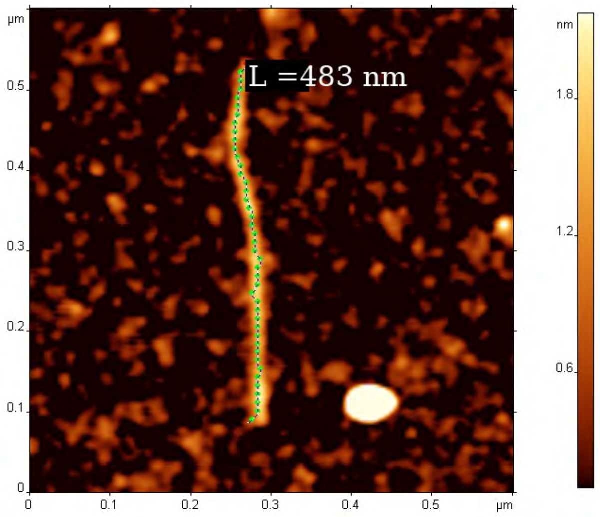
Cross-section 1



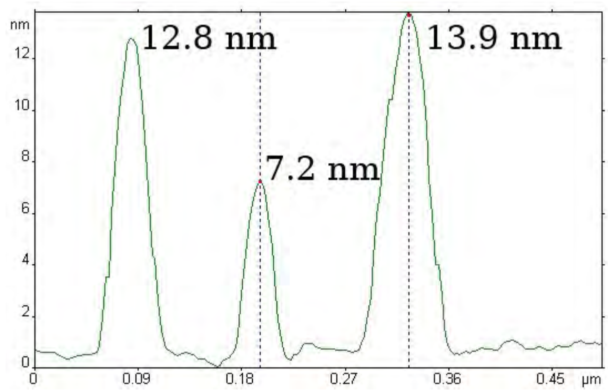


Cross-section 2



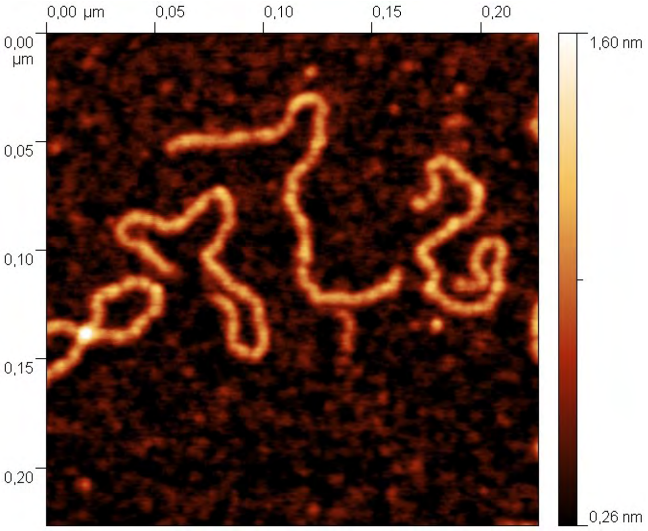


Cross-section 3



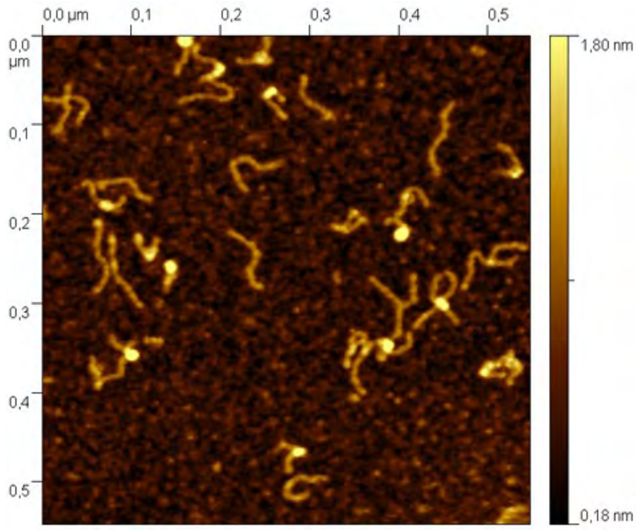
Sample courtesy of NanoDevice Technology.

Life science research



832 bp DNA molecules

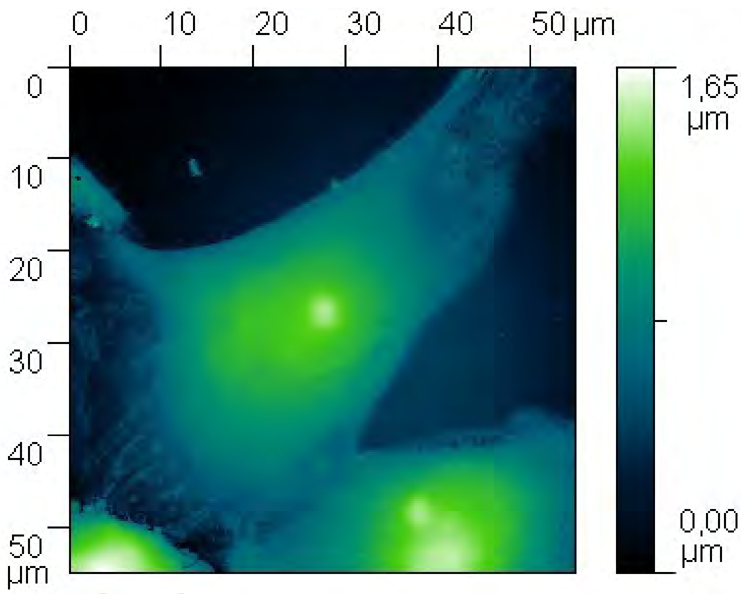
immobilized on functionalized mica.
220 nm scan, true-noncontact mode by fpN10HR probe.



DNA-nucleosome complexes

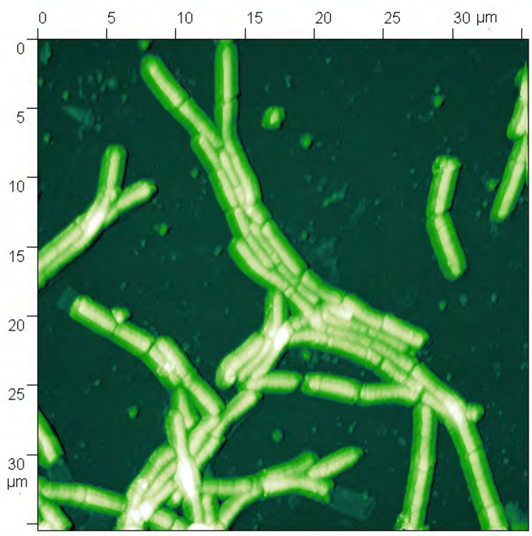
immobilized on functionalized mica.
550 nm scan, true-noncontact mode by fpN10S probe.

Samples courtesy of Dr. L. Shlyakhtenko and Prof. Yu. Lyubchenko, University of Nebraska, Medical Center



Fixed cancer cells

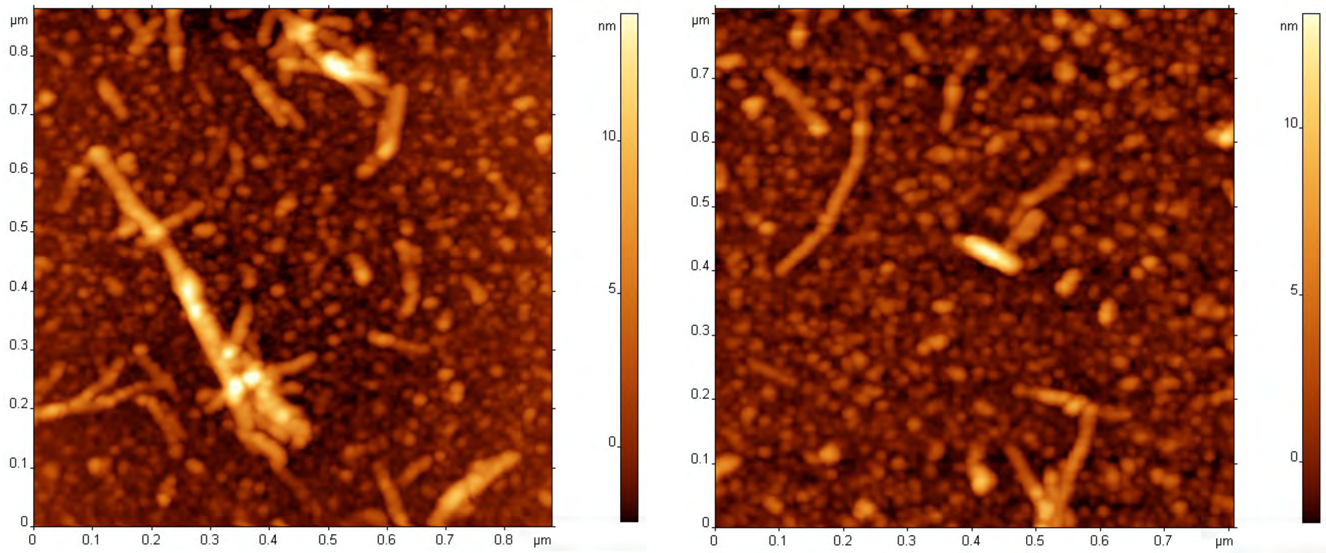
Semicontact AFM mode,
55 microns scan.



Bacillus Cereus vegetative cells

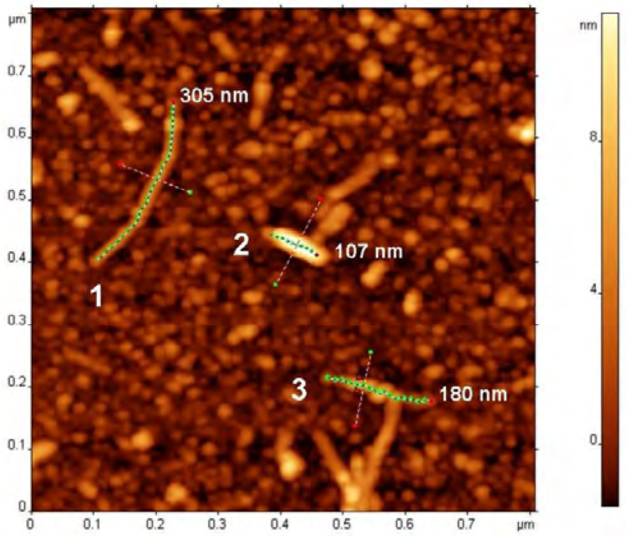
Amplitude image overlaid on topography,
36 microns scan, Z range 700nm.

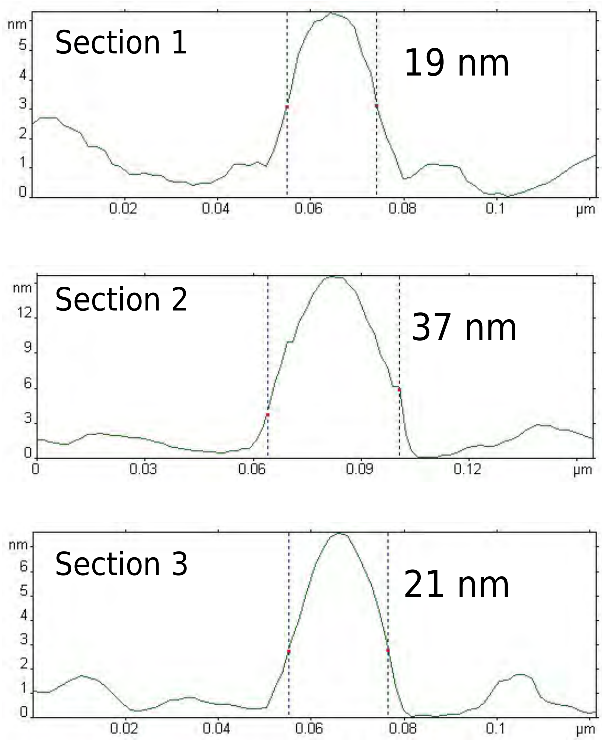
Life science research



Fibrills formed from short peptide

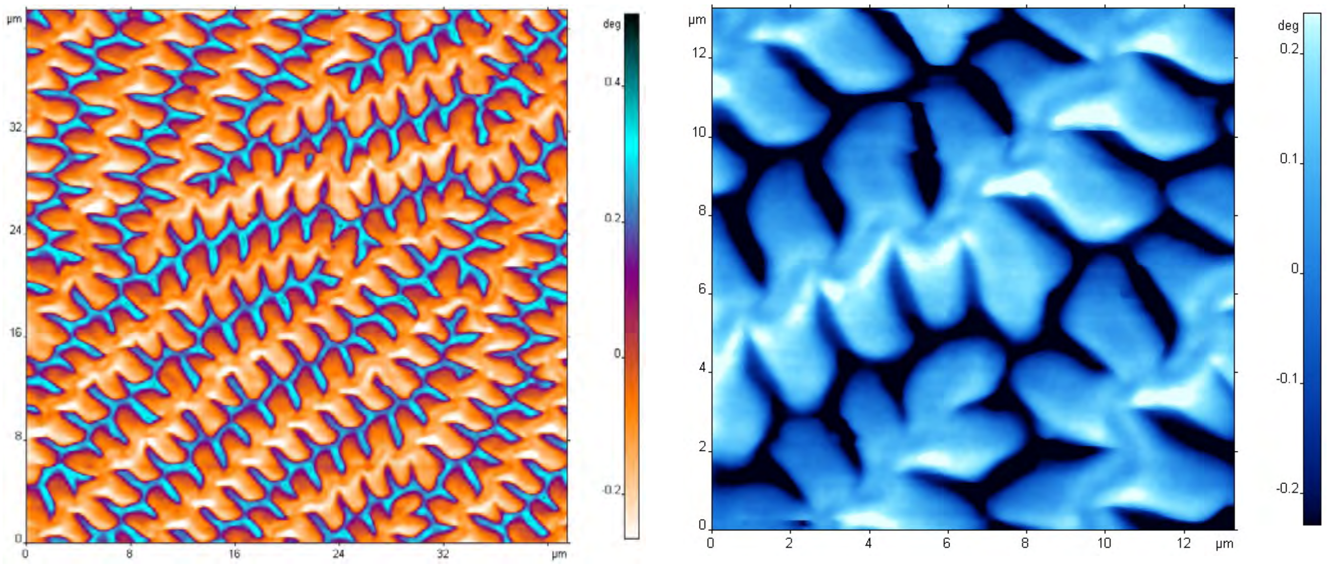
True-noncontact AFM mode, 1 micron scan, fpN10S probe.
Sample courtesy of Dr. I. Lednev, Department of Chemistry
University at Albany, SUNY.



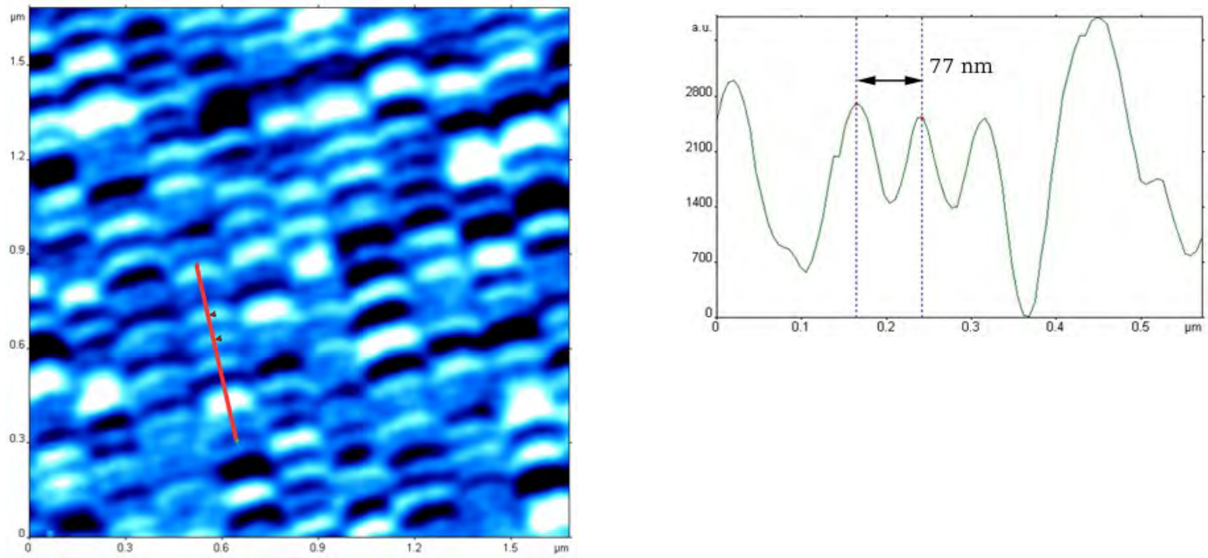


Section analysis of the selected fibrils

Investigation of magnetic materials

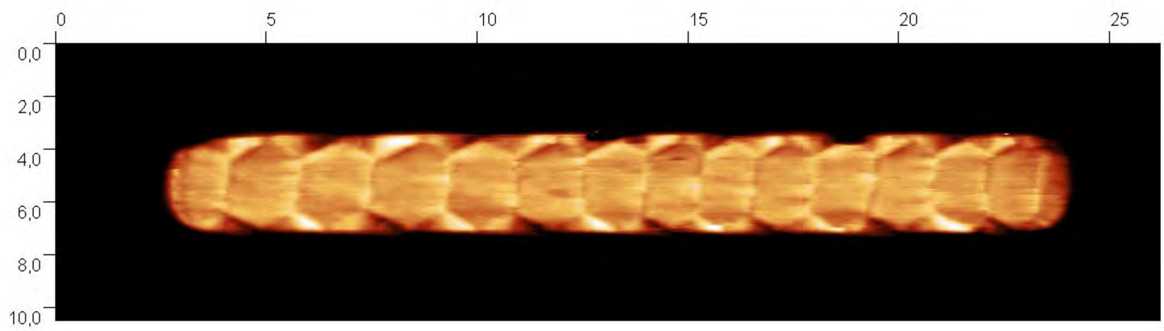


Magnetic structure of surface domains in Yttrium Iron Garnet (YIG) film
MFM image, closed loop active.

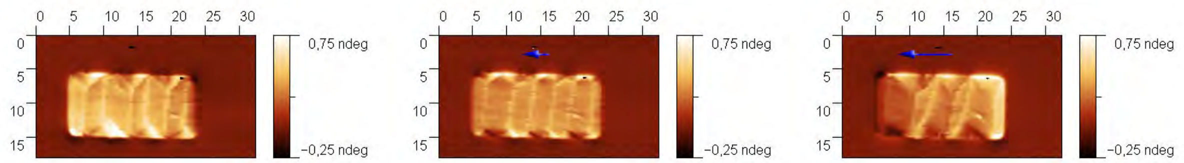


High resolution MFM image of Seagate Hard Drive
750GB, model ST3750640AS.
1.8 microns scan, closed loop active.

Investigation of magnetic materials

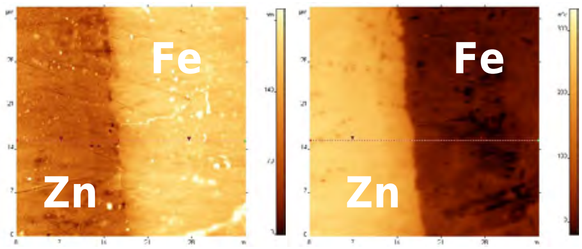


Domain structure of CoCr stripe
Magnetic Force Microscopy (MFM) image.

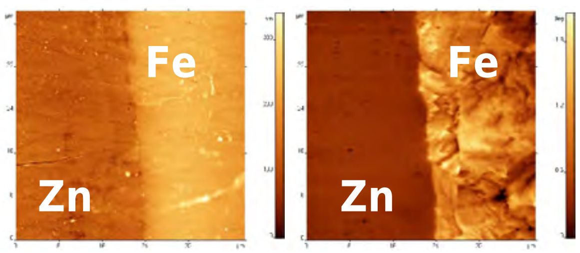


In-situ reversal magnetization of CoCr in external magnetic field

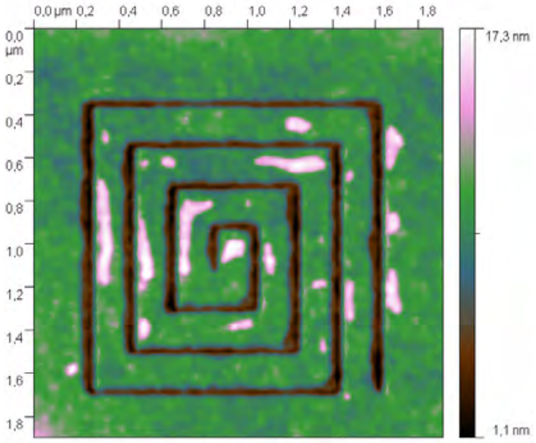
Kelvin Probe Microscopy



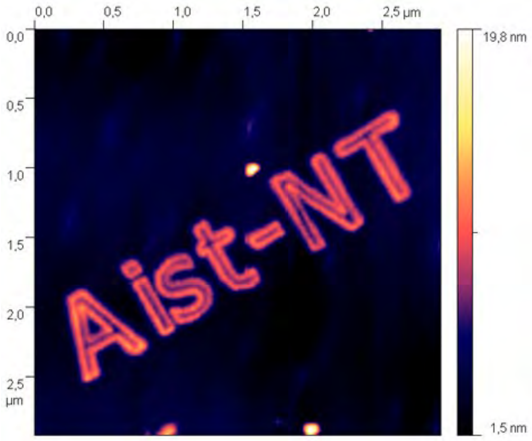
Magnetic Force Microscopy



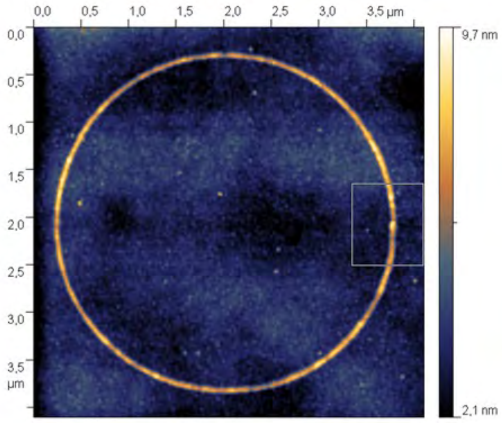
Nanolithography

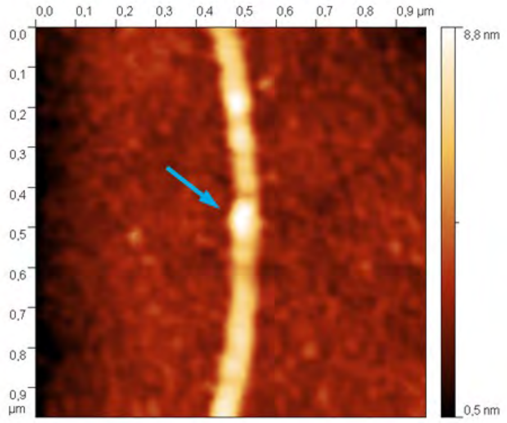


Dynamic force lithography
Dynamic force lithography on polymer film.
1,9 microns scan.



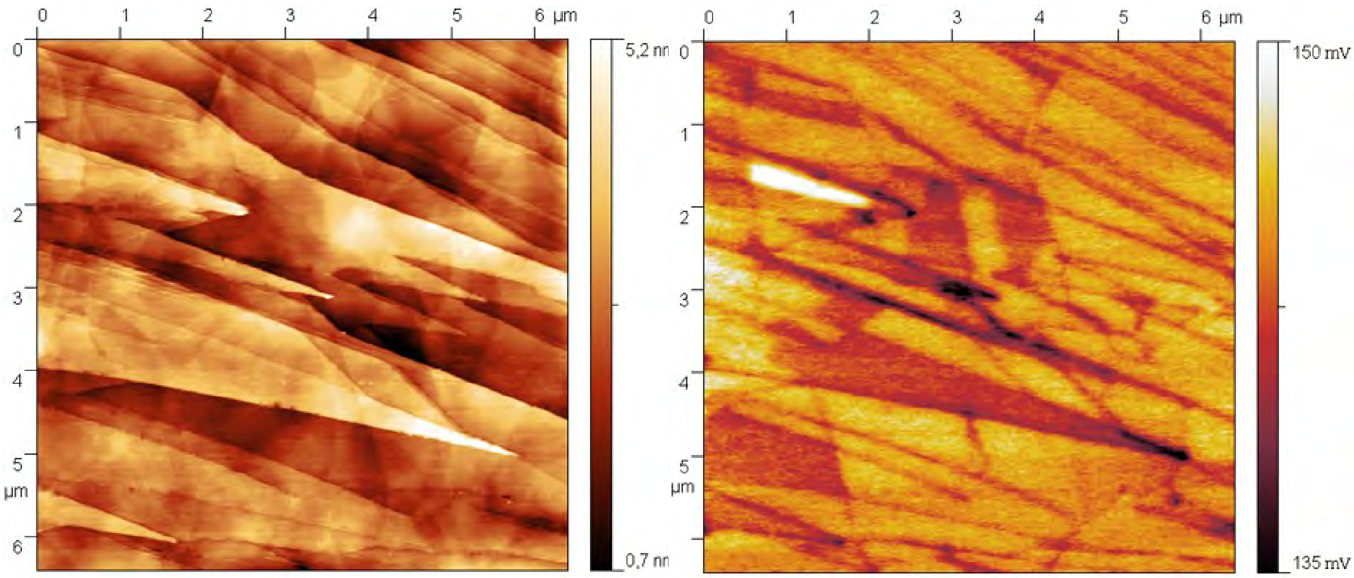
Local anodic oxidation nanolithography on GaAs.
2,9 x 2,9 microns scan.





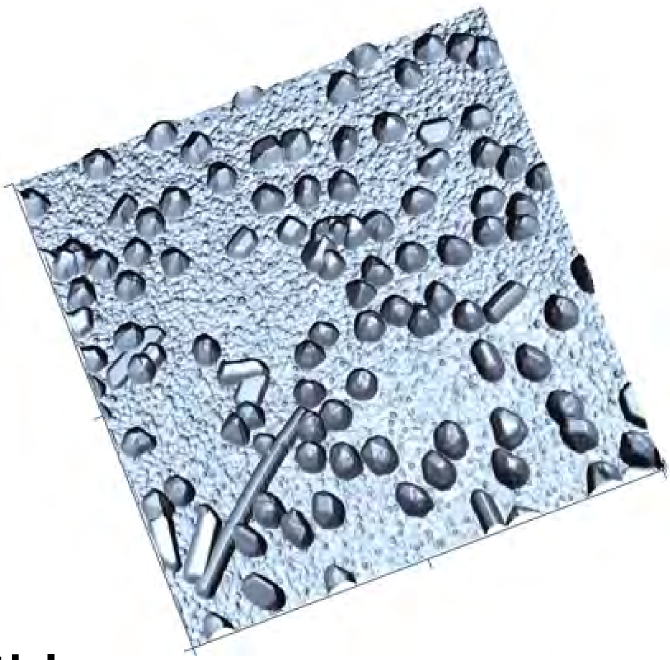
Local anodic oxidation vector nanolithography on CoCr.
4 and 1 microns scans. Arrow shows start and end points of the lithography.

Material science



Kelvin Probe Microscopy

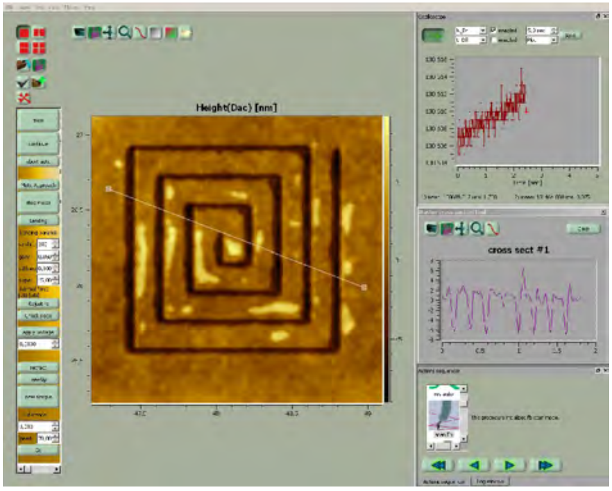
Topography and Kelvin Probe Microscopy images of HOPG.
6 microns scan.

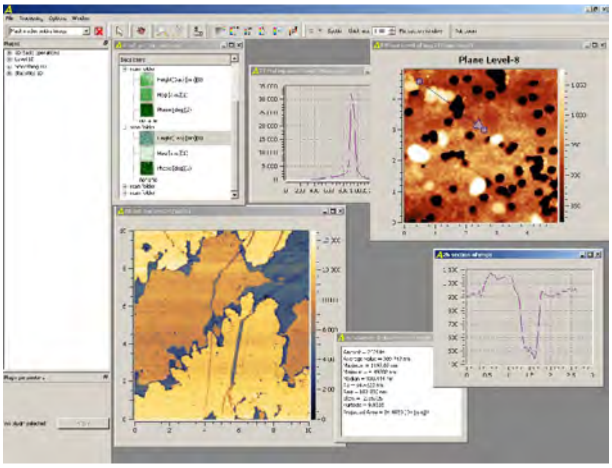


Ag nanoparticles

130 nm Ag nanoparticles immobilized on the metal surface, 3.6x3.6 µm scan.
A number of different crystalline shaped nanoparticles are clearly seen on this image.

Software





- Automatic alignment of registration system;
- Automatic configuration and presets for standard measuring techniques;
- Automatic cantilever resonance frequency adjustment;
- Capability to work with force curves;
- Macro language Lua for programming user functions, scripts and widgets;
- Capability to program controller with DSP macro language in real time without reloading control software;
- Capability to process images including cross-sections, fitting and polynomial smoothing up to 8 degree;
- FFT processing with capability to filter and analyse images;
- Nanolithography and nanomanipulation;
- Processing up to 5000x5000 pixel images.

Specifications

Measuring Modes

- Contact AFM in air/(liquid optional);
- Semicontact AFM in air/(liquid optional);
- True Non-contact AFM;
- Phase Imaging;
- Lateral Force Microscopy (LFM);
- Force Modulation;
- Conductive AFM (optional);
- Magnetic Force Microscopy (MFM);
- Kelvin Probe (Surface Potential Microscopy);
- Capacitance and Electric Force Microscopy (EFM);
- Force curve measurements;
- Piezo Response Force Microscopy;
- Nanolithography;
- Nanomanipulation;
- STM (optional);
- Photocurrent Mapping (optional);
- Volt-ampere characteristic measurements (optional).

Scanner

- **Scanning range:** 100um x 100um x 15um (+/-10%)
- **Scanning type:** by sample
- **XY non-linearity:** 0.05%
- **Z non-linearity:** 0.05%
- **Noise:**
  - 0.1nm RMS in XY dimension in 200Hz bandwidth with capacitance sensors on;
  - 0.02nm RMS in XY dimension in 100Hz bandwidth with capacitance sensors off;
  - <0.04nm RMS Z capacitance sensor in 1000Hz bandwidth;
- **Digital closed loop control:** for X,Y,Z axes
- **XY resonance frequency:** 7 kHz (unloaded)
- **Z resonance frequency:** 15 kHz (unloaded)
- Active elimination of XY phase lag, overshooting and ringing results in fast scanning without any dynamic image distortion
- Motorized approach range 18 mm
- **Motorized sample positioning:** range – 5x5mm, positioning resolution - 1um.

AFM Head

- **Laser wavelength:** 1300 nm
- **Max. sample size:** 40x50 mm, 15 mm thickness.
- **Registration system noise:** <0.03 nm (HE001 head), <0.1 nm (HE002 head)
- **Fully motorized:** 4 stepper motors for cantilever and photodiode automated alignment

Optical access

- **Video microscope** with XY positioner
- **HE001 head** (top objective: 10x, NA = 0.28)
  - ✓ Optical resolution: 1 µm
  - ✓ Field of view: from 900 µm to 140 µm
- **HE002 head** (top objectvie: 100x, NA = 0.7)
  - ✓ Optical resolution: 0.4 µm
  - ✓ Field of view: from 100 µm to 50 µm

Controller electronics

- Modular fully digital expandable controller;
- High speed DSP 190 MHz;
- USB 2.0 interface;
- High speed 500 kHz 18-bit ADC, 20 channels;
- 5 MHz frequency range registration system;
- 2 lock-in amplifiers with 5 MHz frequency range;
- 6 digital 32–bit generators 5 MHz frequency range, 0.01 Hz resolution;
- Software controlled modulation possibilities for probe, X, Y and Z scanners, Bias voltage and two external outputs;
- HV amplifiers -5 ÷ 120V, 0.4 ppm noise ;
- AC, DC Bias Voltage -10 ÷ 10V, 2 MHz frequency range;
- Control of 7 stepper motors;
- Digital inputs/outputs for integration with external equipment;
- Analog inputs/outputs for integration with external equipment.