Nano and Giga Challenges in Electronics, Photonics and Renewable Energy

NGC 2017

Scanning Probe Technology for Surface Structures Characterizations: High resolution in Microscopy and Spectroscopy

18 September 2017, 3:00 – 3:45 pm

Victor A. Bykov, professor,
Russian Nanotechnologies Society & и NT-MDT Spectrum Instruments, President

NT-MDT Spectrum Instruments

1959, Era of Microelectronics Started

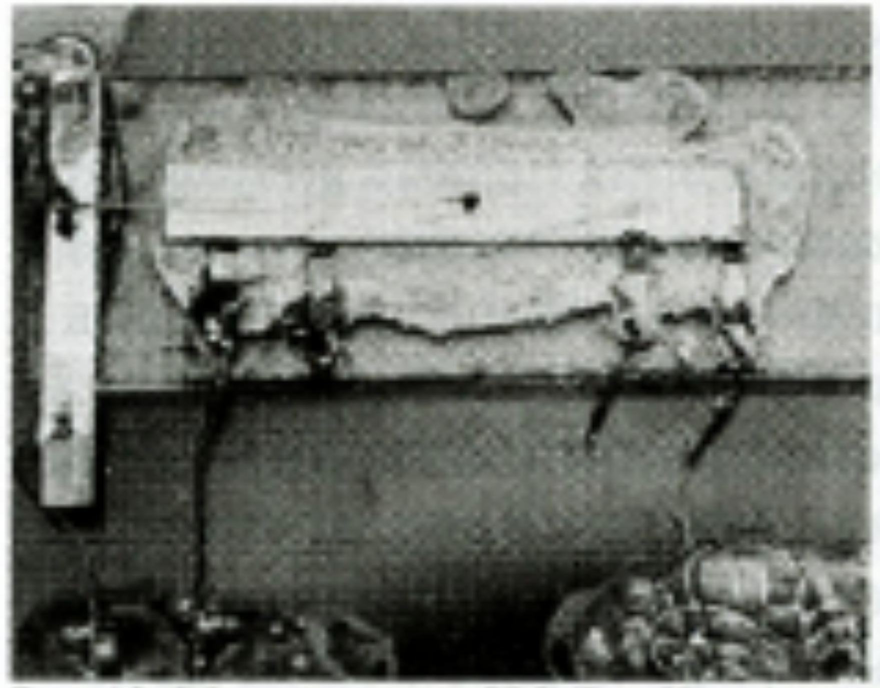


Рис.12. Макет первой ИС Дж. Килби

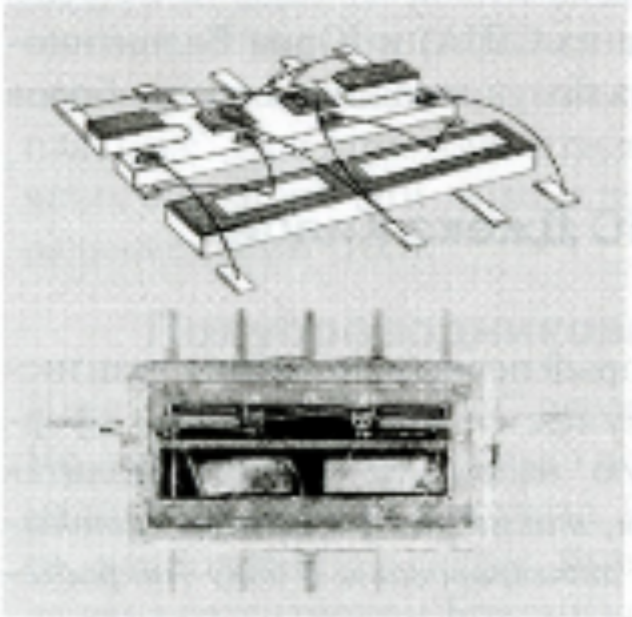


Рис.13. ИС «Type 502» Килби

Рис.15. Фотография ИС Micrologic в журнале «Life»

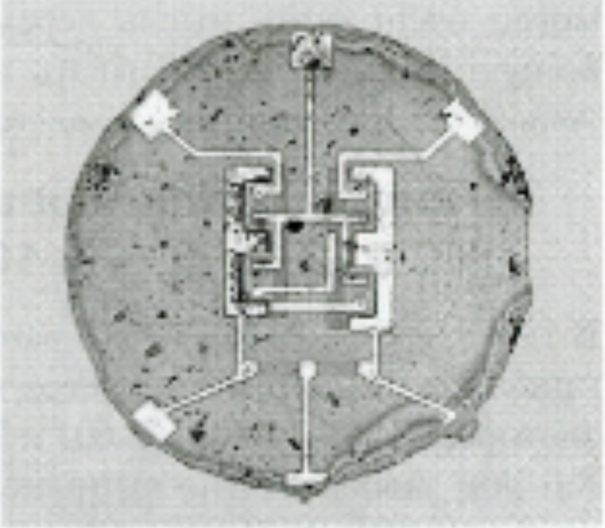
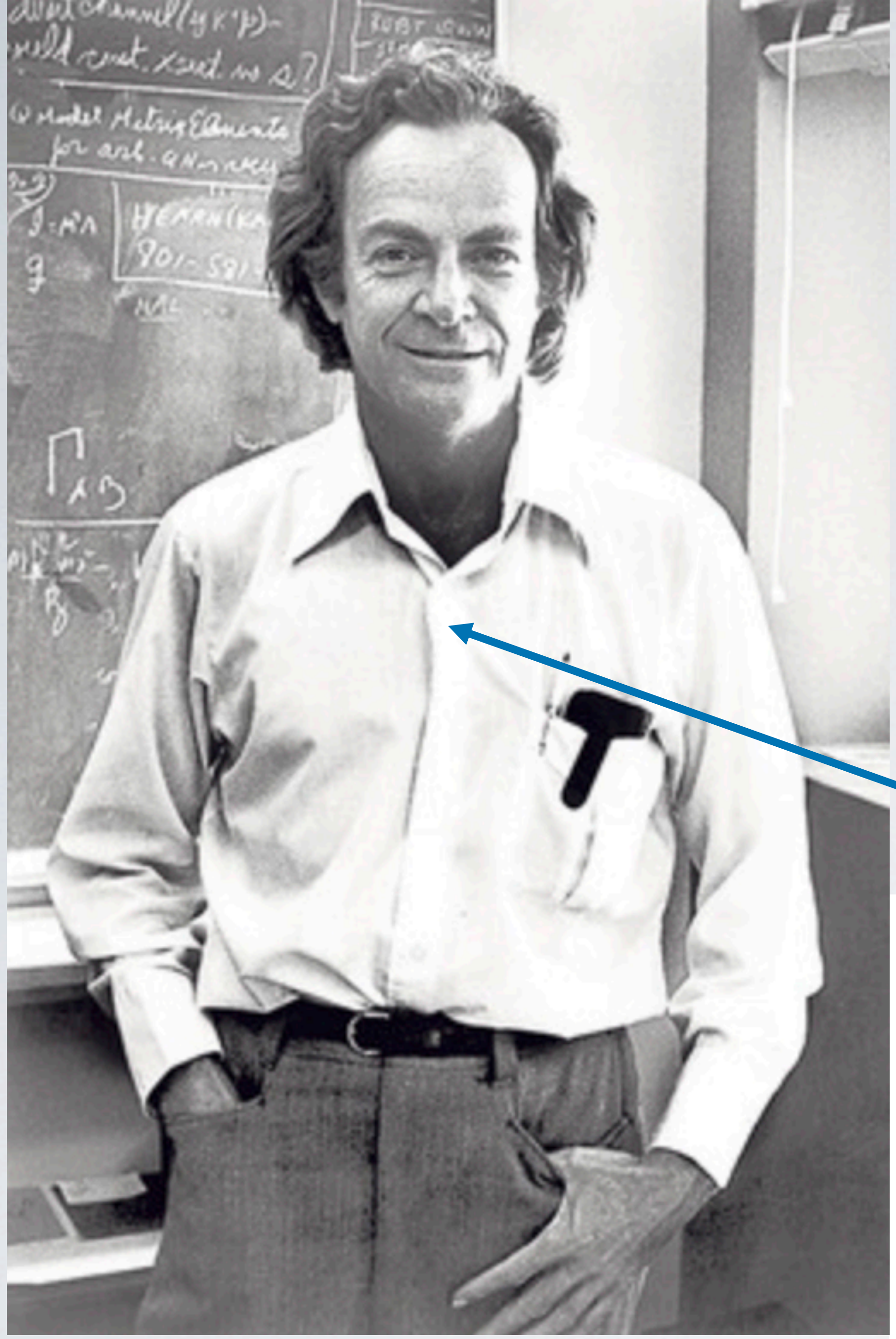
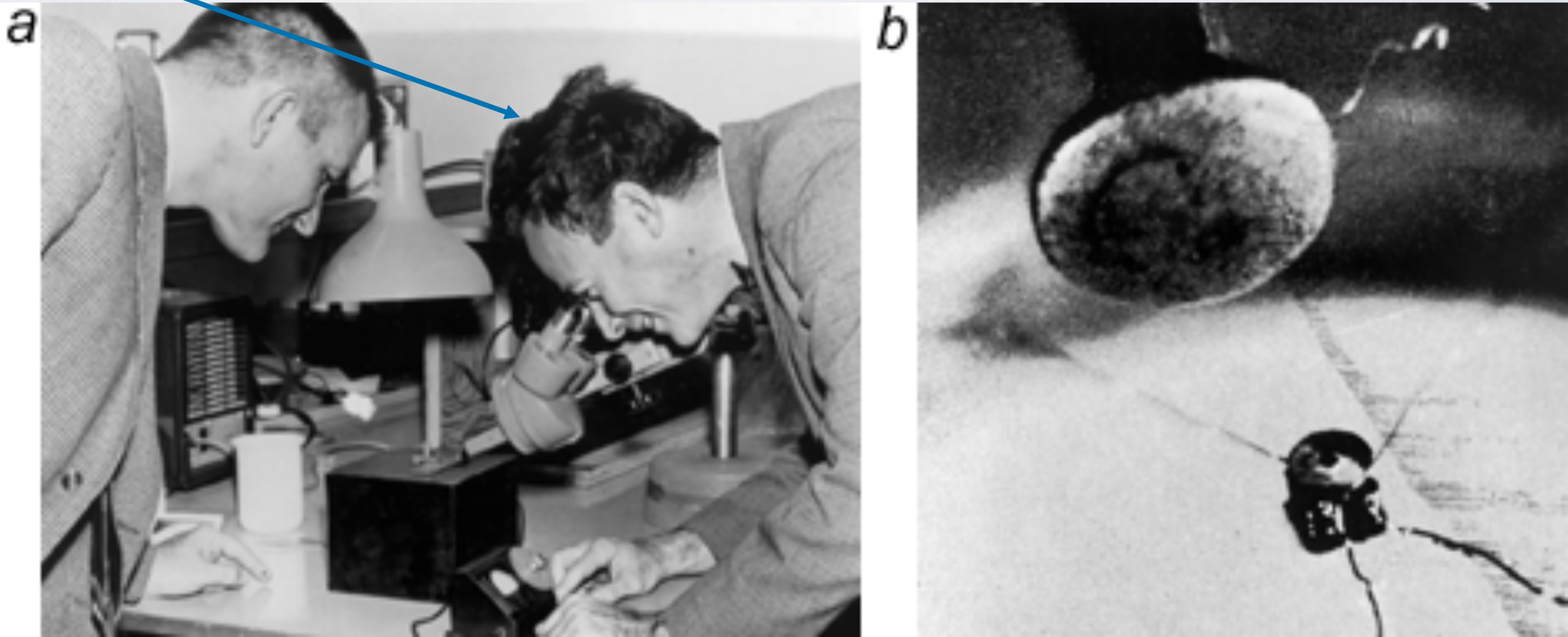


Рис.14. Экспериментальный триггер Р.Нойса

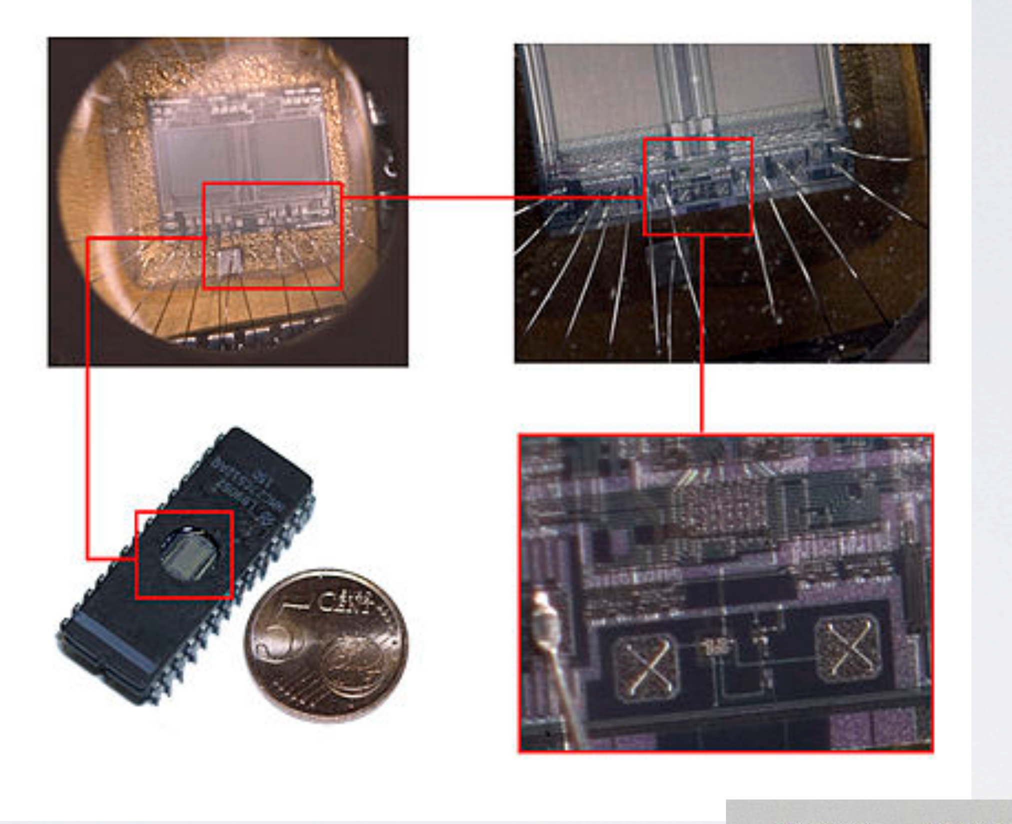


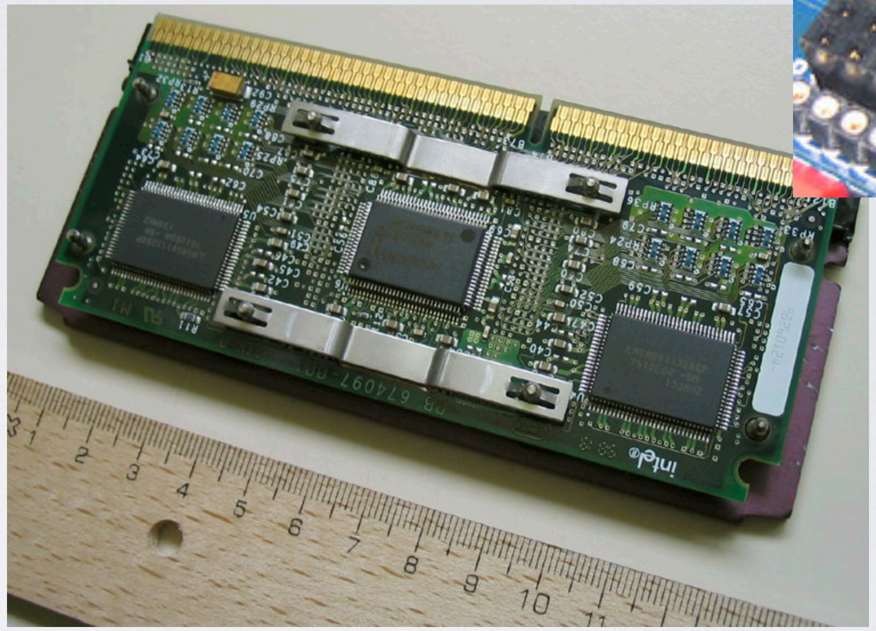
The iconic Richard Feynman is a popular choice, on the strength of his 1959 lecture "There's plenty of room at the bottom" http://physicsworld.com/cws/article/print/2006/jun/01/small-returns-for-nanoscience



NT-MDT Spectrum Instruments

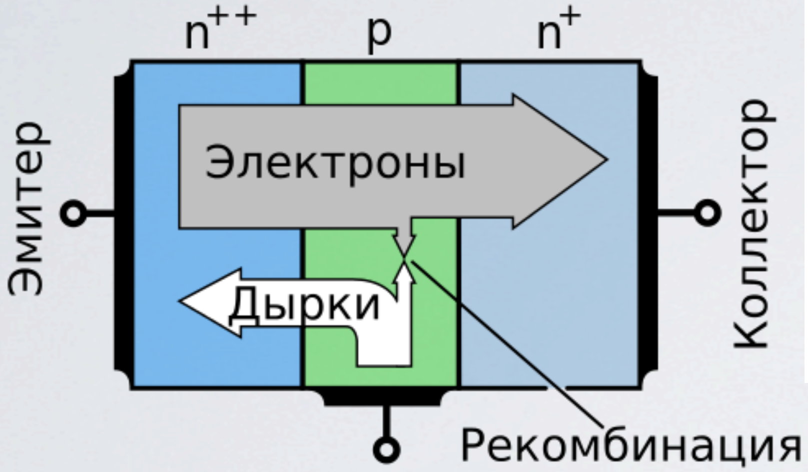
From Transistors to Microchips

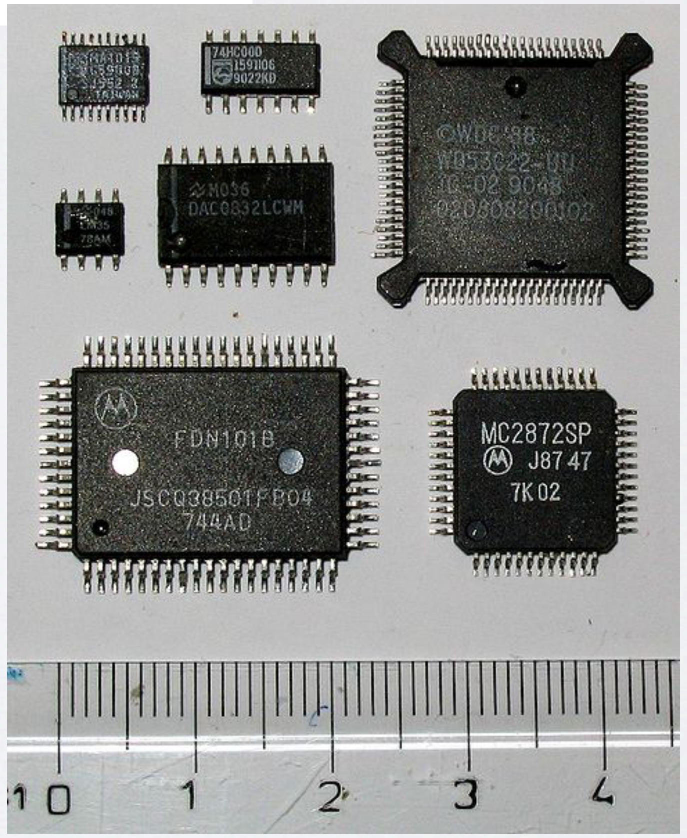




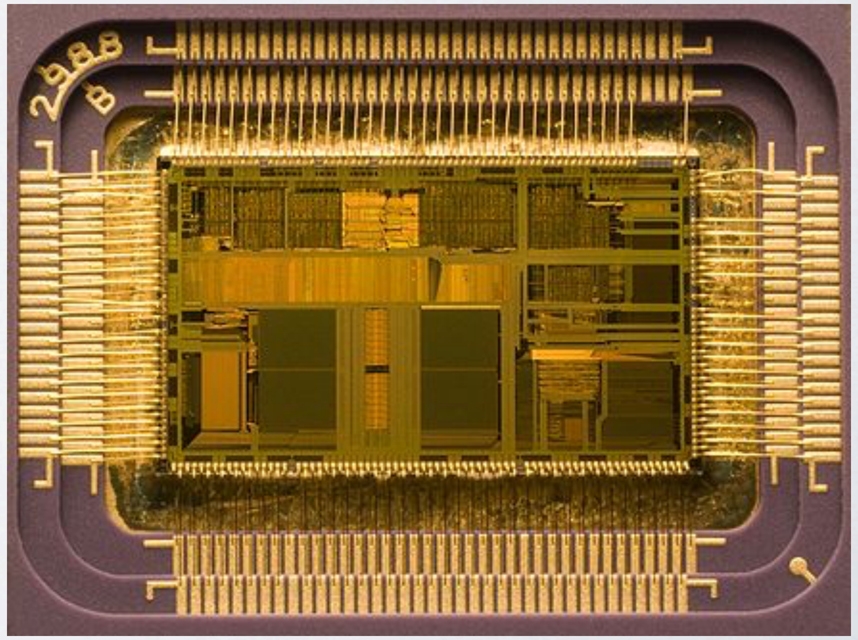
Programming Logics Chips

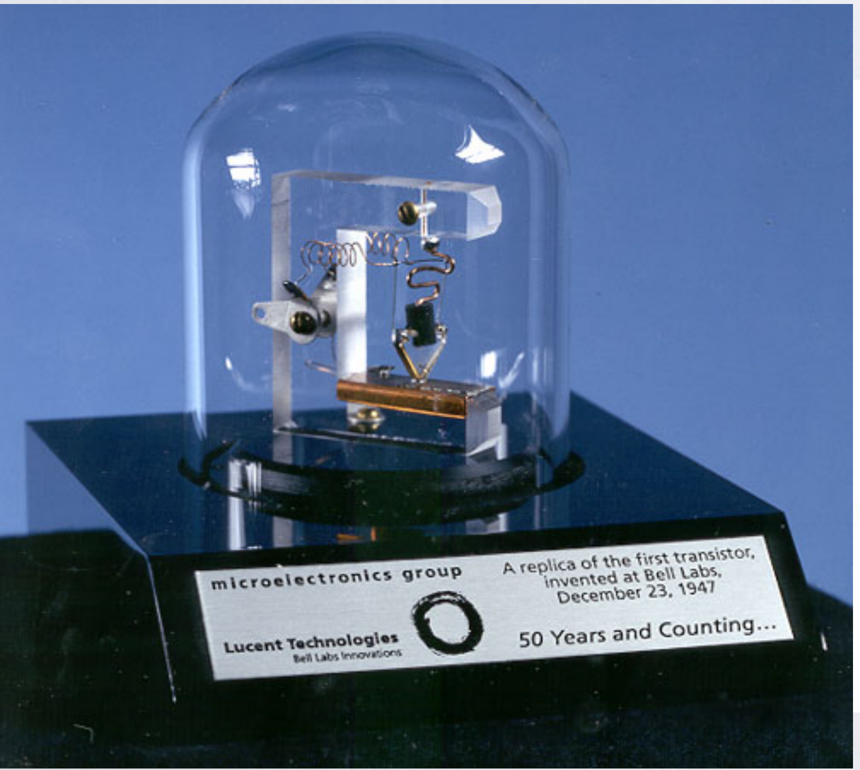
Transistors

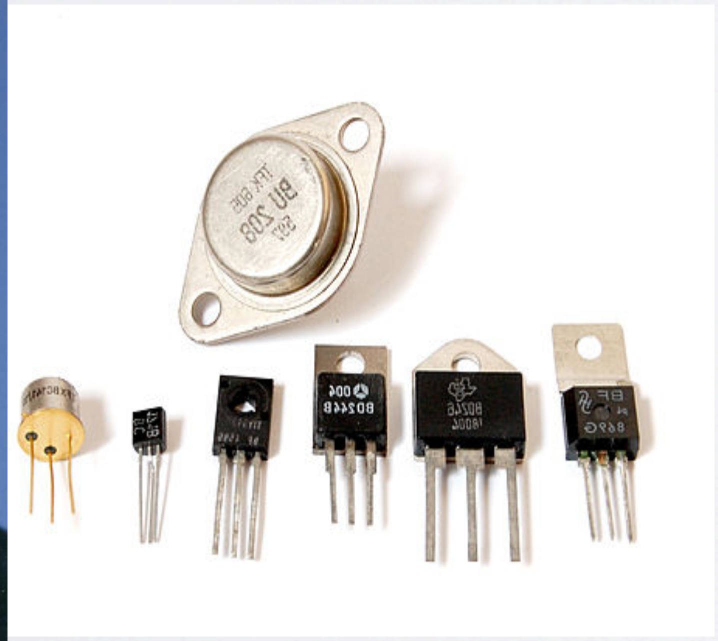




Microprocessors





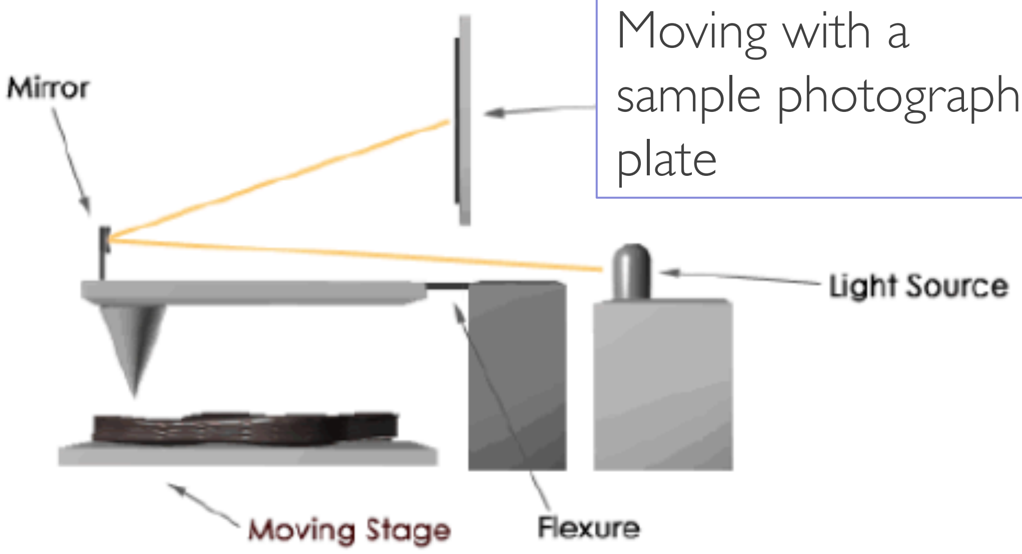


SPM Development & Progress based on:

- **Methods Ideas;**
- **MEMS;**
- **Controllers (real progress based on microchips progress);**
- **Computer progress & SW;**
- **Internet Technologies Progress;**
- **Design Ideas**

Stylus Profiler (1929 –Schmalz)

The profiler, invented by Schmalz in 1929, utilized an optical lever arm to monitor the motion of a sharp probe mounted at the end of a cantilever. A magnified profile of the surface was generated by recording the motion of the stylus on photographic paper. This type of "microscope" generated profile "images" with a magnification of greater than 1000X.

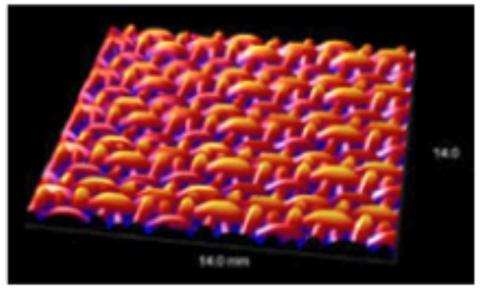


Moving with a sample photographic plate

From electronics in the device - only a light bulb. Information receiver - photographic plate

- Generated profile images up to ~1000X magnification
- Problems with large features (bent probes)

US quarter dollar, 11mm x 18mm scan.



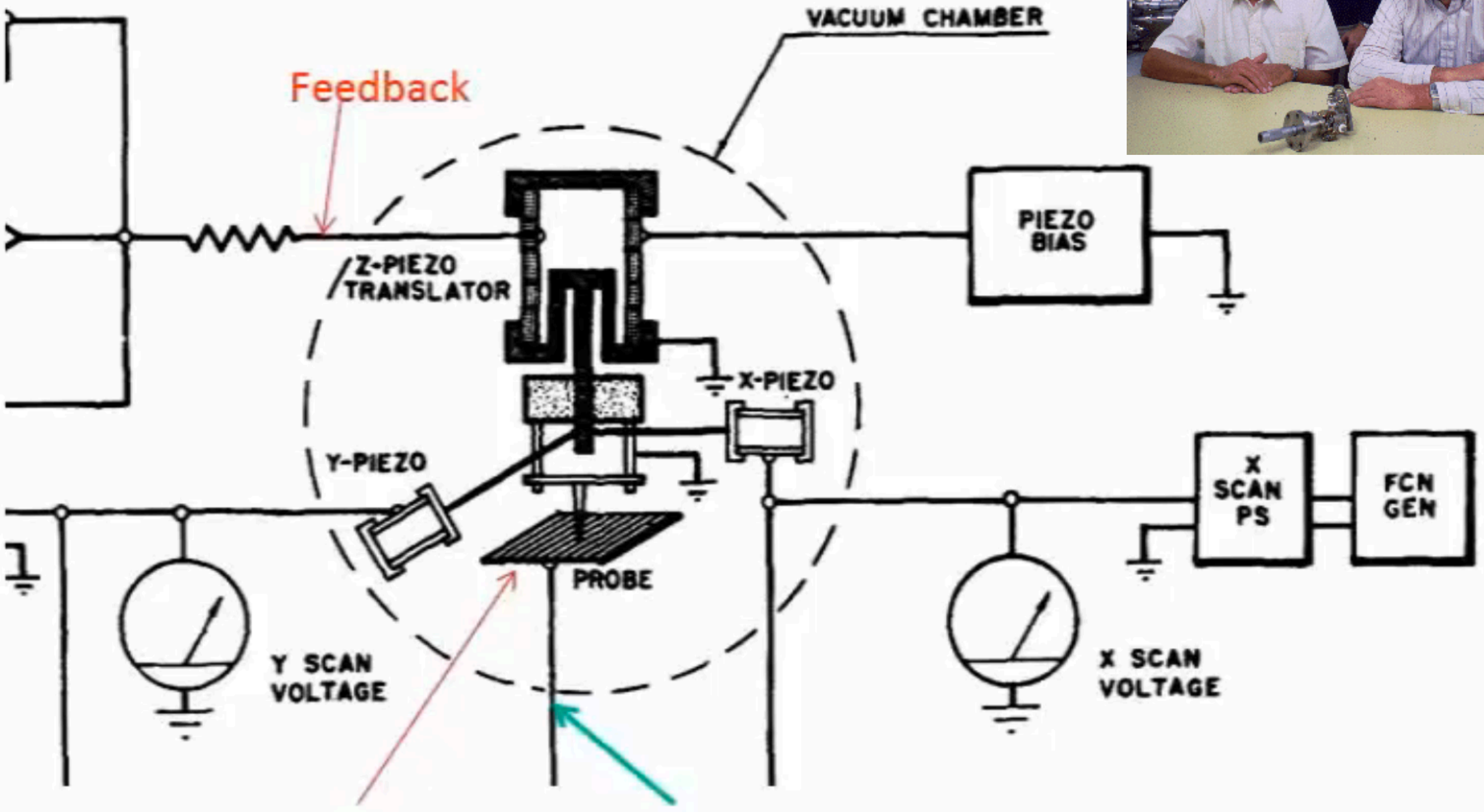
Polyester mesh, 12mm x 12mm scan.

http://www.pacificnanotech.com/afm-history_single.html

NT-MDT Spectrum Instruments

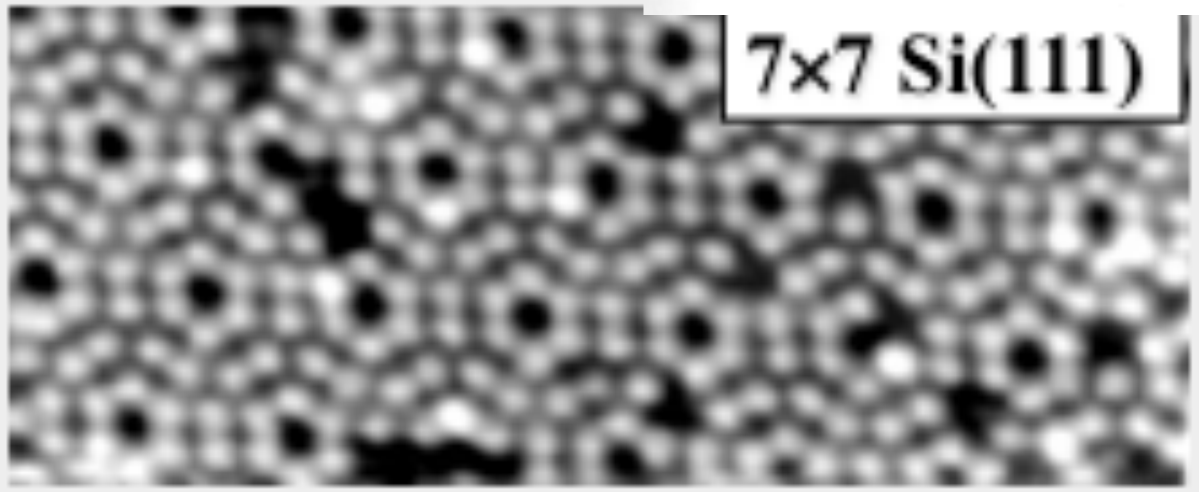
The Review of Scientific Instruments, July 1972

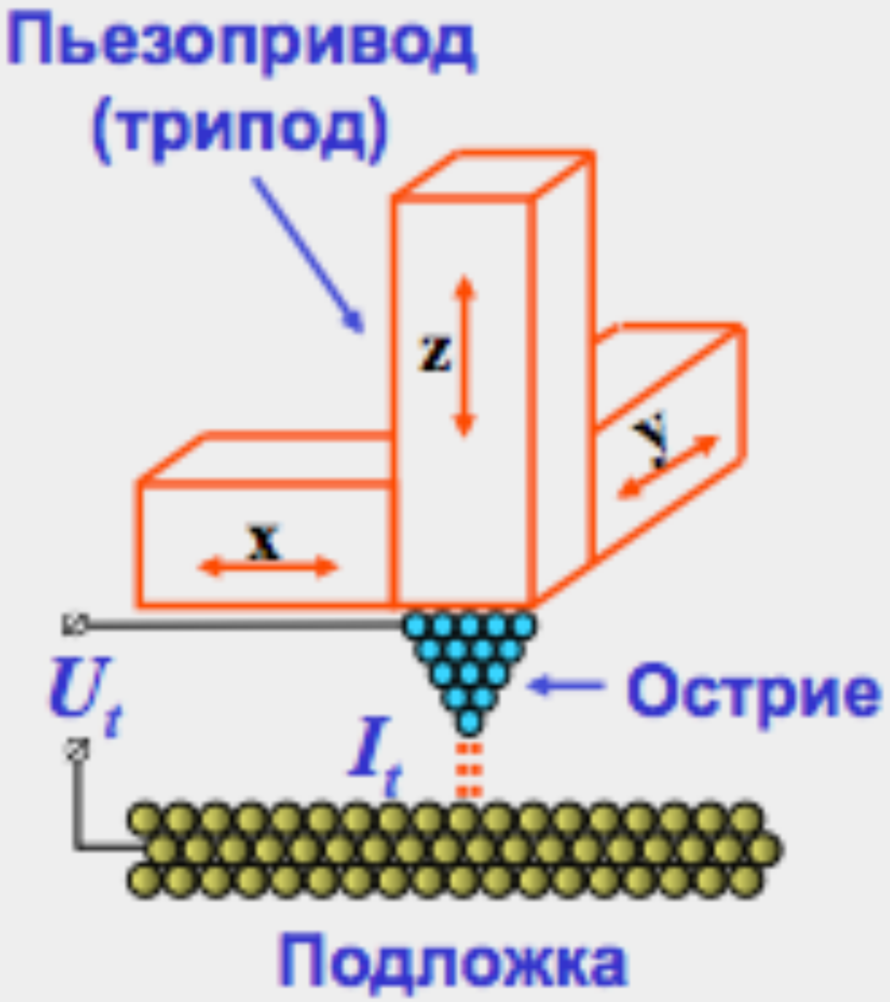
7 Years before the first publication of Binnig and Rohrer



NT-MDT Spectrum Instruments

1982 г. Открытие метода сканирующей туннельной микроскопии (СТМ)

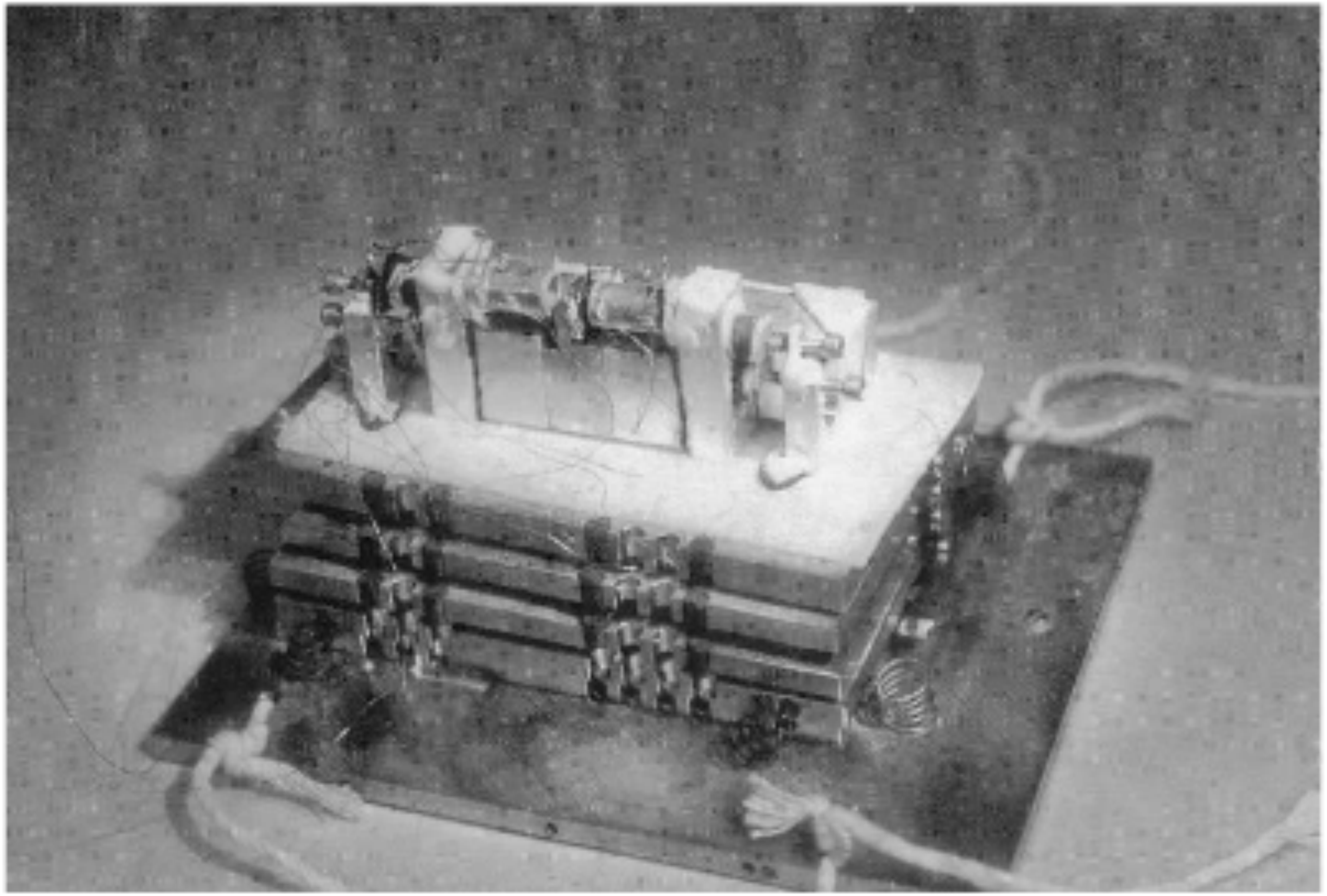




$$I_t \sim e \int \rho_e(E)\rho_f(E)D(E)dE$$

Phys. Rev. Lett. – 1983. V50.– P. 120

The first AFM



G. Binnig, Ch. Gerber and C.F. Quate, Phys. Rev. Lett. 56, 930 (1986)

NSTC
A Nanotechnology platform

NT-MDT
Spectrum Instruments

Atomic Force Microscope

G. Binnig[(a)] and C. F. Quate[(b)]
Edward L. Ginzton Laboratory, Stanford University, Stanford, California 94305

and

Ch. Gerber[(c)]
IBM San Jose Research Laboratory, San Jose, California 95193

(Received 5 December 1985)

R 9 PHYSICAL REVIEW LETTERS 3 MARCH 1986

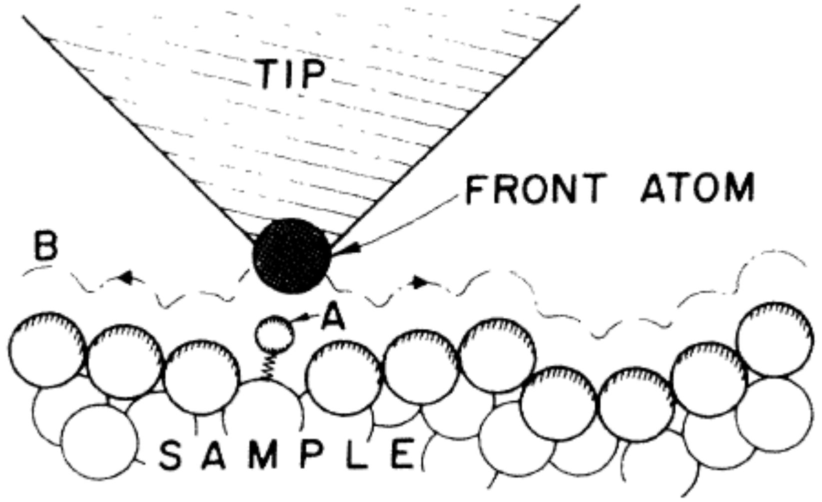


FIG. 1. Description of the principle operation of an STM as well as that of an AFM. The tip follows contour *B*, in one case to keep the tunneling current constant (STM) and in the other to maintain constant force between tip and sample (AFM, sample, and tip either insulating or conducting). The STM itself may probe forces when a periodic force on the adatom *A* varies its position in the gap and modulates the tunneling current in the STM. The force can come from an ac voltage on the tip, or from an externally applied magnetic field for adatoms with a magnetic moment.

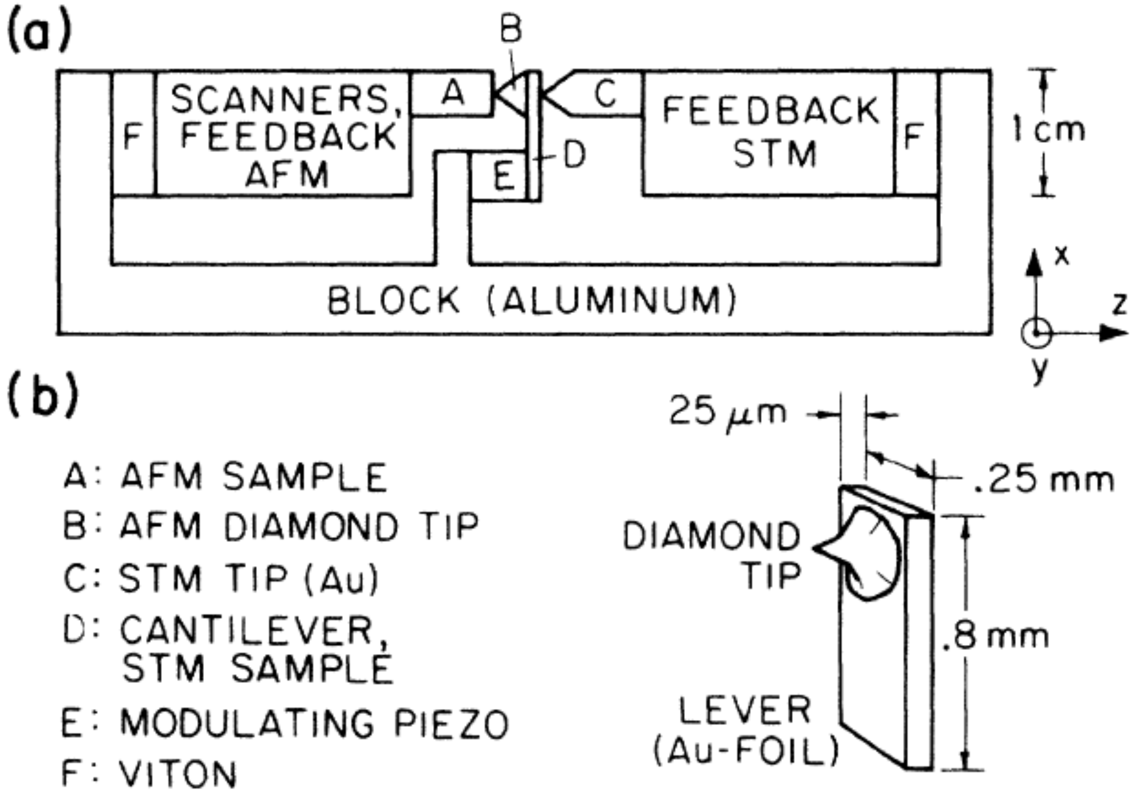
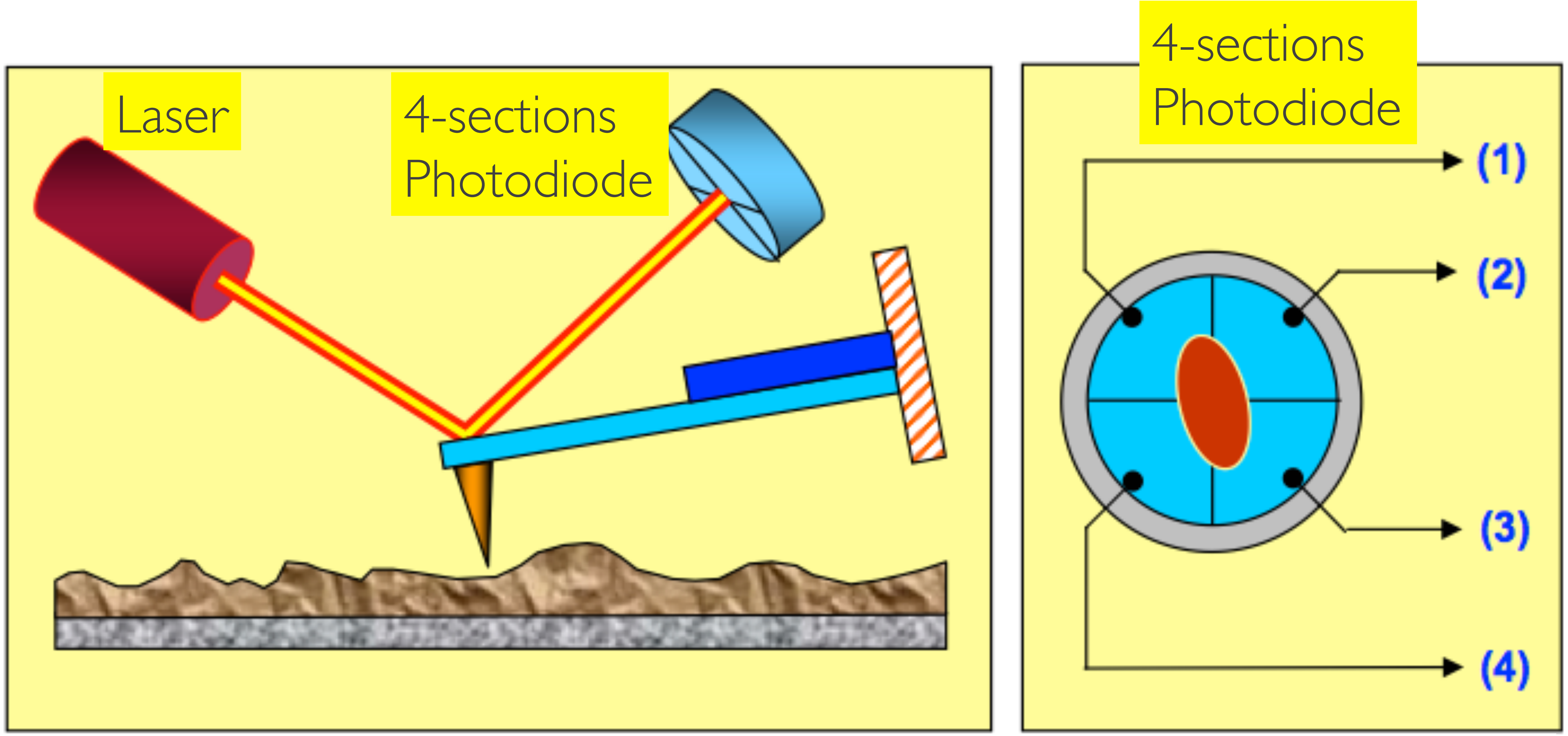
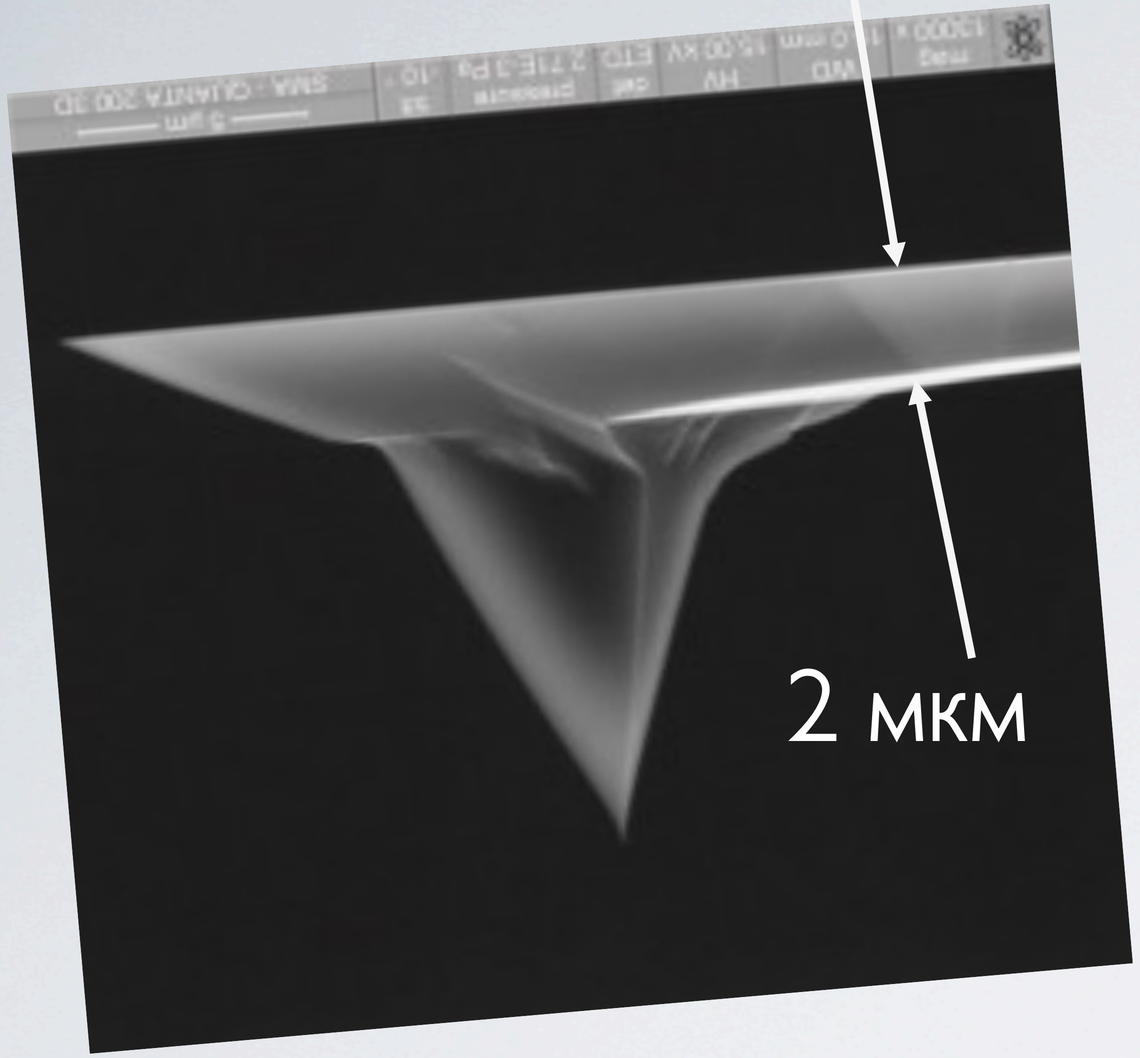


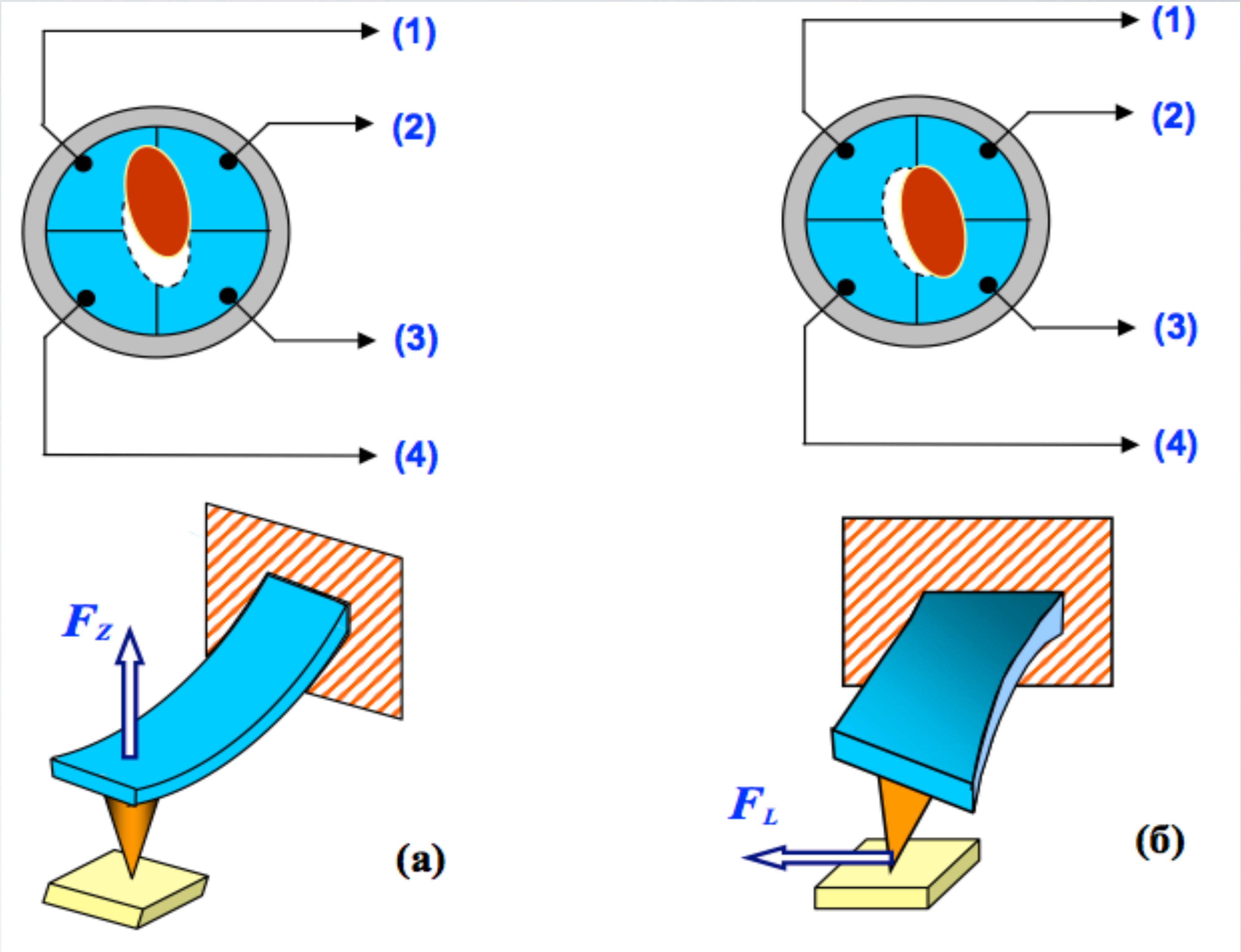
FIG. 2. Experimental setup. The lever is not to scale in (a). Its dimensions are given in (b). The STM and AFM piezoelectric drives are facing each other, sandwiching the diamond tip that is glued to the lever.



Meyer G., Amer N.M. Erratum: novel optical approach to atomic force microscopy// Appl. Phys. Lett. 53 (24), 2400-2402, (1988)



Si – cantilever, SEM image



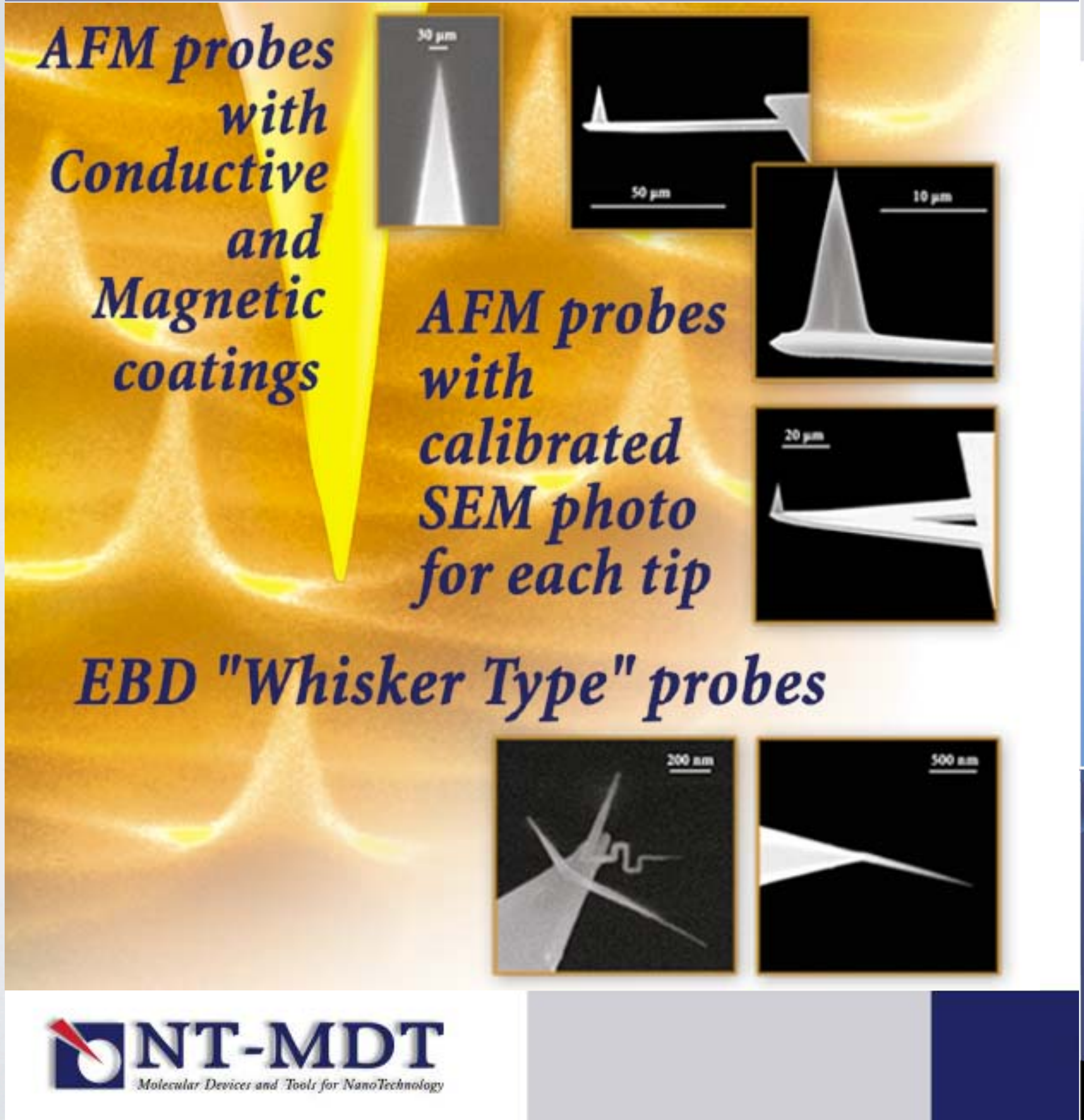
$$\Delta I_z = (\Delta I_1 + \Delta I_2) - (\Delta I_3 + \Delta I_4)$$

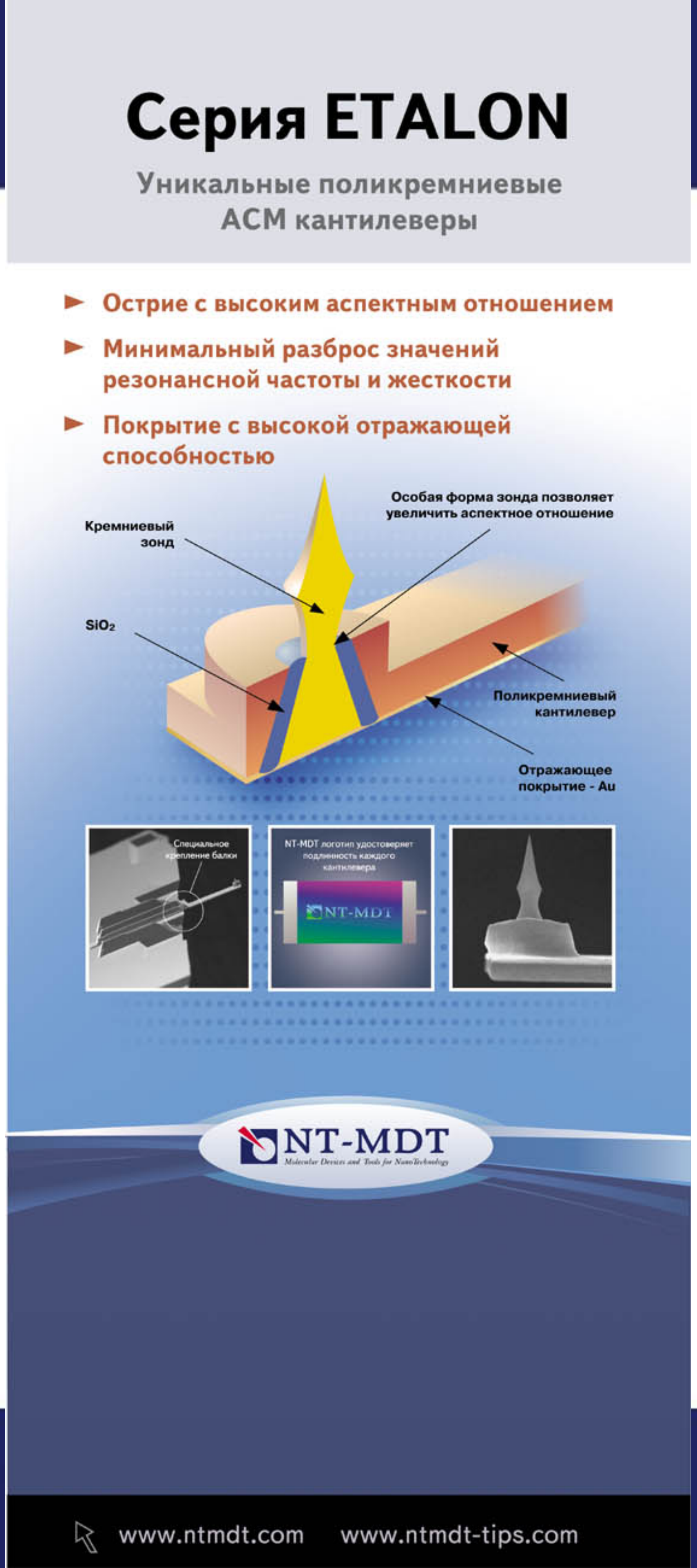
$$\Delta I_L = (\Delta I_1 + \Delta I_4) - (\Delta I_2 + \Delta I_3)$$

NT-MDT Spectrum Instruments

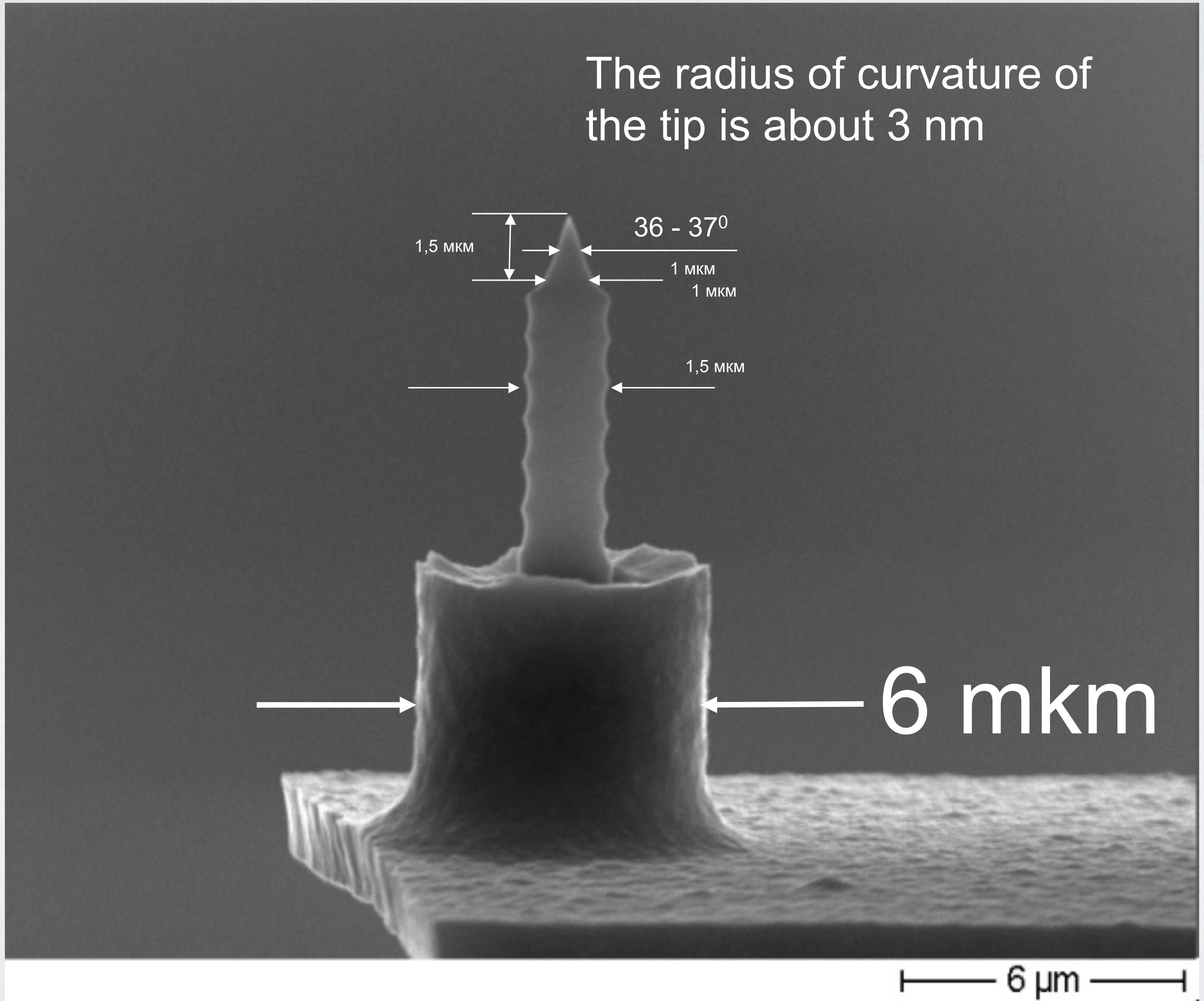
System sensitivity - up to 0,1 Angstroms =0,01 nm

Cantilevers

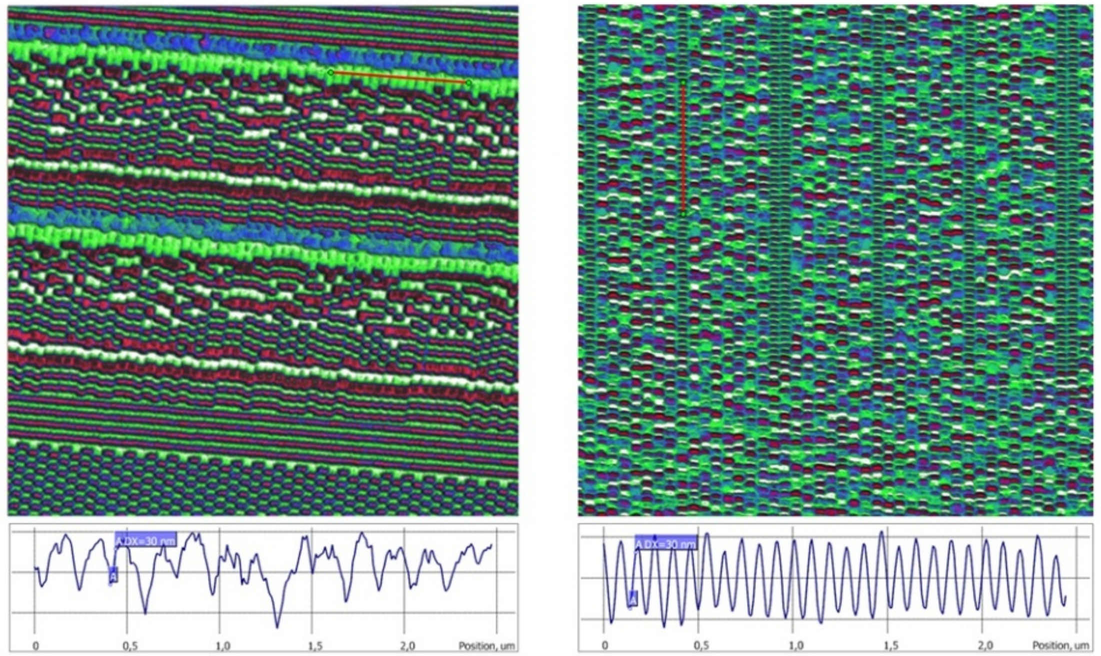




Cantilevers of a new type - a polycrystalline beam and a single-crystal needle, a spread of resonance frequencies - 5%



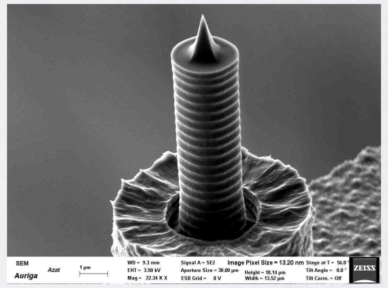
AFM cantilevers of ETALON series with CoFe magnetic tip-side layer



AC-MFM image of servo sector of high-density hard disk drive
Scan size: 10×10 μm² (with 5 nm step)
Section size: 2,5 μm

AC-MFM image of user data sector of high-density hard disk drive
Scan size: 8×8 μm²(with 5 nm step)
Section size: 2,5 μm (section of AGC preamble area)

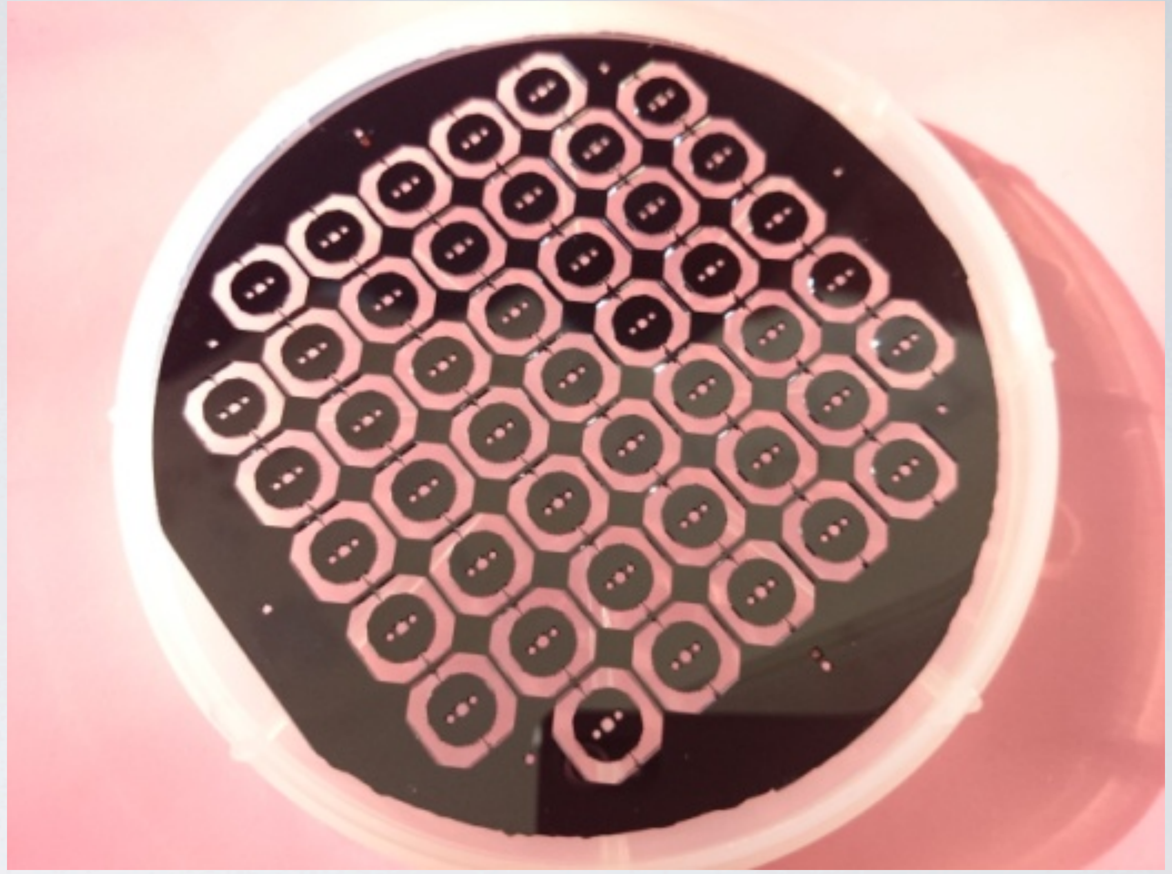
- Stable parameters of a bulk (+/- 10% F_{res} and +/- 20% stiffness dispersion);
- High lateral resolution due to a small (<30 nm) curvature radius of a tip;
- High resolution of magnetic contrast (around 30 nm) shown during measurements of 1 Tb hard disk drive;
- Special tip shape that enhances magnetic properties of a probe.

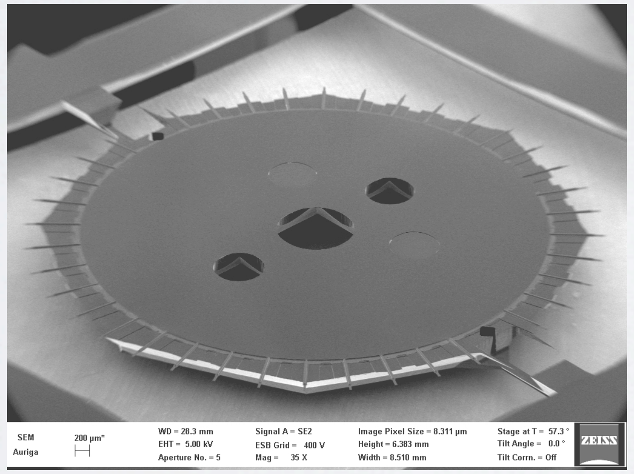


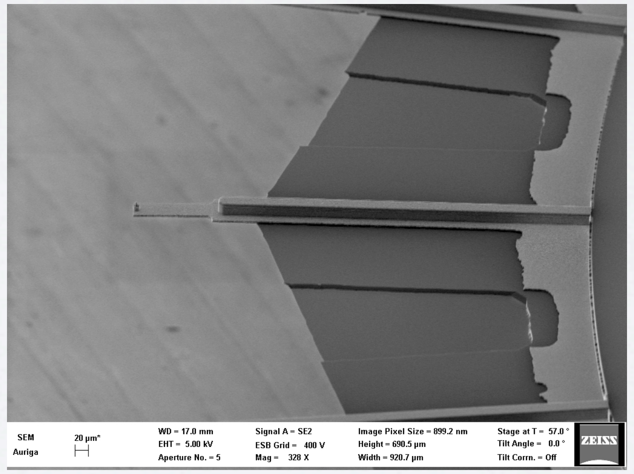
Cartridge with multi-probe technology

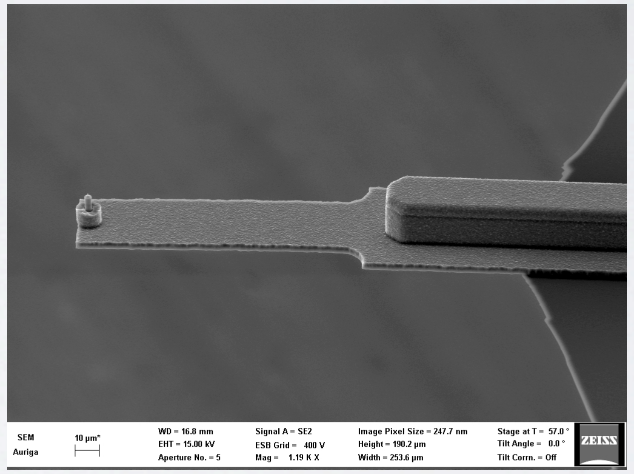
The new Revolution Cartridge with multi-probe technology for automated replacement of cantilevers makes a breakthrough in AFM usability:

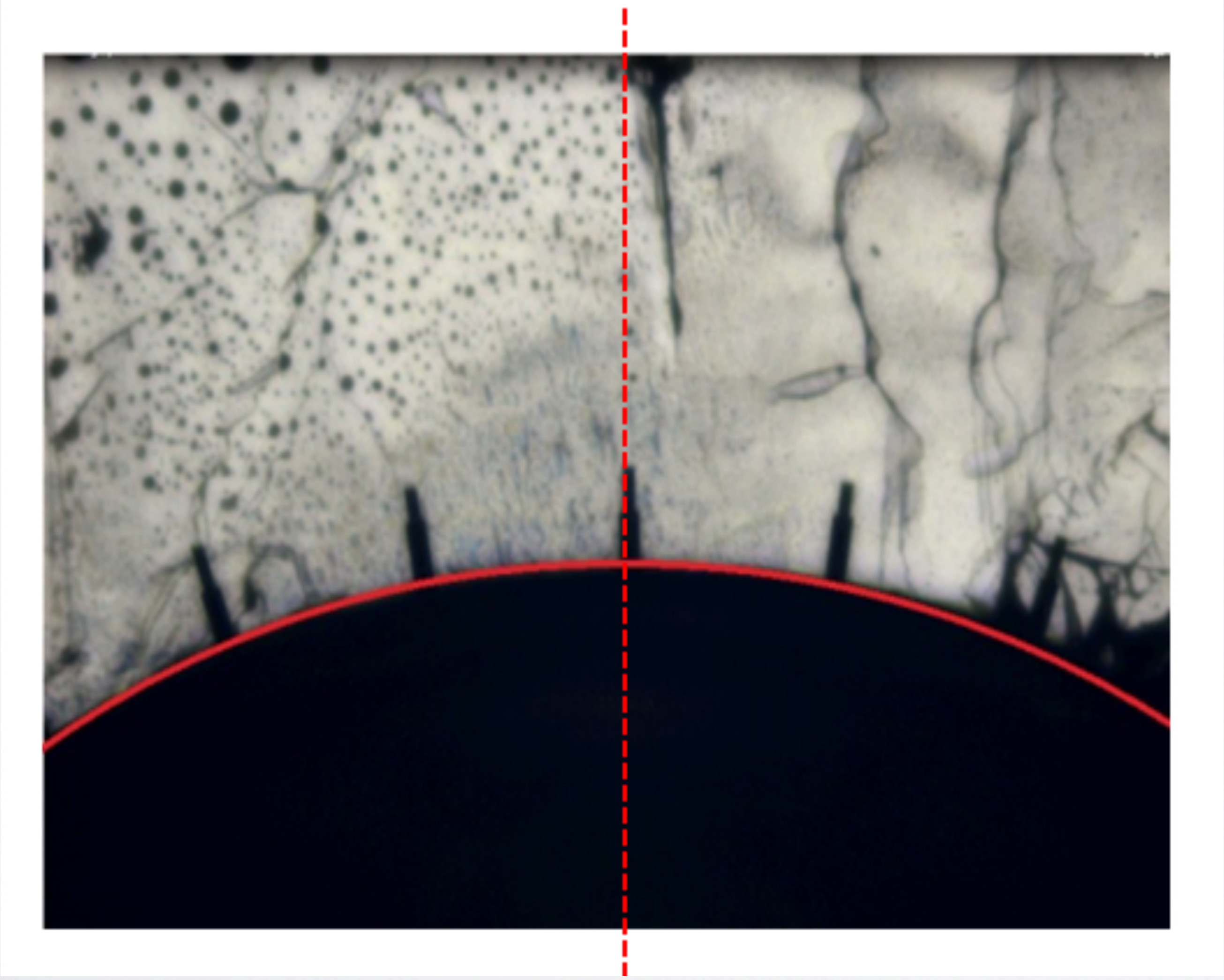
- 38 tips on Cartridge
- Fast tip exchange
- Fully automated operation

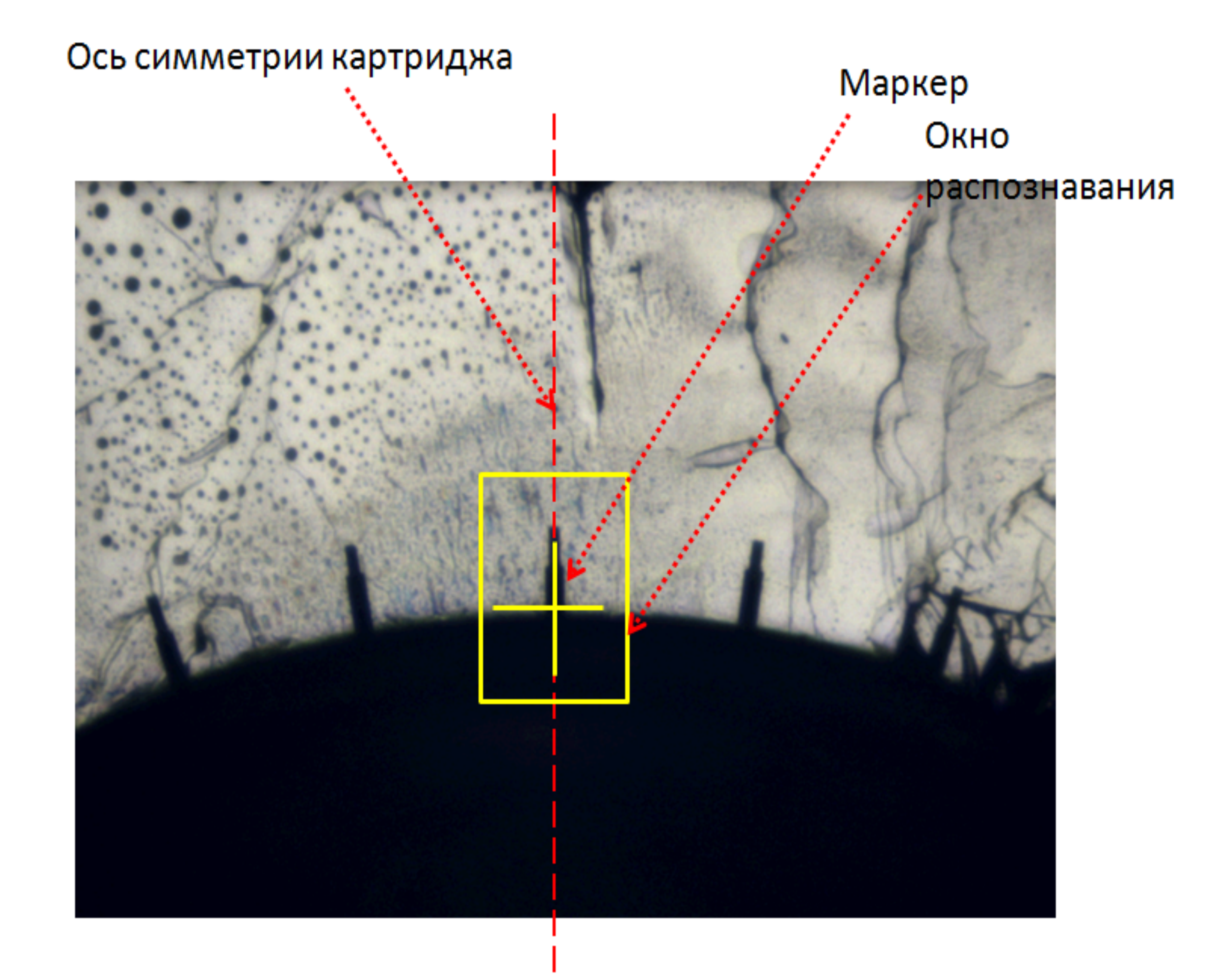










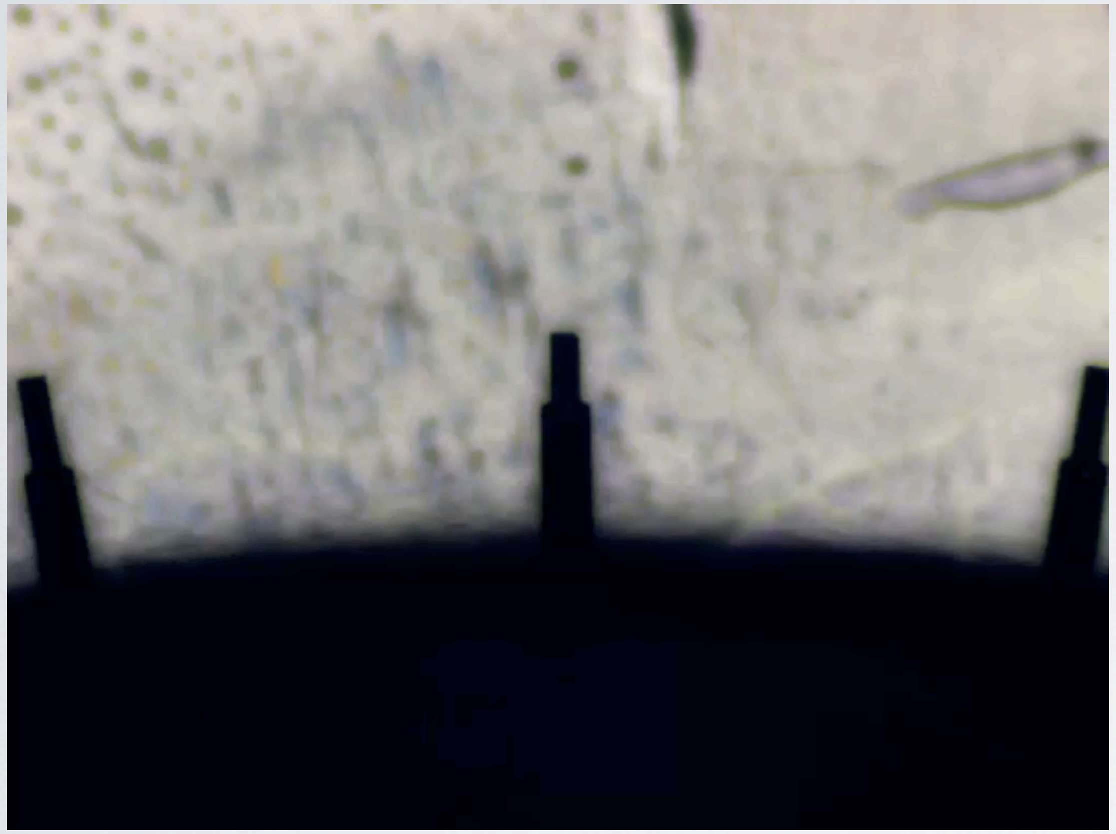

Ось симметрии картриджа
Маркер
Окно
распознавания

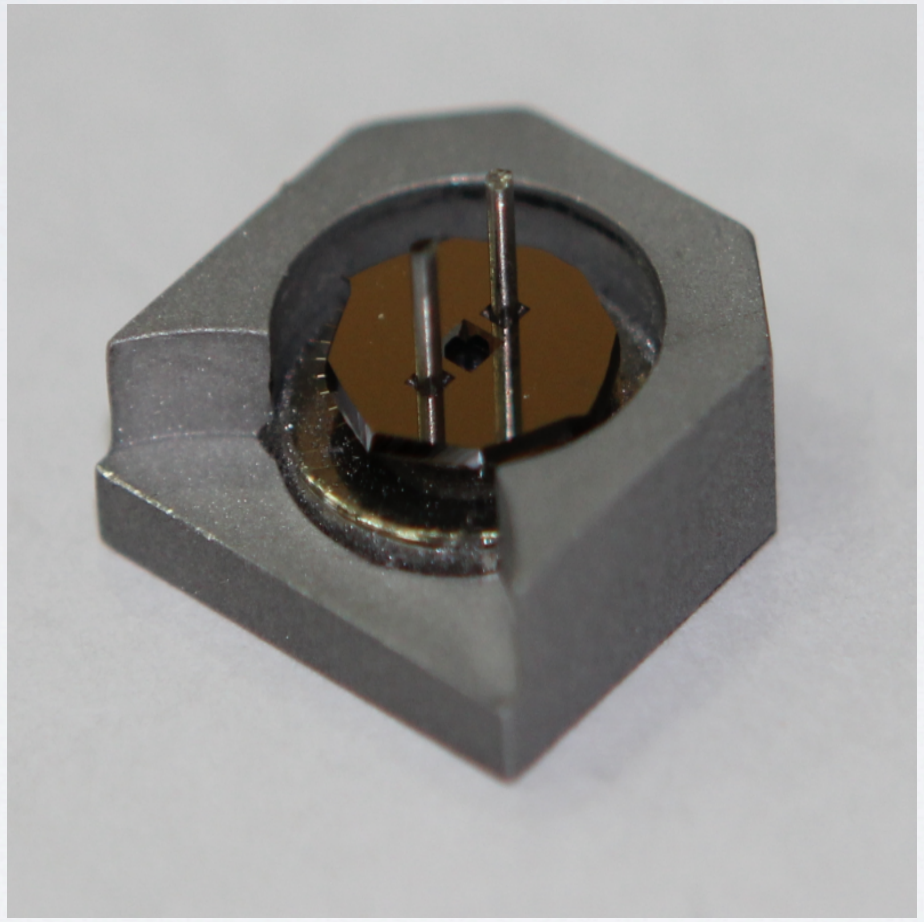
AFM for everyone: operation simplicity

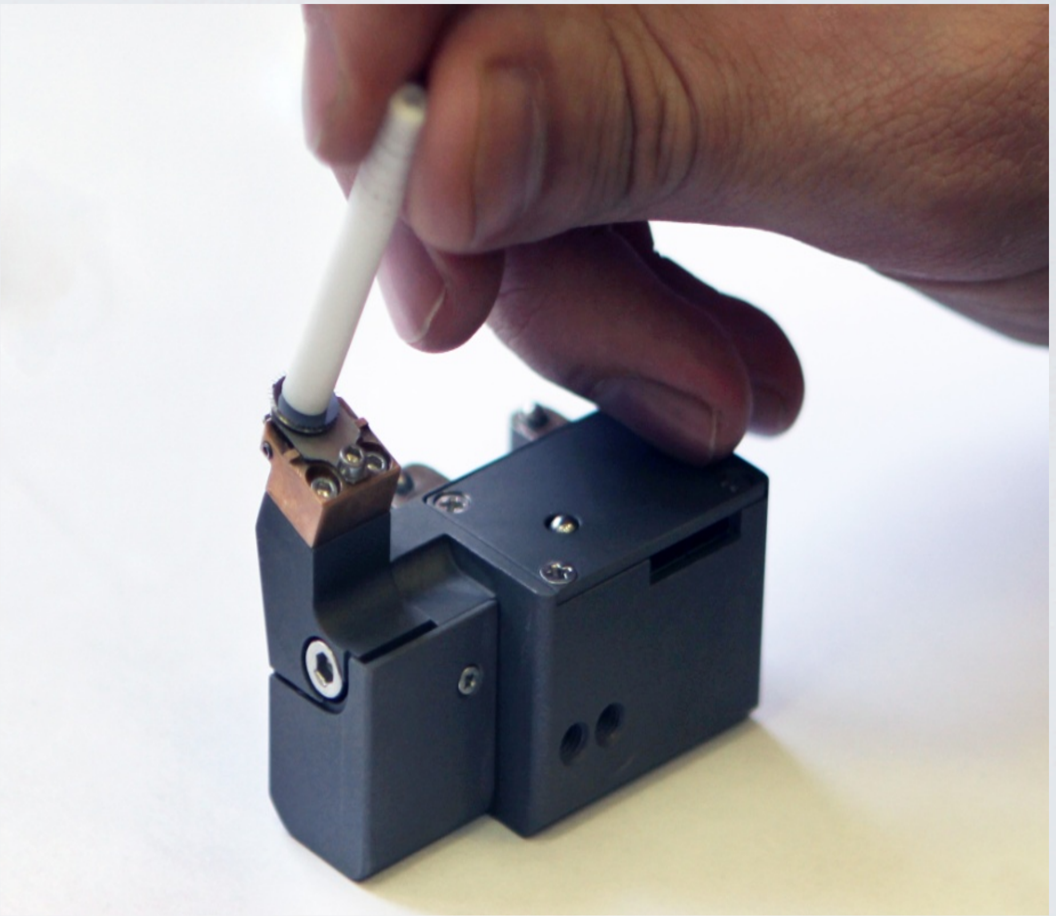
Safe package

Fixing tool

Cartridge probe installation



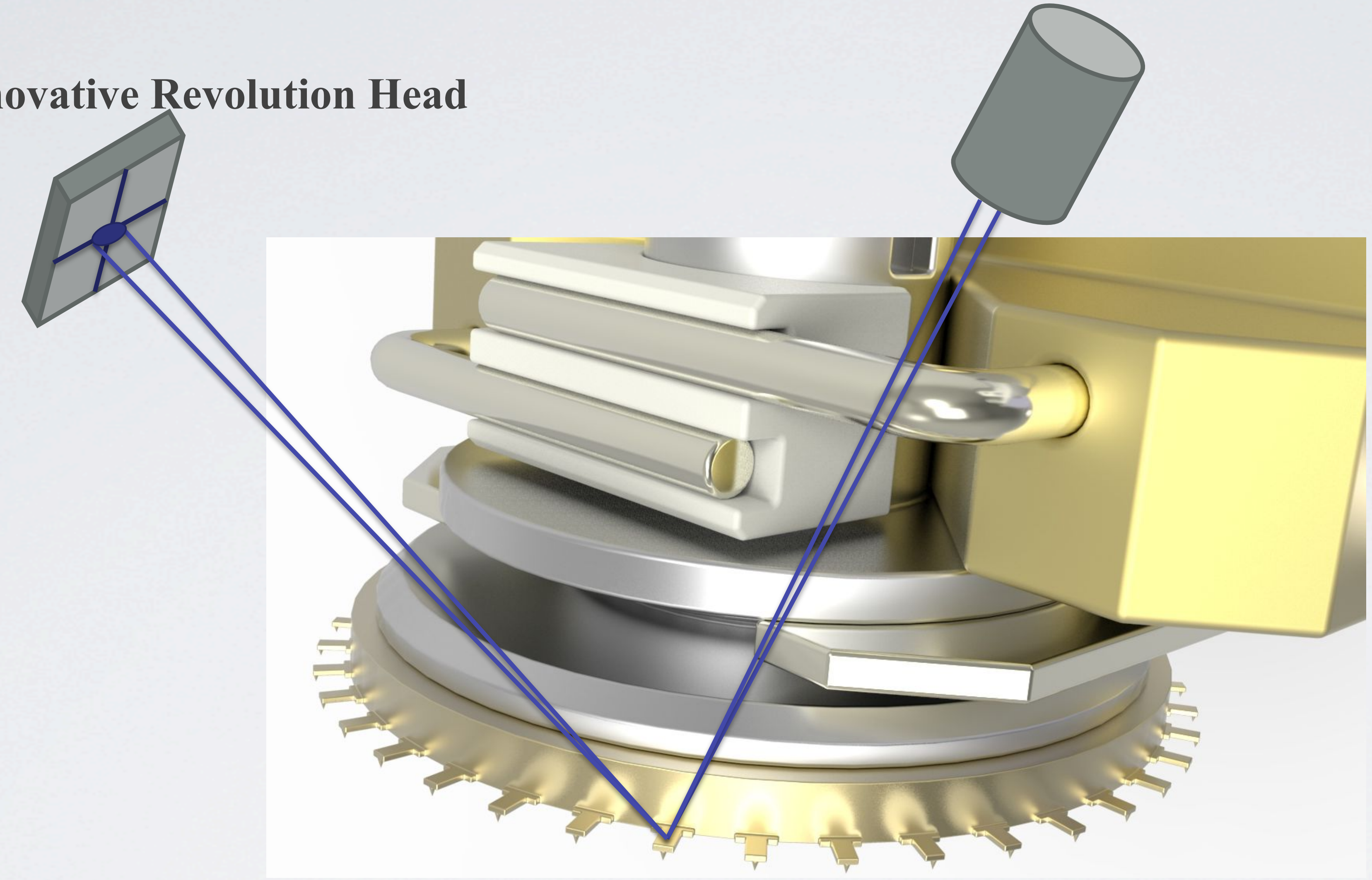




Installation and handling of multi-probe Cartridge is even easier than with traditional AFM cantilever

2014 - 2016 - BREAKTHROUGH in SPM technique Cartridge !!!
Research works were carried out for own funds since 2007

Innovative Revolution Head

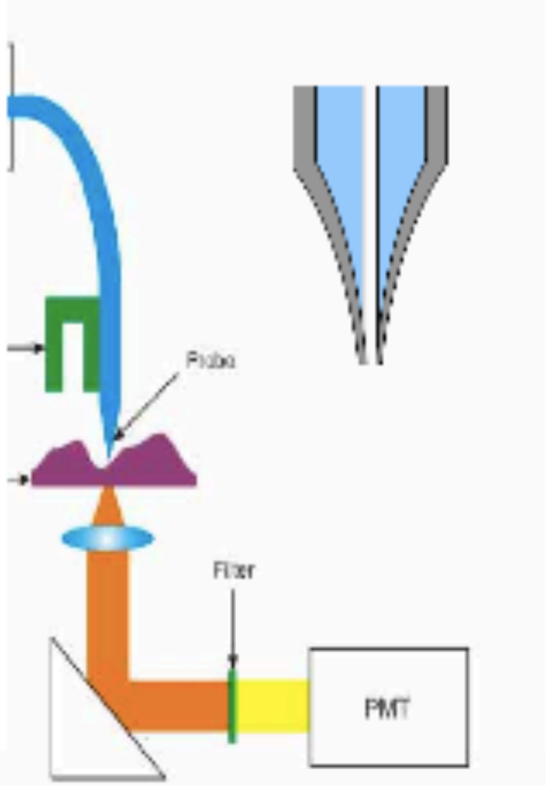


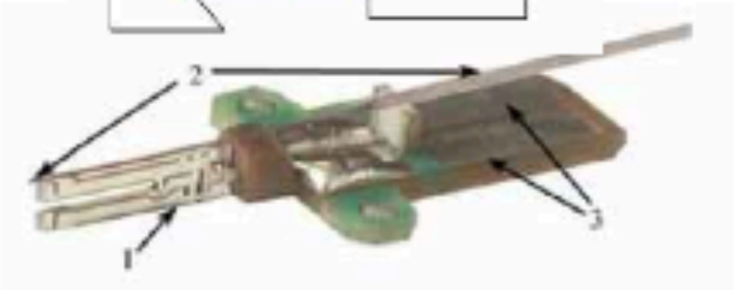
Заявка 96123099/09 от 06.12.1996, патент: «Многозондовый кантилевер для сканирующего зондового микроскопа» RU 2124251 C1; Заявка 2003116596/28 от 05.06.2003, патент: "Многозондовый датчик контурного типа для сканирующего зондового микроскопа"; патентообладатель "НТ-МДТ"; http://www.ntmdt.ru/titanium/page/revolution-cartridge-t; Заявка на патент № 2013143064 от 24.09.2013, Многозондовый датчик контурного типа для сканирующего зондового микроскопа.

NT-MDT Spectrum Instruments

SNOM techniques supported by NT-MDT

Straight quartz fiber with aperture (glued to tuning fork)

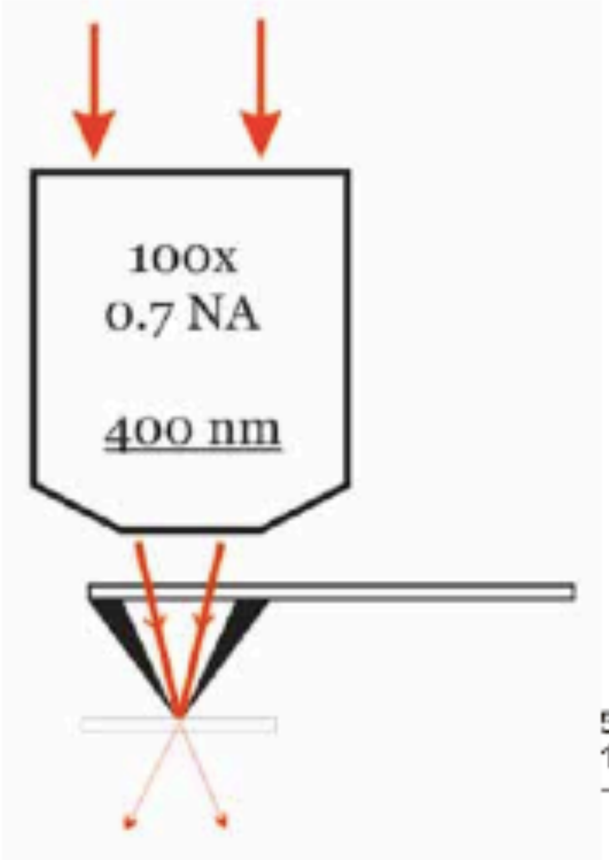


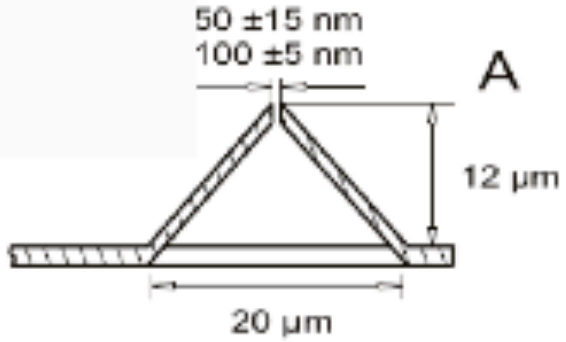


NT-MDT produces (for >10 years) both SNOM hardware and SNOM probes for various ranges of wavelengths (from UV to IR).

All SNOM modes are supported

Silicon cantilevers with aperture

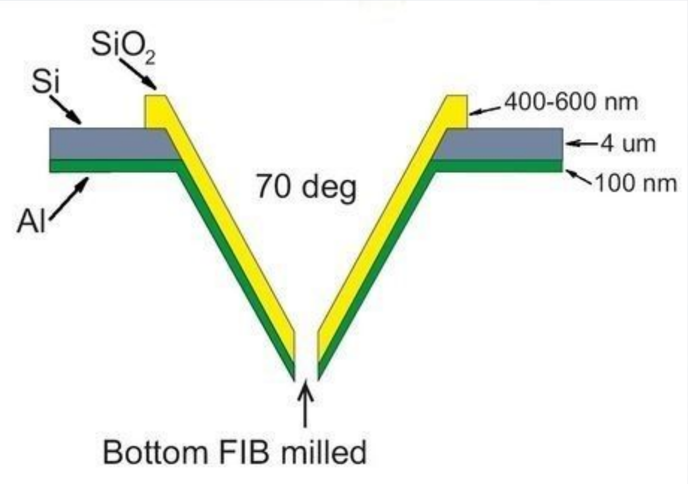




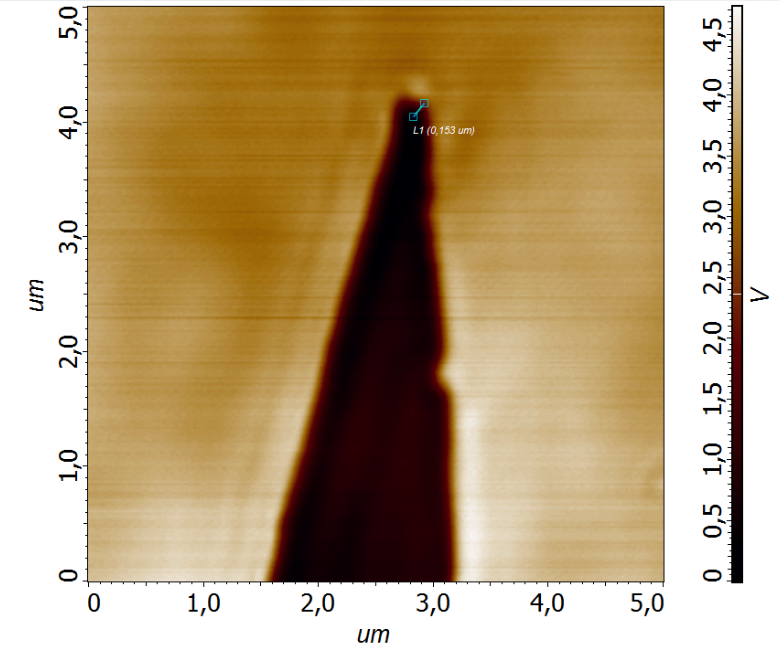
NT-MDT produces all hardware and software to work with such probes at all SNOM modes.

SNOM cantilever probes are produced by Nascatec, Germany

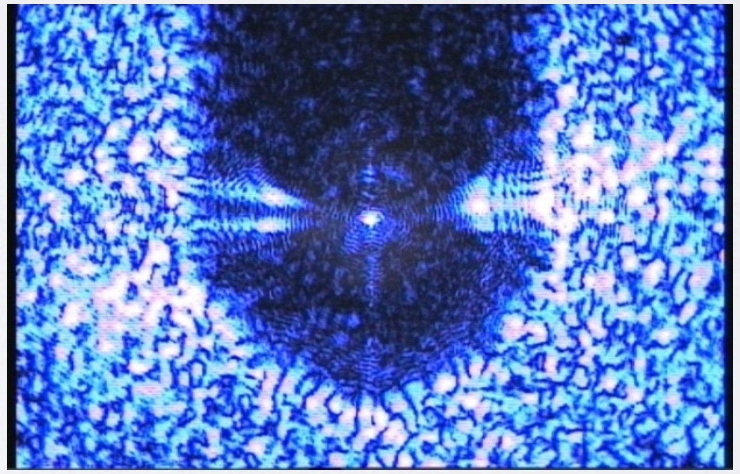
SNOM aperture cantilevers



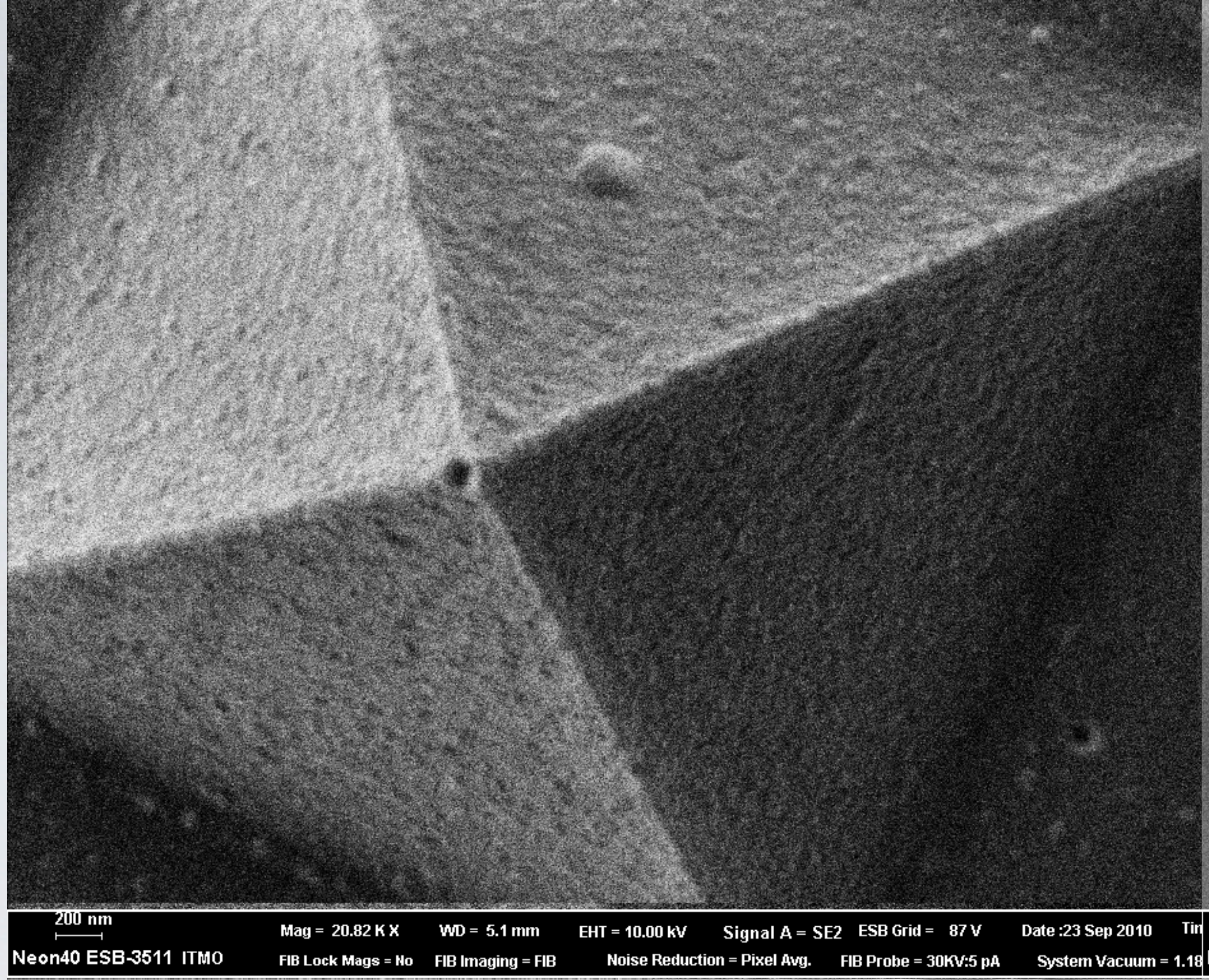
- Pyramid LxWxH = 20x20x13 um;
- Aperture around 150 nm;
- Both for contact and noncontact modes.

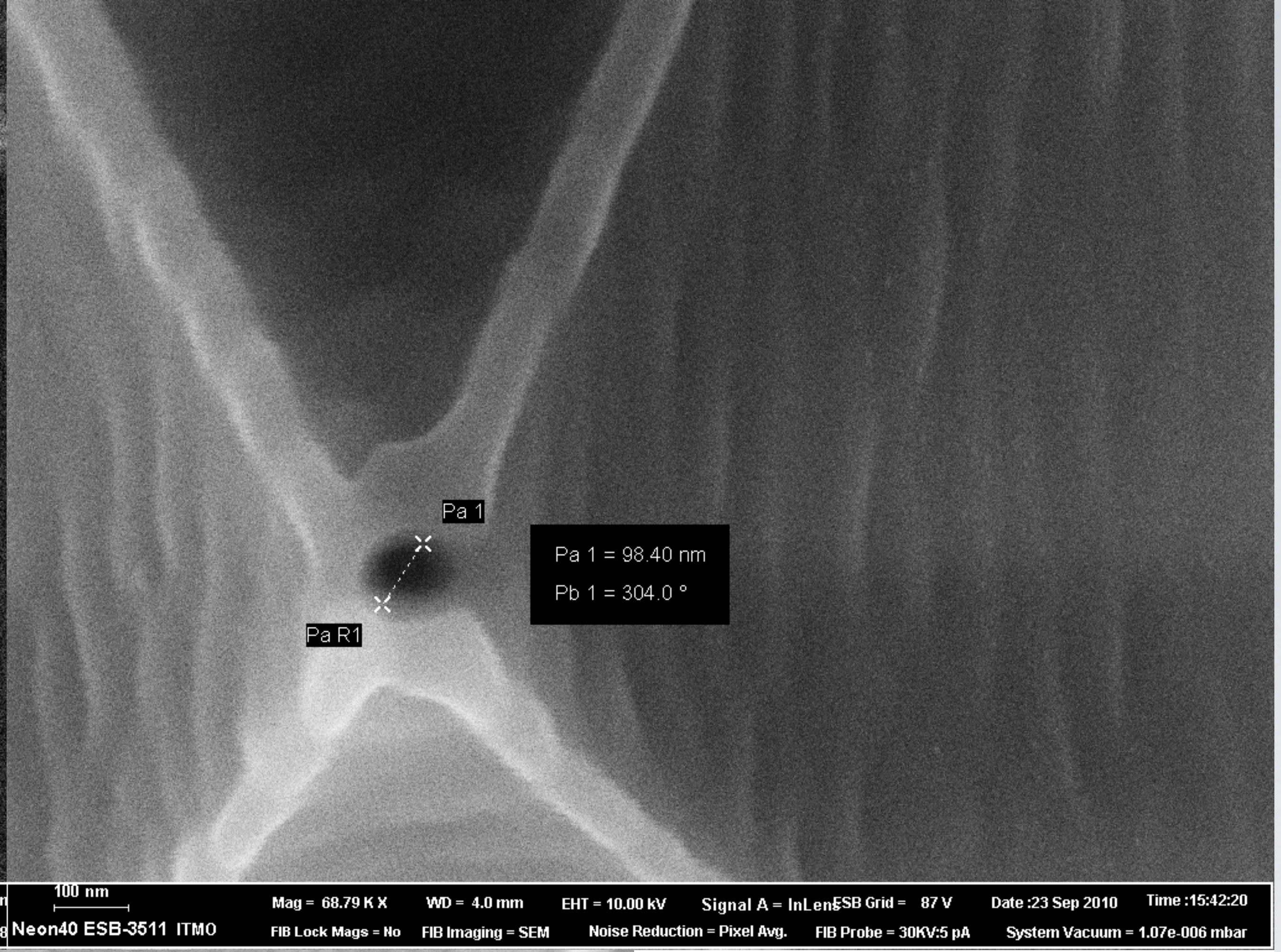


SNOM scan of the test grating



Optical image of an aperture lighten



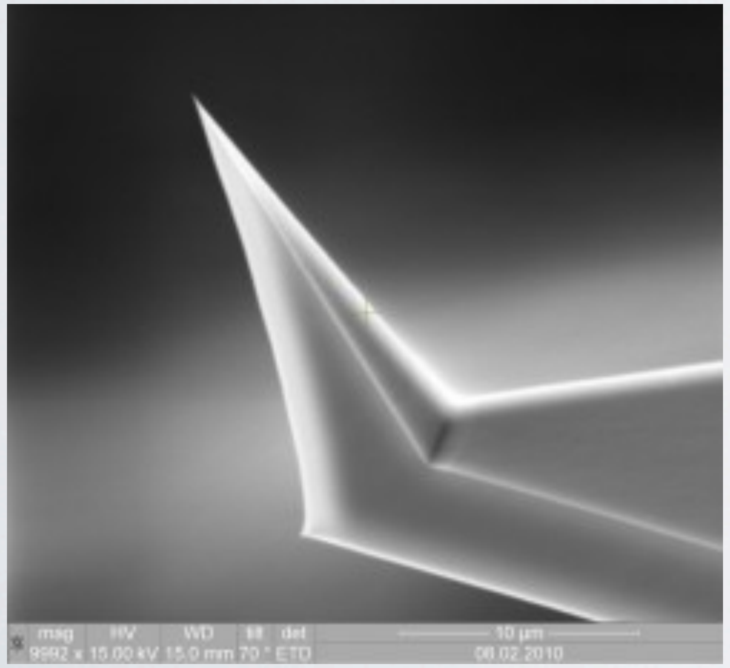


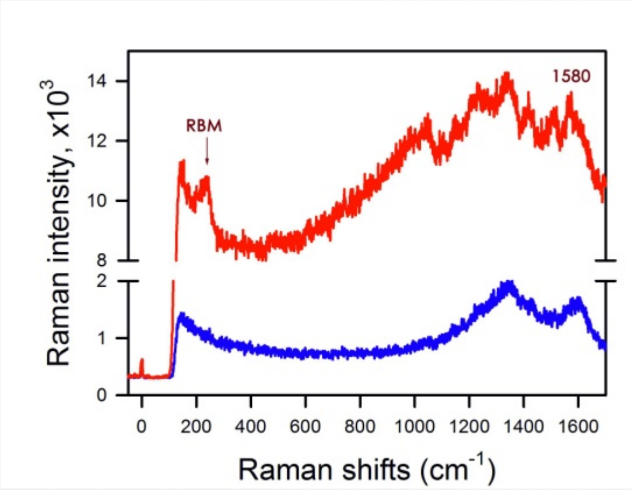
NT-MDT
Molecular Devices and Tools for NanoTechnology

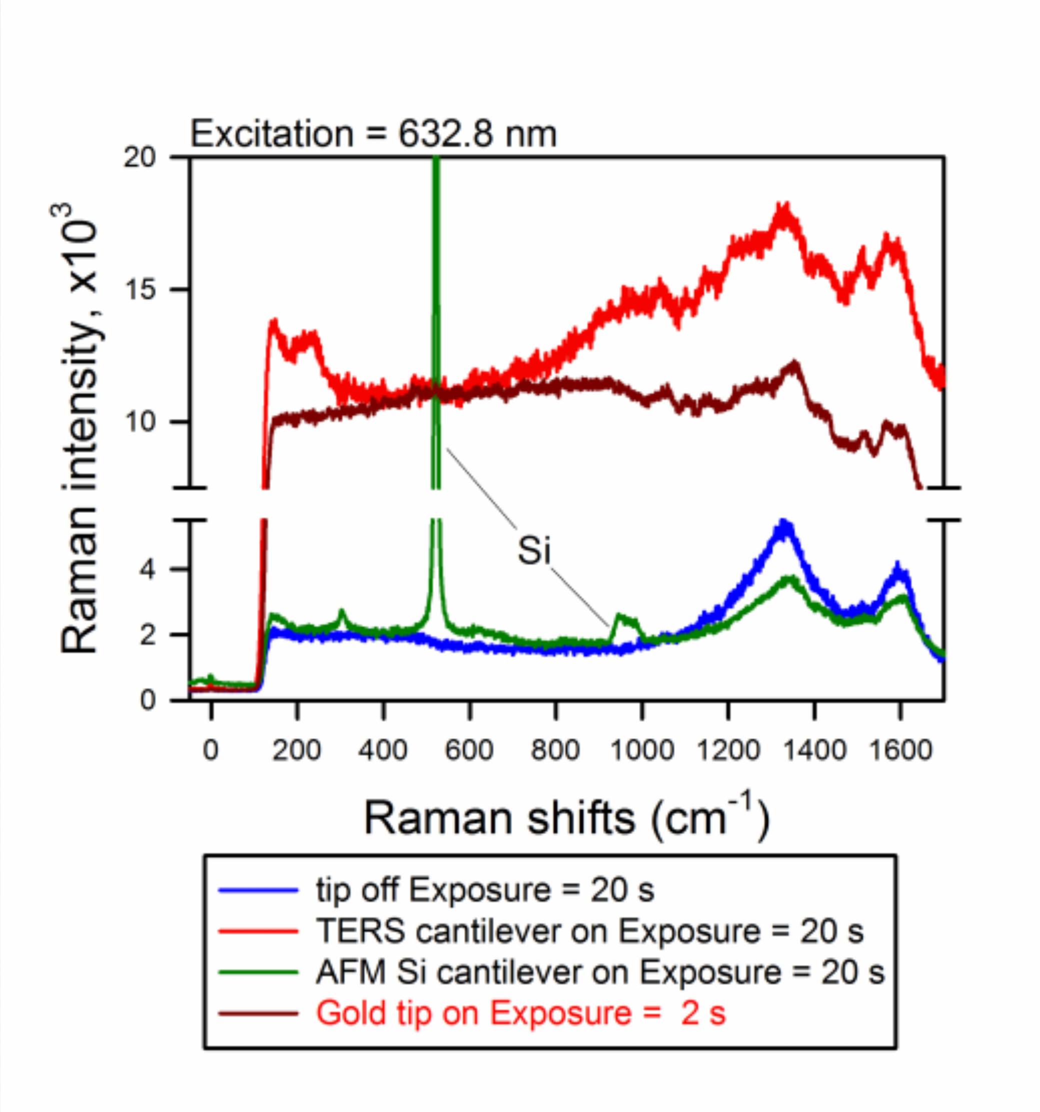
hoice is granted

TERS AFM probes (based on VIT_P model)

- Enhancement factors: 100x and more
- Lateral resolution in TERS: down to 10nm
- High speed TERS mapping
- Top-down illumination configuration (opaque samples)
- Increased lifetime (more than 1 month).

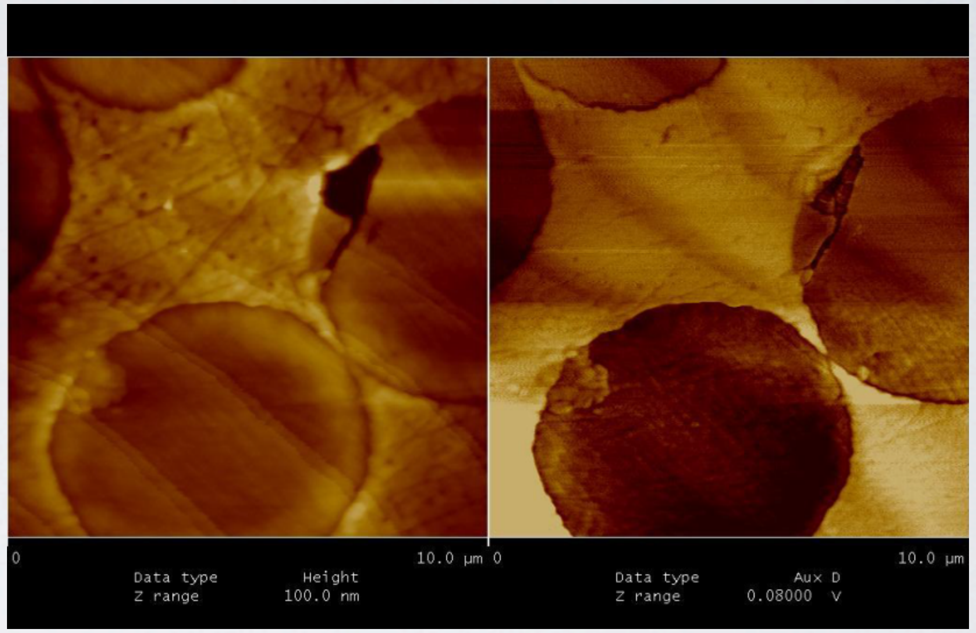






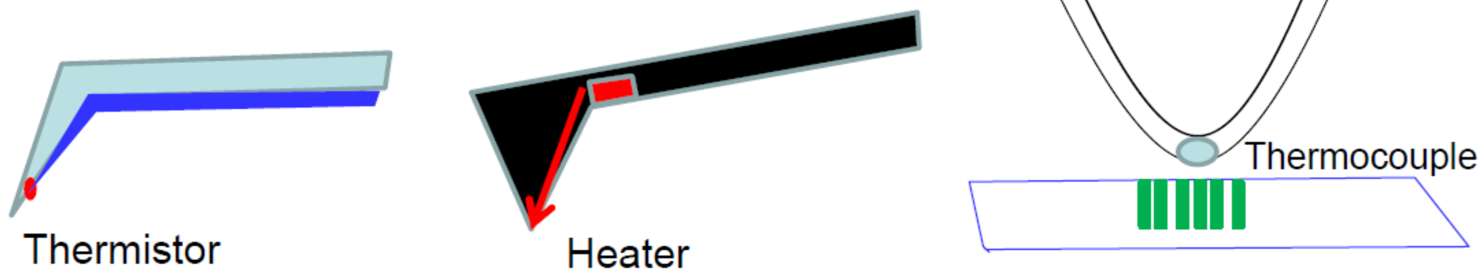
NT-MDT and AppNano common project of a new SThM system with thermocouple AFM cantilevers:

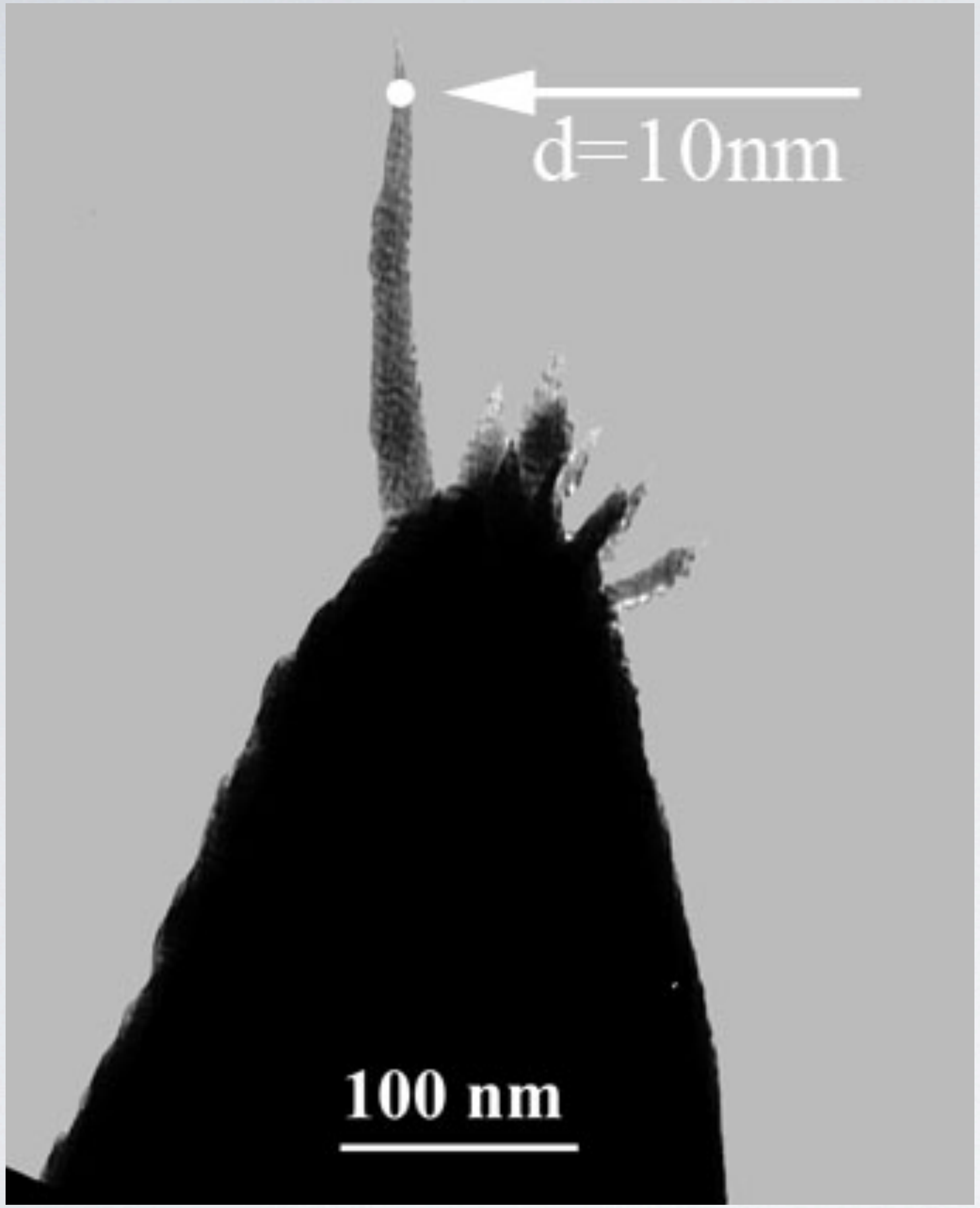
- Direct temperature measurements at the probe's top;
- Quantitative measurements;
- Large temperature range.



Carbon fibers embedded in epoxy

	Conventional Technology	**APPNANO**
Tip ROC (nm)	100 nm	**> 50nm**
Lateral Thermal Resolution	100 nm	**up to 20nm**
Thermal Sensor	Thermistor	**Thermocouple**
Location	Near the Apex	**At the Apex**
Maximum Temperature	160° C	**700° C plus**

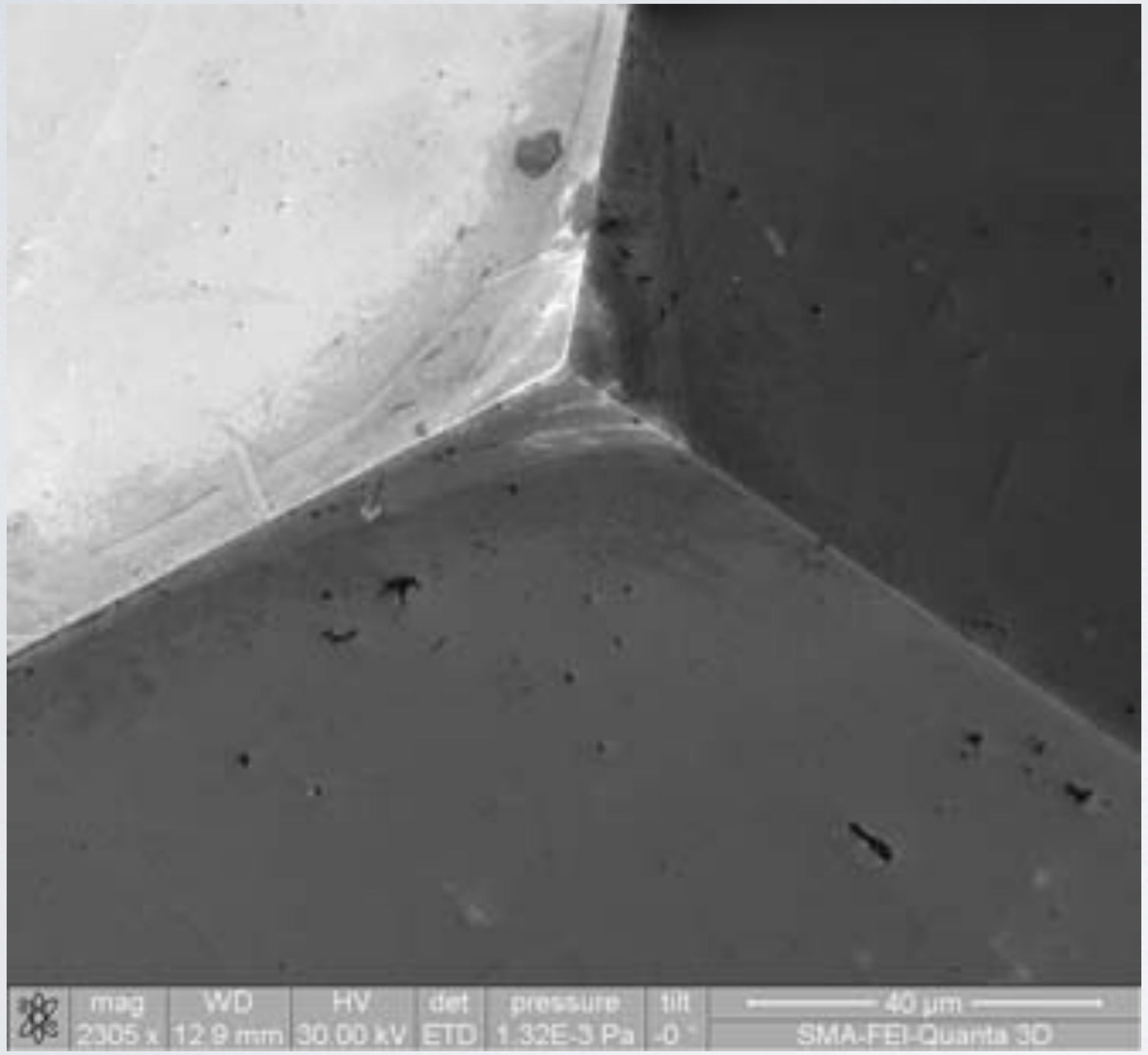




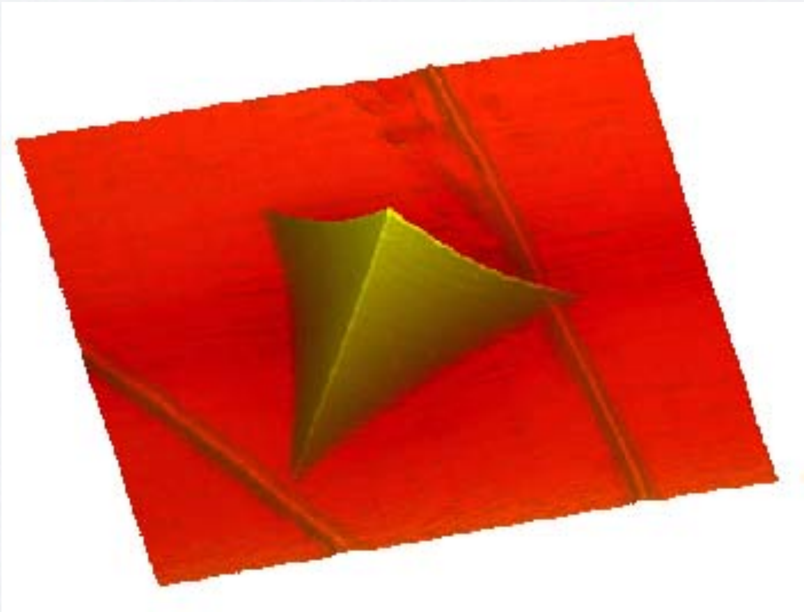
SEM image of tip with plasma process growing carbon whisker , radius of curvature – 1 nm!

(carbine form - $(-C \equiv C-)_n$

Piezo ceramic Cantilever with diamond crystal tip for hardness investigation of hard and ultra hard materials



TEM immade of tip



Piezocantilevers

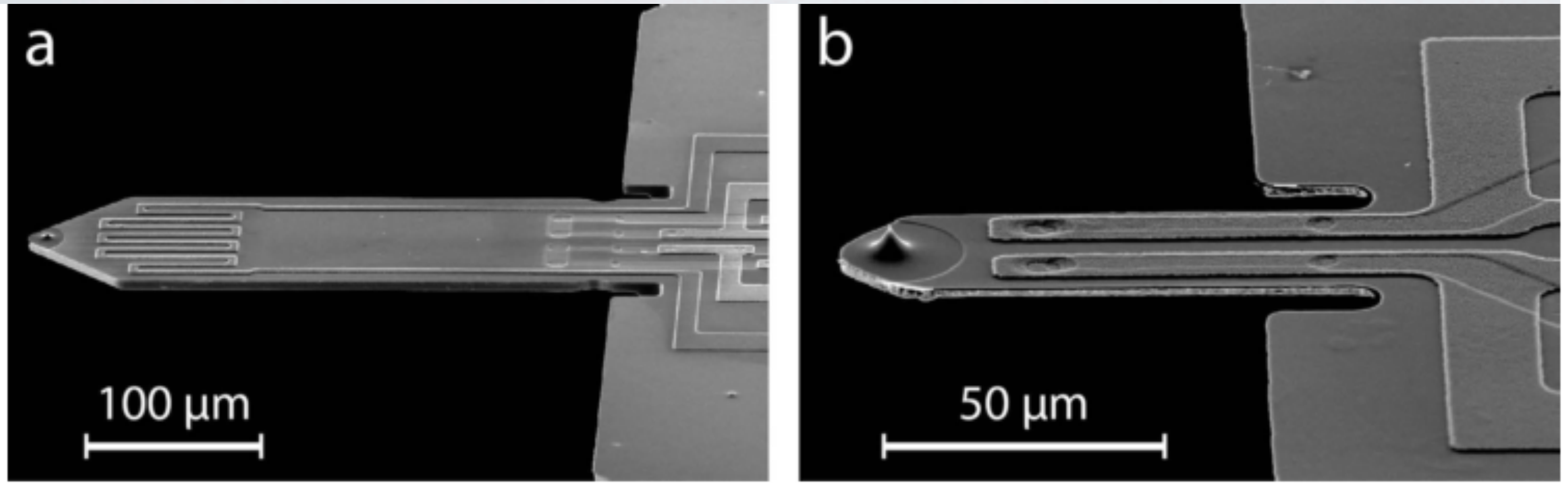
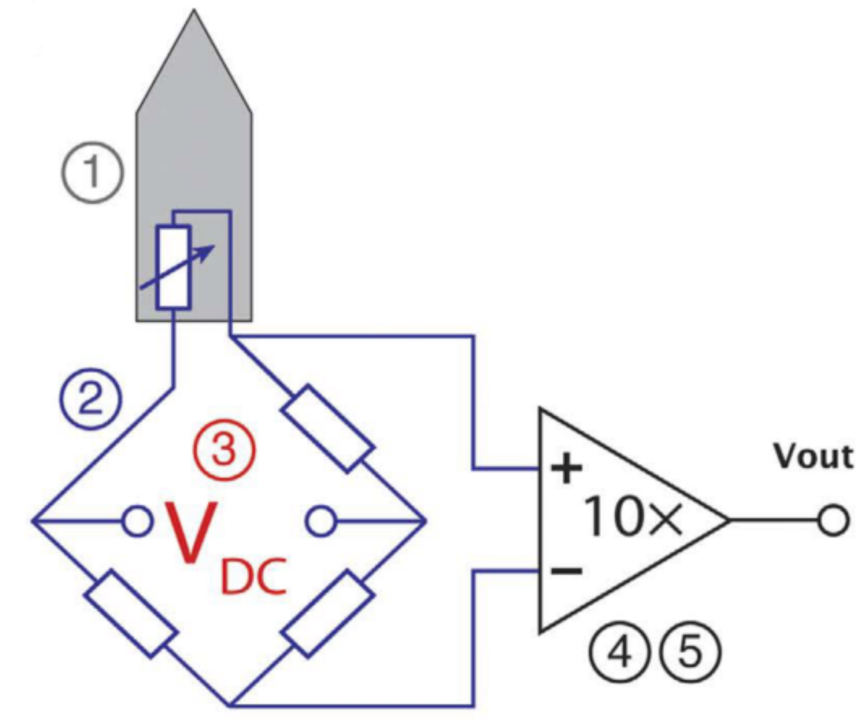
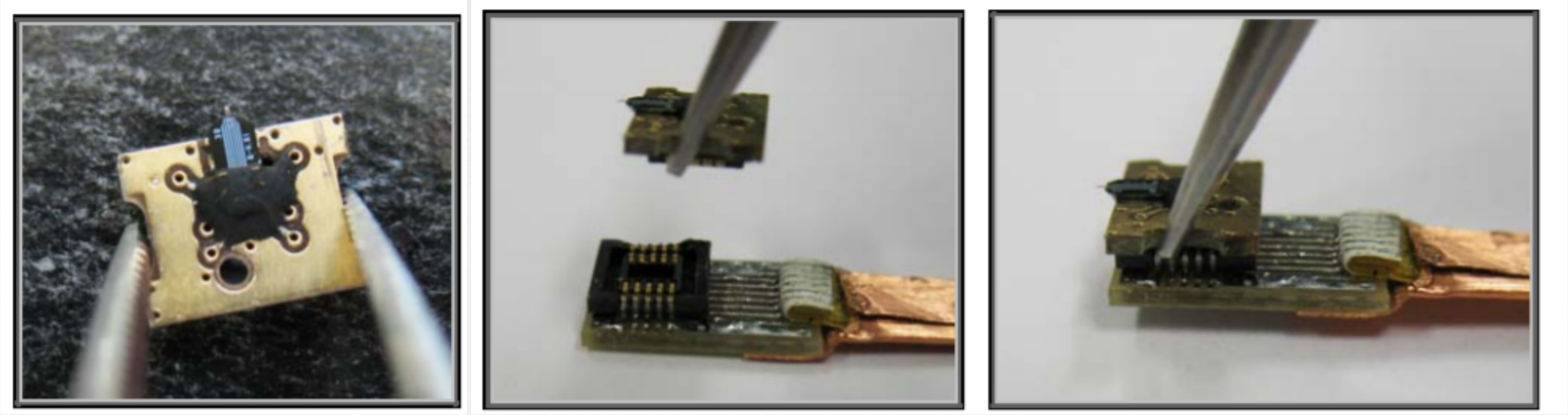


Figure 4. SEM images of representative (**a**) 300 × 100 µm and (**b**) 70 × 30 µm silicon piezoresistive cantilevers used for noise measurements and AFM imaging. (**a**) The large-sized piezoresistive cantilever has a meander-like patterned heater resistor for thermal actuation (close to the free end, not used in measurements) and two active piezoresistors (close to the fixed end). (**b**) The small-sized piezoresistive cantilever has two active piezoresistors along its length.

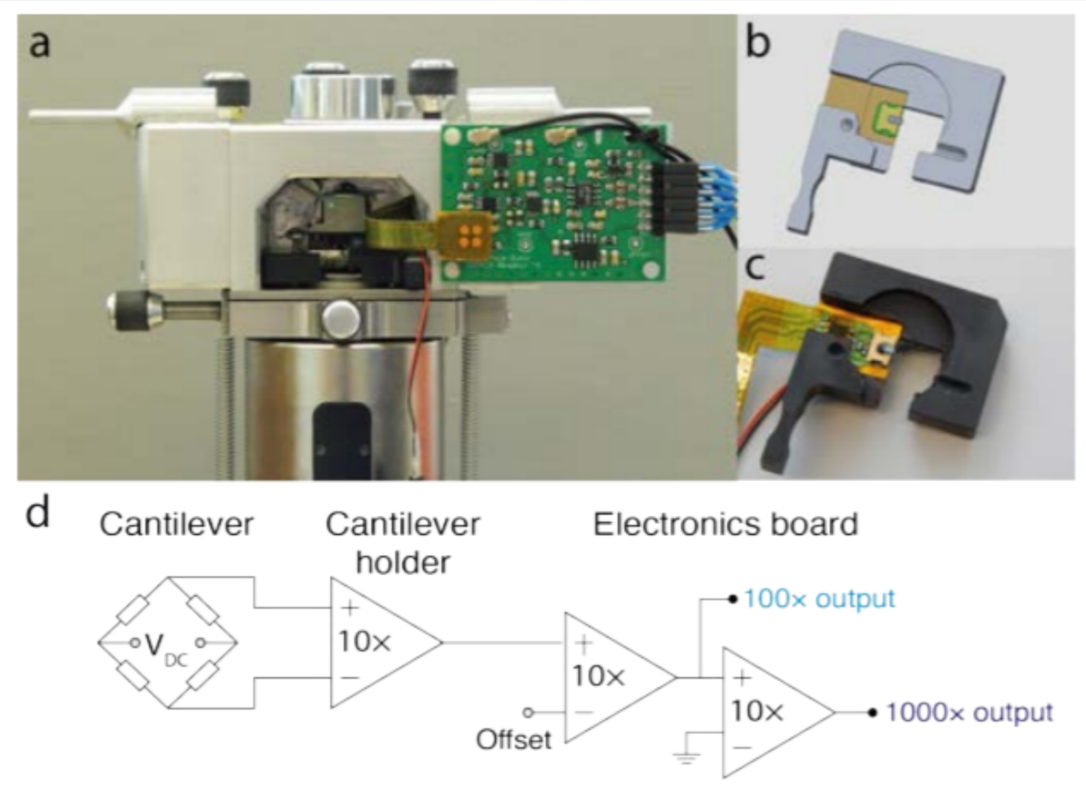


SCL Sensors



Установка зондового датчика

Censitivity



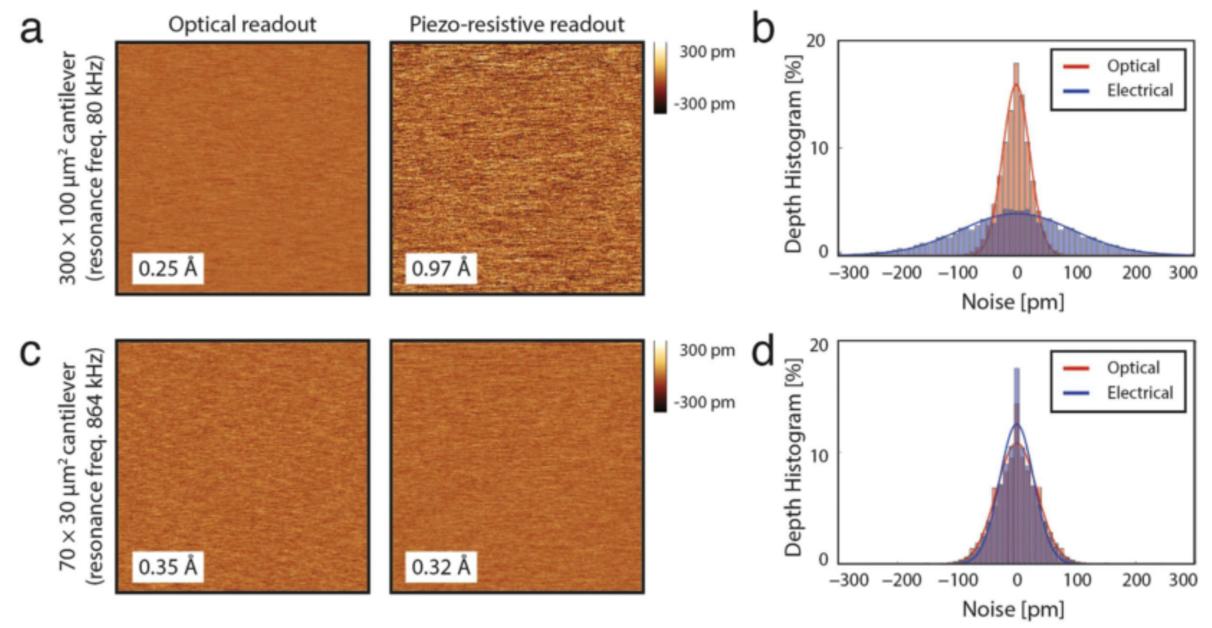
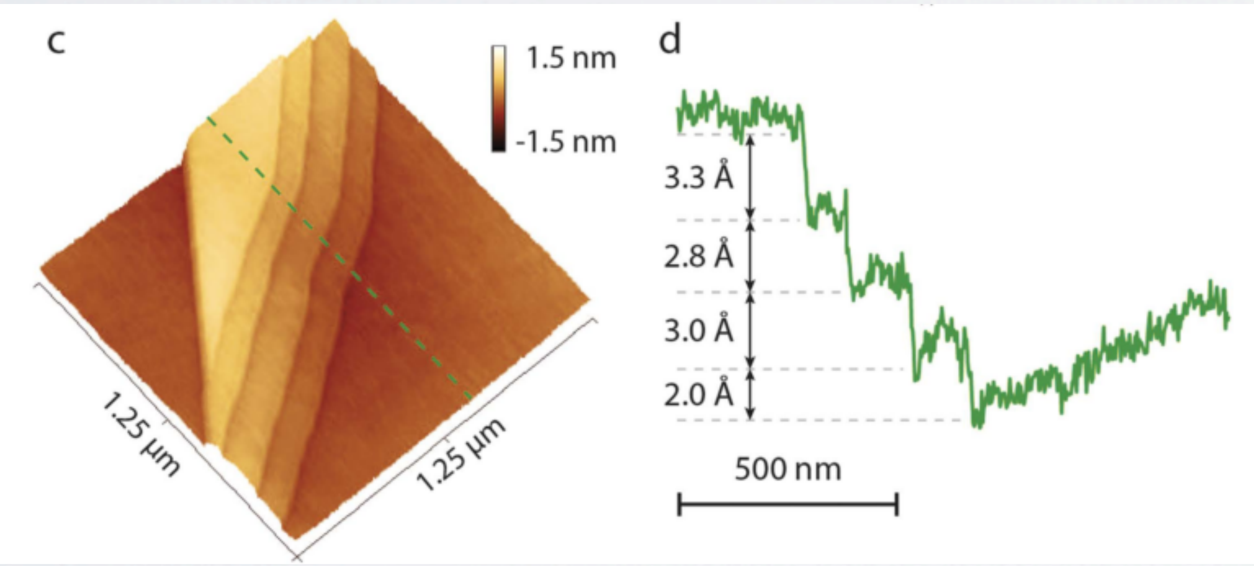
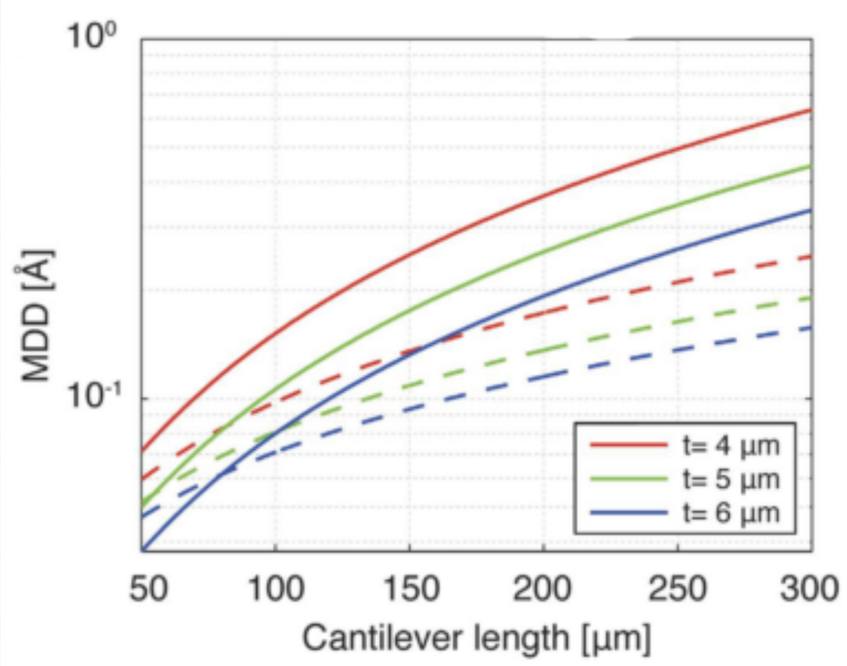
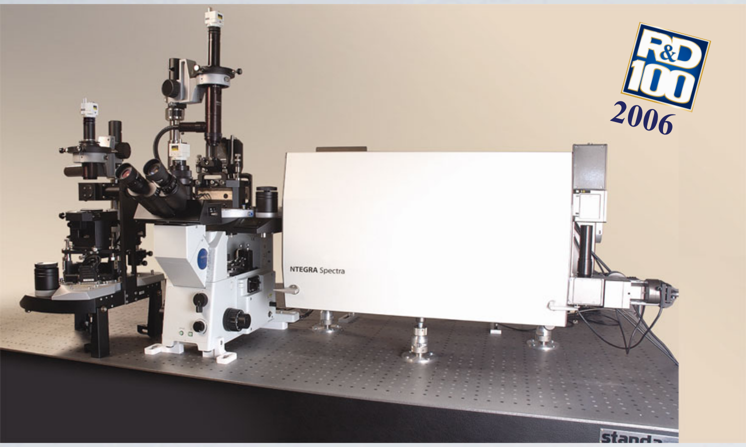


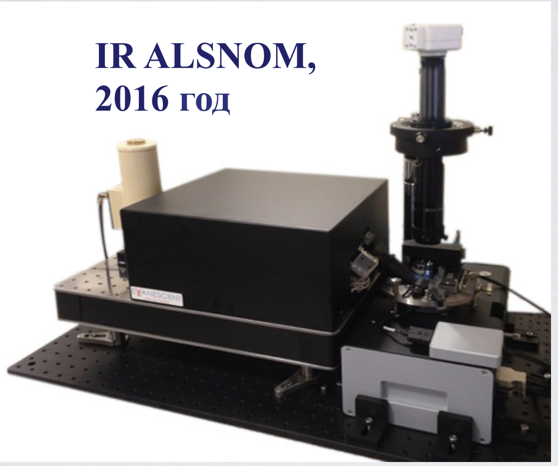
Figure 5. Noise measurements with OBD and piezoresistive readout. 300 × 100 µm piezoresistive cantilever: (**a**) Deflection noise measured with OBD and piezoresistive readout and (**b**) the corresponding noise histograms. 70 × 30 µm piezoresistive cantilever: (**c**) Deflection noise measured with the OBD and piezoresistive readout and (**d**) the corresponding noise histograms.



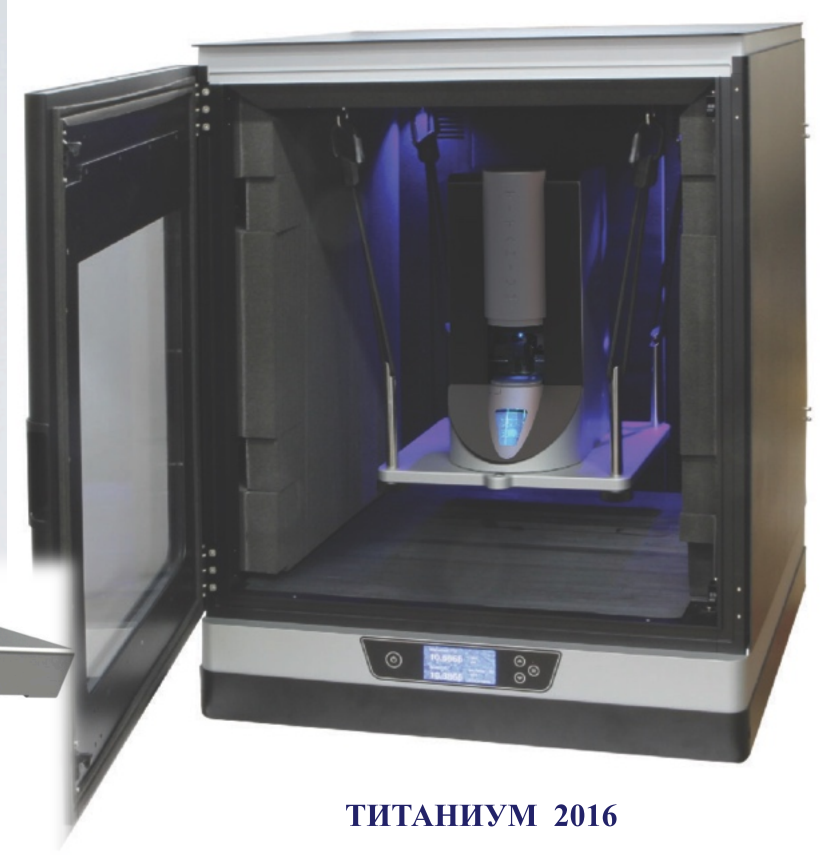


Dukic, M., Adams, J. D. & Fantner, G. E. Piezoresistive AFM cantilevers surpassing standard optical beam deflection in low noise topography imaging. *Sci. Rep.* **5,** 16393 (2015).





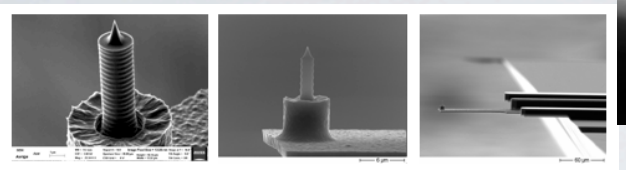
IR ALSNOM,
2016 год

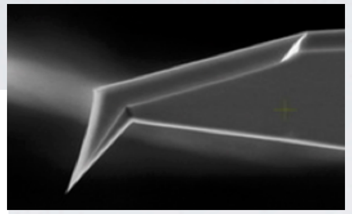


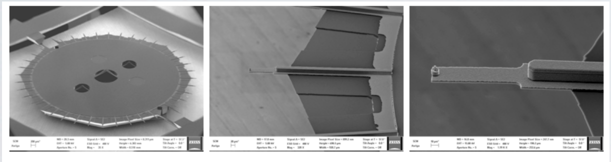
ТИТАНИУМ 2016

ИНТЕГРА-СПЕКТРА-4Р 2016

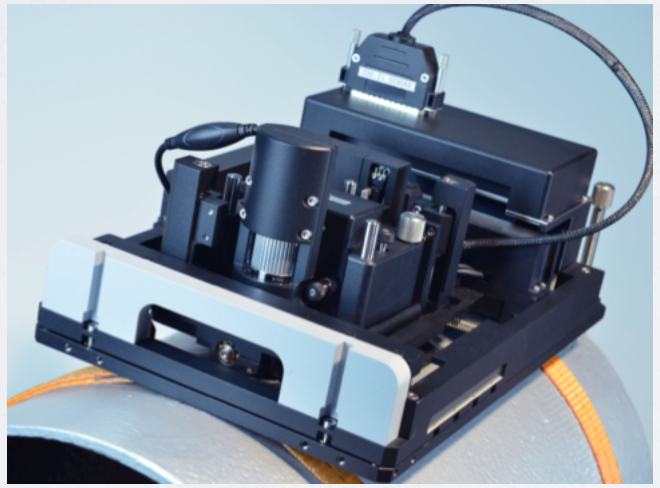
polySi-Technology, R_c- 3-5 nm

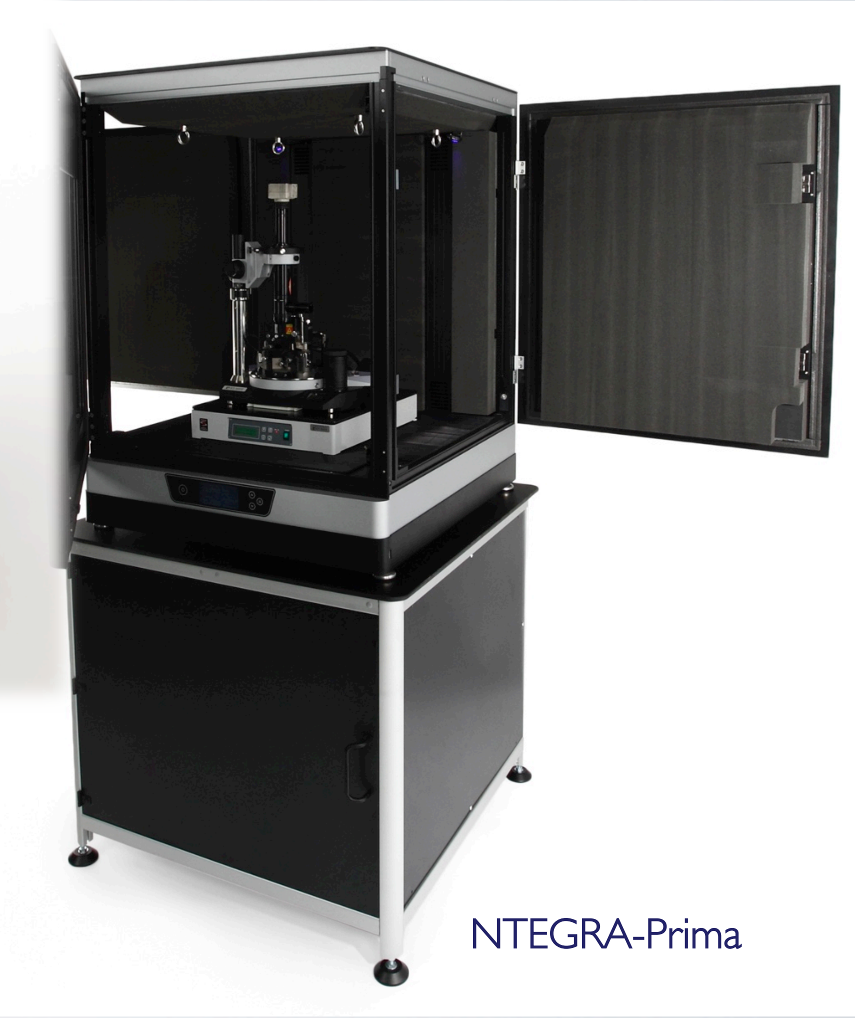






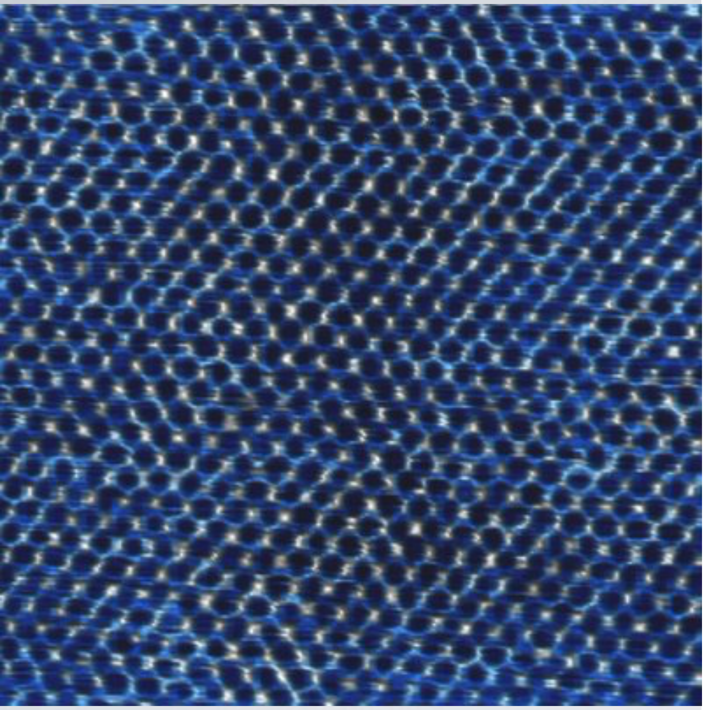
Новые типы кантилеверов (2015 -2016 г.г.)



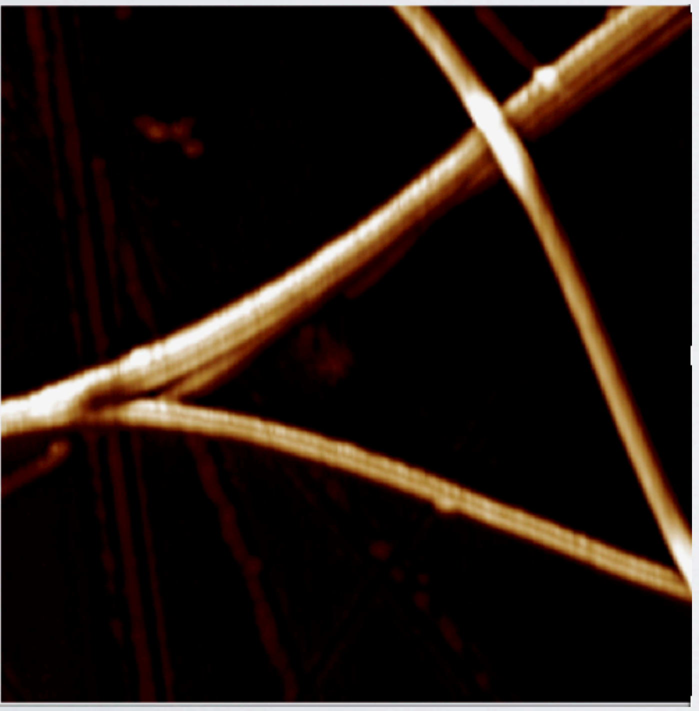


NTEGRA-Prima

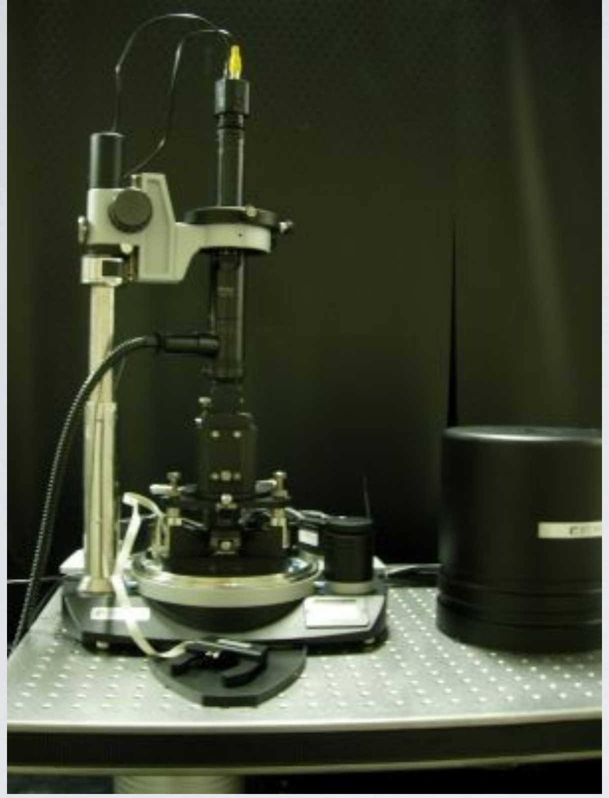
NT-MDT
Spectrum Instruments



5x5 nm, HOPG, VEGA-2017

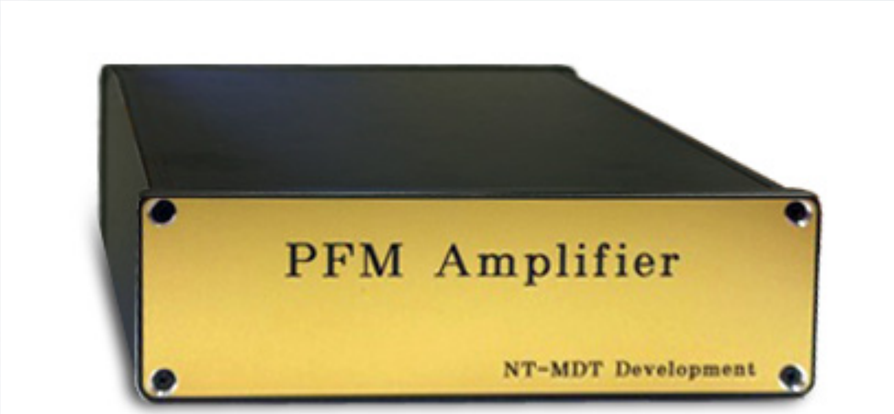


Peptide nanotubes of diphenilalanine. 8×8 mkm. Dielectric constant



BLU_322NTF – Controller P9, Digital feedback

SAM01 Signal Access Module



BL_PFMA100

SPM controller for NTEGRA systems (6U case). Contains multifrequency AFM board with DS. Bipolar HV board XYZ (± 300 V). Power input 90-240 V, 50Hz/60Hz. Power 200 W. Allows installation 2+3 additional expansion boards:- High Voltage board for flexture stage operation (BRHV030)- Thermocontroller board (BRTC015, BRTC020)- Operational board for Nanoindentation (BRIN003)

External PFM amplifier (-100V; +100V), Band: DC – 500 kHz, dimensions 25x17x5.5cm. Must be used with Signal Access Module SAM01.

BRTC015

Thermocontroller boardSU045NTF, SU005NTF, SCC08NTF, SCC09NTF, liquid and EC cells for Ultra controllers. Operates: SU_Next, with temperature control. Should be used together with BRTC020 if cooling is needed. Consumed power: 80W.Big.

BL01EMF

External controller for electromagnets of EMF series

BRTC020

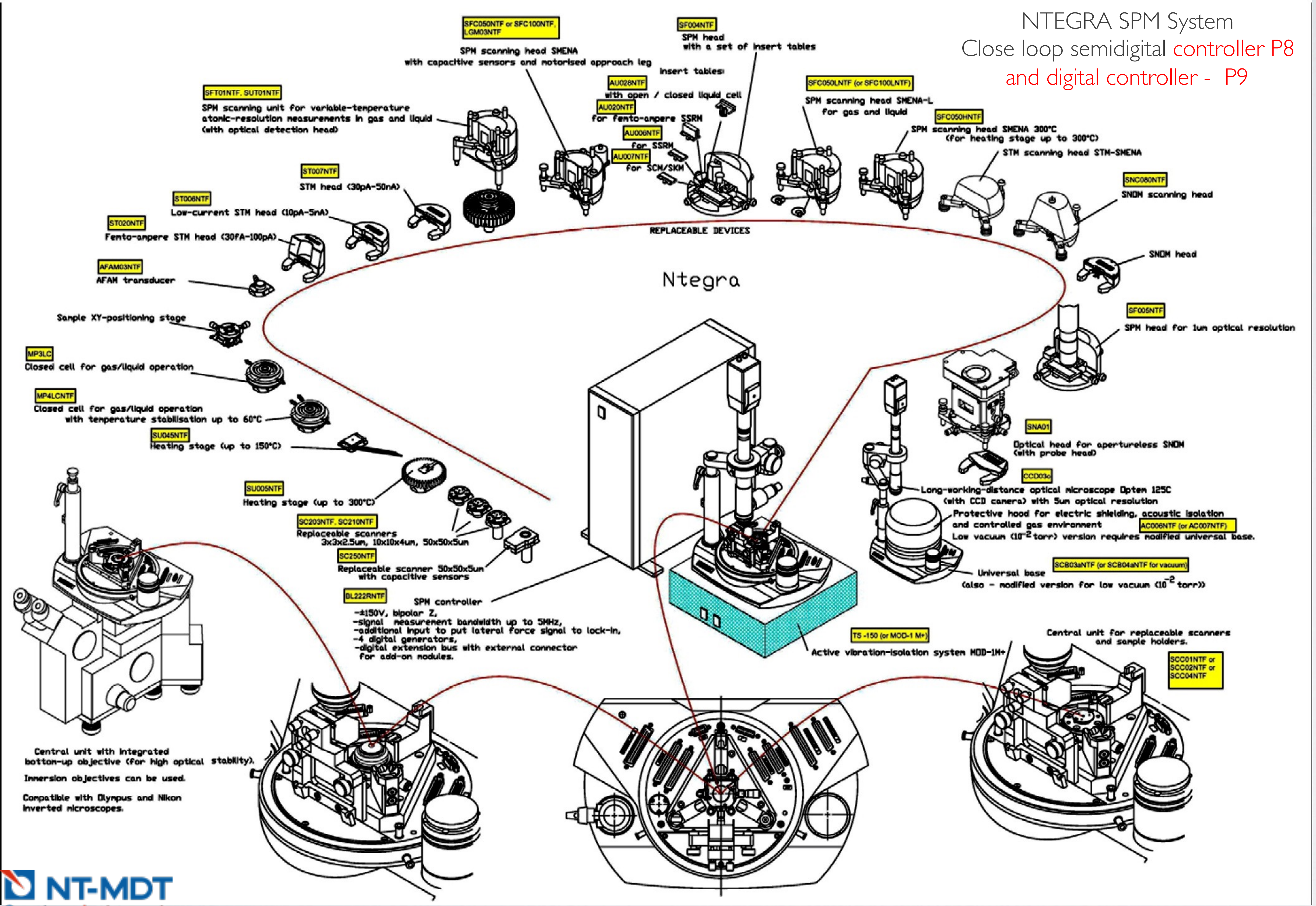
Power board for chiller.Small.

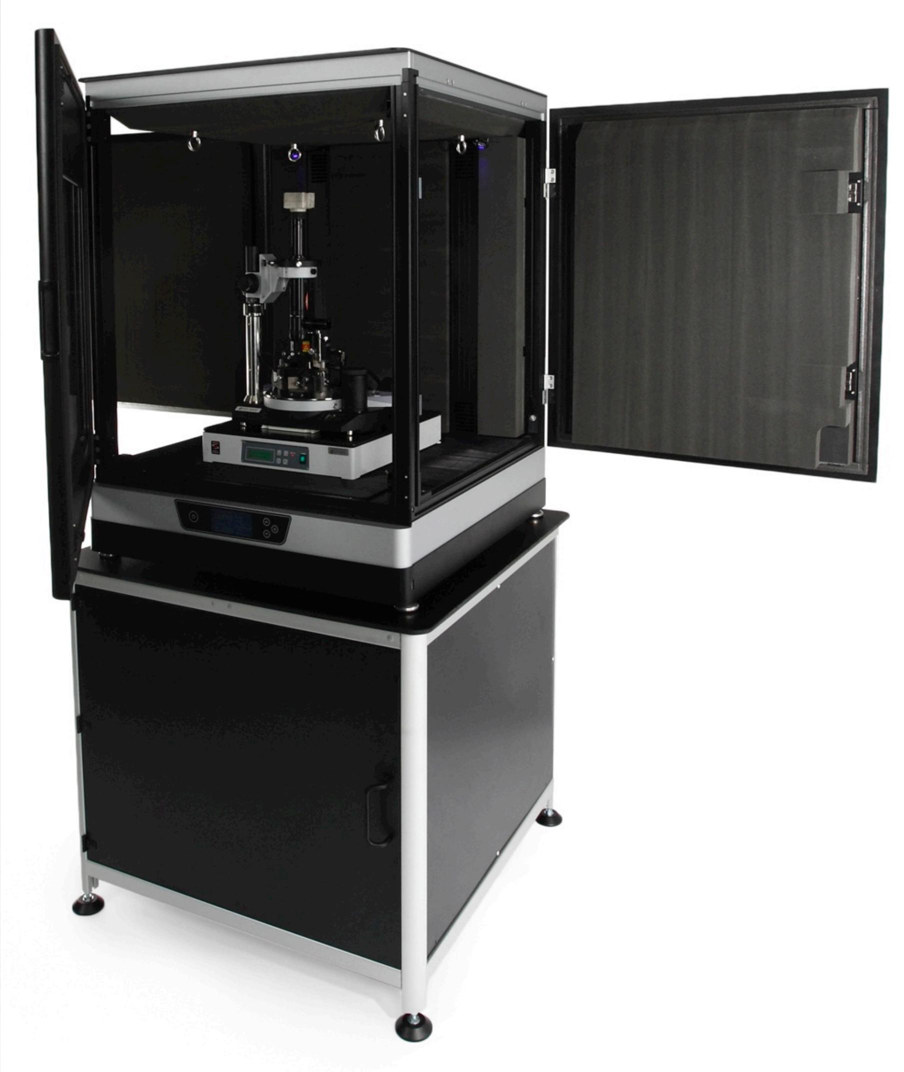
- Number of scanning signals: up to 24
- Signal processing: buffer size 512 Mbit, 3x 340 MHz FPGA, 320 MHz DSP Synchronous detectors: 2 analog LEDs, 3 digital LEDs (support for multi-frequency AFM techniques)
- Generators: 6 digital oscillators, 32 bit, Synchronous detectors
- Bias voltage: +/- 10 V AC and DC (independent bias to sample and probe), +/- 150 V AC and DC (optional)
- Self-diagnosis: automatic

- Auto-tuning of scan parameters: drive amplitude, synchronous detector gain, operating point of the OS circuit, amplification of the OS circuit, scanning speed, configuration of advanced techniques
- Automation options: setting up the optical recording system, multiple scanning for a given scenario within the area of 200x200 mm (for VEGA SPM), overlaying optical and AFM images, panoramic optical review, autofocusing on the cantilever, autofocusing on the sample
- Programming tools: Nova PowerScript language, integration with LabView, integration with user database
- Database of received images Interface: USB

NTEGRA SPM System

NTEGRA SPM System
Close loop semidigital controller P8
and digital controller - P9

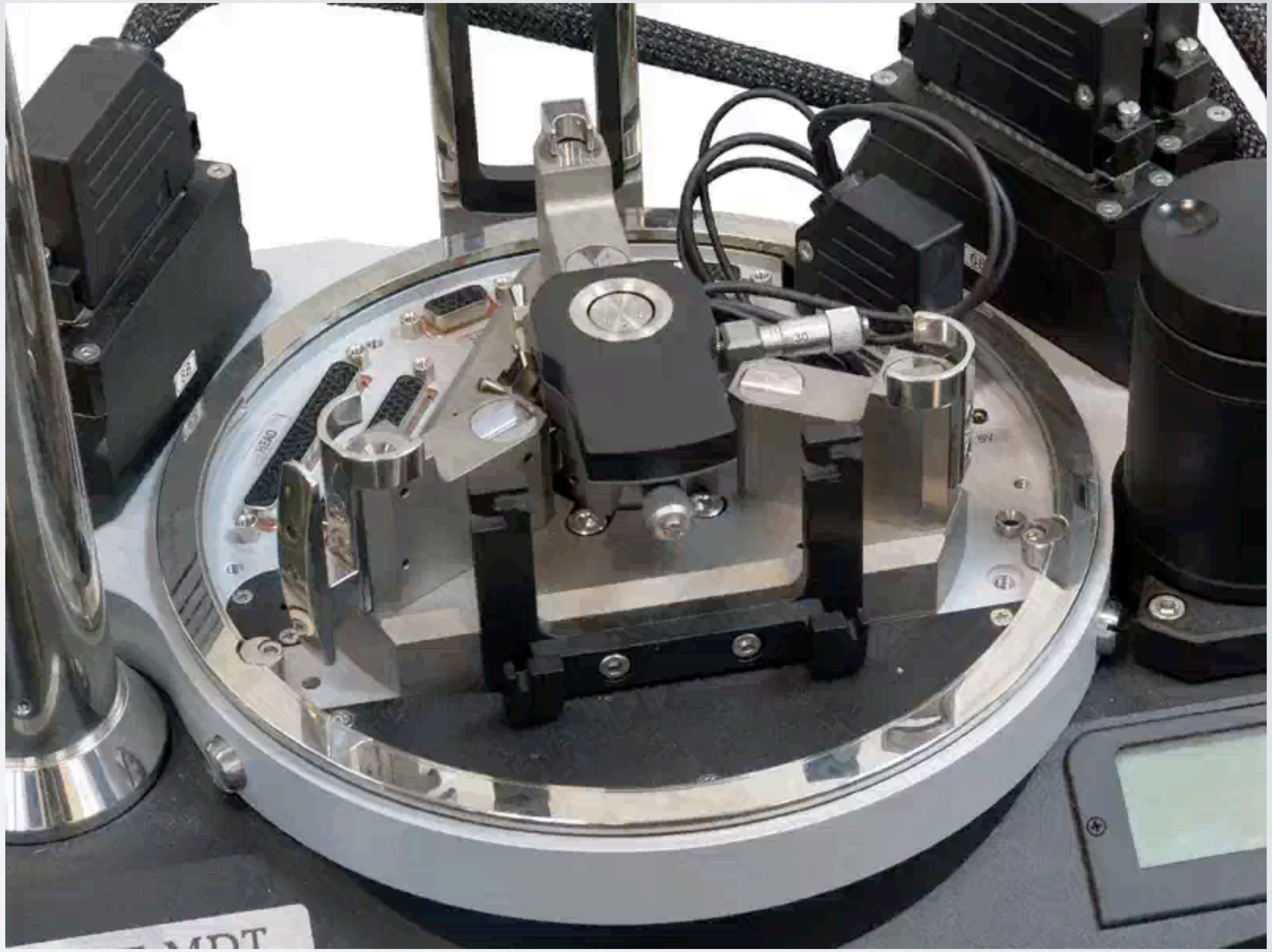




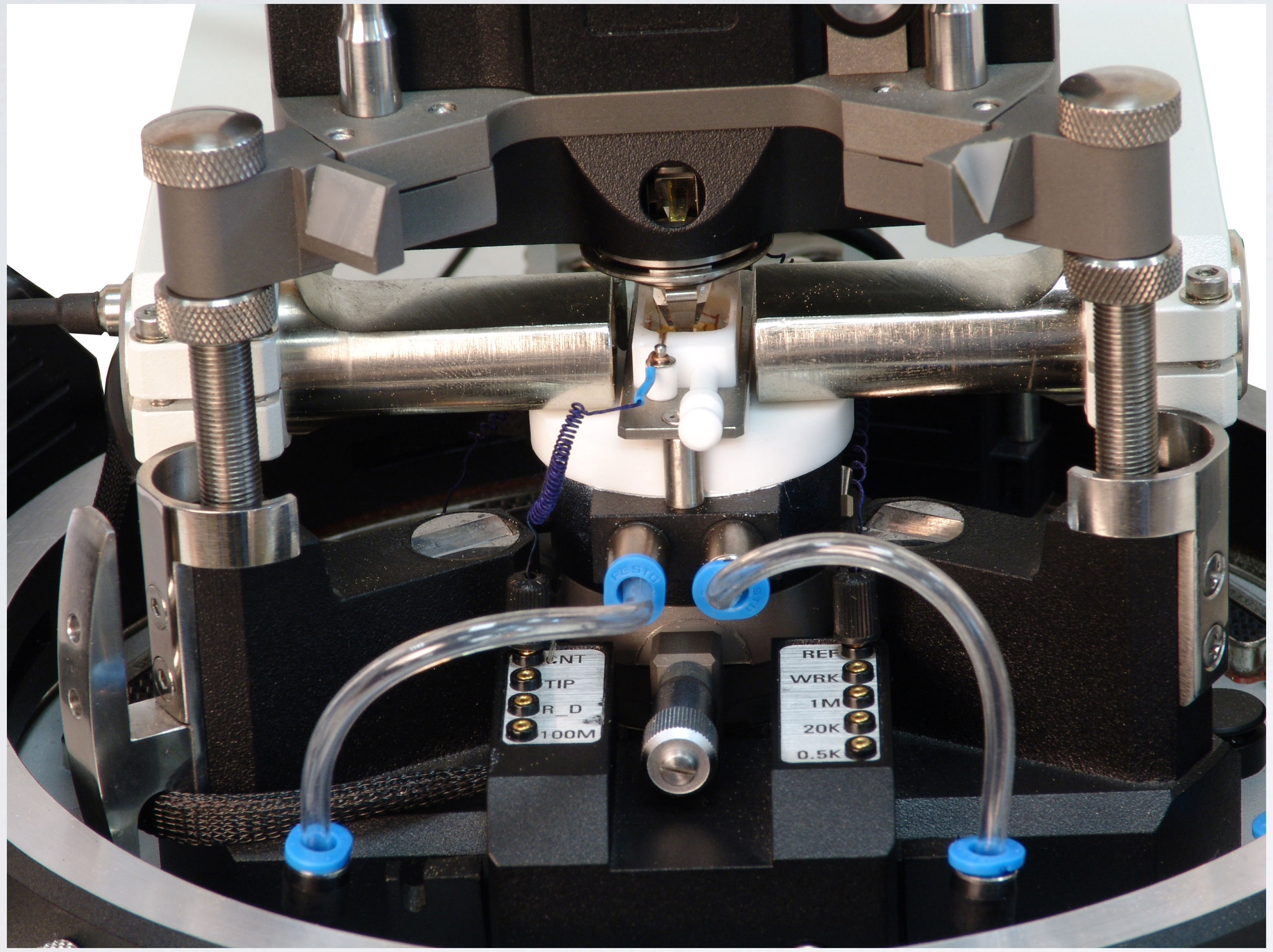
Контроллер BL222RNTF

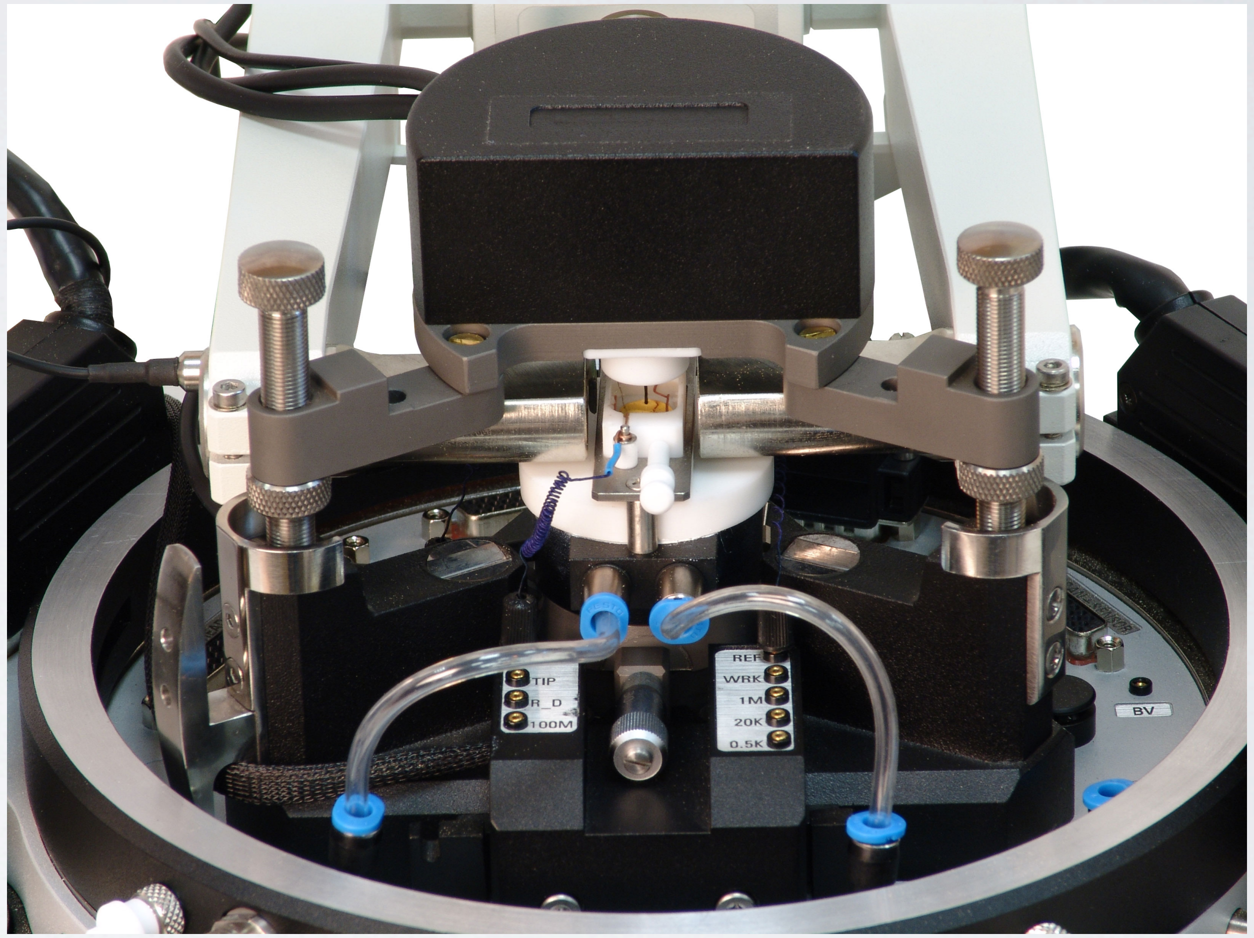
NT-MDT
Spectrum Instruments


TS-150

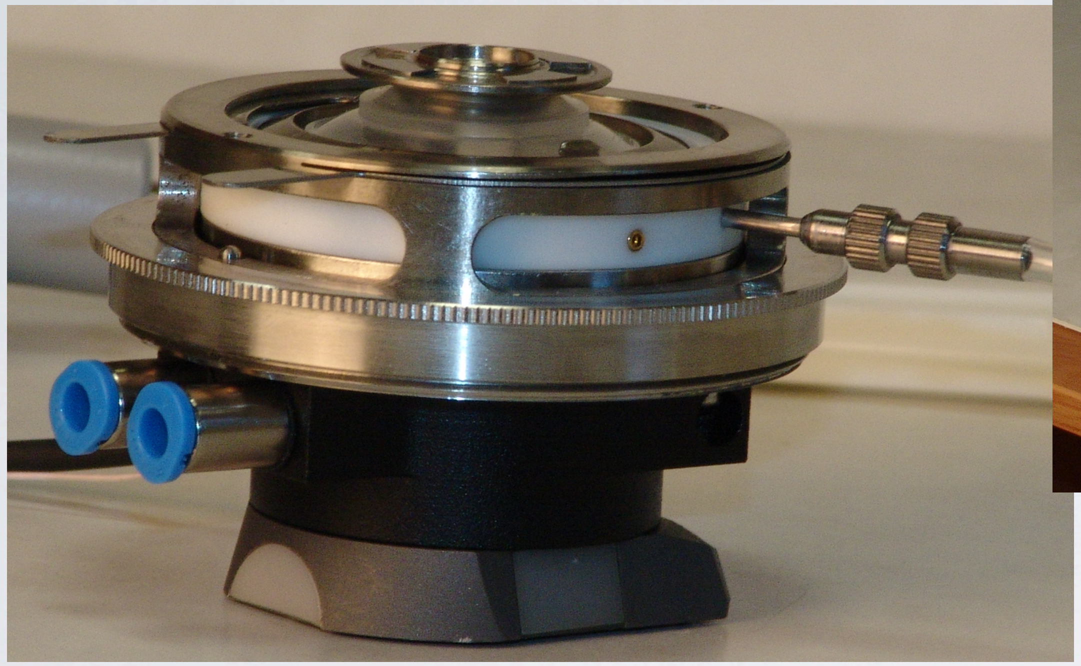


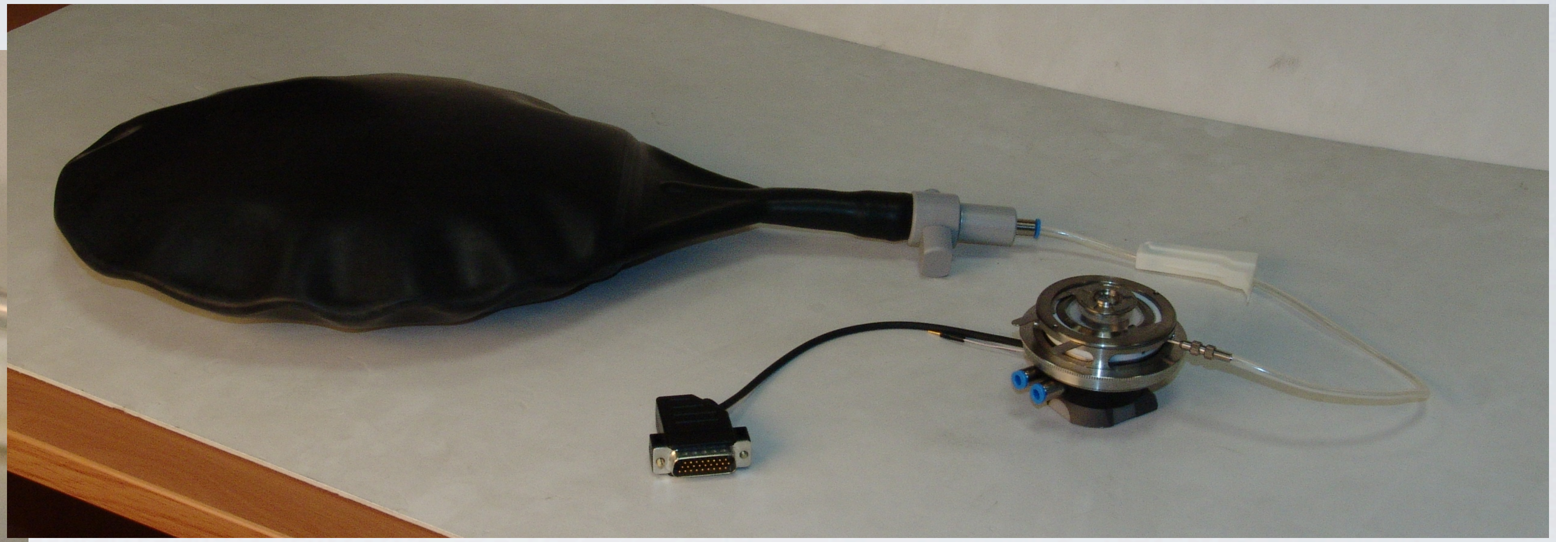
EC NTEGRA: AFM and STM Design

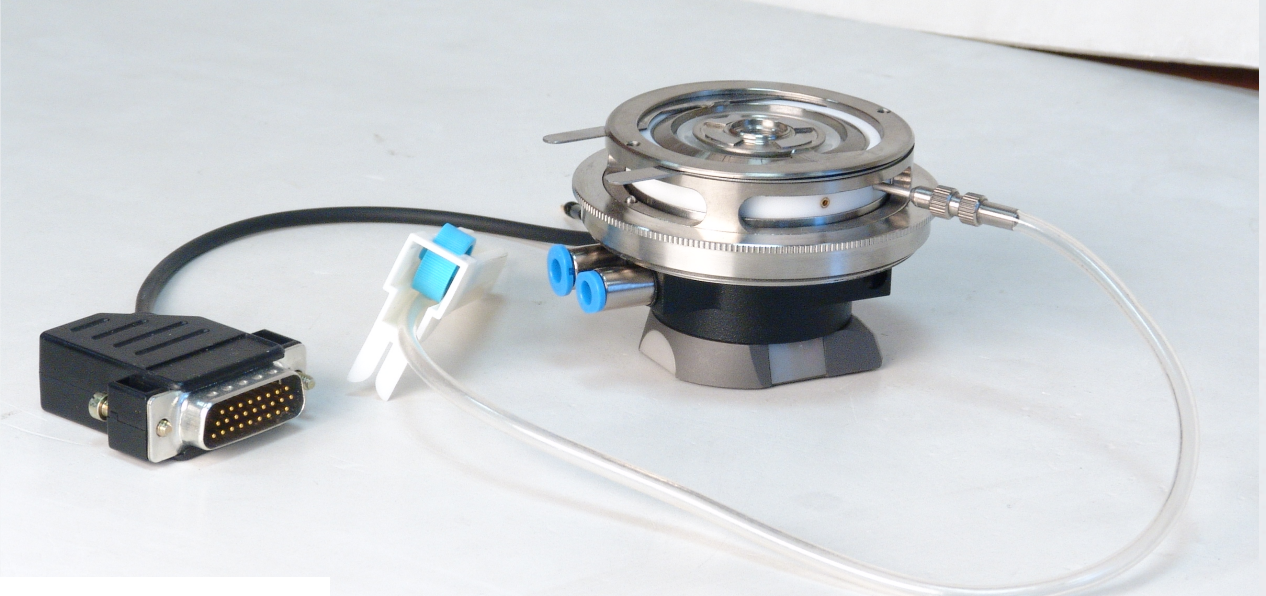


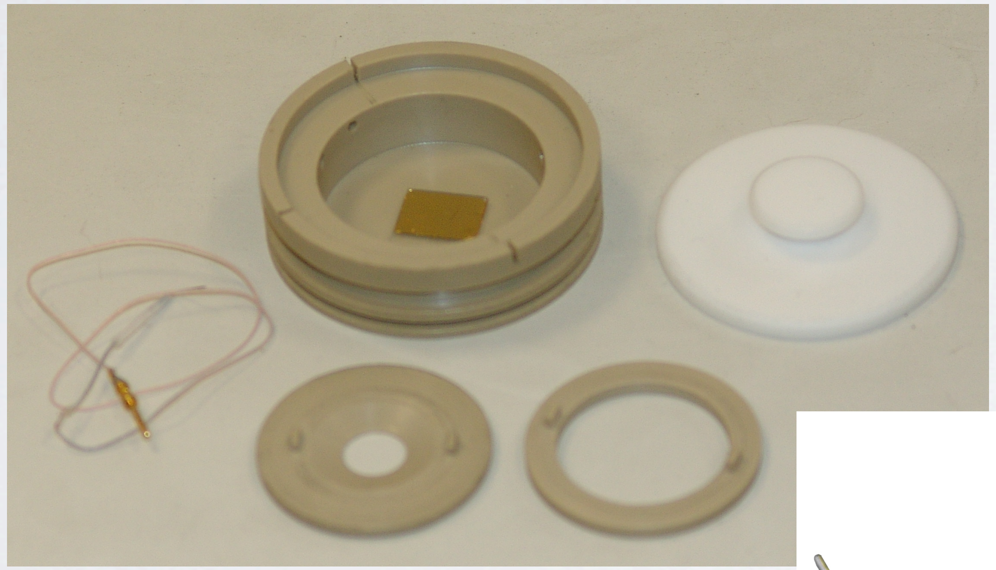


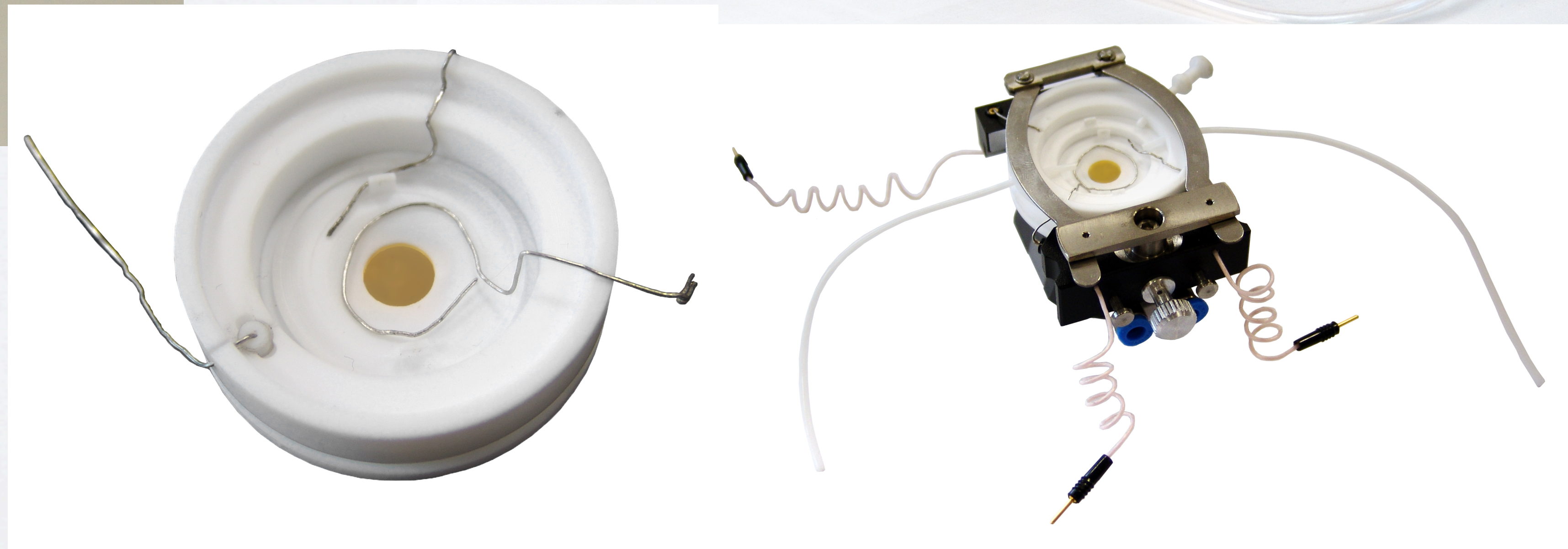
The Design of EC Cells for the NTEGRA



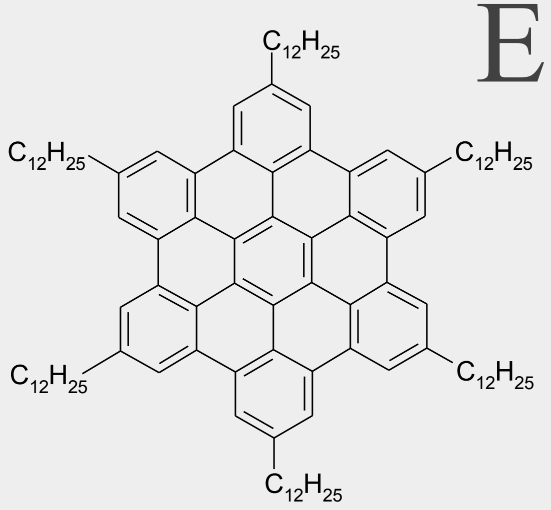




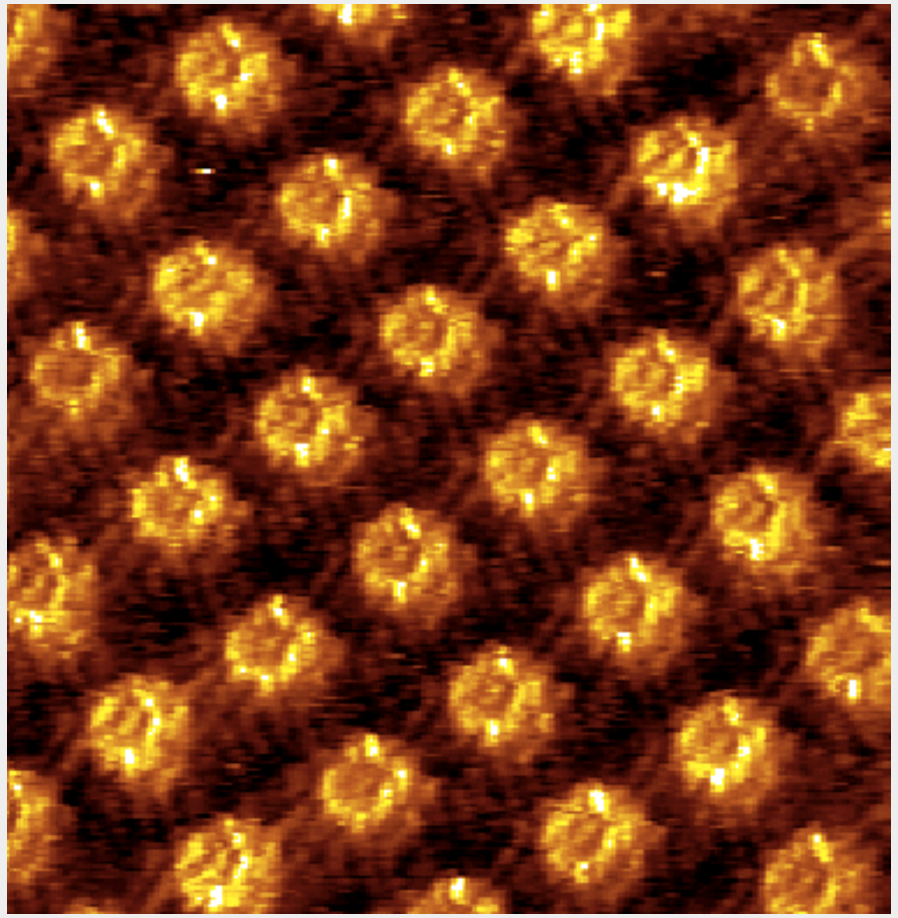




Effect of a substrate on the structure of monolayers

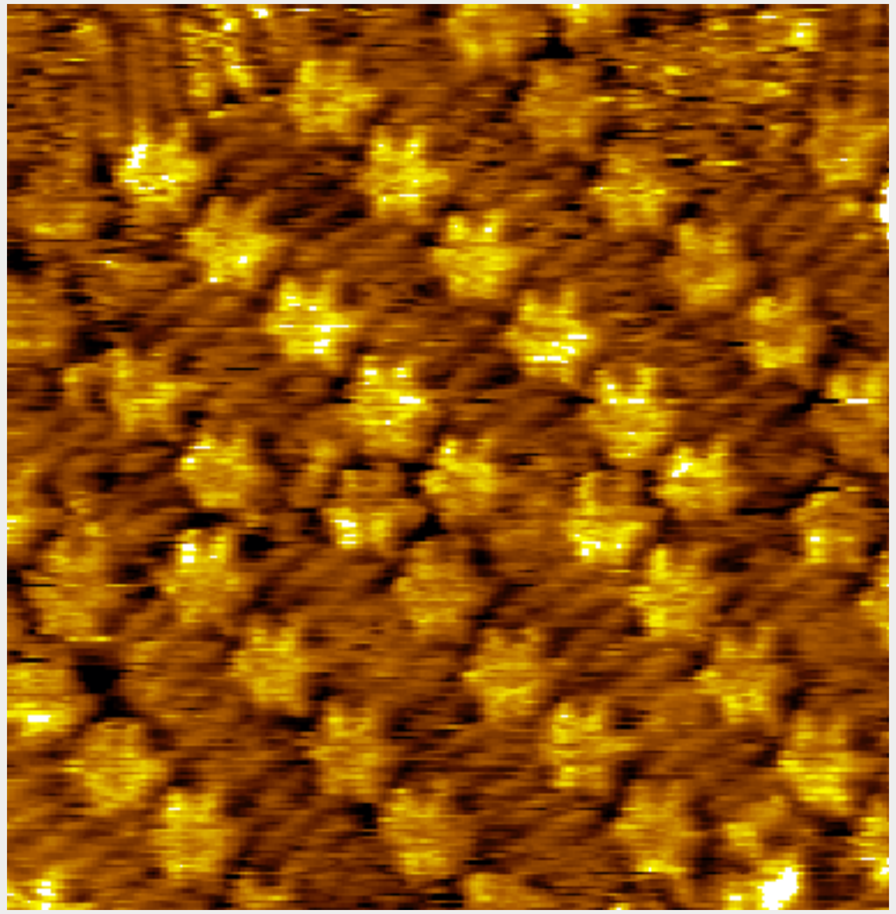


HBC-C_{12} on HOPG



13×13 nm^2

HBC-C_{12} on Au(111)

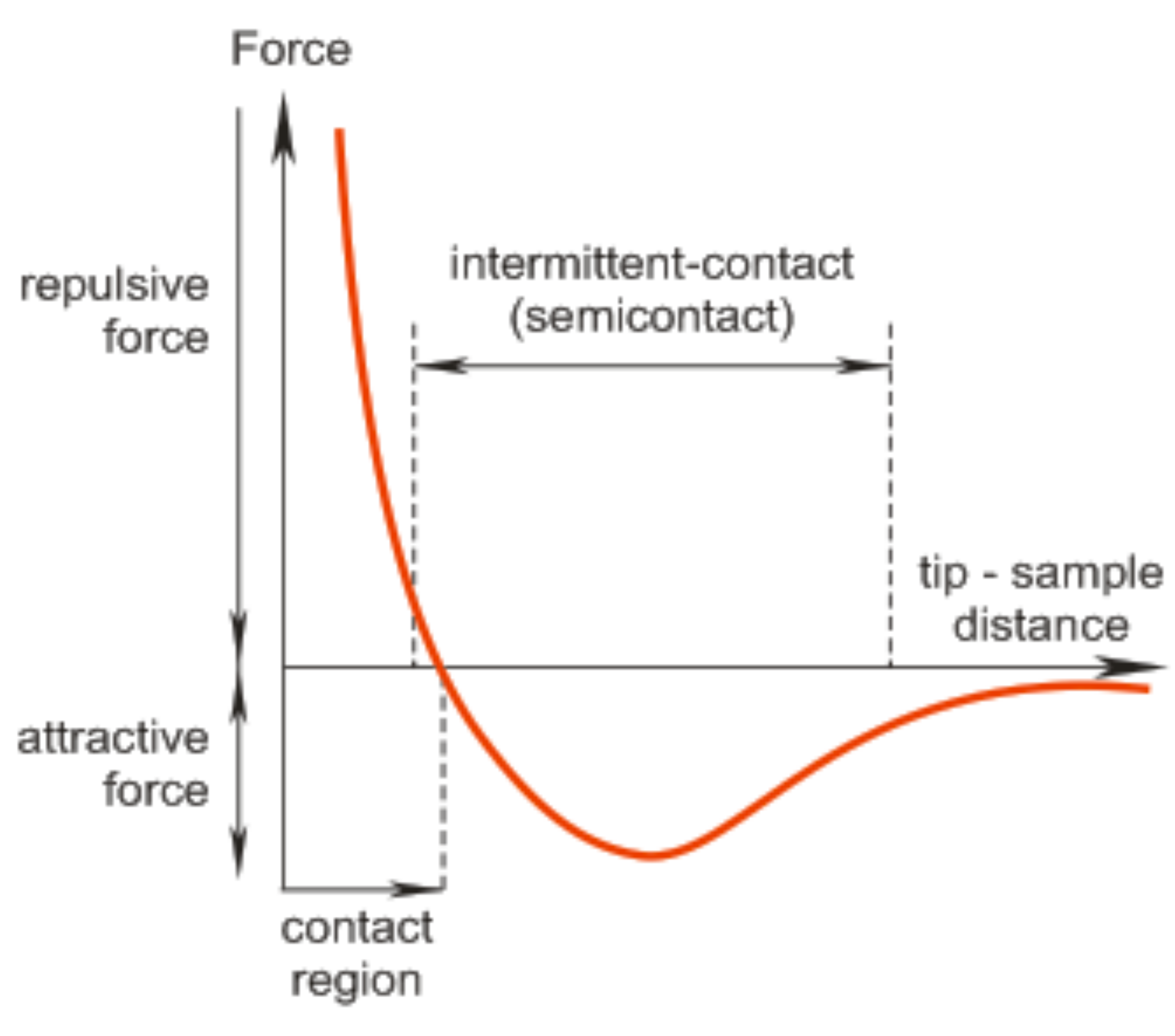


16×16 nm^2

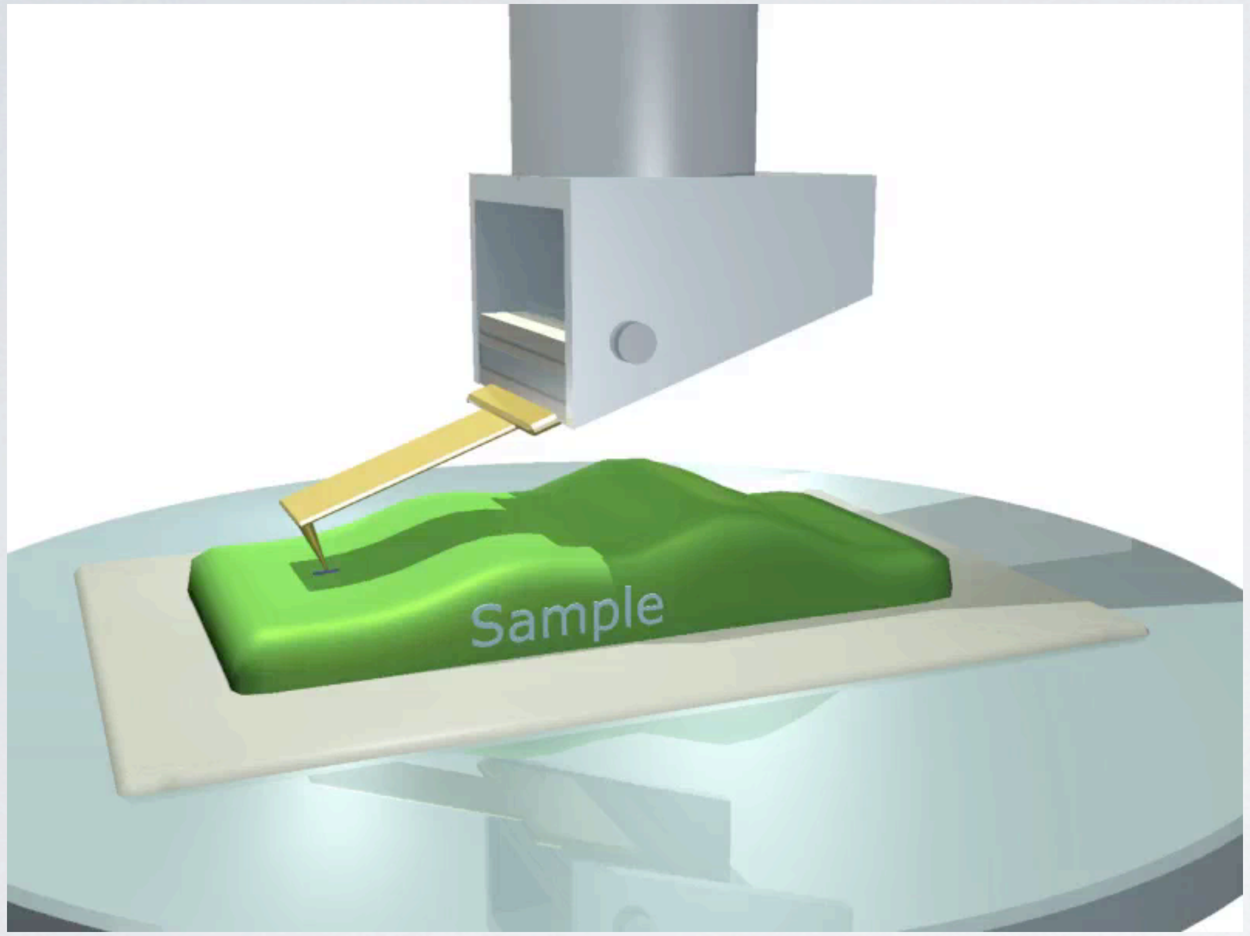
J. Am. Chem. Soc. 127, (2005)

Corresponding member. NAS Ukraine, Prof. Alexander Marchenko

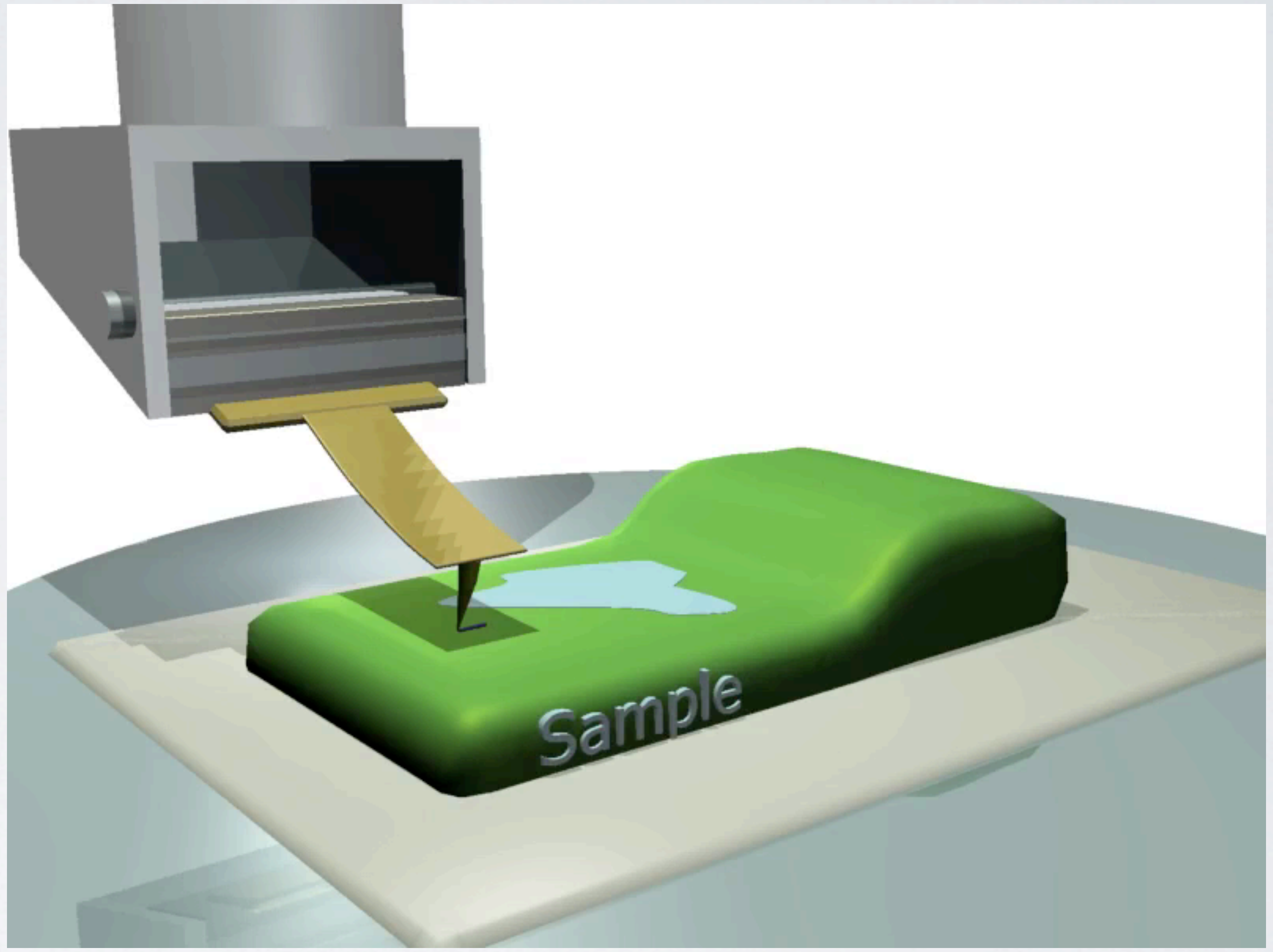
NT-MDT Spectrum Instruments


Force
repulsive
force
attractive
force
intermittent-contact
(semicontact)
tip - sample
distance
contact
region

Contact Scanning Modes



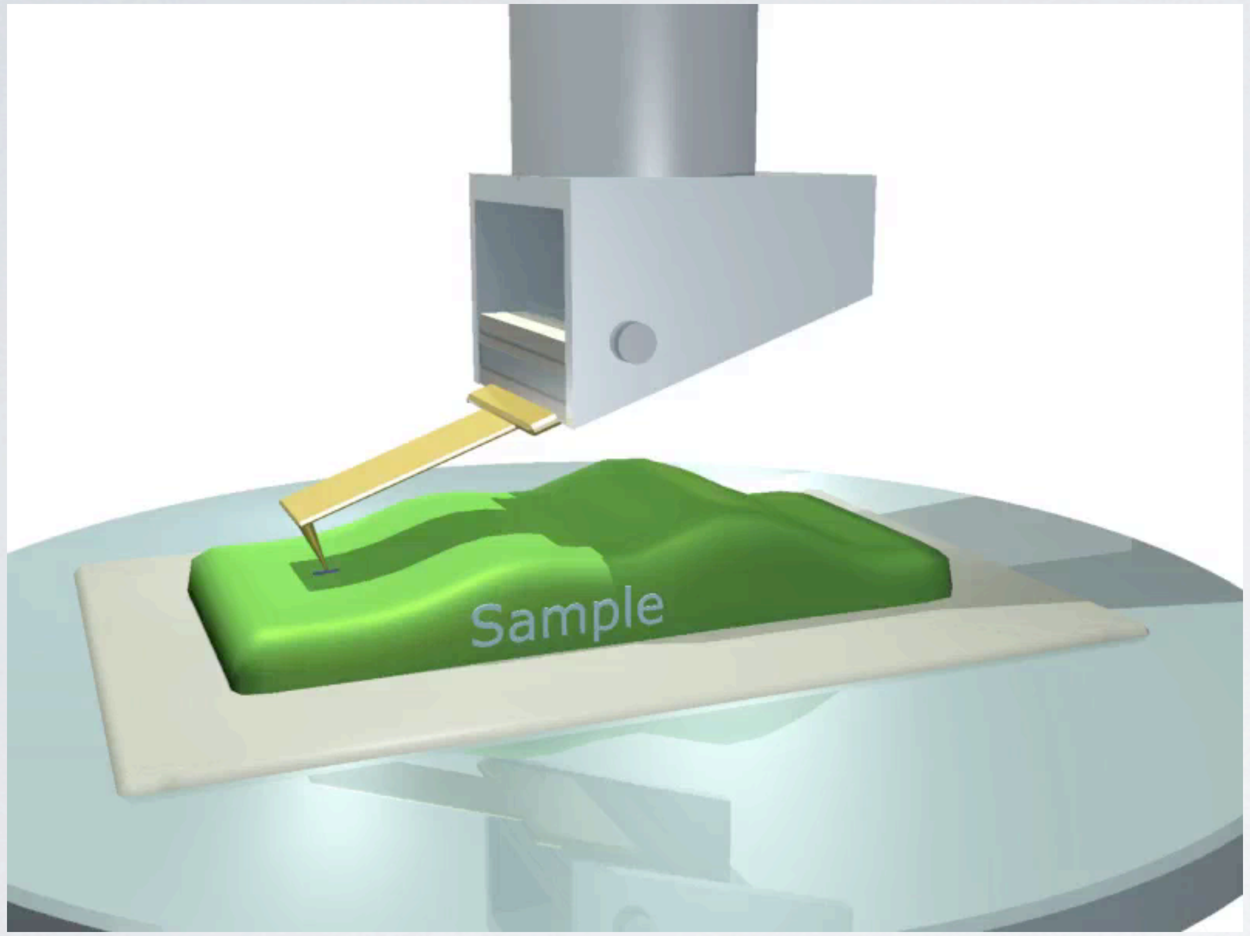
Constant Force Mode

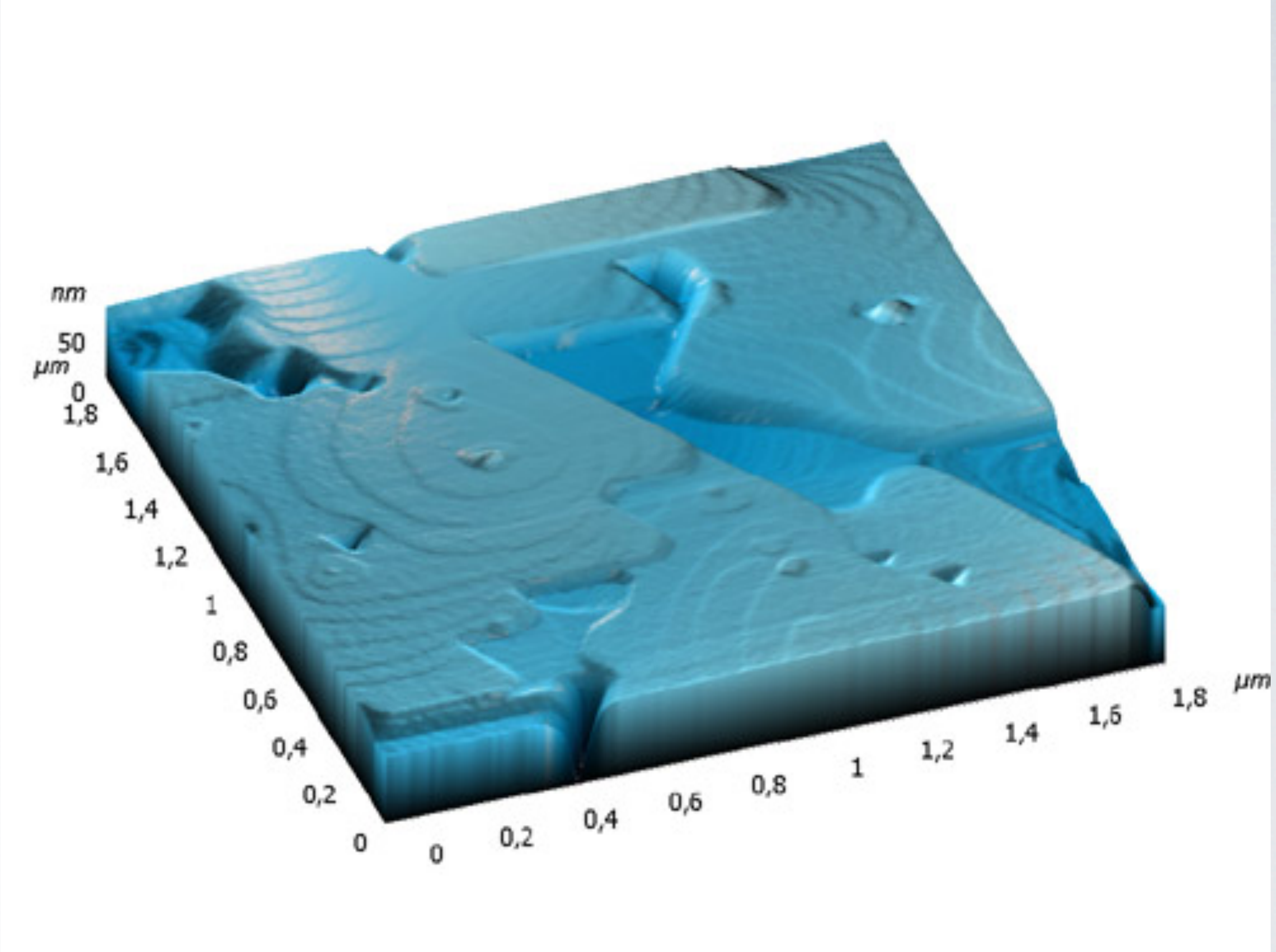


Lateral Force Mode

NT-MDT Spectrum Instruments

Contact Scanning Modes

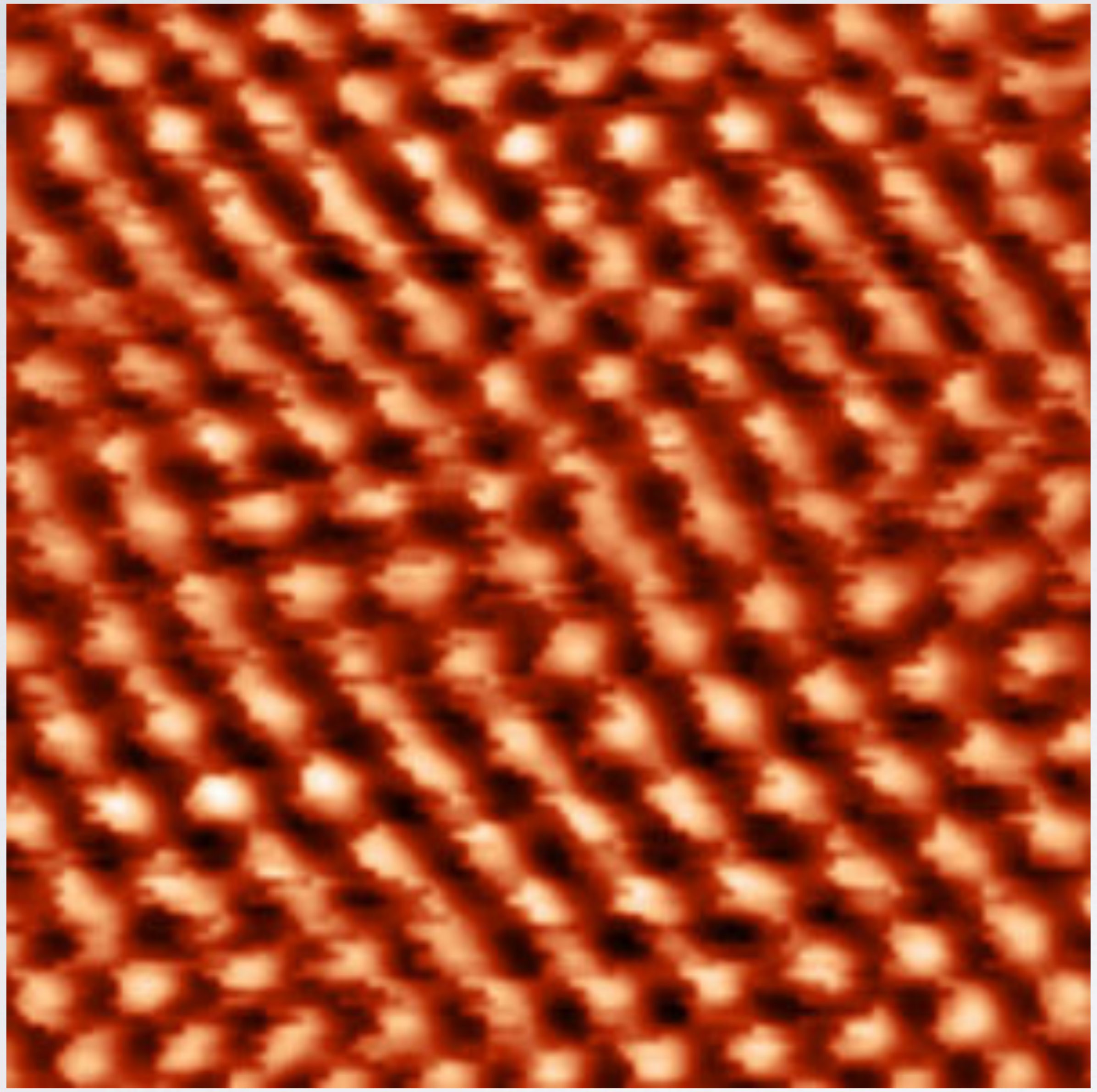




Constant Force Mode

Monoatomic stapes of CaF_2 epitaxial layers on Si

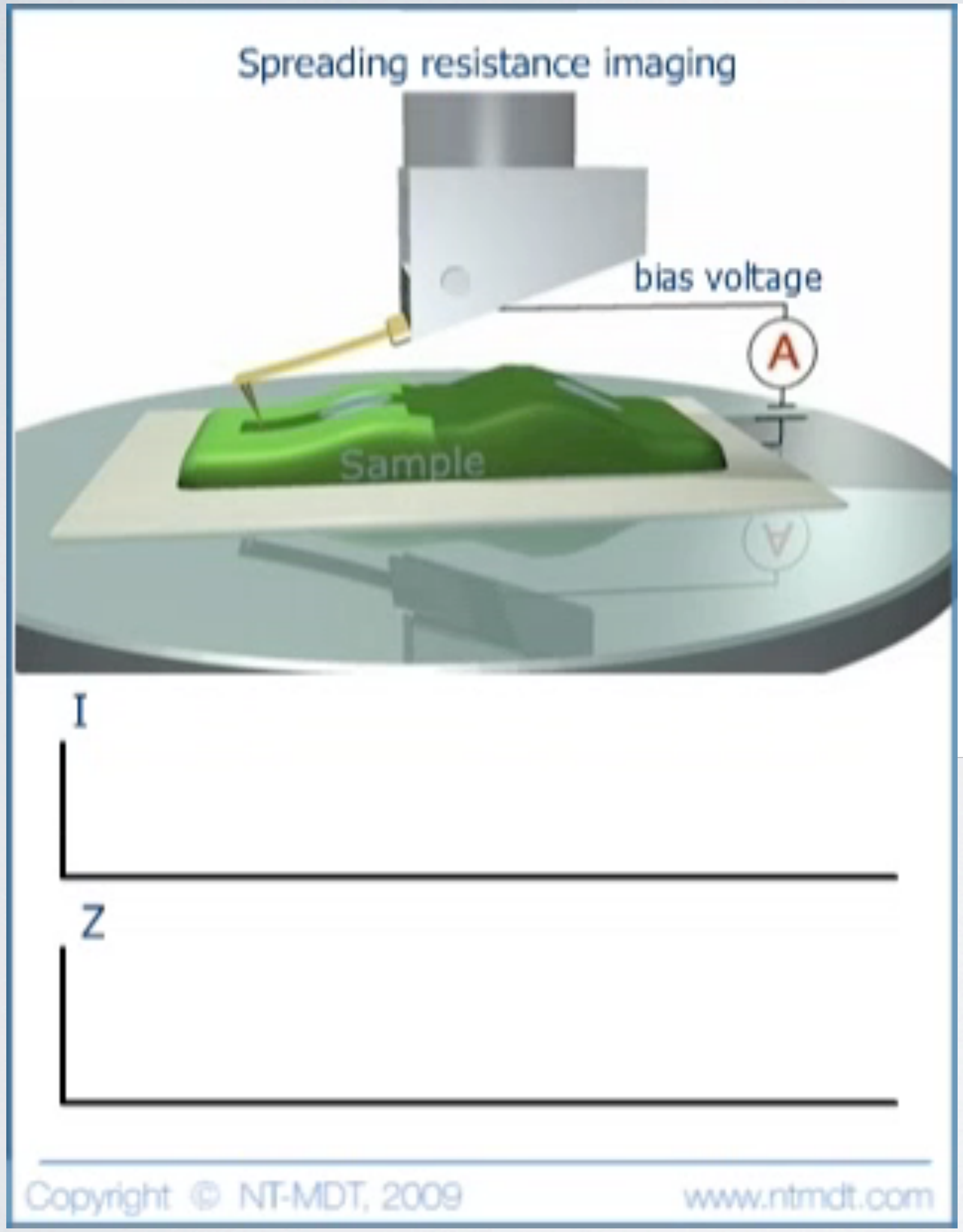
Lateral force microscopy

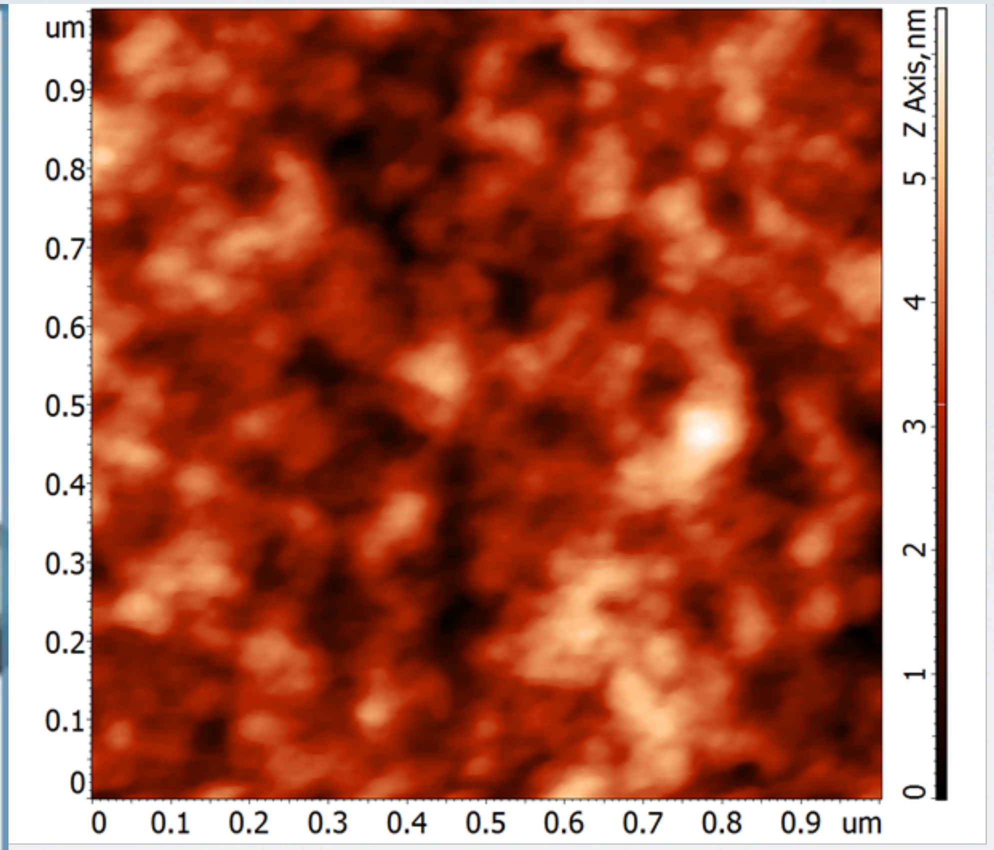


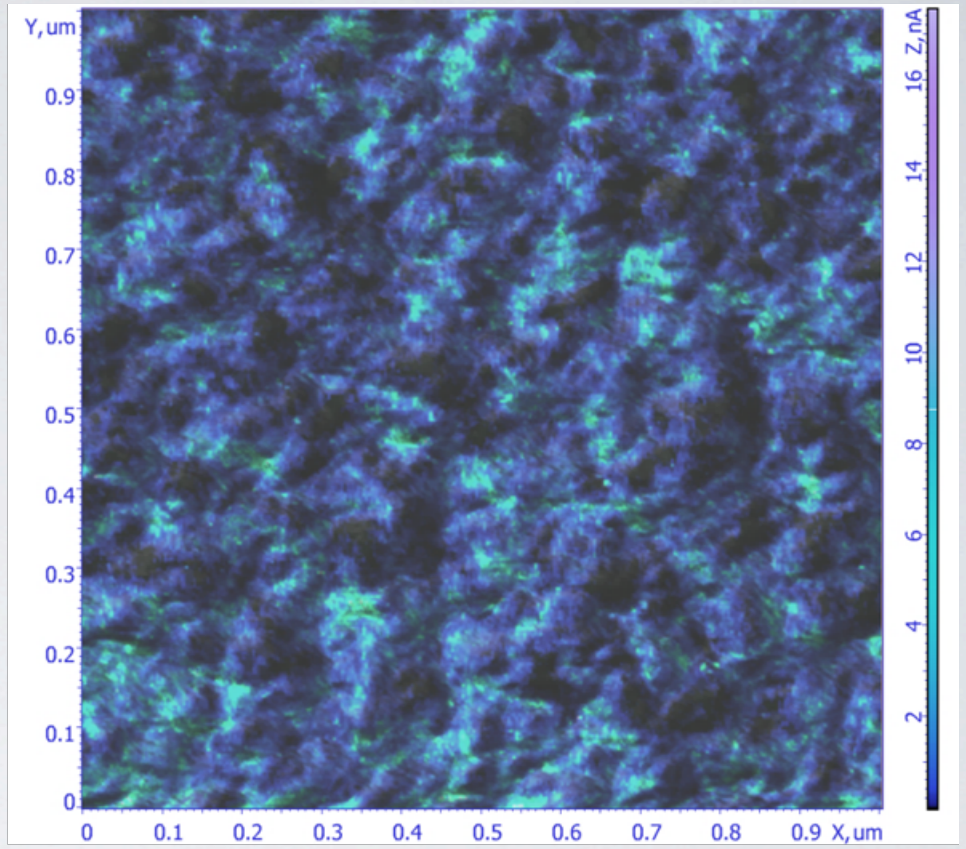
HOPG

Graphen, 30x30 мкм

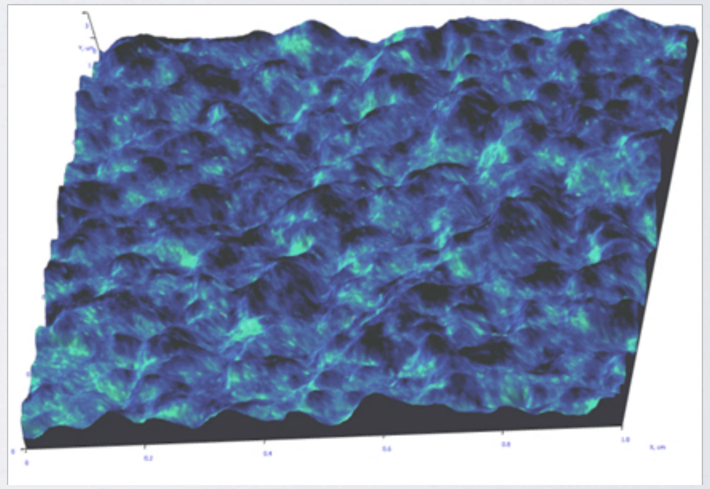
Contact Scanning Modes







AFM images of In_2O_3(left) and spreading resistance maps (right). The scanning area is 1 μm x 1 μm. The spreading current is superimposed on the relief image. The bottom right is a 3D image of flow and relief flow. The voltage between the sample and the probe is U = 2.3 V.



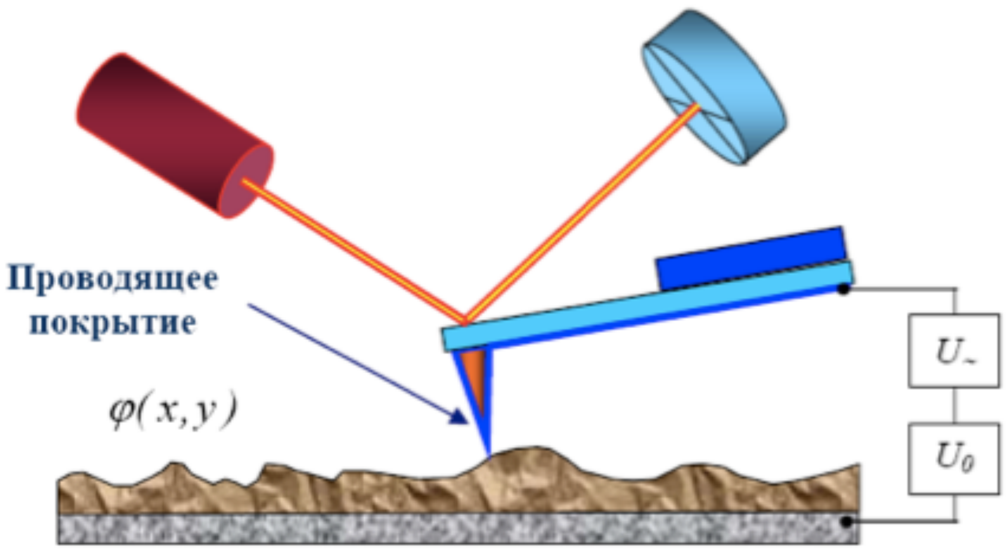


Схема измерения электрического взаимодействия зонда с образцом

$$E = \frac{C \cdot U^2}{2}$$

$$F_{ED} = -\frac{\partial E}{\partial Z} = -\frac{1}{2} \cdot U^2 \cdot \frac{\partial C}{\partial Z}$$

$$U = \big(U_0 - \varphi(x,y)\big) + U_1 \times \sin(\omega t)$$

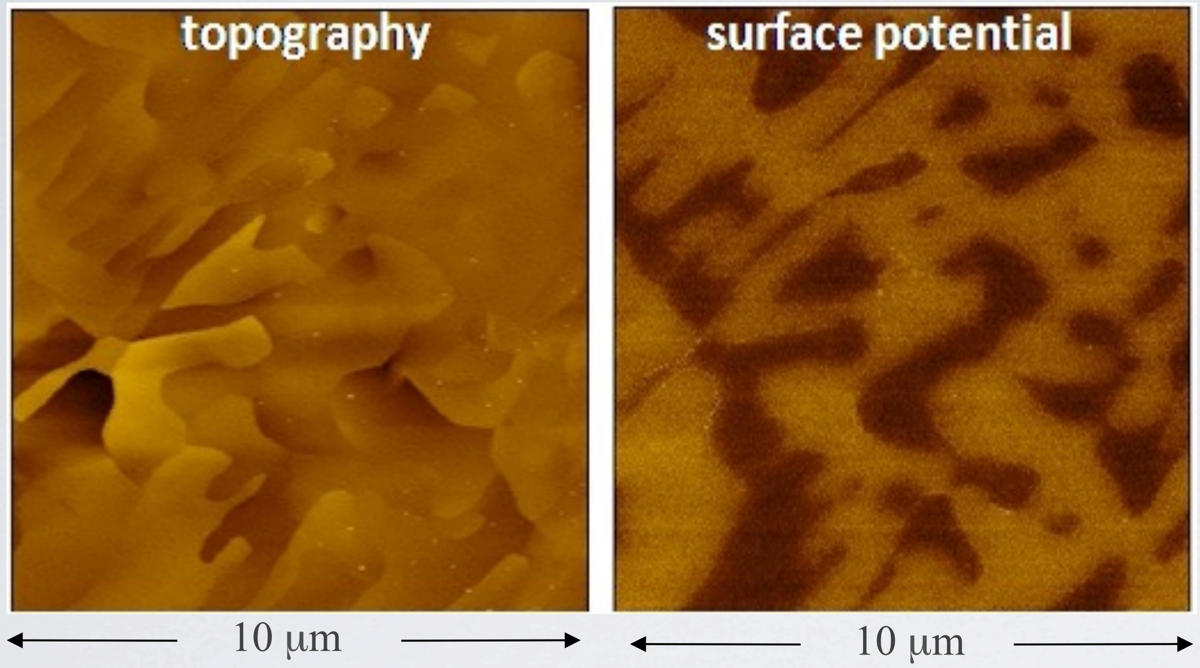
$$F_{ED_Z} = -\left[\frac{1}{2} \times \left((U_0 - \varphi(x,y))^2 + \frac{1}{2} \times U_1^2\right) + (U_0 - \varphi(x,y)) \times U_1 \times \sin(\omega t) - \frac{1}{4} \times U_1^2 \times \cos(2\omega t)\right] \times \frac{\partial C}{\partial Z}$$

$$F_z = F_{z,DC} + F_{z,\omega} + F_{z,2\omega}$$

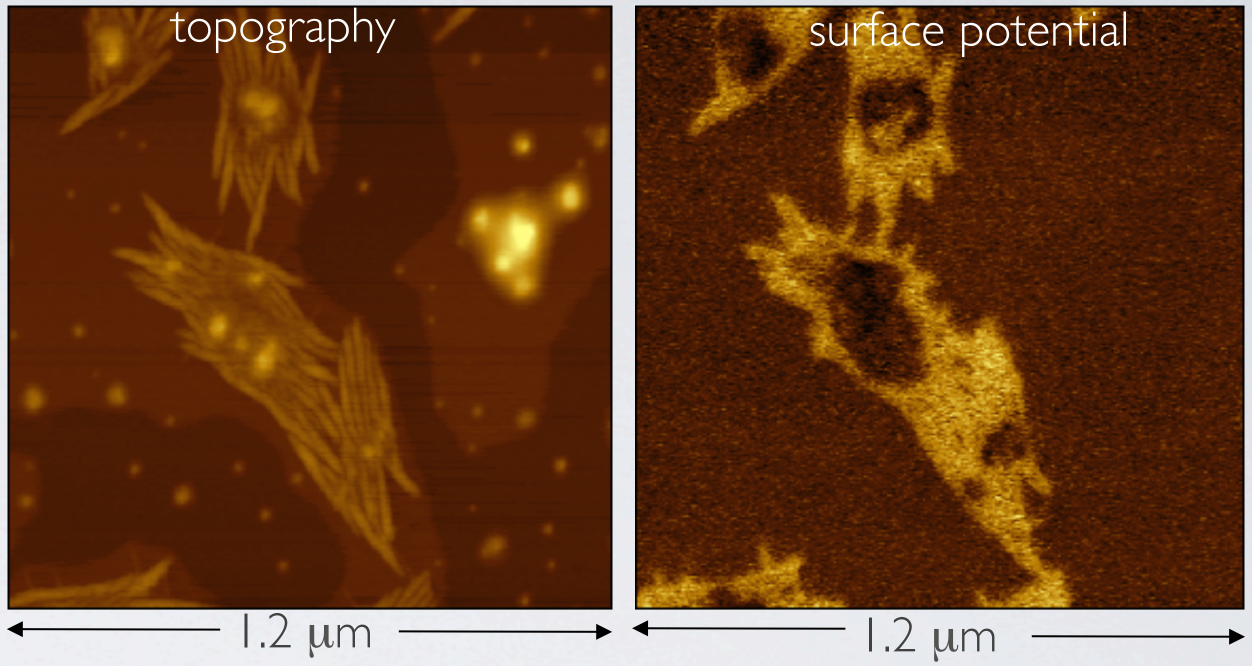
$$F_{z,\omega} = -\left[(U_0 - \varphi(x,y)) \times U_1 \times \sin(\omega t)\right] \times \frac{\partial C}{\partial Z} \qquad F_{z,2\omega} = \left[\frac{1}{4} \times U_1^2 \times \cos(2\omega t)\right] \times \frac{\partial C}{\partial Z}$$

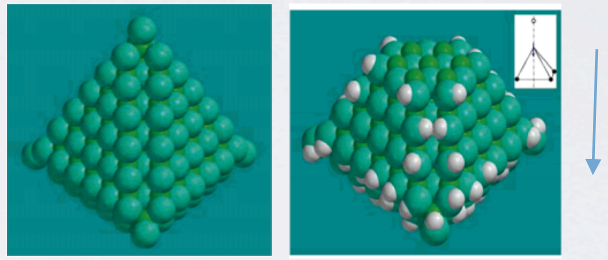
Kelvin Force Microscopy of Metals & Semiconductors

Soldering material - Bi/Sn alloy

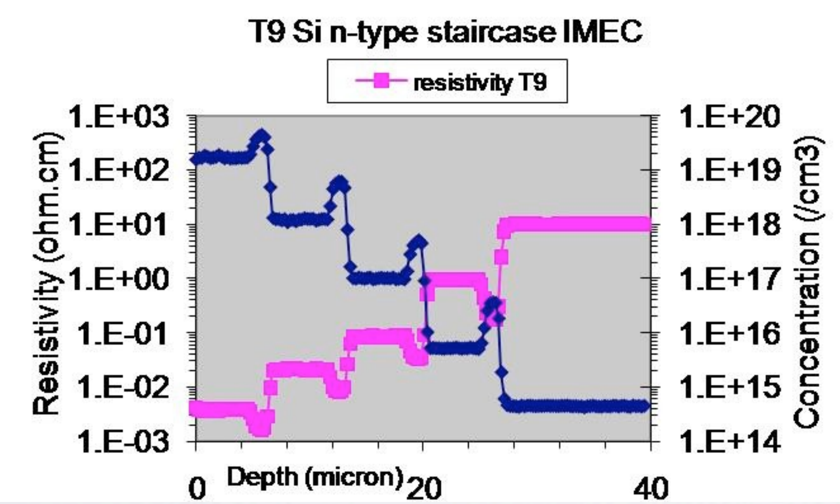


CdTe nanowires





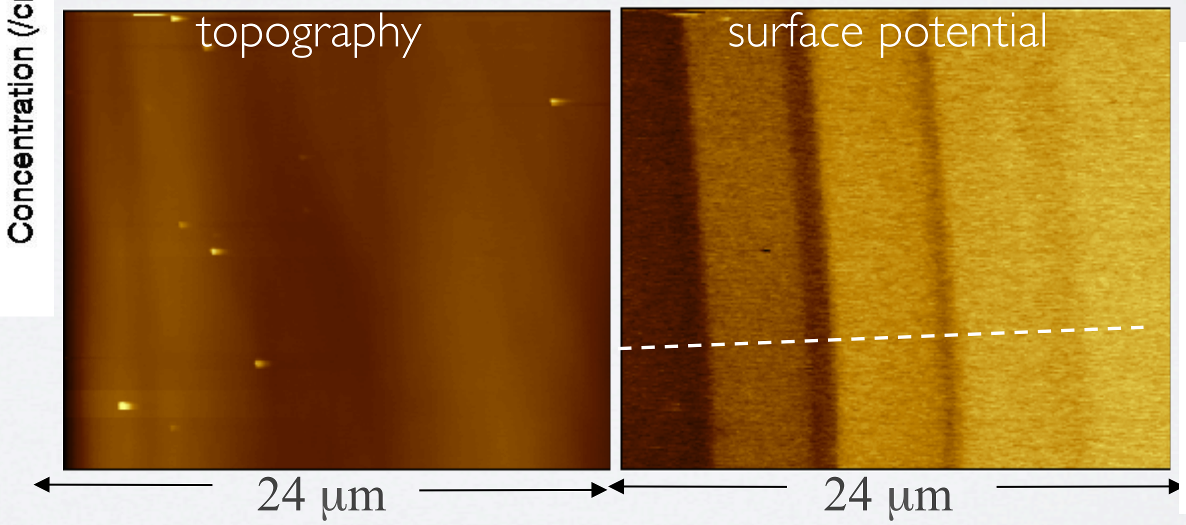
Work functions: Bi – 4.22 eV, Sn – 4.42 eV

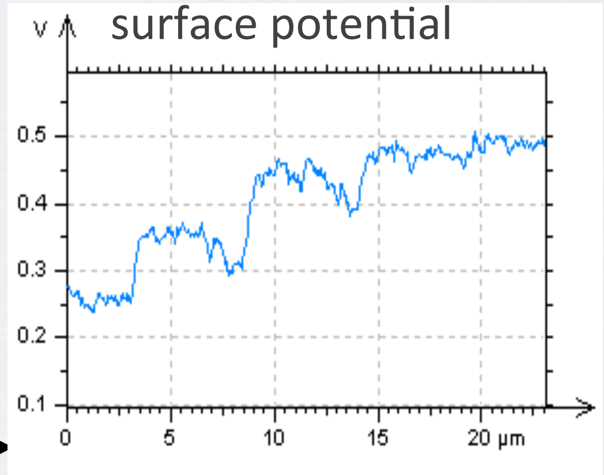


Doping level, cm^{-3}	Bulk Fermi, eV
7×10^{19}	-4.073
1.1×10^{15}	-4.311

Matsukawa et al *APL 2003*, 82, 2166

Mapping Dopant Density of Semiconductors





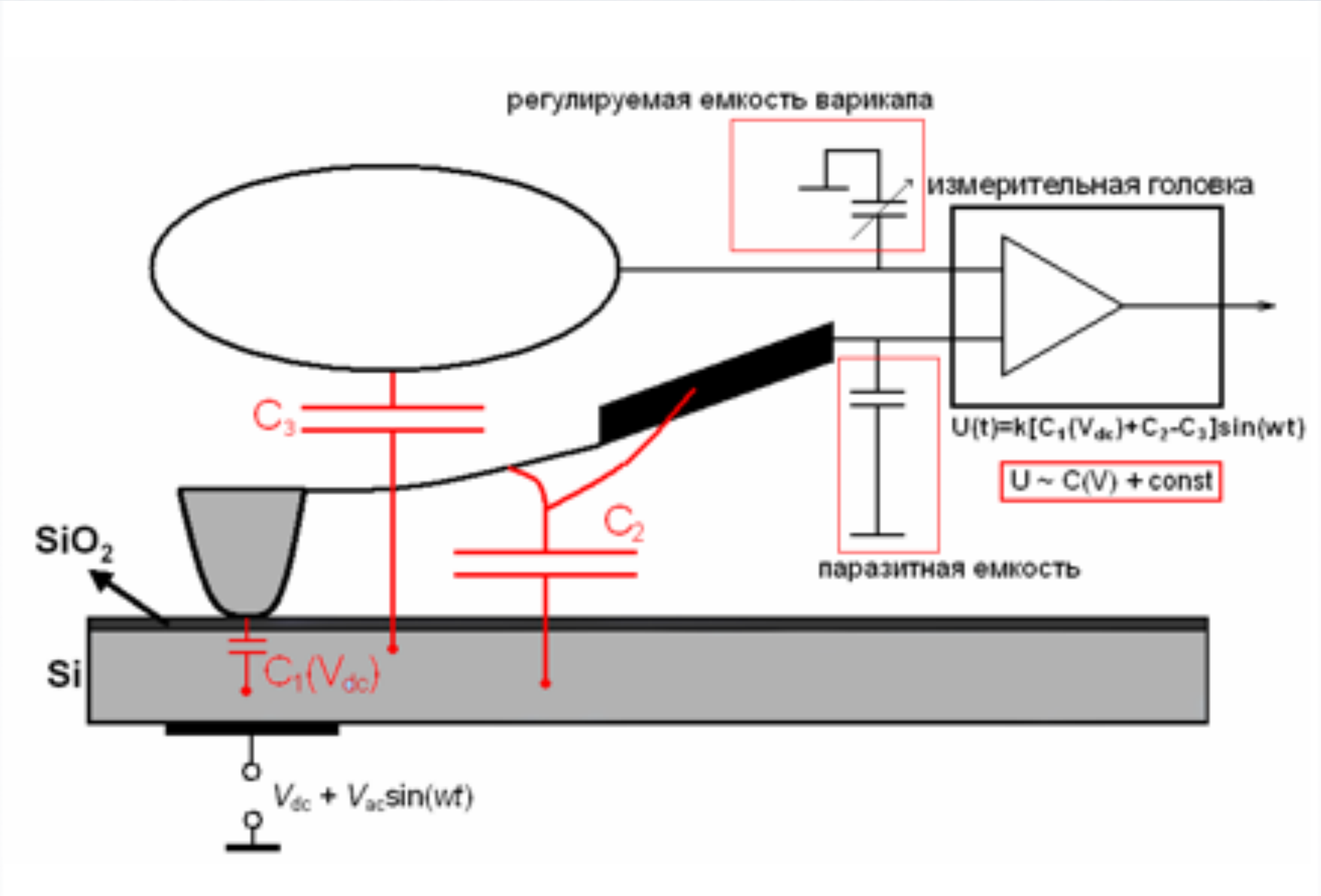
Stray capacitance compensation

A method has been developed in the NT-MDT company to compensate the stray capacitance

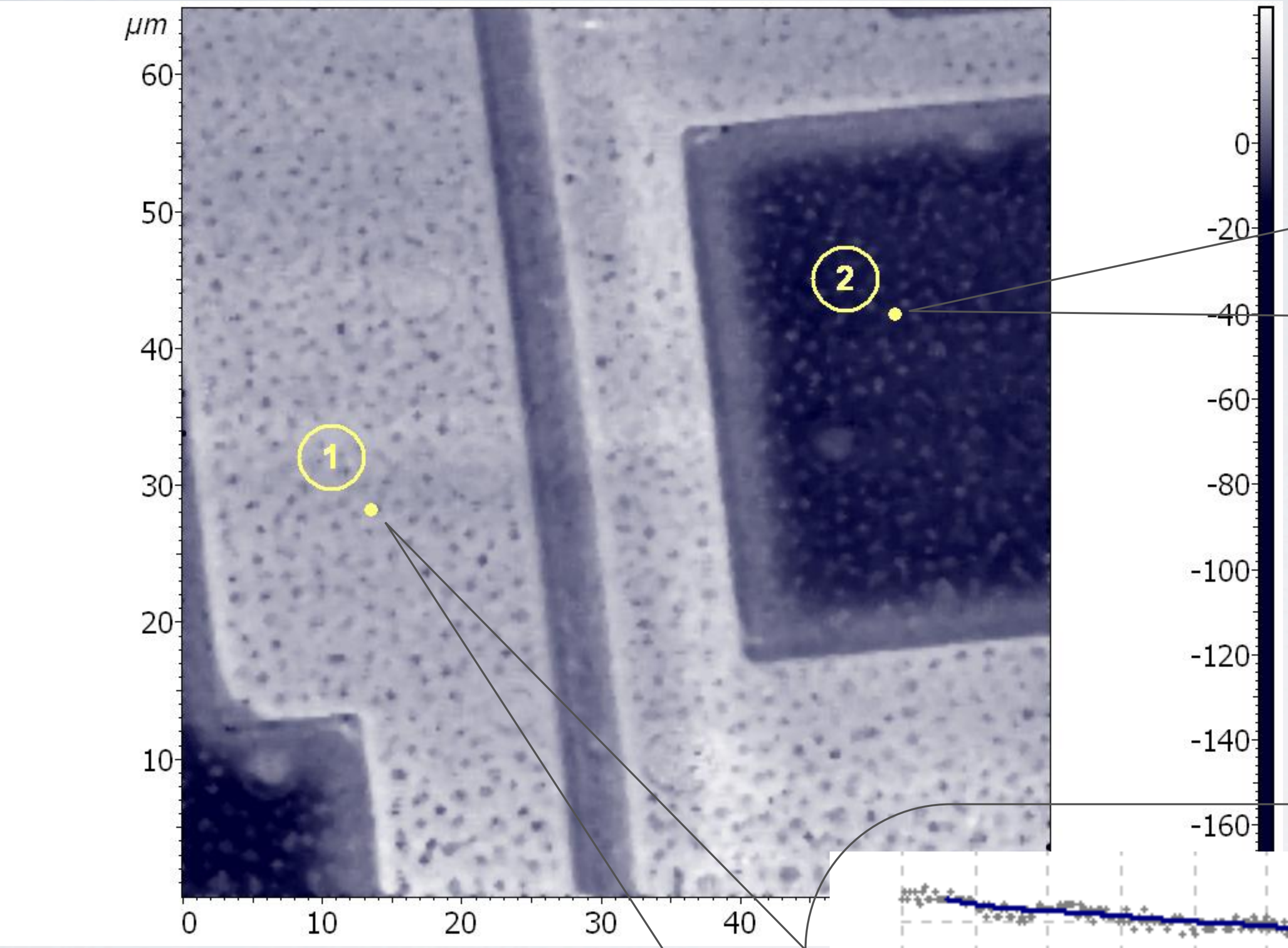
There have been suggested two sequential steps to compensate stray capacitance:

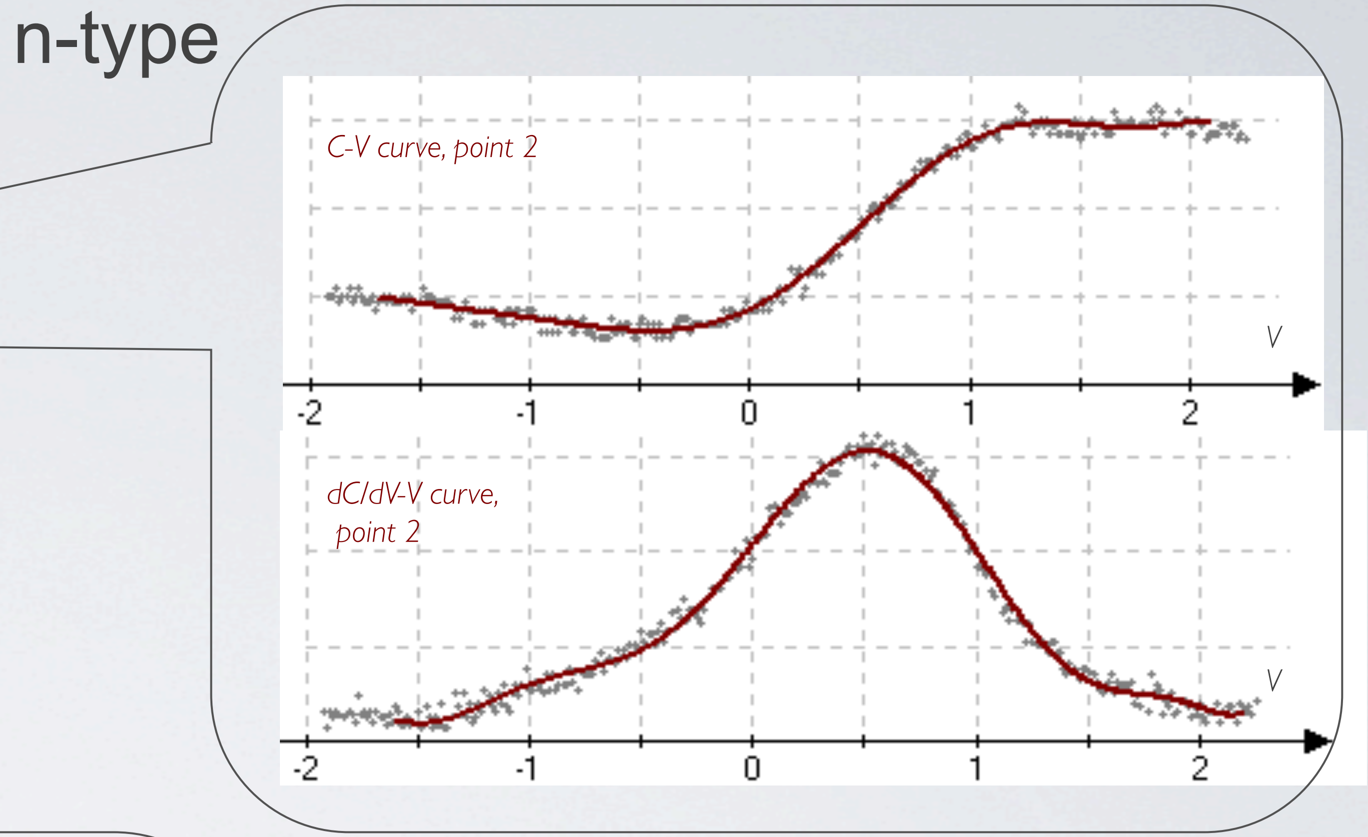
1. Electro-mechanical: a ring-shaped compensation electrode is placed above the cantilever and the chip
   - compensation achieved is about 0.01 pF

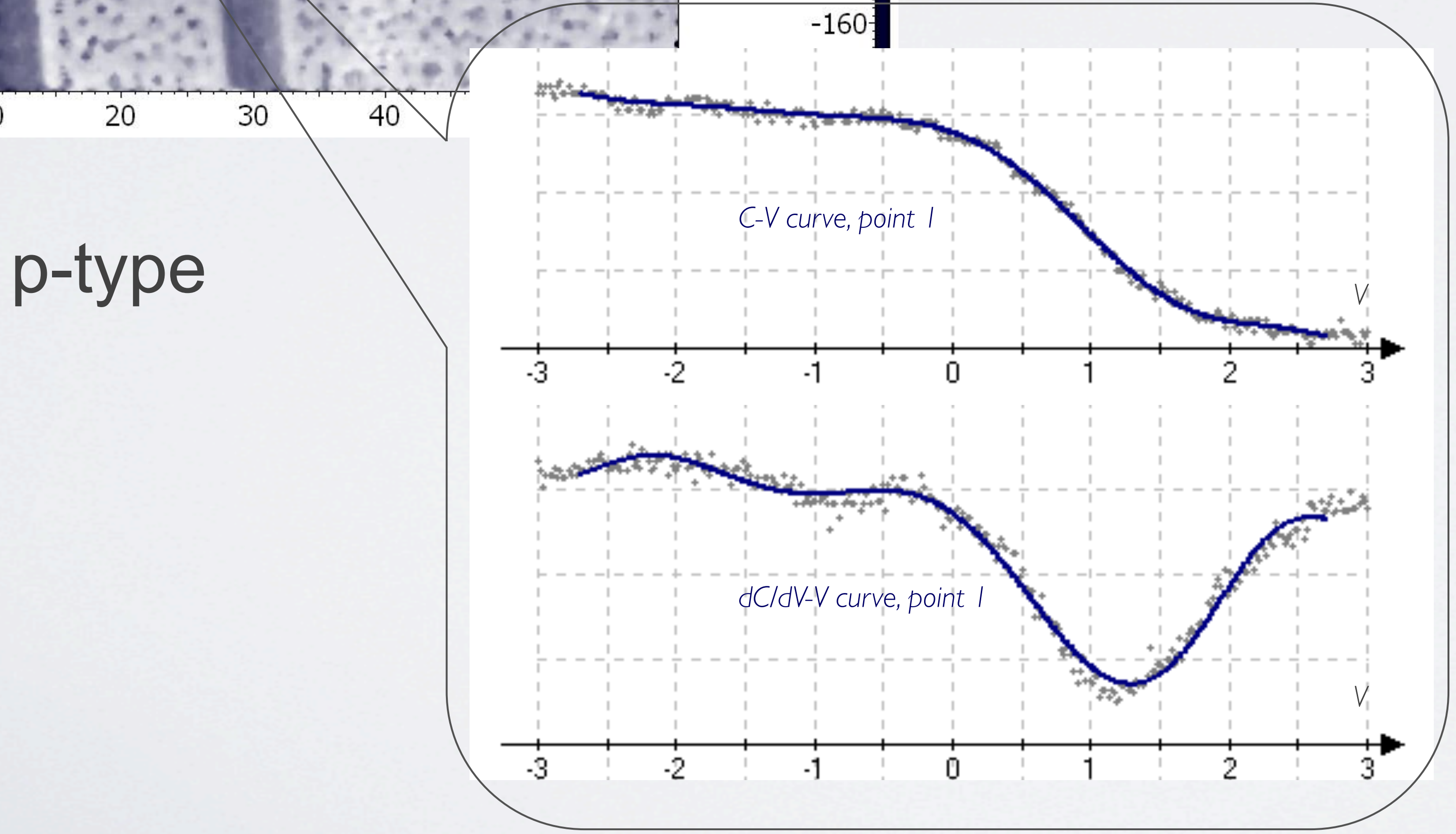
2. 2. Electrical compensation: one of the measuring head inputs is connected to the device bus line through an voltage variable-capacitance diode
   - it compensate the stray capacitance to about 0.001 pF



Contact capacitance microscopy- SCM







Different character of *C-V* and *dC/dV-V* curves allows to determine the type of semiconductor material (*p-* or *n-*).

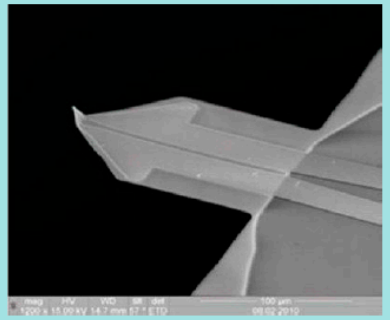
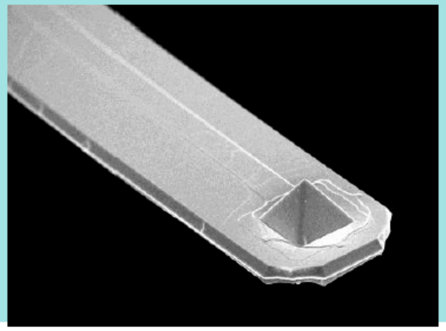
Curves are measured without any averaging; time of measurement in each point of curve is 1 ms

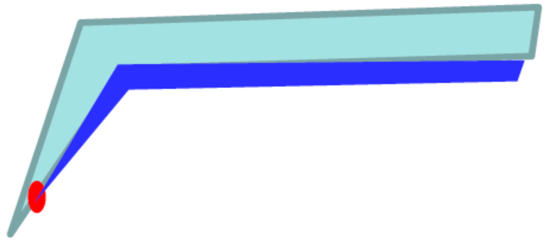
NT-MDT Spectrum Instruments

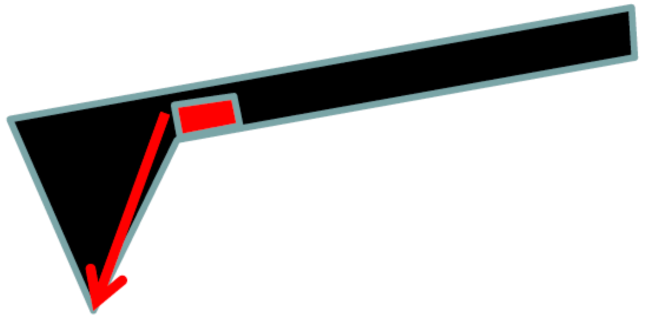
Cantilevers for thermoconductivity measurements

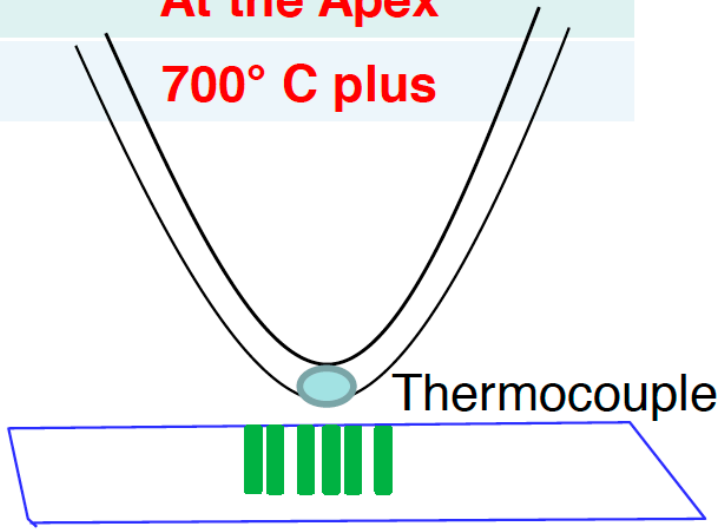
AppNano

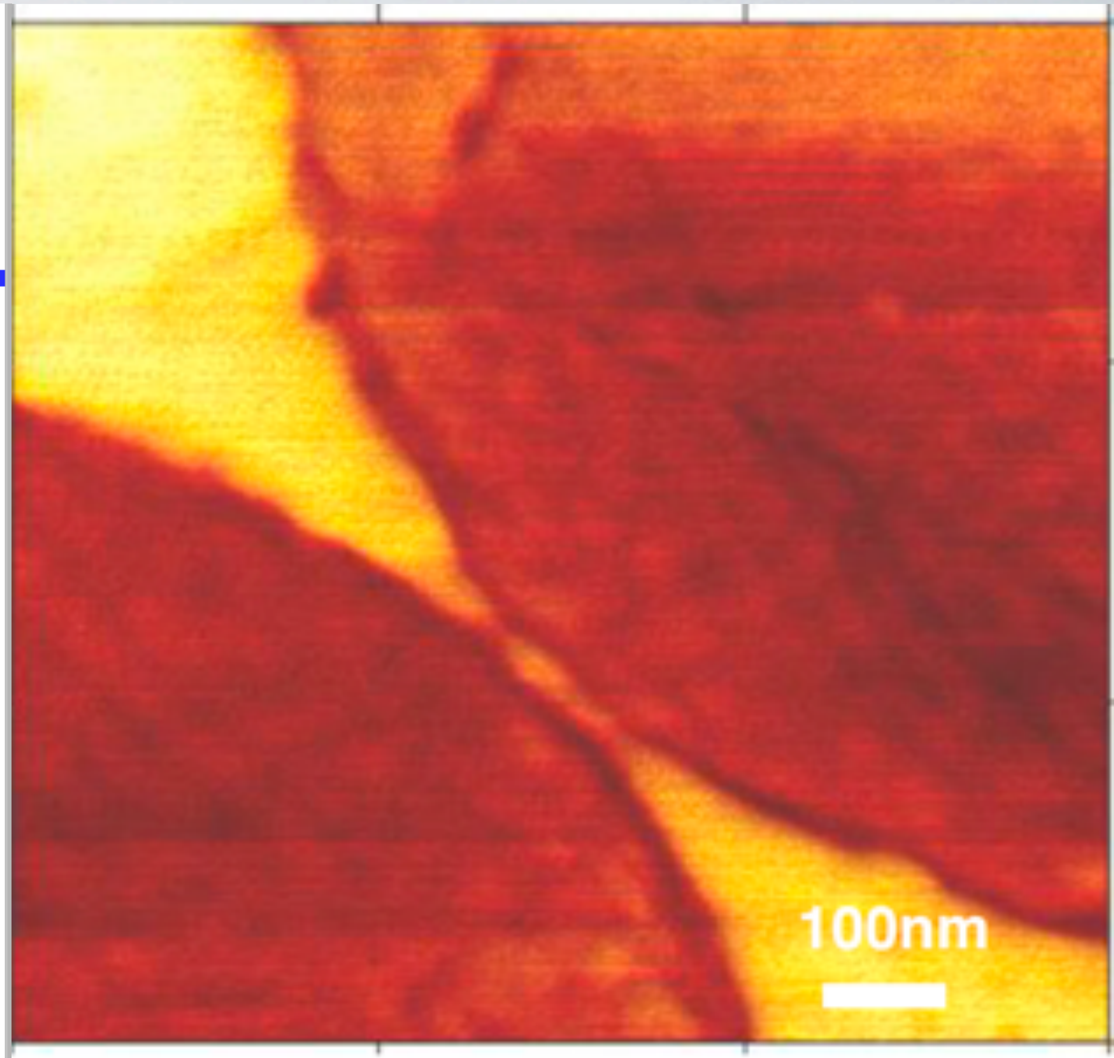
The Difference

STHM Probes		
	Conventional Technology	**APPNANO**
Tip ROC (nm)	100 nm	**> 50nm**
Lateral Thermal Resolution	100 nm	**up to 20nm**
Thermal Sensor	Thermistor	**Thermocouple**
Location	Near the Apex	**At the Apex**
Maximum Temperature	160° C	**700° C plus**

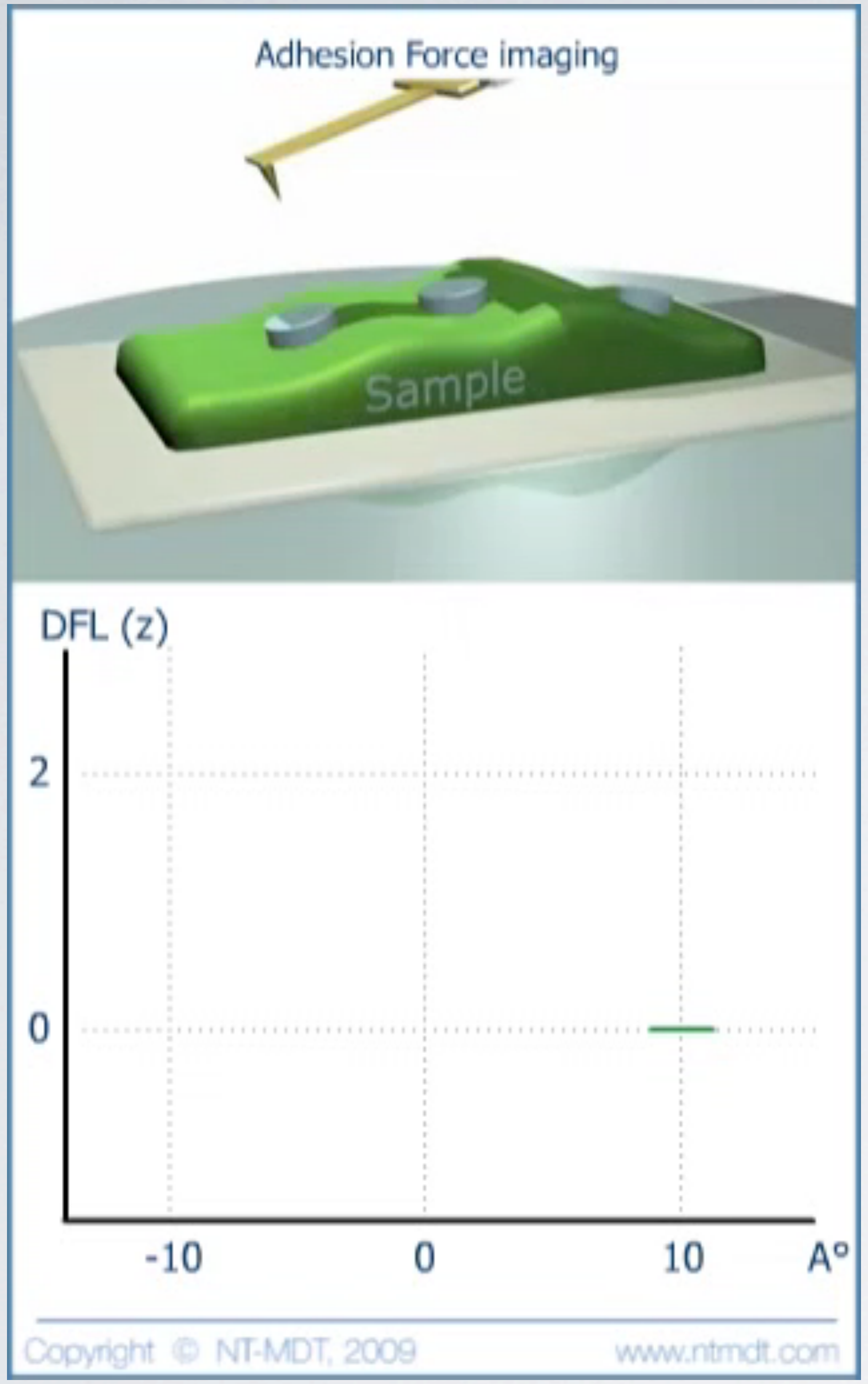

Thermistor


Heater





X,Y resolution 25 нм, 0,005K – temperature resolution



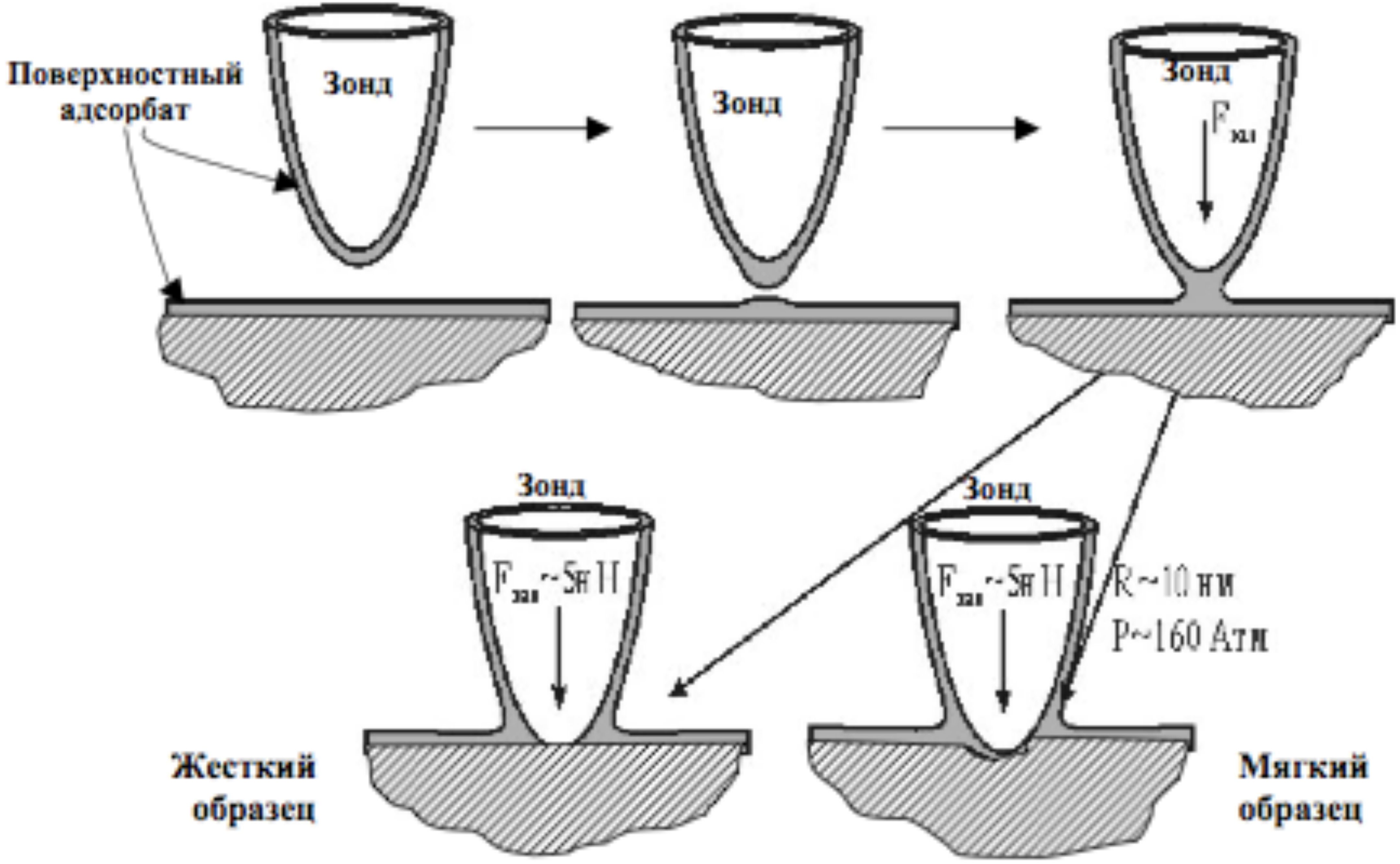
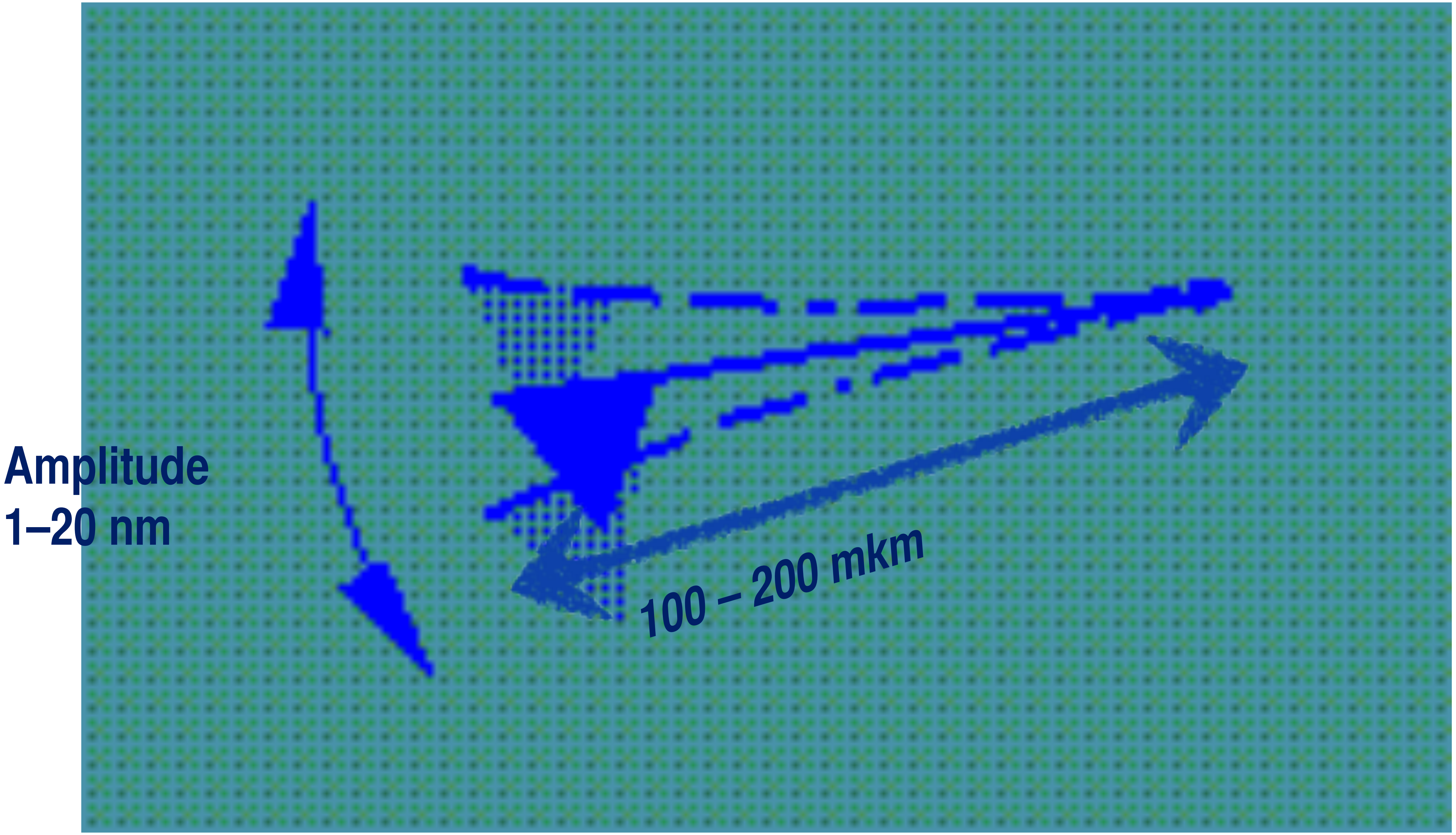
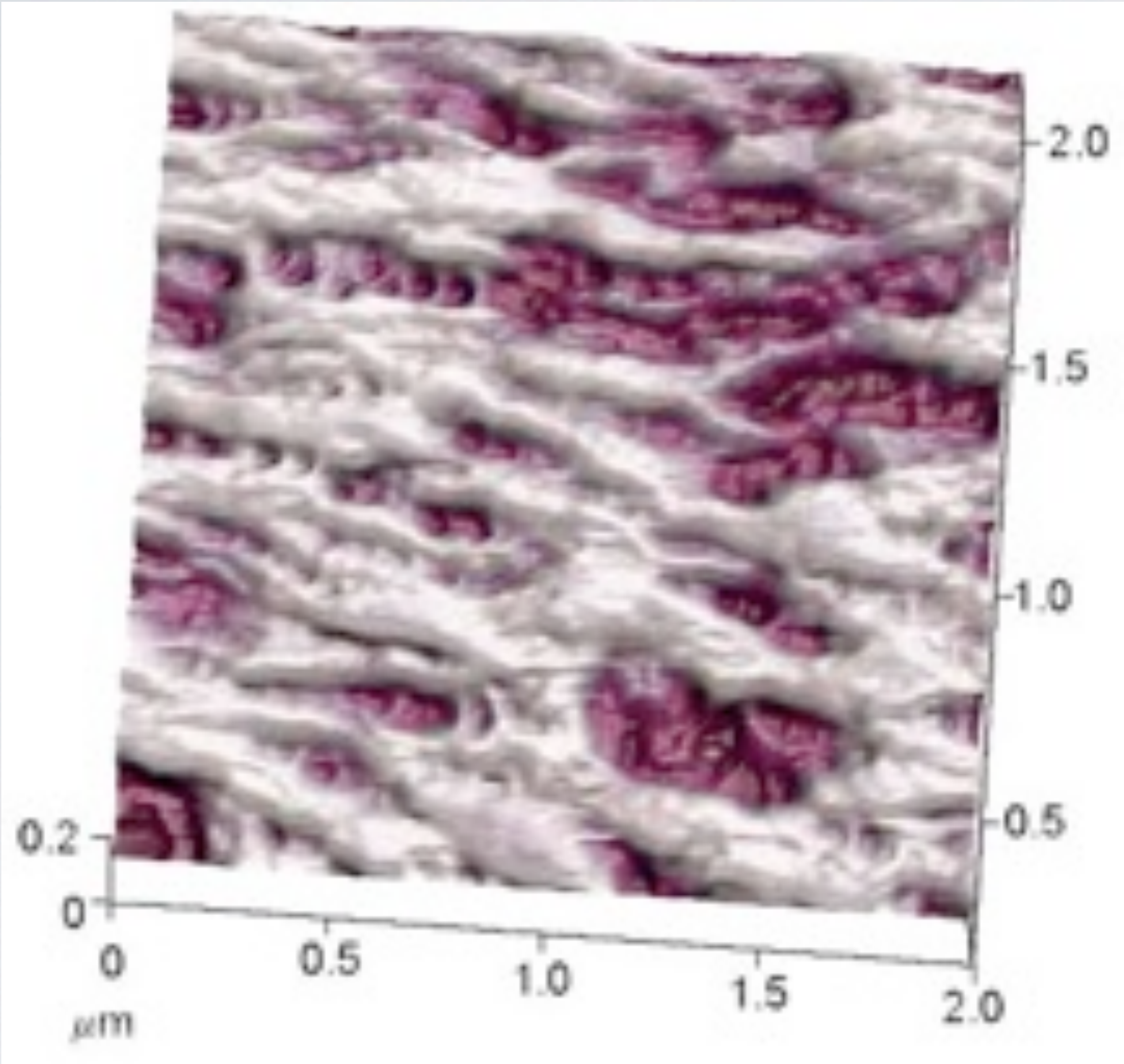


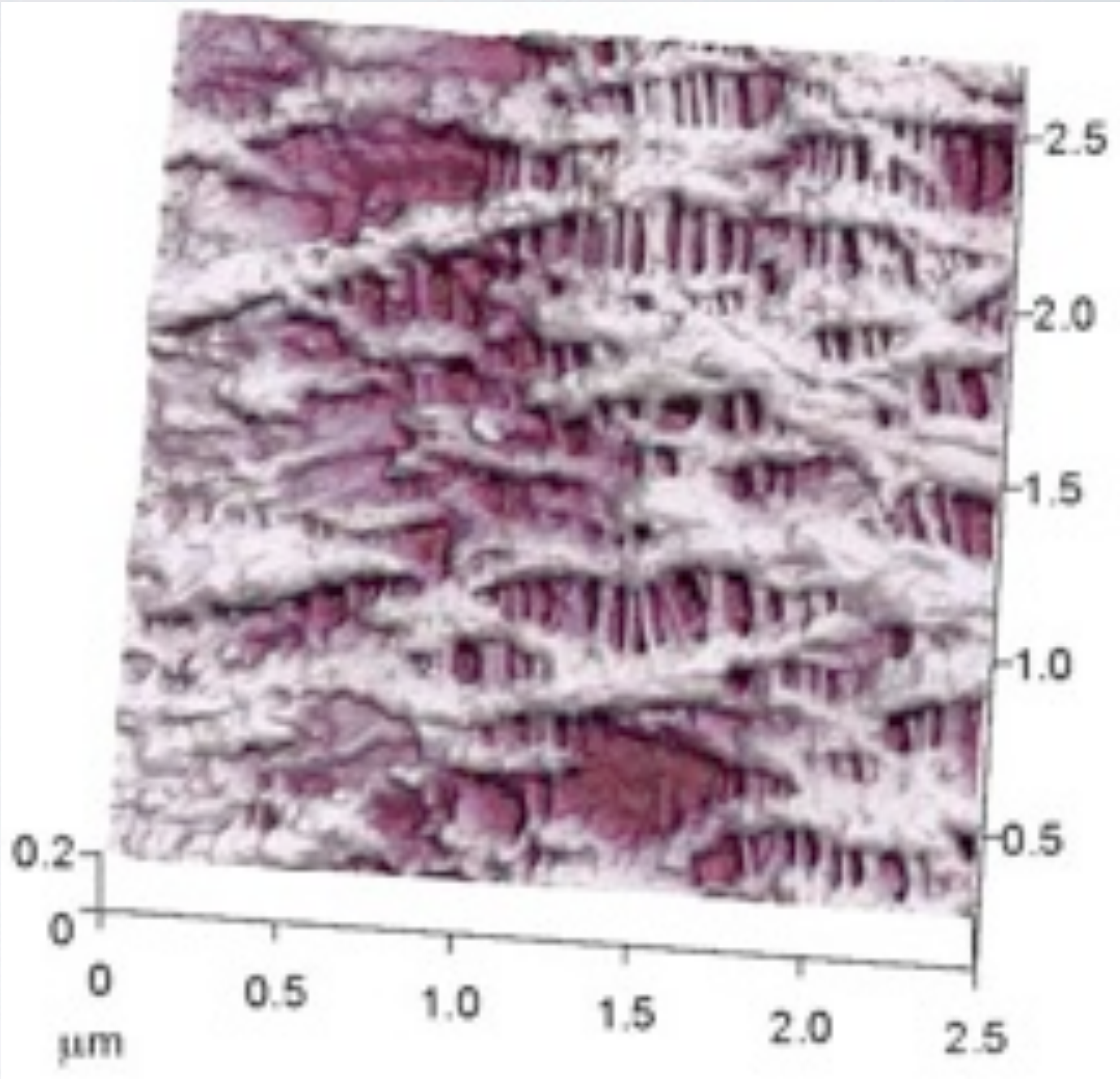
Рис.1.20. схематическое изображение процесса подвода зонда и образца в присутствии подвижного (текучего) поверхностного адсорбата

Christopher Gerber suggested working as an oscillating cantilever, 1992, which President Digital Instruments Dr. Vergil Ellings called Tapping mode

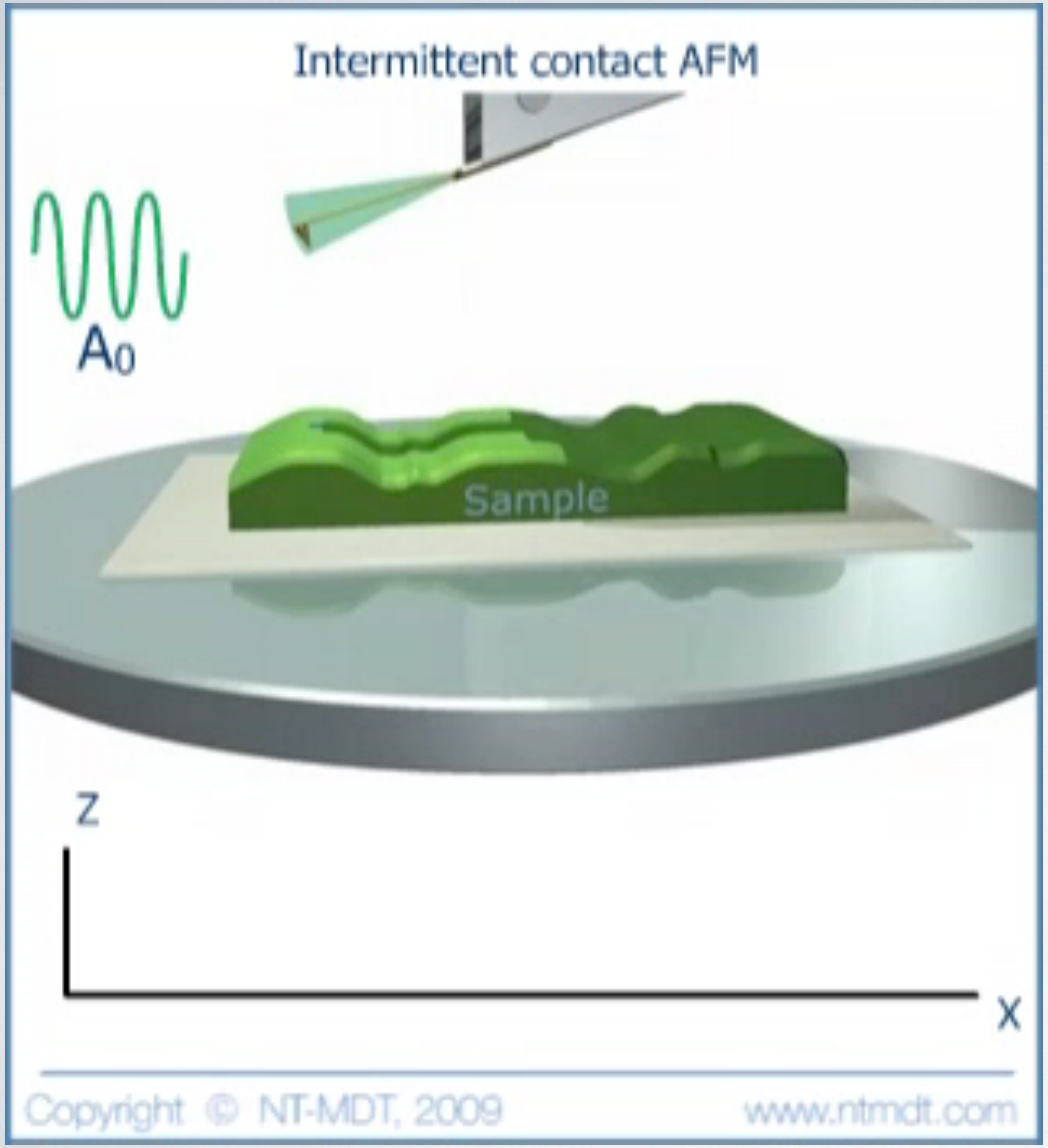


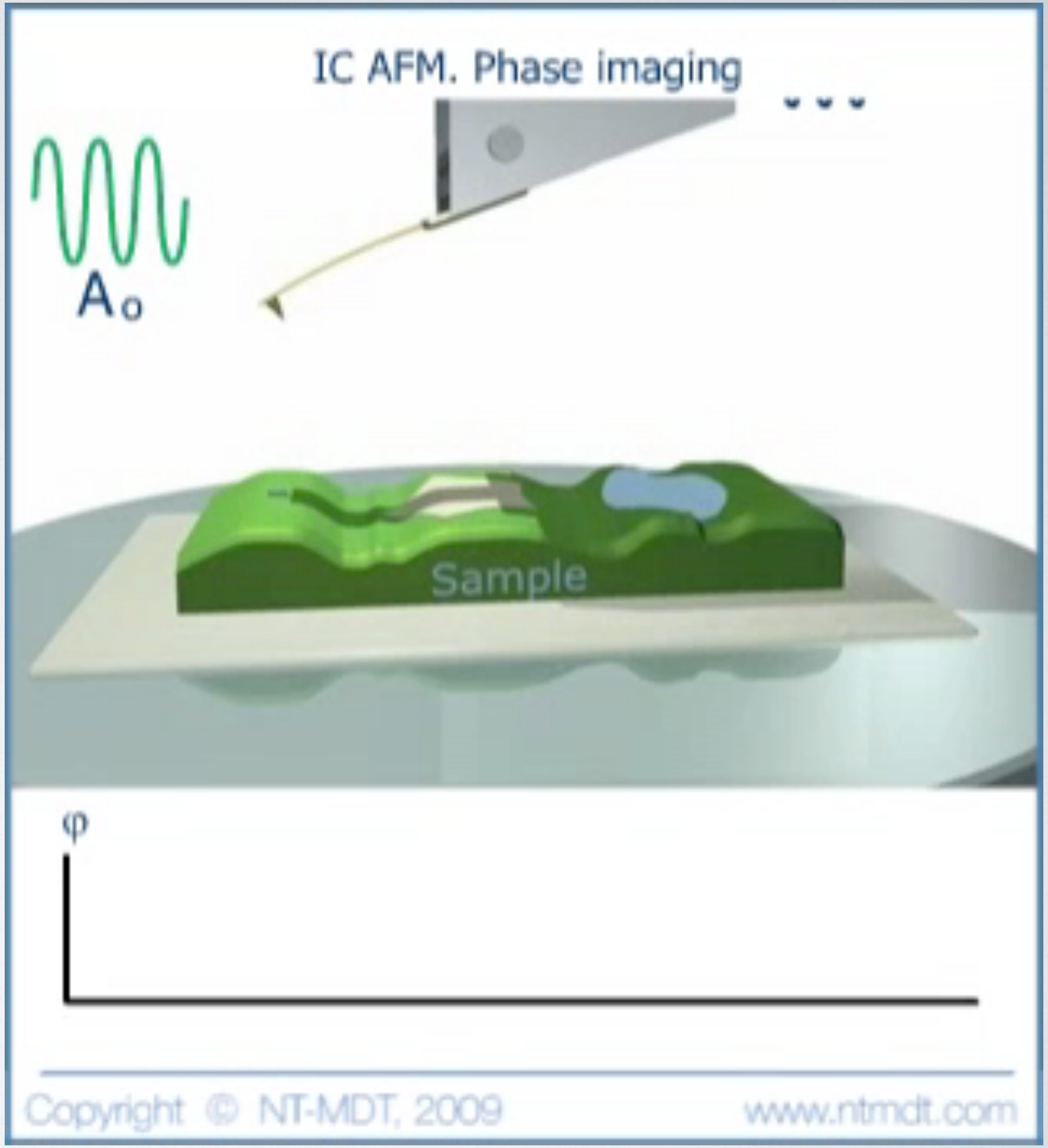
Intermittent (tapping) mode – nondistructable AFM for the flax materials

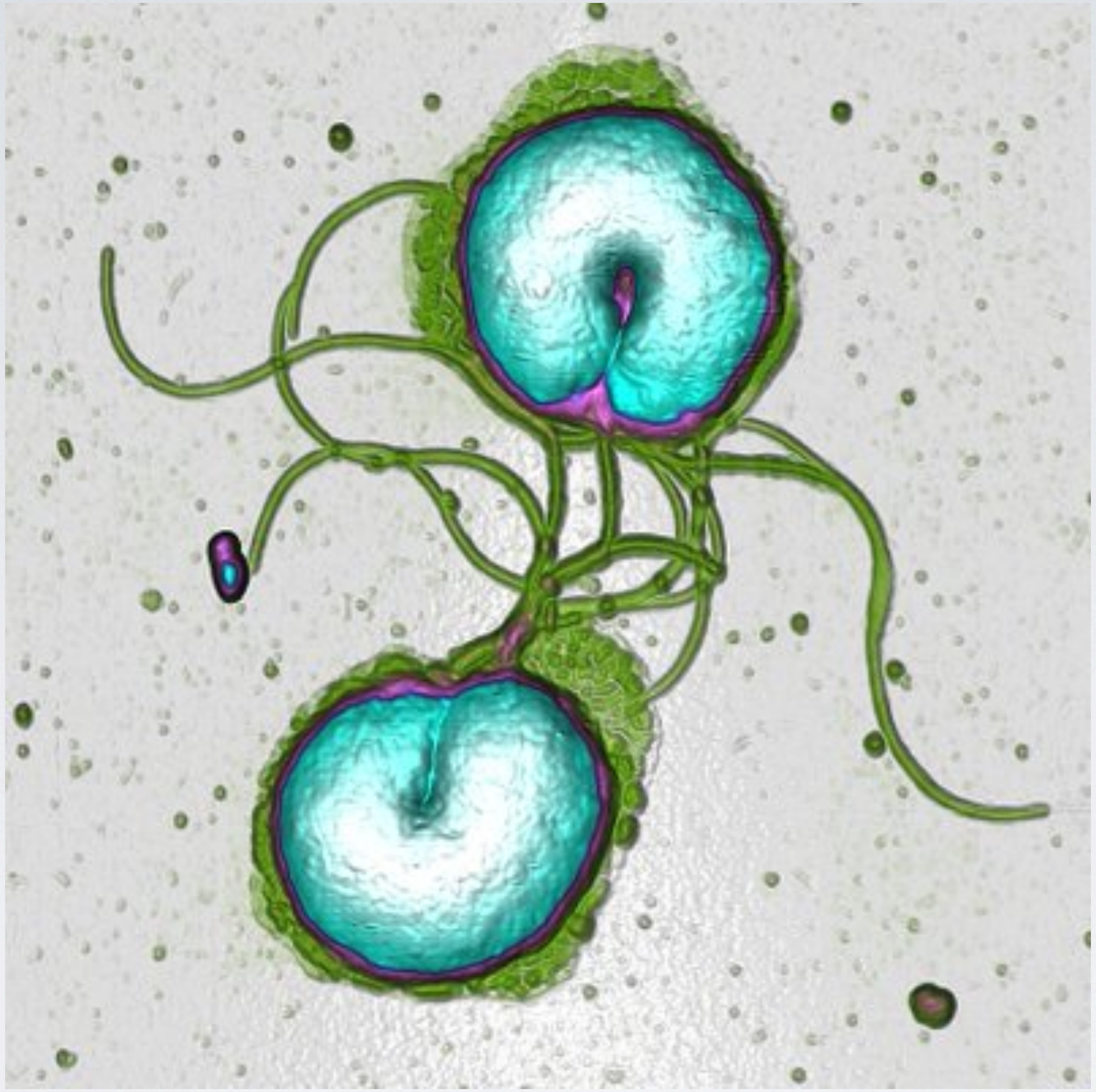




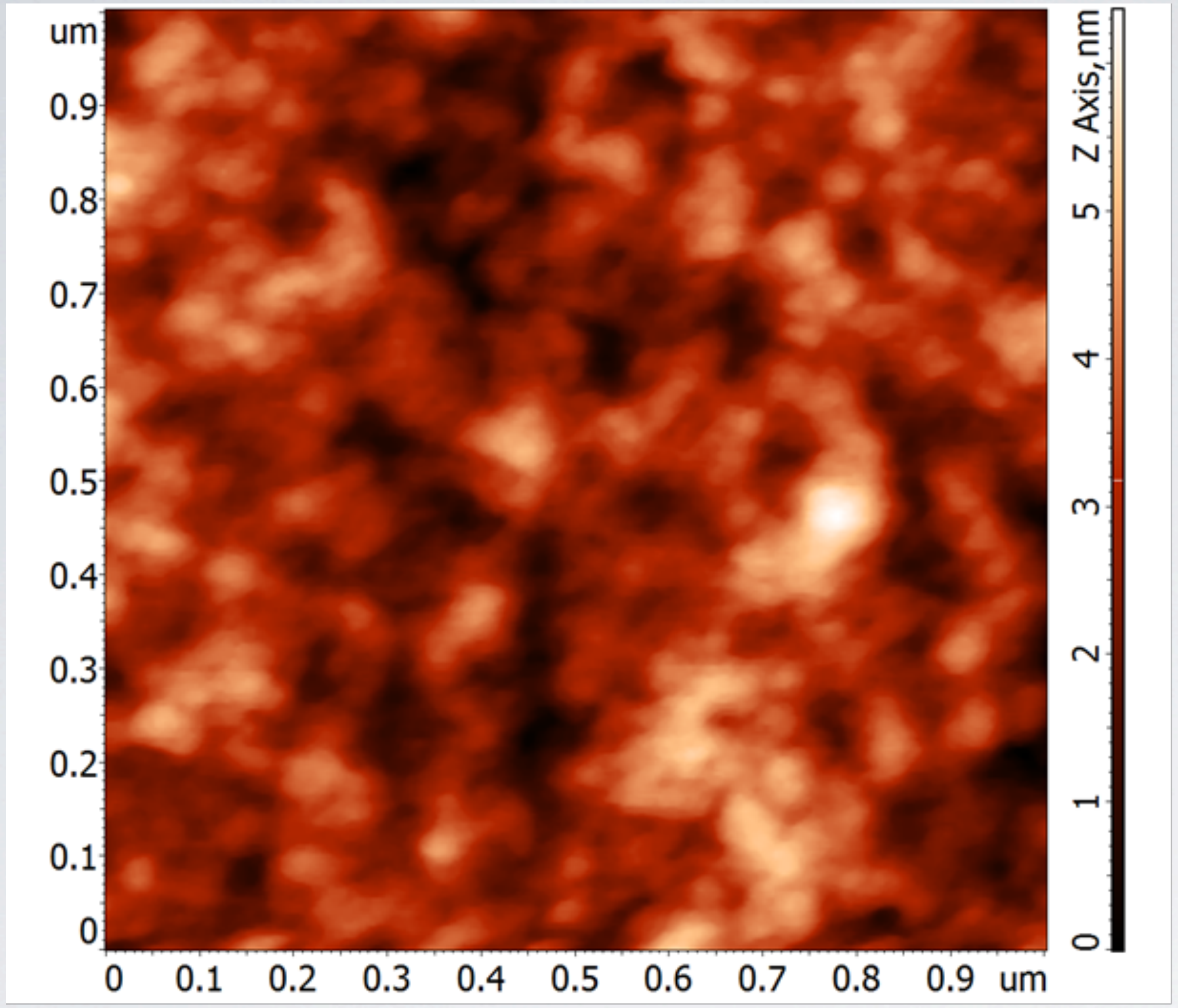
Contact (left) and resonant AFM mode image of the polymer membrane. On left image all thin veins were crumpled during the scanning in the contact mode

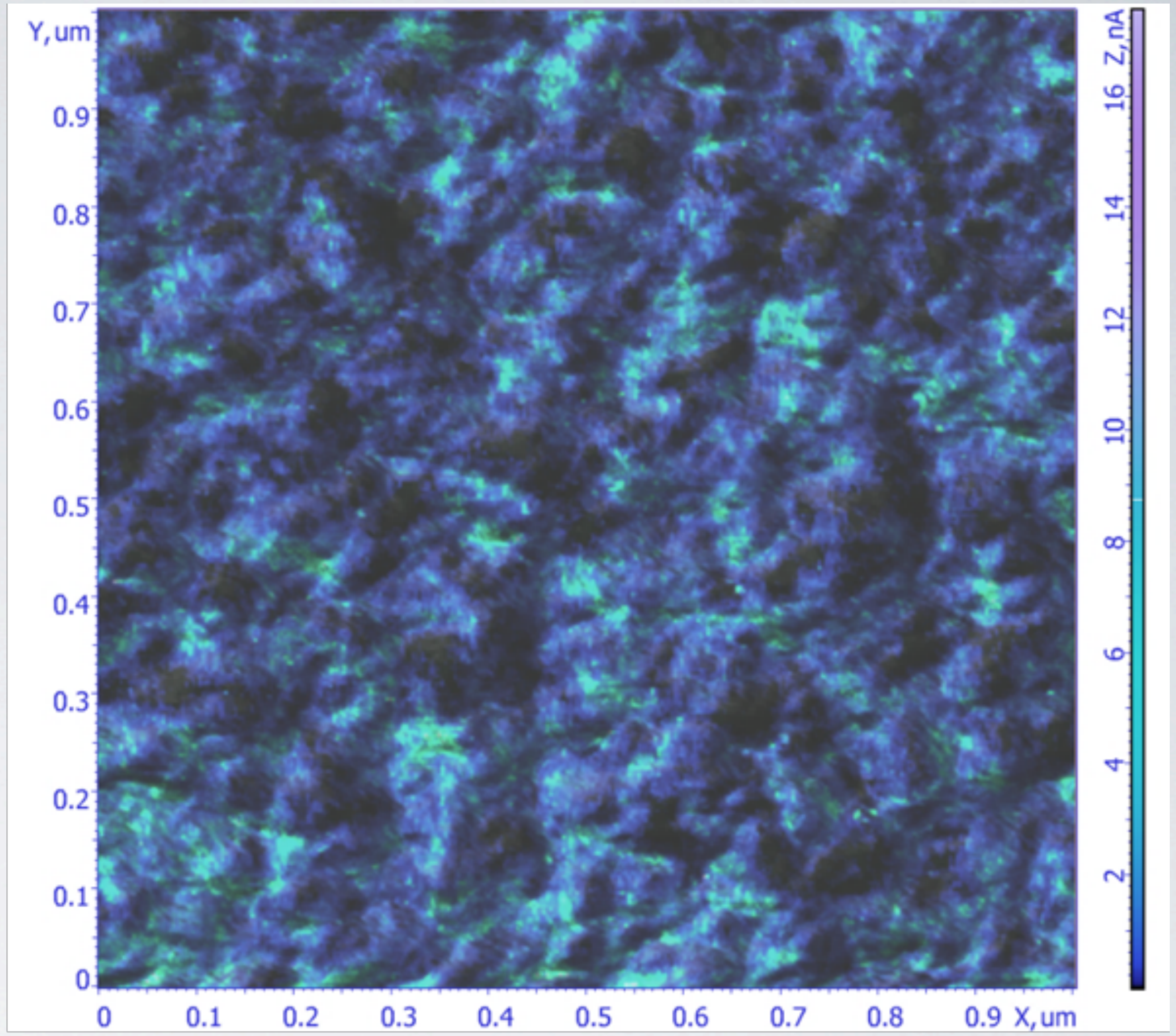

Intermittent contact AFM
A0
Sample
Z
X
Copyright © NT-MDT, 2009
www.ntmdt.com

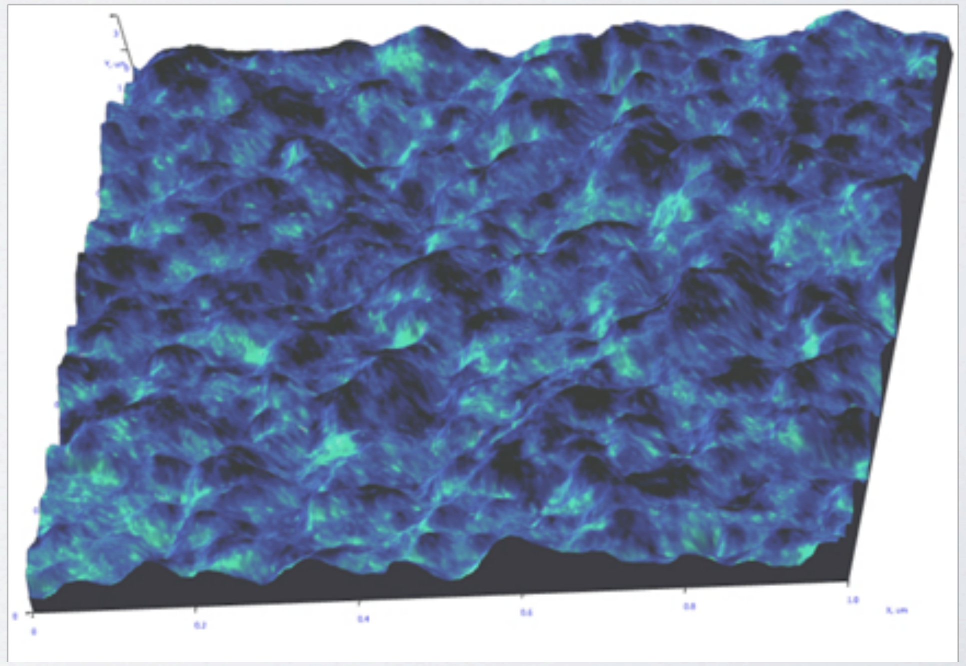

IC AFM. Phase imaging
A0
Sample
φ
Copyright © NT-MDT, 2009
www.ntmdt.com



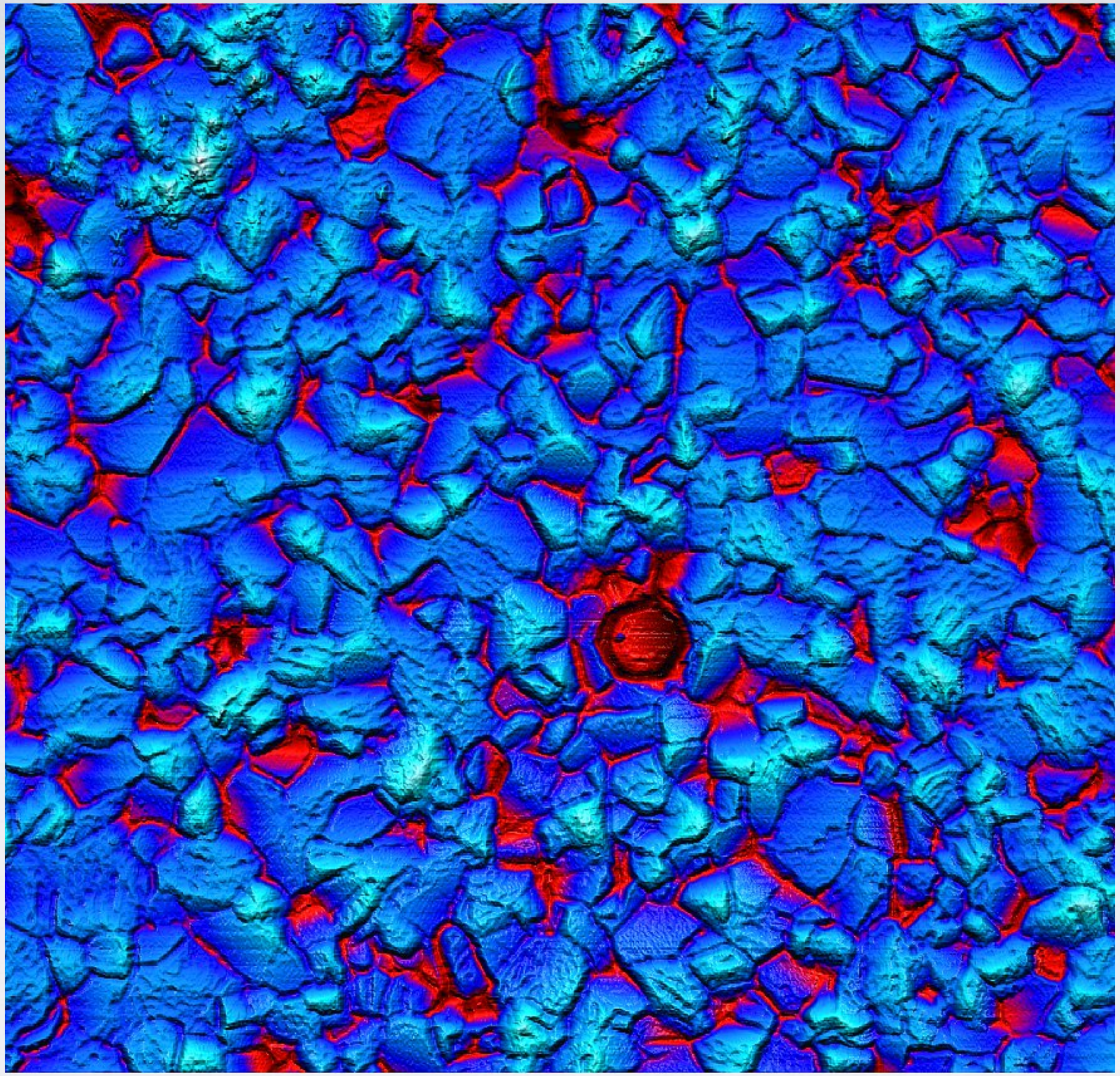
7x7 µm AFM image of two H. Pylori bacteria converting into coccoid form.
Image made by Dr. I.A. Budashov, MSU, Institute of Biochemical Physics
Sample: Dr. K.T. Momynaliev, Scientific Research Institute of Physical-Chemical Medicine





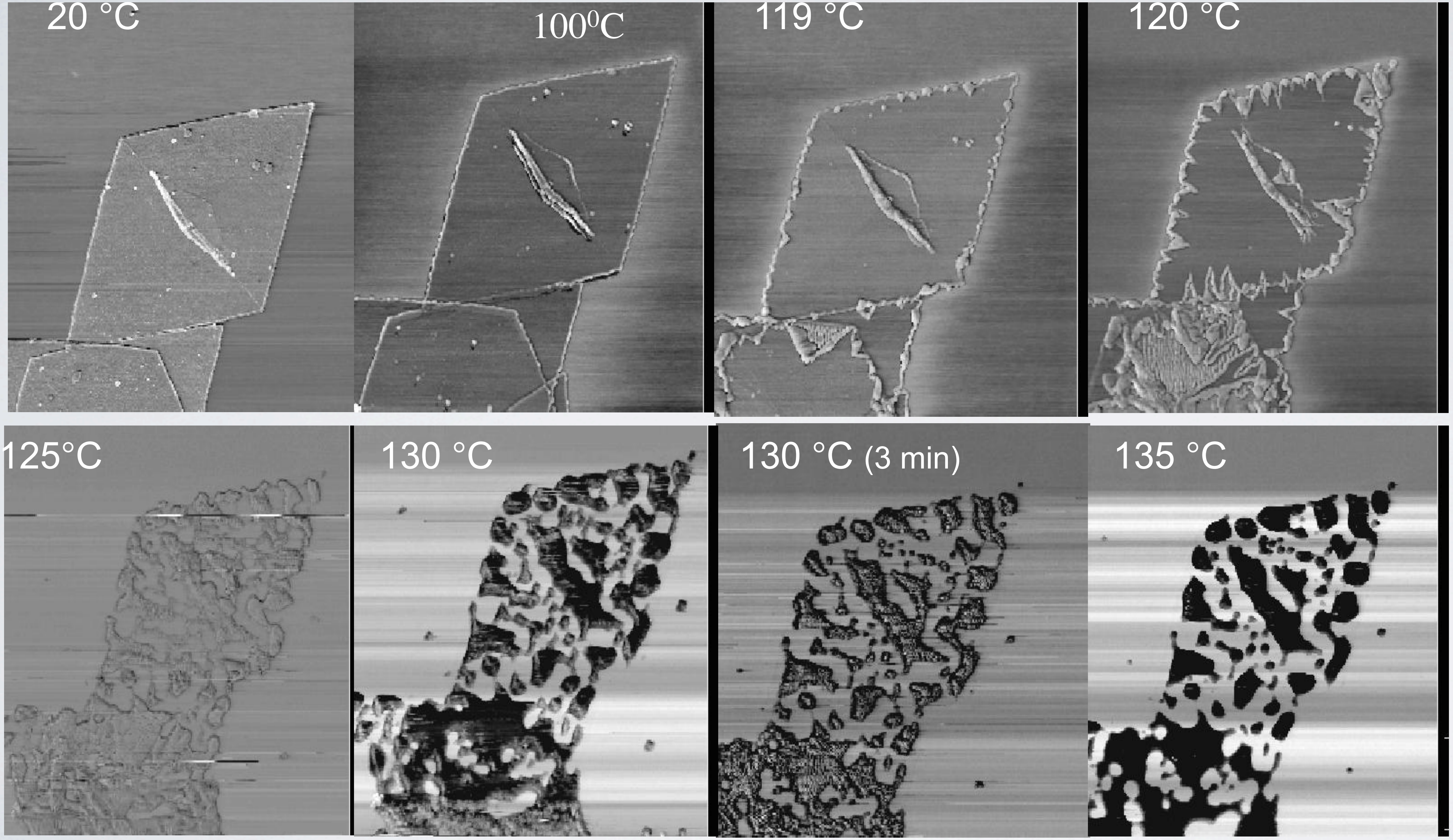


AFM images of In_2O_3(left) and spreading resistance maps (right). The scanning area is 1 μm x 1 μm. The spreading current is superimposed on the relief image. The bottom right is a 3D image of flow and relief flow. The voltage between the sample and the probe is U = 2.3 V.



10x10 mKm, transparent electrodes from In_2O_3

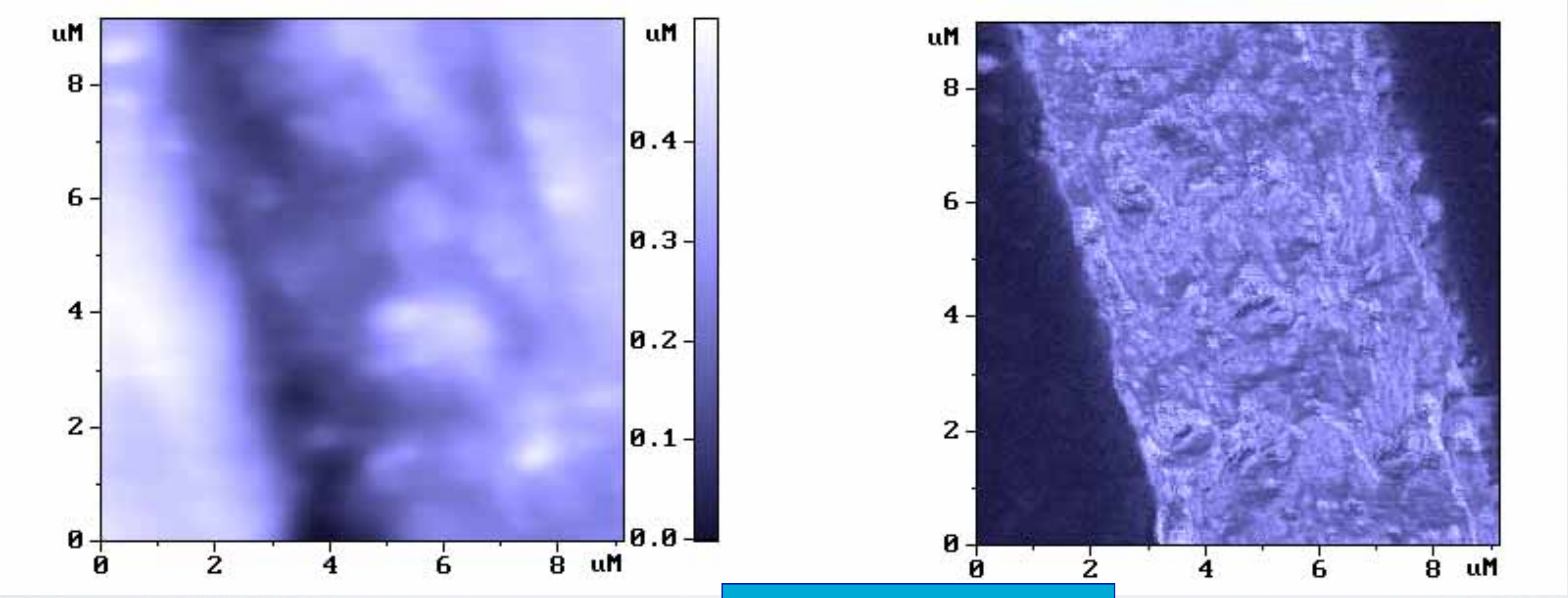
One serial of Phase images of one isolated polyethylene single crystal deposited on clean mica and annealing with in-situ NT-MDT heating-stage

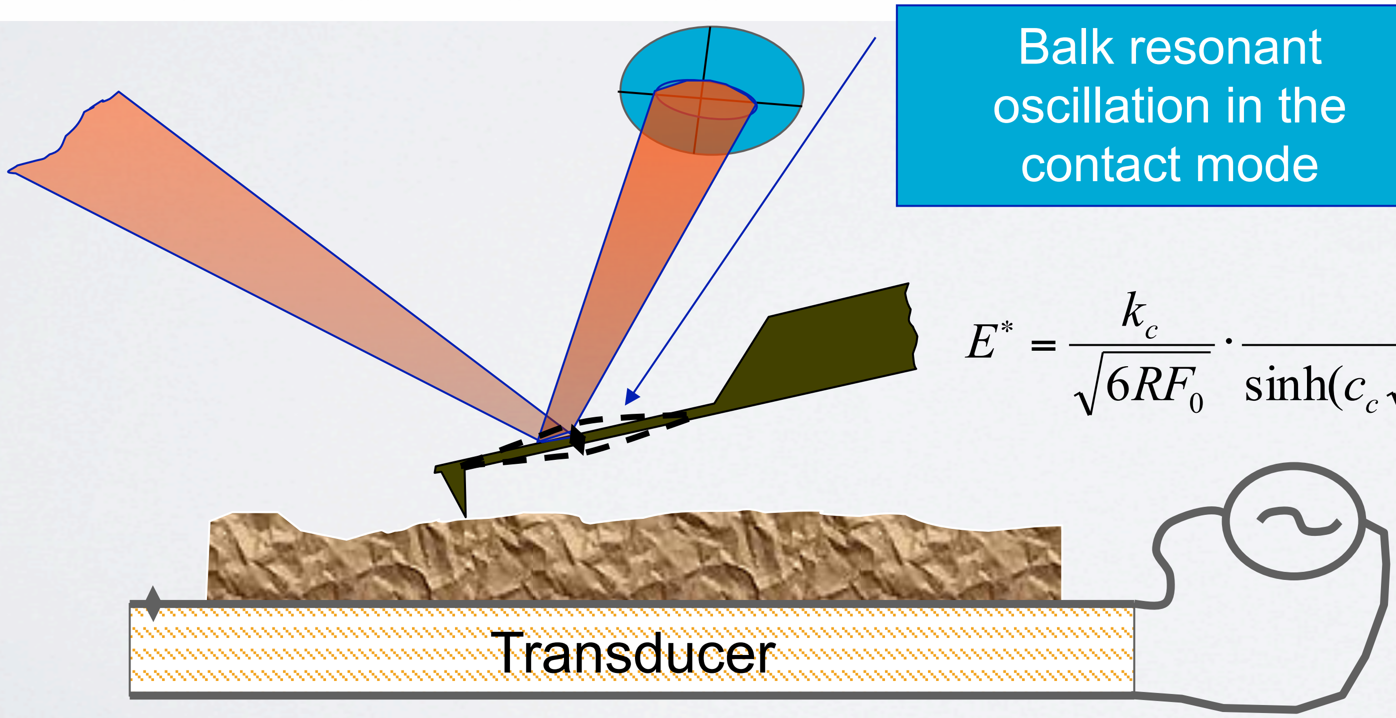


Phase imaging of malting process

(M. Tian, DPI, TU/e)

AFAM – High resolution Young module distribution



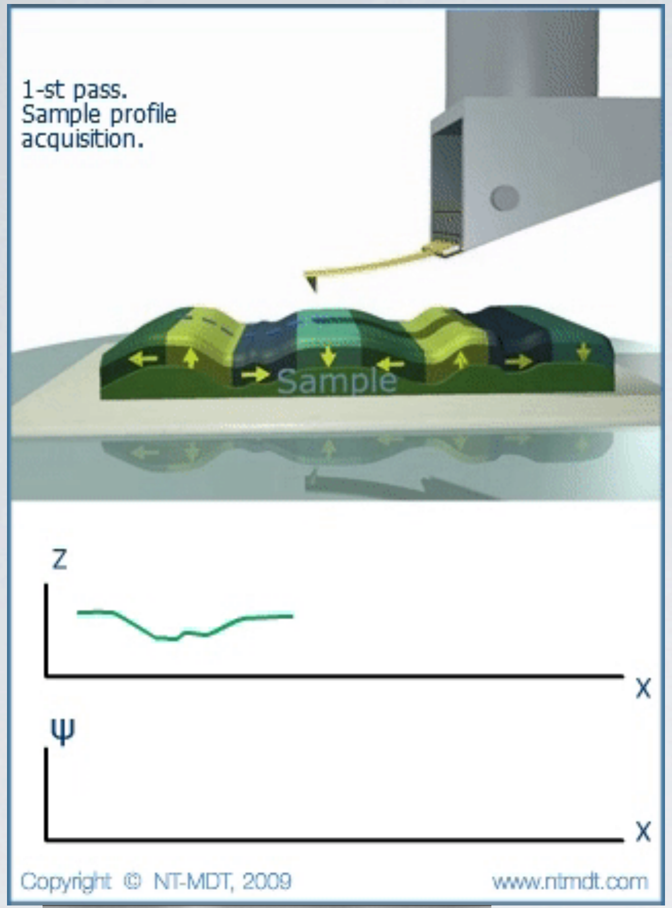


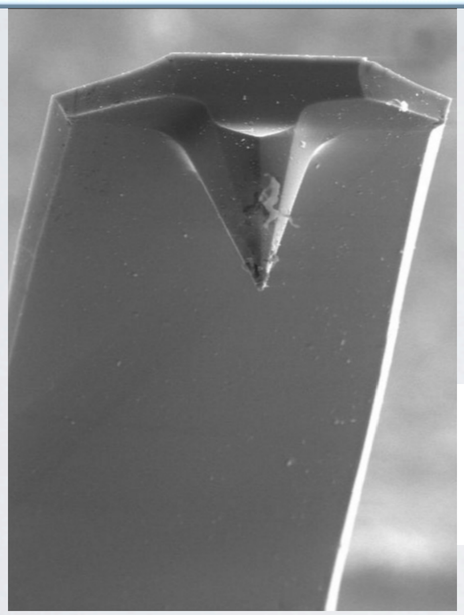
Balk resonant oscillation in the contact mode

Слоистый полиэтилен высокой и низкой плотности

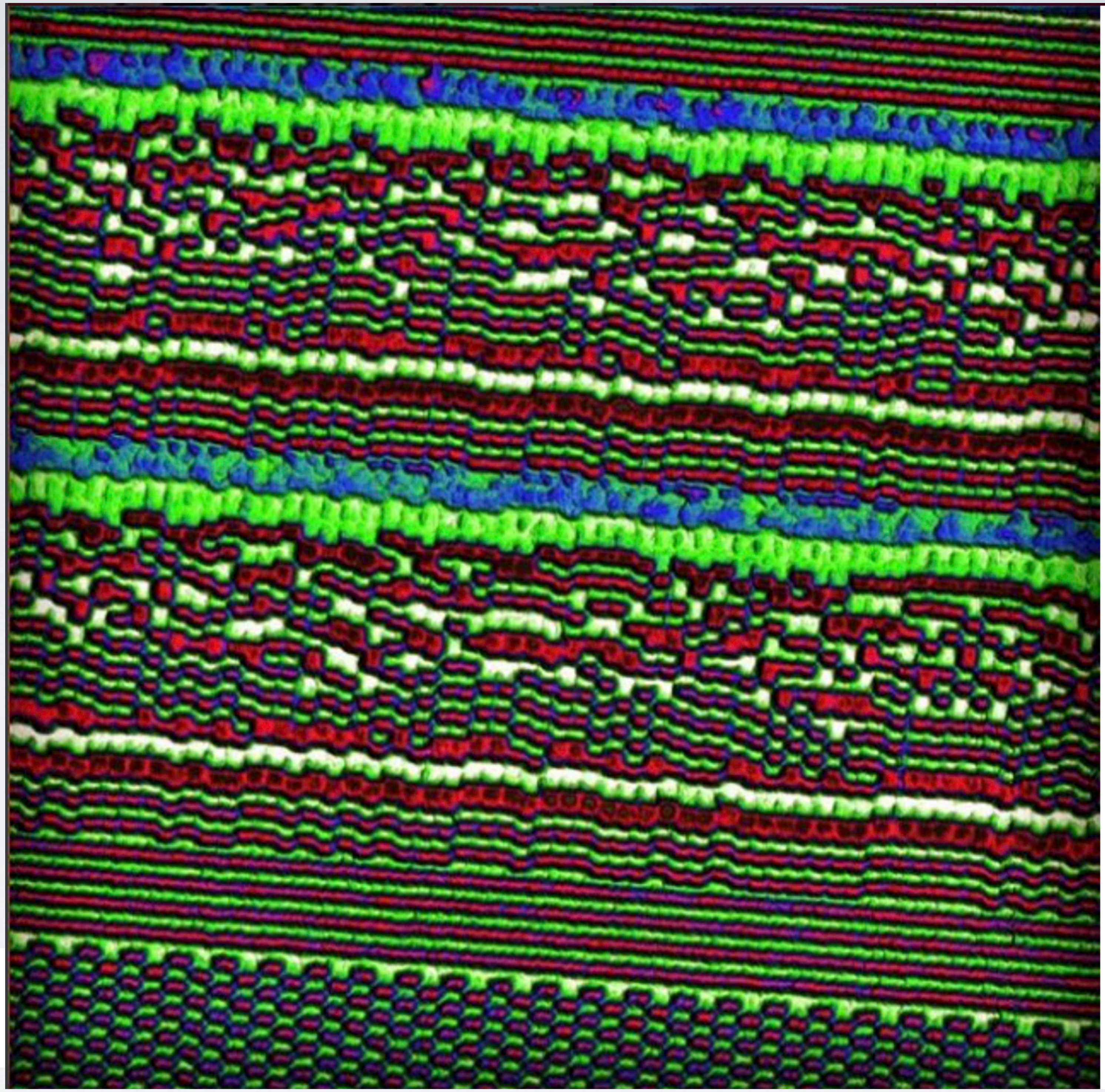
$$E^* = \frac{k_c}{\sqrt{6RF_0}} \cdot \frac{1+\cos(c_c\sqrt{f_n})\cosh(c_c\sqrt{f_n})}{\sinh(c_c\sqrt{f_n})\cos(c_c\sqrt{f_n}) - \sin(c_c\sqrt{f_n})\cosh(c_c\sqrt{f_n})} \cdot \frac{(c_c\sqrt{f_n})^3}{3}$$

$$2\pi \cdot f_n = \omega_n = \frac{2\pi(k_n L)^2}{c_c^2} \qquad c_c = L\sqrt{2\pi}\sqrt[4]{\frac{\rho A}{EI}}$$





Co/Fe coating cantilever



24 отметок «Нравится» 7 нед.

ntmdt #MFM image of 1TB #harddrive fragment captured by #ntmdt NA_FM/CoFe magnetic #afm probe demonstrating 30 nm lateral resolution in air. #scan size: 10x10 um. Image courtesy: Arseny Kalinin. #nanotechnology #нанотехнологии #microscope #microscopy #science #datastorage #нтмдт #atomicforcemicroscopy

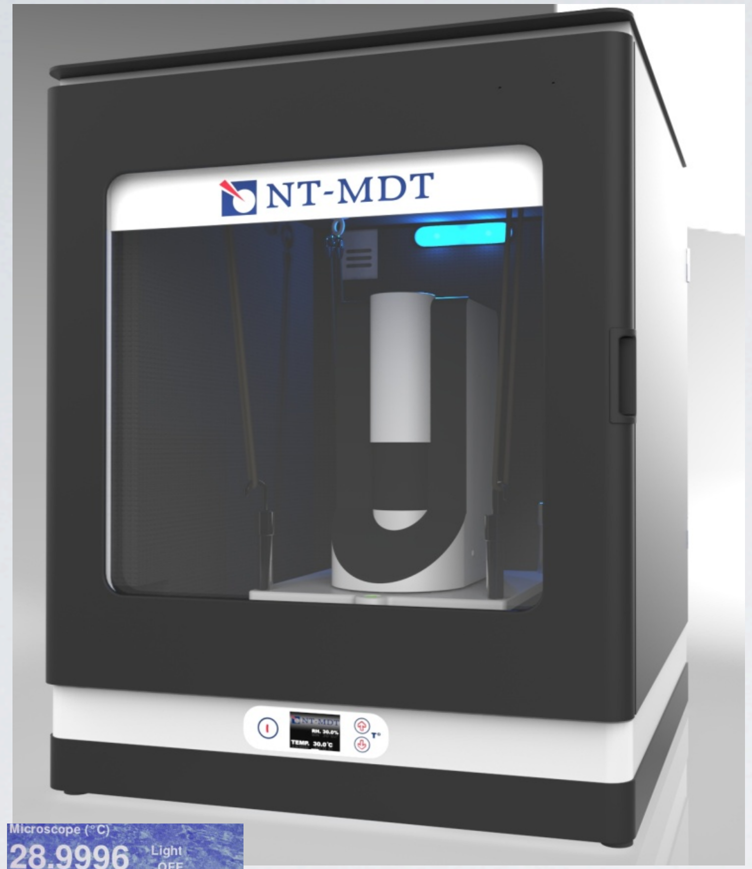
fancy_corpse 😍😍😍😍

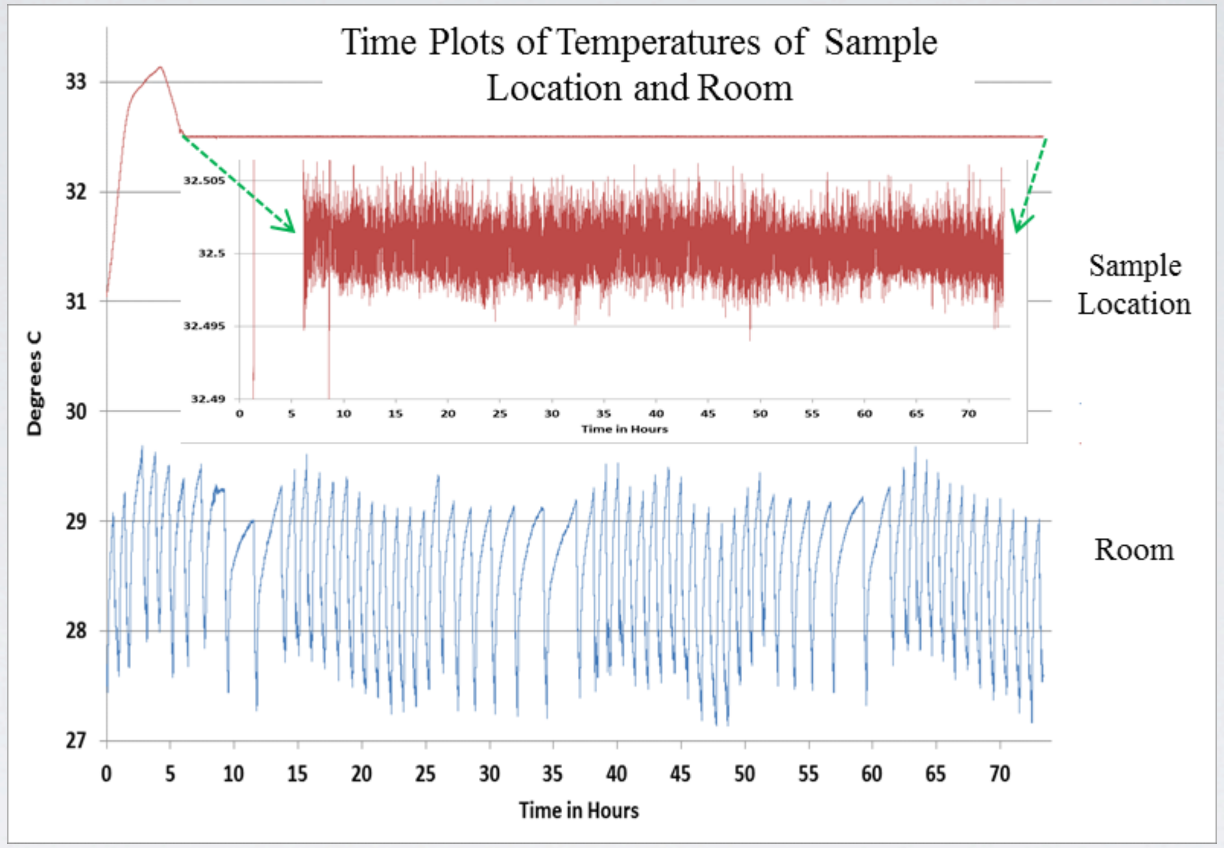
Войдите, чтобы поставить «Нравится» или прокомментировать.

MFM image of magnetic memory disk fragment

Measurement step -10 nm, Arseny Kalinin, NT-MDT SI, January 2016, NTEGRA-Prima

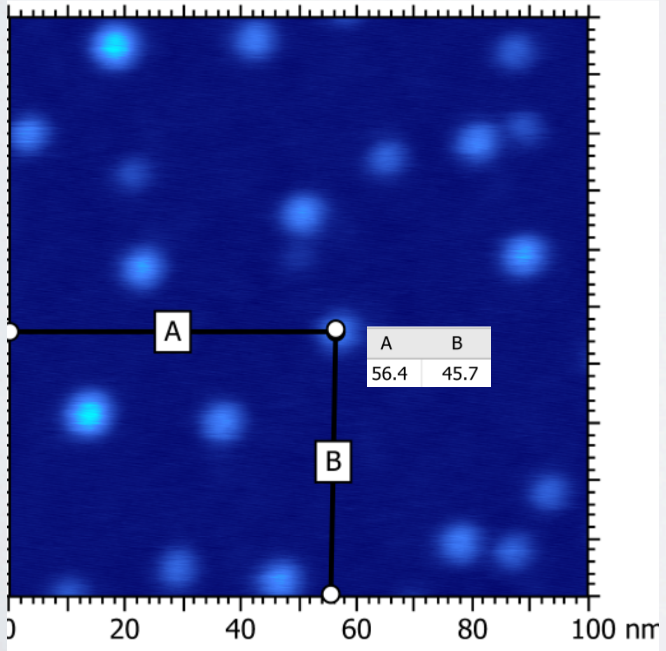
Thermal, Acoustic, Vibration Enclosure

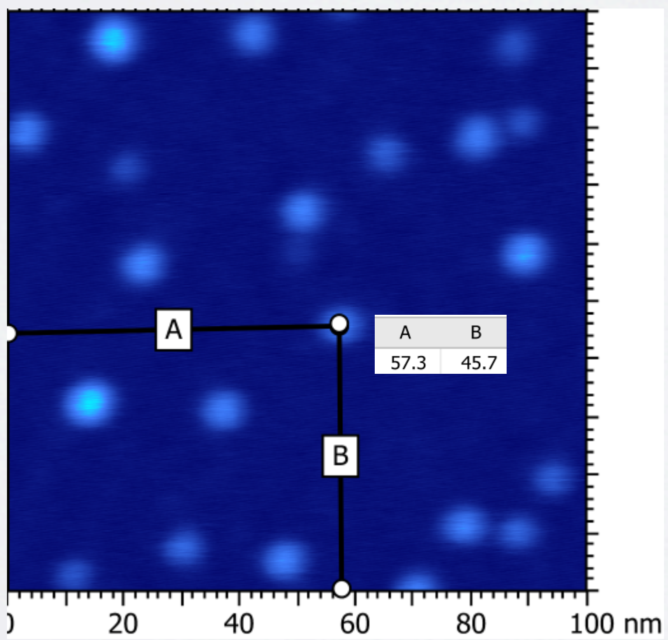


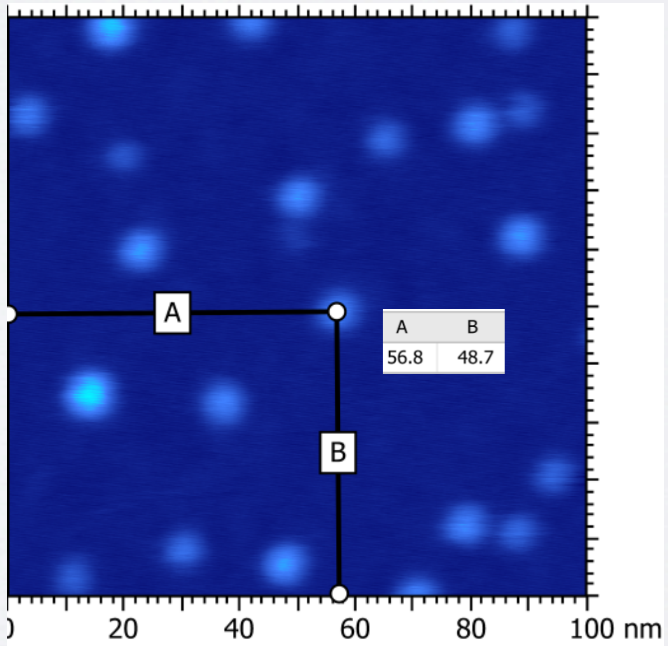


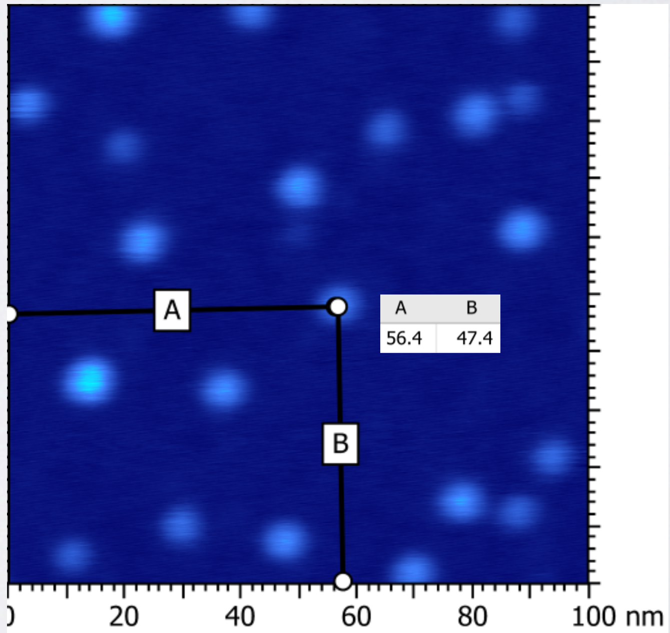
- Temperature stability better than 0.005C
- Thermal drift lower than 0.2 nm/min

Silver Nanoparticles on Mica: Scans (512×512) with 1 Hz rate









NT-MDT Spectrum Instruments

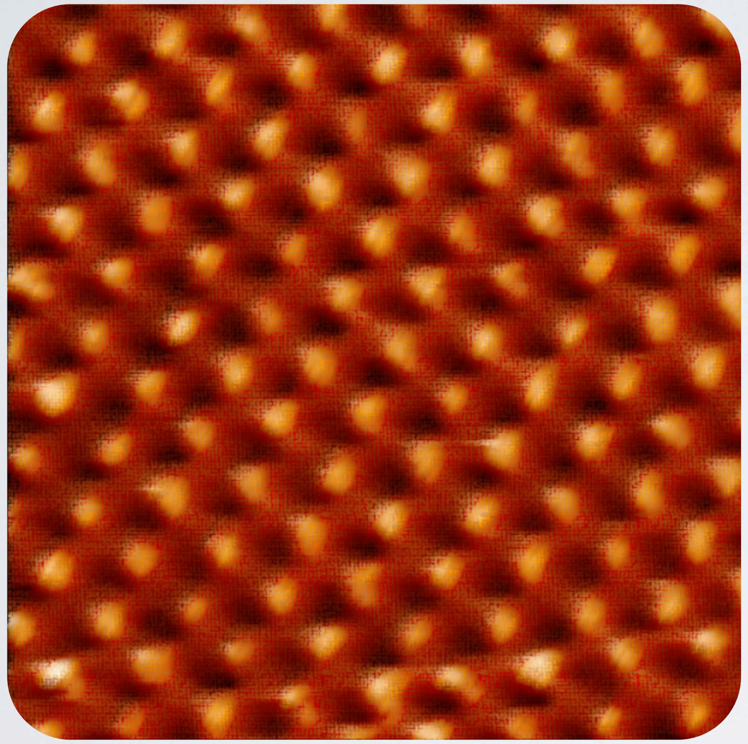
Scan time – 8,5 min, between scans 12 hours

High resolution, low noise and drift, a full set of functions

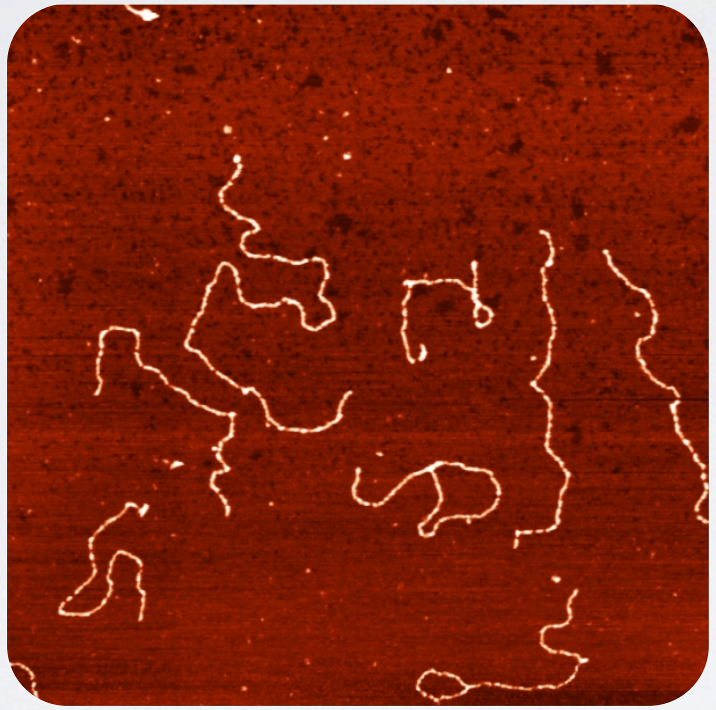
Improved Optical Beam Deflection Sensor **noise**
<25 fm/√Hz

Improved Hi-Voltage **noise < 1mV/600V**

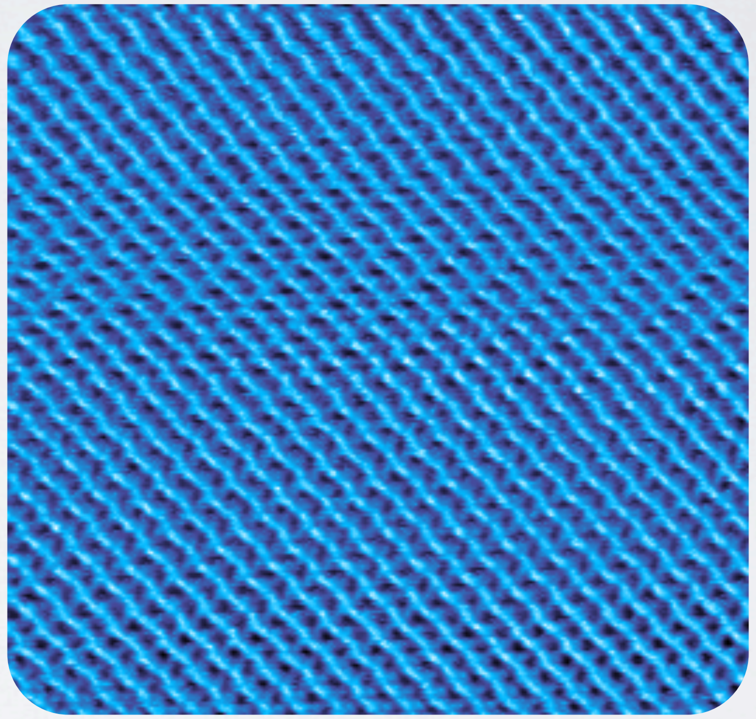
Time-proven capacitive sensors **Closed Loop**
noise: < 0.3 nm



3.5×3.5 nm
HOPG atomic resolution,
STM mode



1.5×1.5 um
DNA on mica

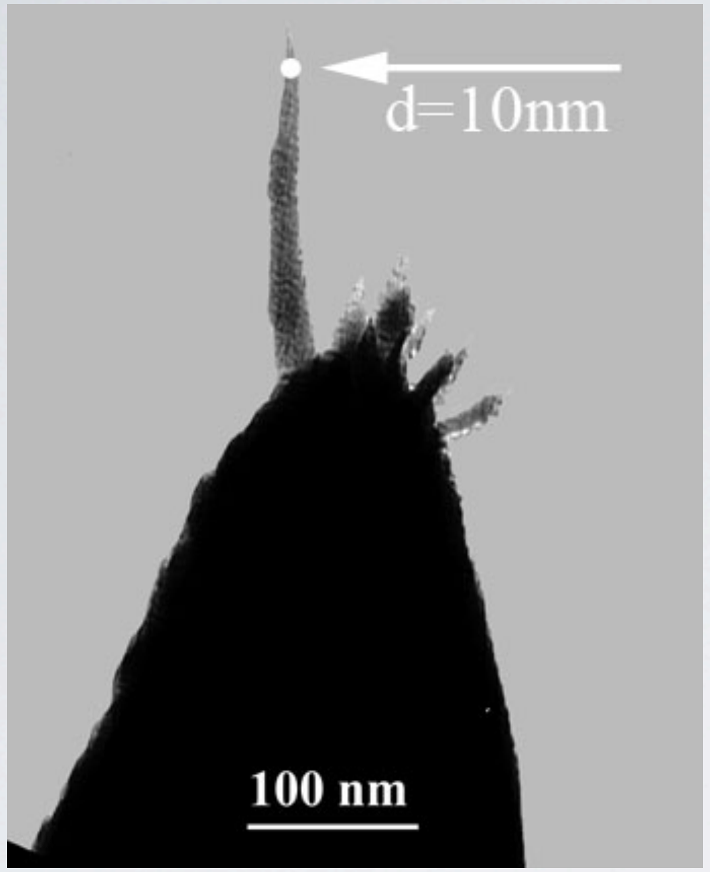


7×7 nm
Calcite atomic resolution,
AM-AFM in liquid

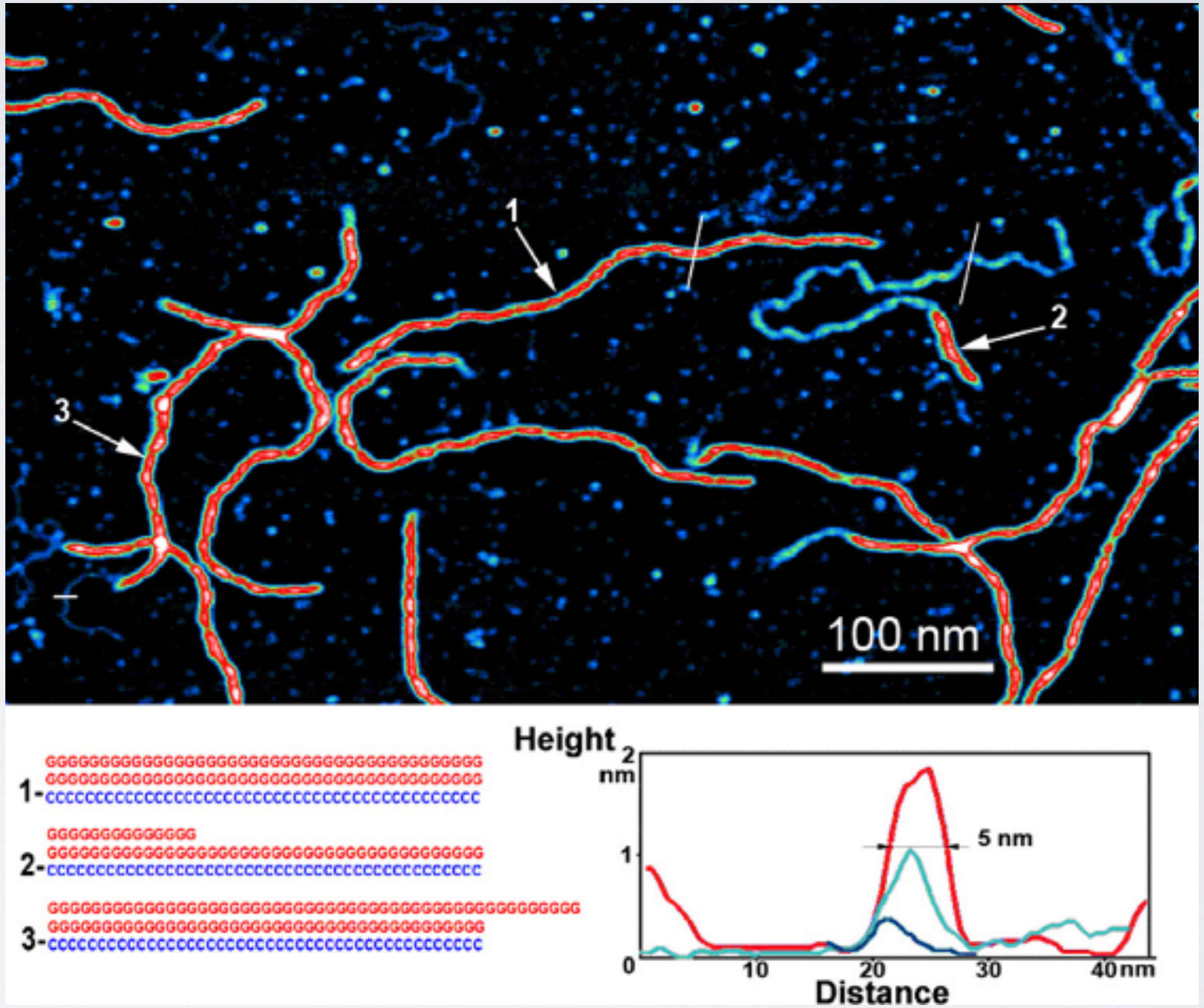
Calcite atomic resolution, AM-AFM in liquid, 800x800 points, scanning speed – 2Hz. NSG probe.

NT-MDT Spectrum Instruments

Fragments of DNA molecules

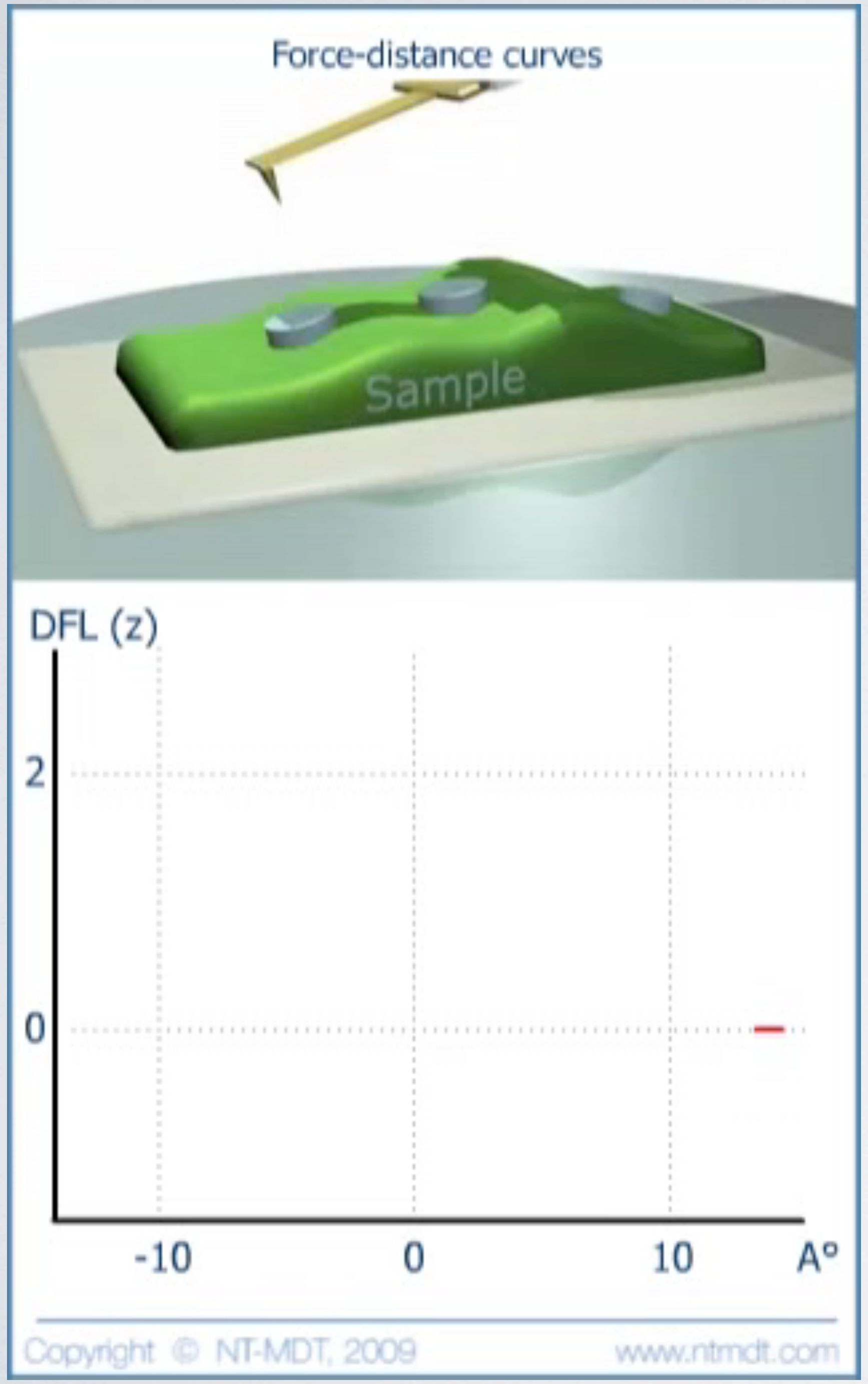


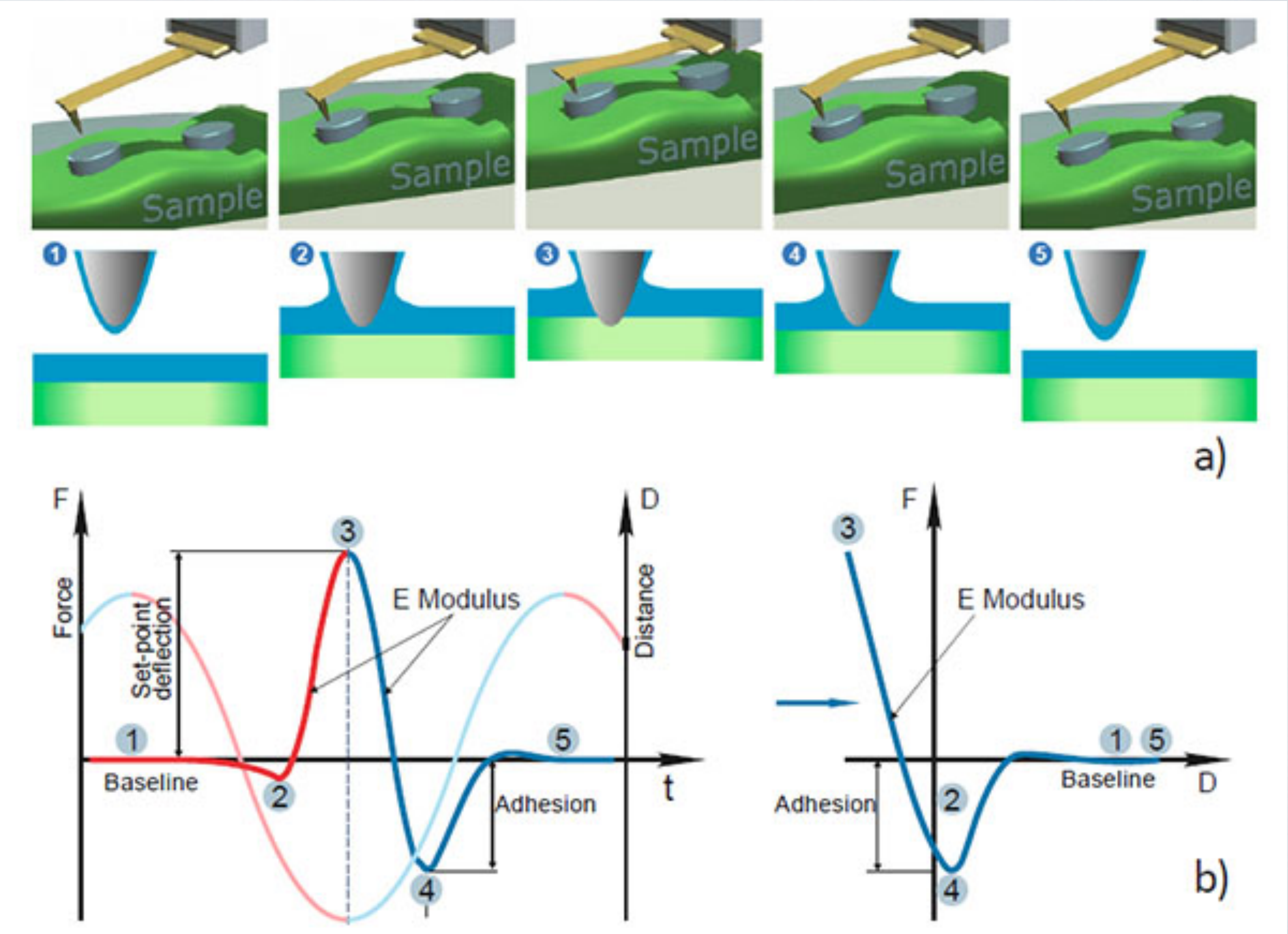
SEM image of carbine whisker tip



AFM image of high-resolution DNA triplex poly(dG)–poly(dG)–poly(dC) (Dmitry Klinov1, Benjamin Dwir1, Eli Kapon1, Natalia Borovok, Tatiana Molotsky and Alexander Kotlyar - Nanotechnology

HybriD mode: Topography, Elasticity modulus, Lift and Land Adhesion, Work of Adhesion, Current, Viscoelasticity – based on each point Force-Distance dependence registration



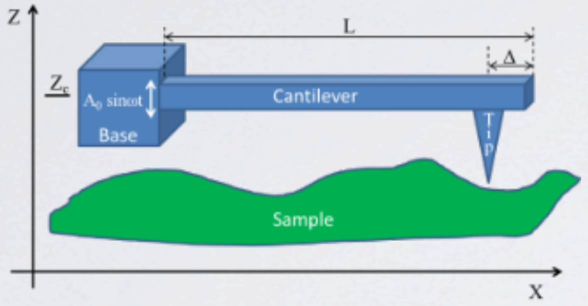


Basics of the Oscillatory Resonant AFM Modes

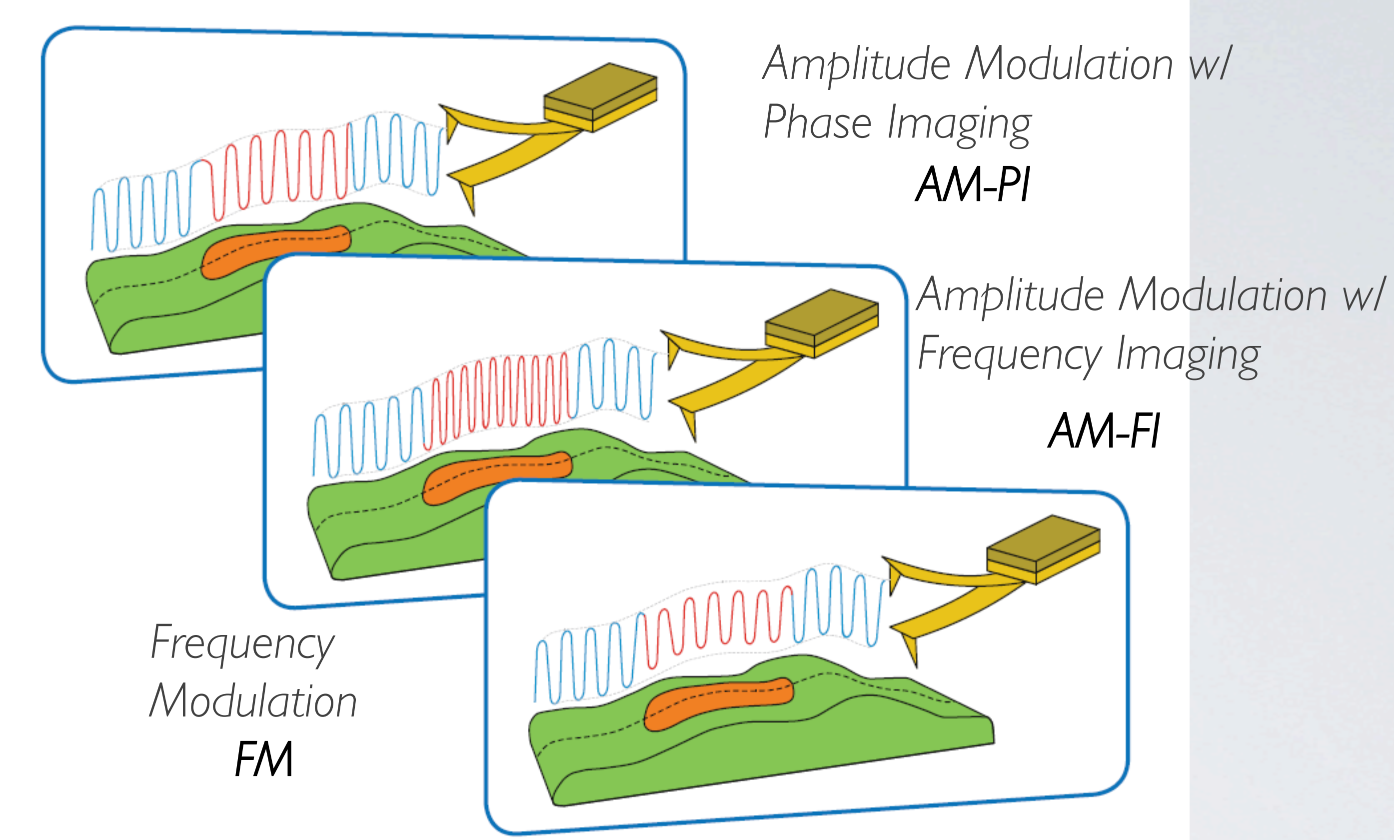
Euler-Bernoulli Equation

$$\frac{\partial^2 Z(x,t)}{\partial t^2} + 2\beta \frac{\partial Z(x,t)}{\partial t} + a^2 \frac{\partial^4 Z(x,t)}{\partial x^4} = [H(Z(x,t)) - p]\delta(x-(L-\Delta)$$

$$\begin{cases} \sqrt{1+G^2}\sin\theta = \dfrac{1}{N}\displaystyle\int_0^{\pi}[F_a - F_r](Z_c + A\cos y)\sin y\,dy + \dfrac{A}{A_0} \\ \sqrt{1+G^2}\cos\theta = -\dfrac{1}{N}\displaystyle\int_0^{\pi}[F_a + F_r](Z_c + A\cos y)\cos y\,dy - G\dfrac{A}{A_0} \end{cases}$$

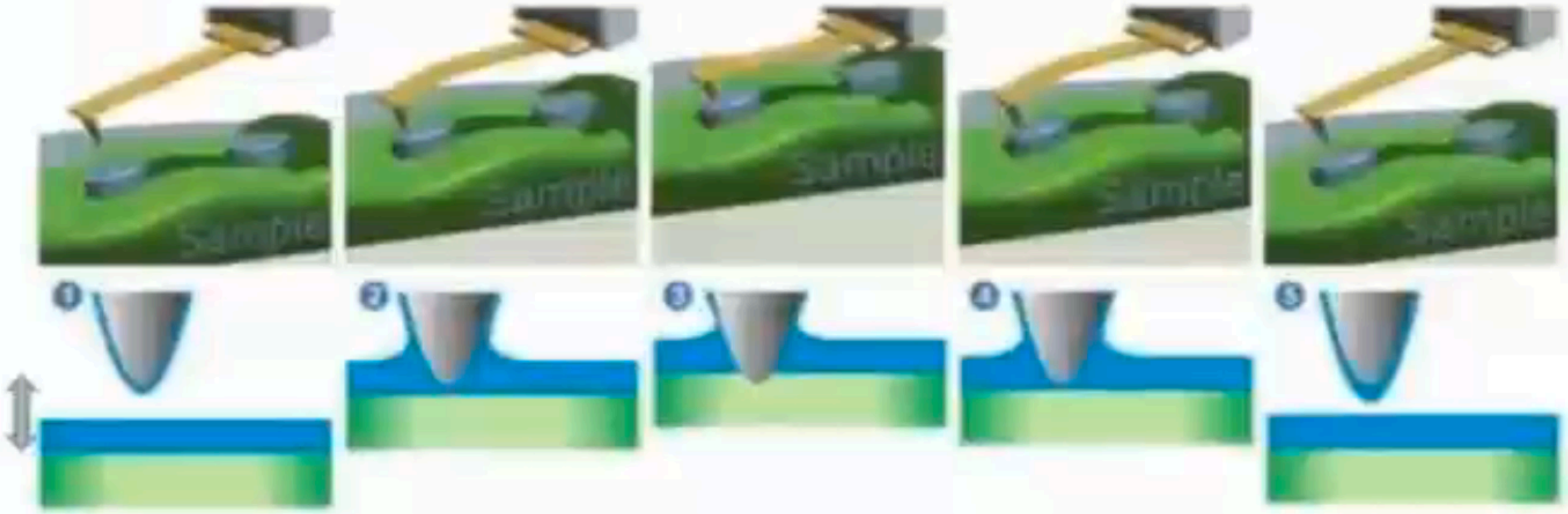


$$N = \frac{\pi A_0 \omega_1^2 \rho S L}{4Q_1}; \quad G = 2Q_1$$



Name	Fixed Variables	Means of Control	Imaging	Measurements	Dissipation
Amplitude Modulation/ Phase Imaging - AM-PI	$\Delta\omega$=0; $A(\omega_1)$=constant	Generator at ω_1; Z-servo for $A(\omega_1)$	$Z\&\theta$	$A\&\theta$ by LIA	$\frac{1}{2}\frac{kA_{sp}^2\omega_1}{Q_1}\left[\frac{A_0}{A_{sp}}\sin\theta_{AM} - 1\right]$
Frequency Modulation - FM	$\theta=90^o$; $\Delta\omega$=constant	PLL for θ-servo; Z-servo for $\Delta\omega$	$Z\&A$	$A\&\Delta\omega$ by PLL	$\frac{1}{2}\frac{kA^2\omega_1}{Q_1}\left[\frac{A_0}{A}\sqrt{1+G_{sp}^2} - 1\right]$
Amplitude Modulation/ Frequency Imaging - AM-FI	$\theta=90^o$; $A(\omega)$=constant	PLL for θ-servo; Z-servo for $A(\omega)$	$Z\&\Delta\omega$	$A\&\Delta\omega$ by PLL	$\frac{1}{2}\frac{kA_{sp}^2\omega_1}{Q_1}\left[\frac{A_0}{A_{sp}}\sqrt{1+G^2} - 1\right]$

Basics of the Hybrid Mode



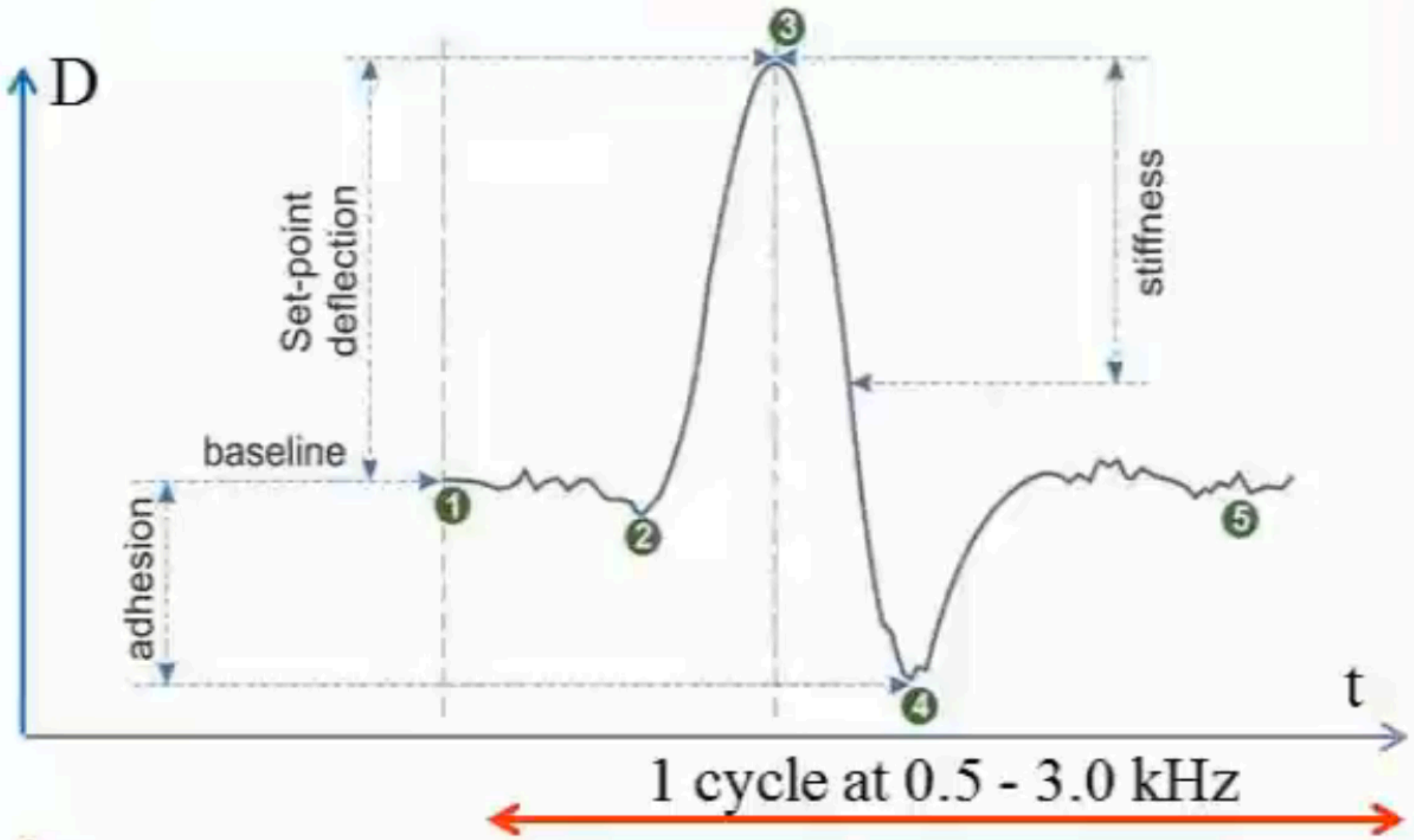
Predecessors

H. Becker, et al "Stylus profiler featuring an oscillating probe" US Patent 2728222, 1955.

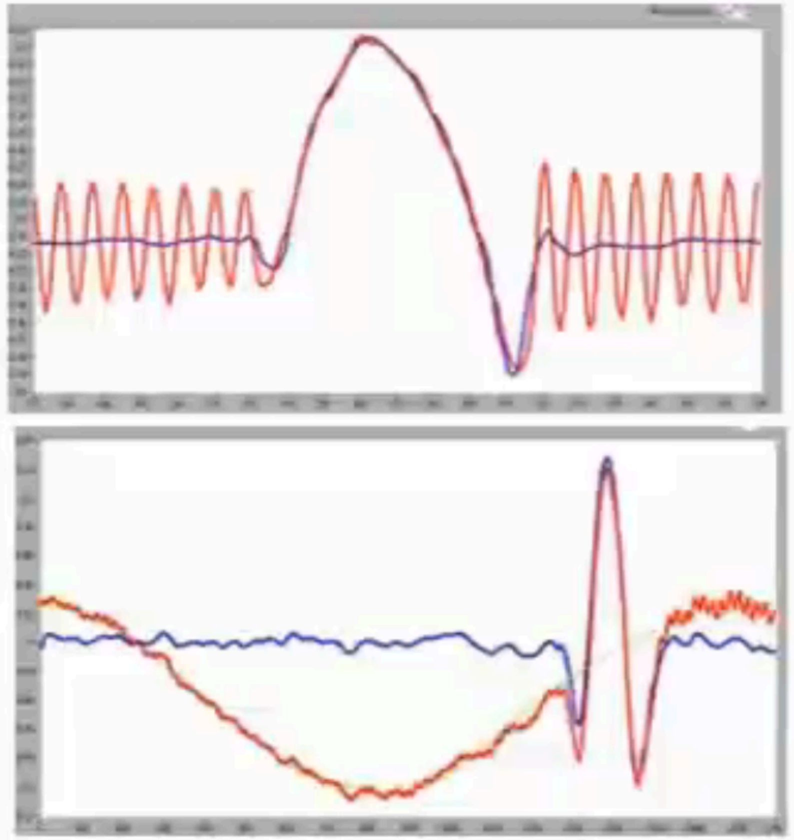
V. Elings, & J. Gurley "Jumping probe microscope" US Patent 5,229,606, 1993.

Pulsed Force (Witec), Jumping Mode (NanoTech), Peak Force (Bruker), Anasys

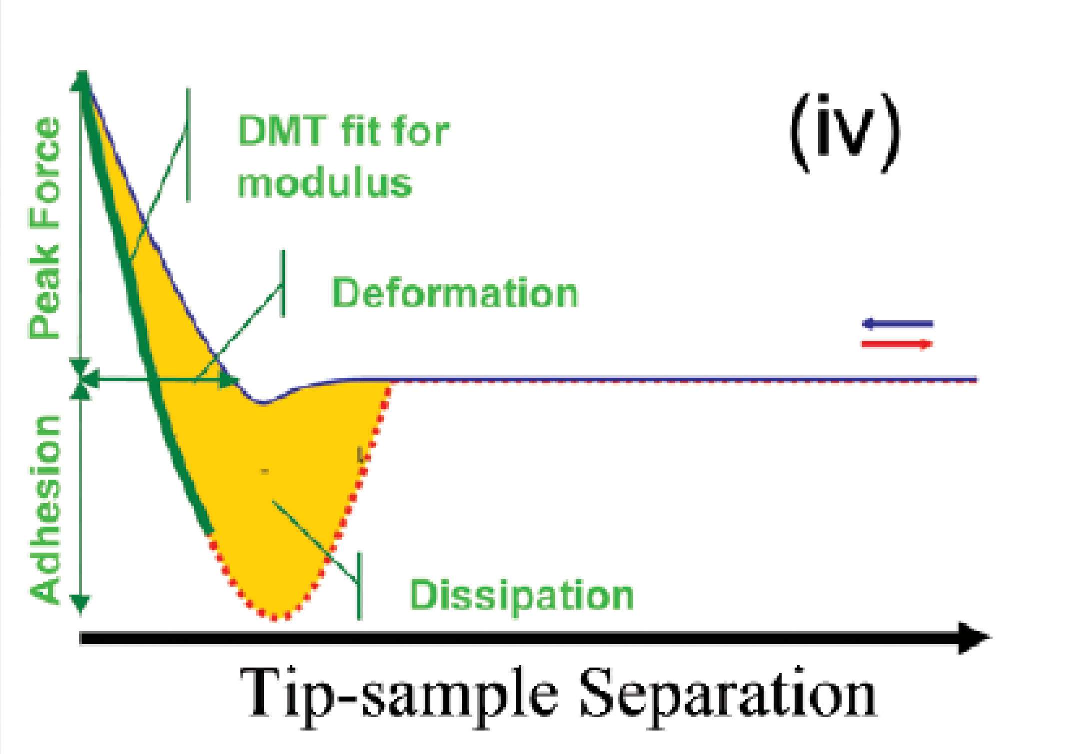
Temporal Deflection Plot – The Bank of the Local Properties!

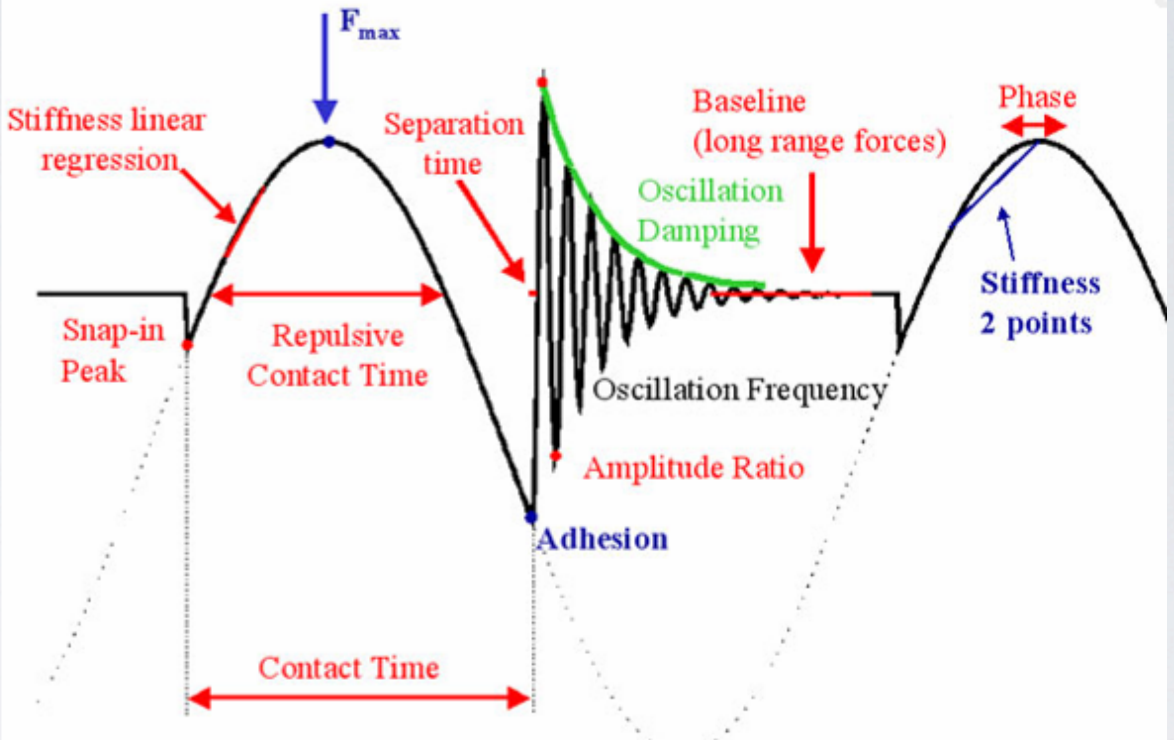


Real-time Wavelet Filtering



Свойства материалов, получаемые из силовой кривой

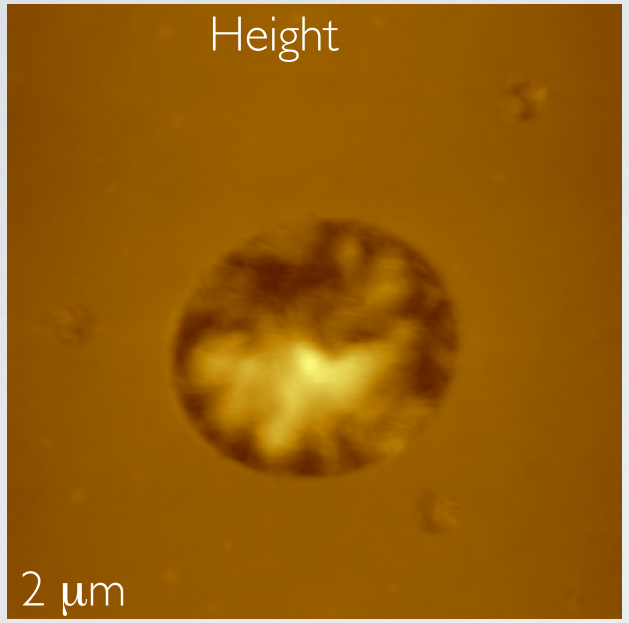




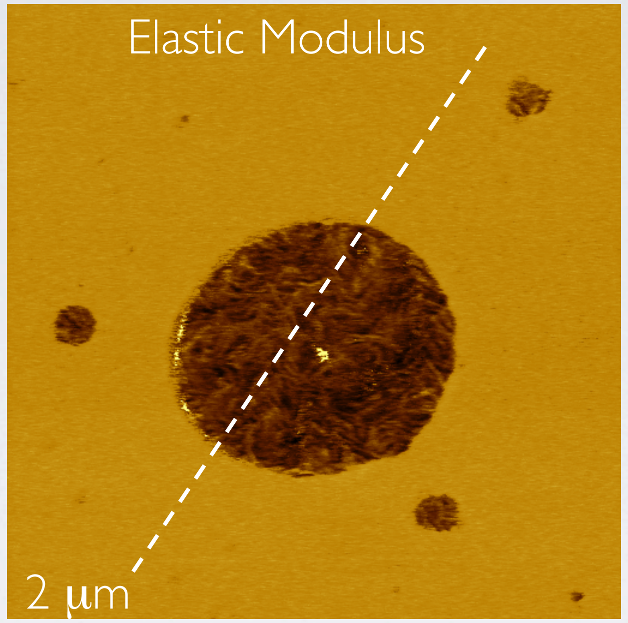
Из каждой силовой кривой вычисляются следующие значения:
- Высота рельефа при заданной силе прижима (Set Point)
- Модуль упругости
- Сила адгезии
- Деформация (твердость)
- Энергия диссипации
- Добротность затухающих колебаний

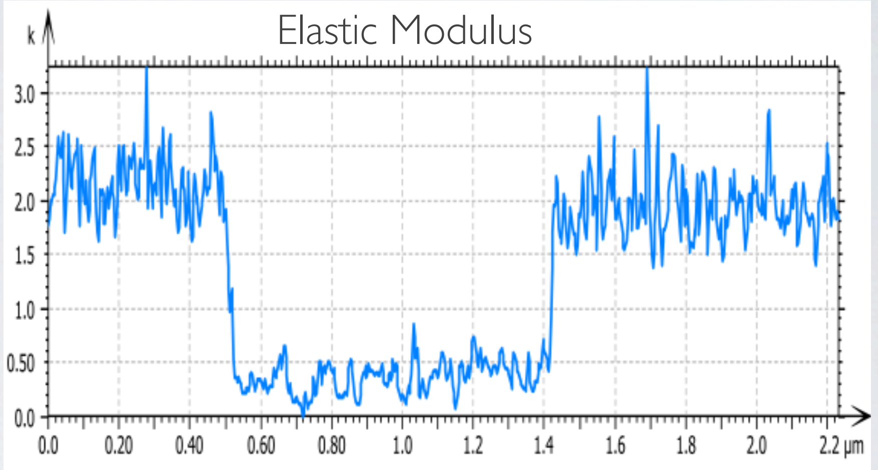
Probing of Local Mechanical Properties

Quantitative Nanomechanical Measurement s in Hybrid Mode



PS/HDPE



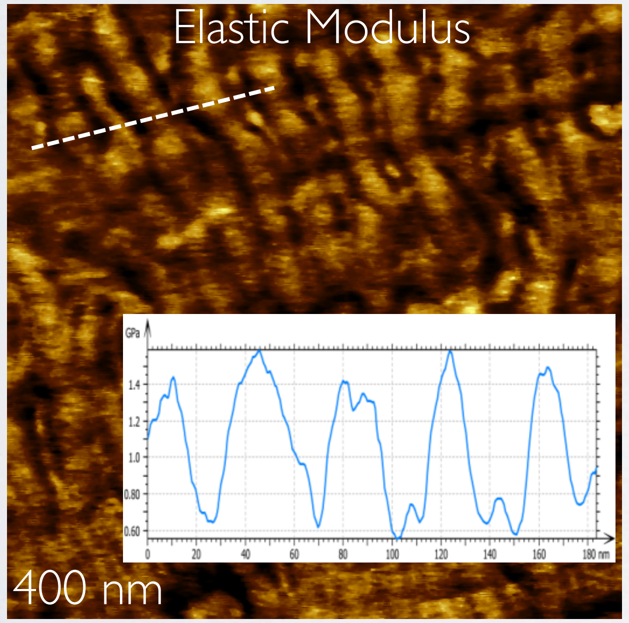


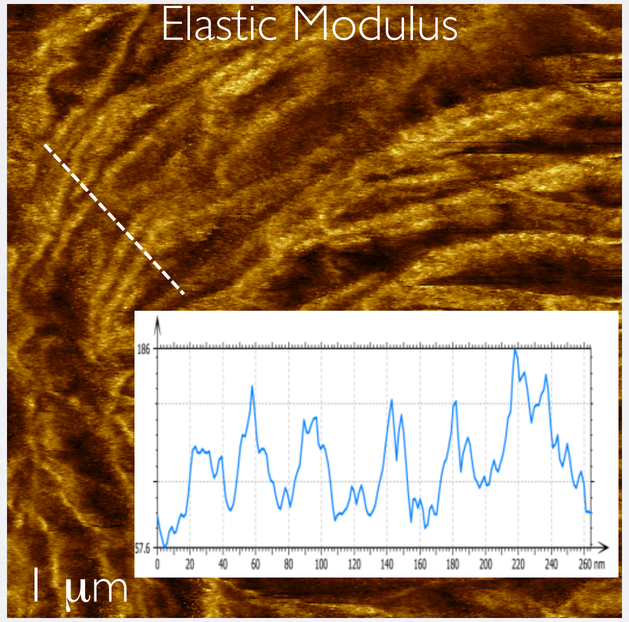
LLDPE

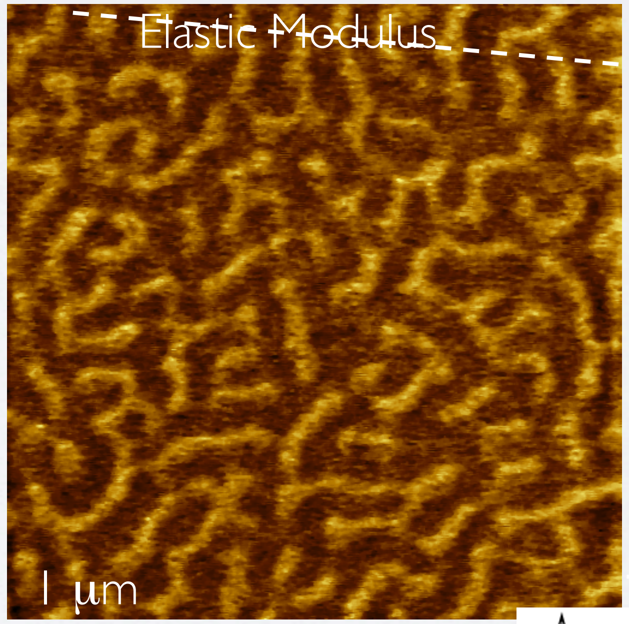
High Density Polyethylene

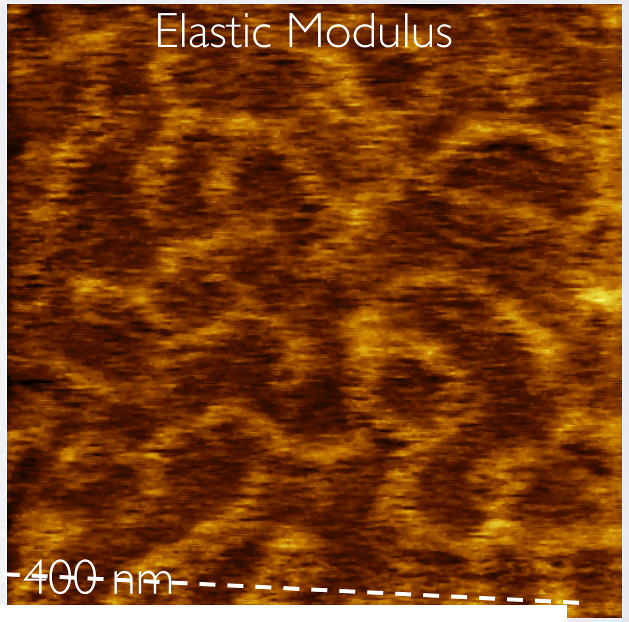
Low Density Polyethylene

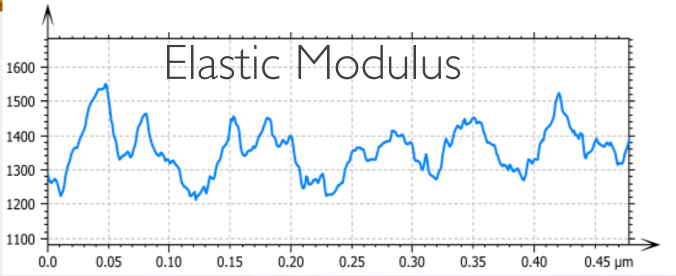
PS-b-PMMA



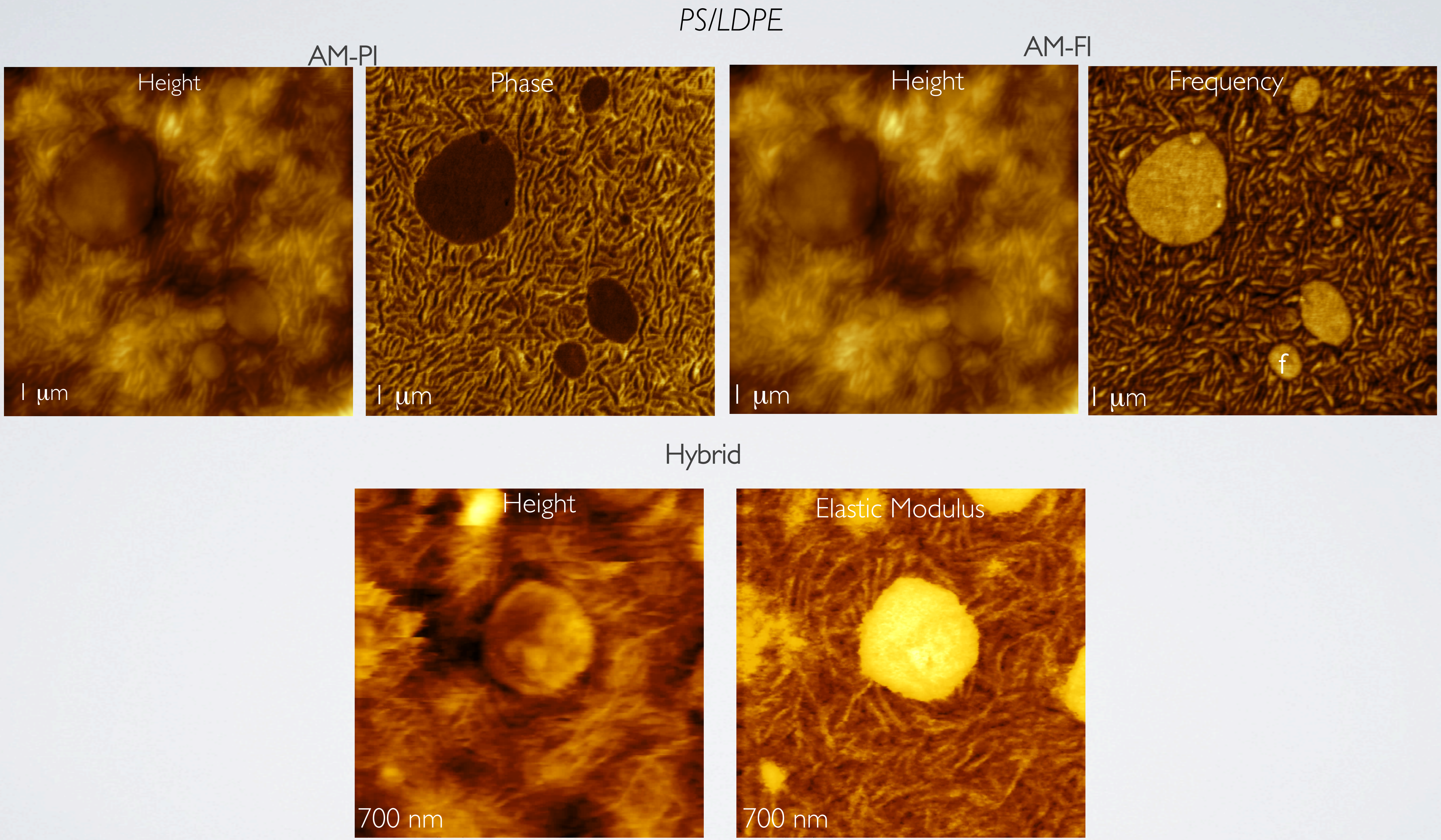




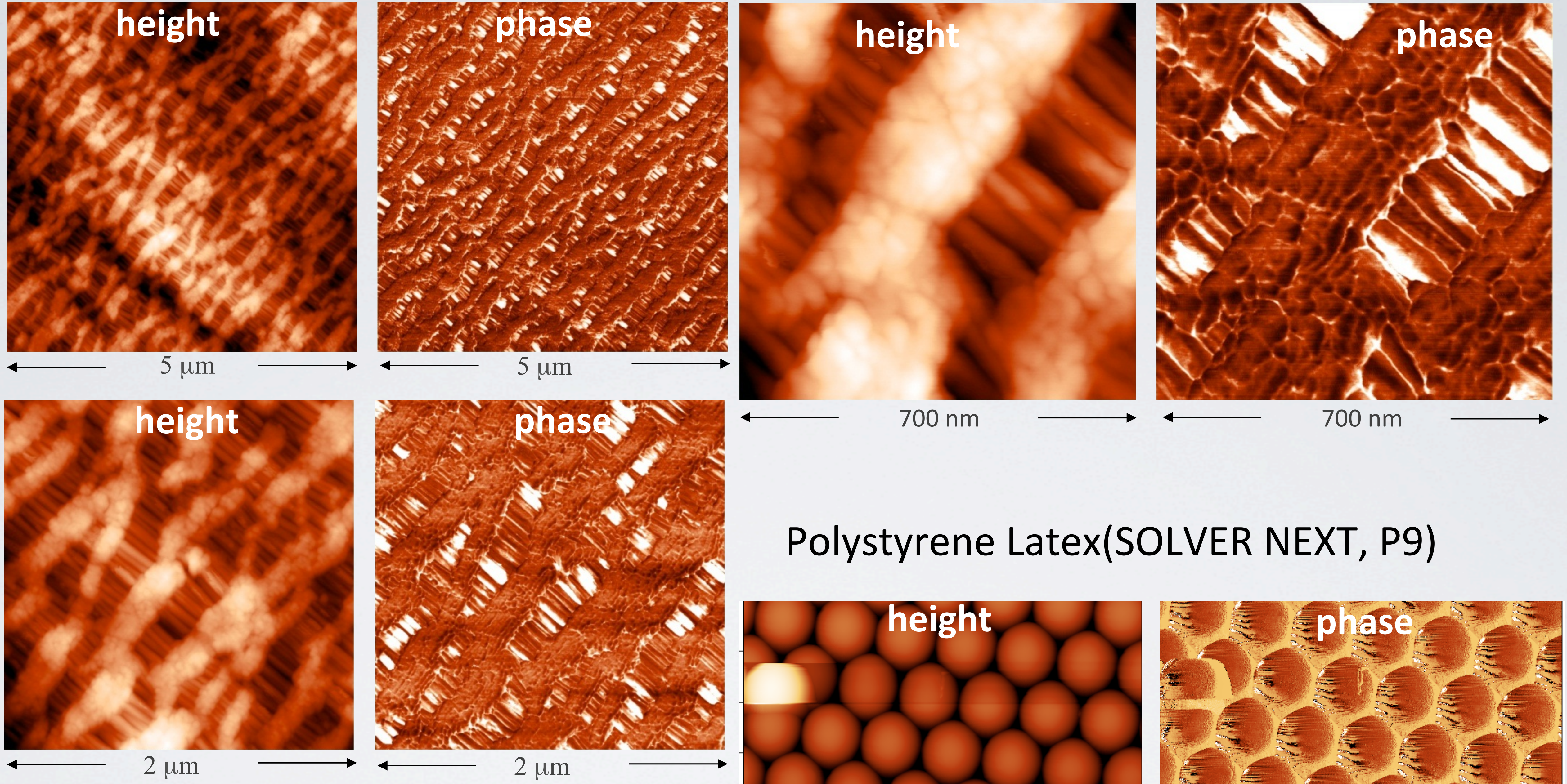




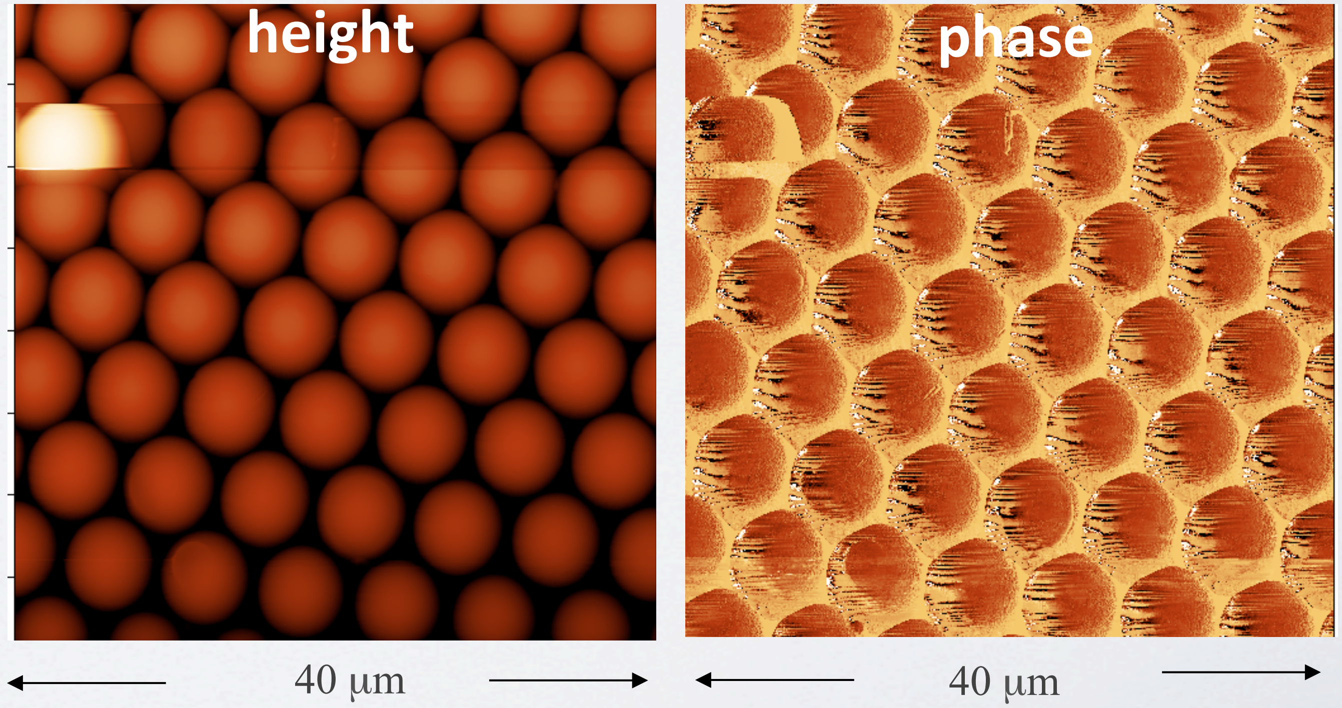
Compositional Imaging of Heterogeneous Materials



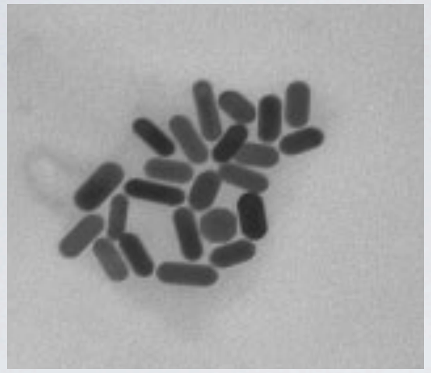
Visualization of Microporous Polypropylene Membrane (Celgard™) (NTEGRA, P8)

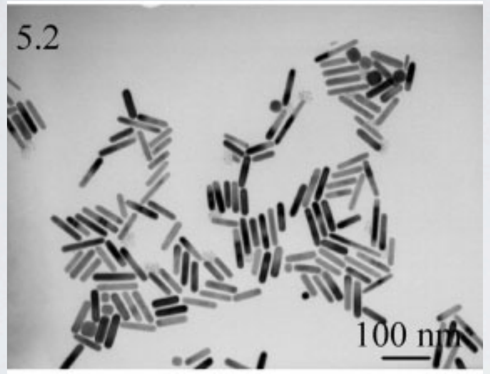


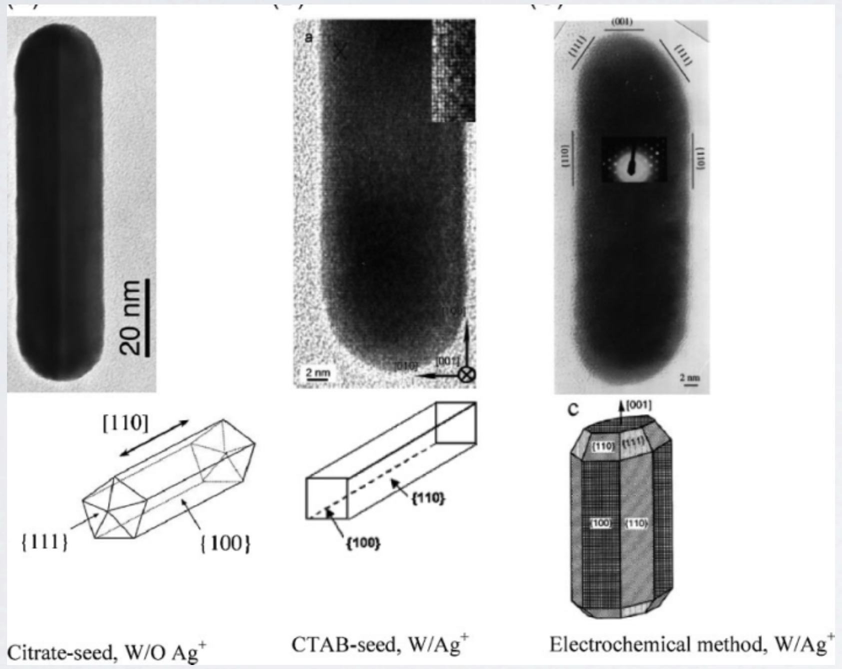
Polystyrene Latex(SOLVER NEXT, P9)

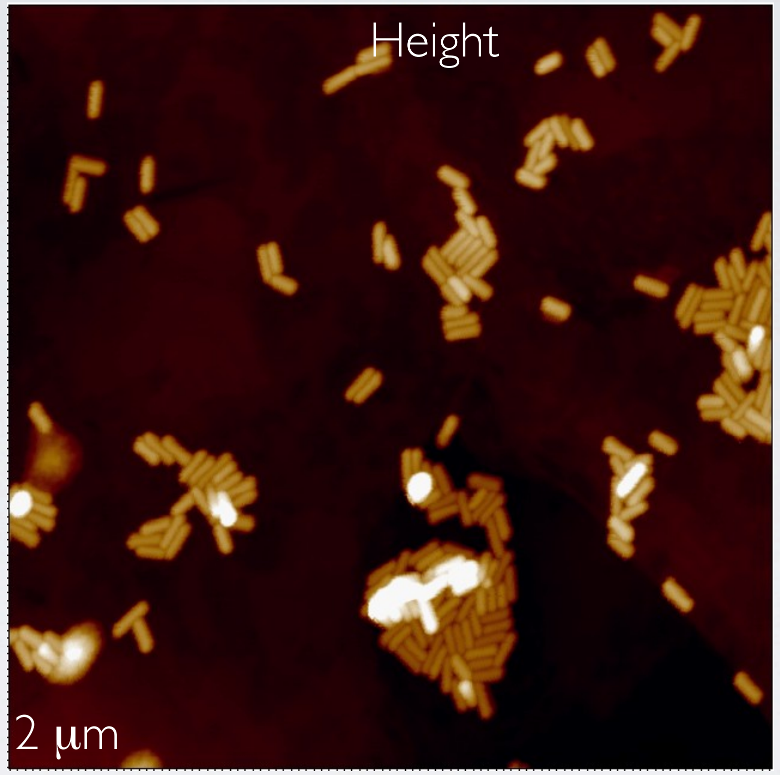


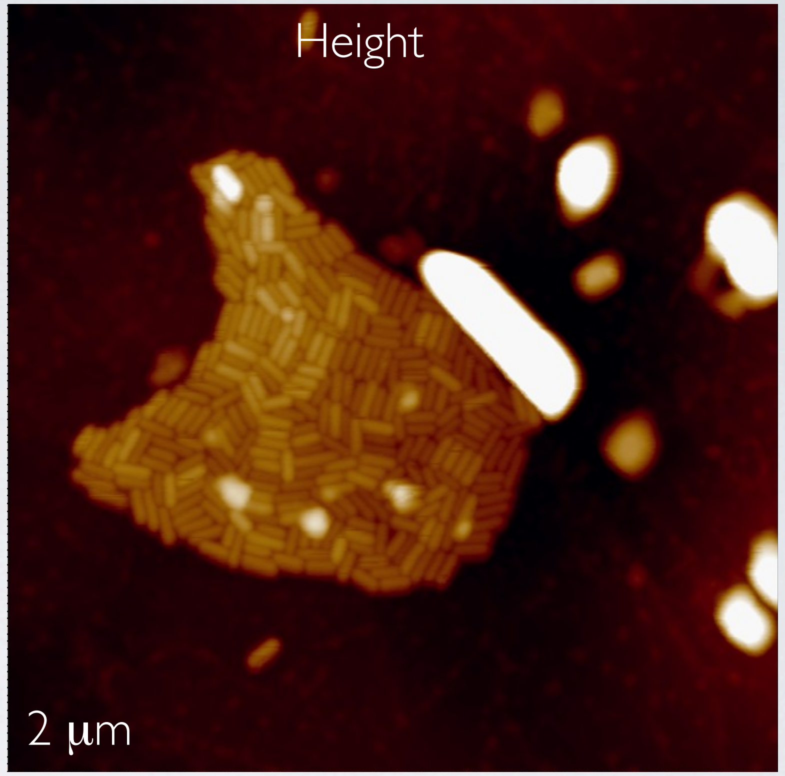
Case 3: Exploring Au Nanorods

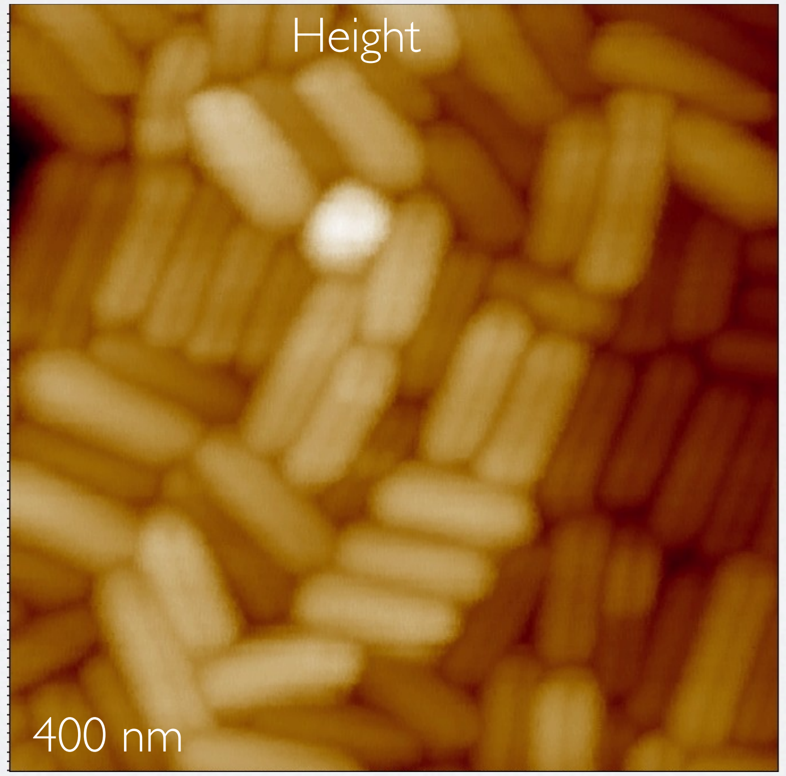


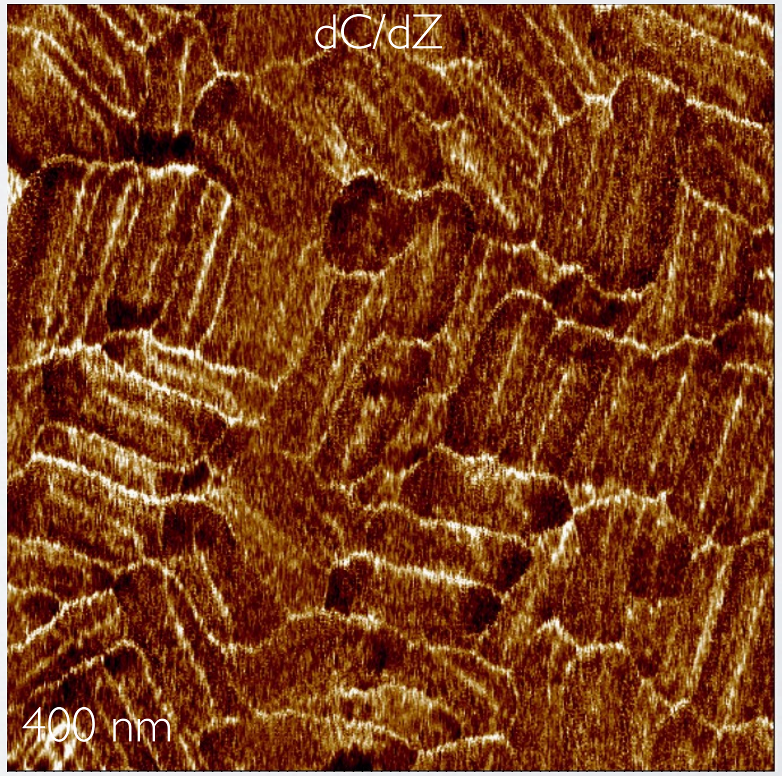






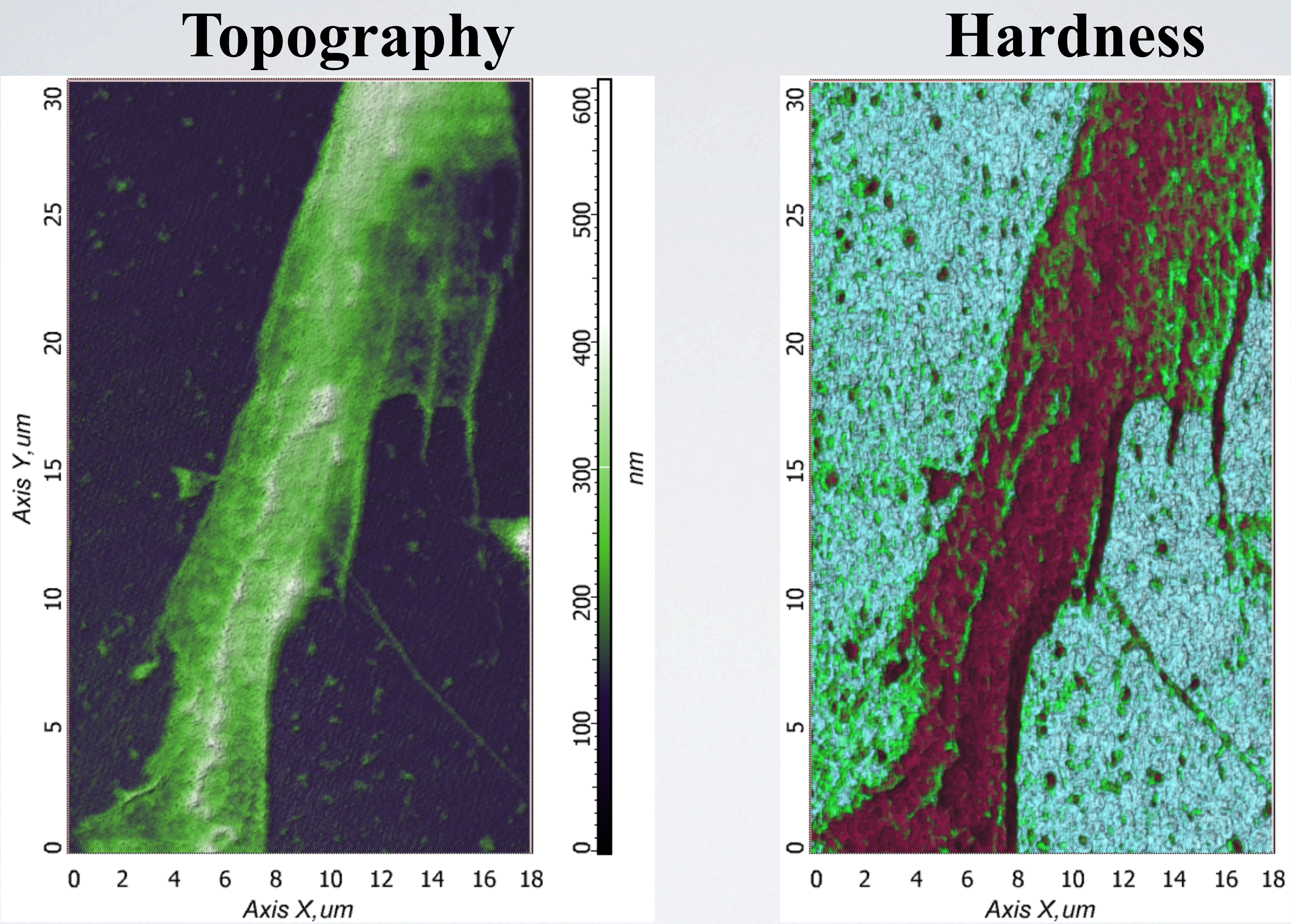






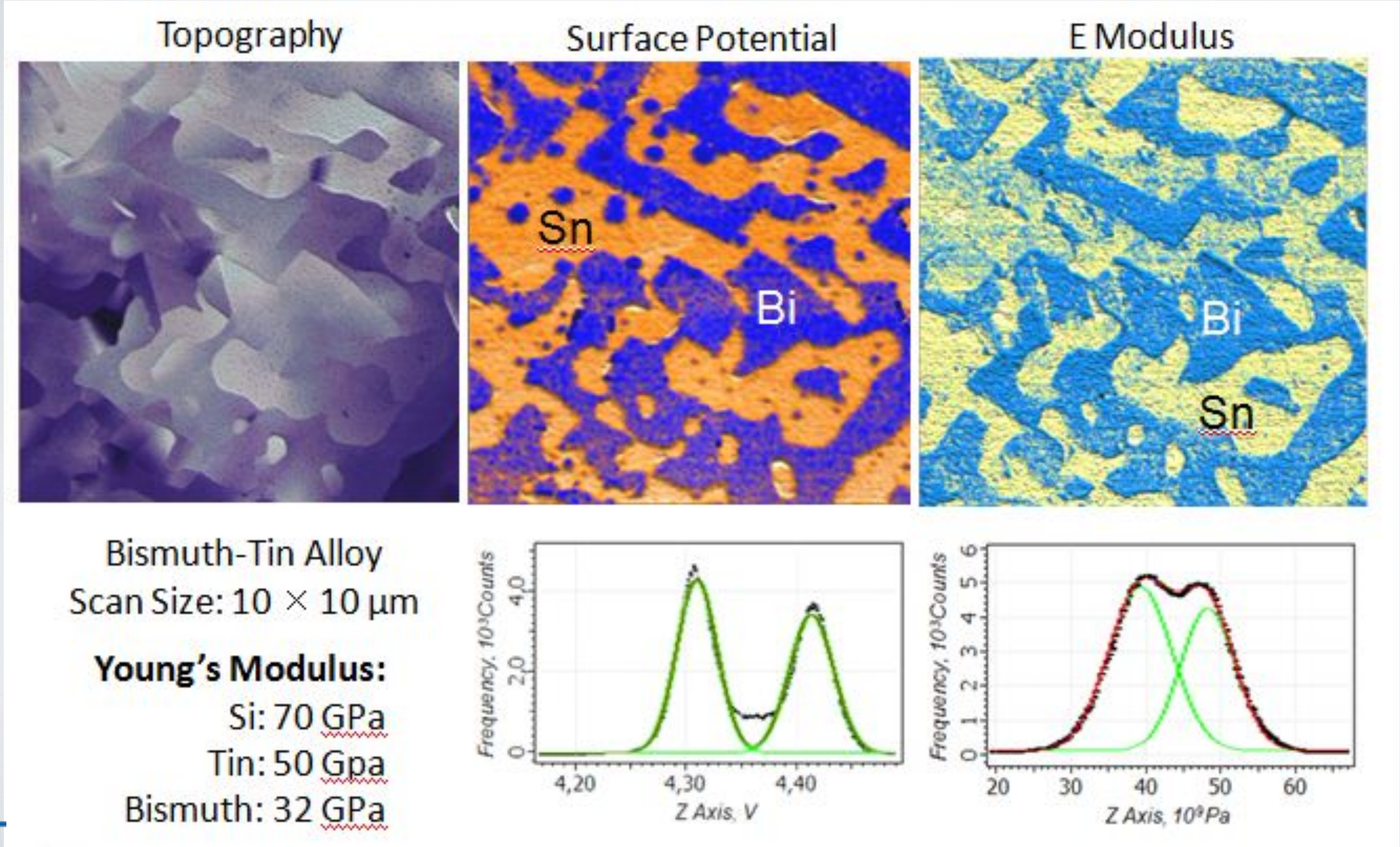
Ongoing cooperation with Prof. Nicholas Kotov, Dr. J.-Y. Kim (Uni Michigan)

LIVING stem cells



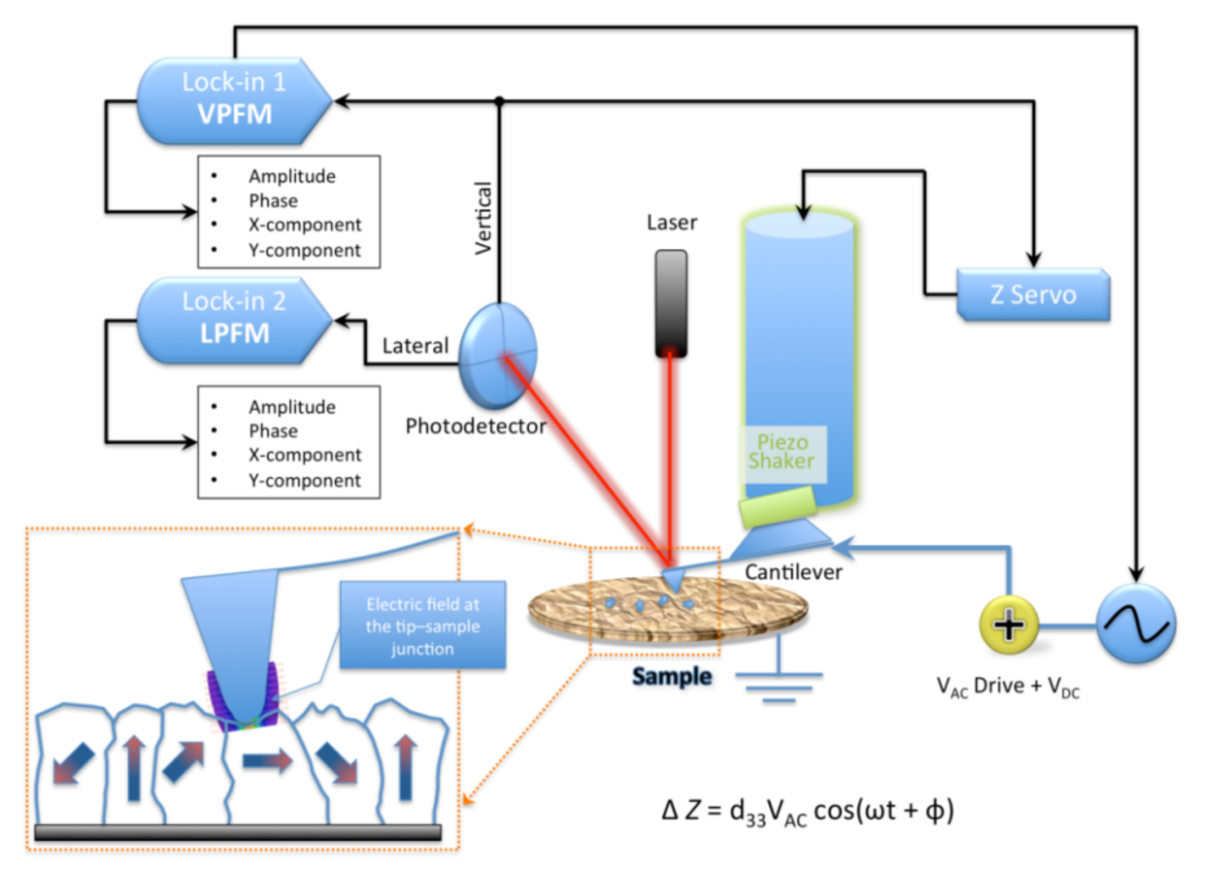
An array of data from 180x300 power curves allows you to build a stiffness map of the sample (on the right) and an image of its relief (on the left)

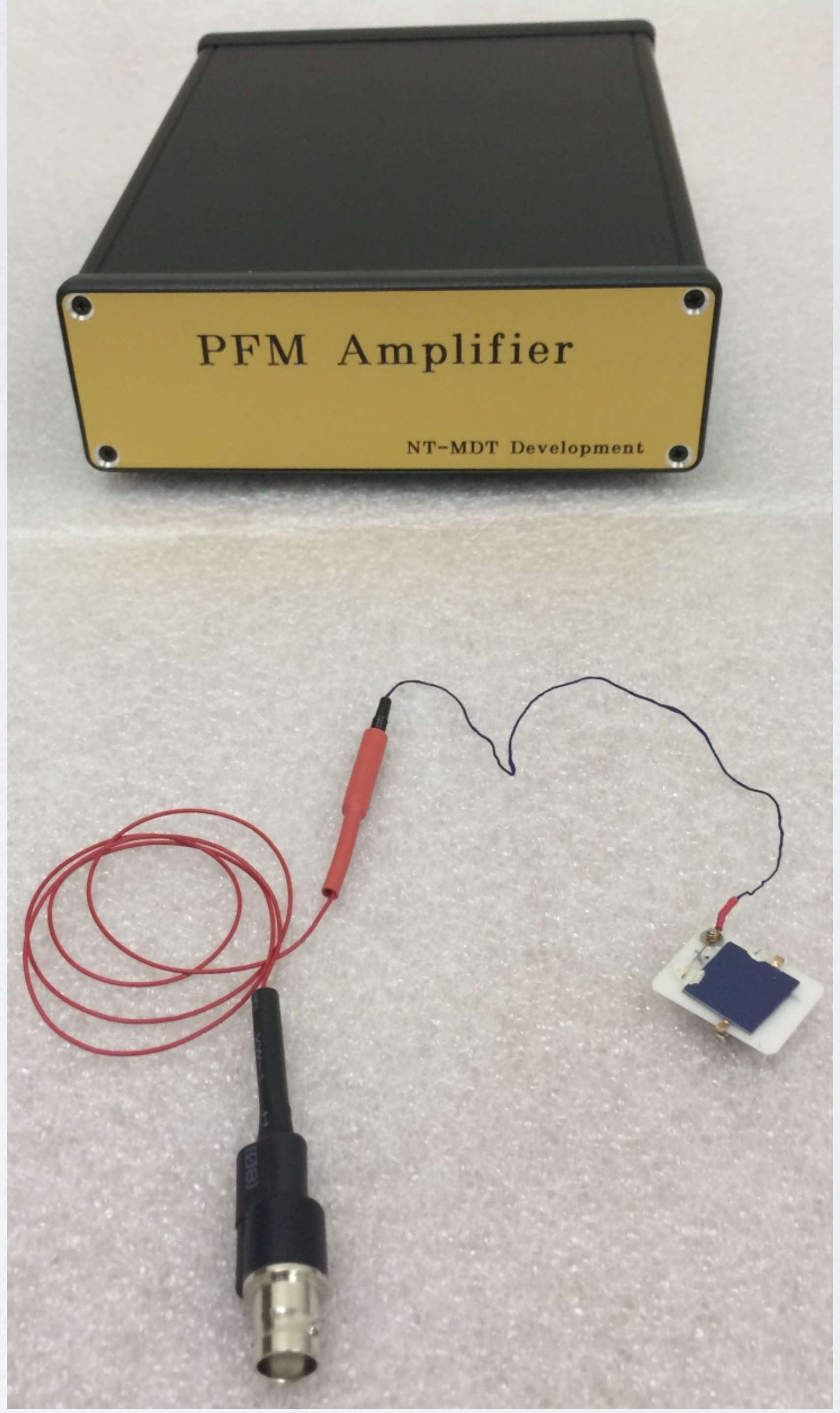
HybriD Mode: composite materials study



NT-MDT Spectrum Instruments

High-Voltage Piezoresponse Force Microscopy





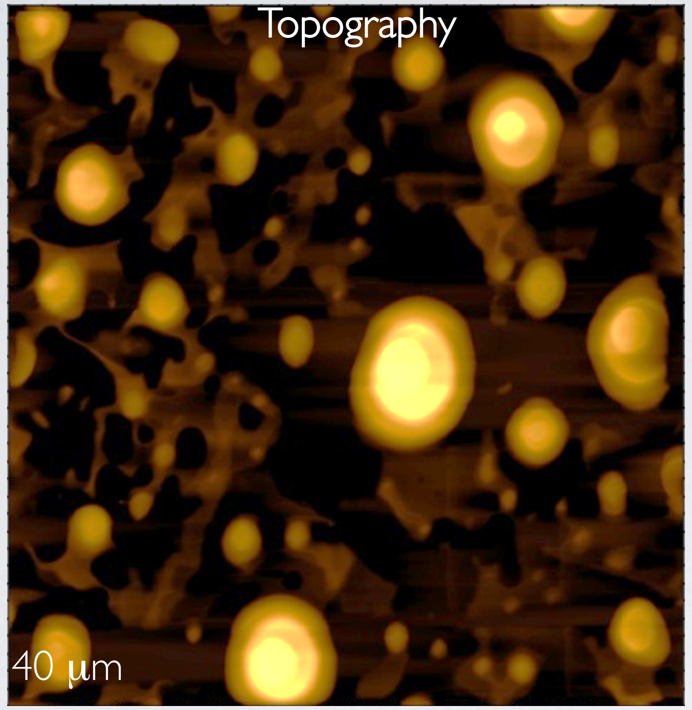
The key feature of PFM applications is the contamination free detection of the small amplitude and phase changes of a sample piezoresponse induced by applying the external voltage. In our microscope the only way to achieve this is by applying the voltage excitation to the sample by a separate cable with the probe being grounded. Additionally, a low-cost PFM amplifier was designed and it enables the excitation voltages up to 100V.
Broadband (up to 4 MHz) electric modes.

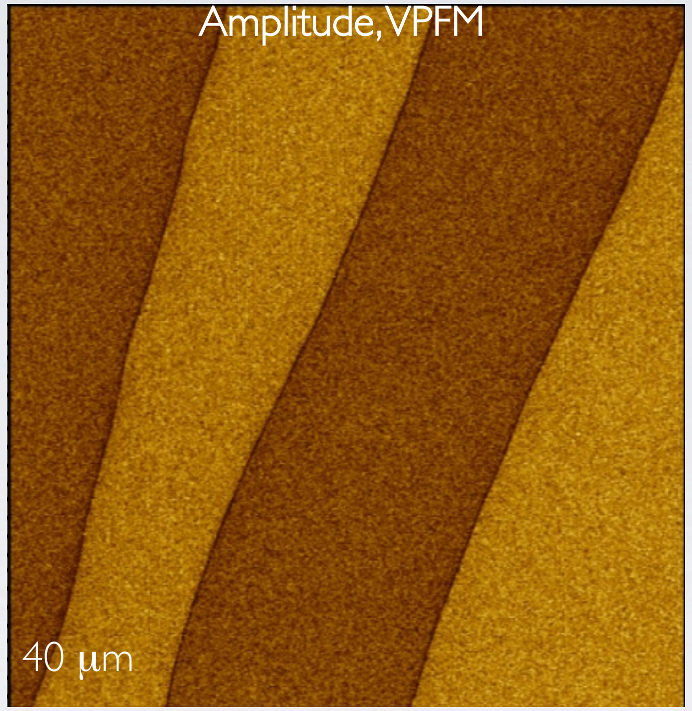
PFM domain structure image on Three Glycine Sulfate

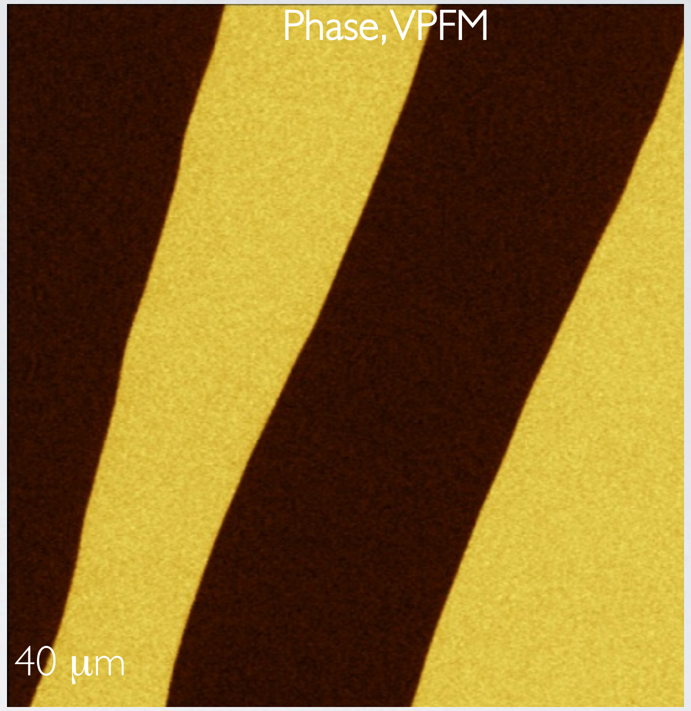
Triglycine sulfate
TGS, 30C

Curie Temper.
48.85C

PFM: 3V@70 kHz



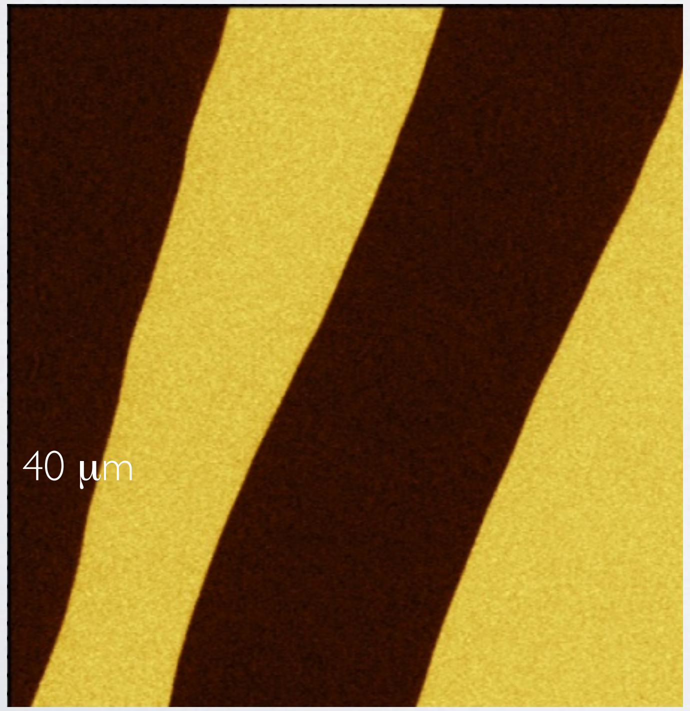


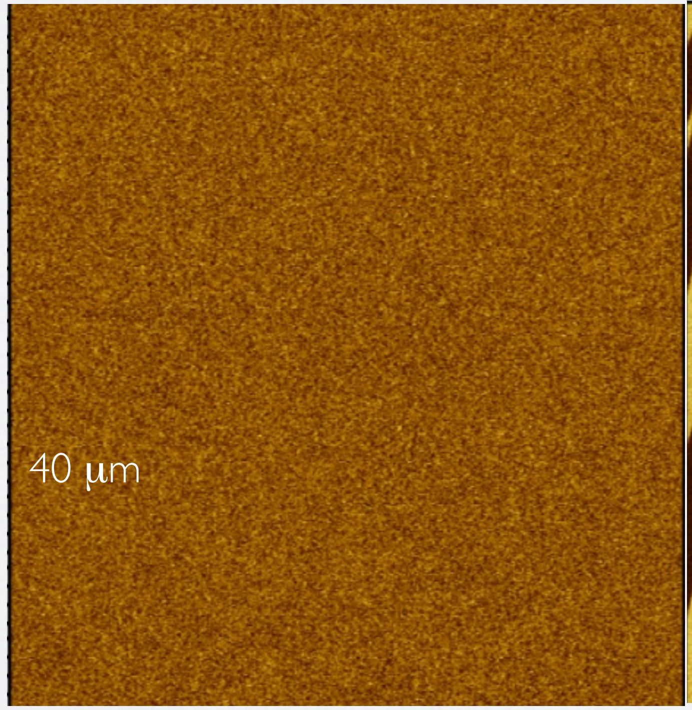


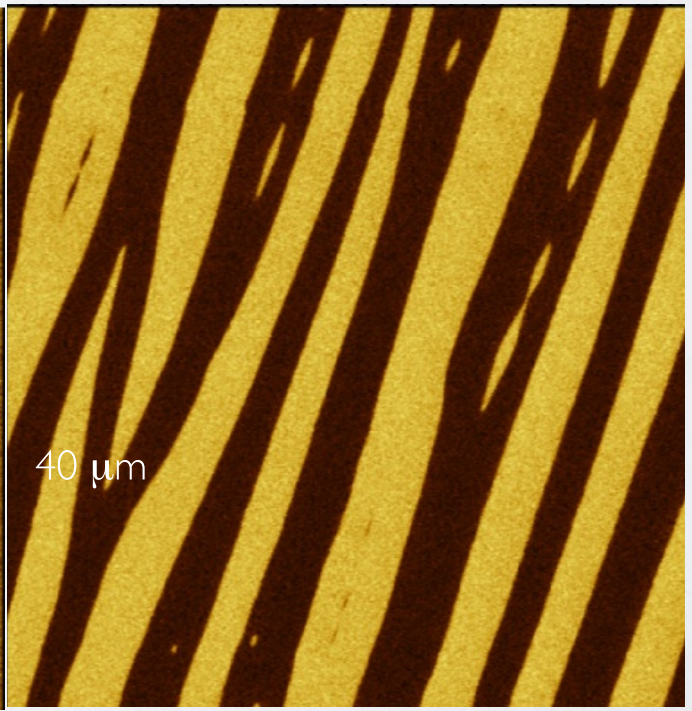
30C
Phase
→
60C
Phase
→
45C
Phase

Variable Temperature Studies

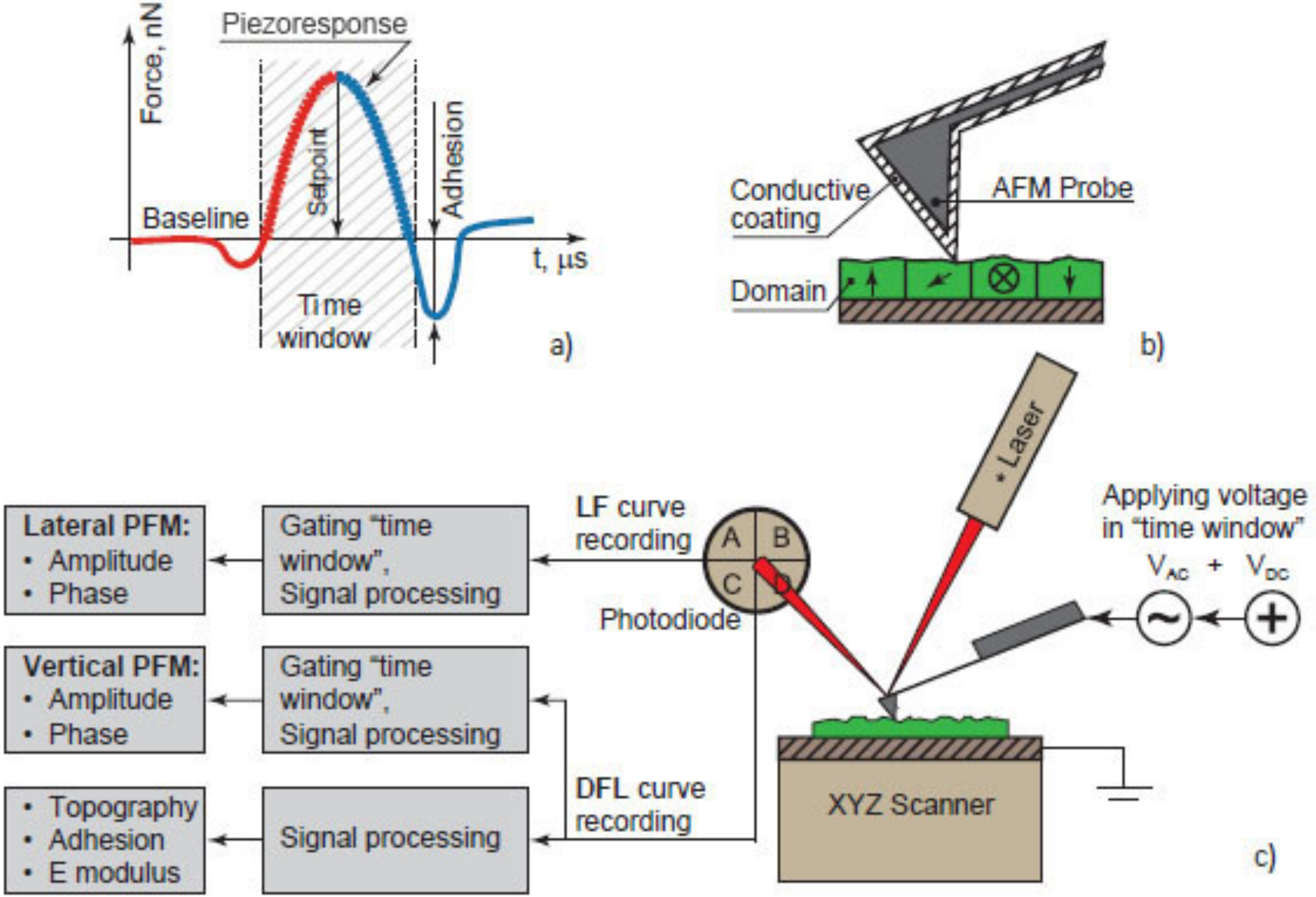
Sample courtesy
Dr. R. Gainutdinov
(Moscow)







NT-MDT Spectrum Instruments

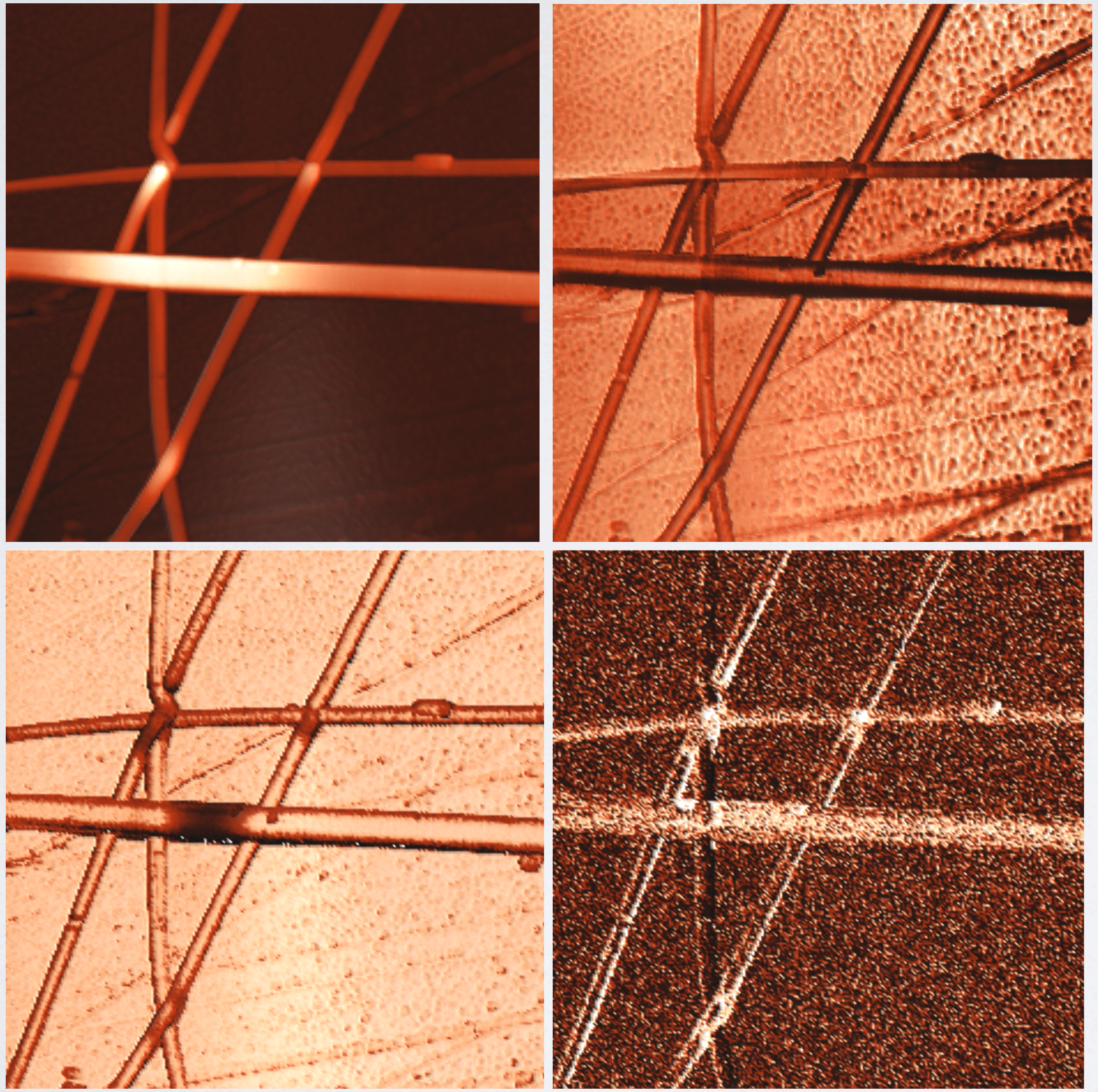


Piezoresponse
Force, nN
Setpoint
Adhesion
Baseline
t, µs
Time window
a)
Conductive coating
AFM Probe
Domain
b)
Laser
Applying voltage in "time window"
V_{AC} + V_{DC}
Lateral PFM:
• Amplitude
• Phase
Gating "time window", Signal processing
LF curve recording
A B C D
Photodiode
Vertical PFM:
• Amplitude
• Phase
Gating "time window", Signal processing
• Topography
• Adhesion
• E modulus
Signal processing
DFL curve recording
XYZ Scanner
c)

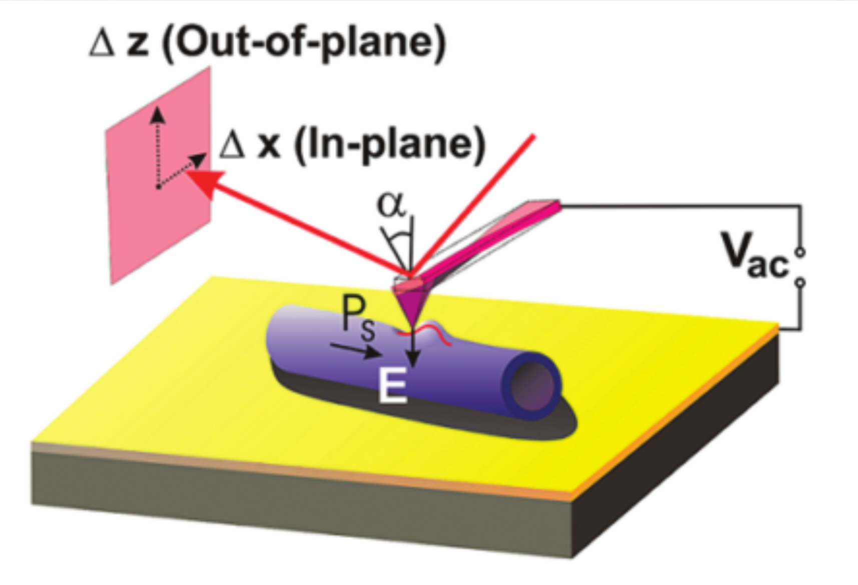
Controller HybriD 2.0

HybriD PFM

Topography Adhesion



Elasticity PFM Phase (LF)



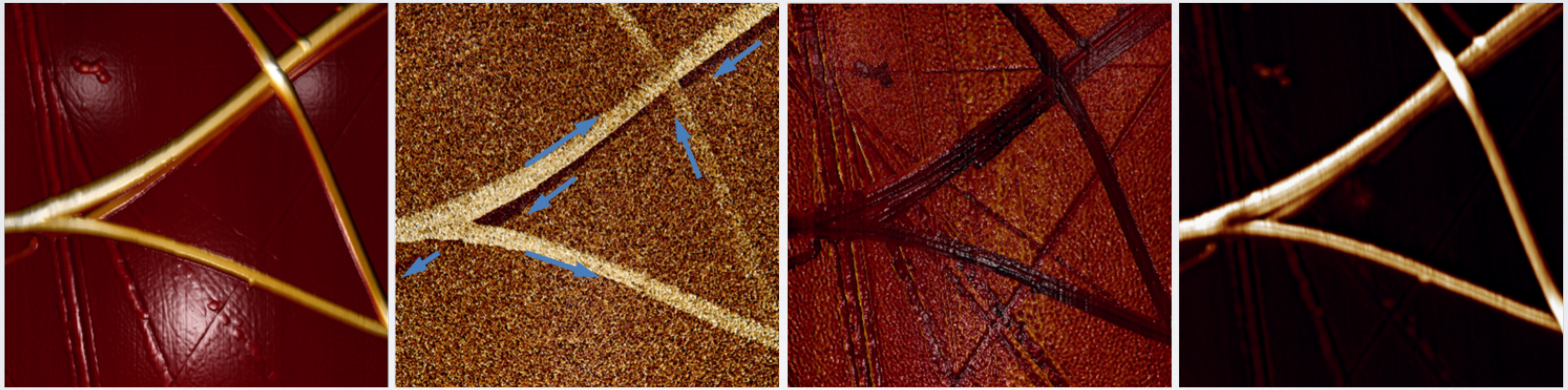
HD PFM контрасты пептидных нанотрубок на дифенилаланине

Sample courtesy: A.L. Kholkin, University of Aveiro. Размер скана 5×5 мкм.

HybriD PFM: The results of measurements

❖Retraction of the probe at each point allows measurement of the piezoelectric response of fragile and poorly fixed samples by minimizing the lateral interaction of the probe with the surface
❖The possibility of simultaneous carrying out of resonance electrostatic measurements makes it possible to analyze images more comprehensively.

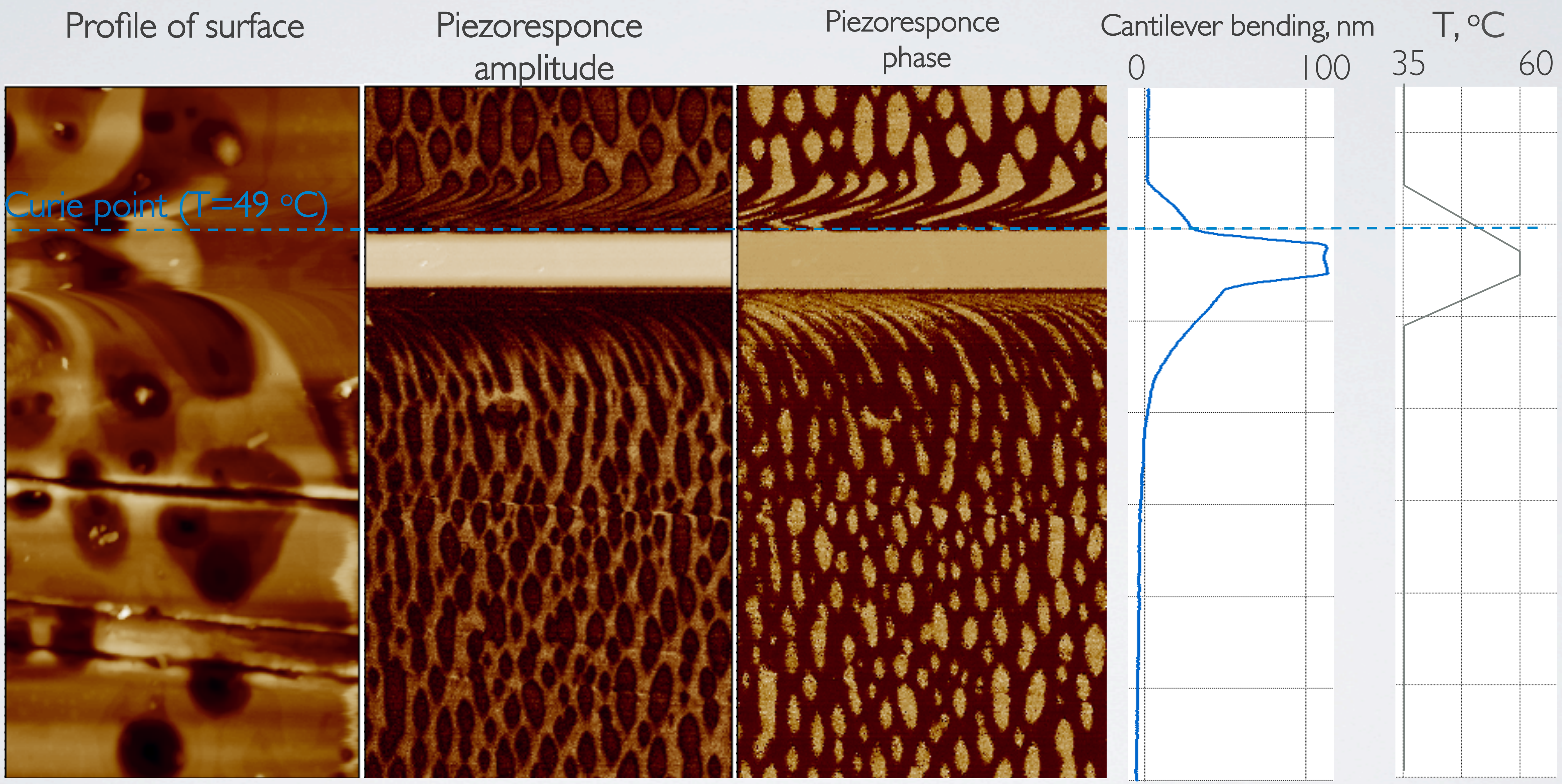
Topography of sample | The Phase of lateral piezoresponce | Adhesion force | The dielectric constant



Peptide nanotubes of diphenilalanine. 8×8 mkm.
Arrows indicate the direction of polarization of the tubes.
The sample prepared by: Dr. A.L. Kholkin, University of Aveiro, Portugal

HybriD PFM: The results of measurements

❖Accounting for the drift of the cantilever beam bend at each scan point Allows correct measurements of the piezoelectric response at a sample temperature gradient



Triglycine sulfate crystal. 8 × 15 μm. The transition through the Curie point is demonstrated when the sample is heated from 35 °C to 60 °C during continuous scanning. Sample provided by R. Gainutdinov, IC RAS

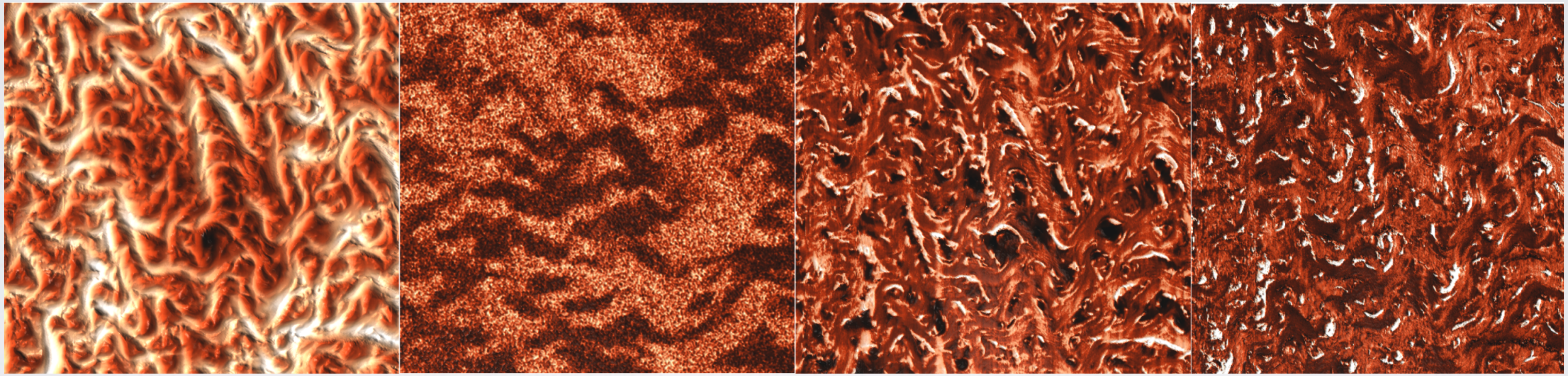
NT-MDT Spectrum Instruments

HybriD PFM: The results of measurements

❖Отвод зонда в каждой точке позволяет измерение пьезоотклика образцов с сильно развитым рельефом

❖Возможность одновременного анализа модуля упругости и силы адгезии зонд-образец позволяет получение более комплексной информации об образце

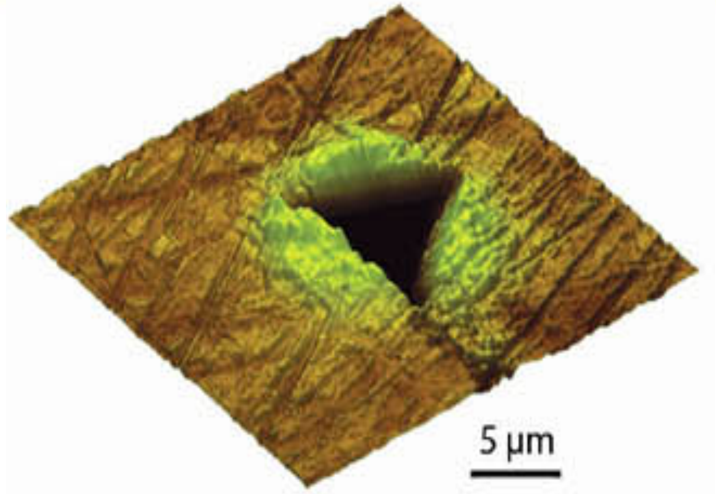
Рельеф поверхности	Фаза латерального пьезоотклика	Модуль Упругости	Сила адгезии зонд-образец



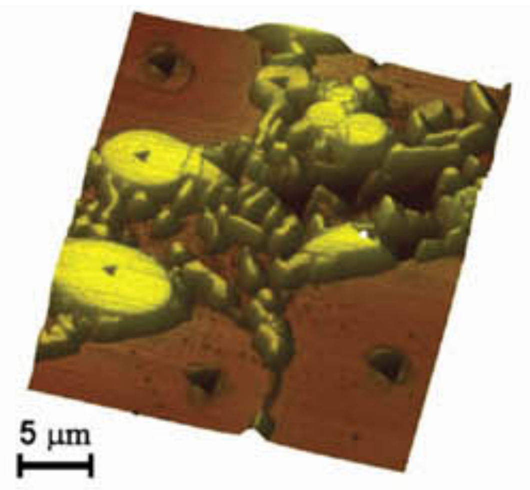
Матрица коллагена стромы сетчатки. 15×15 мкм, перепад высот 900 нм.
Образец предоставлен: M. Paukshto, Fibralign Corporation, USA

- ❖ Retraction of the probe at each point allows measurement of the piezoelectric response Samples with highly developed relief
- ❖ The possibility of simultaneous analysis of the modulus of elasticity and the strength of the probe-sample adhesion allows obtaining more complex information about the sample

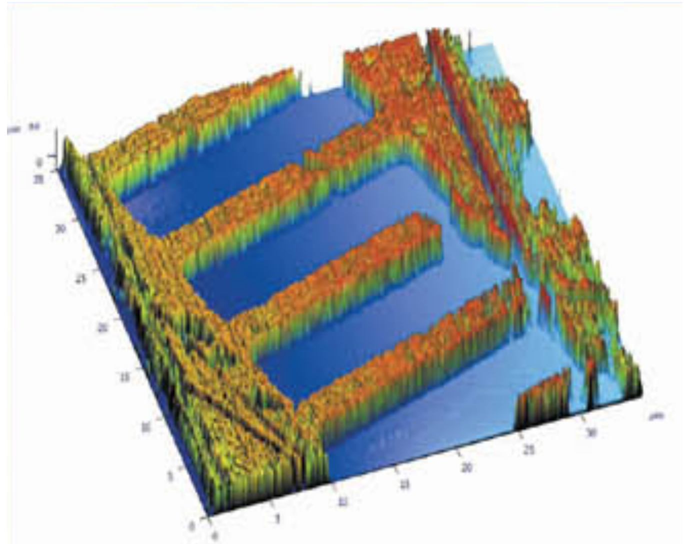
Nanointendation



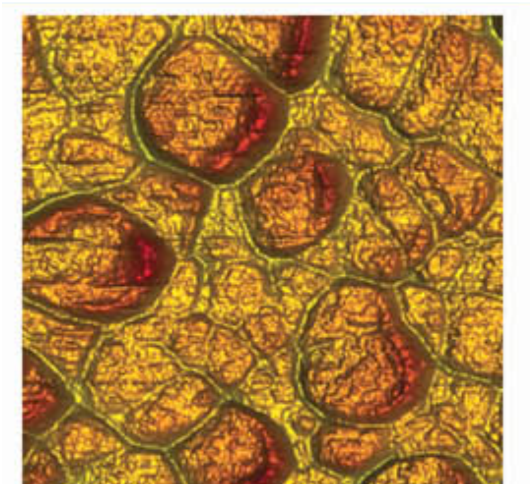
Indentation of the metallic material surface. Imagine option is necessary for studying the pile-ups surrounding the residual imprint



Topography of aluminium alloy D16 after indentation. The same probe is used for topography scanning and following indentation of the chosen areas



Conductivity map of the golden film on the silicon substrate

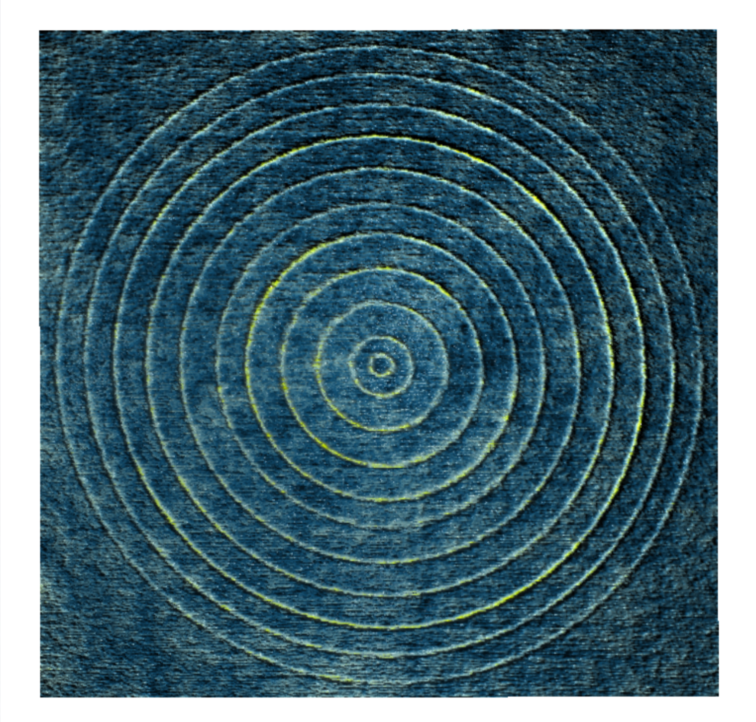


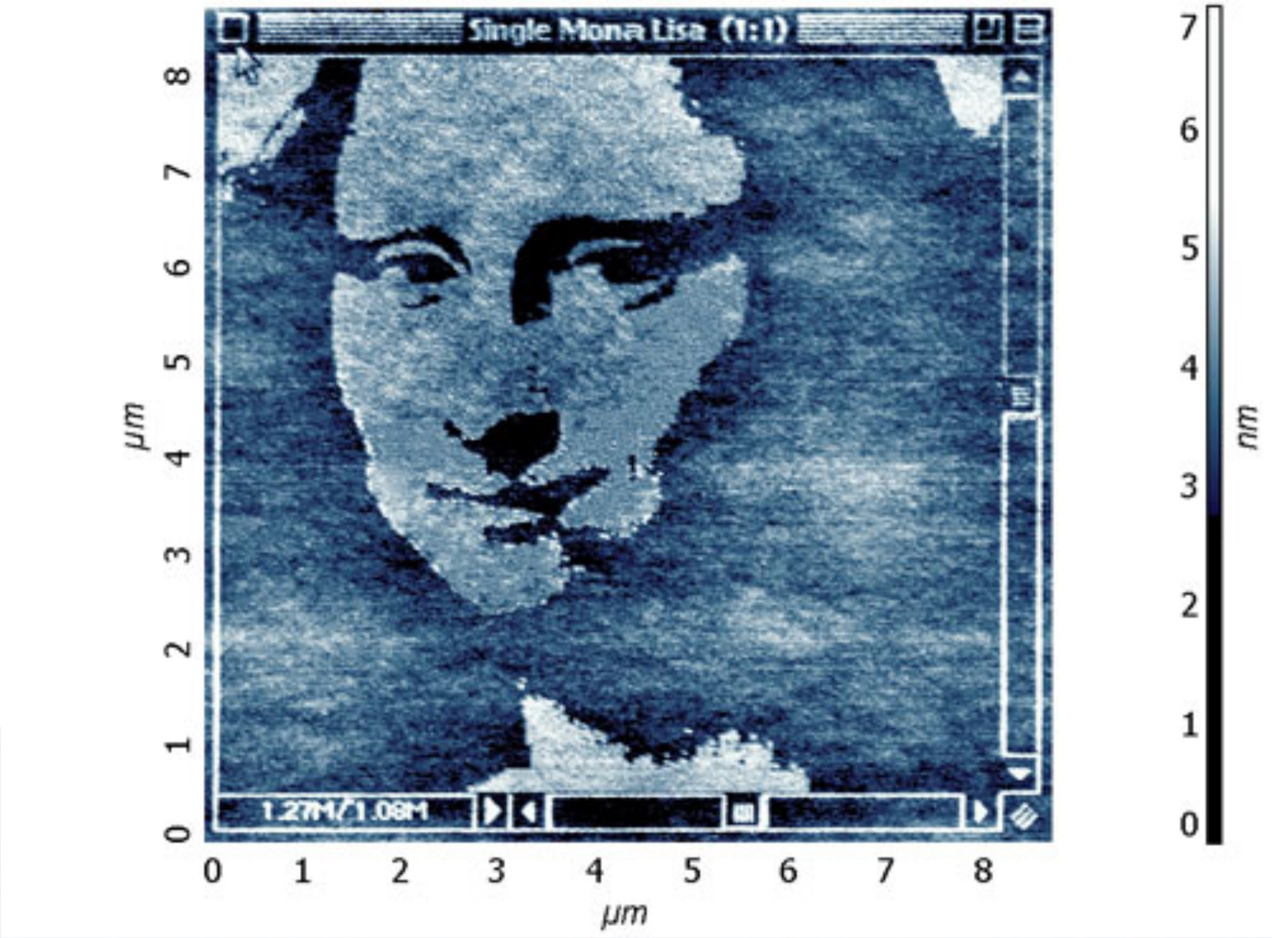
Elastic modulus map of the polycrystalline SIC

AFM Lithography

Local oxidation of Ti, TiO_2 on Ti

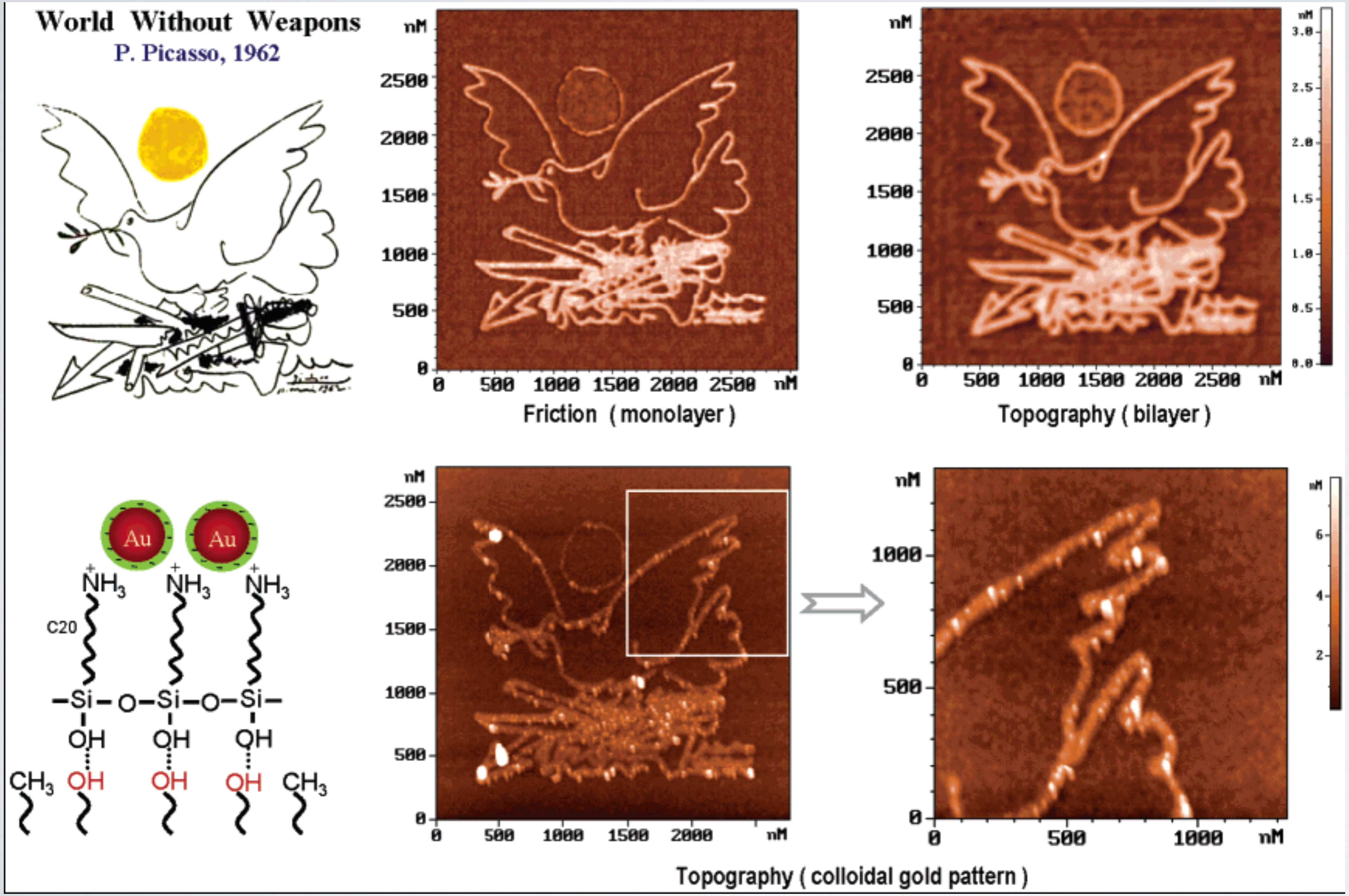
Current Lithography, 512*512 points, Ti oxide on Ti, NRAGRA System with capacitance 3-D positions sensors





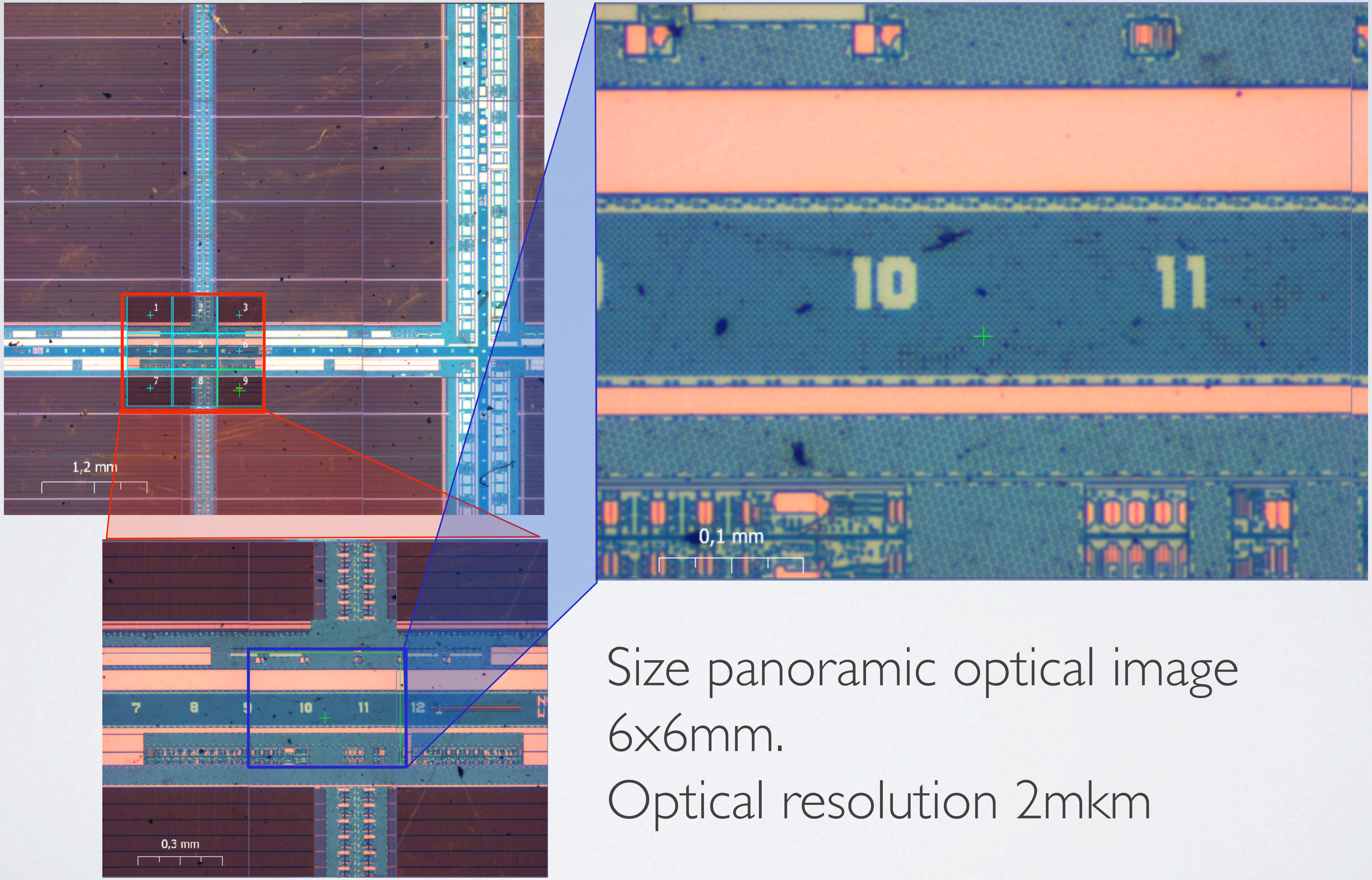
NT-MDT Spectrum Instruments

SPM constructive Lithography (Au_{55} selective adsorbtion)



Maoz, R., Frydman, E., Cohen, S., Sagiv, J. - J. Adv. Mater. 2000, 12, 725 – 731.

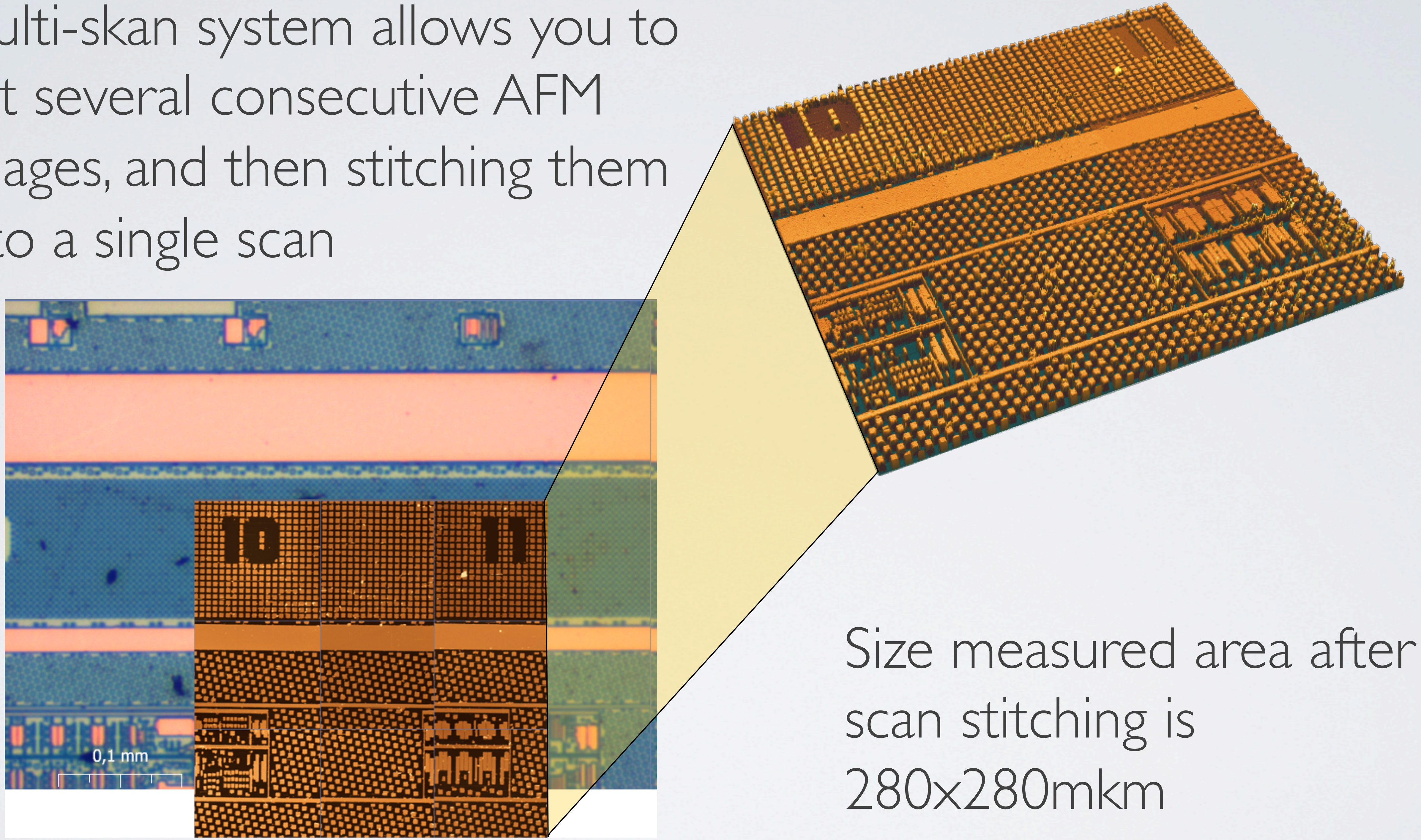
Multi-scan



Size panoramic optical image 6x6mm.
Optical resolution 2mkm

Multi-scan

Multi-skan system allows you to get several consecutive AFM images, and then stitching them into a single scan

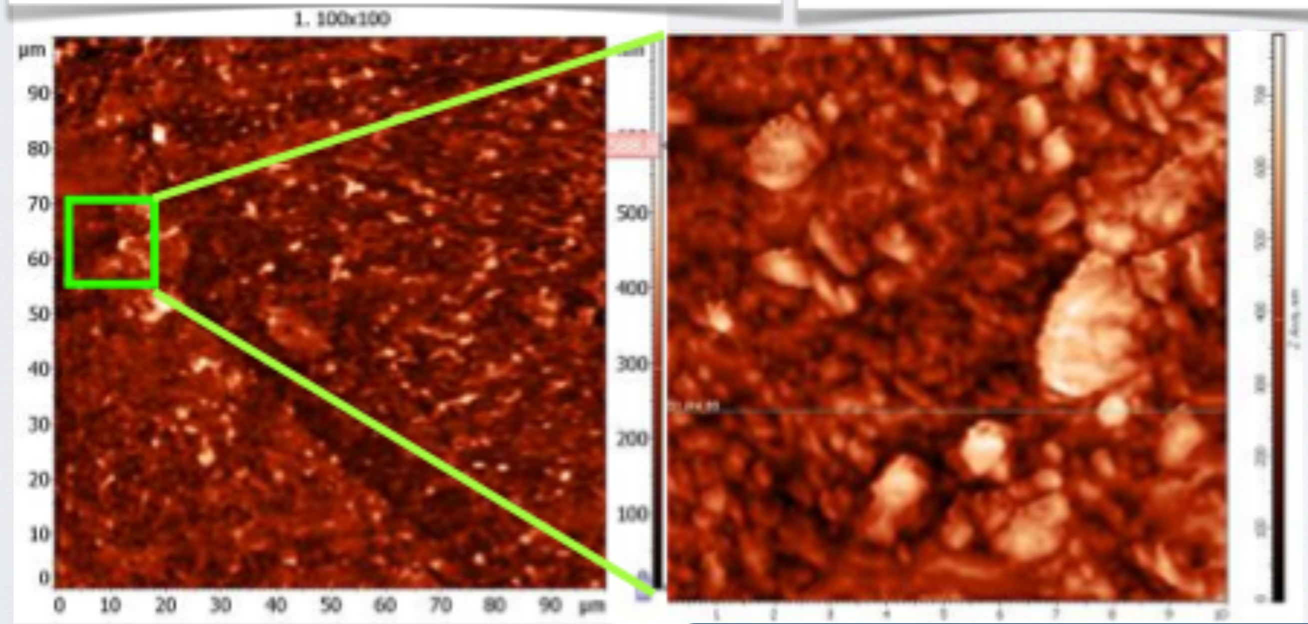


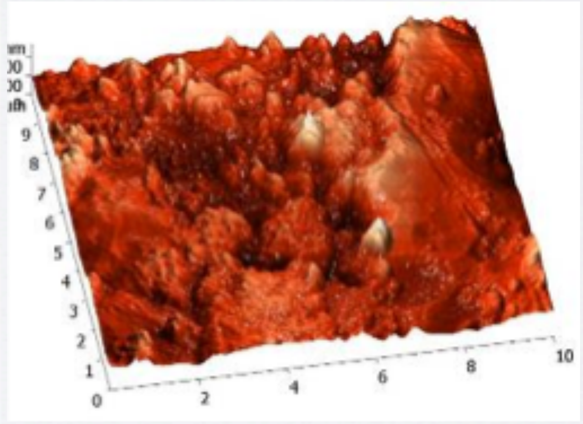
Size measured area after scan stitching is 280x280mkm

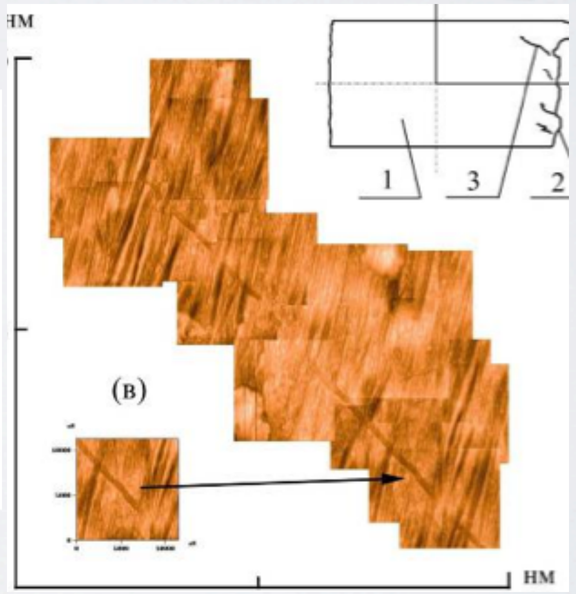
SOLPER-PIPE

Defectoscope based on AFM

- Non destructive testing
- Works in any position
- Motorized X, Y stepper
- High-resolution optics

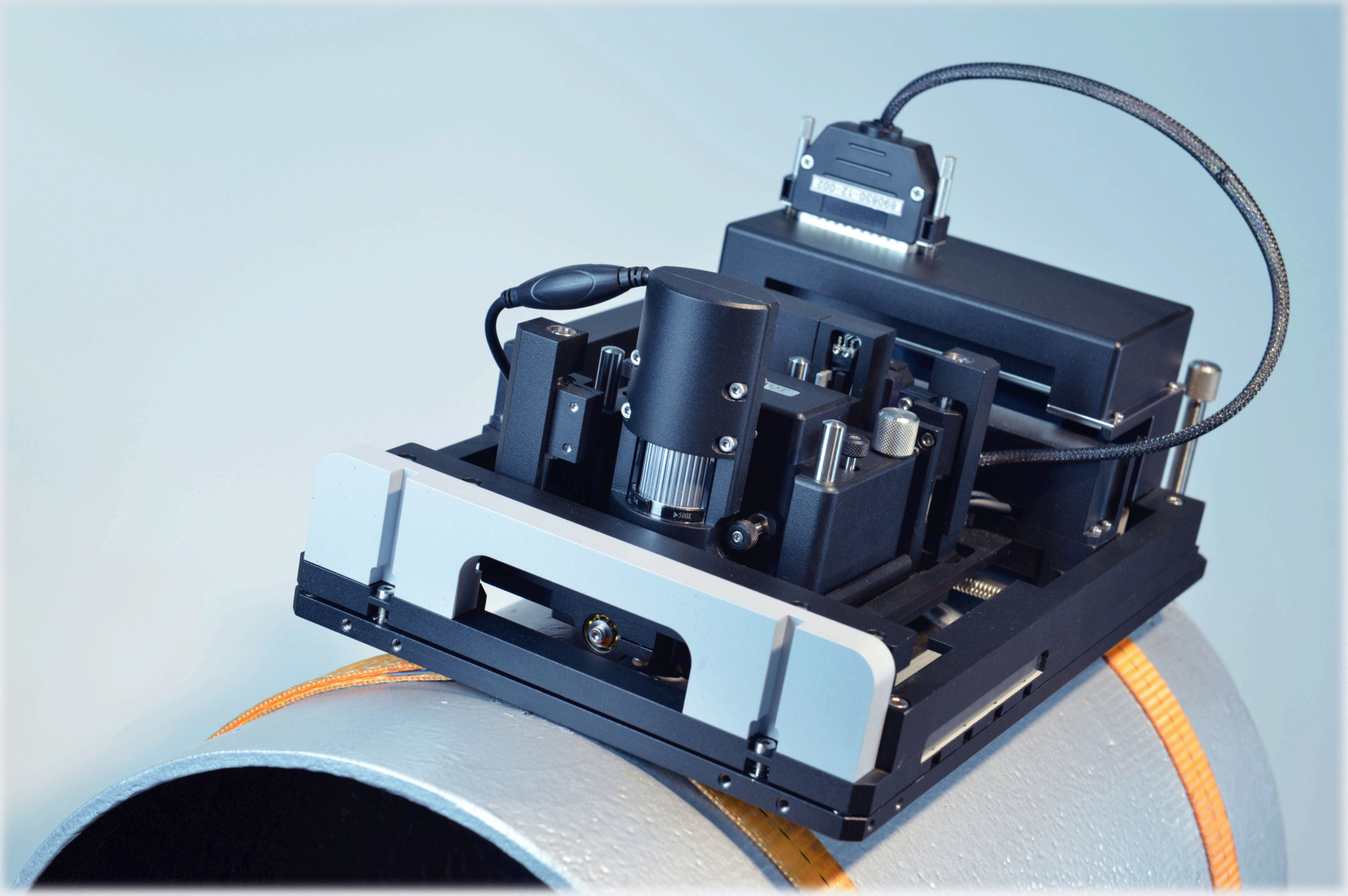




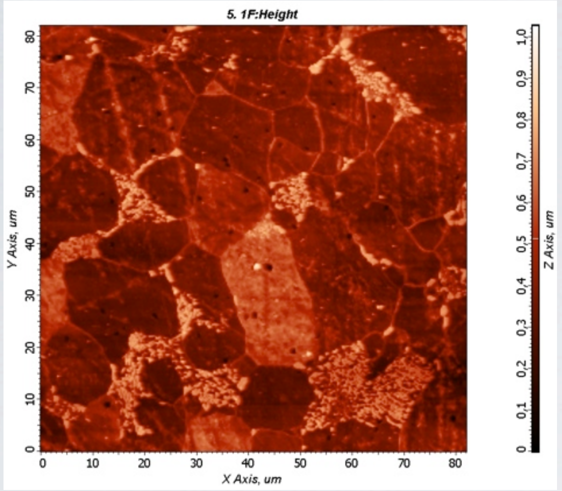


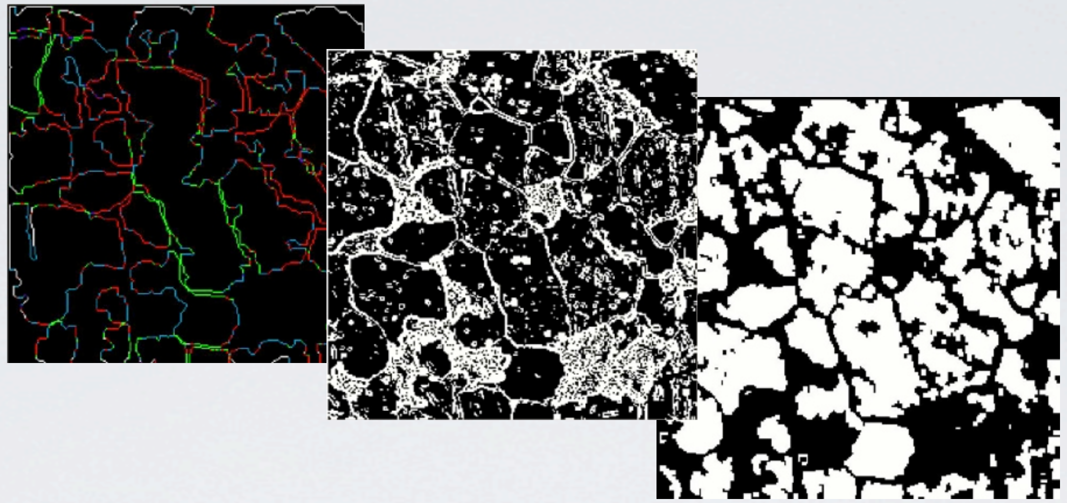
NT-MDT
INTEGRATED SOLUTIONS FOR NANOTECHNOLOGY

SOLVER-PIPE



Special Images Analysing

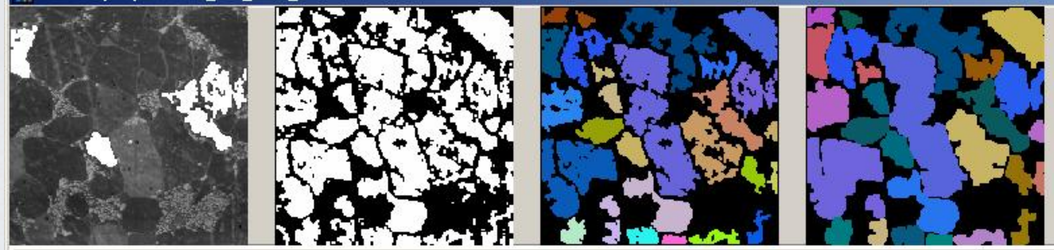




Параметры изображения

Имя	Среднее	СТО
СТО Z, нм	45,96	15,80
СТО Z по контуру гранул, нм	90,71	29,75
P*P/(4pi*S),	2,20	0,95
Вытянутость	1,70	0,51
Угол, градусы	-8,96	51,26
Перим./Вып.обол.	1,17	0,15
Длина границ типа "ступень", %	24,8	
Длина границ типа "хребет", %	44,5	
Длина границ типа "ров", %	2,0	
Ширина границ типа "ступень", мкм	1,94	1,25
Ширина границ типа "хребет", мкм	3,15	1,49
Ширина границ типа "ров", мкм	2,54	1,30
Высота границ типа "ступень", нм	164,69	78,43
Высота границ типа "хребет", нм	539,42	98,71
Высота границ типа "ров", нм	310,75	70,10
Нормированная длина вектора направленности	0,0	
Угол между вектором направленности и OX, гра	8,7	
Доля площади, занимаемая гранулами	0,7	
Среднее Z в области между гранулами, нм	464,24	
СТО Z в области между гранулами, нм	131,90	
Отношение СТО Z внутри и вне гранул	0,35	
S_mean,	417,03	
S_a, нм	88,82	
S_q, нм	107,55	
S_z, нм	545,90	
S_sk	0,70	

Анализ гранул obr1-2_bez_travl_3



Минимальная площадь гранулы, кв. мкм 20,00 Применить ☑ Включая границы

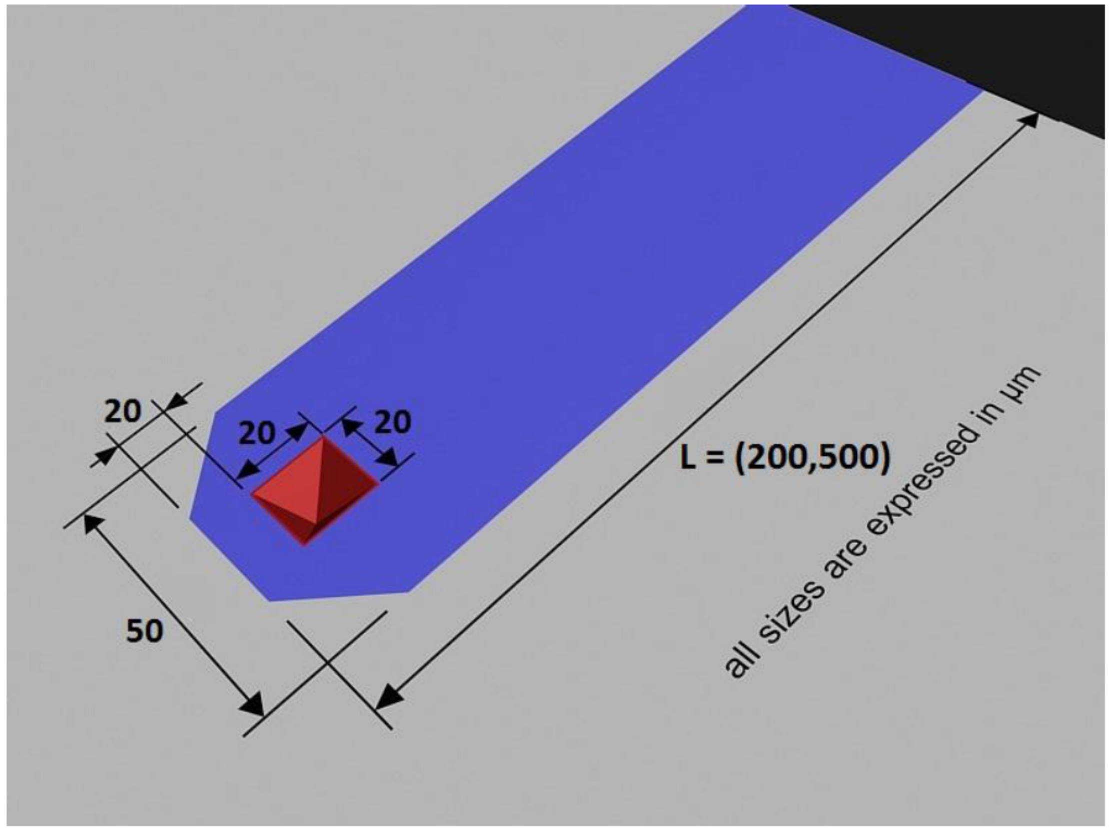
Показать параметры изображения | Анализ дефектов | Анализ линейных надрезов | Визуальный анализ

N	D,	S, кв. мкм	Периметр, мкм	DZ,	Среднее Z, нм	СТО Z, нм	СТО Z по контуру	P*P/(4pi*S),	Вытянутость	Угол, градусы	Перим./Вып
Среднее	11,24	160,52	62,65	370,89	365,52	45,96	90,71	2,20	1,70	-8,96	1,17
СТО	5,88	168,89	42,80	140,74	70,92	15,80	29,75	0,95	0,51	51,26	0,15
1	6,86	51,34	34,27	351,62	440,38	45,45	80,30	1,82	1,65	8,75	1,13
2	20,42	427,43	170,41	492,50	366,54	44,12	78,69	5,41	1,30	-38,54	1,65
3	16,63	252,86	74,46	546,82	330,77	43,58	75,55	1,74	1,76	-42,04	1,09
4	5,44	34,09	24,25	242,54	346,39	45,92	68,92	1,37	1,56	-28,27	1,04
5	11,66	132,84	55,42	281,16	555,03	44,01	57,33	1,84	2,07	83,65	1,06
6	13,95	204,32	93,65	517,19	370,03	46,85	125,24	3,42	1,33	62,24	1,43
7	28,42	763,65	180,70	797,39	478,09	99,81	100,68	3,40	2,66	-71,66	1,24
8	8,89	92,34	57,09	236,67	398,15	39,02	129,18	2,81	1,38	14,08	1,32
9	5,52	37,50	29,09	373,73	388,16	44,30	81,87	1,80	1,38	-14,41	1,08
10	14,40	222,81	89,59	489,40	361,35	48,74	72,60	2,87	1,02	0,00	1,41
11	14,46	214,23	97,66	434,80	350,76	48,82	101,75	3,54	2,32	-50,12	1,25
12	13,91	190,16	63,25	391,45	308,96	36,45	87,93	1,67	1,12	-47,90	1,13
13	7,96	65,59	34,05	223,30	347,72	34,72	65,44	1,41	1,38	-63,17	1,05
14	16,85	309,06	96,60	426,47	361,25	46,98	107,63	2,40	1,56	-56,36	1,25
15	11,28	122,71	46,65	245,18	327,46	37,20	81,78	1,41	1,80	8,90	1,05

Автоматизированный подсчет зёрен и расчет соотношения фаз

NT-MDT cantilever SNOM: contact AND non-contact probes

1) Lever sizes and the pyramid position:

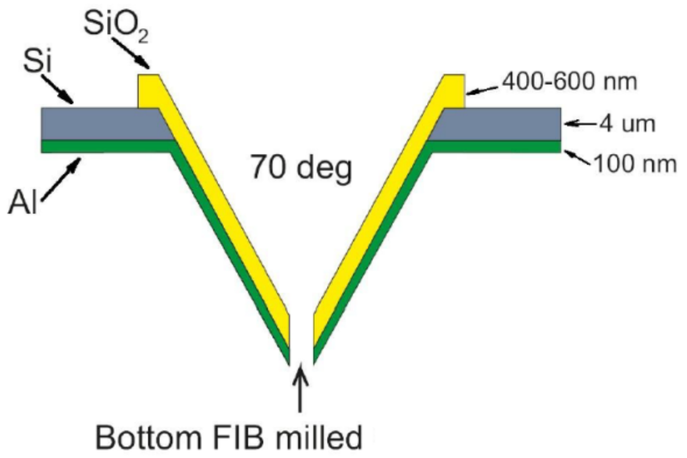


Pyramid LxWxH = 20x20x13 (70 deg)

	Spring Constant (N/m)			Frequency (kHz)			Length (micron)			Width (micron)			Thickness (micron)		
	Nominal	Min	Max	Nominal	Min	Max	Nominal	Min	Max	Nominal	Min	Max	Nominal	Min	Max
NonContact	16.5	5.9	39.0	130	88	180	200	190	210	55	54	57	4	3	5
Contact	1.01	0.41	2.30	20.8	15	27	500	490	510	55	54	57	4	3	5

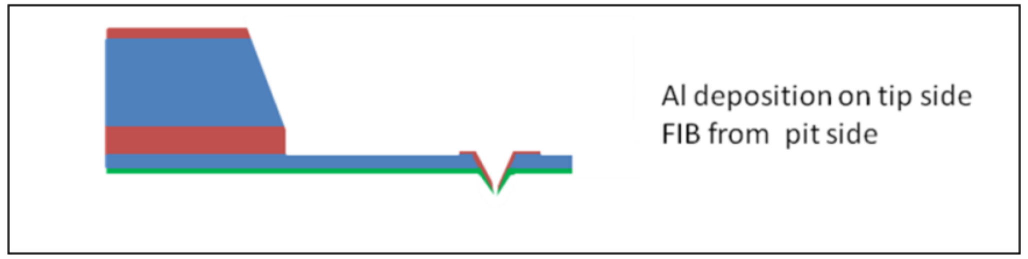
Probe	Resolution	TR@ 473	Visible in camera
1 contact	150 nm	~3*10-4	Yes
1 contact	???	.3*10-4	Yes, not clearly
1 noncontact	110 nm	~0.16*10-4	Yes, not clearly
2 noncontact	120 nm	~0.5*10-4	yes
3 noncontact	135 nm	~0.7*10-4	yes
4 noncontact	100 nm	~0.2*10-4	yes
5 noncontact	150 nm	~1.6*10-4	yes

2) Tip shape and aperture size:

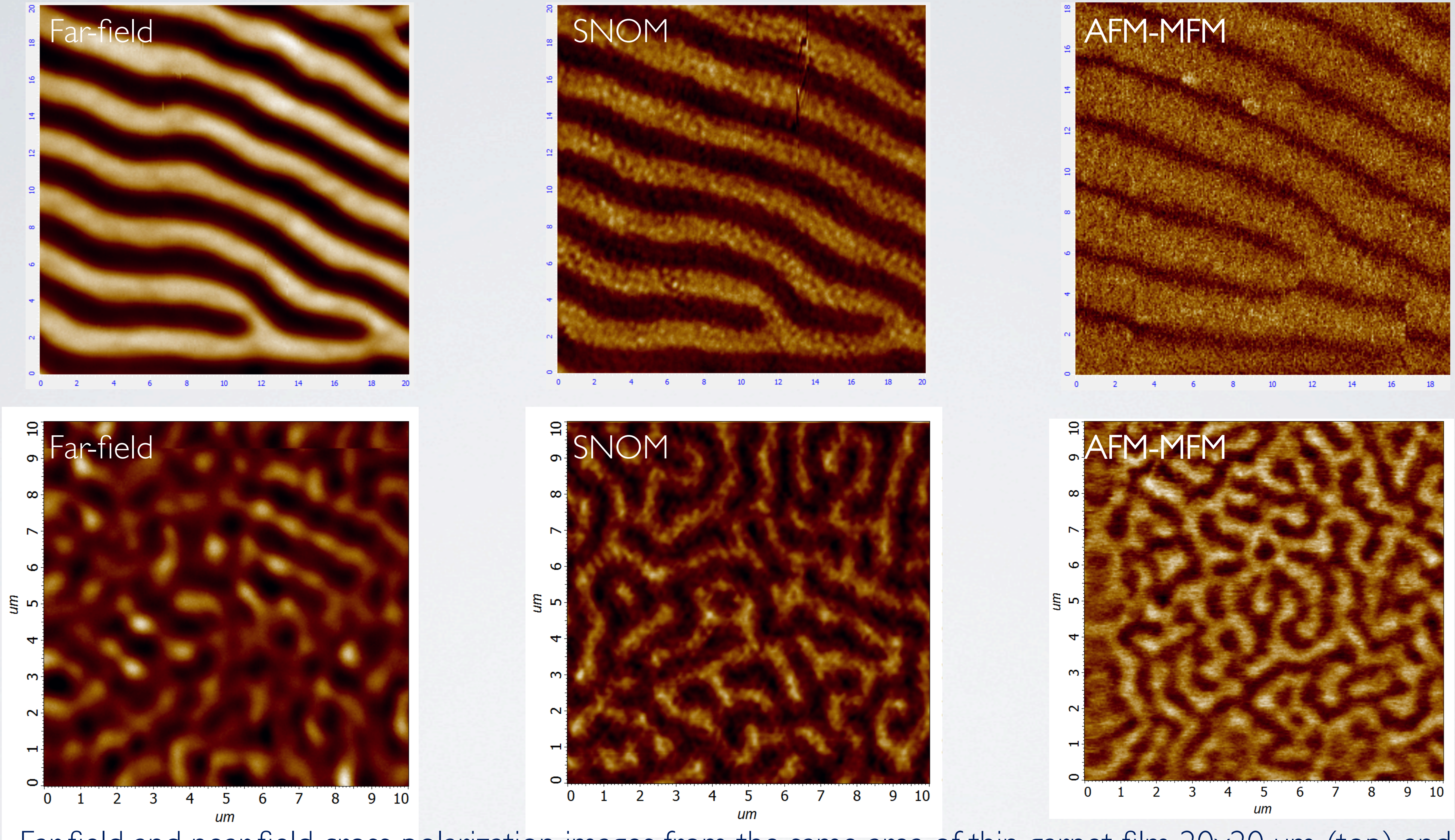


Pyramid (SiO2) thickness 400-600 nm

3) Coating: Al, about 100 nm, coating from bottom side. Bottom FIB milling is done after coating. Typical aperture diameter about 170 ±25nm.



Magneto-optic effects detected by cantilever based aperture SNOM

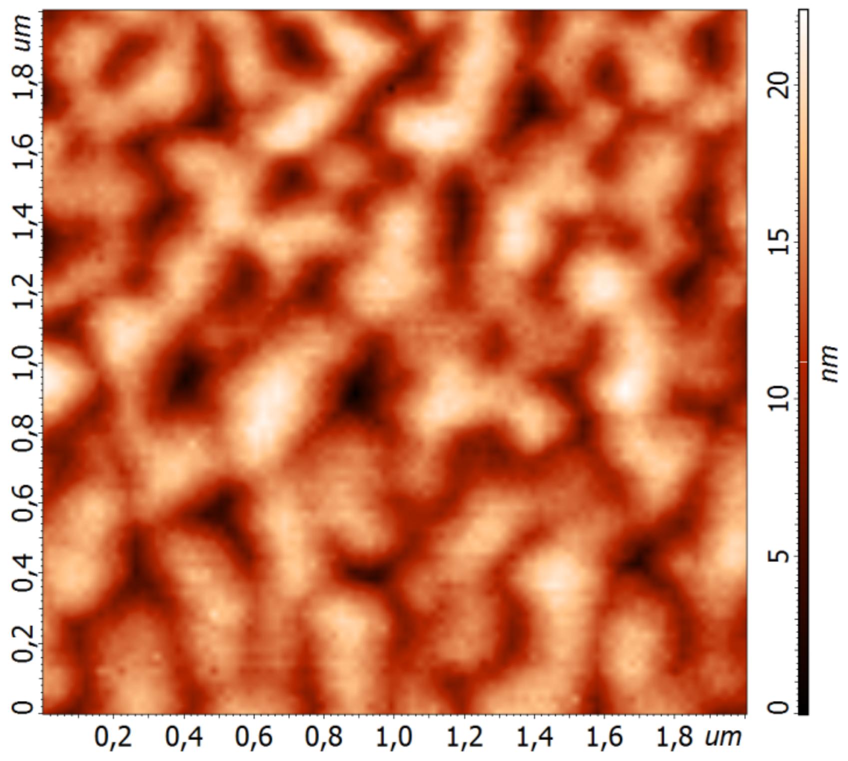


Far-field and near-field cross-polarization images from the same area of thin garnet film 20x20 um (top) and 10x10 um (bottom). 473 nm laser used. Comparison with MFM images from same sample (right).

Sample courtesy: T.V. Mikhailova, A.R. Prokopov, A.N. Shaposhnikov. Vernadsky Crimean Federal University

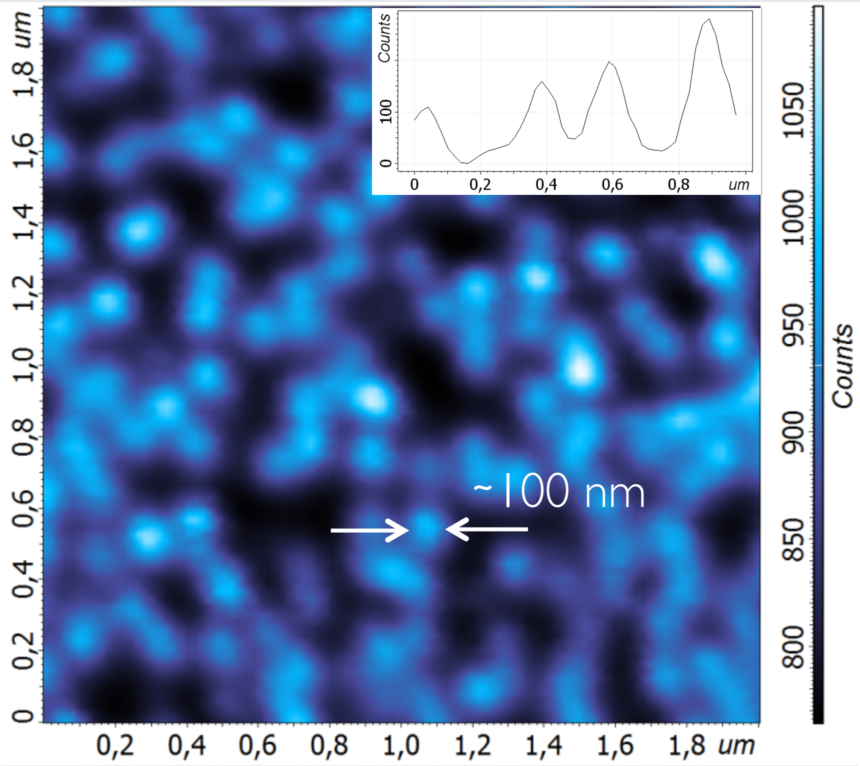
SNOM of quantum dot photoluminescence
InP quantum dots, GaInP cap layer

AFM Topography



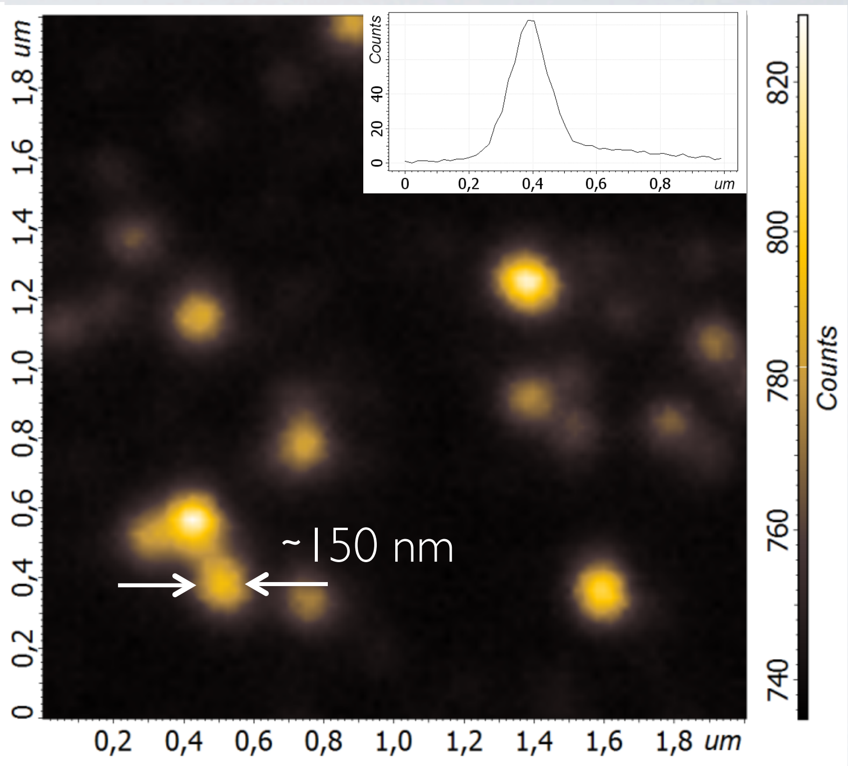
Cap layer only (QDs not visible)

PL SNOM, 700-770 nm



20-50 nm dia. QDs

PL SNOM, 800-810 nm

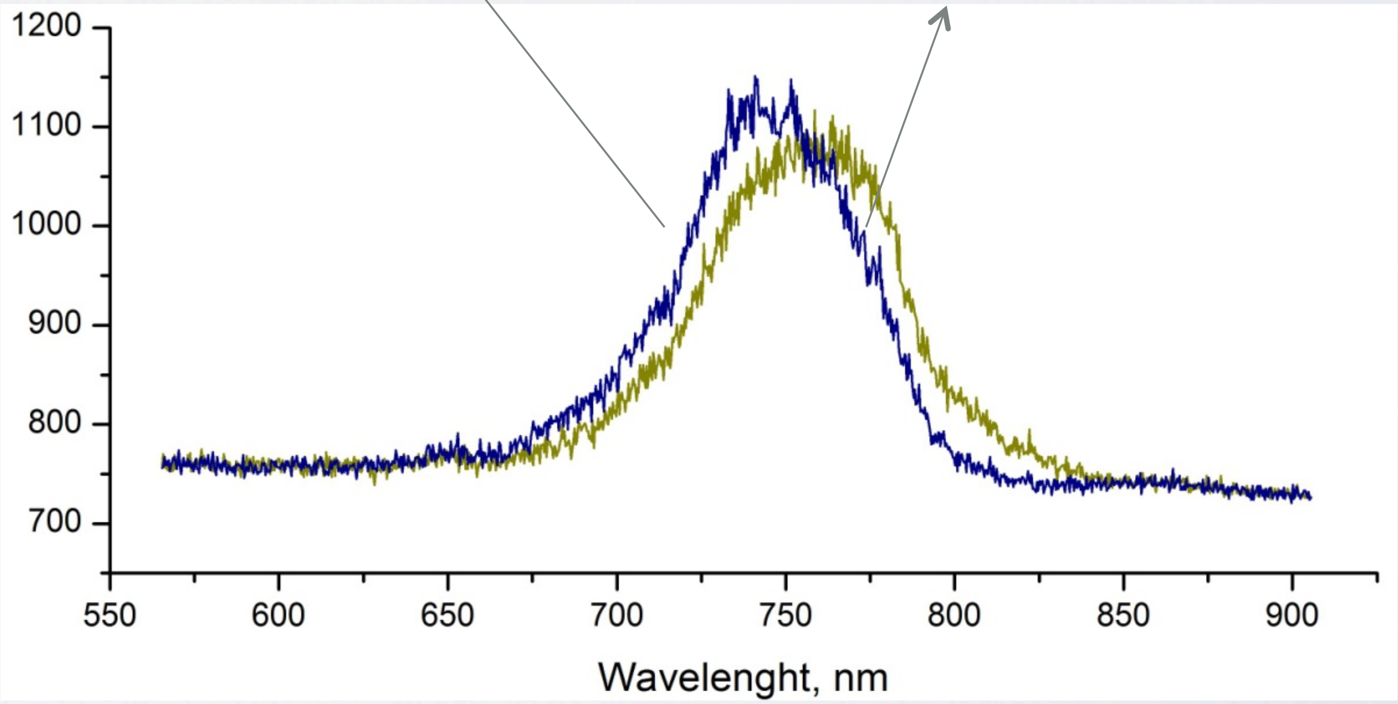


100-200 nm dia. QDs

2x2 μm scans

Simultaneously obtained topography (left) and SNOM maps of photoluminescence (PL) in 700-770 nm (center) and 800-810 nm (right) spectral regions. 100x100 pixels, 0.1 s/point

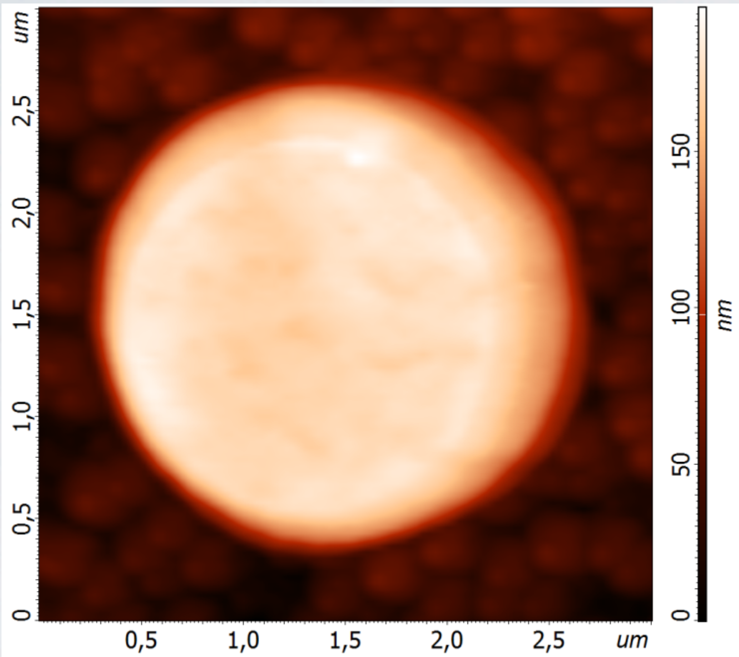
Images obtained by cantilever based SNOM in with excitation and collection via the same SNOM aperture



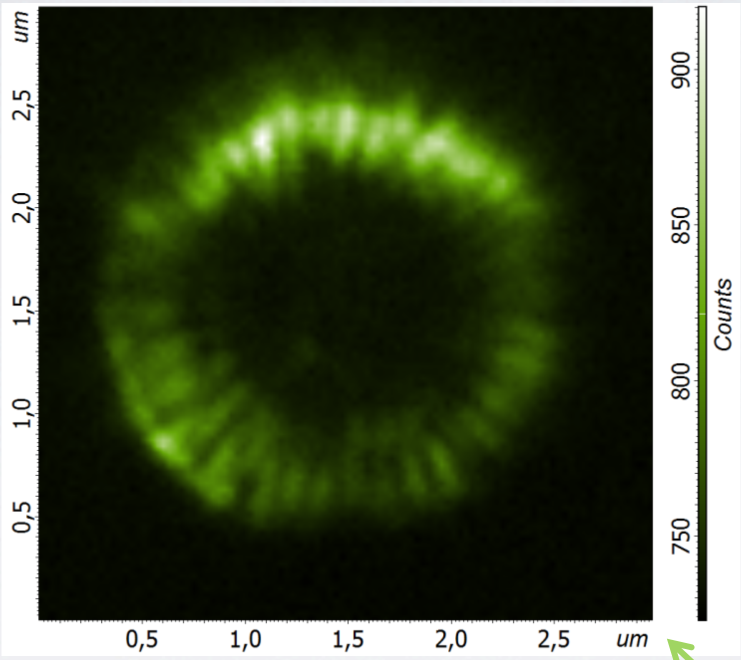
A. Mintairov, A. Ankudinov, A. Shelaev, P. Dorozhkin, Ioffe Institute & NT-MDT

Whispering gallery light modes in microdisks with InP/GaInP self-organized quantum dots

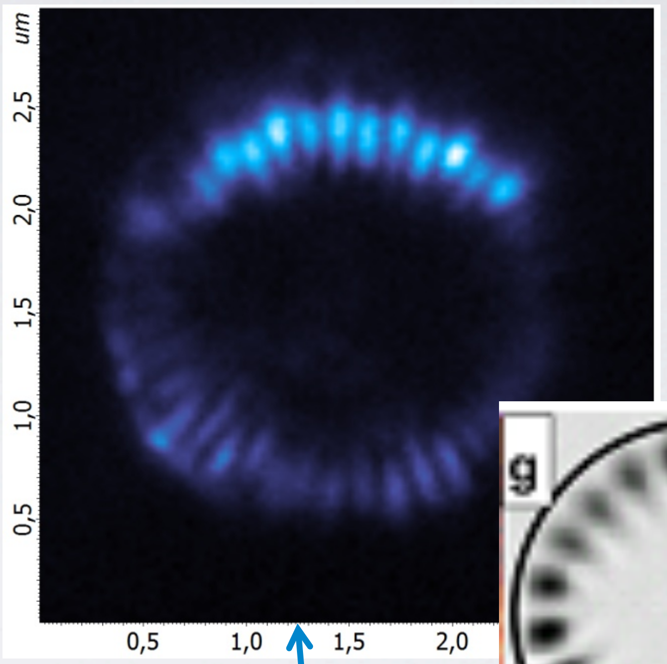
Topography

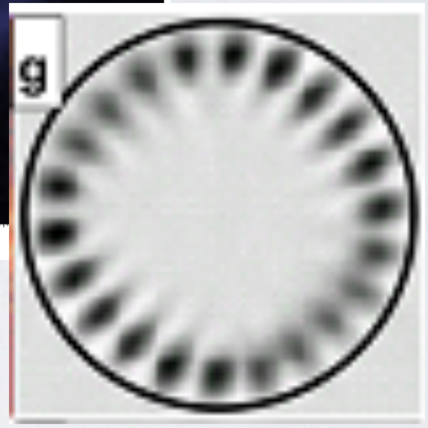


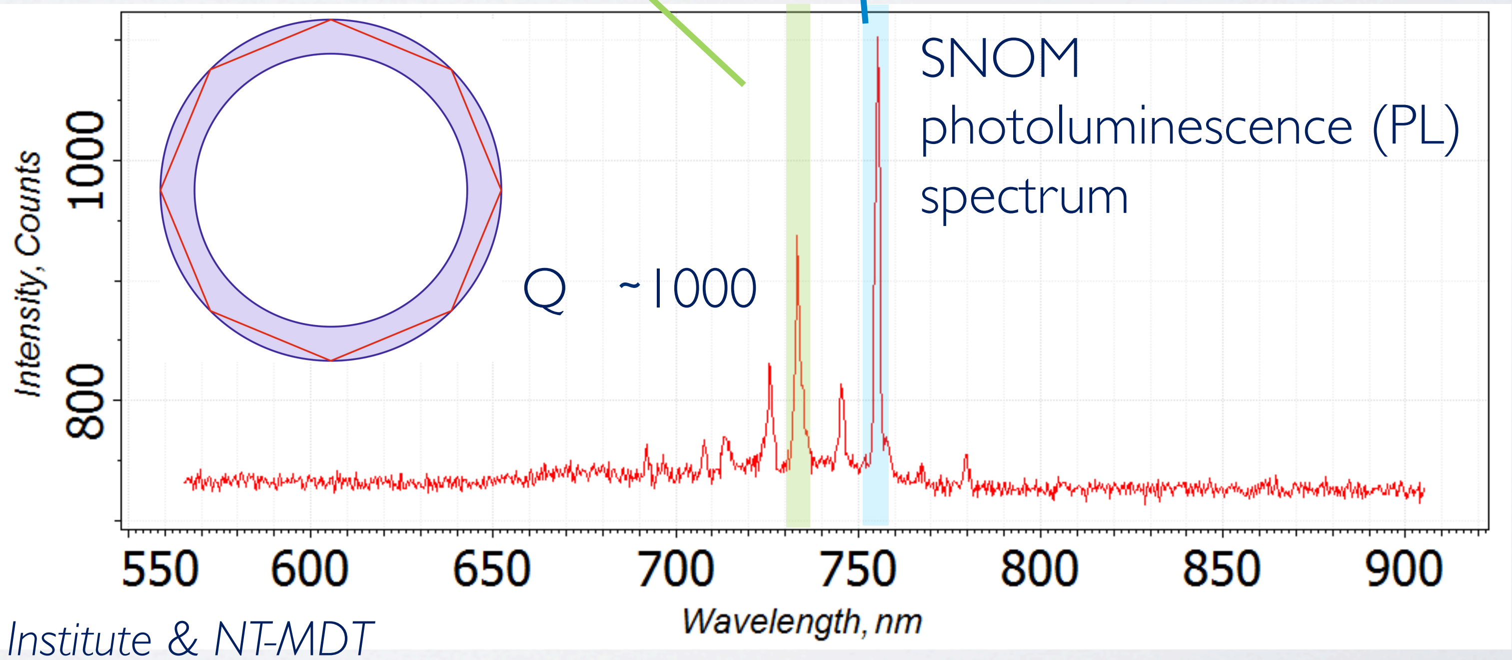
SNOM PL, 732-735 nm
TE20 mode



SNOM PL, 753-757 nm
TE18 mode







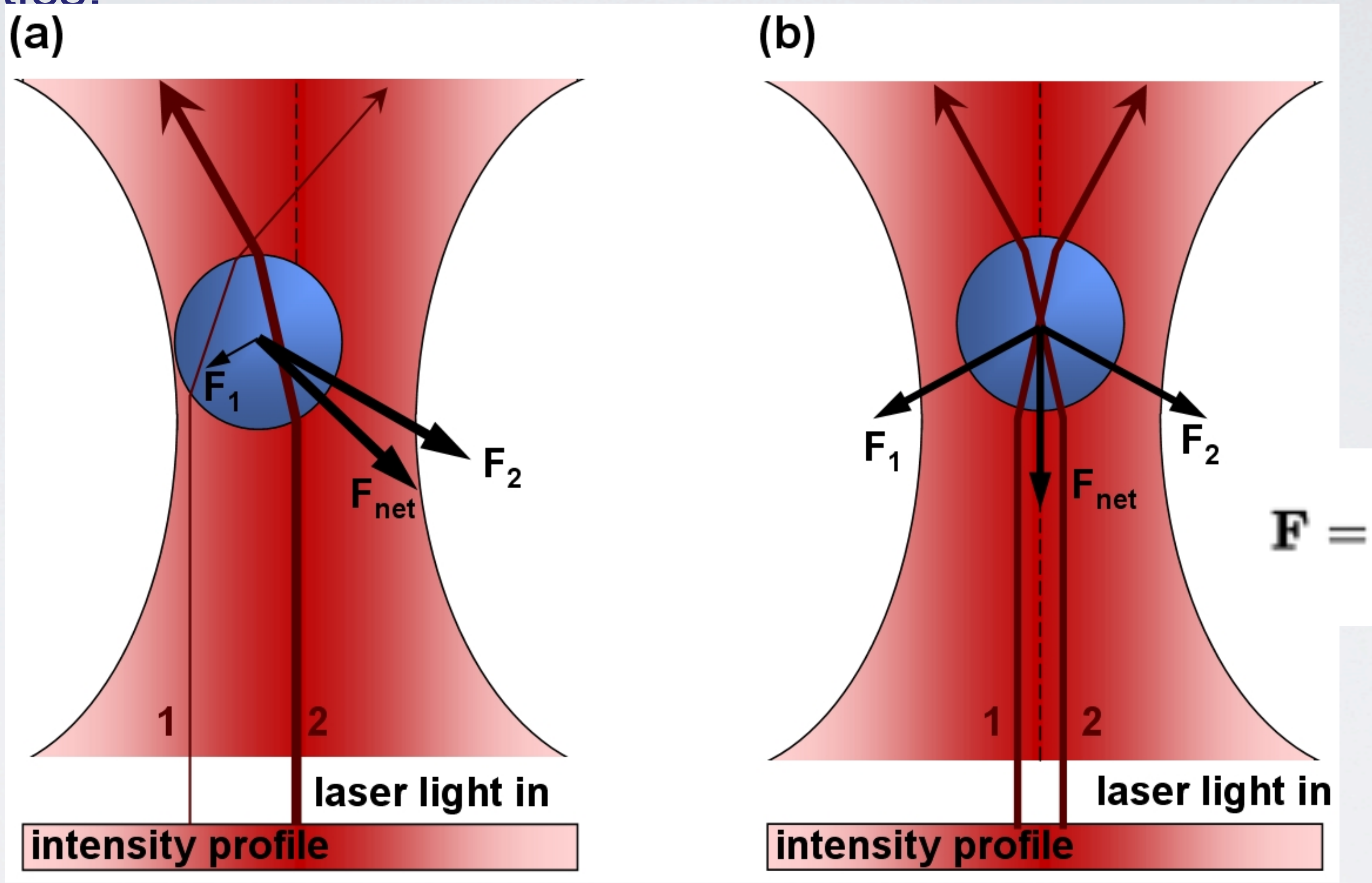
Simultaneously obtained topography (left) and SNOM maps of light whispering gallery modes in the ranges 753-757 nm band (center) and 732-735 nm (right). 100x100 pixels, 0.1 s/point

Images obtained by cantilever SNOM with side illumination

A. Mintairov, A. Ankoudinov, A. Shelaev, P. Dorozhkin, Ioffe Institute & NT-MDT

Optical tweezers

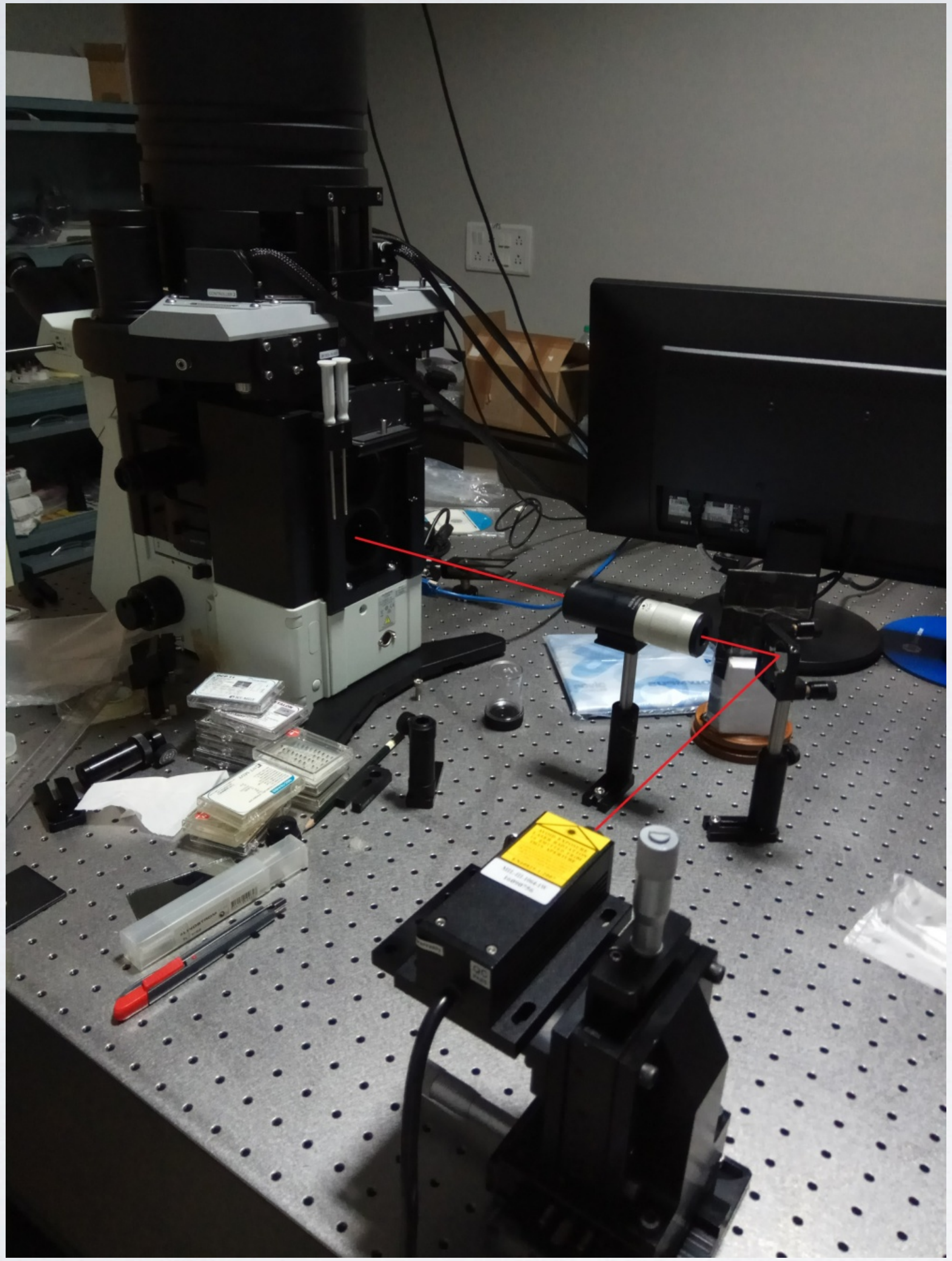
At r> λ, scattering of Mie takes place, we can use the approach of wave optics.



$$\mathbf{F} = \frac{1}{2}\alpha\nabla E^2.$$

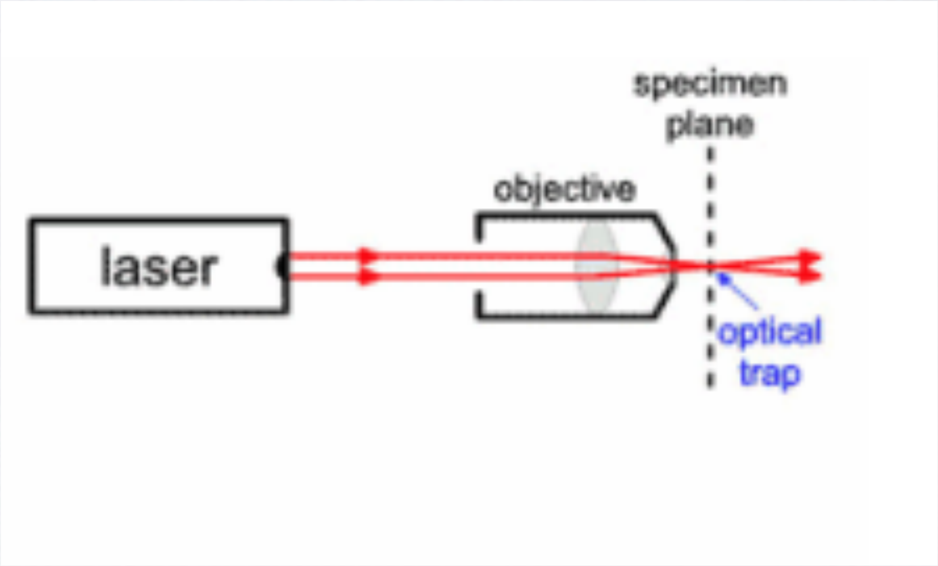
Объяснение на основе волновой оптики. Когда шар смещается от центра пучка, как на рисунке (a), наибольшее изменение импульса лучей с большей интенсивностью вызывает появление силы, направленной к центру ловушки. Когда шар расположен в центре пучка, как показано на рисунке (b), сила указывает в сторону сужения

Department of Physics Bangalore University,Praveen Parthasarathi

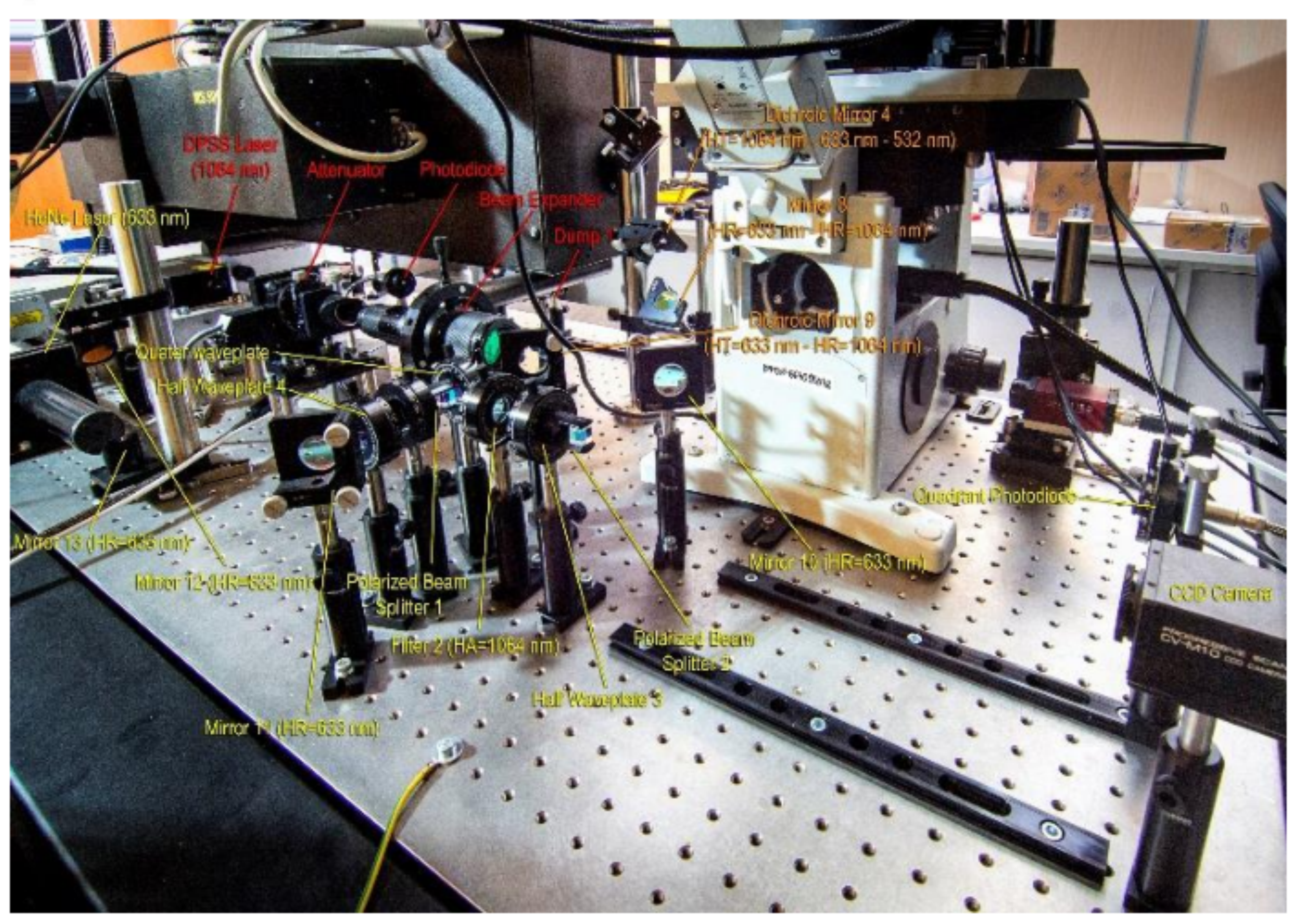


Базовый вариант пинцета на базе инвертированного микроскопа

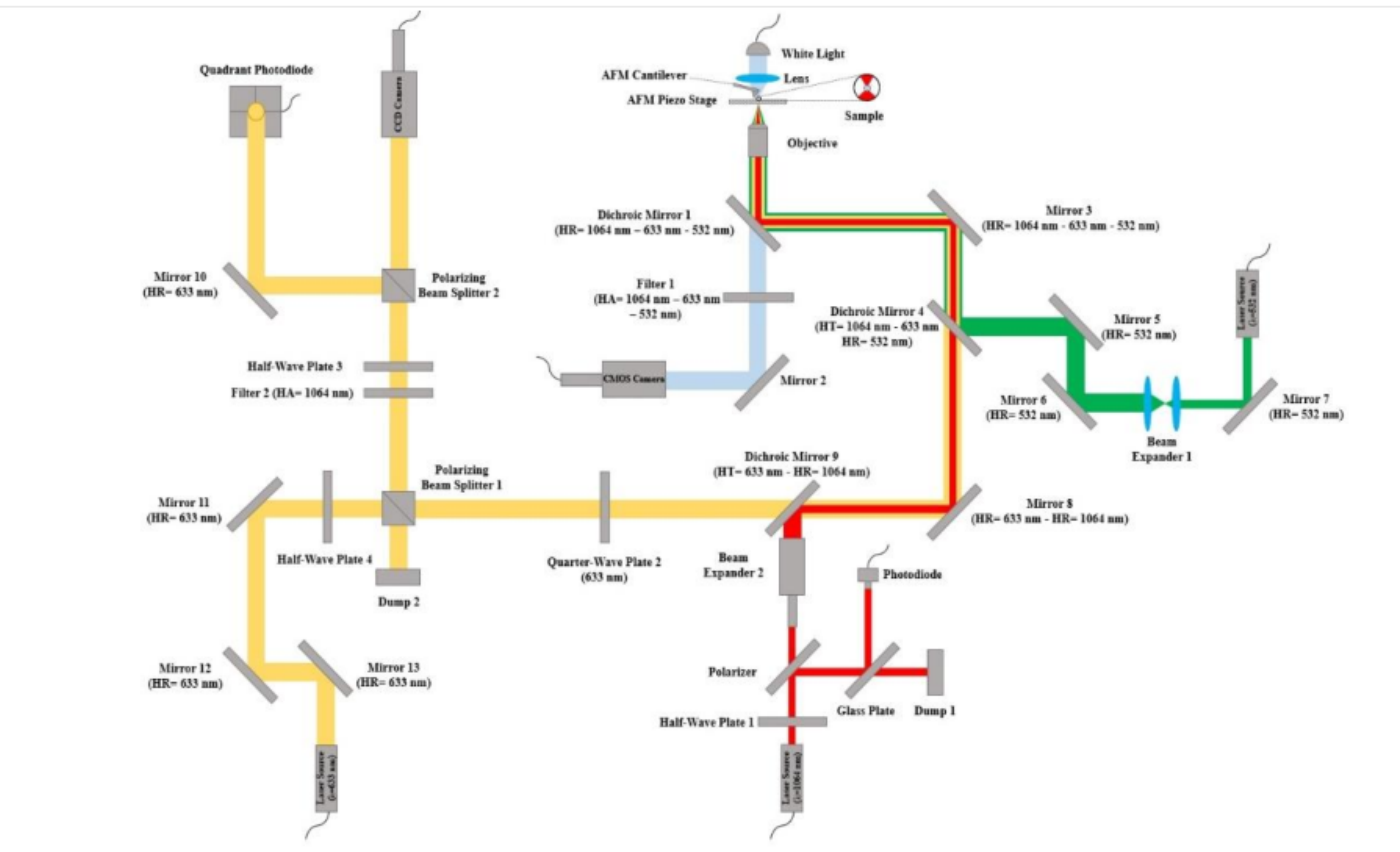
Только захват частиц, без измерения силы.



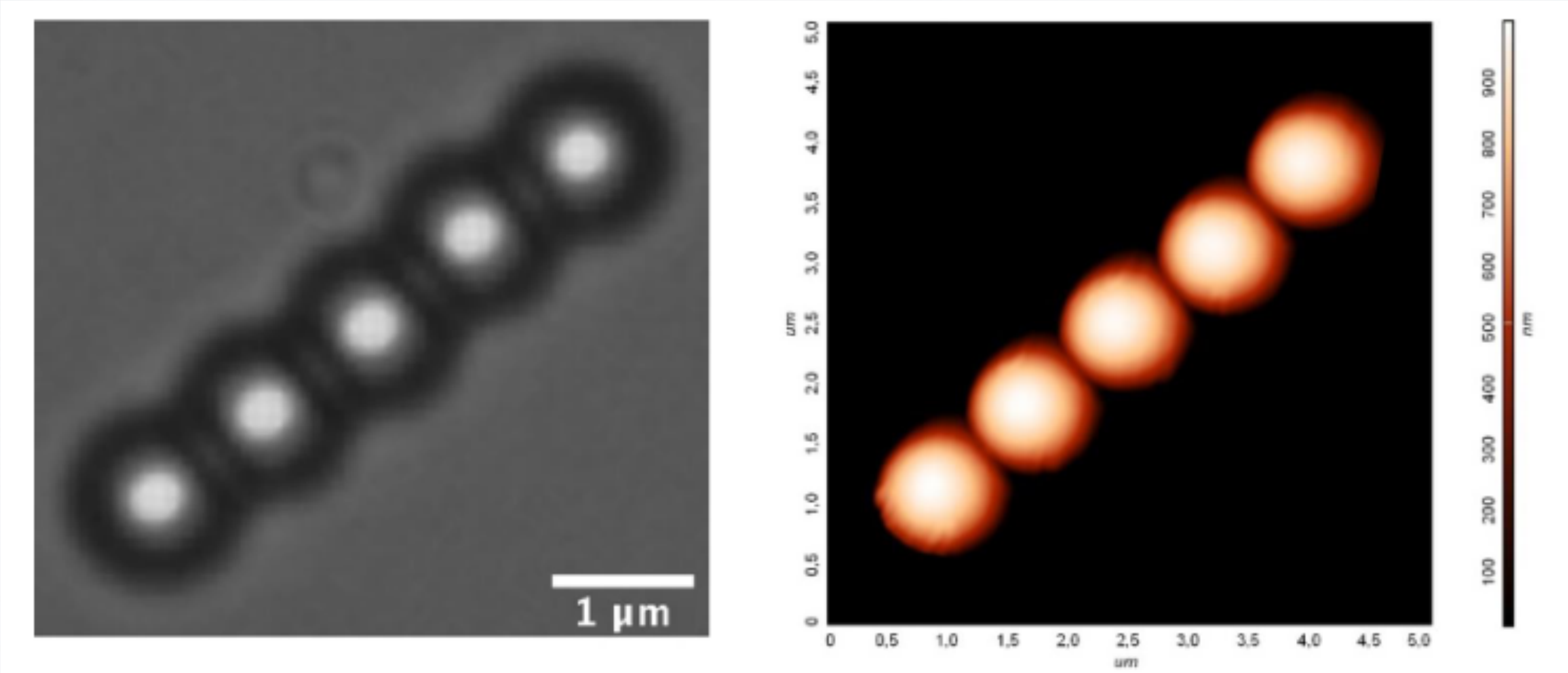
Institute of Fundamental Technological Research,
Polish Academy of Sciences, Warsaw, Poland,Filippo Pierini



Institute of Fundamental Technological Research,
Polish Academy of Sciences, Warsaw, Poland,Filippo Pierini



Манипуляция нанообъектами



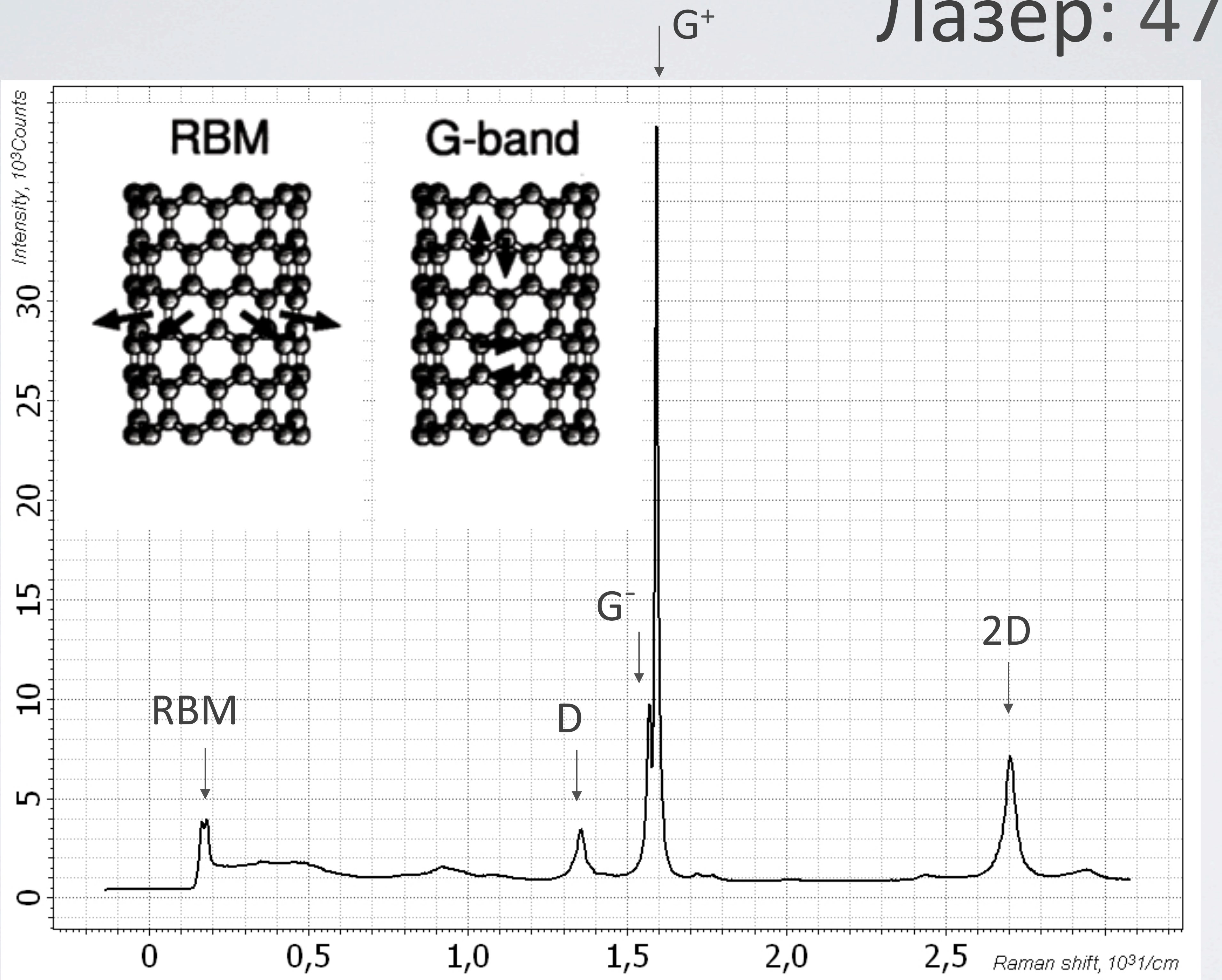
Optical Microscope

AFM

Surface functional groups, how to find out what they are?

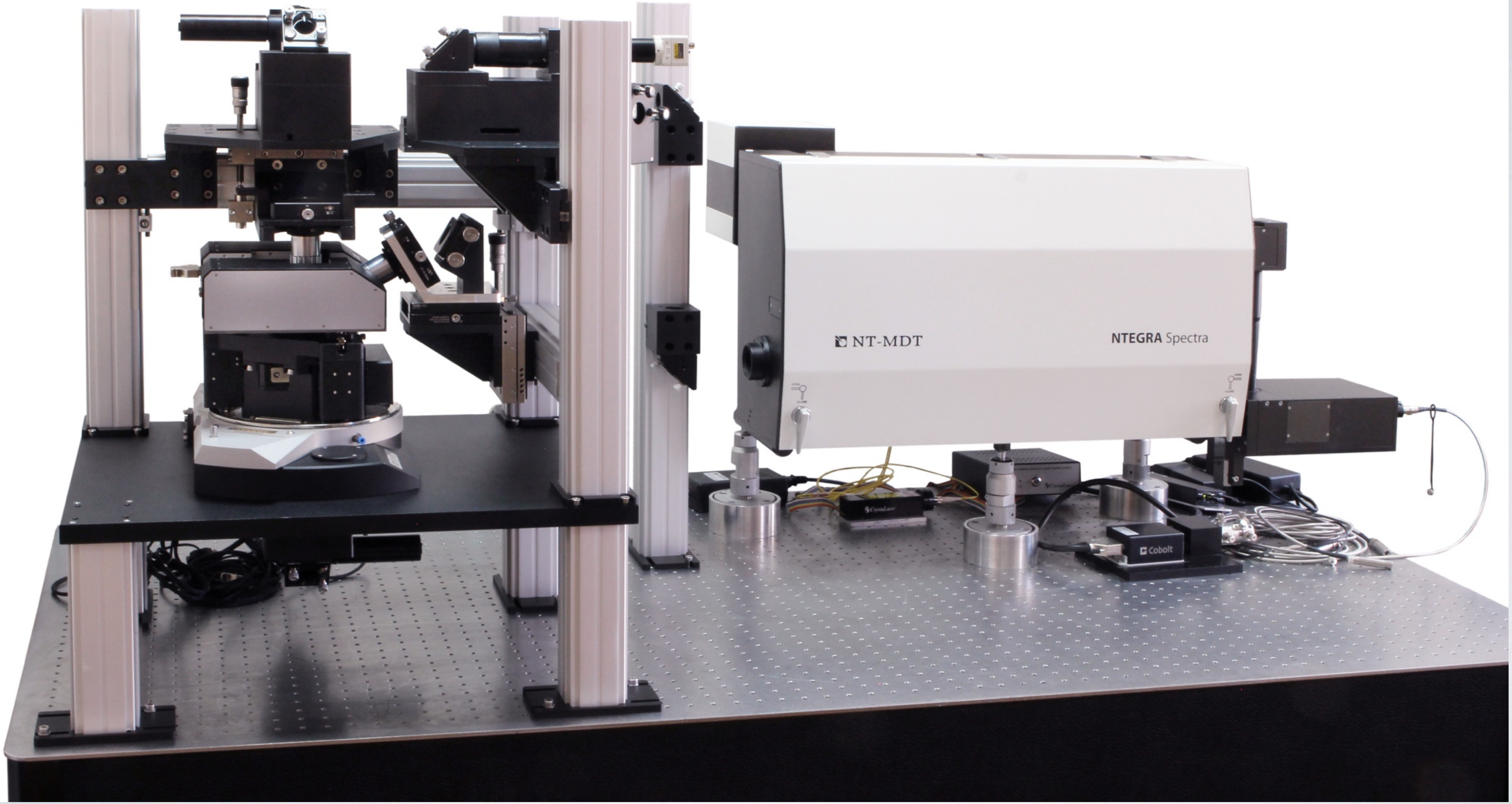
Molecule vibrations and absorption. Emission of light

Лазер: 473 nm



Variations with a change in the polarizability, Raman spectroscopy

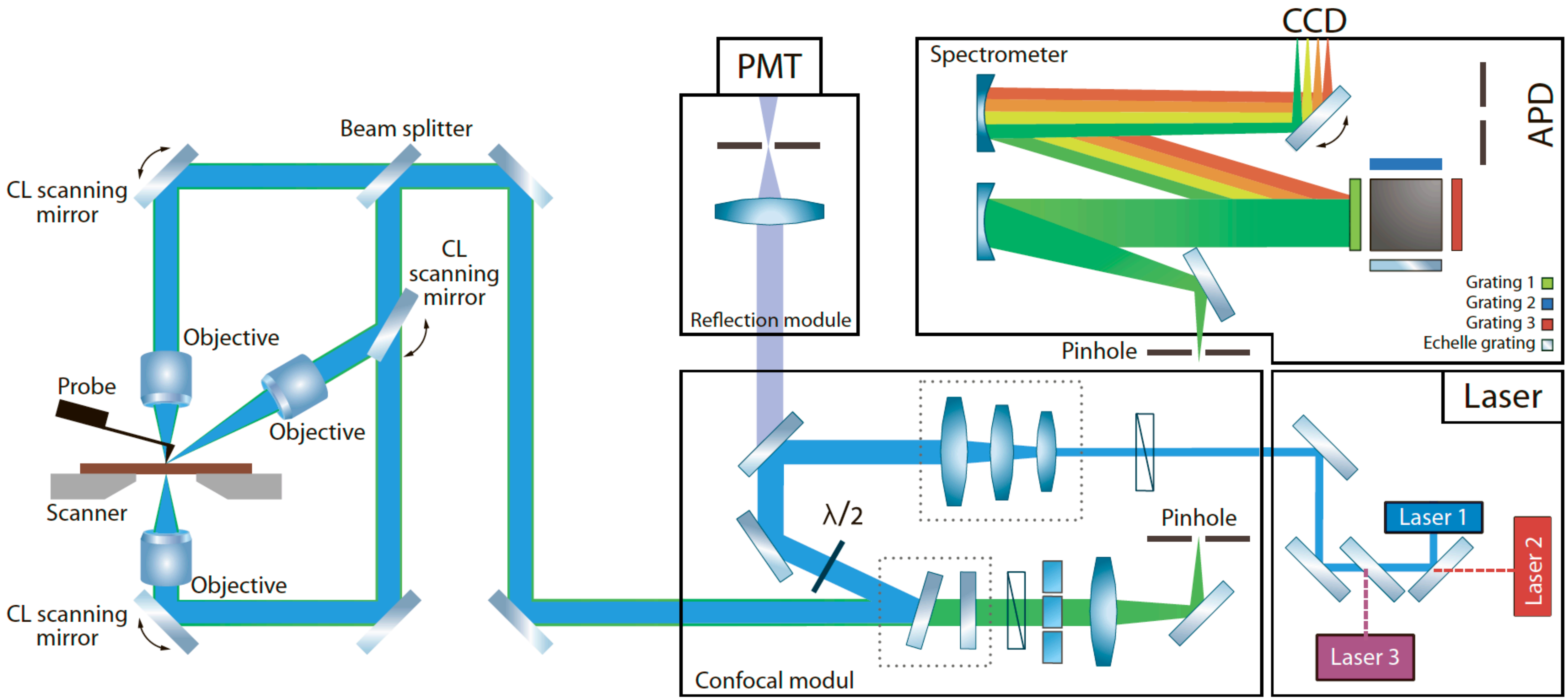
NTEGRA-SPECTRA-II, 2016



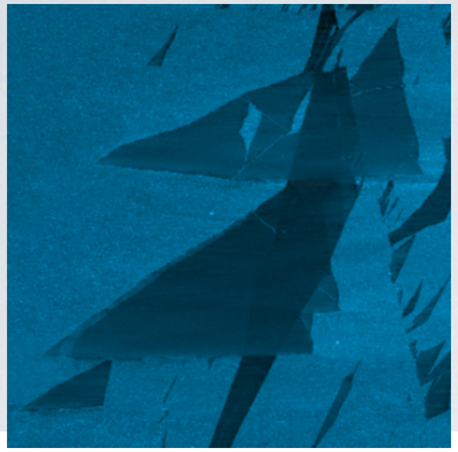
NT-MDT
Spectrum Instruments

Operation scheme

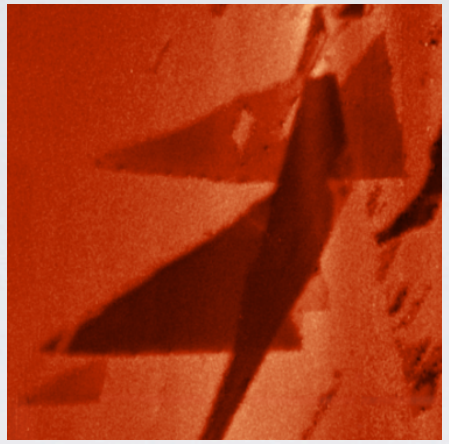
Принцип работы



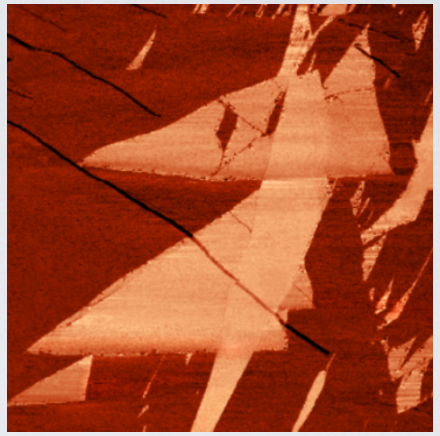
Graphene, AFM + Confocal Raman spectroscopy A single scan - a lot of data



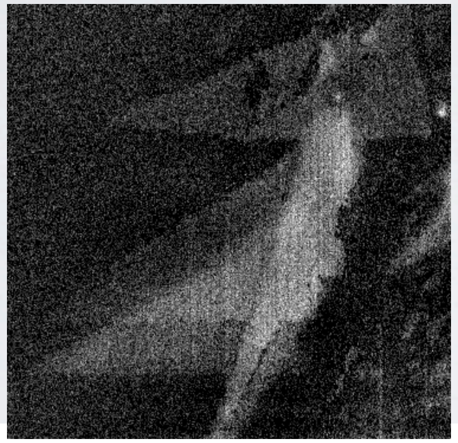
Lateral Force Microscopy
(friction)



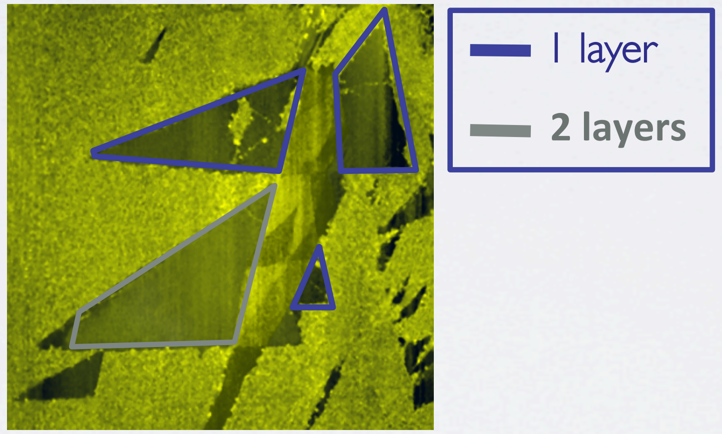
Electrostatic Force Microscopy
(charge distribution)



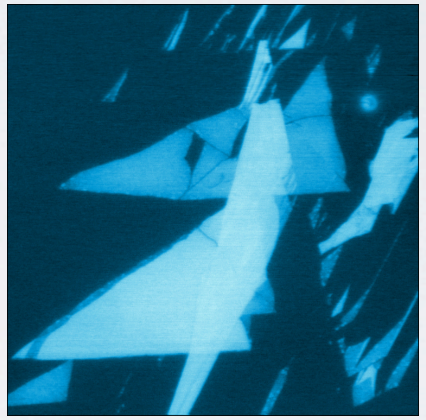
Force Modulation Microscopy
(elasticity)



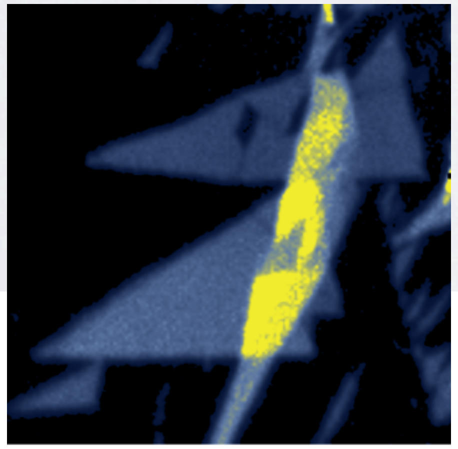
Capacitance Microscopy



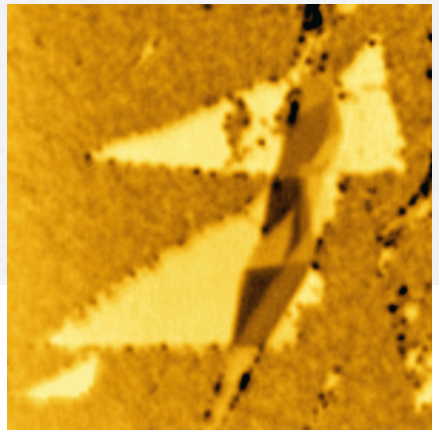
AFM Topography
Size: 30*30 μm



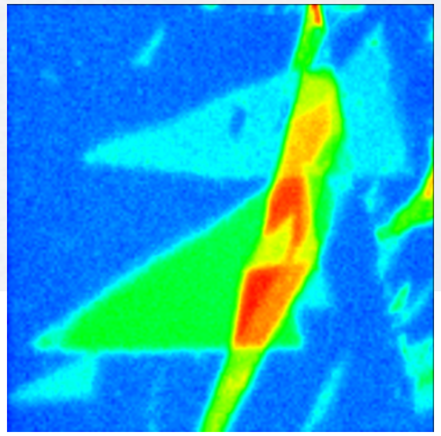
Scanning Kelvin Probe Microscopy
(surface potential)



Raman Map, 2D Band position

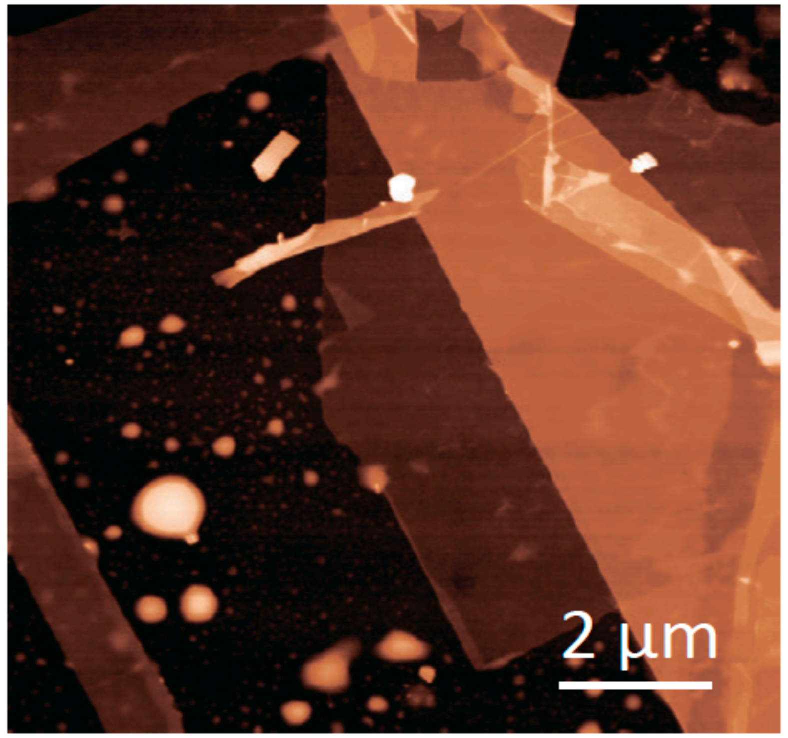


Confocal Rayleigh Microscopy

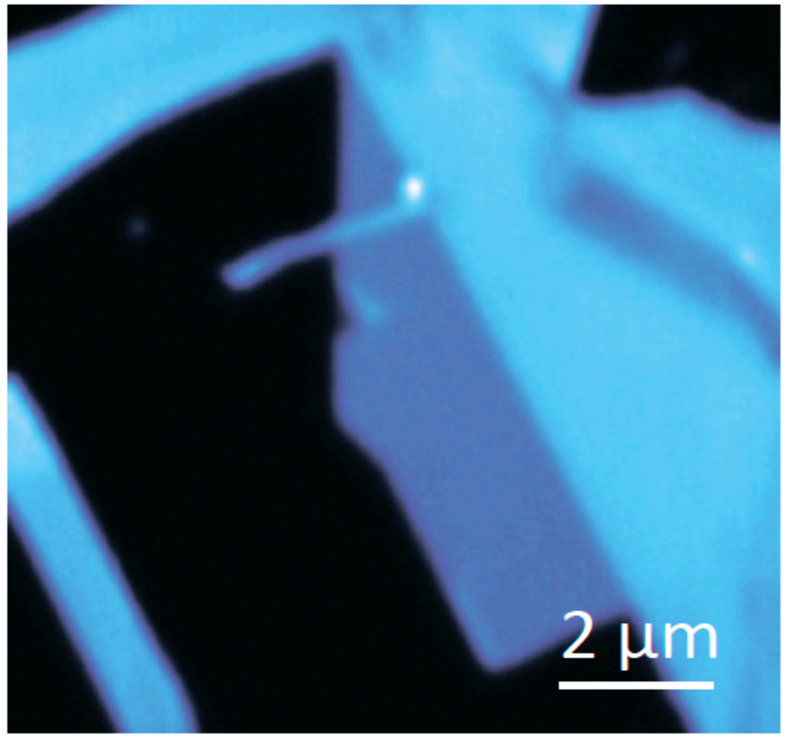


Raman Map, G-band Intensity

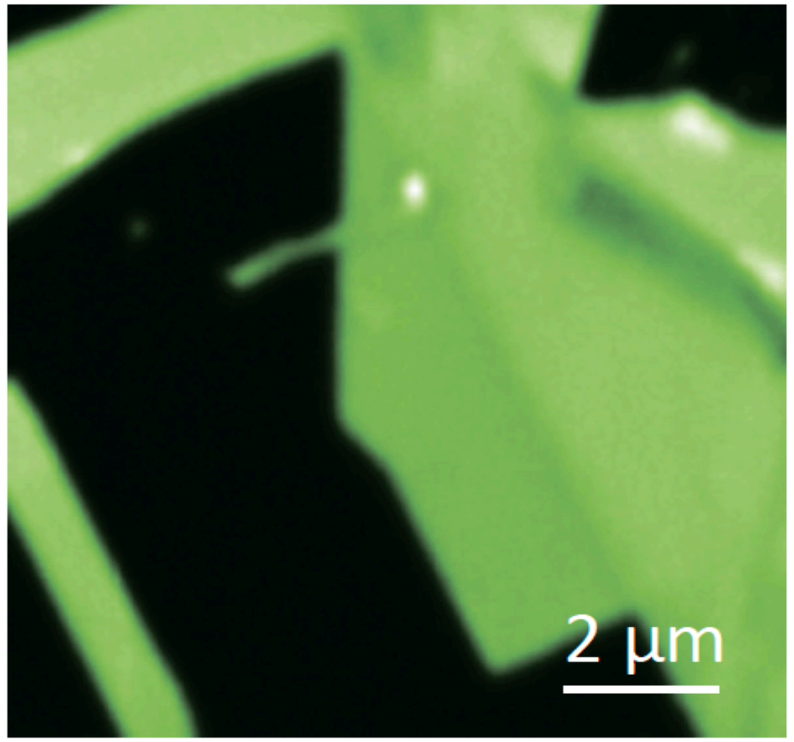
Flakes of graphene on Si/SiO_2



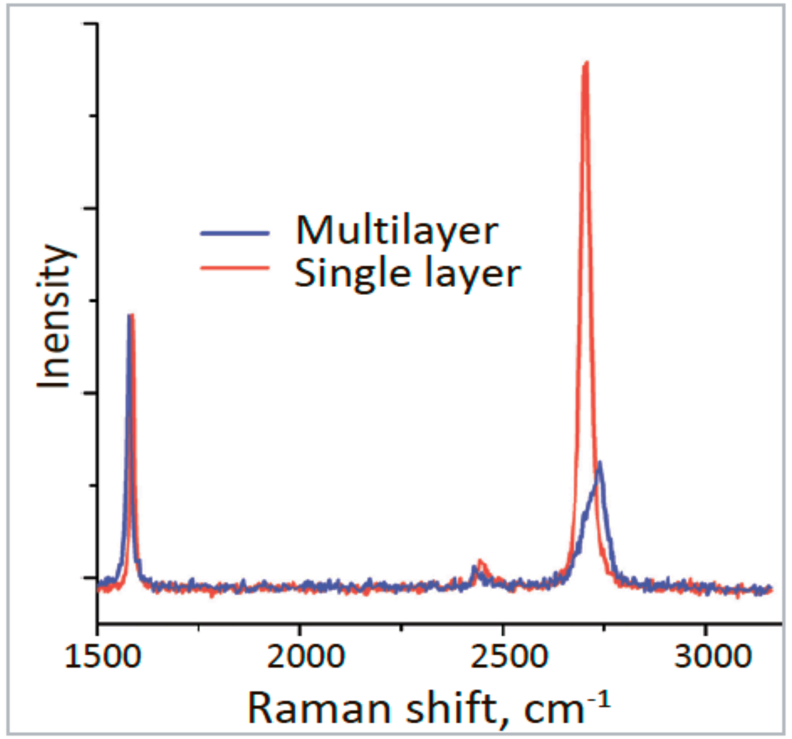
Рельеф



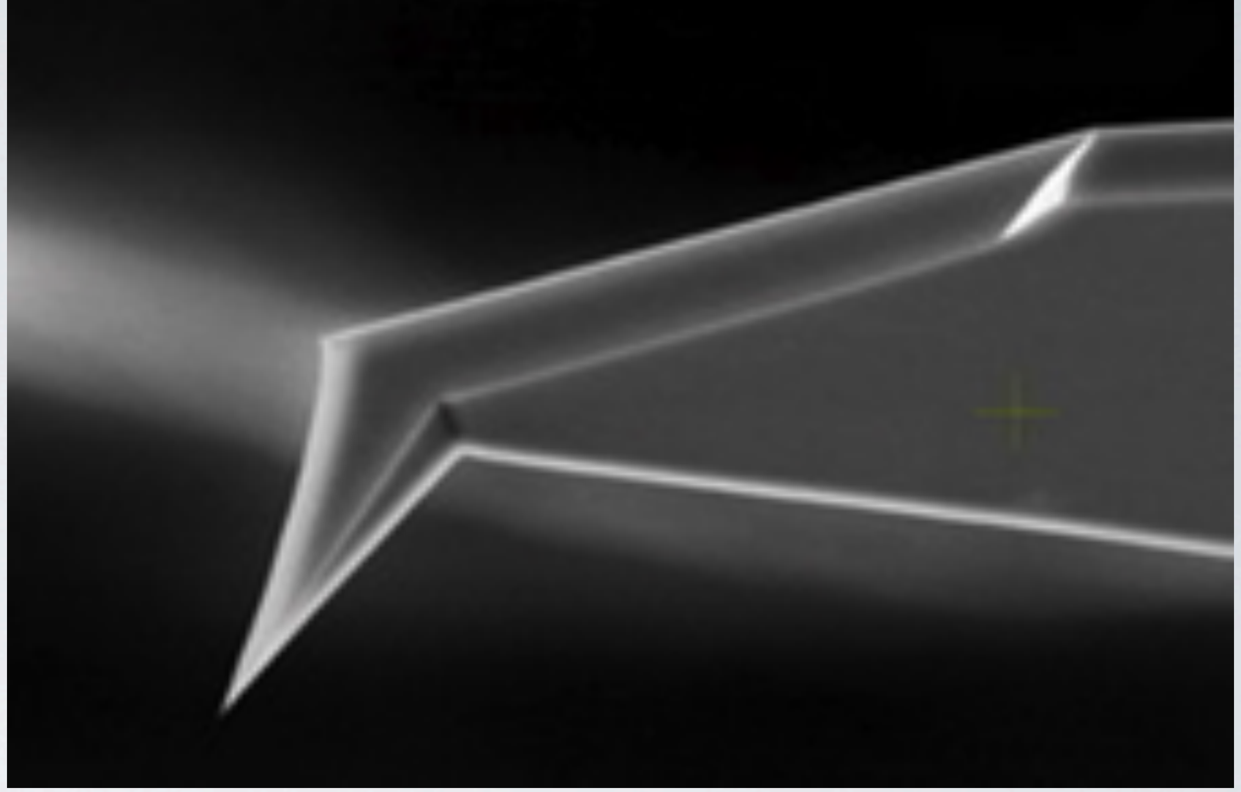
Интенсивность G полосы

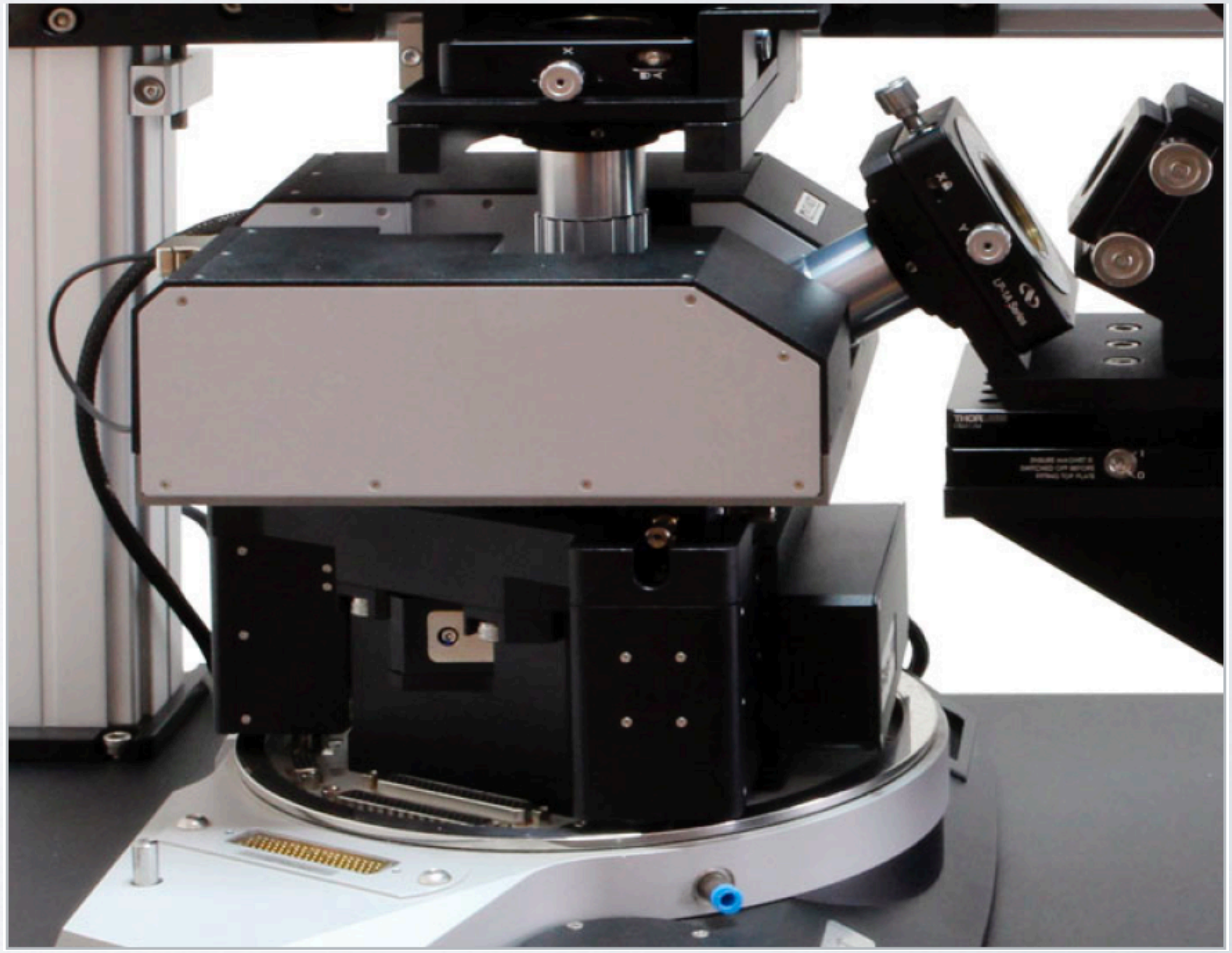


Инденсивность 2D полосы

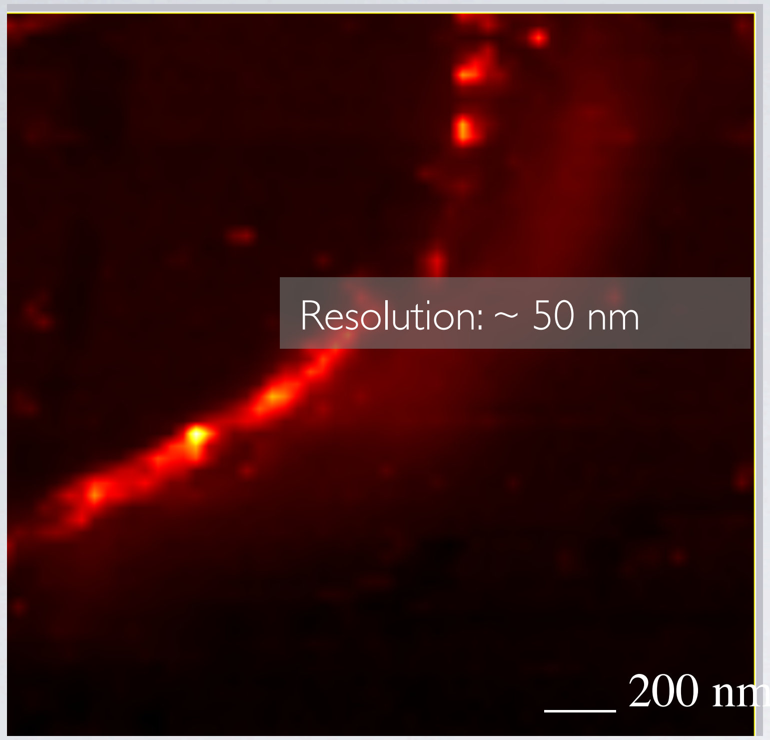


Рамановский спектр

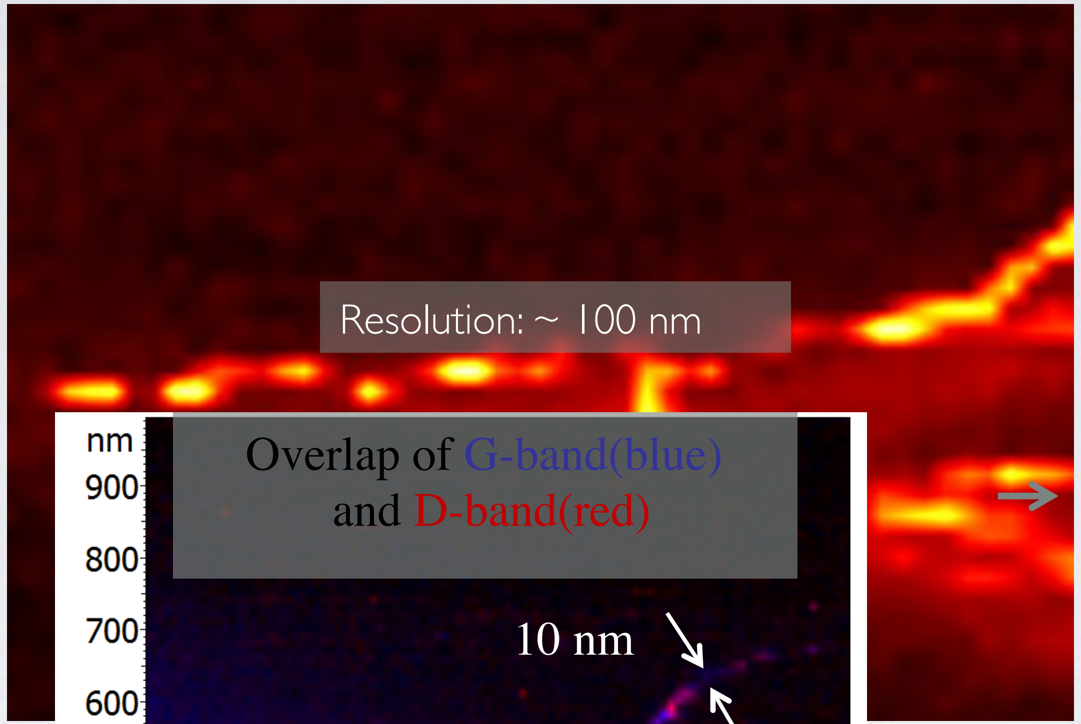




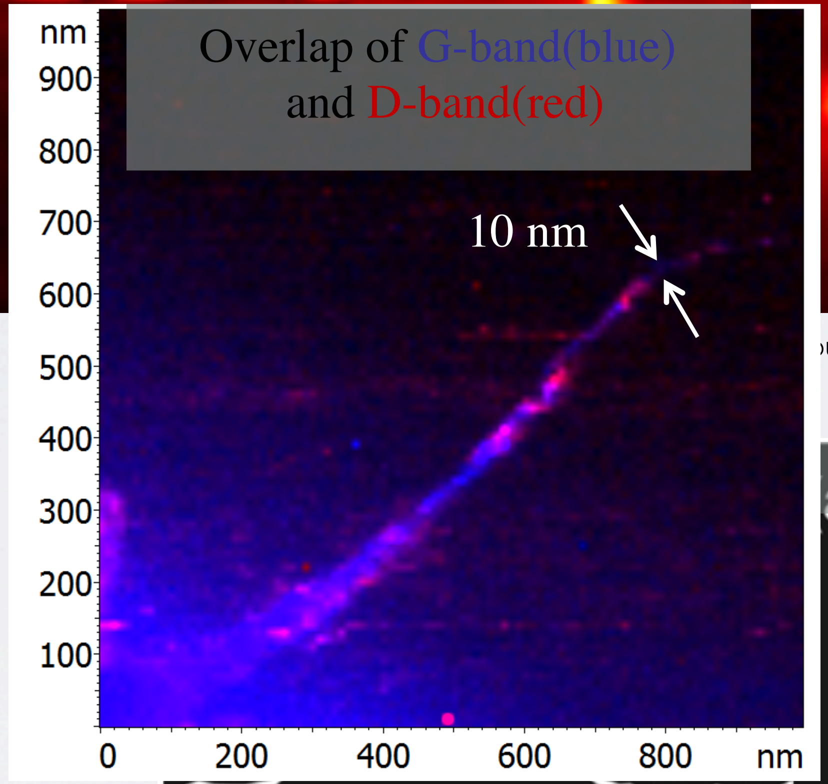
TERS of Carbone nanotubes

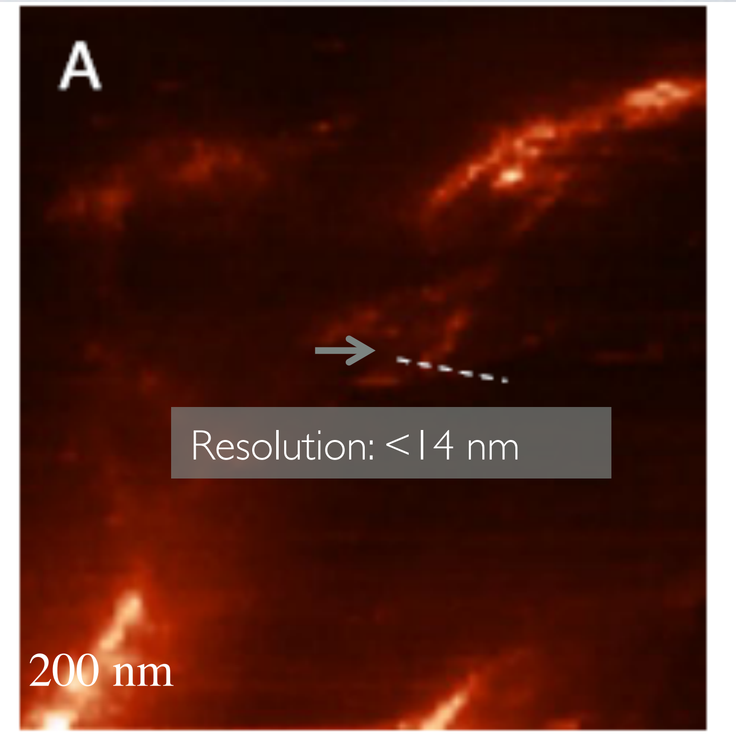


S.S. Kharintsev, G. Hoffmann, P.S. Dorozhkin, G. de With, and J. Loos, Nanotechnology 18 (2007), 315502



ublished

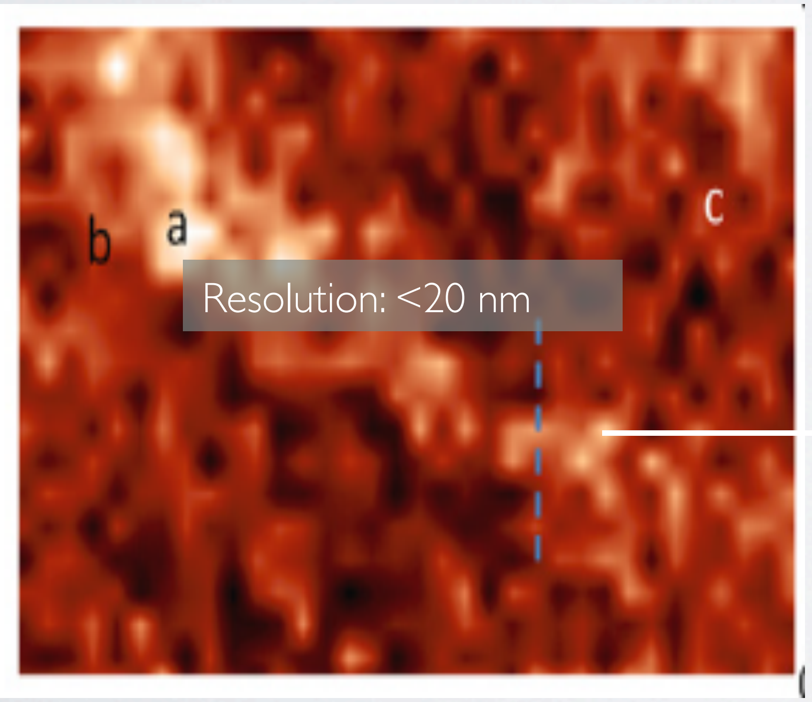




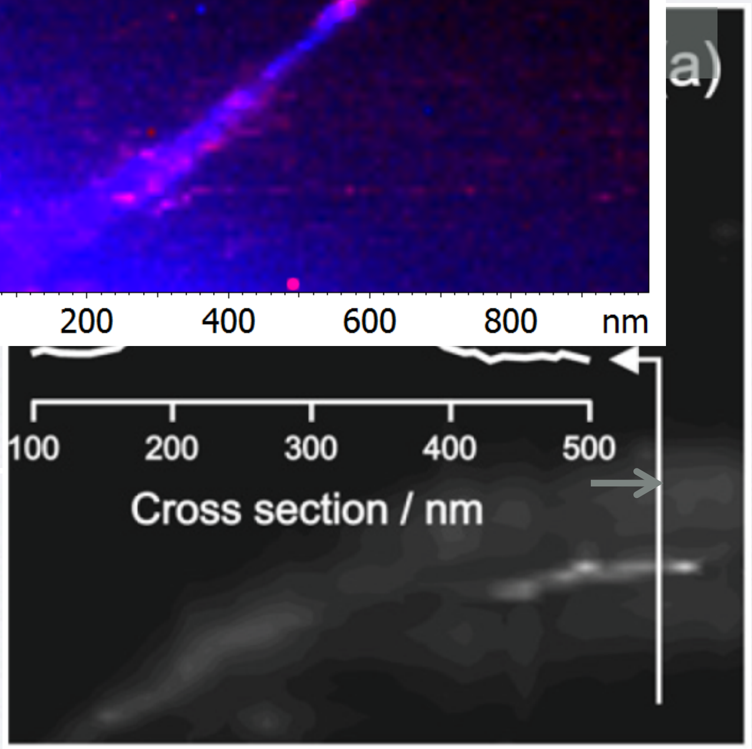
Chan K.L., Kazarian S.G., Nanotechnology 21, 445704 (2010)

Resolution: <14 nm

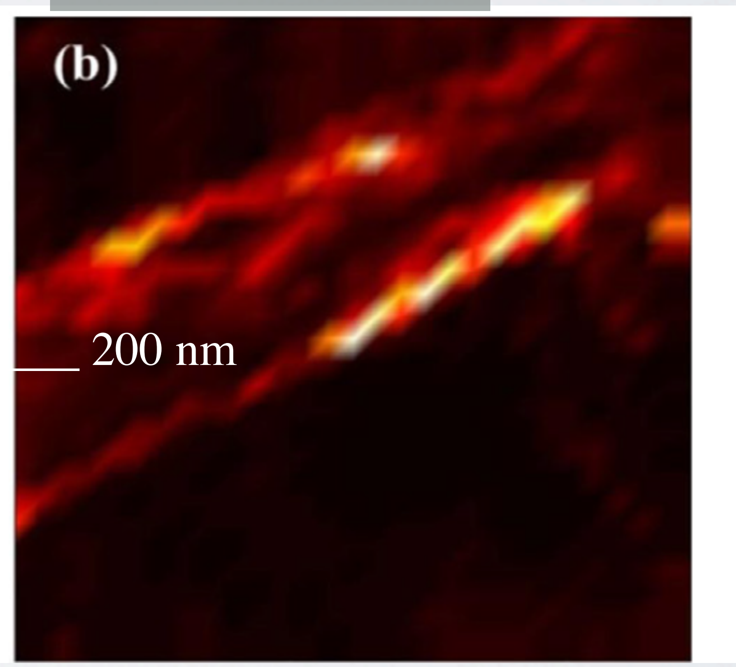
Resolution: ~30 nm



Chan K.L., Kazarian S.G., Nanotechnology 22, 175701 (2011)



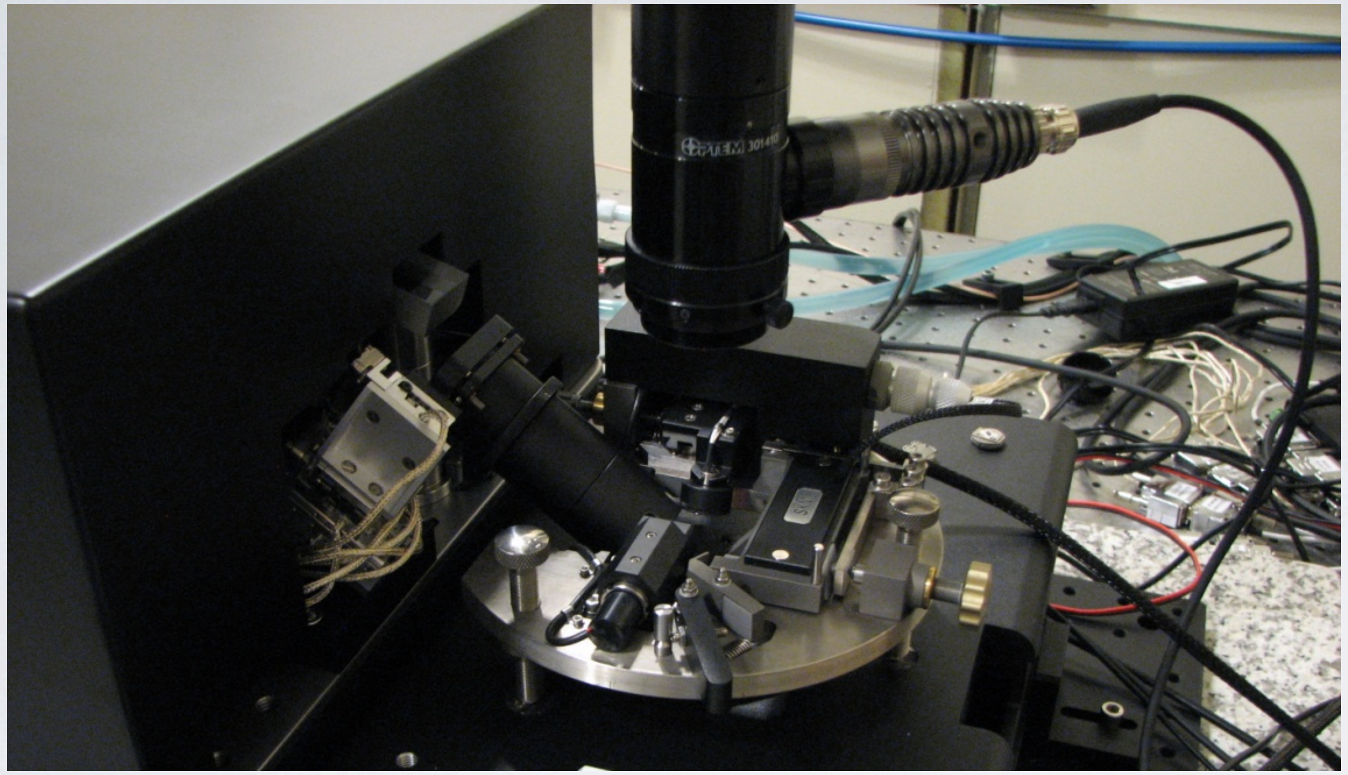
S. Kharintsev, G. Hoffmann, A. Fishman. & M. Salakhov J. Phys. D: Appl. Phys. 46 (2013) 145501

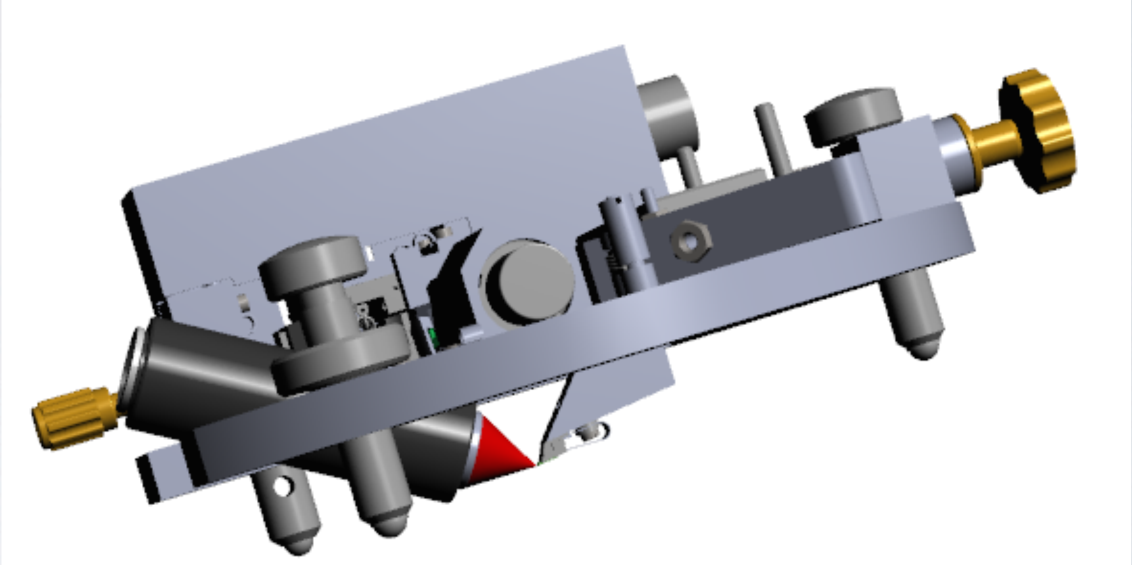


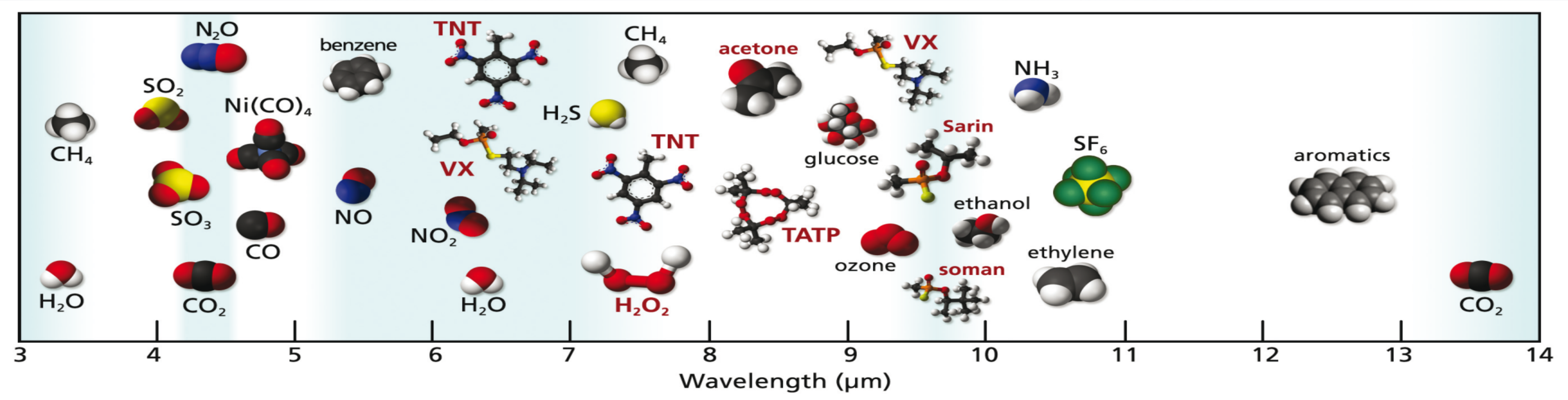
M. Zhang, J. Wang, Q. Tian, Optics Communications 315, 164 (2014)

NT-MDT Spectrum Instruments

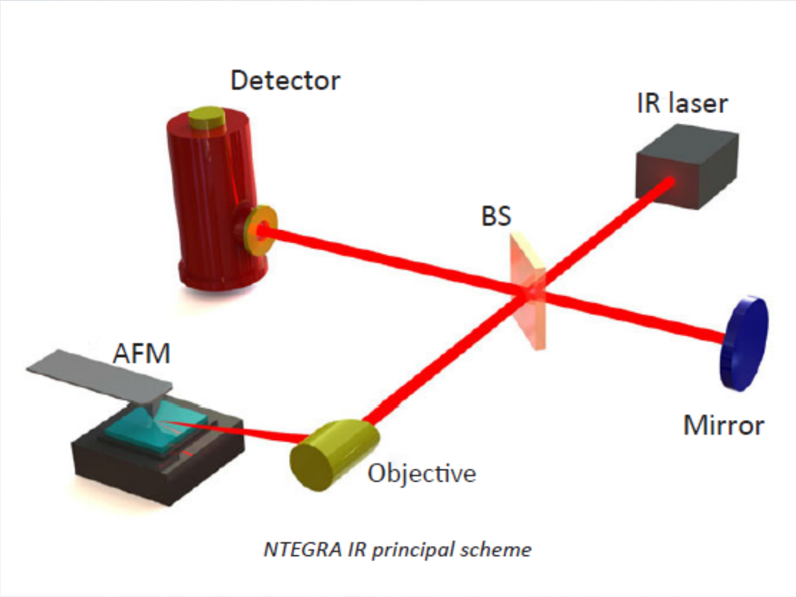
s-SNOM Head with IR objective

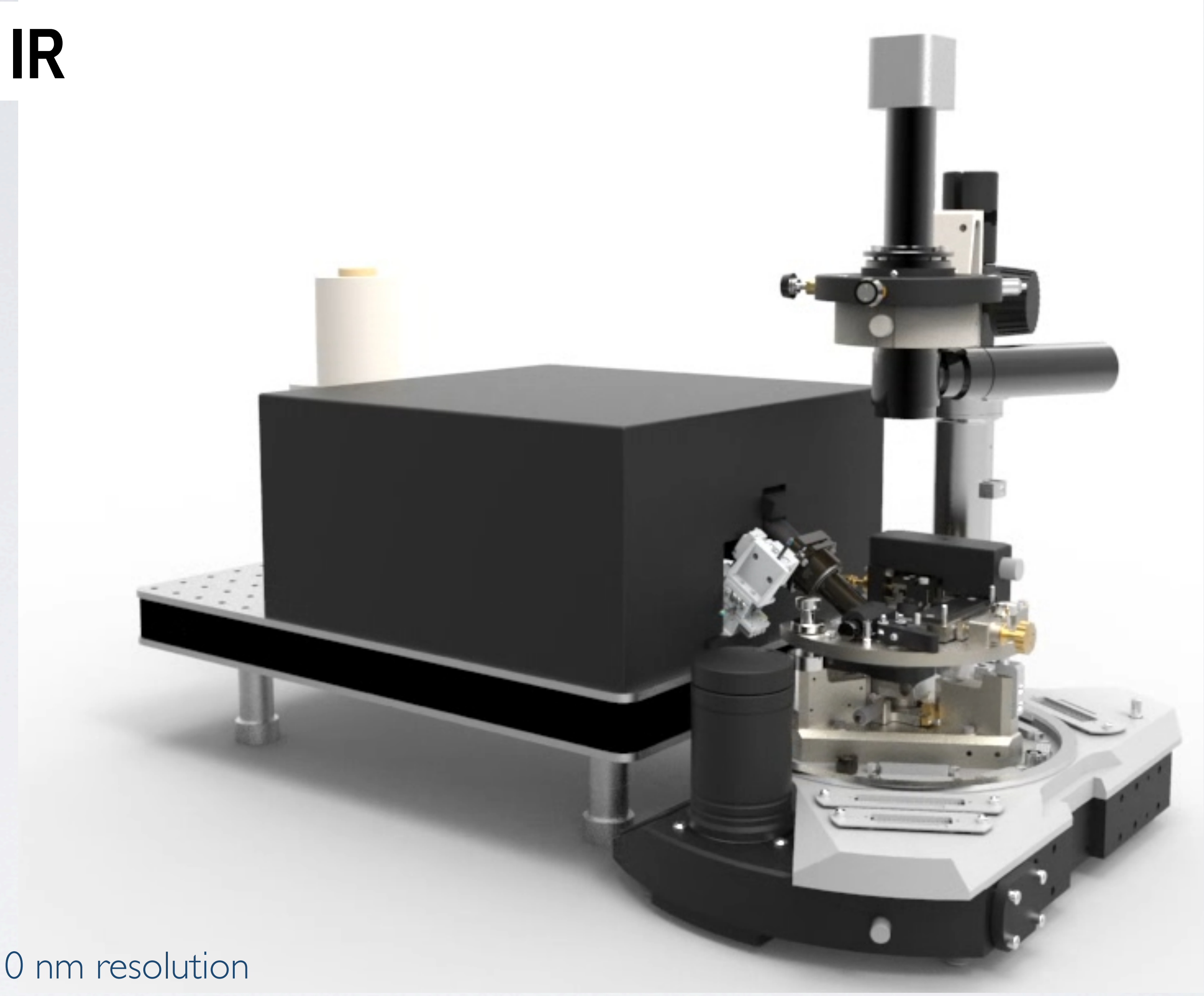






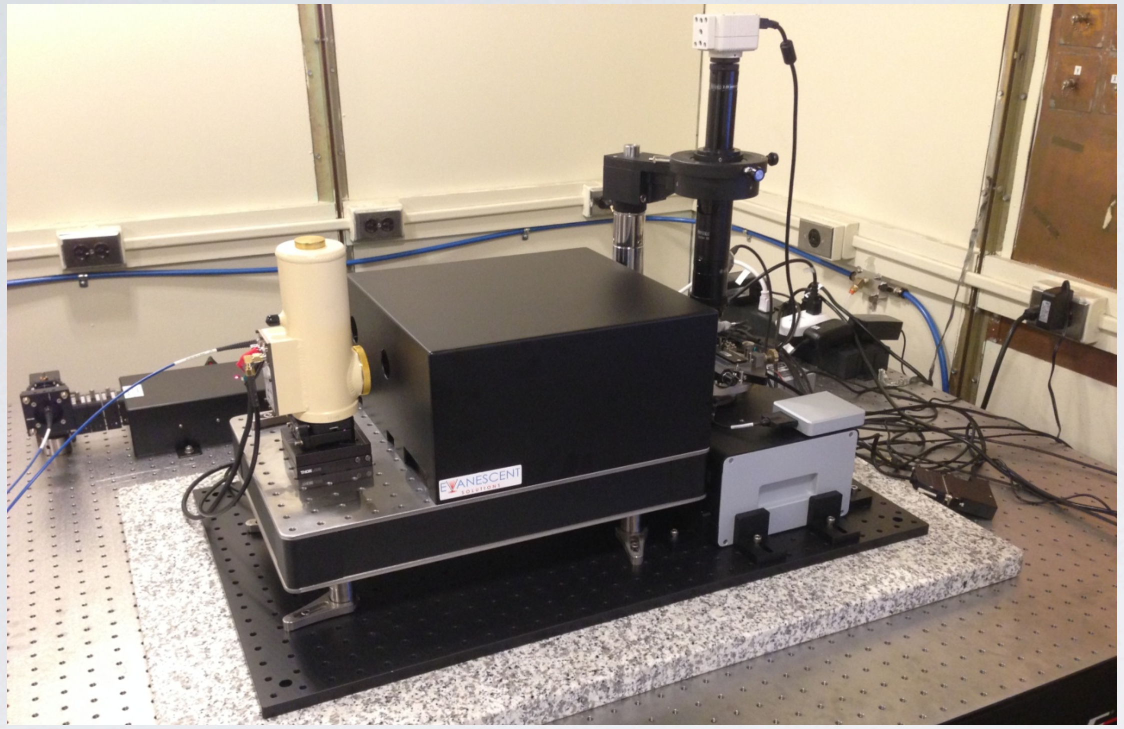
NTEGRA IR



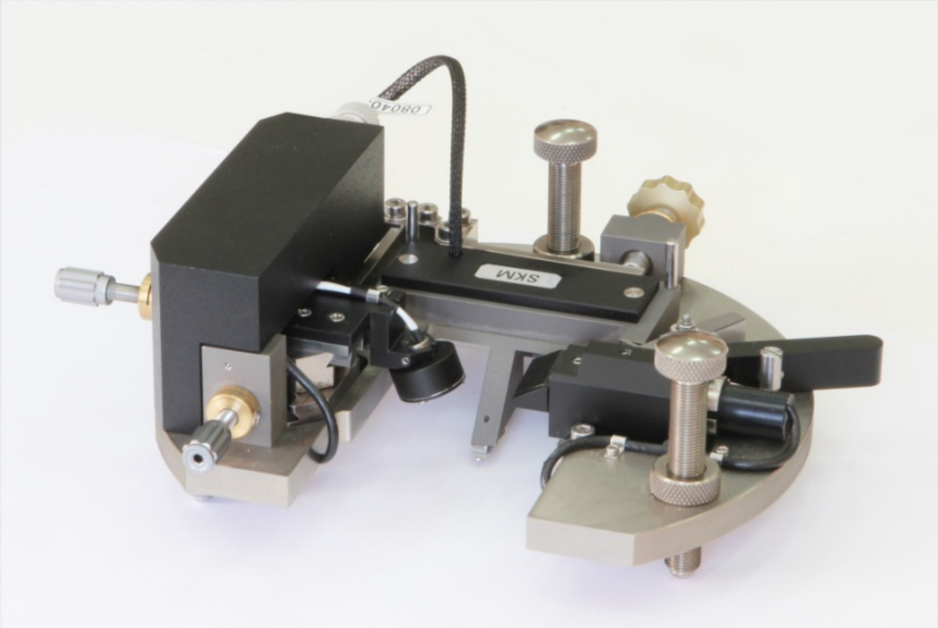


- IR microscopy and spectroscopy with 10 nm resolution
- Wide spectral range of operation: 3-12 μm
- Incredibly low thermal drift and high signal stability
- Versatile AFM with advanced modes: SRI (conductivity), KPFM (surface potential), SCM (capacitance), MFM (magnetic properties), PFM (piezoelectric forces)
- HybriD Mode - quantitative nanomechanical mapping
- Integration with Raman (optionally)

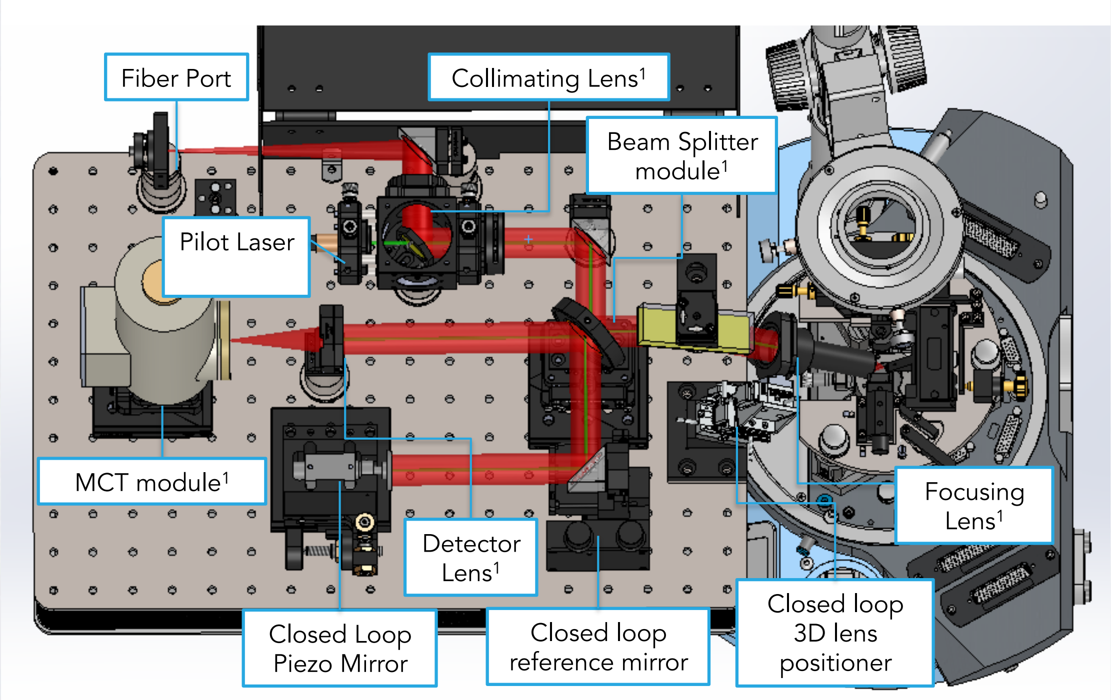
NTEGRA NANO INFRARED: s-SNOM investigation in IR Spectra Region

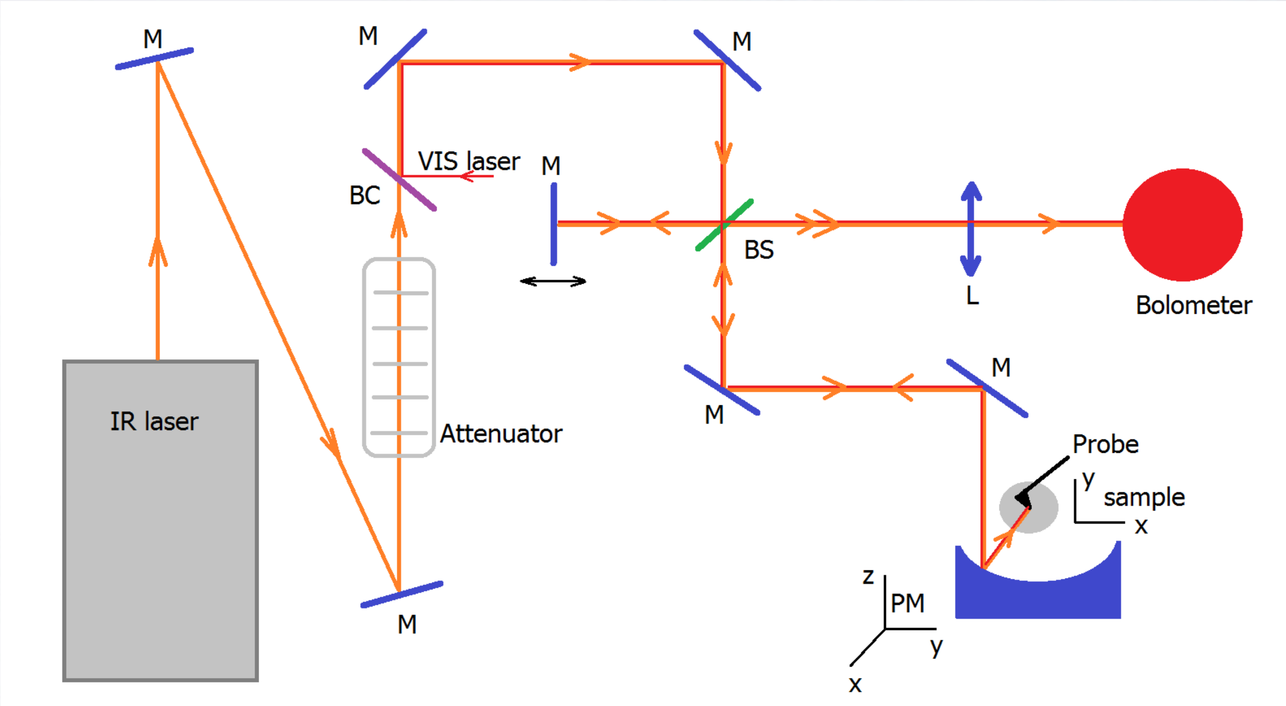


ИНТЕГРА нано-ИК (университет Стони Брук, NY)



Измерительная АСМ-головка с доступом для параболического зеркала

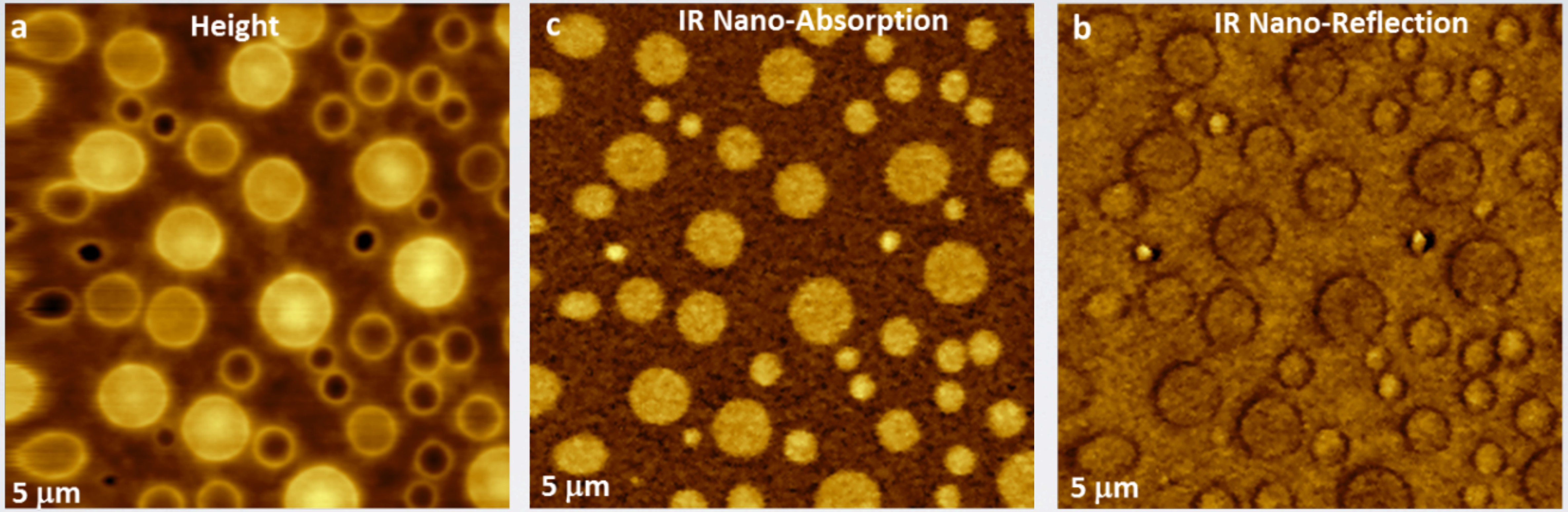




Оптические схемы прибора: ввод излучения лазера по волокну с фокусировкой и сбором рассеянного излучения через объектив (слева) и прямой ввод лазерного излучения с фокусировкой и сбором с помощью параболического зеркала (справа)

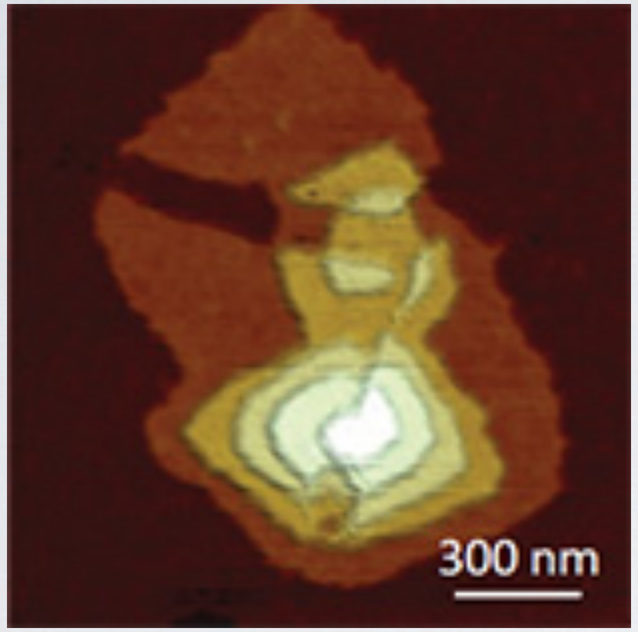
Contrasts of IR absorption and reflection on polymer structures

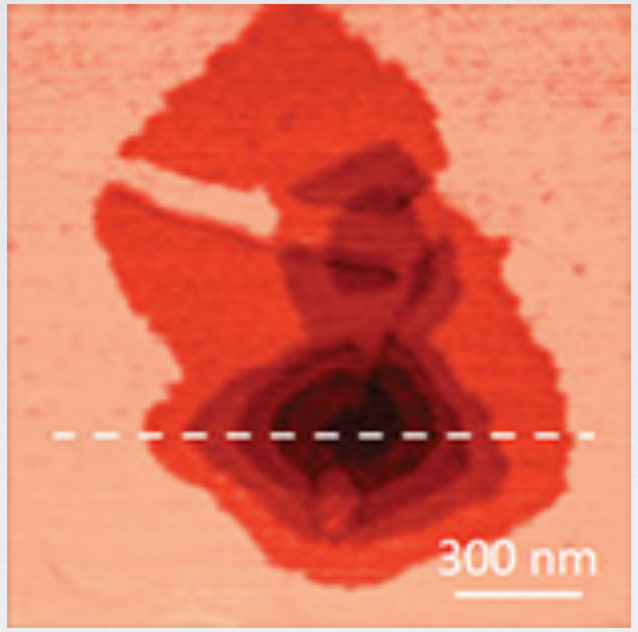
Thin film of polystyrene / polyvinyl acetate on the surface of ITO

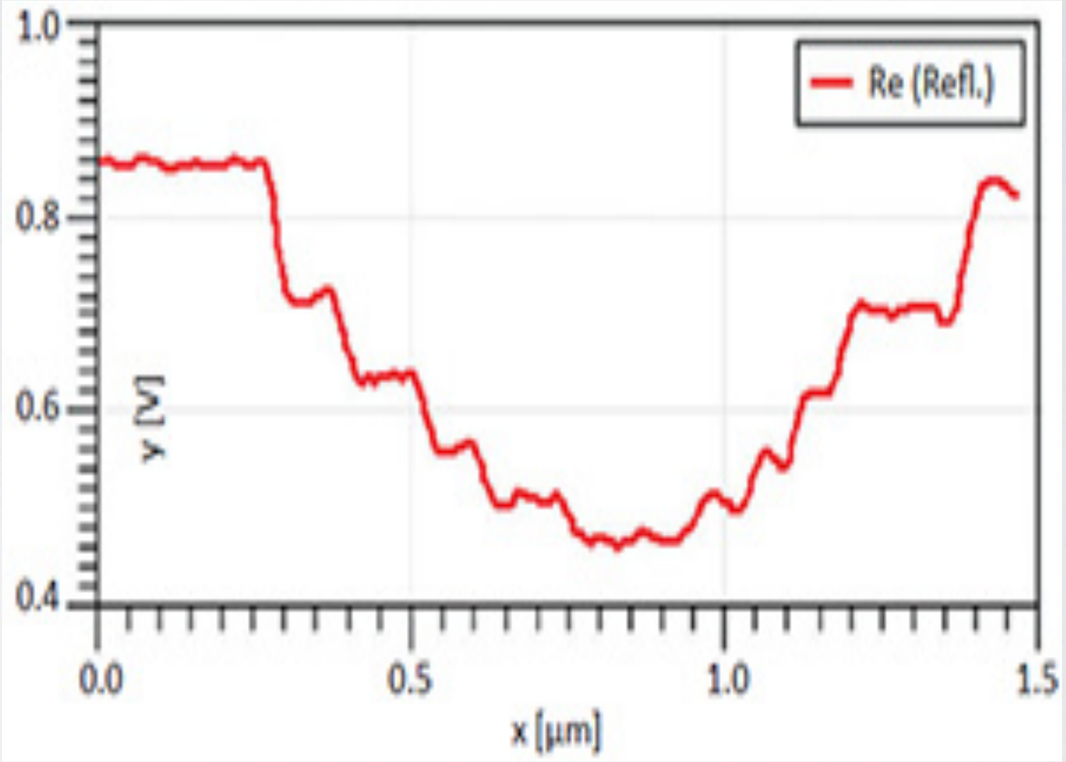


The surface relief (on the left), the contrast of the IR absorption (in the center), and the IR reflection (right) Wavelength: 10.6 μm The absorption and reflection contrasts were obtained by sequentially measuring the s-SNOM signal for two positions of the reference mirror of the interferometer. The initial setting of the mirror position is performed over the ITO substrate

Ultrafine films: monolayers of oligothiophene on silicon



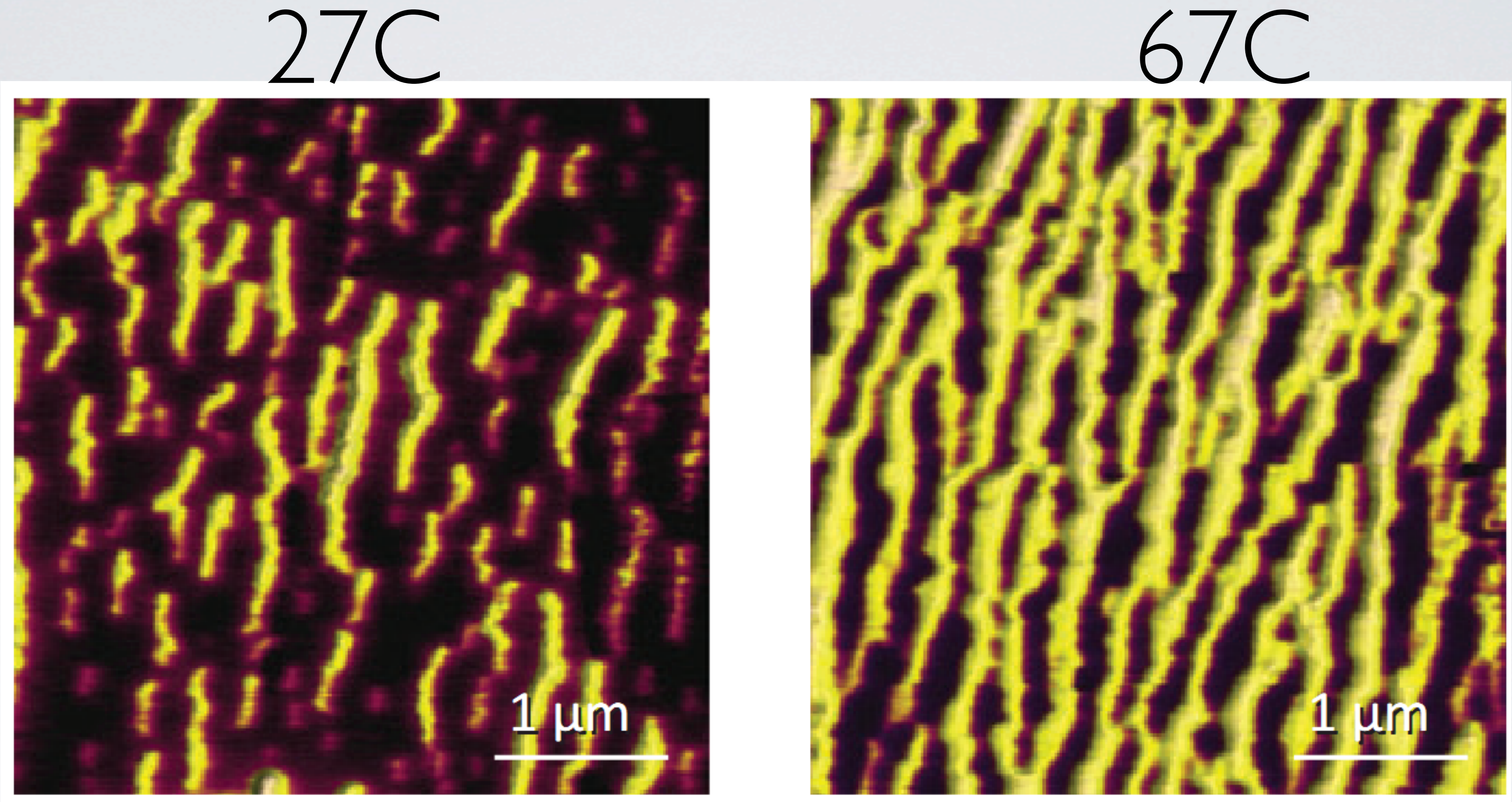




The surface relief (on the left), the contrast of the IR reflection (in the center) and its cross section (on the right) Wavelength: 10.6 μm In the IR image, each of the steps with a height of 3.4 nm is well solvable

Sample courtesy to Dr. A. Mourran (DWI, Aachen, Germany). Measured by Dr. G. Andreev (EVS Co)

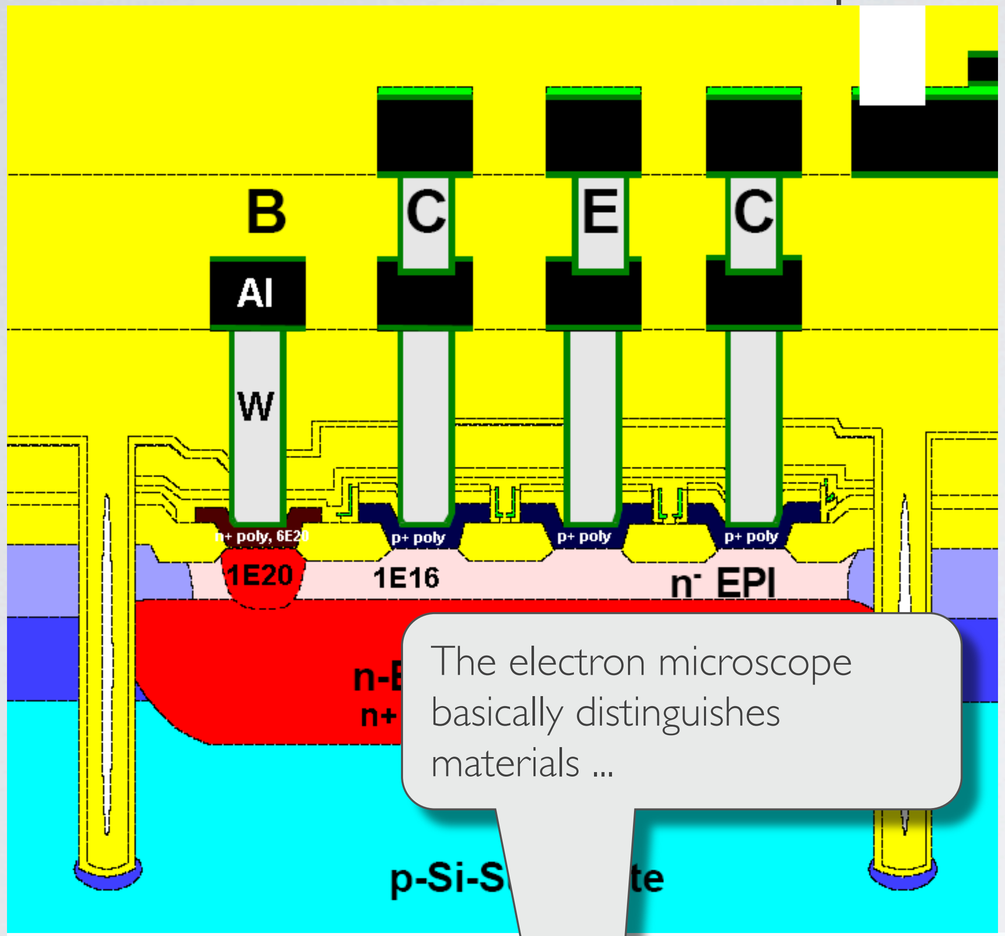
Temperature dependences of s-SNOM contrasts: VO_2



Imposition of contrast of IR reflection and surface relief at 27 ° C (left) and 67 ° C (right)

Sample courtesy to prof. Liu (Stony Brook University, New York, USA)

Bipolar transistor (Si) Skew plate with a planar p-n-p transisto



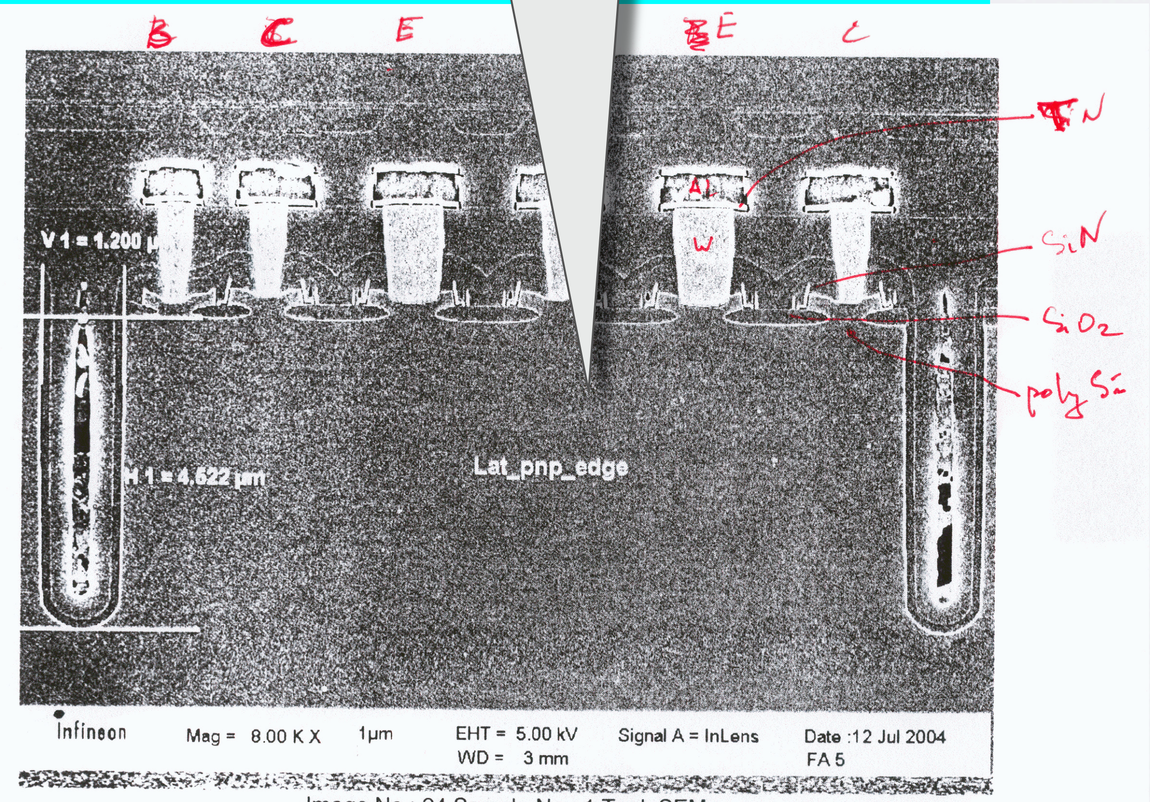
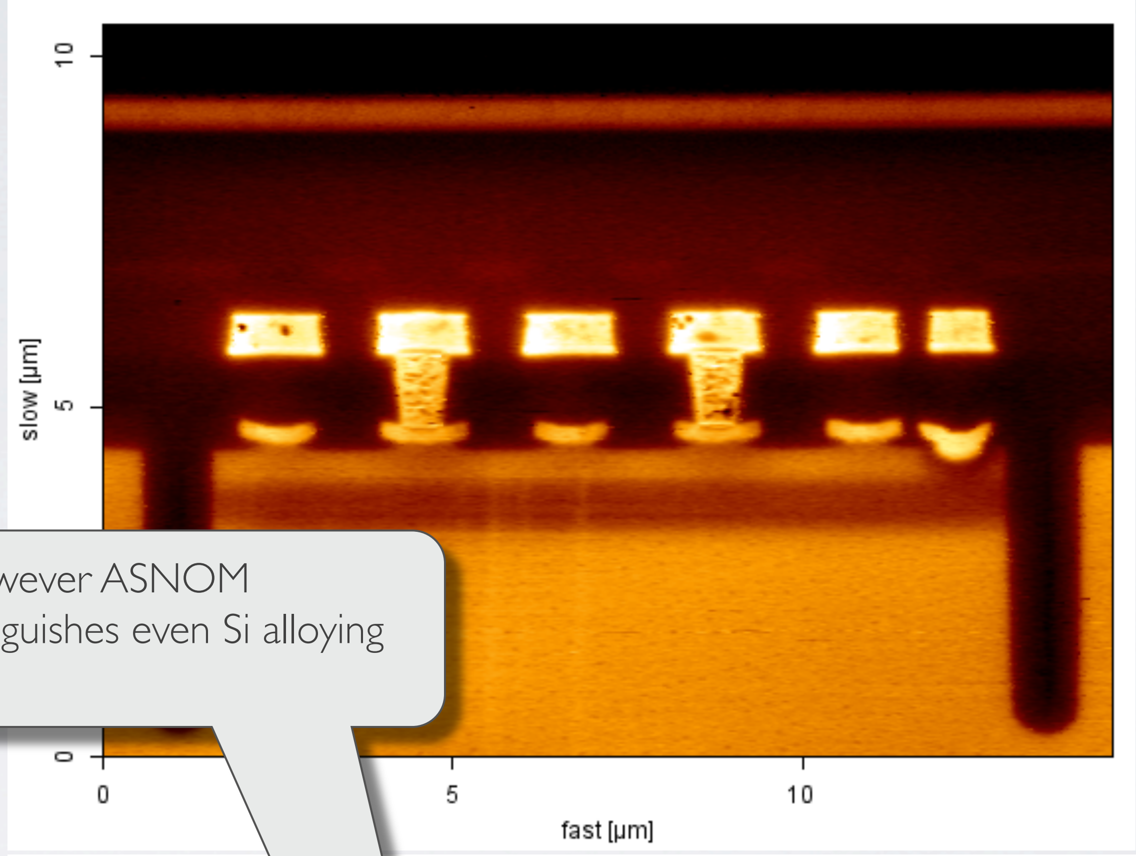
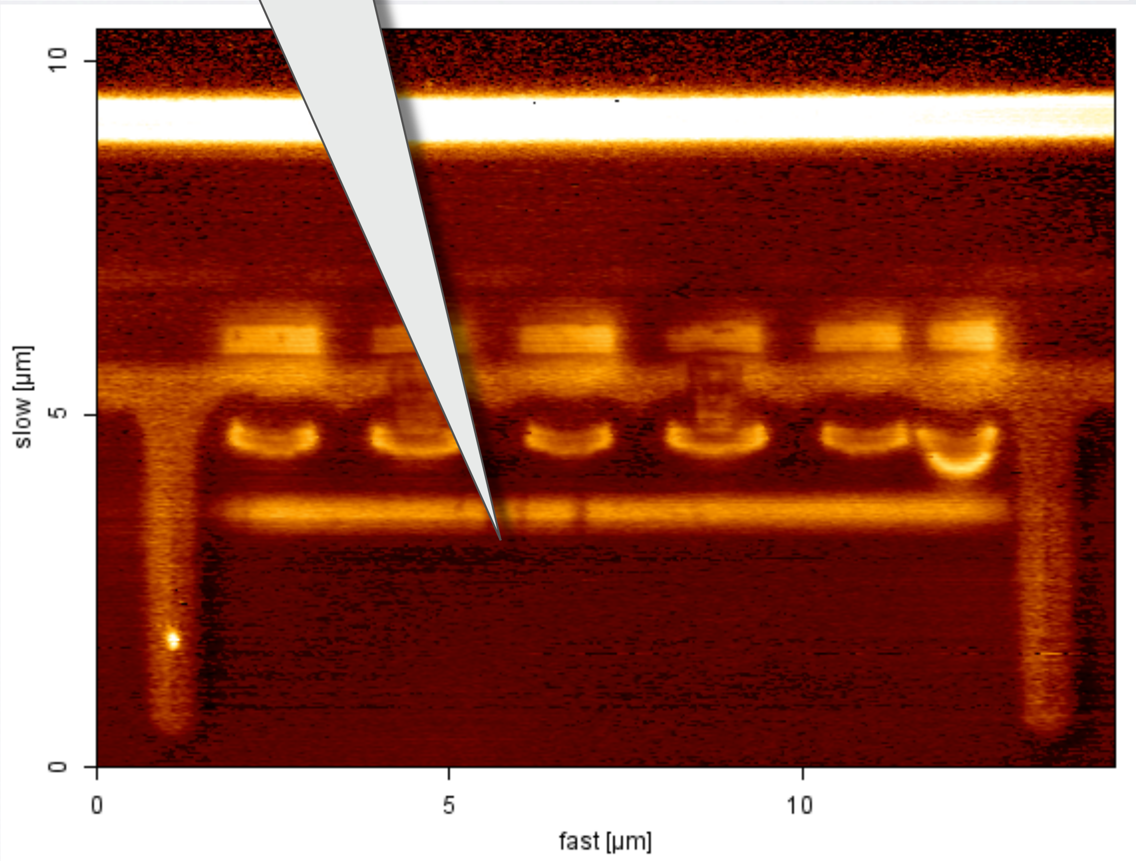


Image No.: 24 Sample No.: 1 Tool: SEM
Lateral pnp transistor, edge - Panorama with trench

The electron microscope basically distinguishes materials ...

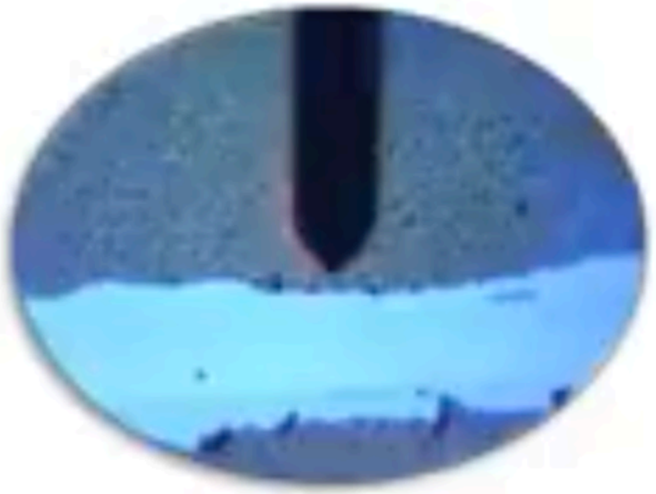


... however ASNOM distinguishes even Si alloying



NT-MDT Spectrum Instruments

*Fast*Spectra: Reverse Osmosis Membrane



Optical Image

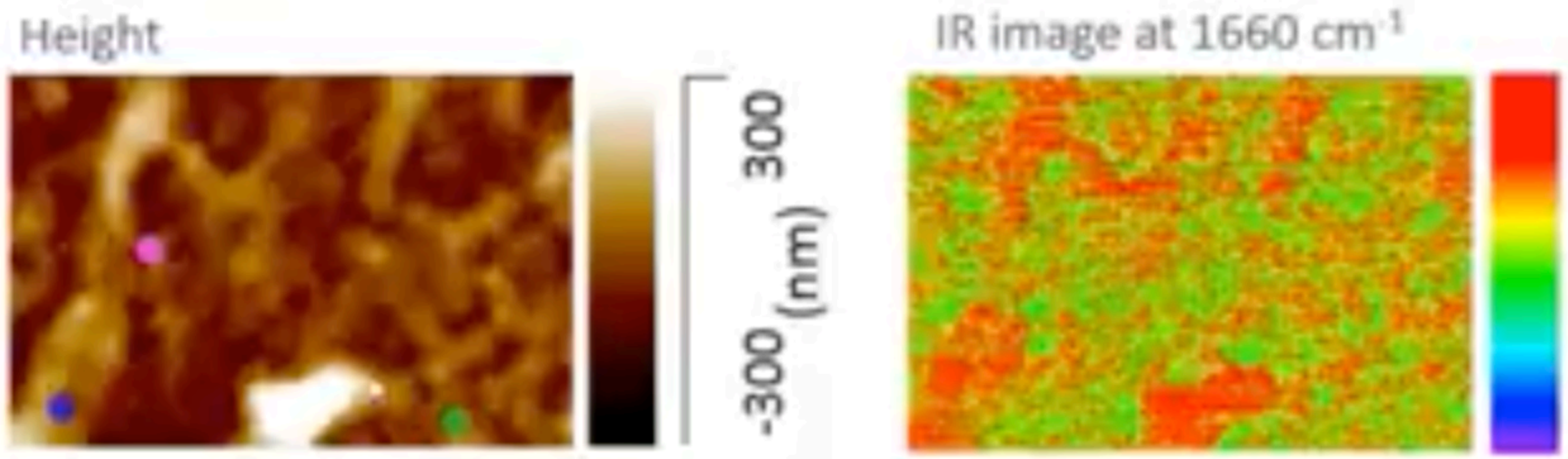
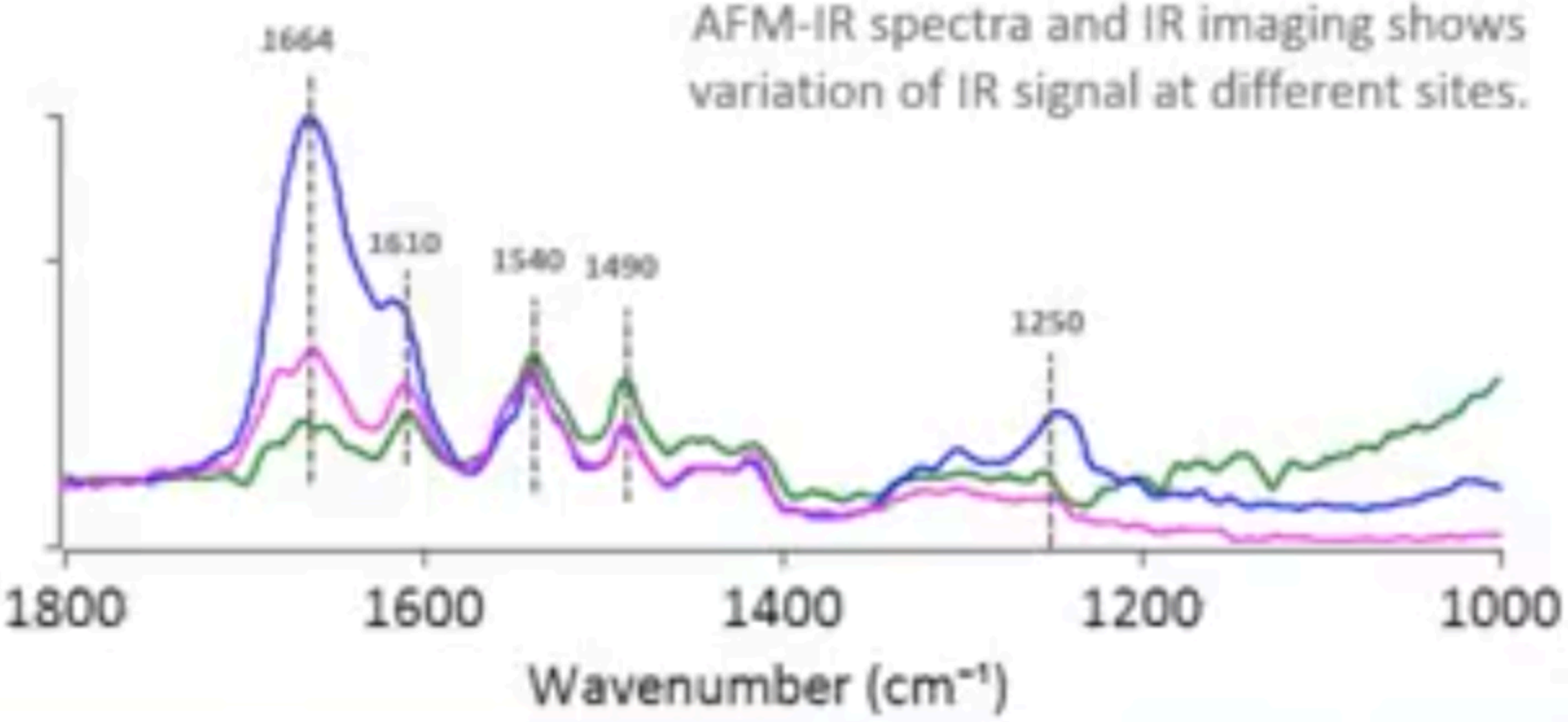
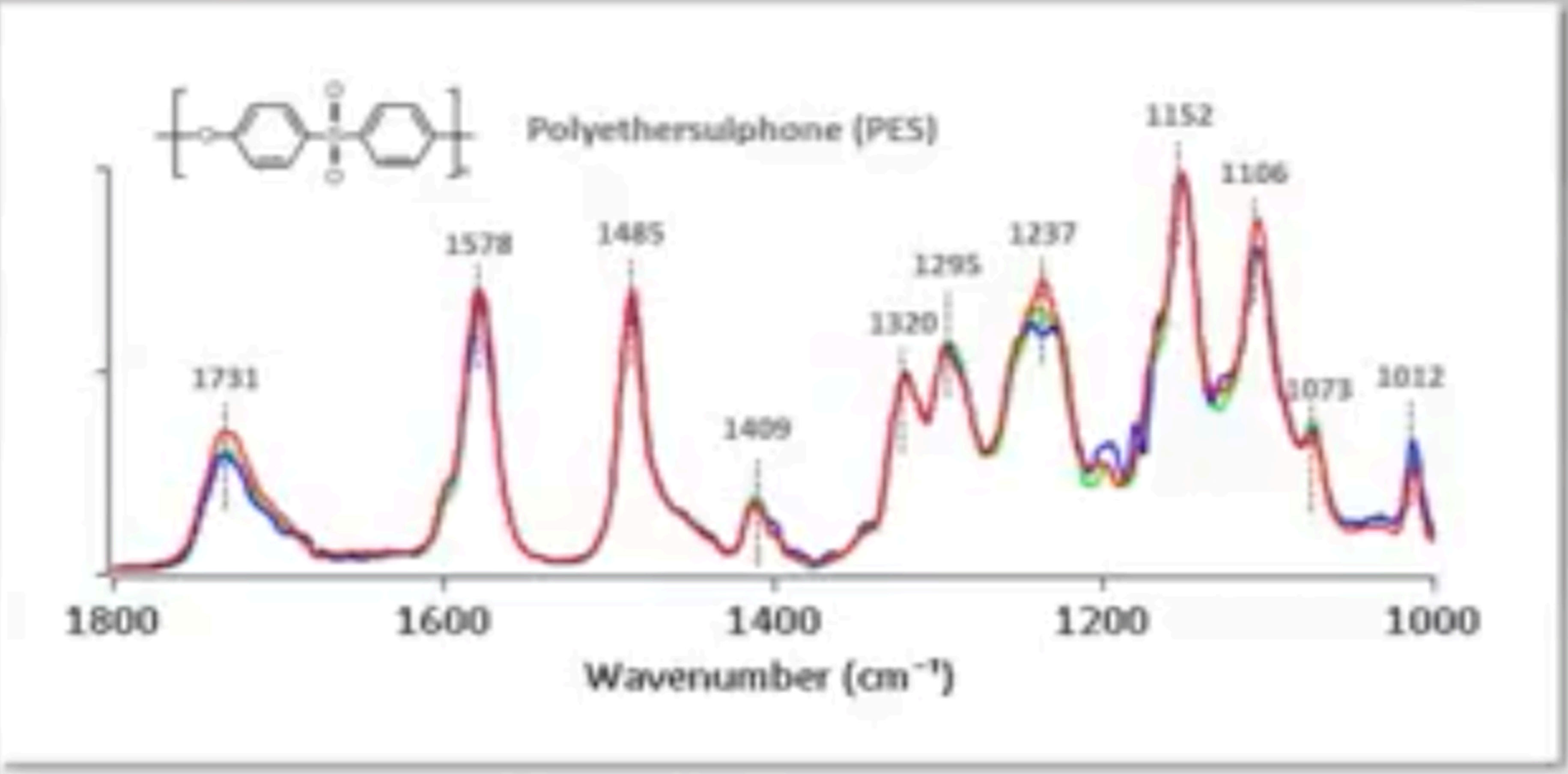


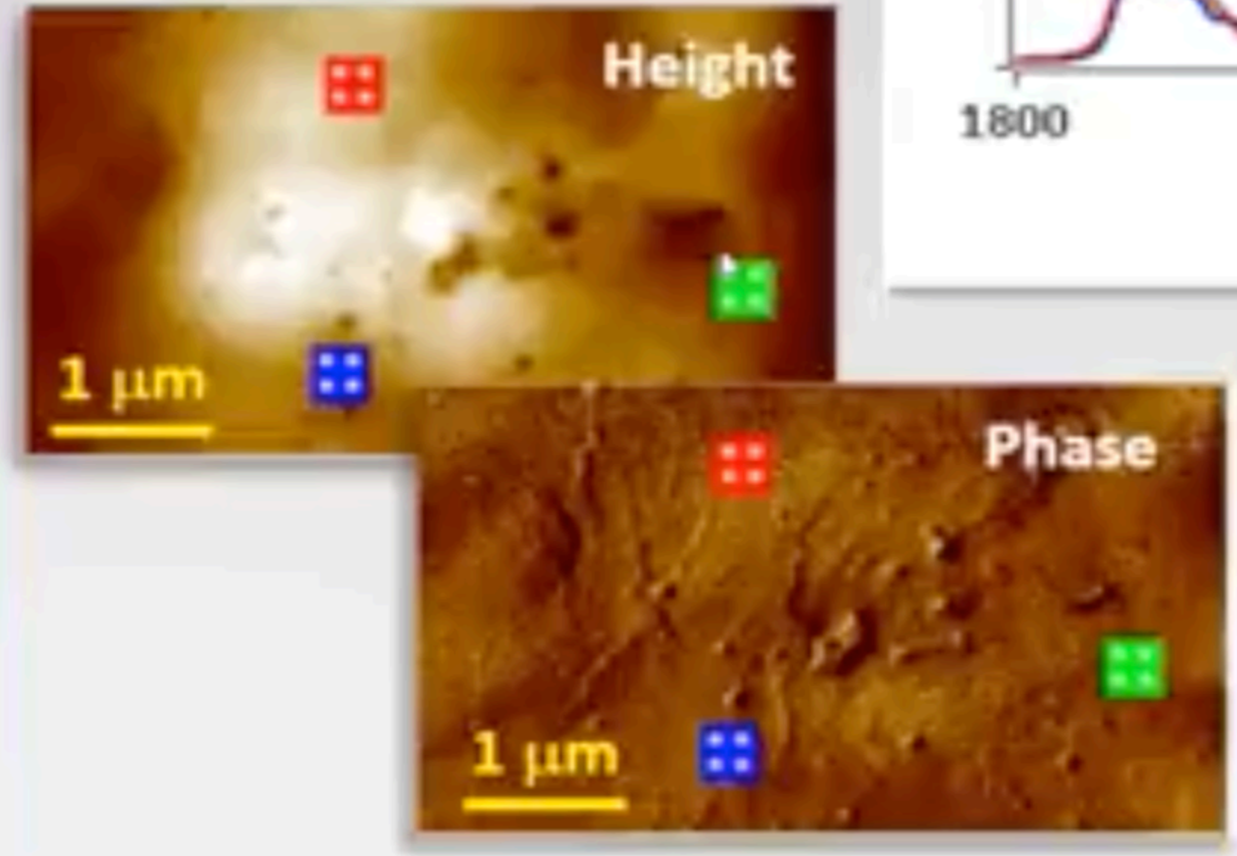
Image size: 15 um x 10 um

AFM-IR spectra and IR imaging shows variation of IR signal at different sites.



*Fast*Spectra: polyethersulfone



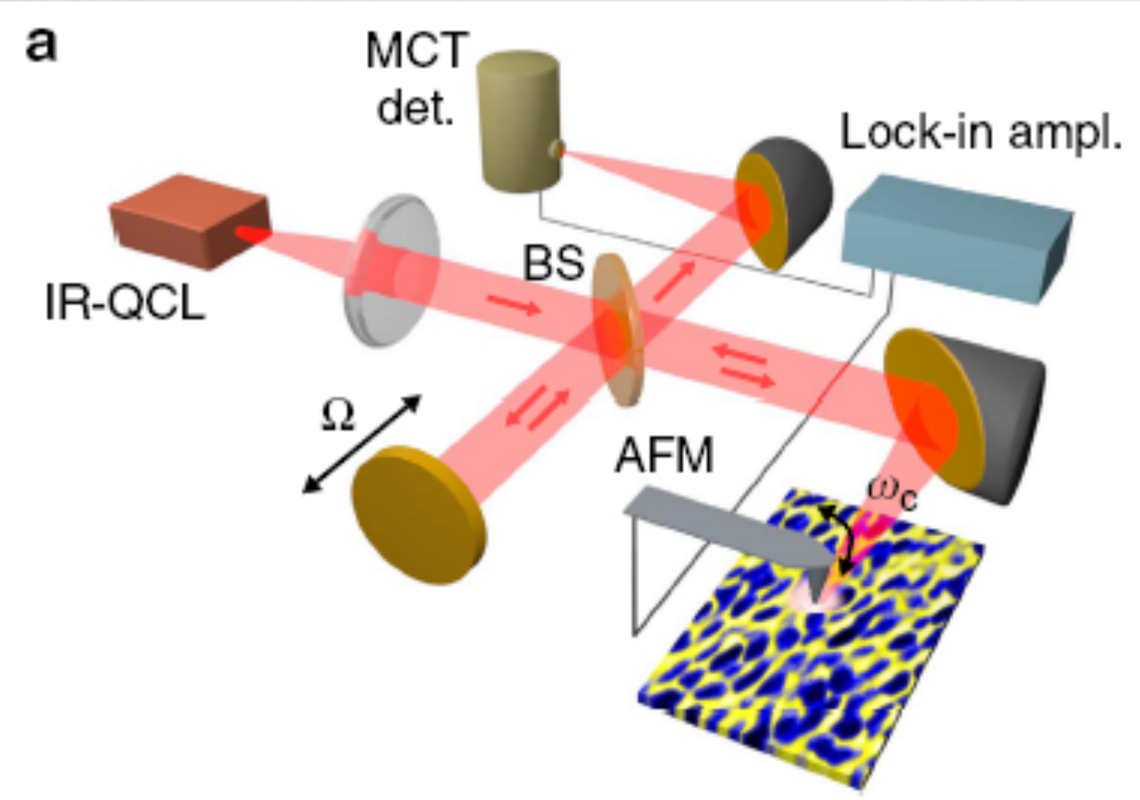


Spectral assignments

S = O sym. stretch:1152,1295
CSO_2C asym. stretch: 1320
C-O asym. stretch: 1000-1240
Benzene ring stretch: 1485, 1578
Carbonyl: 1731

The development of ASNOM studies using broadband radiation sources - ASNOM

Cascade laser



Pollard, B.; Muller, E. A.; Hinrichs, K. & Raschke, M. B. Vibrational nano-spectroscopic imaging correlating structure with intermolecular coupling and dynamics.//*Nat Commun, Nature Publishing Group, a division of Macmillan Publishers Limited All Rights Reserved.*, **2014**, *5*, 3587

Incoherent source (globar)

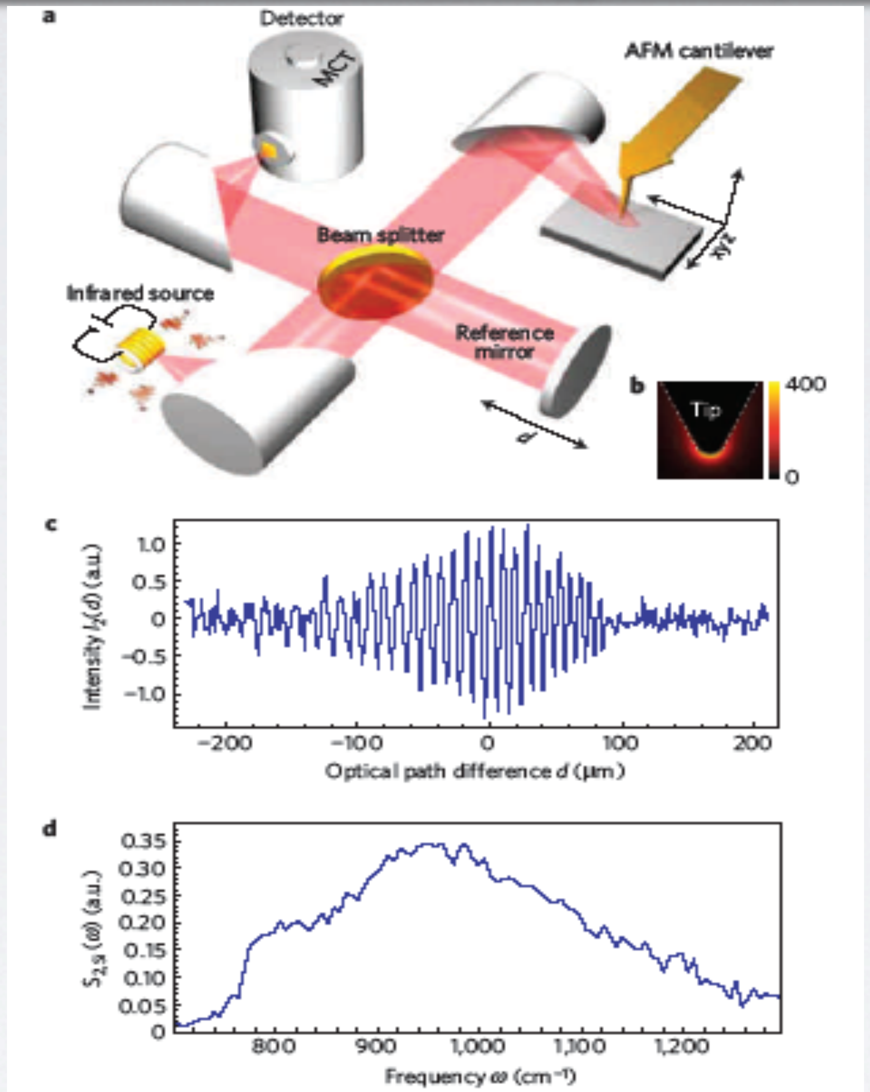
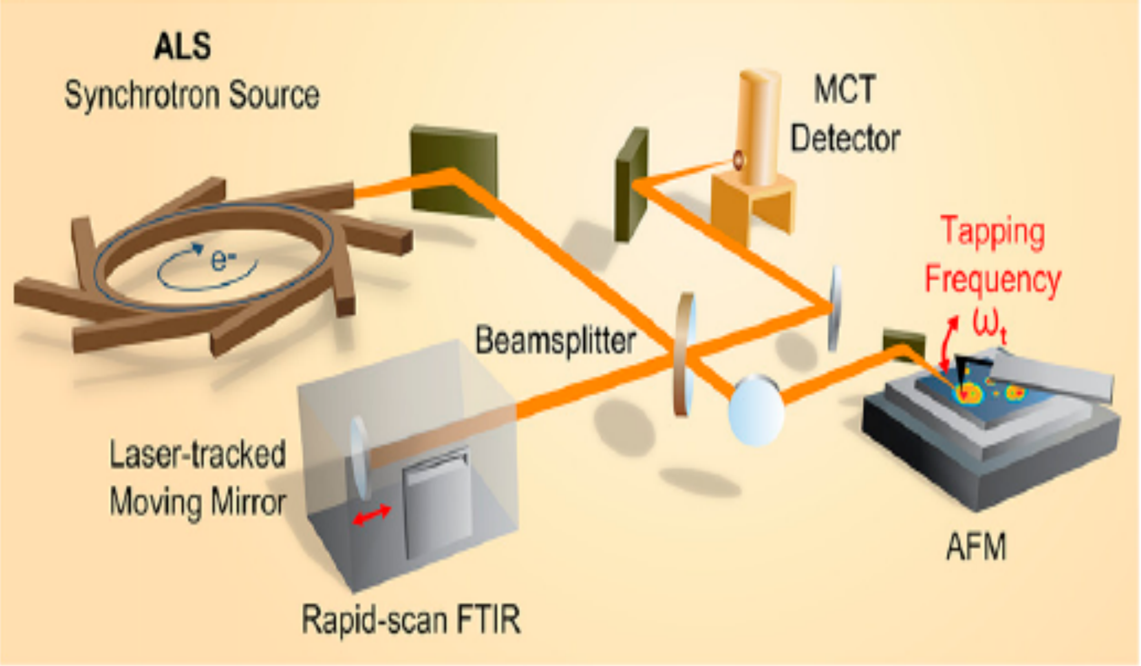


Figure 1 | Near-field spectroscopy with a thermal source. a, Experimental set-up. **b,** Numerical calculation showing the field distribution at the apex of a metal tip (10 μm long, 100 nm apex diameter), which is illuminated

F.Huth, M.Schnell, J.W.N.Ocelic, R.Hillenbrand, Infrared-spectroscopic nanoimaging with a thermal source.//Nature Materials, **2011**, 10, 352–356

Synchrotrone

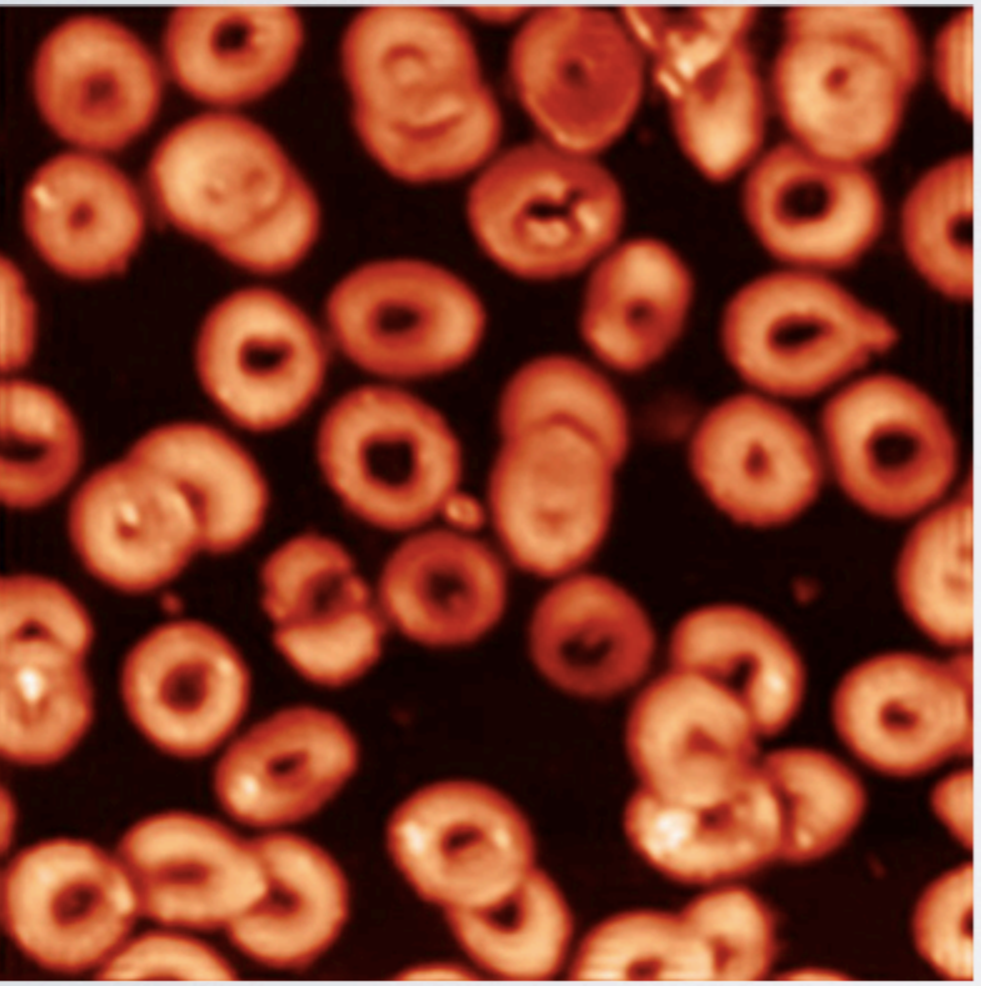


H.A. Bechtel, E.A. Muller, R.L. Olmon, M.C. Martin, M.B. Raschke, Ultrabroadband Infrared Nanospectroscopic Imaging PNAS, 2014, **111**, 7191-719

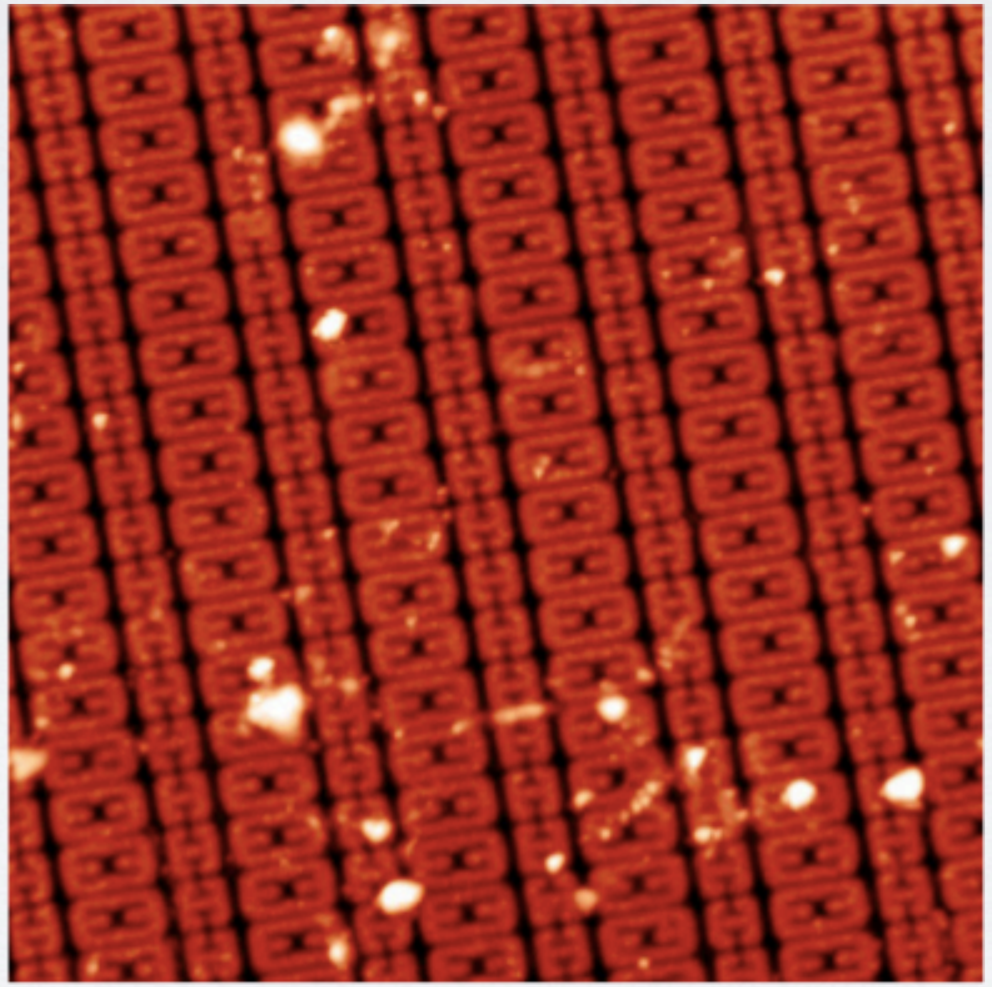
NT-MDT Spectrum Instruments

NANOEDUCATOR-II

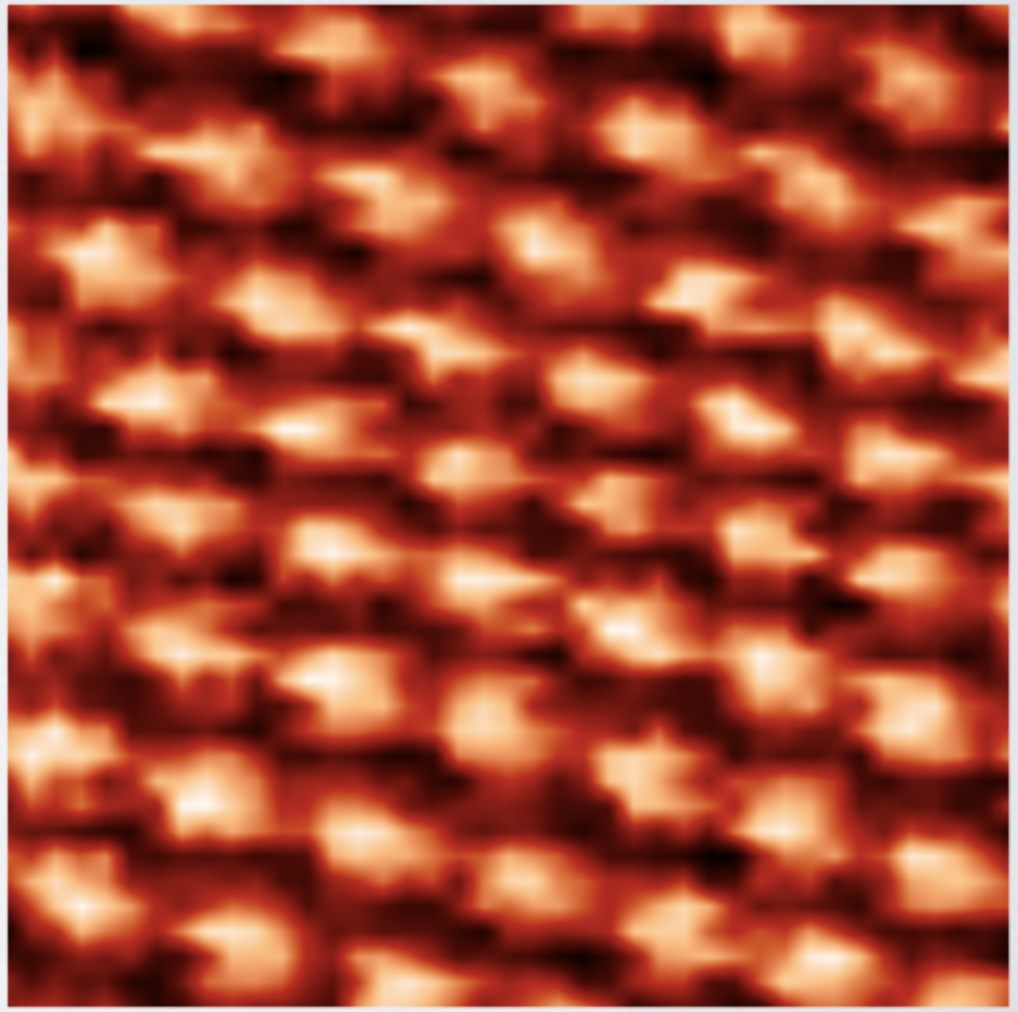
NANOEDUCATOR-2 allows and obtains atomic resolution, and measures the sizes and properties of microcircuits and investigates biological structures



Human erythrocytes, AFM
scan size 50×50 μm



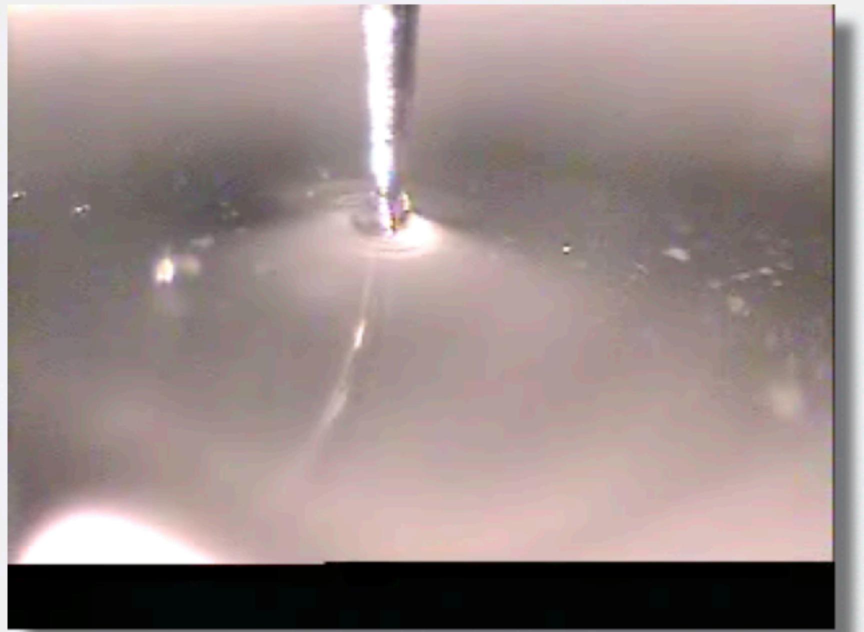
IC, AFM
scan size 30×30 μm



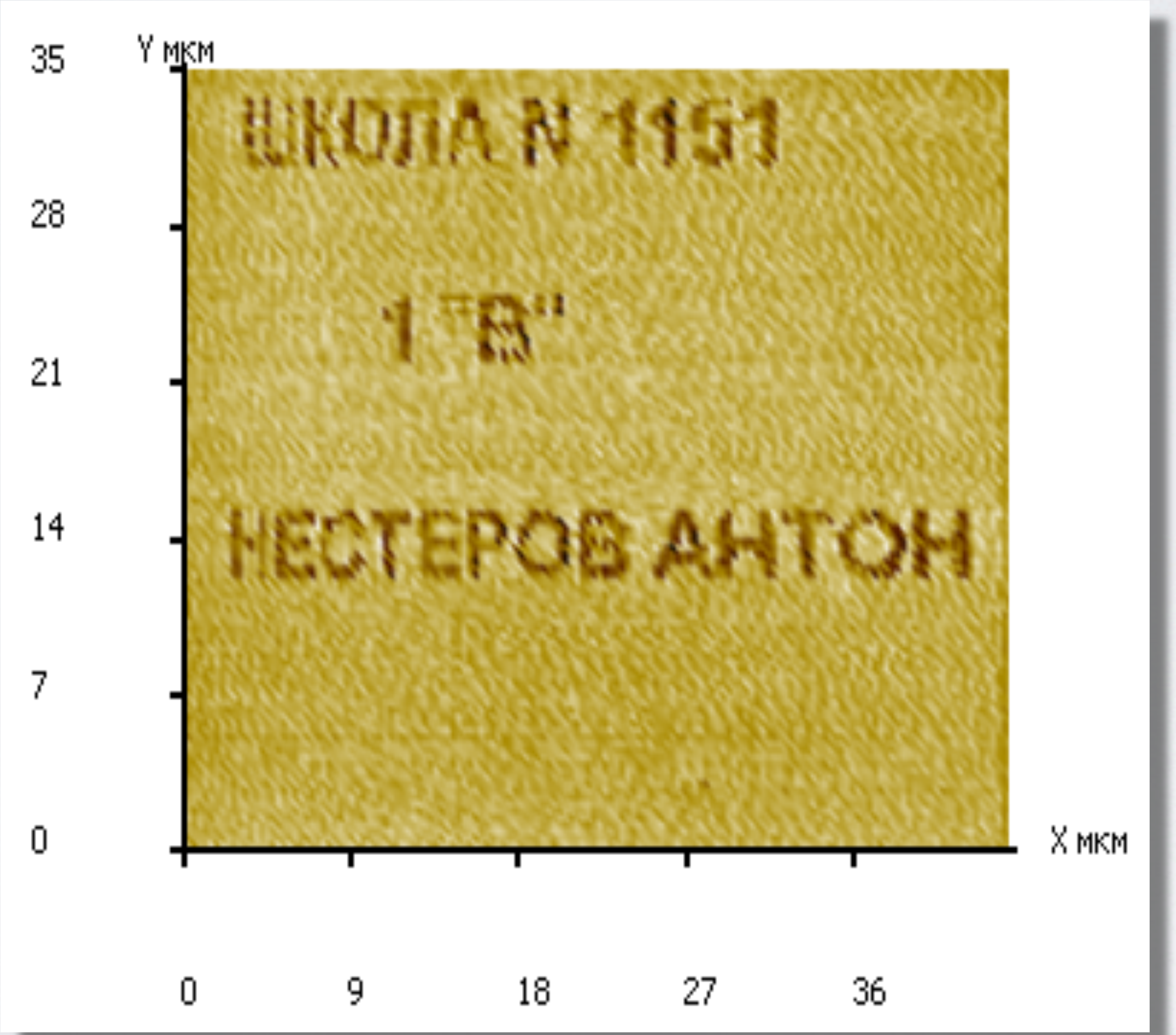
HOPG, atomic resolution, STM
scan size 2×2 nm

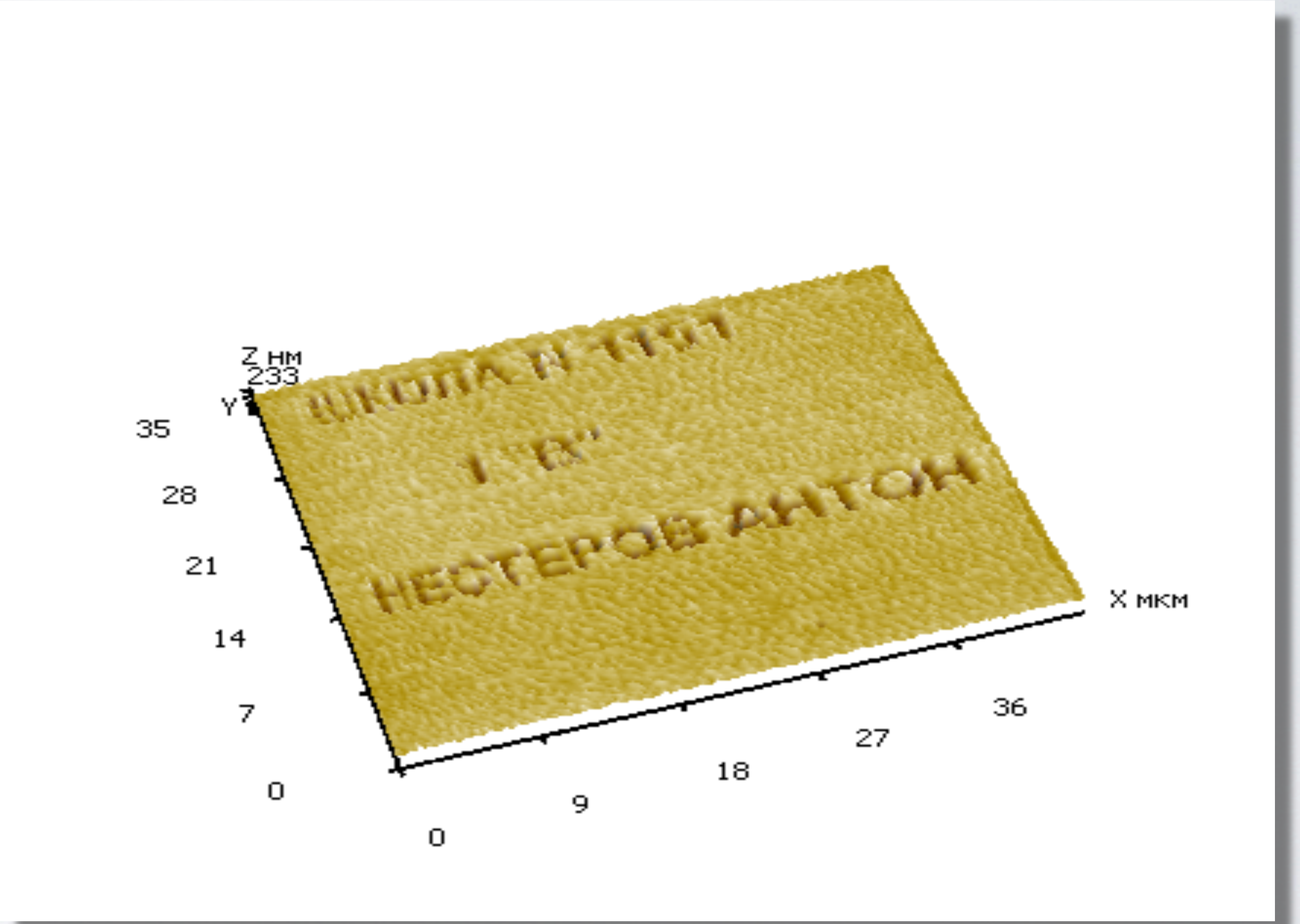
Zelenograd Education Administration State comprehensive school № 1151. Work of the pupil of 1 class "B" Nesterov Anton

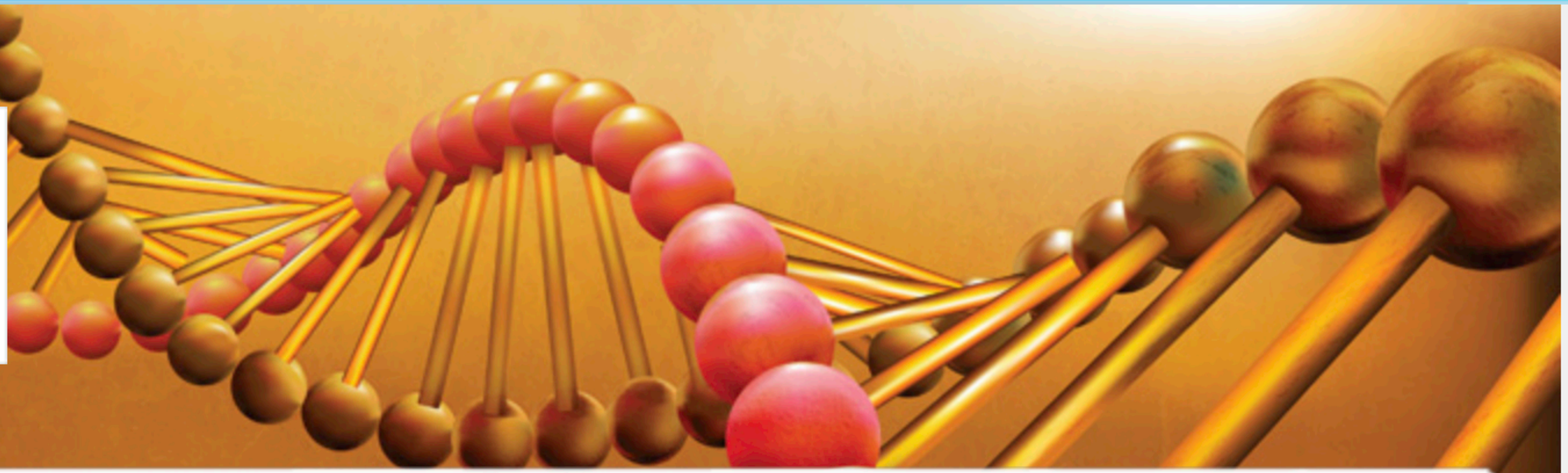
A sharp needle is made of wire. It must be sharpened with a special device. The wire is lowered into a soap solution. The tension is applied and the wire is sharpened



NANOEDUCATOR: Nano-litography made on plastic disk







НАНОТЕХНОЛОГИЧЕСКОЕ ОБЩЕСТВО РОССИИ

+ Опубликовать...

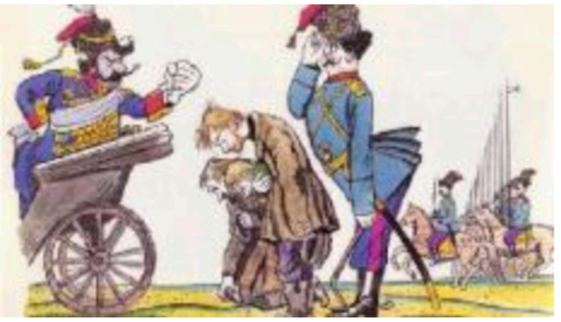
Публикации

опубликовать статью

НОР , 14.02.2017

Поздравление с юбилеем академика Евгения Каблова

Комментариев: 1 Участников дискуссии: 2



Георгий Малинецкий, 15.02.2017

Кризис жанра

Комментариев: 0

НАНОТЕХНОЛОГИЧЕСКОЕ ОБЩЕСТВО РОССИИ

НОР , 13.02.2017

Конференция Нанотехнологического общества России

Комментариев: 0

Дискуссия месяца

«Что я тут?»

Комментариев: 3, вступить в дискуссию

Блоги

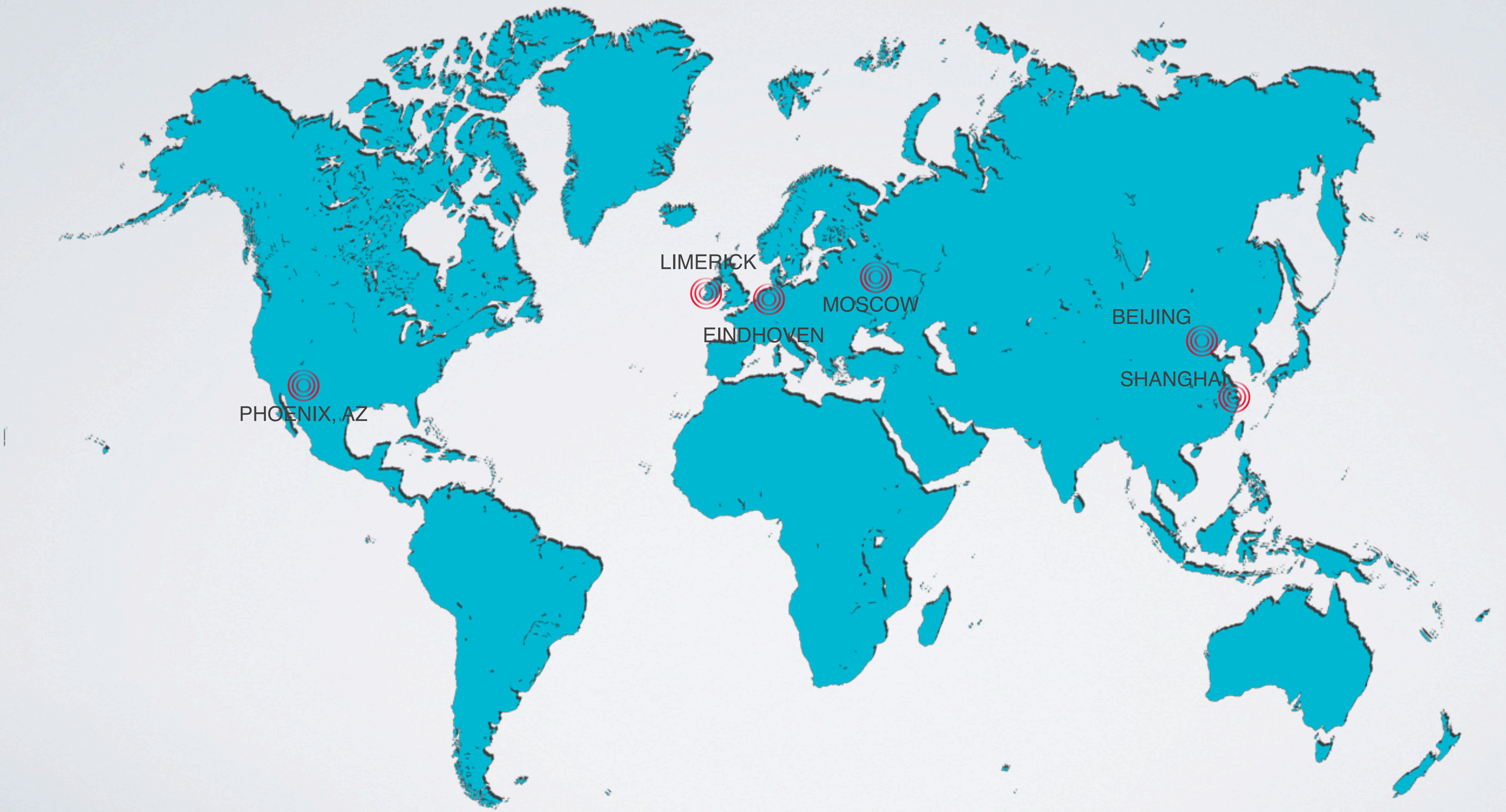
создать свой блог

НОР

Приглашение на семинар НОР-МИФИ

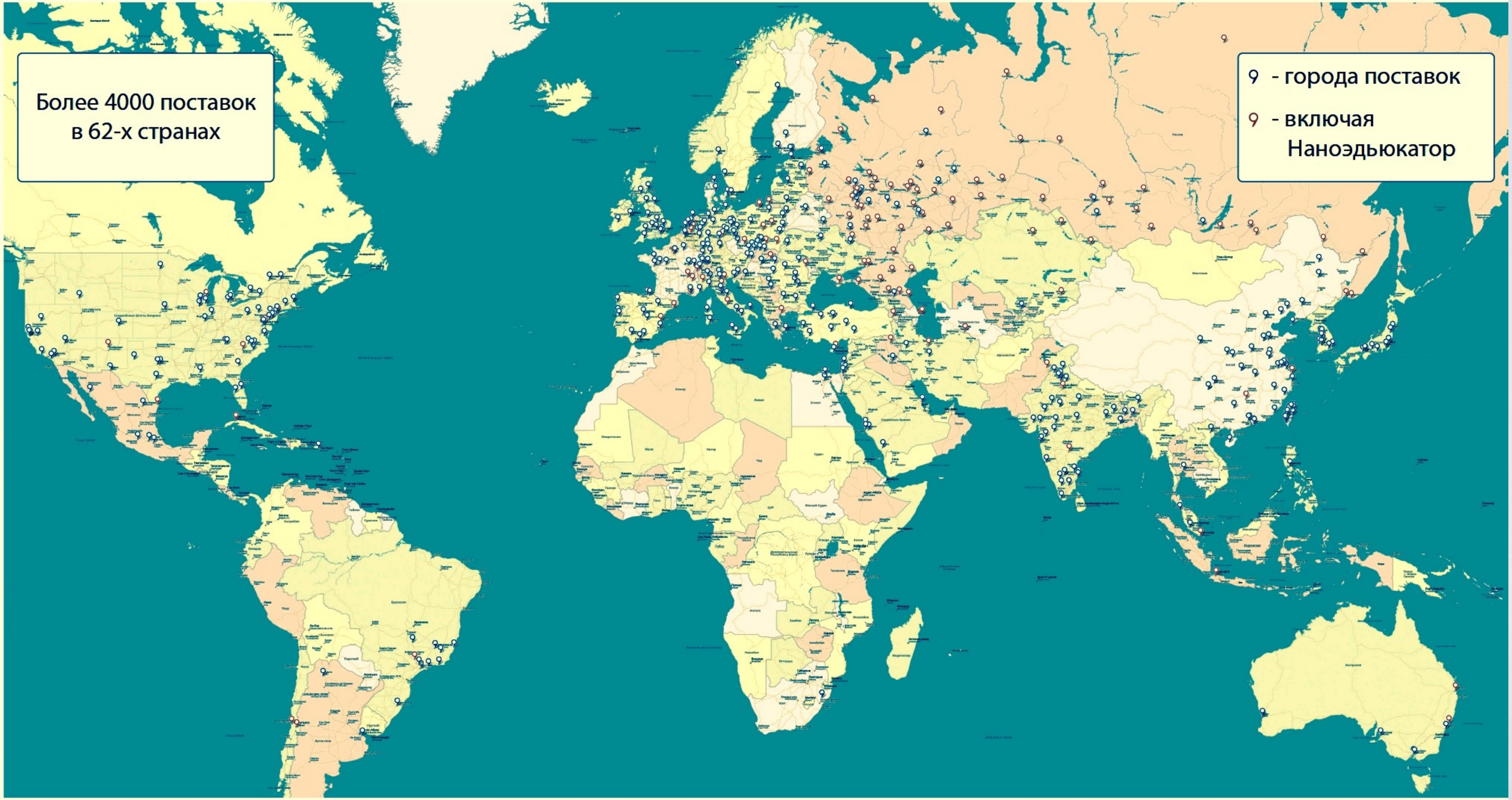
Просмотров: 2848

World Representations of «NT-MDT Spectrum Instruments



NT-MDT Spectrum Instruments

География поставок оборудования по России и миру



NT-MDT
Spectrum Instruments