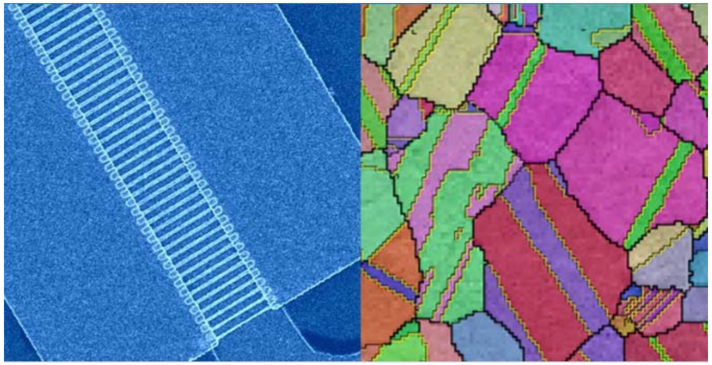
Touching the Nanoworld.

Various Ways for Surface Characterization at Nanoscale by means of AFM

Workshop on Nanomaterials Characterization.
Purdue University, Discovery Park. March, 22nd 2018

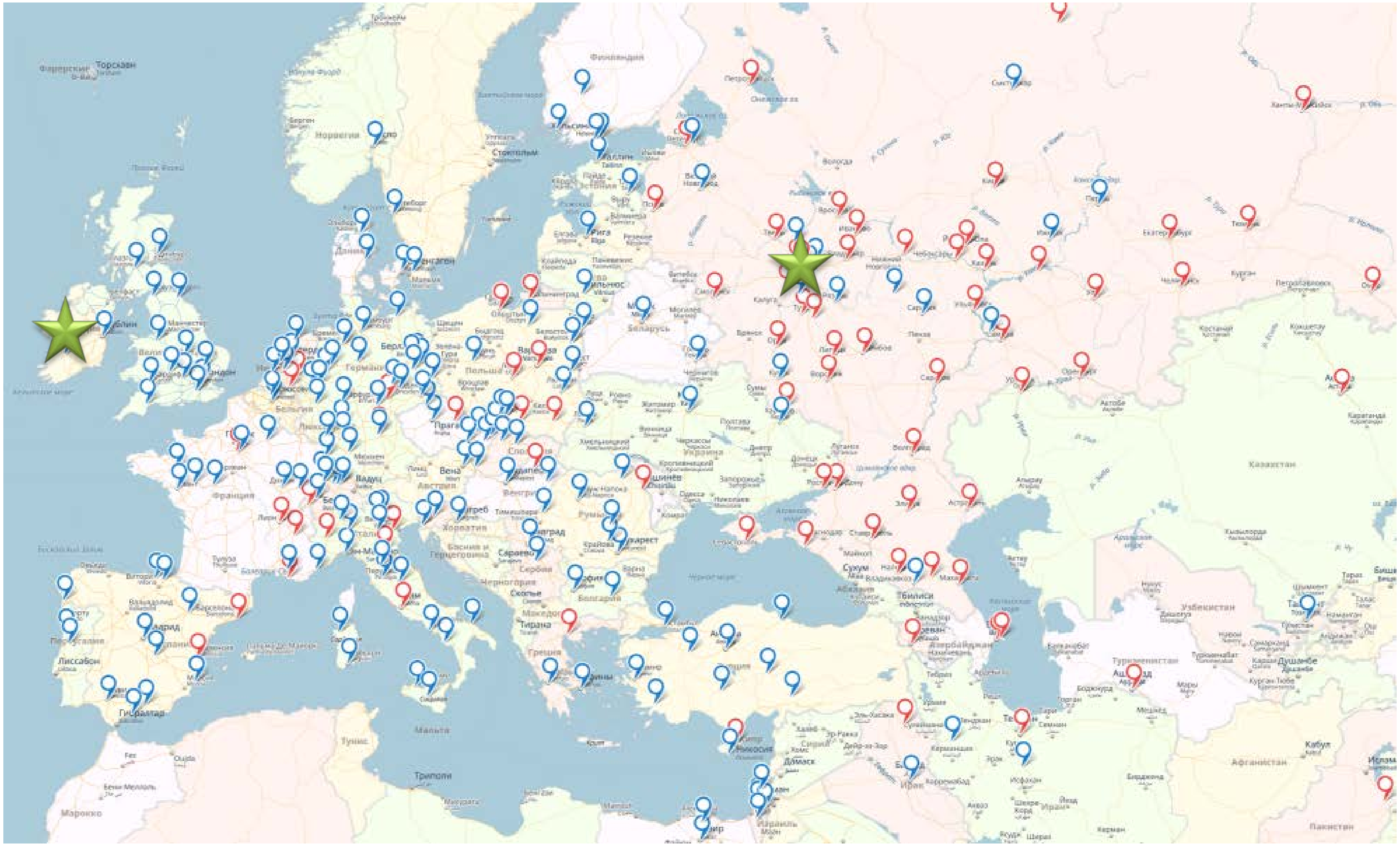
Dr. Stanislav Leesment, Senior Application Scientist
NT-MDT Spectrum Instruments



NT-MDT Spectrum Instruments

- **29 years as a manufacture of Scanning Probe Microscopes (SPM), established 1989.**
- **Global distribution channel**
- **Global infrastructure for sales, applications and support**
- **Over 150 employees globally**
- **More than 4000 system installation in 62 countries**
- **One of the 3 largest SPM companies globally**

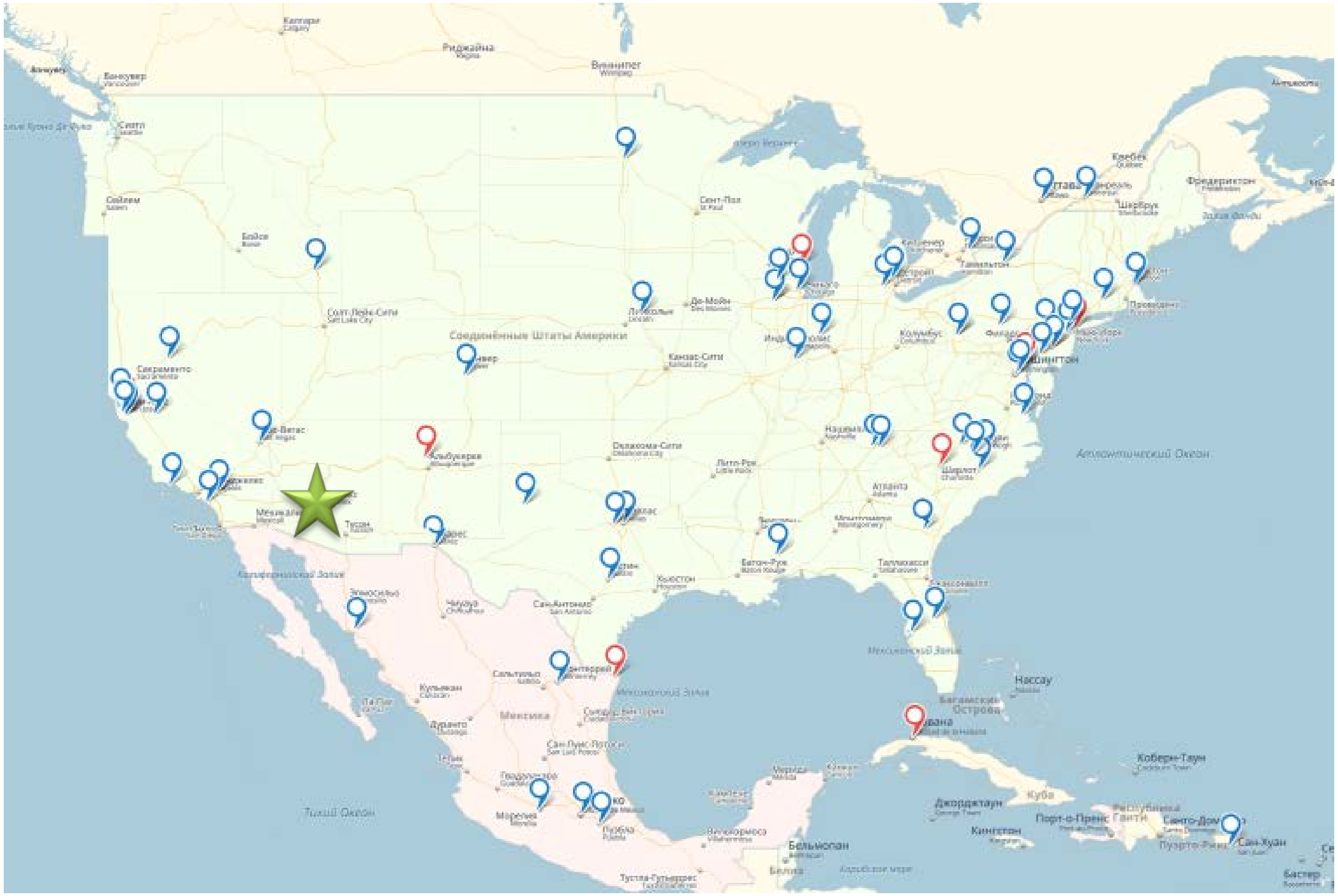
NT-MDT Spectrum Instruments



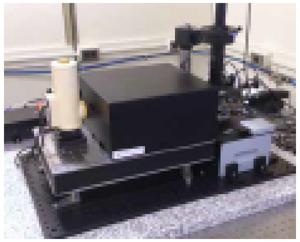
NT-MDT
Spectrum Instruments

NT-MDT SI World Distribution

NT-MDT Spectrum Instruments



Product Line

AFM				AFM-Raman / IR / TERS	
 2011	 2009				
SOLVER NANO	NEXT/ TITANIUM	NTEGRA	VEGA	NTEGRA SPECTRA II	NTEGRA Nano IR
• Compact desktop AFM/STM for both education and science • Full set of AFM/STM modes • High AFM/ STM performance • Closed-loop Scanner	• AFM/STM with exceptional level of automation • Fast, precise and low-noise closed-loop scanner • High resolution imaging due to extremely low noise and high stability • Full set of standard and advanced AFM/ STM modes • HybriD Mode™	• Modular high performance AFM/STM for wide range of applications • Low noise and high resolution • Full set of standard and advanced AFM/STM modes • HybriD Mode™	• Automated high-resolution AFM for up to 200x200 mm samples • Ultra stable AFM • Full set of standard and advanced AFM modes • HybriD Mode™ • ScanTronic™	• SPM • Automated AFM laser, probe and photodiode • Confocal Raman / Fluorescence / Rayleigh Microscopy • Tip Enhanced Raman Scattering (TERS) • TERS optimized system for all possible excitation/detection geometries • HybriD Mode™	• IR sSNOM system • High resolution AFM • Stabilized CO_2 laser • HybriD Mode™

Agenda

Part I – Introduction and "Getting in Contact"

- AFM operational principles
- 3 main ways AFM interacts with the surface
- Contact mode related AFM techniques

Part II – Resonance Oscillatory Modes

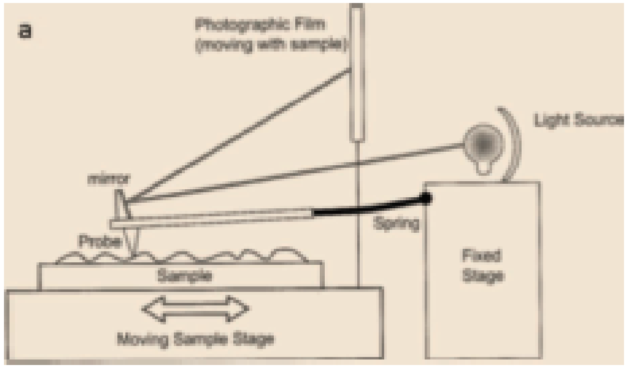
- Approach of resonant interaction
- Tapping Mode – a "good child"
- Tips for getting a perfect image in Tapping
- Tapping-related AFM techniques
- Tracking the frequency

Part III – Non-Resonant Oscillatory HybriD Mode

- Tracking the topography
- QNM – Quantitative Mechanical Mapping
- HybriD Mod related AFM techniques
- Few words about Optics

Discussion

AFM History and Background



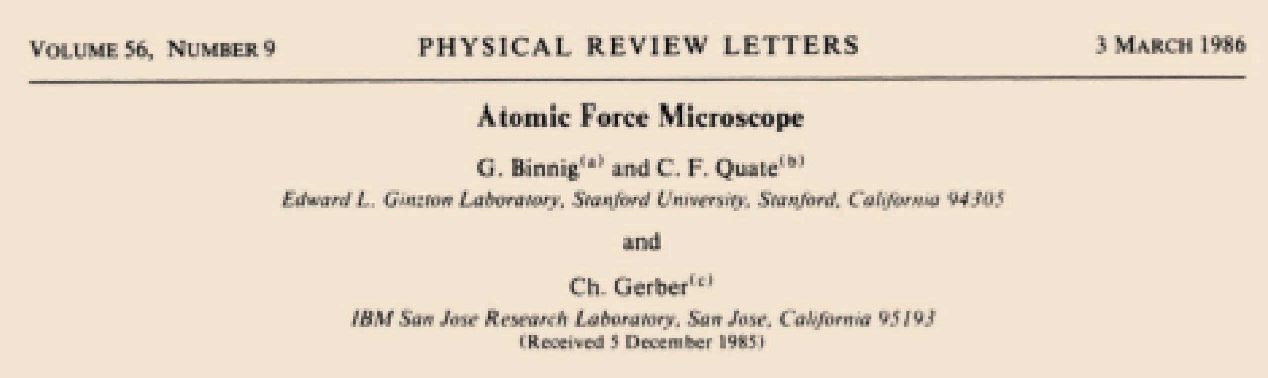
Surface stylus profiler
G. Schmaltz, U. Glätte , Zeitschrift des Vereins deutscher Ingenieure, Oct 12, 1929, pp. 1461-1467

1966 – tunnel effect used for sample topography research (R. Young, J. Ward, F. Scire)

1981 – STM atomic resolution achieved (G. Binnig and F. Rohrer, Nobel prize 1986)

1985 – first AFM introduced (G. Binnig et. al.)

1998 – first combined AFM-Raman system introduced (NT-MDT)

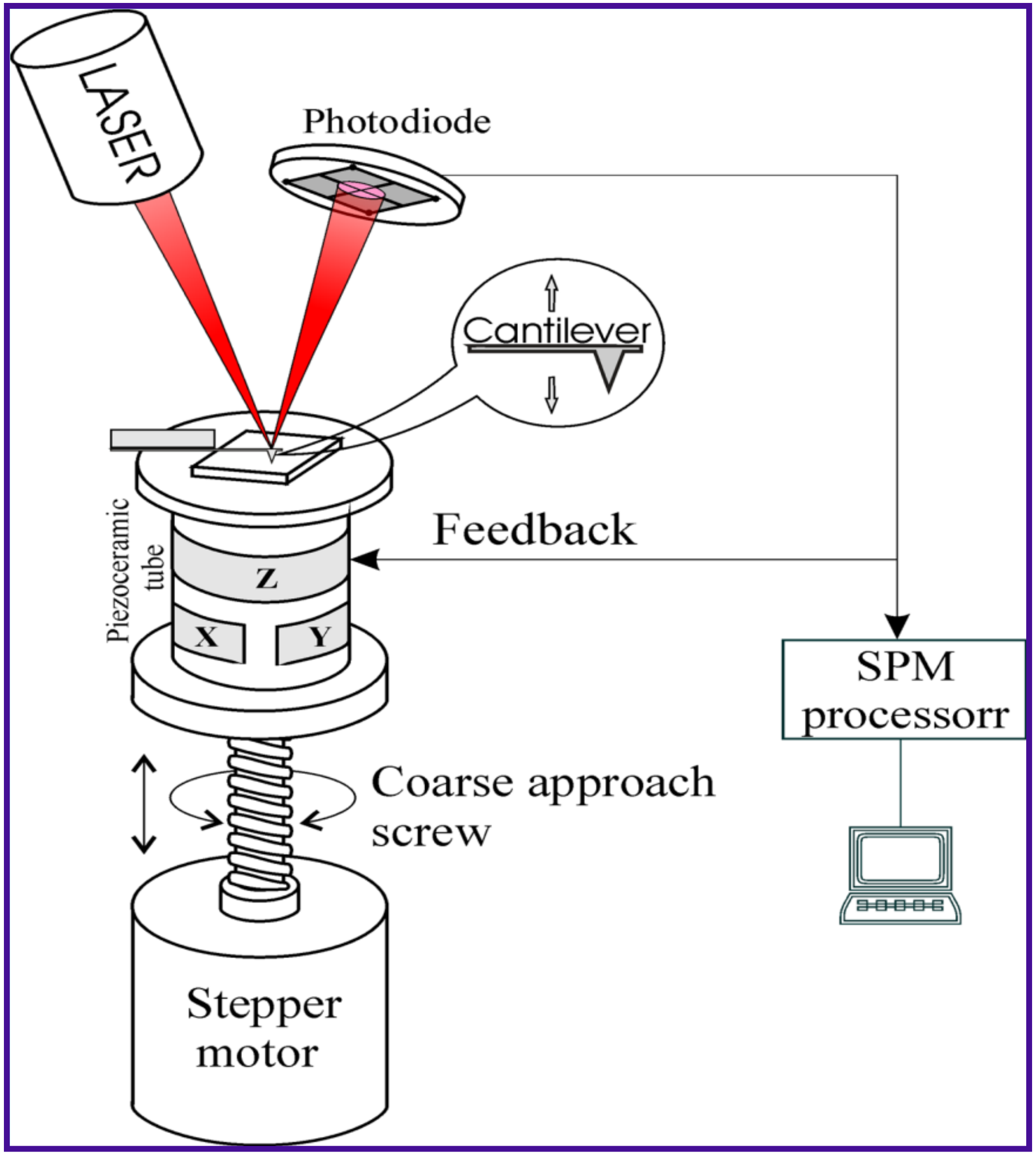


VOLUME 56, NUMBER 9 PHYSICAL REVIEW LETTERS 3 MARCH 1986

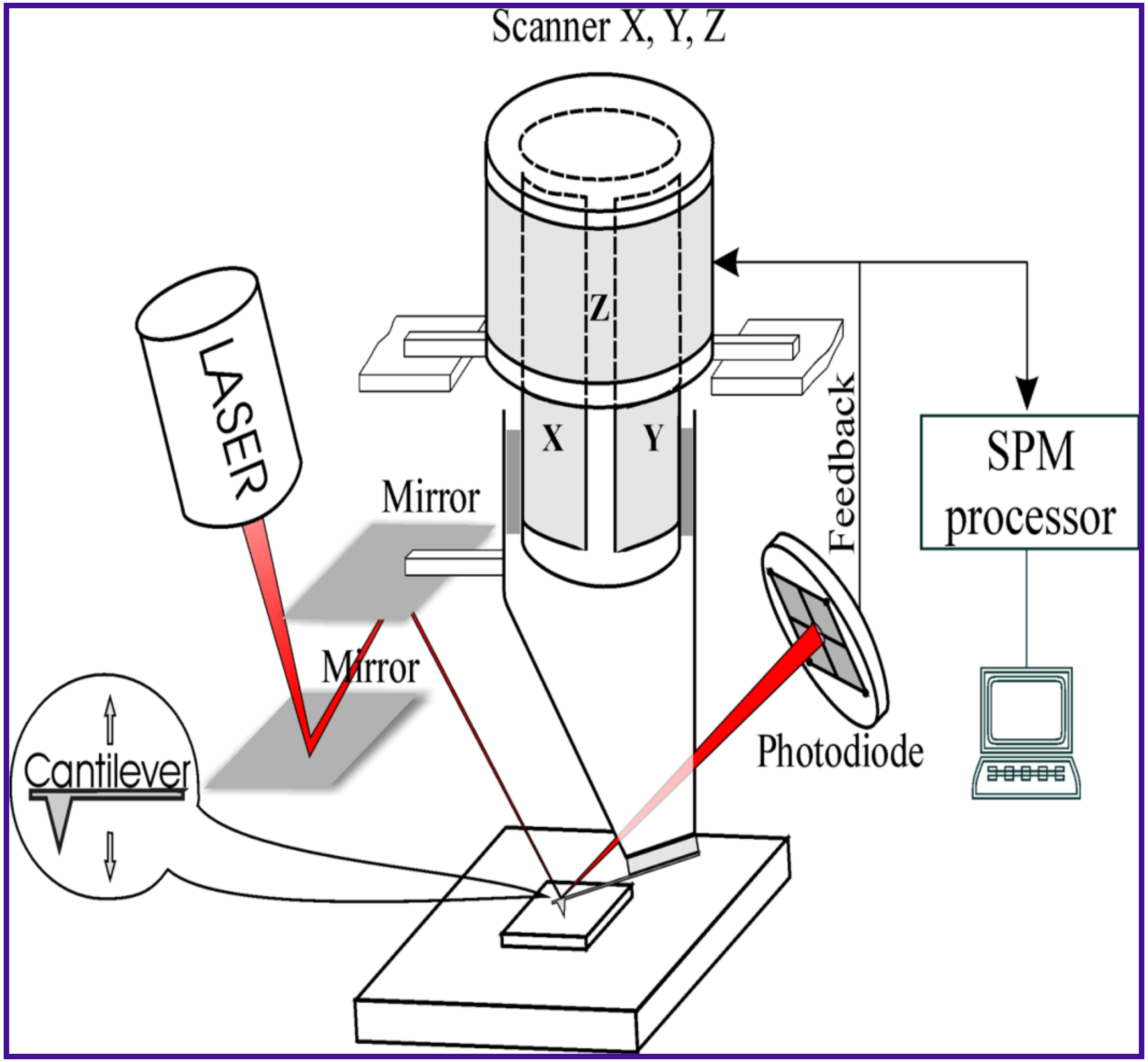
Atomic Force Microscope

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)

AFM Operational Principle



AFM Operational Principle



Tip scanning configuration

AFM Types

Atomic Force Microscopy

Contact Mode

Lateral force imaging, force modulation, contact resonance, PFM

Oscillatory Resonant Modes

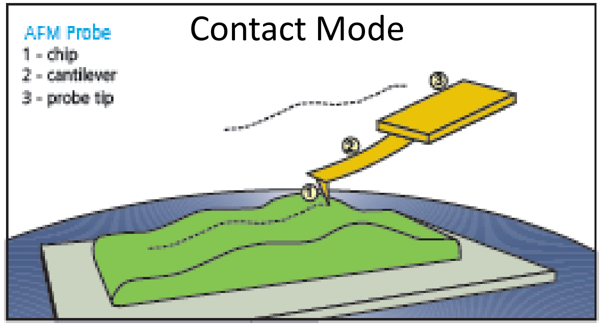
Amplitude modulation with phase and frequency imaging, frequency modulation, single- and double pass methods

Oscillatory Non-Resonant Modes

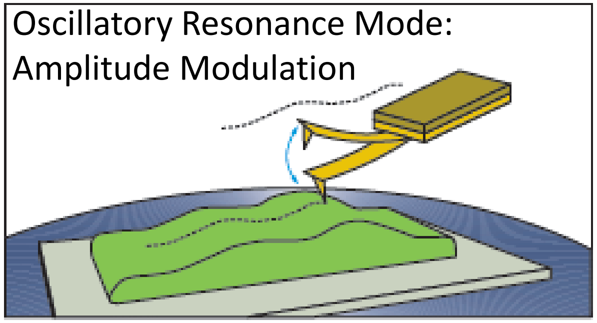
Jumping mode, HybriD™ mode, etc

Combination with Spectroscopy Methods:

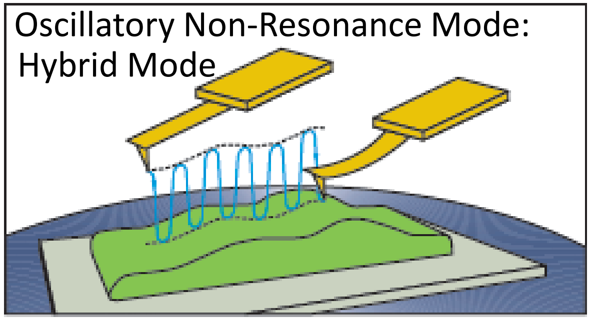
Optical, Raman, IR, etc



Contact Mode

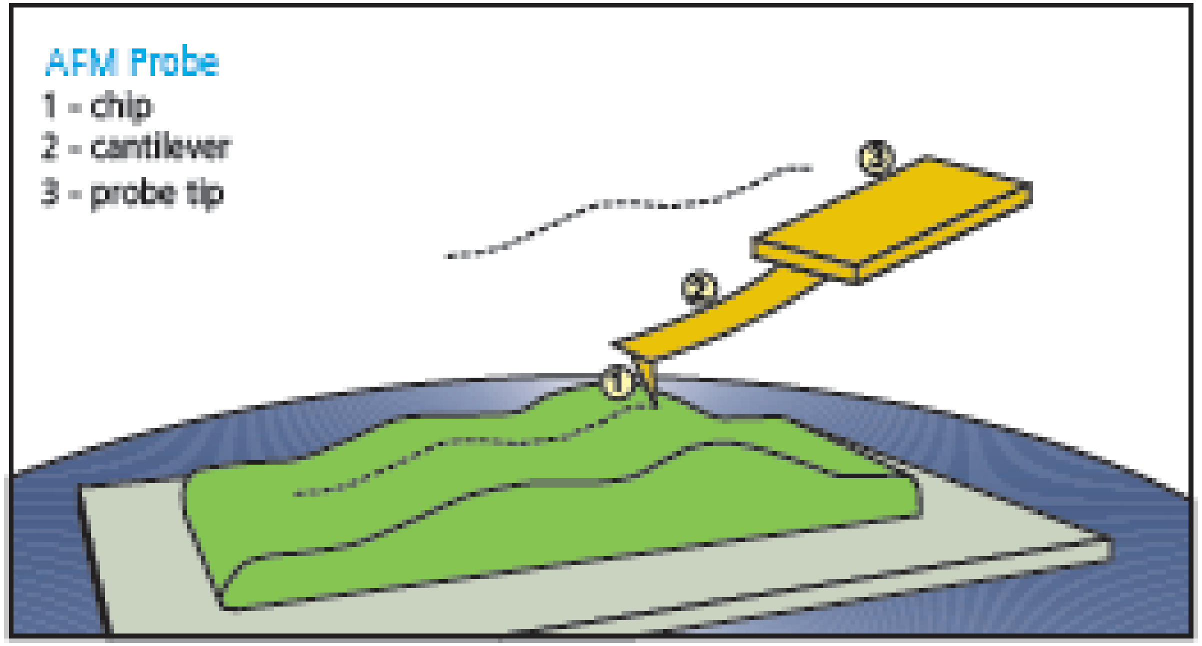


Oscillatory Resonance Mode:
Amplitude Modulation

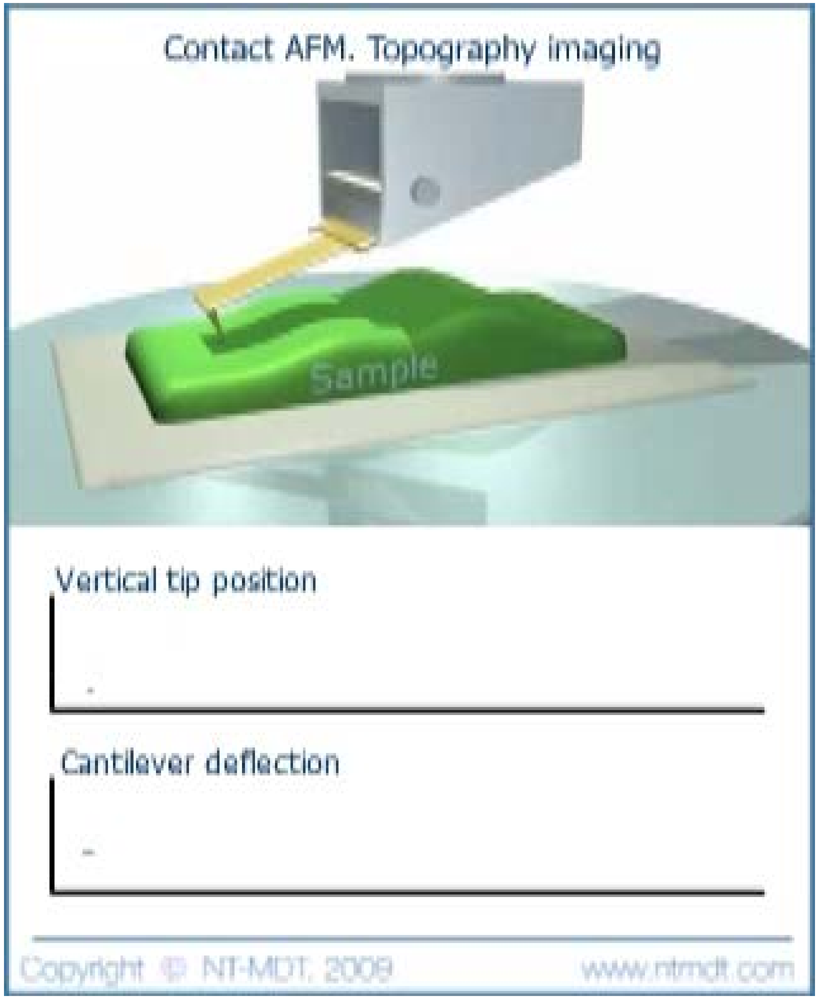


Oscillatory Non-Resonance Mode:
Hybrid Mode

Contact Mode



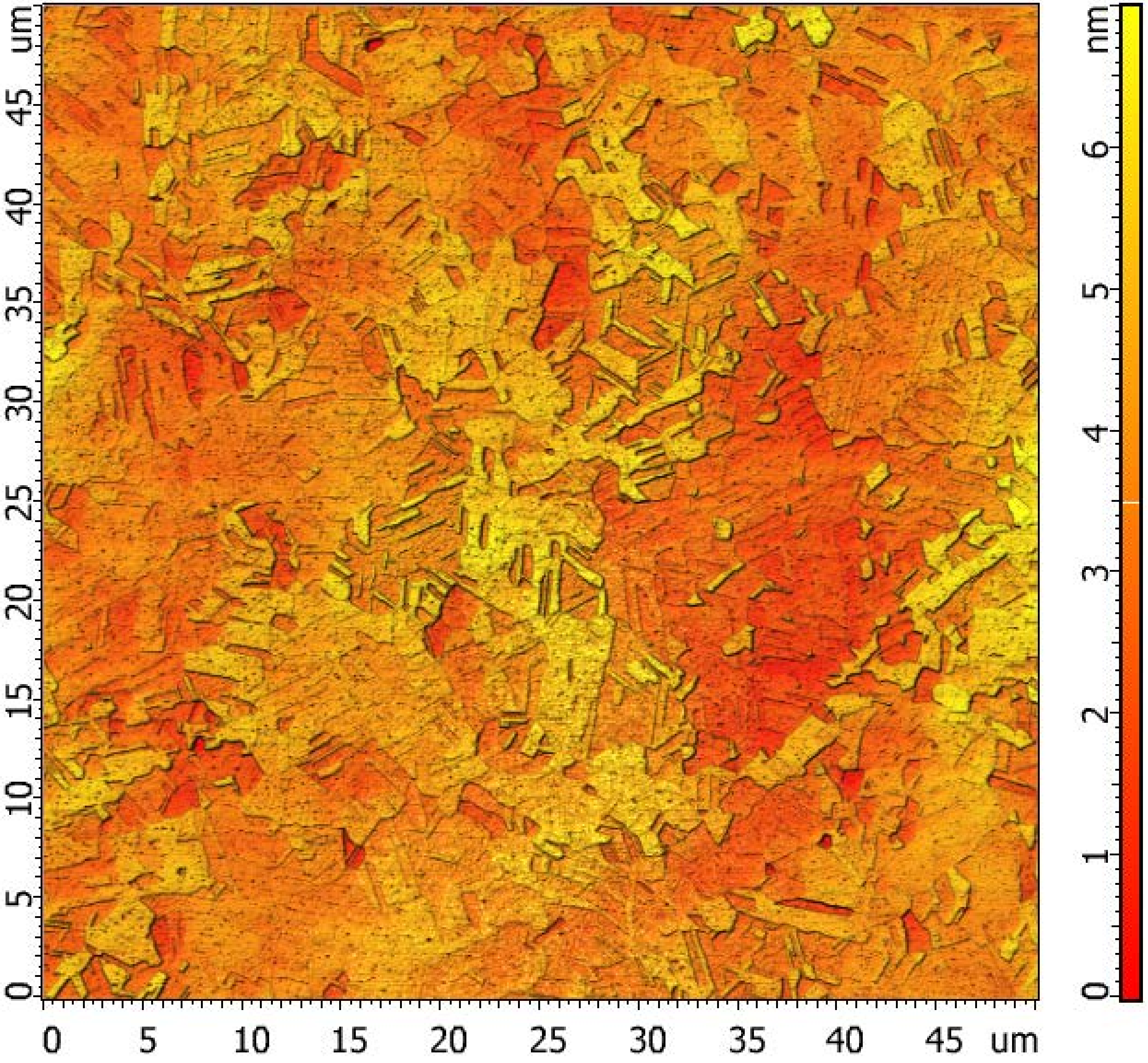
Contact Mode



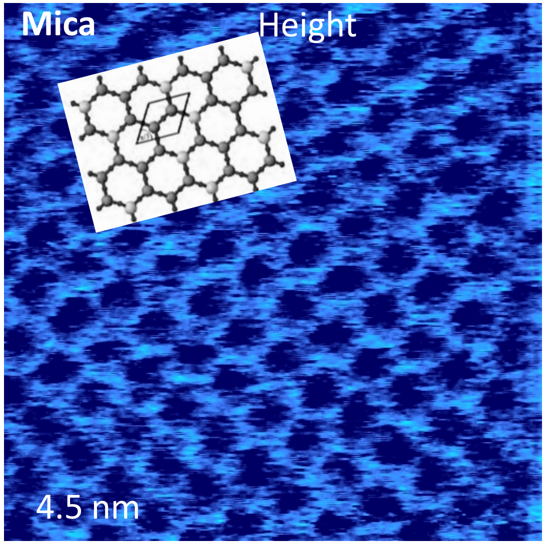
$$F = -kz$$

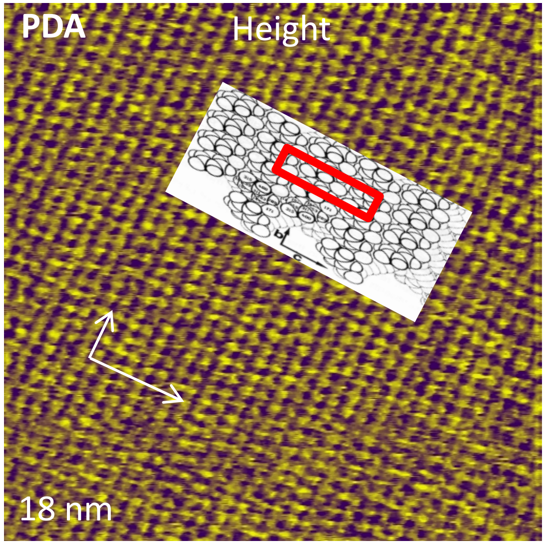
According the Hook’s law, Force interaction between tip and the sample is proportional to tip bending and the cantilever stiffness. Stiffness for contact mode cantilevers can vary from 0,01 to several N/m

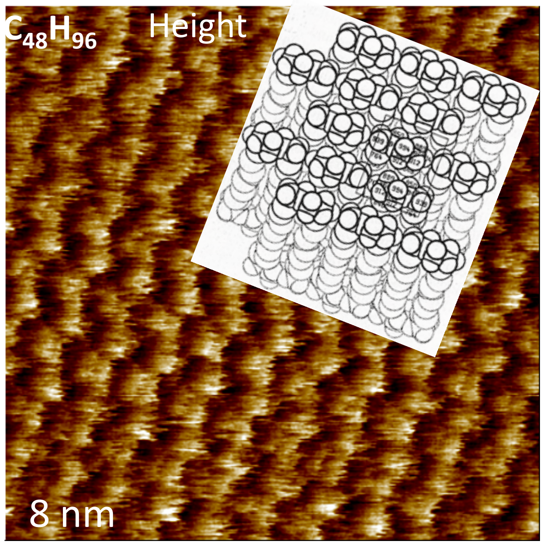
Contact Mode



Atomic Resolution

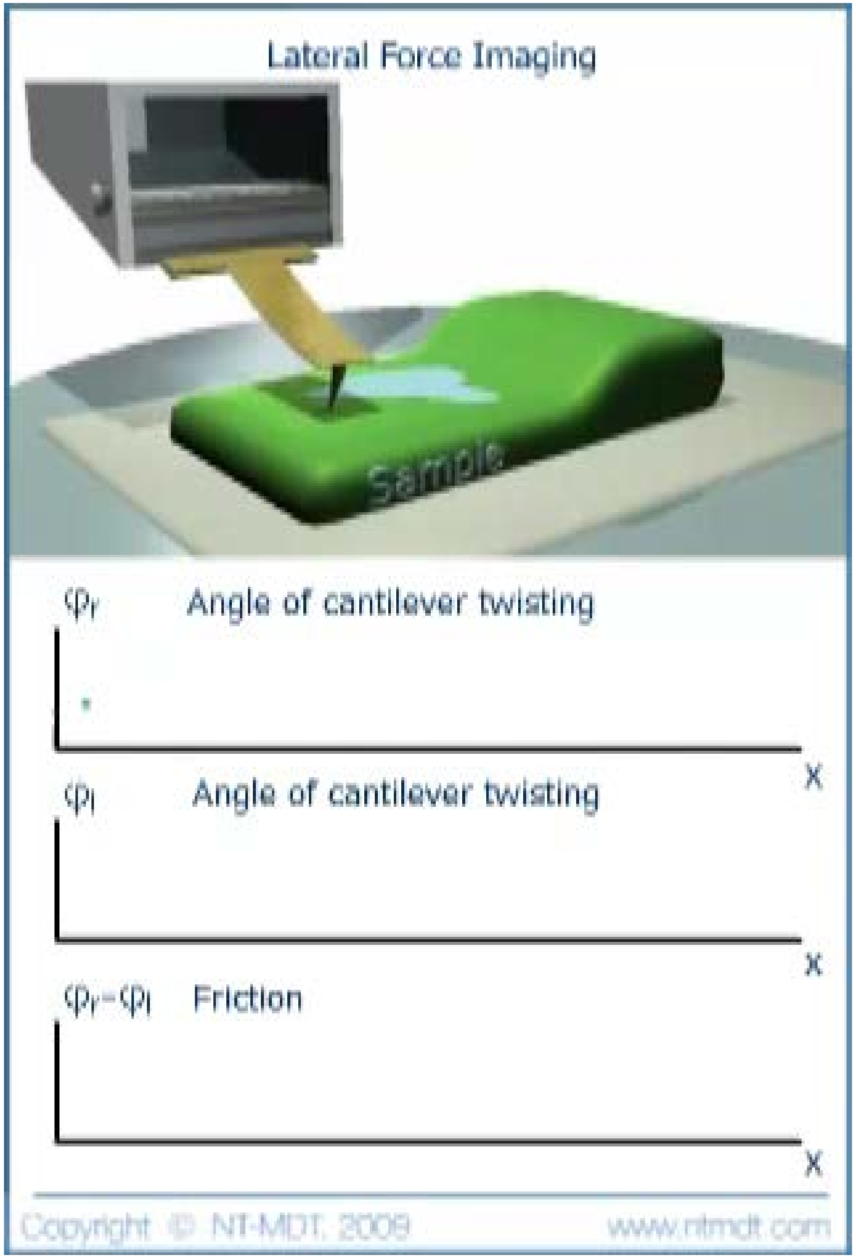




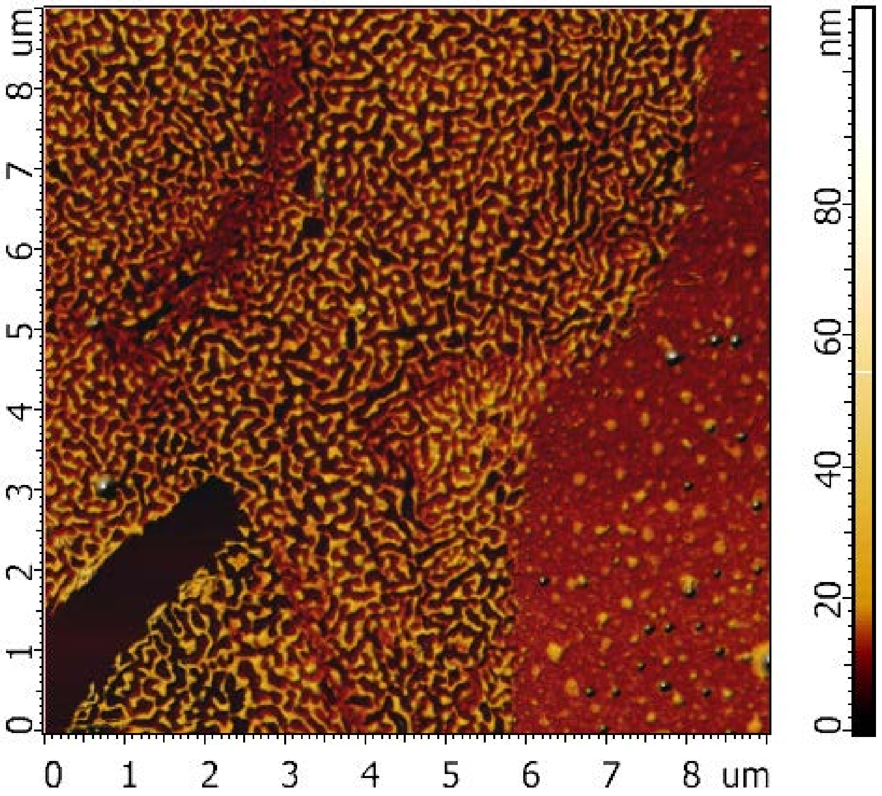


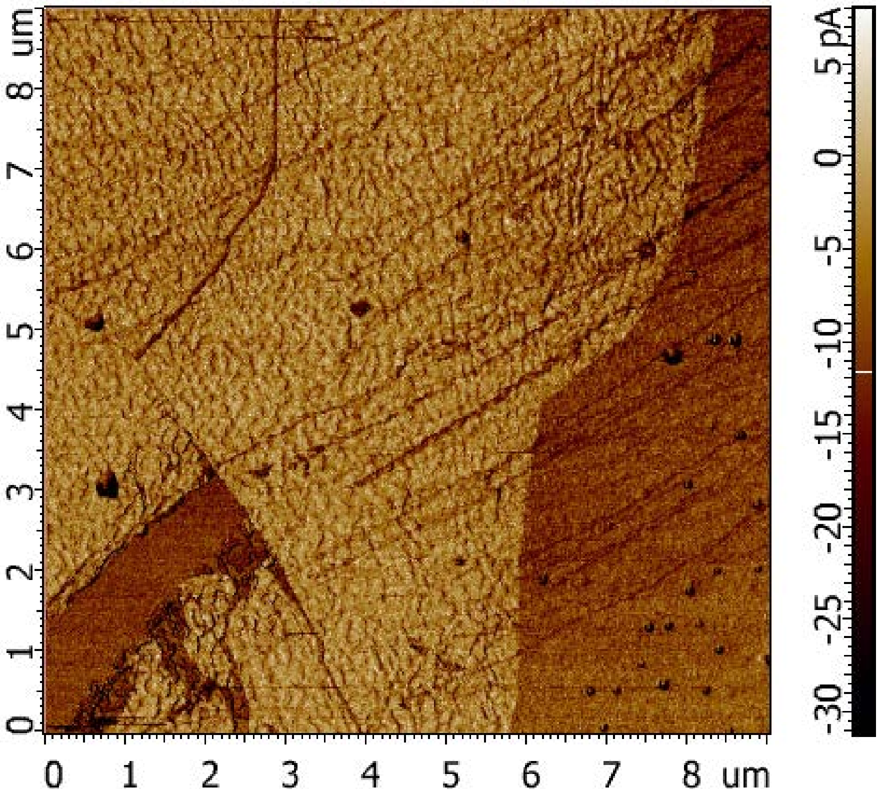
Brick Road Effect

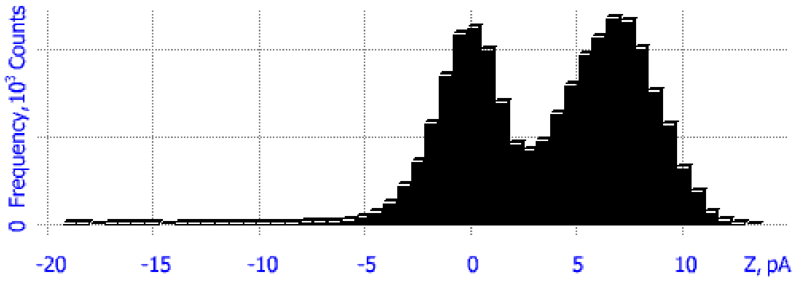
Lateral Force (Nanotribology)



Lateral Force (Nanotribology)

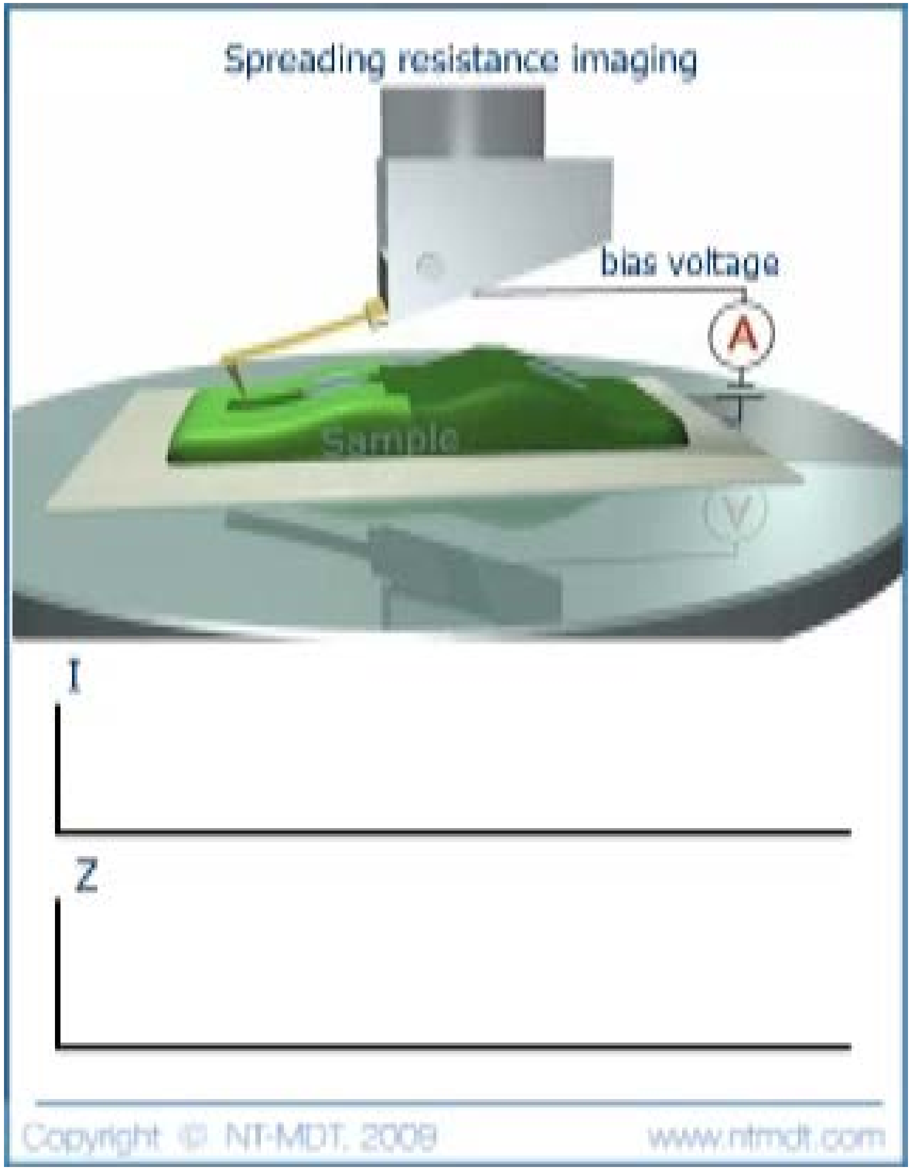




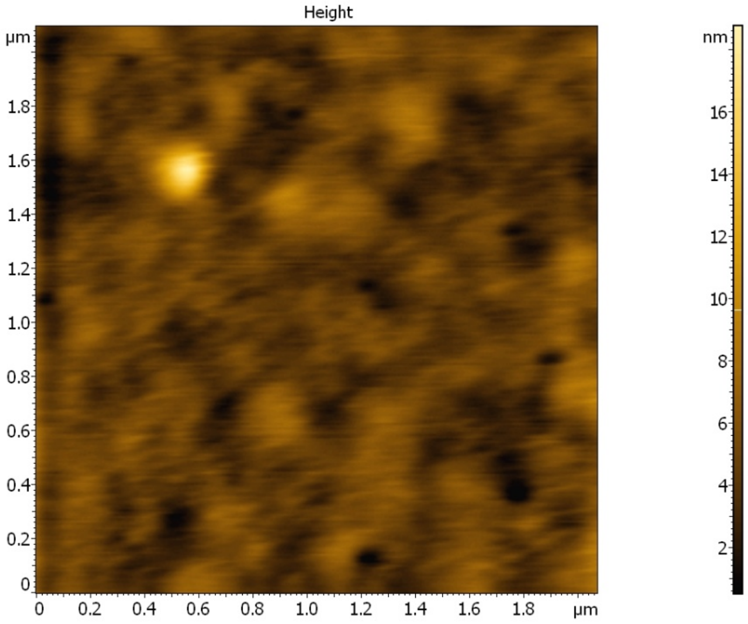


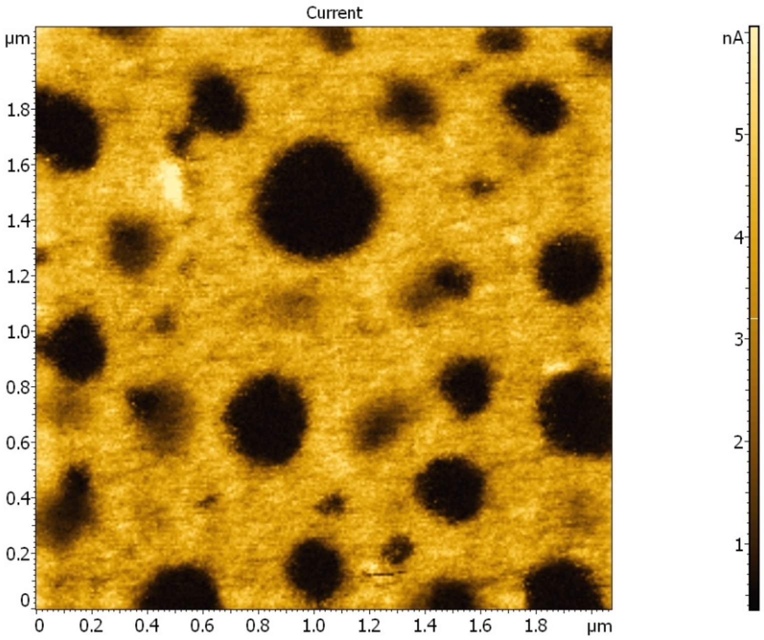
Spectrum Instruments

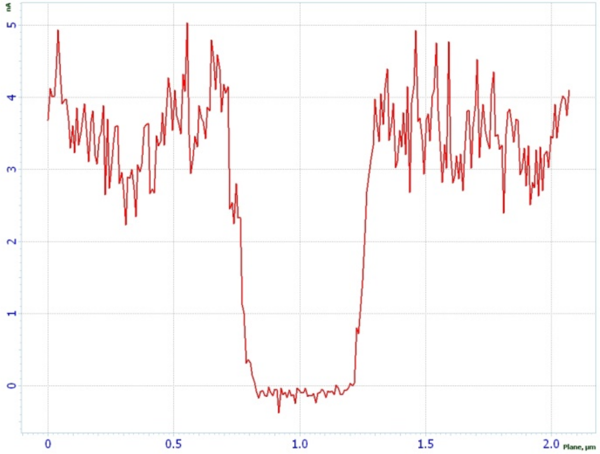
Spreading Resistance



Spreading Resistance



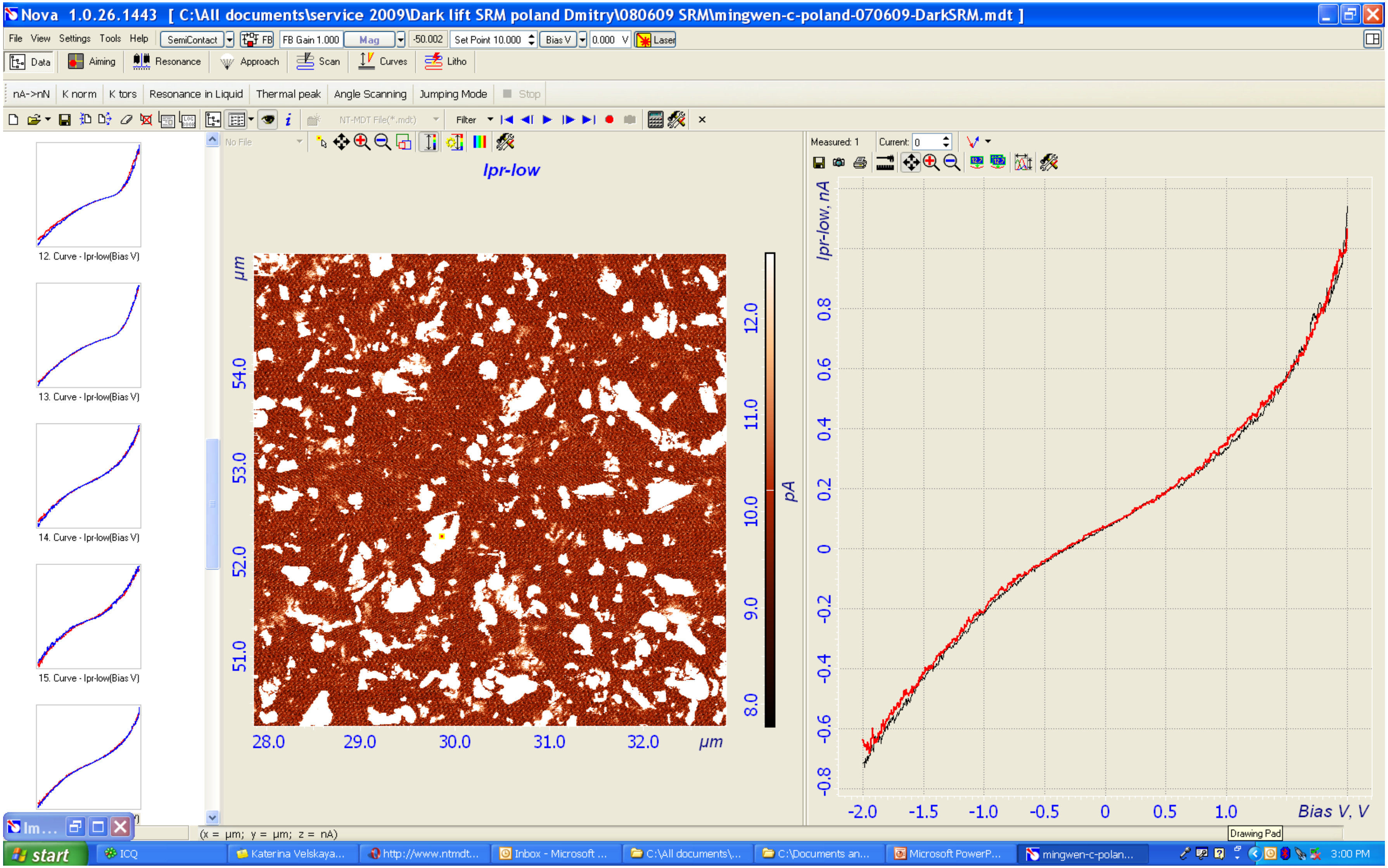




Top left topography obtained in SSRM mode (-5V), top right – current mapping, bottom right current cross-section profile.

Scan size: 2 2 µm

I/V Spectroscopy



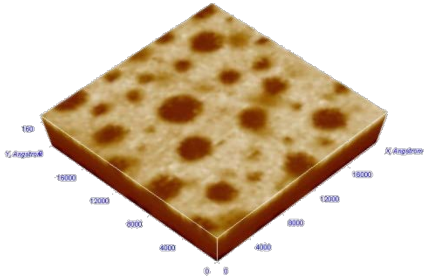
Nova 1.0.26.1443 [C:\All documents\service 2009\Dark lift SRM poland Dmitry\080609 SRM\mingwen-c-poland-070609-DarkSRM.mdt]

SemiContact FB Gain 1.000 -50.002 Set Point 10.000 Bias V 0.000 V

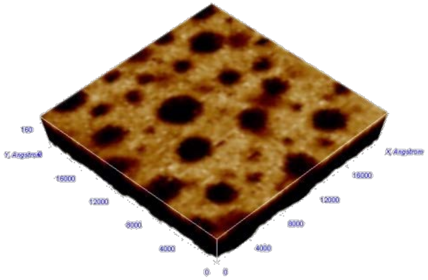
Measured: 1 Current: 0

(x = μm; y = μm; z = nA)

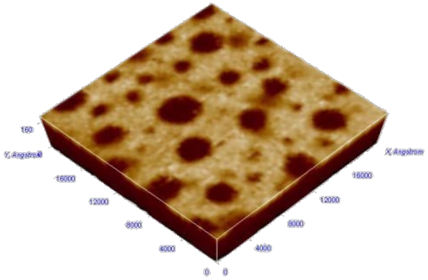
I/V Spectroscopy



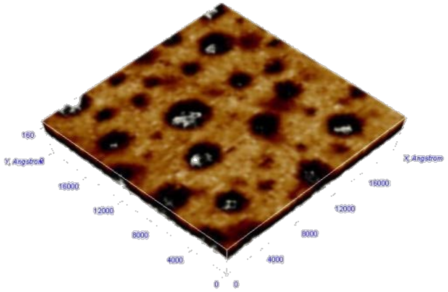
-10 V



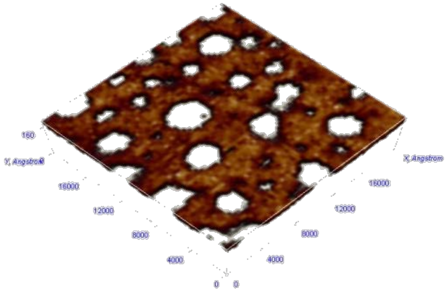
-5 V



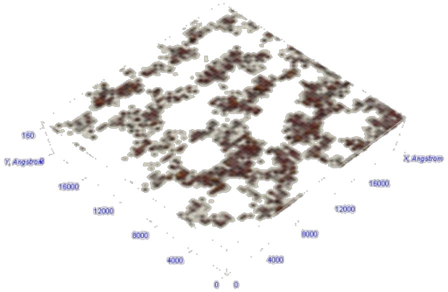
-1 V



+1 V

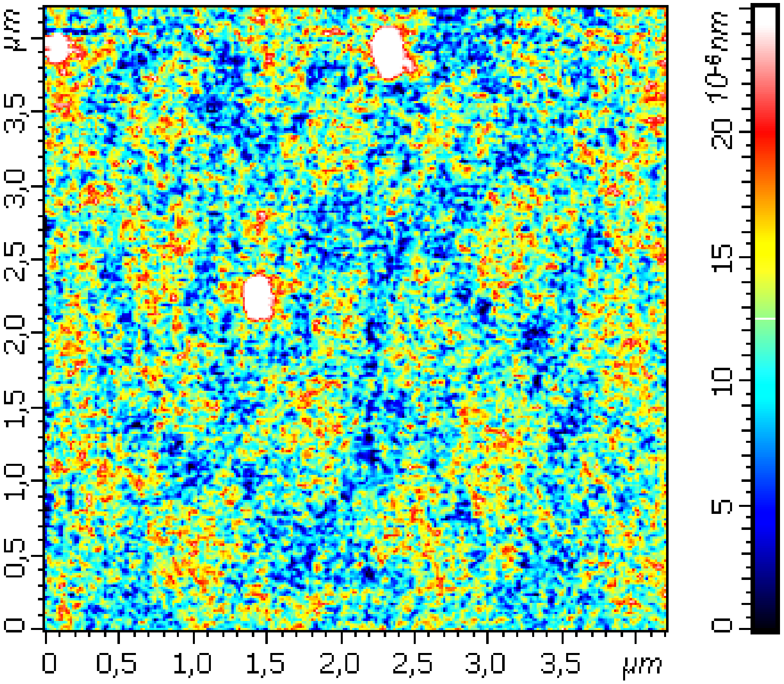


+5 V

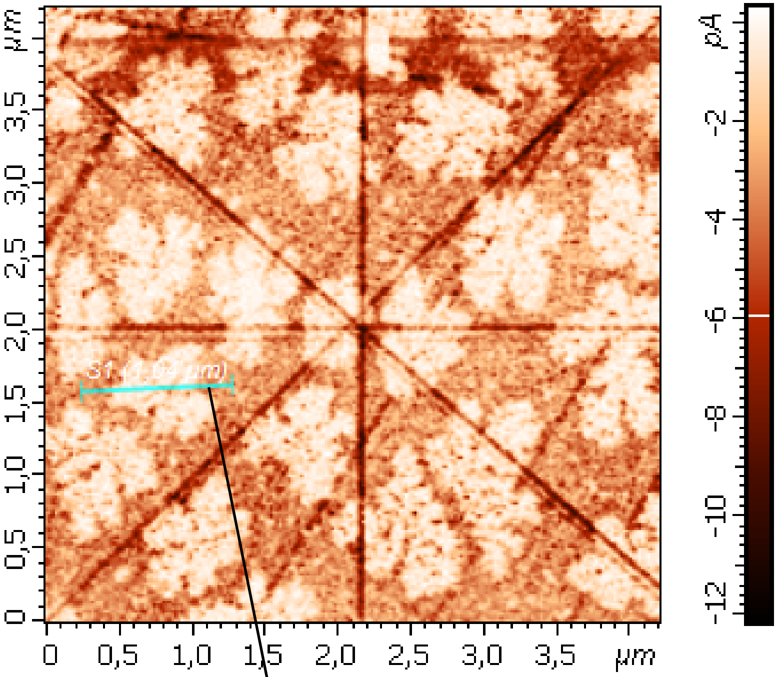


+10 V

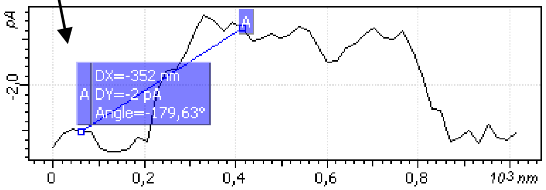
Conductivity Map of OTS



Topography



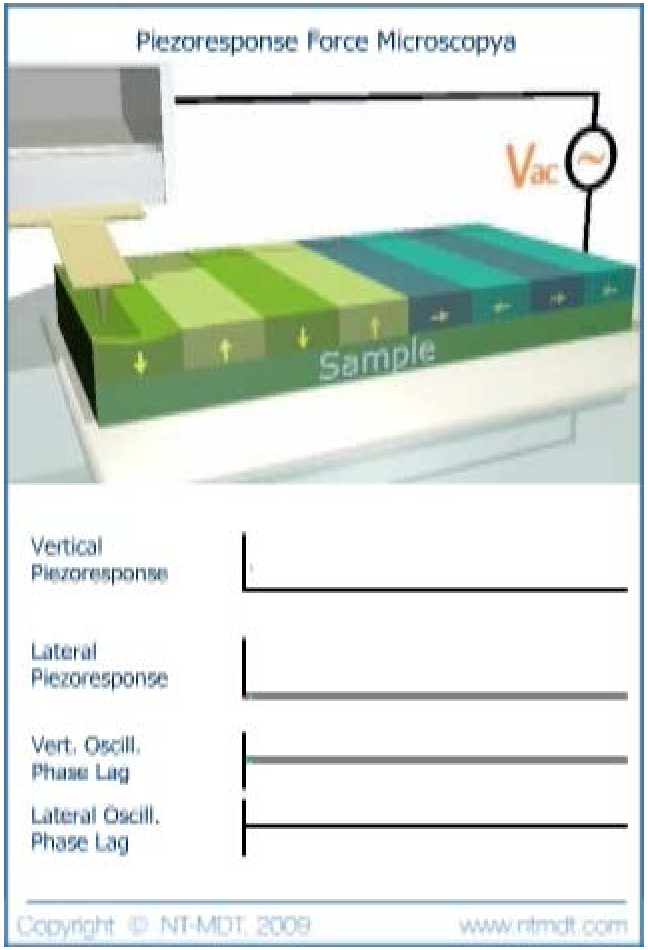
Current



Current contrast of
“Flowers” about 2 pA

Sample Courtesy: Prof. Jacob Sagiv, Weizmann Institute of Science, Israel

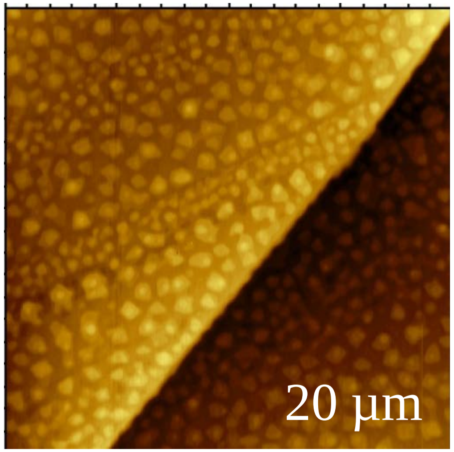
Piezo Force AFM



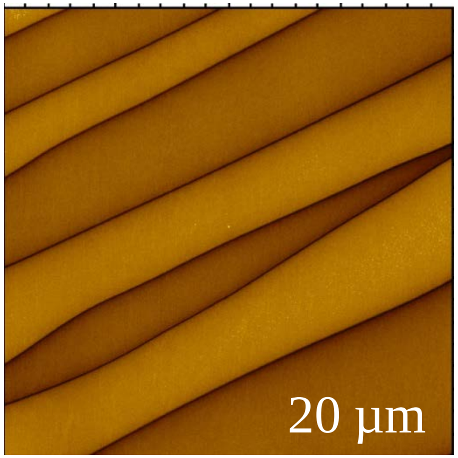
PFM studies of TGS sample.

- *Cantilevers (40 N/m) with Pt coating were used for measurements*
- *AC-sample mode with 10V@100kHz applied was used for PFM measurements.*

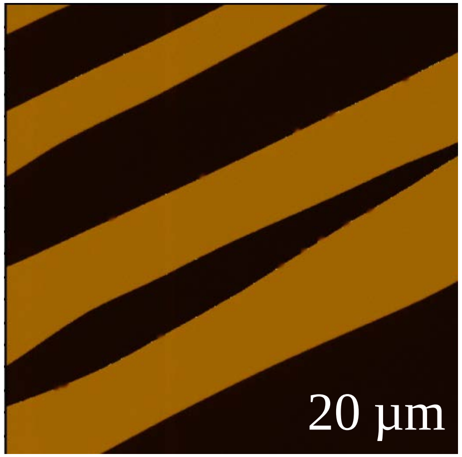
Topography



VPFM Amplitude



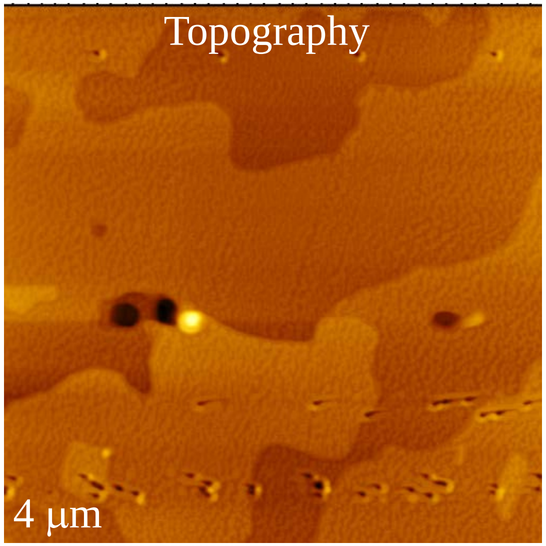
VPFM Phase

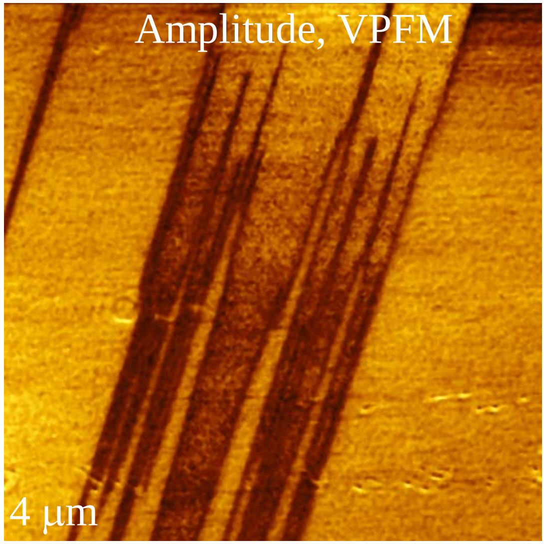


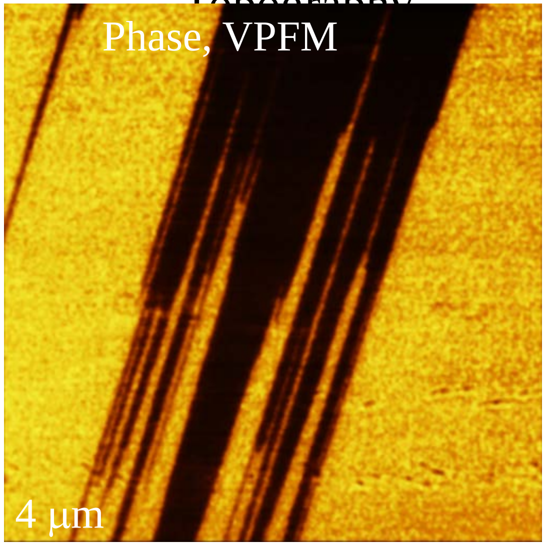
VPFM and LPFM

High-Temperature Molecular Ferroelectric Crystal of Diisopropylammonium Bromide (DIPAB)

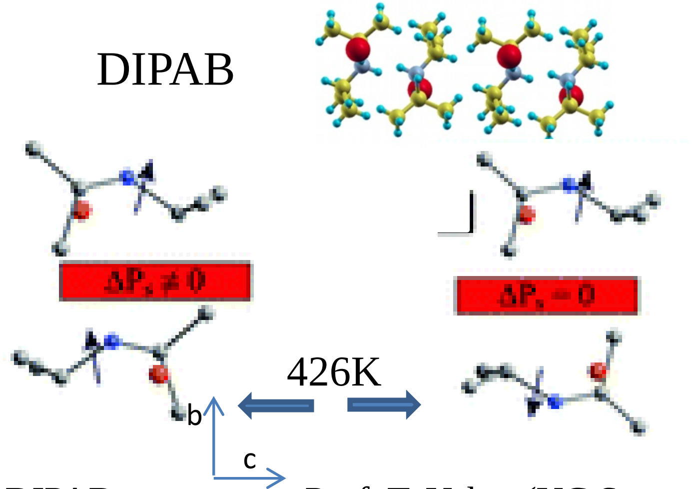
PFM:
60V@100kHz

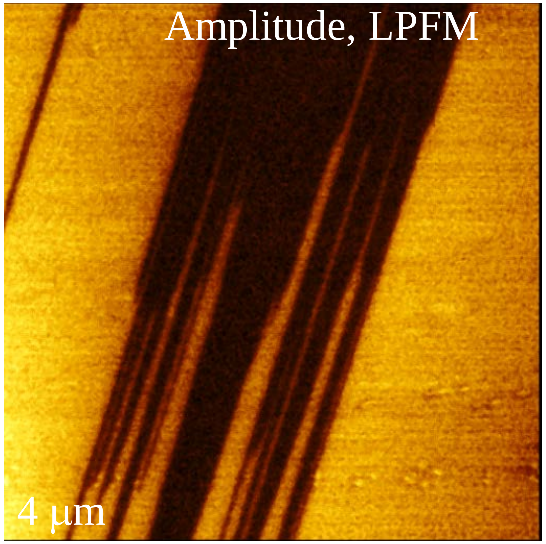

Topography

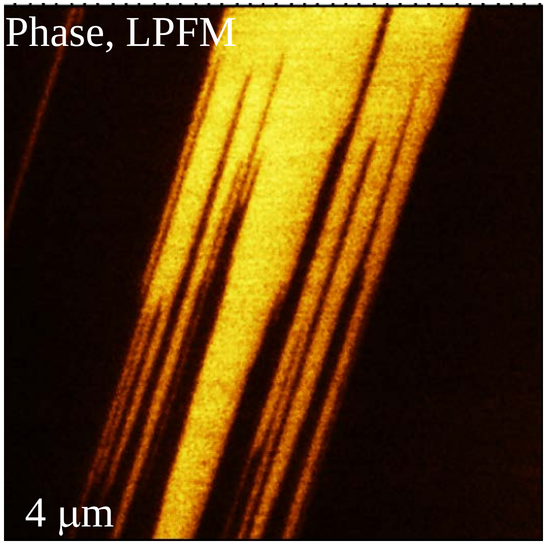

Amplitude, VPFM


Phase, VPFM

DIPAB

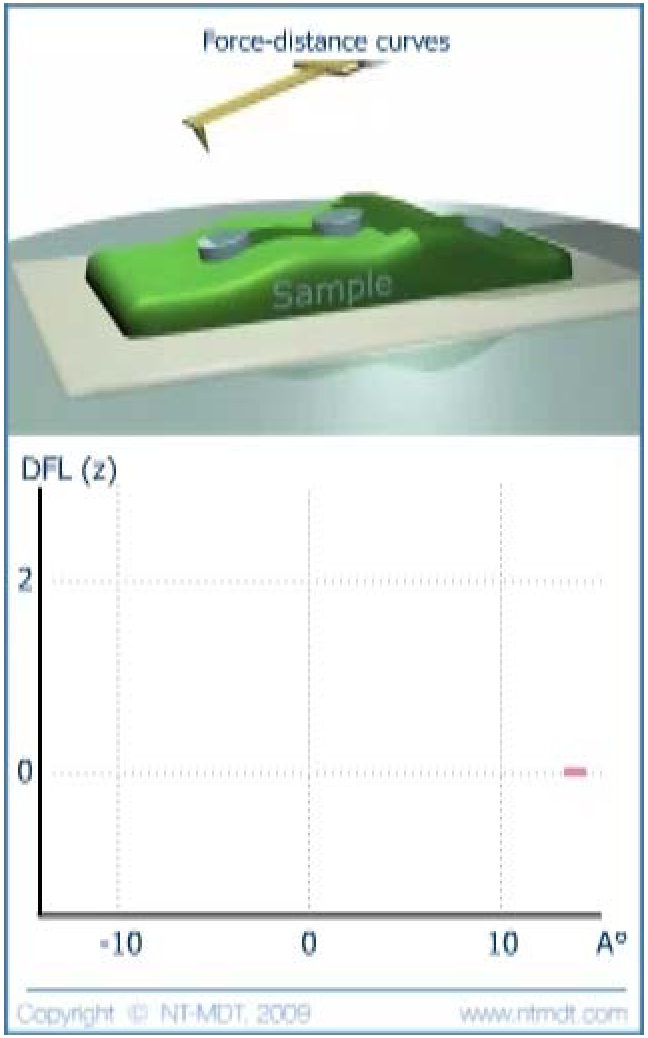


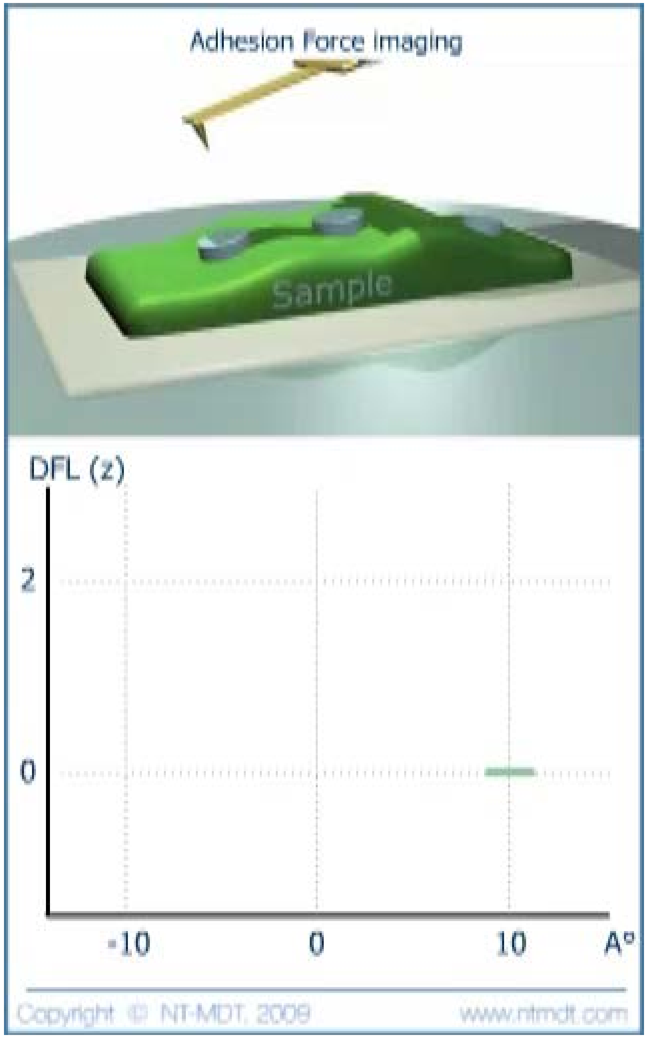

Amplitude, LPFM


Phase, LPFM

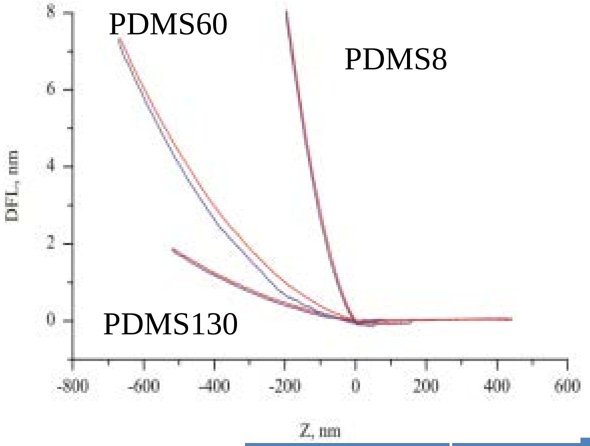
DIPAB – courtesy Prof. T. Usher (UC San Bernardino)

Atomic Force Spectroscopy Principle





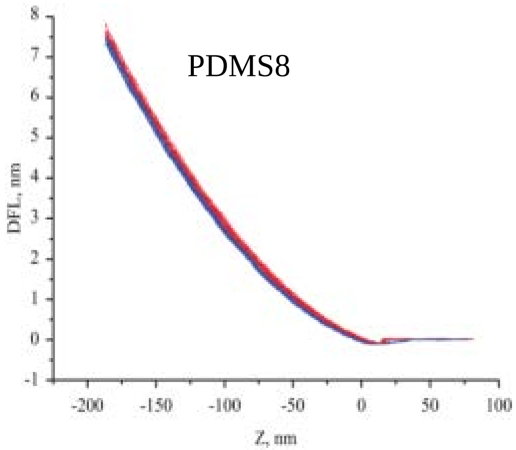
Force Curves on Different Materials



Standard Models for AFM

Rubbery materials:
PDMS8, PDMS60 and PDMS 130

Models: Hertz, Sneddon, JKR, DMT



Polymer Material	Elastic Modulus Macro	Elastic Modulus AFM	Work of Adhesion Macro	Work of Adhesion AFM
PDMS-8	13.4MPa	13.9MPa	49 J/m^2	32 J/m^2
PDMS-60	1.61MPa	1.74MPa	58 J/m^2	52.2 J/m^2
PDMS-130	0.74MPa	0.66MPa	47–58 J/m^2	42.1 J/m^2

Force Curves measured on PS/PBD