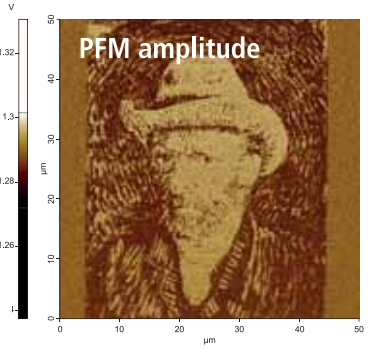
Volume 04

Park Systems Atomic Force Microscopy

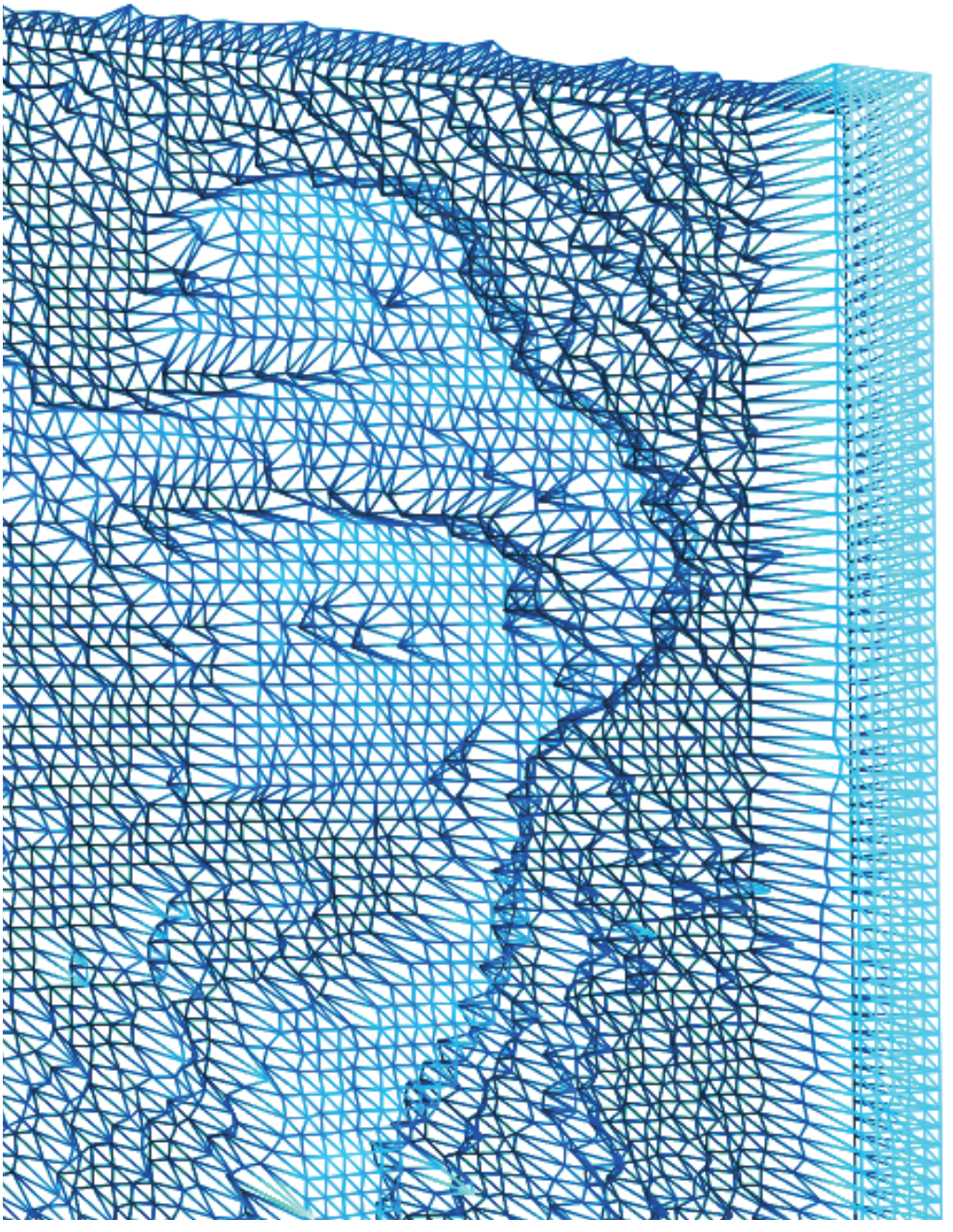
IMAGE GALLERY

Here, at Park Systems, we offer a full range of advanced imaging solutions for a wide variety of research applications. Enjoy the images in the gallery which highlight examples from a wide variety of sample types and imaging modes.

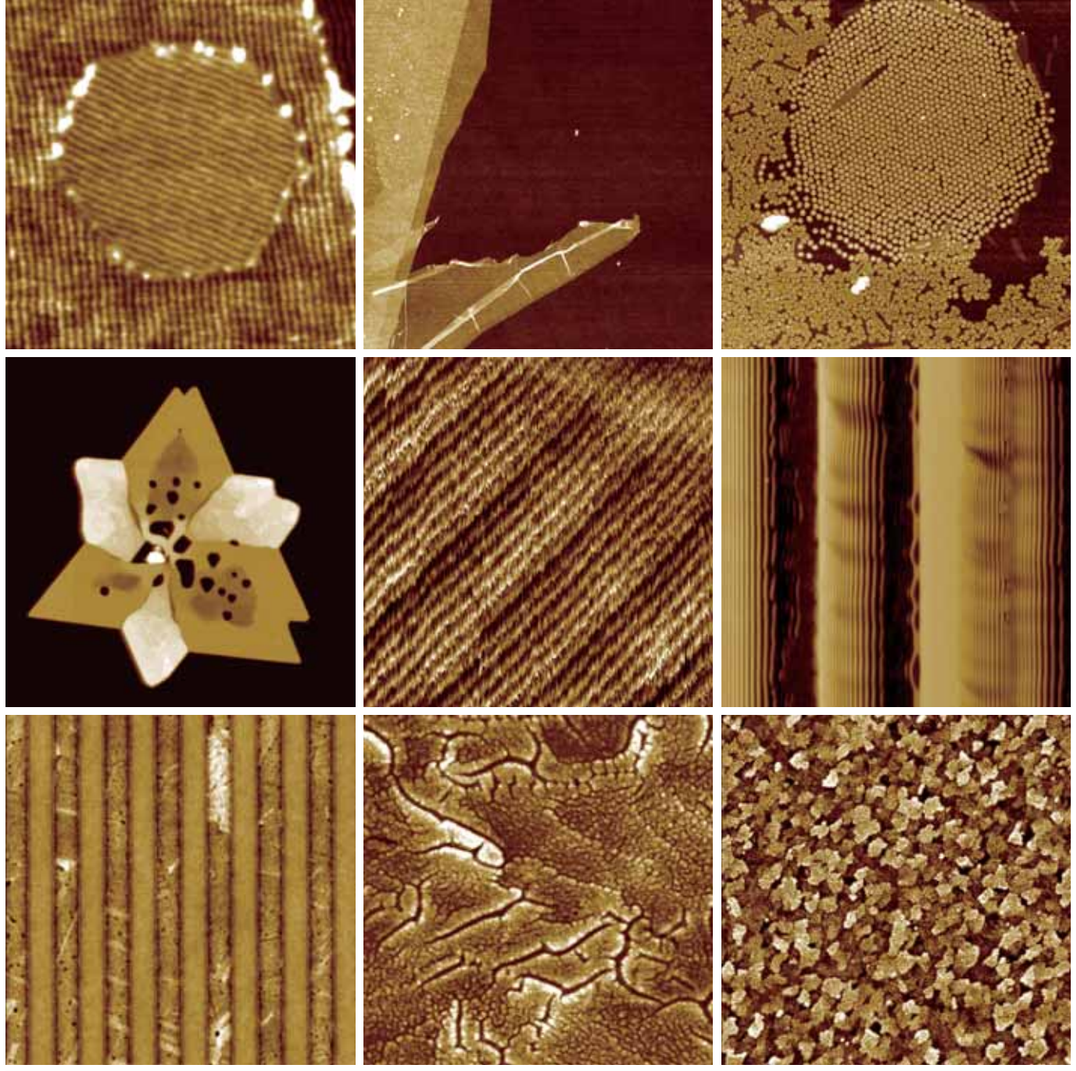


Re-arranged polling direction of PZT domains using bias lithography mode

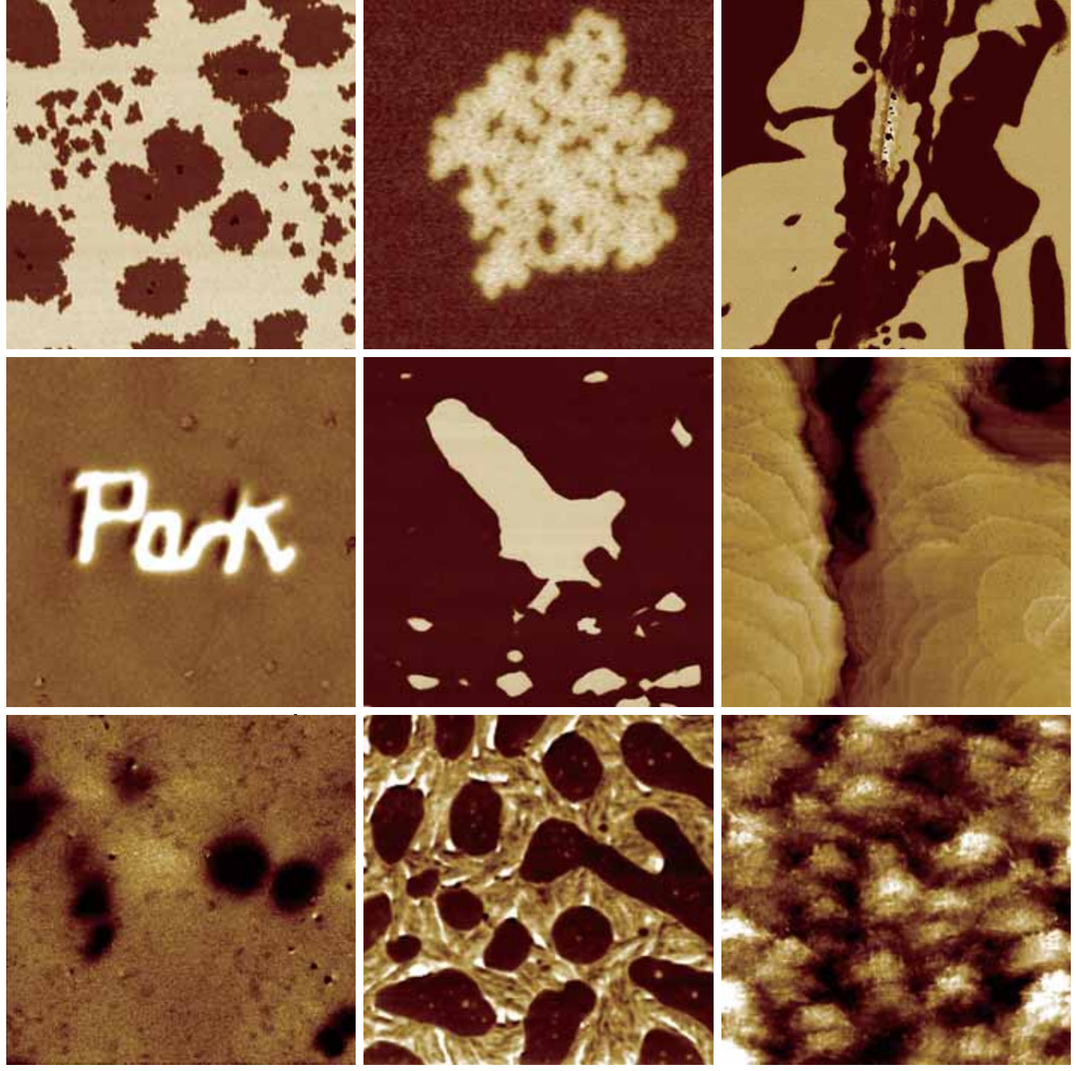
Page 41



Park SYSTEMS

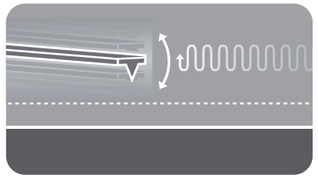


Topography



Advanced Modes

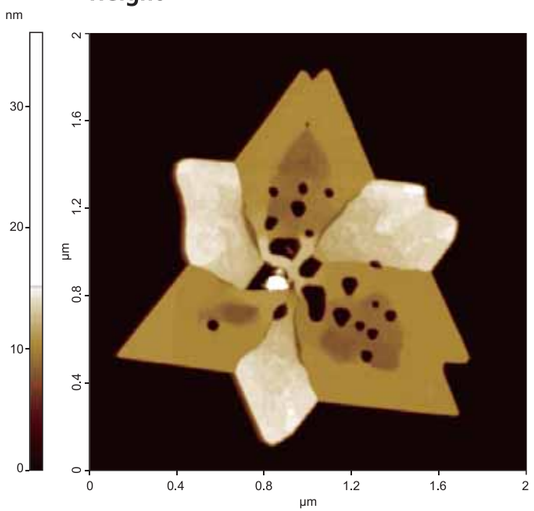
Mica composite flake



True Non-contact™ Mode

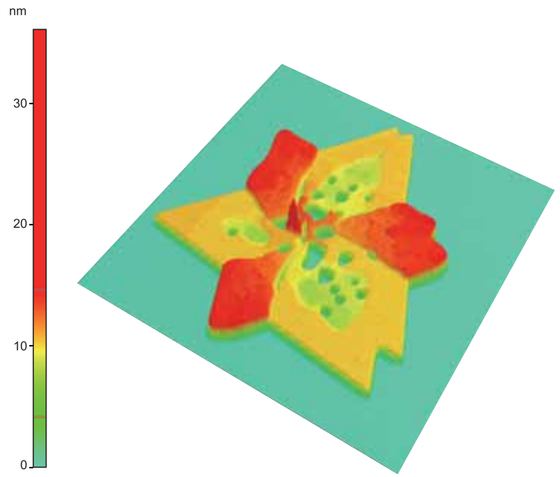
In this technique, the cantilever oscillates just above the surface as it scans. A precise, high-speed feedback loop prevents the cantilever tip from crashing into the surface, keeping the tip sharp and leaving the surface untouched. As the tip approaches the sample surface, the oscillation amplitude of the cantilever decreases. By using the feedback loop to correct for these amplitude deviations, one can generate an image of the surface topography.

Height



Peak to Valley: 39.5 nm
RMS Roughness: 5.8 nm

3D



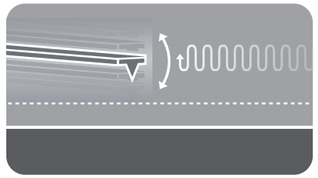
X:Y:Z Scale: 1:1:10

Scanning conditions

System: NX10
Scan Size: 2 µm × 2 µm
Scan Mode: Non-contact mode

Scan Rate: 0.5 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 × 512

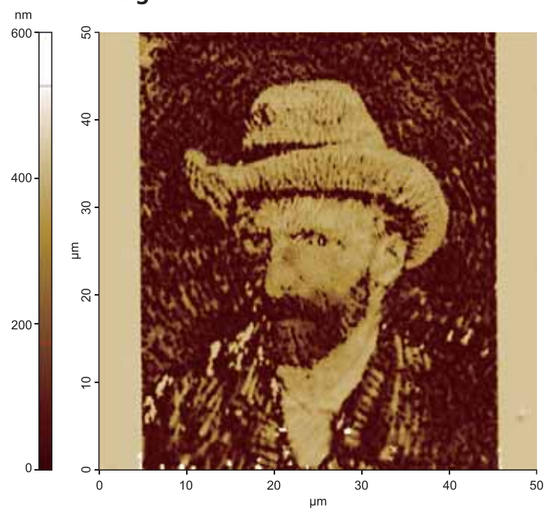
Vincent van Gogh by e-beam lithography



True Non-contact™ Mode

Design for e-beam lithography

Height



Peak to valley: 600 nm
RMS Roughness: 162 nm

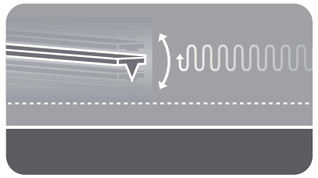
Non-contact image (topography) of e-beam patterned Vincent van Gogh

Scanning conditions

System: NX20
Scan Size: 50 µm × 50 µm
Scan Mode: Non-contact mode

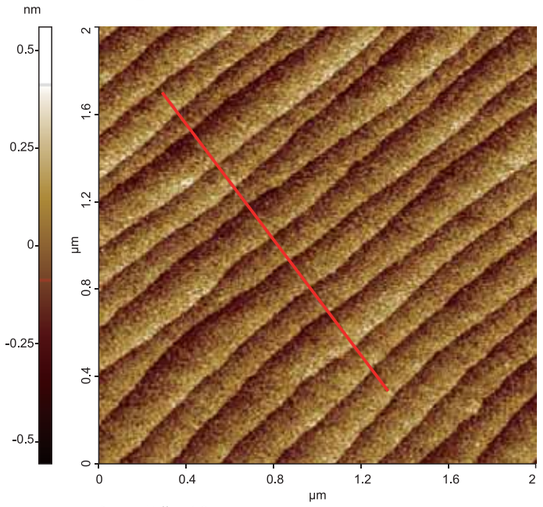
Scan Rate: 0.2 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 x 512

$NbGaO_3$ with 0.4 nm terraces



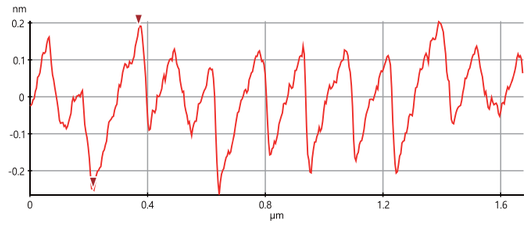
True Non-contact™ Mode

Height



Peak to Valley: 1.2 nm
RMS Roughness: 0.15 nm

Line profile



Cursor	ΔX (µm)	ΔY (µm)
Red	0.154	0.440

ΔY = Terrace

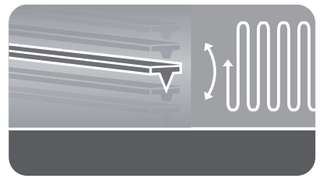
Neodymium Gallate ($NdGaO_3$) substrate with 0.4 nm terraces.

Scanning conditions

System: NX12
Scan Size: 2 µm × 2 µm
Scan Mode: Non-contact mode

Scan Rate: 0.5 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 × 256

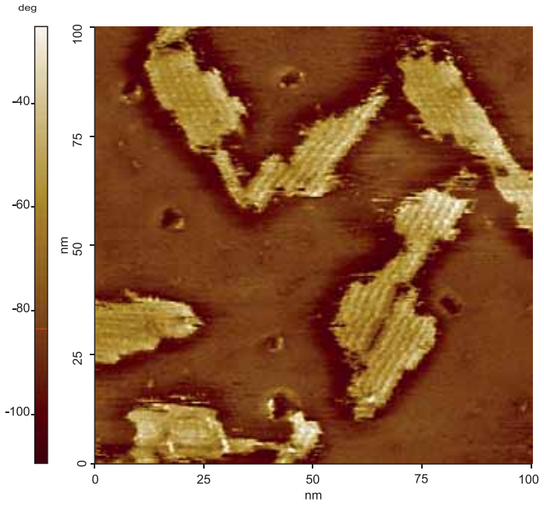
Small scan image of ADS510 on hBN/SiO_2



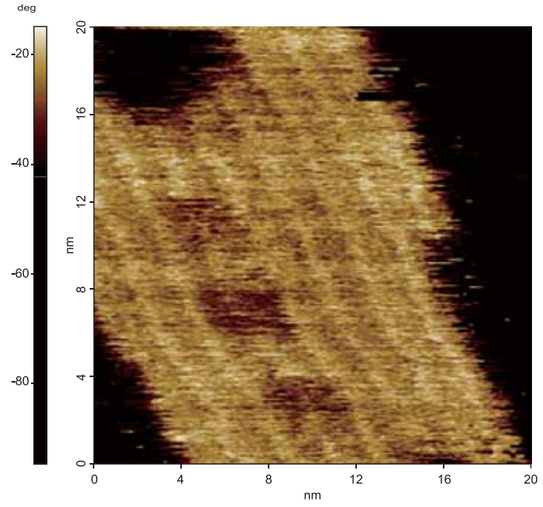
Tapping Mode

In this alternative technique to non-contact mode, the cantilever again oscillates just above the surface, but at a much higher amplitude of oscillation. The bigger oscillation makes the deflection signal large enough for the control circuit, and hence an easier control for topography feedback. It produces modest AFM results but blunts the tip's sharpness at a higher rate, ultimately speeding up the loss of its imaging resolution.

Phase of 100 nm × 100 nm



Phase of 20 nm × 20 nm



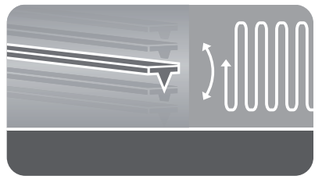
**ADS510 PT molecules adsorbed on hBN/SiO_2.
ADS510 PT is a regiorandom Poly [3-decylthiophene-2,5-diyl] and is commonly referred to as P3DT.**

Scanning conditions

System: NX10
Scan Size: 100 nm × 100 nm, 20 nm x 20 nm
Scan Mode: Tapping mode

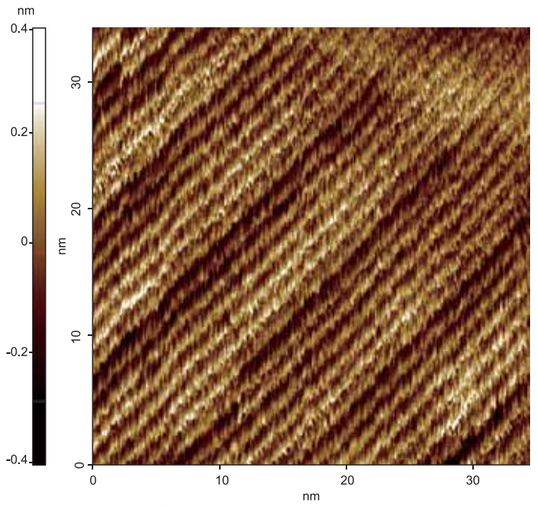
Scan Rate: 3 Hz, 50 Hz
Cantilever: Arrow UHF (f=2000kHz)
Pixel Size: 512 x 512, 512 × 256

Small scan image of polytetrafluoroethylene

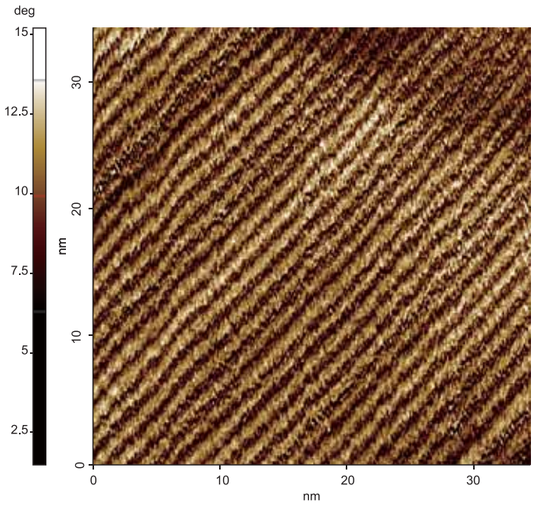


Tapping Mode

Height



Phase



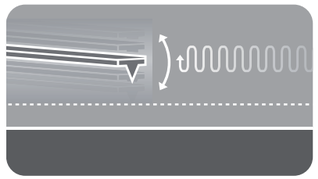
Peak to Valley: 1.4 nm
RMS Roughness: 0.14 nm

Scanning conditions

System: NX20
Scan Size: 35 nm × 35 nm
Scan Mode: Tapping mode

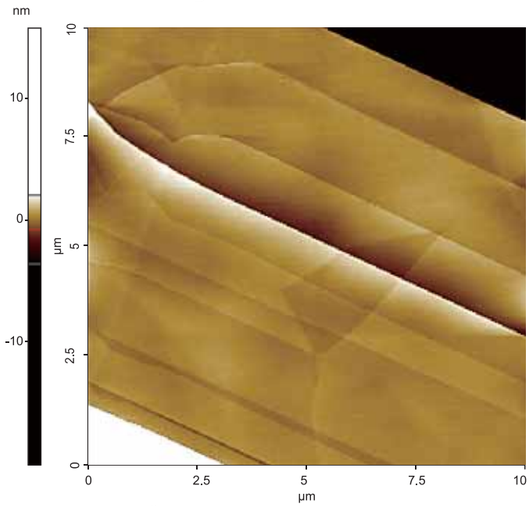
Scan Rate: 6 Hz
Cantilever: Arrow UHF (f=2000kHz)
Pixel Size: 512 x 512

Water droplet on HOPG (1/2)



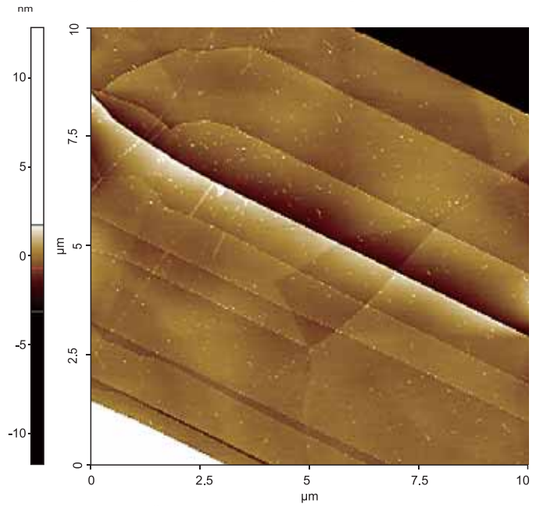
True Non-contact™ Mode

Initial height



Peak to Valley: 24 nm
RMS Roughness: 1.6 nm

Height after droplet deposition



Peak to Valley: 24 nm
RMS Roughness: 1.6 nm

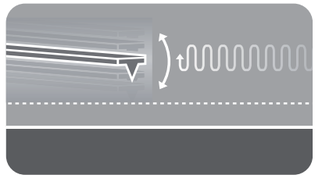
Water droplets deposited on HOPG surface were observed under humid condition in glove box.

Scanning conditions

System: NX10
Scan Size: 10 µm × 10 µm
Scan Mode: Non-contact mode (in glove box)

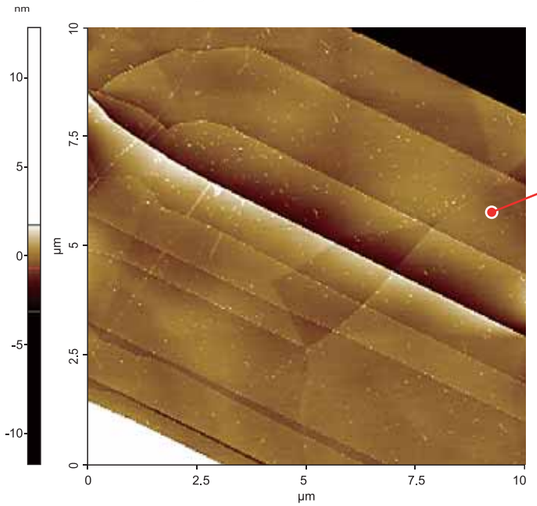
Scan Rate: 0.6 Hz
Cantilever: NSC36 C (k=0.6N/m, f=65kHz)
Pixel Size: 512 × 512

Water droplet on HOPG (2/2)

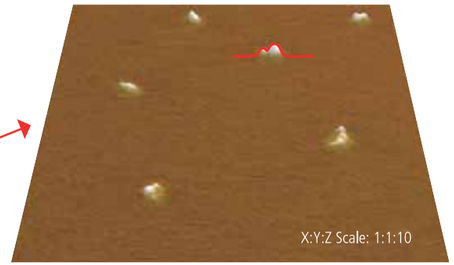


True Non-contact™ Mode

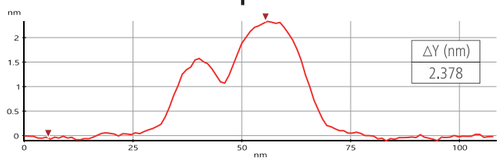
Initial height



Zoom-in 3D



Line profile

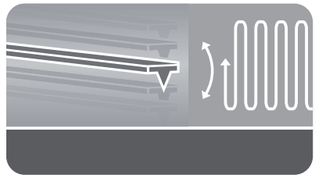


Measured water droplet height: ~2.4nm.

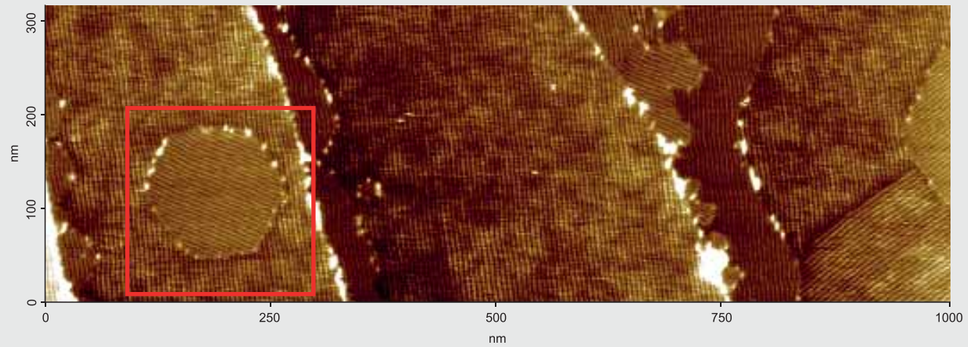
System: NX10
Scan Size: 10 µm × 10 µm, 0.5 µ x 0.5 µm
Scan Mode: Non-contact mode

Scan Rate: 0.6 Hz, 0.5 Hz
Cantilever: NSC36 C (k=0.6N/m, f=65kHz)
Pixel Size: 512 × 512, 512 x 256

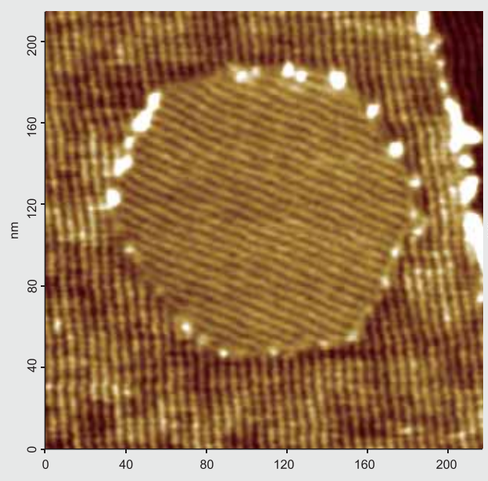
Moiré pattern of Gaphene on hBN



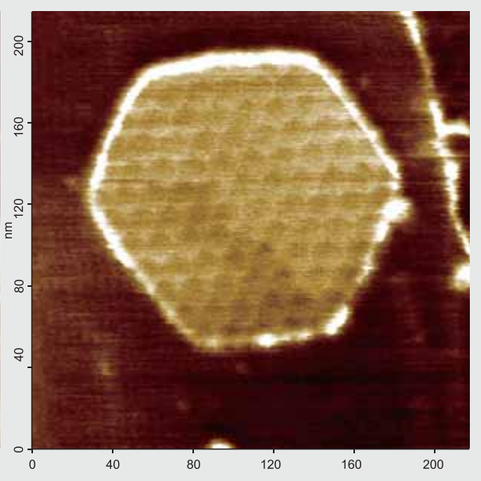
Tapping Mode



Zoom-in (#1)



Zoom-in (#2)



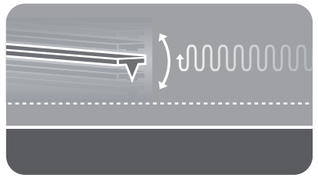
Epitaxial growth of graphene on hBN was carried out by R-PECVD with pure CH_4 as the carbon source.
Moiré pattern was observed on the sample depending on the scan parameters. #1: 10nm Amplitude, 2nm Setpoint #2: 70nm Amplitude, 3nm Setpoint

Scanning conditions

System: NX10
Scan Size: 1 µm × 0.33 µm, 0.22 µ x 0.22 µm
Scan Mode: Tapping mode

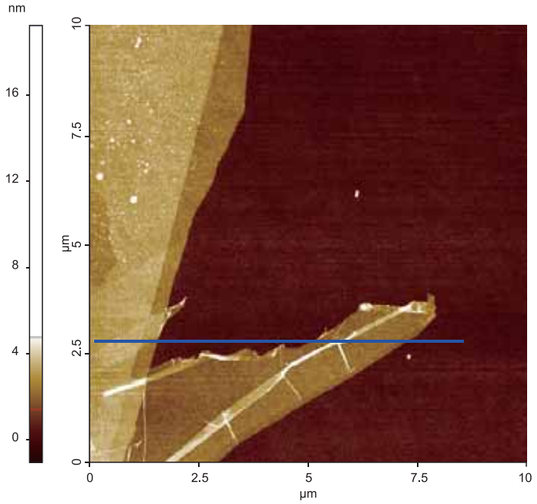
Scan Rate: 2 Hz, 2 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 1024 × 512, 512 × 512

Exfoliated Graphene on SiO_2



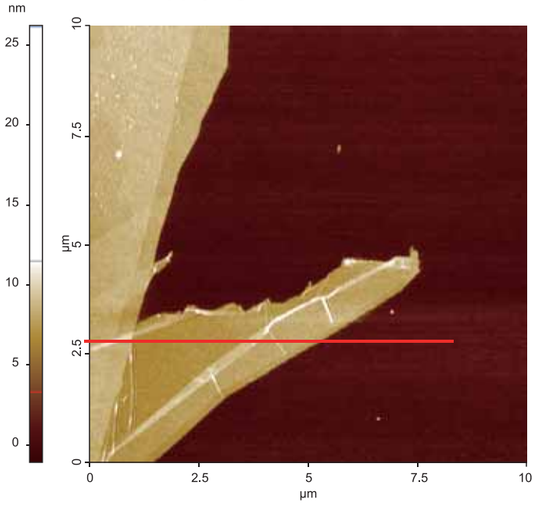
True Non-contact™ Mode

Before applying bias



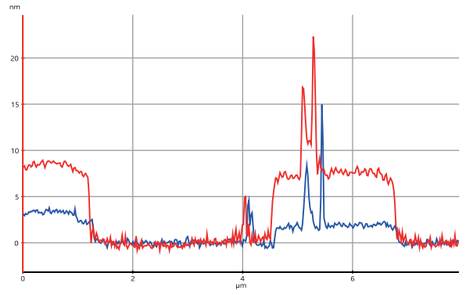
Rpv: 21.3 nm
Rq: 1.4 nm

After applying bias



Rpv: 27.2 nm
Rq: 3.5 nm

Multi-line profiles



The height difference between graphene and SiO_2 was observed after applying 10 V to graphene surface.

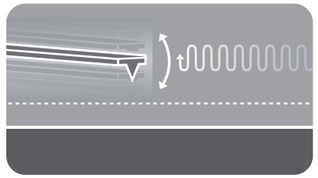
Sample courtesy: Dr. Jia Li, Brown University, US

Scanning conditions

System: NX10
Scan Size: 10 µm × 10 µm
Scan Mode: Non-contact mode

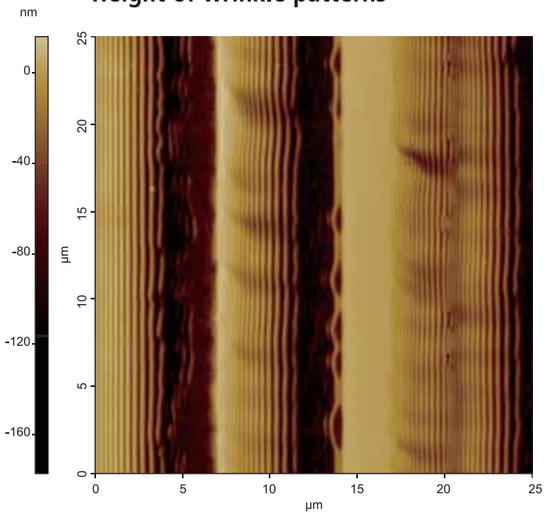
Scan Rate: 1 Hz
Cantilever: NSC36 C (k=0.6N/m, f=65kHz)
Pixel Size: 512 × 256

Patterned surface of epitaxial SiC



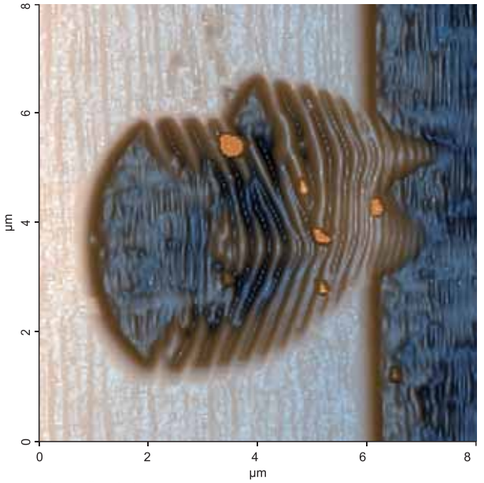
True Non-contact™ Mode

Height of wrinkle patterns



Peak to valley: 195 nm
RMS Roughness: 39 nm

Height of defect



Peak to valley: 278 nm
RMS Roughness: 42 nm

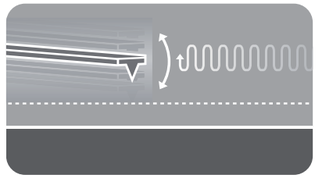
Wrinkle patterns of epitaxial SiC and defect by ion dropping after Cs+ ion gun sputtering.

Scanning conditions

System: NX20
Scan Size: 25 µm × 25 µm, 8 µm × 8 µm
Scan Mode: Non-contact mode

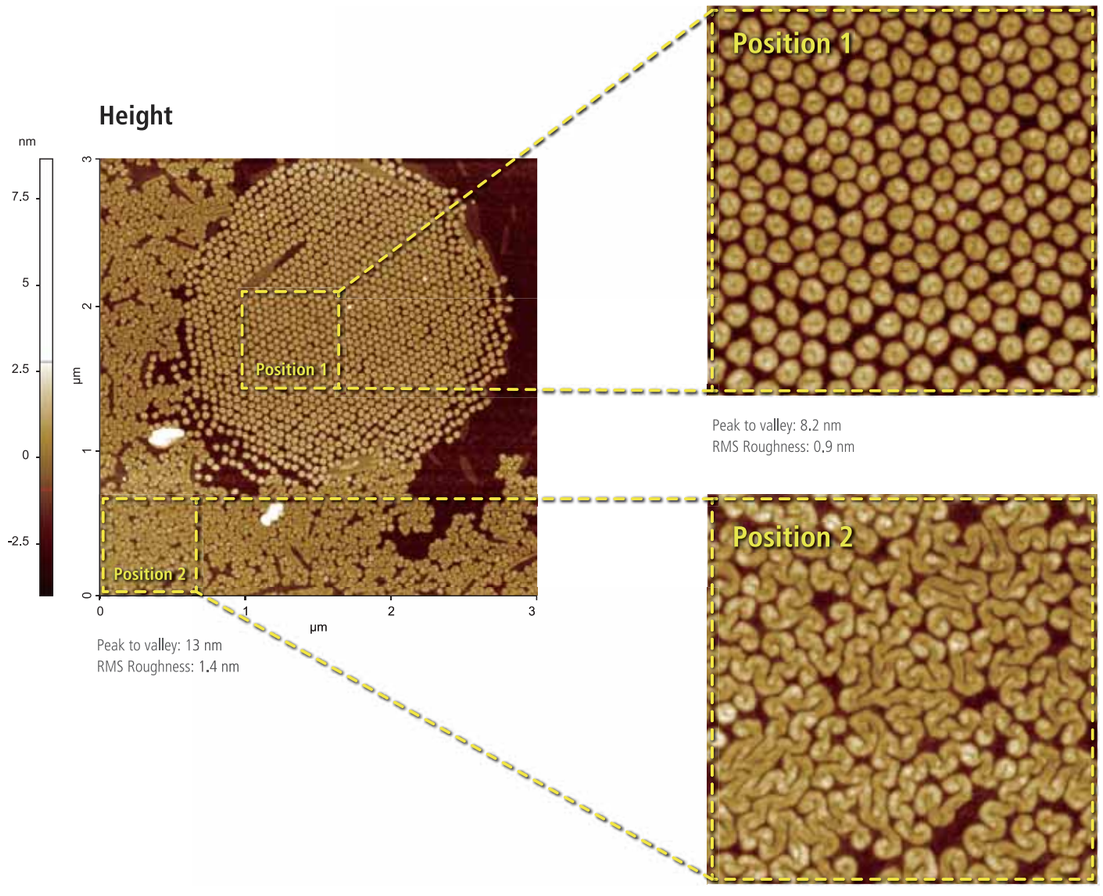
Scan Rate: 0.5 Hz, 0.7 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 256 × 256, 256 × 256

$F_{14}H_{20}$ on Si



True Non-contact™ Mode

Cropped images (800 nm × 800 nm)



Peak to valley: 8.2 nm
RMS Roughness: 0.9 nm

Peak to valley: 13 nm
RMS Roughness: 1.4 nm

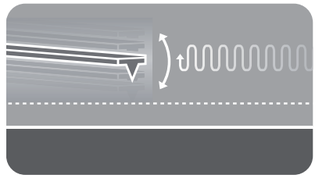
Peak to valley: 5.2 nm
RMS Roughness: 0.7 nm

Scanning conditions

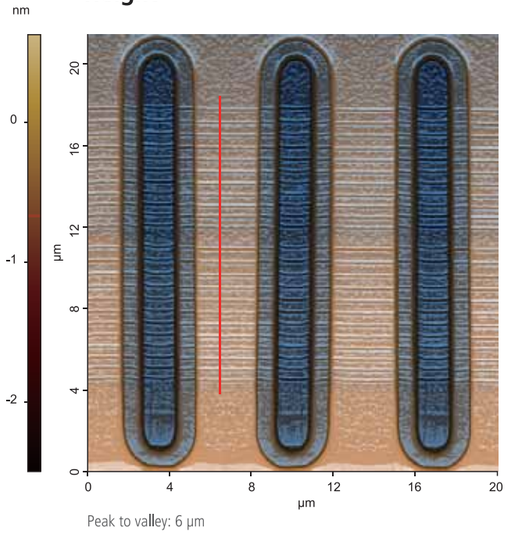
System: NX20
Scan Size: 3 µm × 3 µm
Scan Mode: Non-contact mode

Scan Rate: 1 Hz
Cantilever: Arrow UHF (f=2000kHz)
Pixel Size: 1024 × 1024

3D NAND flash

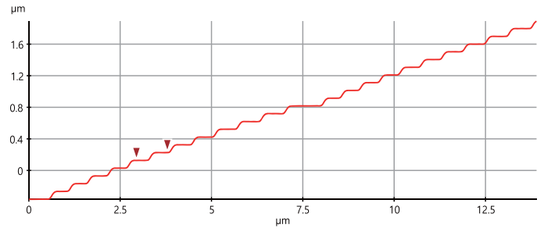


True Non-contact™ Mode



Peak to valley: 6 µm
RMS Roughness: 2 µm

Line Profile



Cursor	ΔX (µm)	ΔY (µm)
Red	0.845	0.100

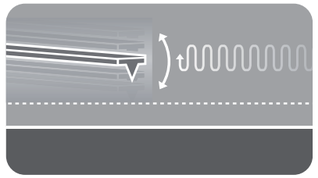
ΔY = Step height

Scanning conditions

System: NX-Wafer
Scan Size: 20 µm × 22 µm
Scan Mode: Non-contact mode

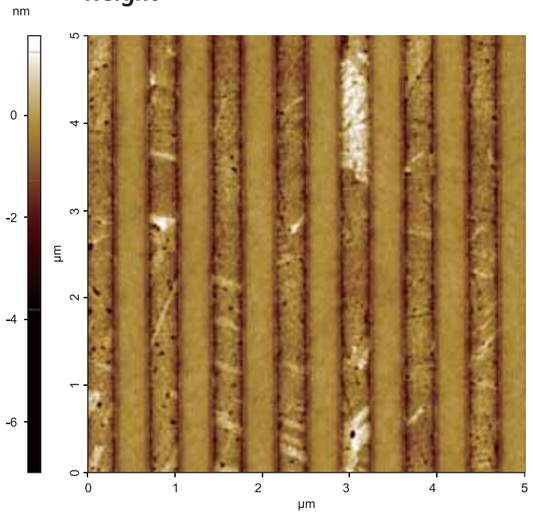
Scan Rate: 0.4 Hz
Cantilever: PPP-NCHR (k=42N/m, f=330kHz)
Pixel Size: 512 × 512

Post CMP wafer

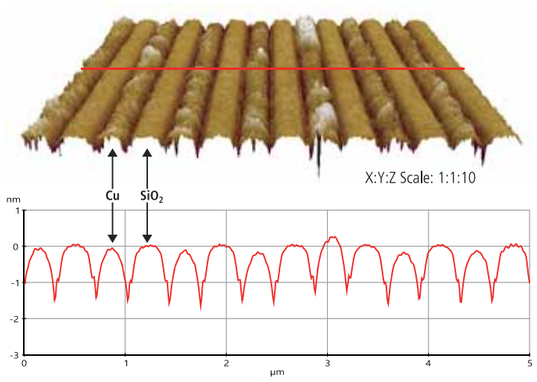


True Non-contact™ Mode

Height



3D



Y: 1 nm/div

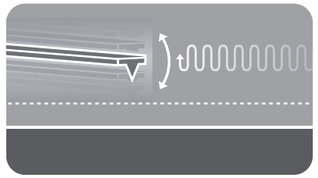
Peak to valley: 8.8 nm
RMS Roughness: 0.54 nm

Scanning conditions

System: NX-Wafer
Scan Size: 5 µm × 5 µm
Scan Mode: Non-contact mode

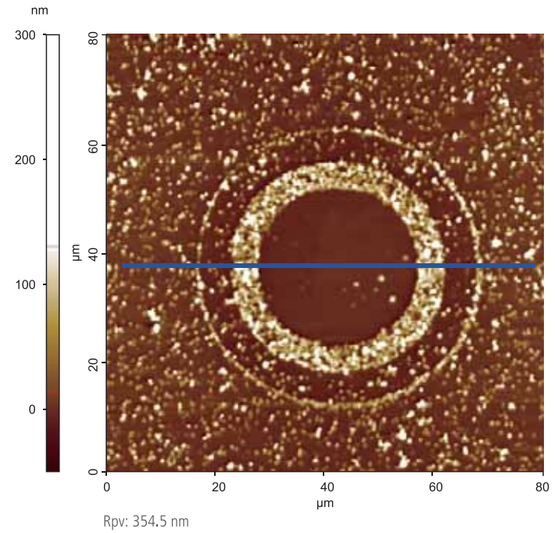
Scan Rate: 0.3 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 x 512

Semiconductor process monitoring; CMP



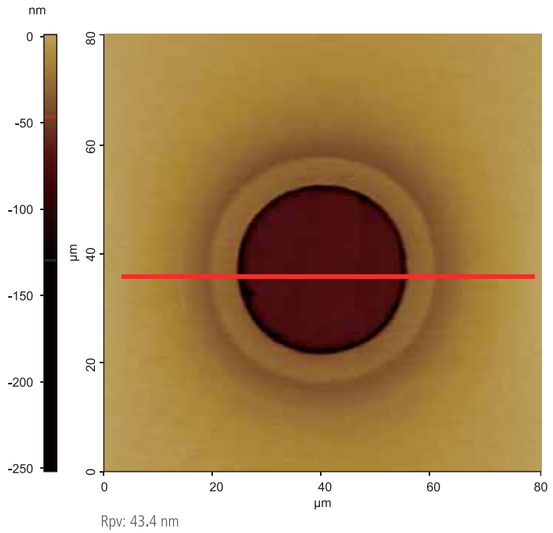
True Non-contact™ Mode

Before CMP



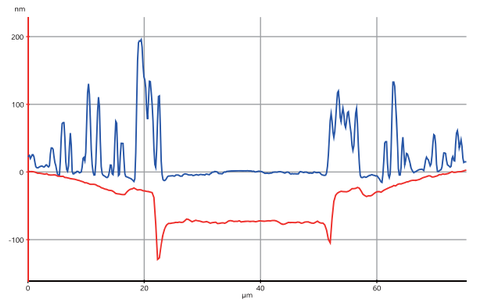
Rpv: 354.5 nm
Rq: 36.5 nm

After CMP



Rpv: 43.4 nm
Rq: 4.1 nm

Multi-line profiles



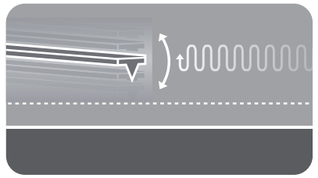
Cu via on SiC wafer. The via pattern surface changed after chemical mechanical polishing (CMP) process.

Scanning conditions

System: NX20
Scan Size: 80 µm × 80 µm
Scan Mode: Non-contact mode

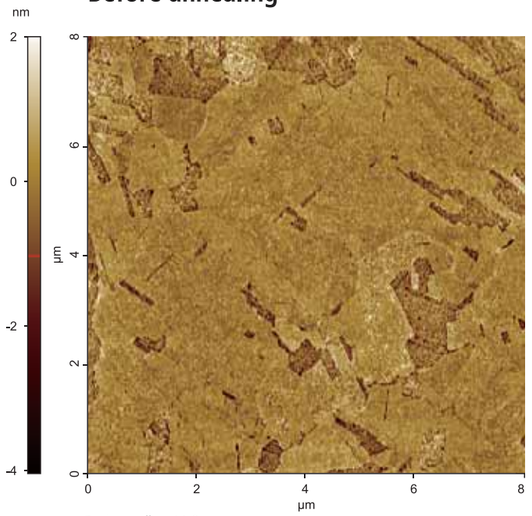
Scan Rate: 0.5 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 x 512

Semiconductor process monitoring; Annealing



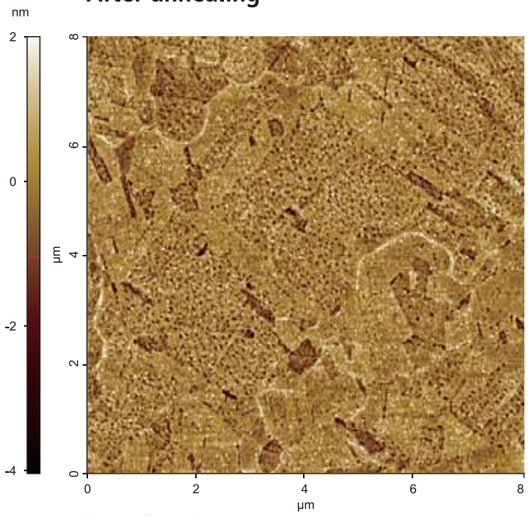
True Non-contact™ Mode

Before annealing



Peak to valley: 11.2 nm
RMS Roughness: 0.52 nm

After annealing



Peak to valley: 14.0 nm
RMS Roughness: 0.72 nm

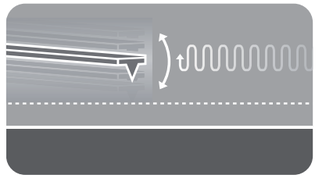
Surface change of Cu pad was observed before and after annealing at the same position.

Scanning conditions

System: NX-Wafer
Scan Size: 8 µm × 8 µm
Scan Mode: Non-contact mode

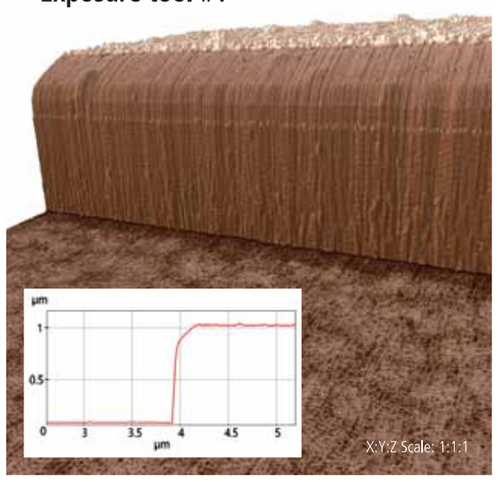
Scan Rate: 0.8 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 × 512

Semiconductor process monitoring; Exposure

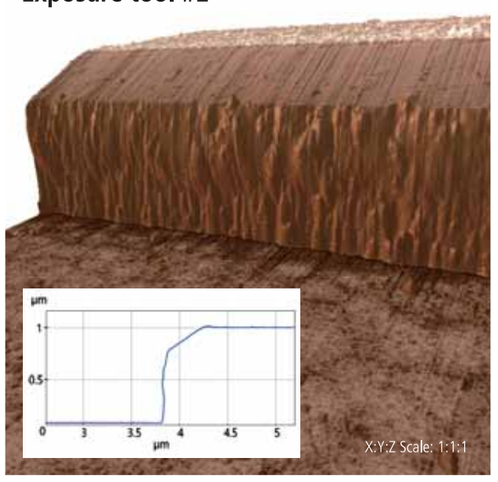


True Non-contact™ Mode

Exposure tool #1



Exposure tool #2



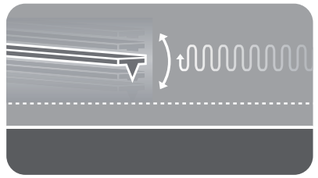
Study on the dependence of exposure tools on sidewall roughness.

Scanning conditions

System: NX-3DM
Scan Size: 50 µm × 50 µm
Scan Mode: Non-contact mode

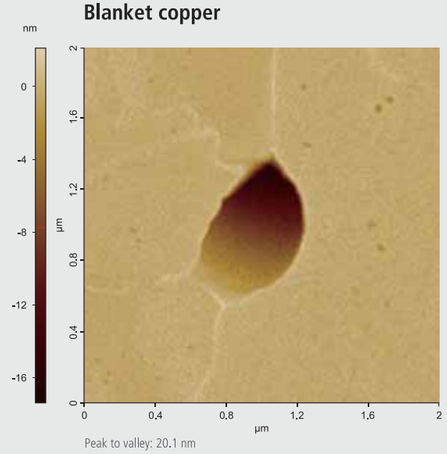
Scan Rate: 0.2 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 × 512

Failure analysis; Defect analysis



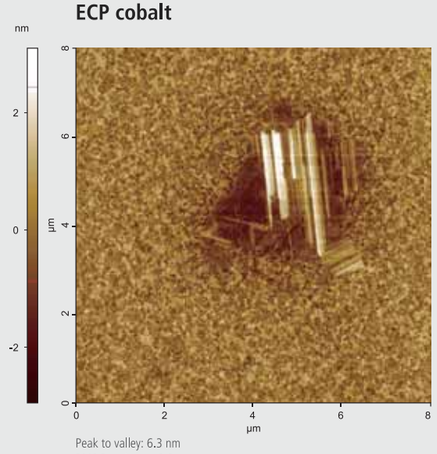
True Non-contact™ Mode

Blanket copper



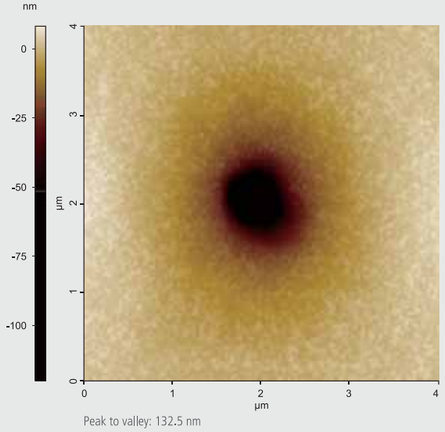
Peak to valley: 20.1 nm
RMS Roughness: 2.3 nm

ECP cobalt



Peak to valley: 6.3 nm
RMS Roughness: 0.8 nm

PVD cobalt



Peak to valley: 132.5 nm
RMS Roughness: 12.9 nm

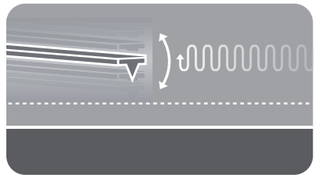
Defect measurements for the different materials and processes. ECP: Electrochemical plating, PVD: Physical vapor deposition.

Scanning conditions

System: NX-Wafer ADR
Scan Size: 2 µm × 2 µm, 8 µm x 8 µm, 4 µm x 4 µm
Scan Mode: Non-contact mode

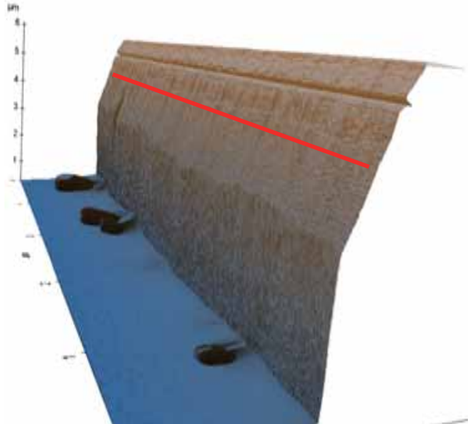
Scan Rate: 1 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 × 256, 512 × 256, 512 × 256

Failure analysis; Position uniformity

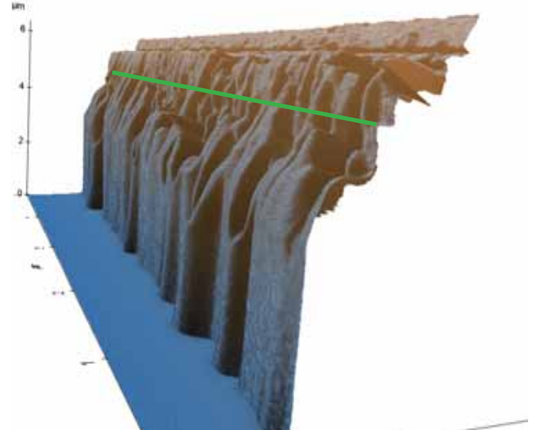


True Non-contact™ Mode

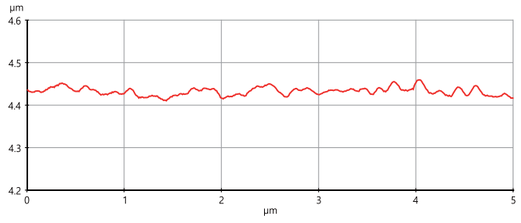
Wafer center



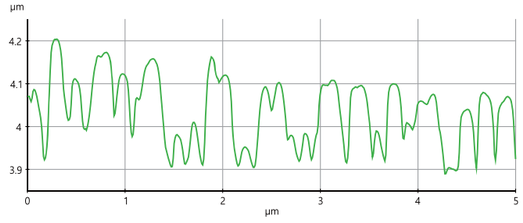
Wafer edge



Line profile of center



Line profile of edge



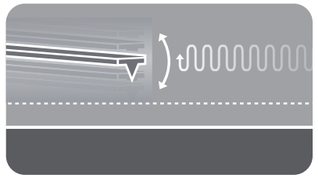
Measurement of sidewall roughness on Si line patterns by location. Despite the same semiconductor fabrication process, there is a difference in roughness between the center and the edge of the wafer.

Scanning conditions

System: NX-3DM
Scan Size: 2 µm × 5 µm
Scan Mode: Non-contact mode

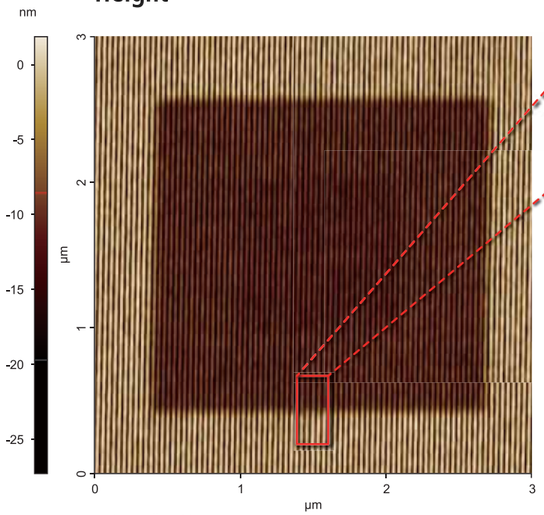
Scan Rate: 0.05 Hz
Cantilever: EBD2-R2-NCLR (k=48N/m, f=190kHz)
Pixel Size: 2048 × 512

Damage of PR patterns

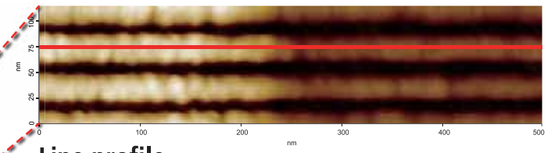


True Non-contact™ Mode

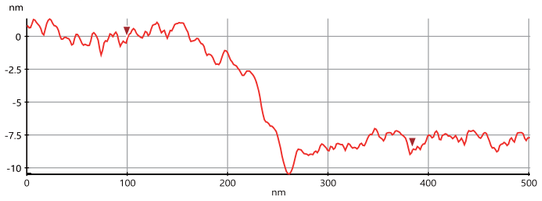
Height



Zoom-in height



Line profile



Cursor	ΔX (µm)	ΔY (µm)
Red	279.372	7.916

Peak to valley: 29.7 nm
RMS Roughness: 7.01 nm

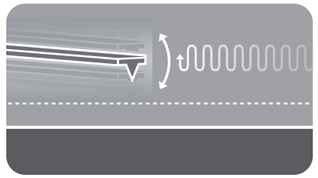
In Photo Resist (PR) patterns, approximately 8 nm height shrinkage was observed due to e-beam damage.

Scanning conditions

System: NX-Wafer
Scan Size: 3 µm × 3 µm, 0.5 µm × 0.1 µm
Scan Mode: Non-contact mode

Scan Rate: 0.5 Hz, 1 Hz
Cantilever: SSS-NCHR (k=42N/m, f=330kHz)
Pixel Size: 512 × 512, 256 x 256

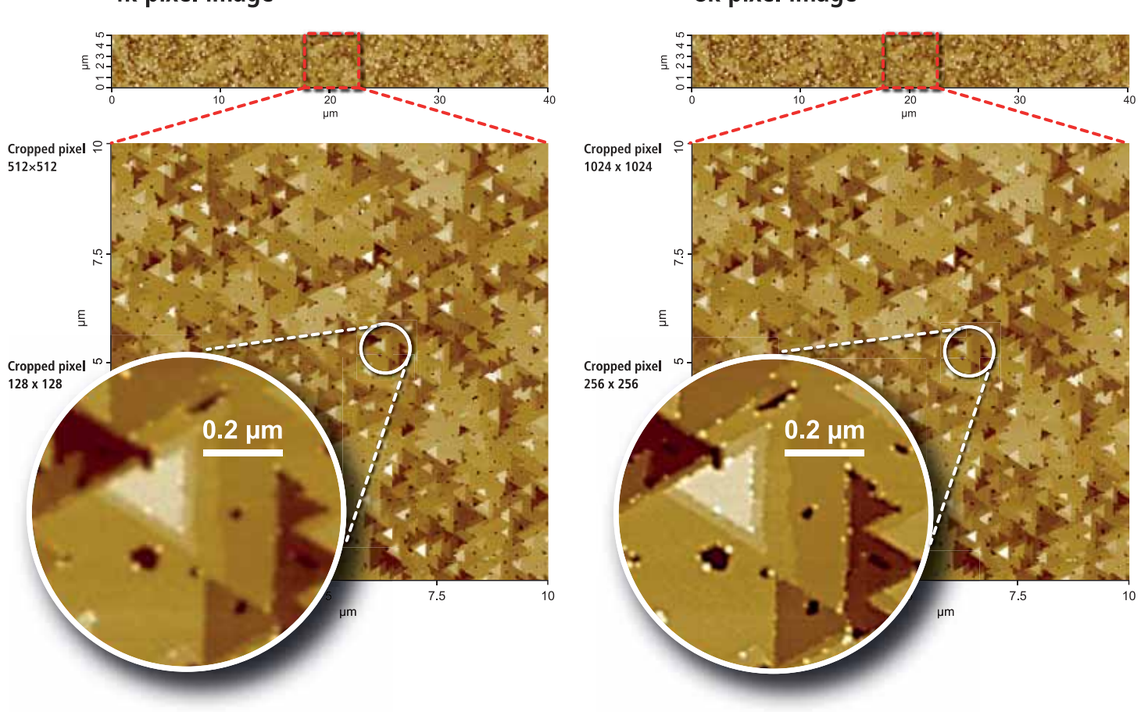
$LiNbO_3$



True Non-contact™ Mode

4k pixel image

8k pixel image

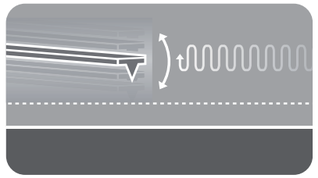


Scanning conditions

System: NX-HDM
Scan Size: 40 µm × 5 µm
Scan Mode: Non-contact mode

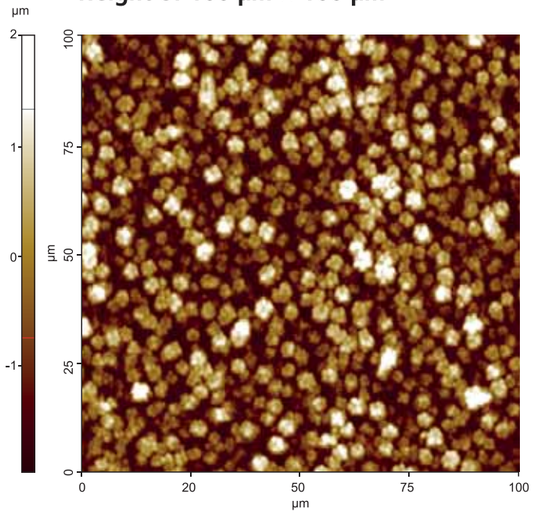
Scan Rate: 0.05 Hz
Cantilever: OMCL-AC240TS (k=2N/m, f=70kHz)
Pixel Size: 4096×512 (left), 8192×1024 (right)

Copper foil



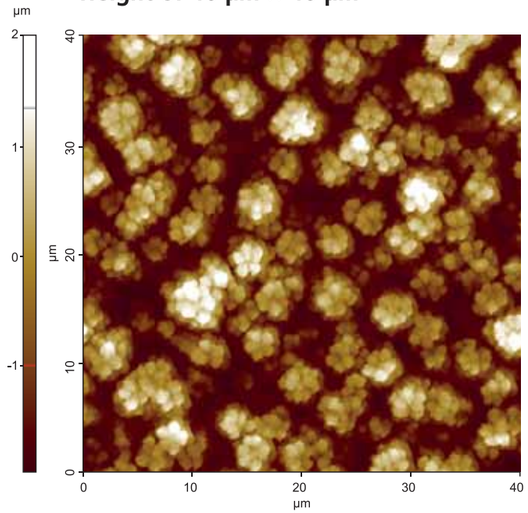
True Non-contact™ Mode

Height of 100 µm × 100 µm



Peak to valley: 4.3 µm
RMS Roughness: 0.7 µm

Height of 40 µm × 40 µm



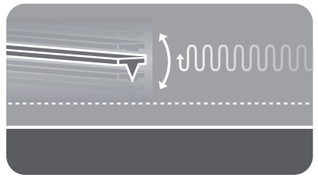
Peak to valley: 4.2 µm
RMS Roughness: 0.7 µm

Scanning conditions

System: NX20
Scan Size: 100 µm × 100 µm, 40 µm x 40 µm
Scan Mode: Non-contact mode

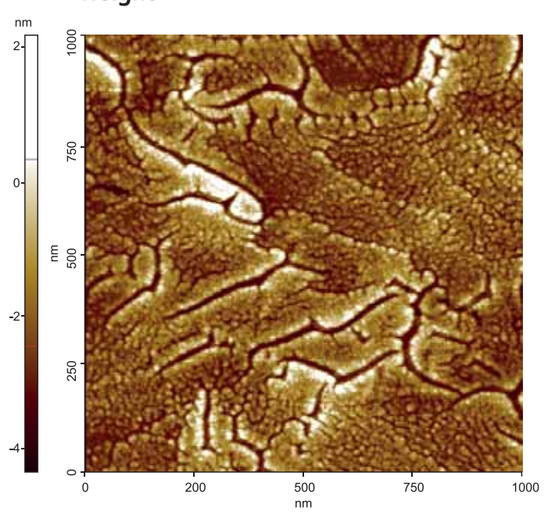
Scan Rate: 0.5 Hz, 0.5 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 x 512, 512 x 512

GaN film



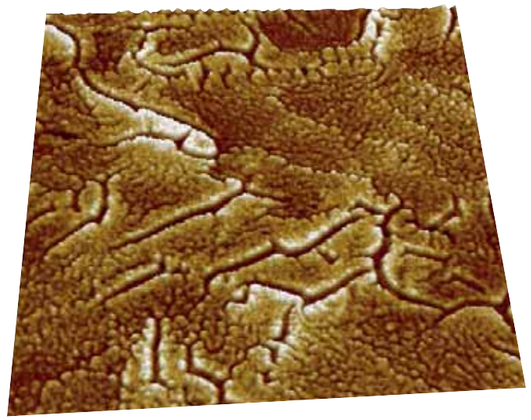
True Non-contact™ Mode

Height



Peak to valley: 6.4 nm
RMS Roughness: 0.8 nm

3D



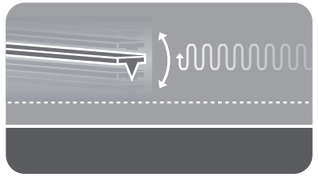
X:Y:Z Scale: 1:1:5

Scanning conditions

System: NX10
Scan Size: 1 µm × 1 µm
Scan Mode: Non-contact mode

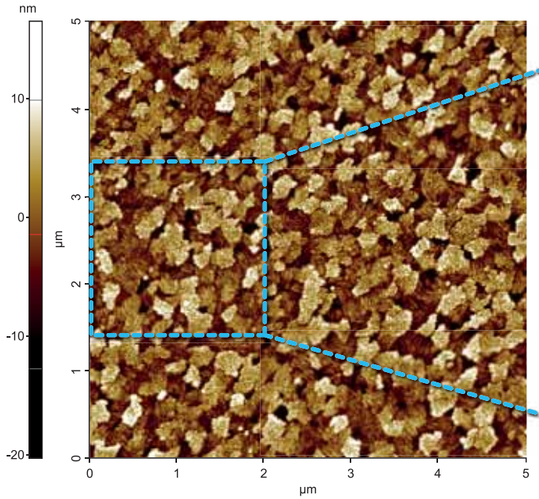
Scan Rate: 1 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 × 512

ITO coated Quarts chip



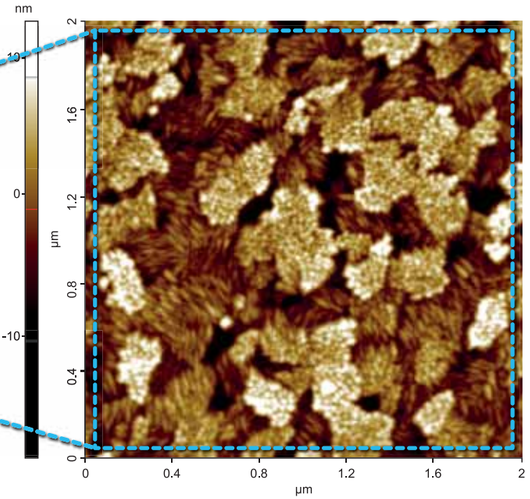
True Non-contact™ Mode

Height



Peak to valley: 37.5 nm
RMS Roughness: 4.8 nm

Zoom-in height



Peak to valley: 33.6 nm
RMS Roughness: 4.6 nm

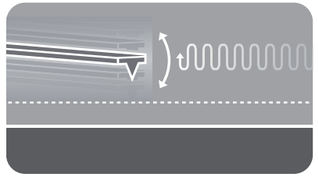
Sample courtesy: Kee-Hyun Paik, Multerra Bio, Inc., US

Scanning conditions

System: NX20
Scan Size: 5 µm × 5 µm, 2 µm × 2 µm
Scan Mode: Non-contact mode

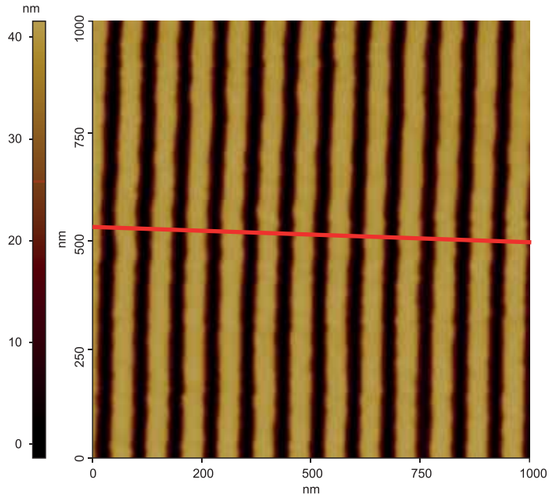
Scan Rate: 0.7 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 512 × 512, 256 x 256

Si grating



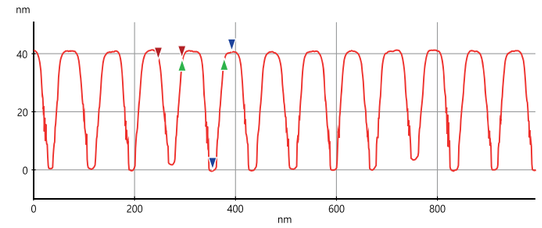
True Non-contact™ Mode

Height



Peak to valley: 44.0 nm
RMS Roughness: 15.7 nm

Line profile



Cursor	ΔX (nm)	ΔY (nm)
Red	46.825	0.536
Green	83.540	0.277
Blue	38.002	40.826

Silicon trench patterns.

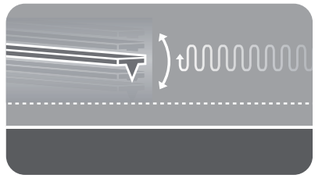
Sample courtesy: Jason Yee, Nova Measurement Instruments, US

Scanning conditions

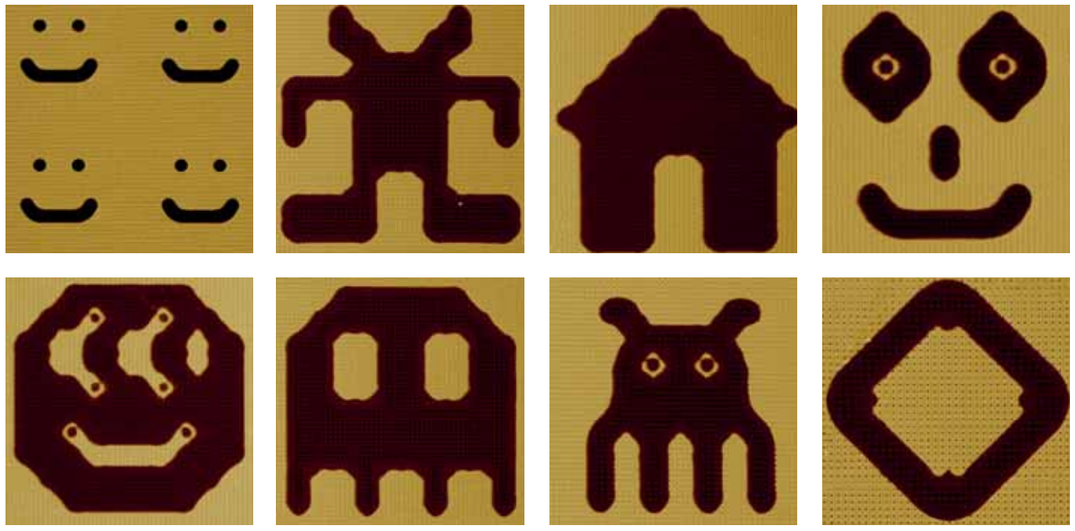
System: NX12
Scan Size: 1 µm × 1 µm
Scan Mode: Non-contact mode

Scan Rate: 0.06 Hz
Cantilever: AC160TS (k=26N/m, f=300kHz)
Pixel Size: 1024×64

Fun grating



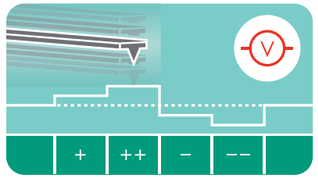
True Non-contact™ Mode



- 8 funny graphics composed from small pixels etched into the polished silicon surface.
- Circular nano-pits created by nano-imprint at the complete surface.

Sample courtesy: Nanosensors (https://www.nanosensors.com)

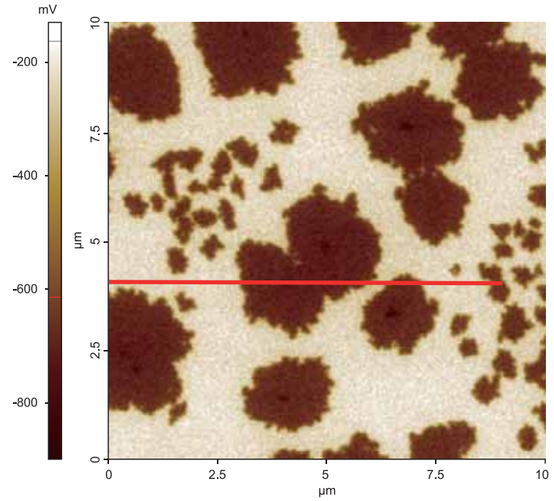
$F_{14}H_{20}$ on Si; Potential



Kelvin Probe Force Microscopy

In Kelvin Probe Force Microscopy (KPFM), the AFM operates in non-contact mode while a conductive cantilever, oscillated at its fundamental resonant frequency, laterally scans over the sample surface. The resulting electrostatic signal provides information related to surface potential and the capacitance gradient. The topographic data is taken by controlling the force between the tip and the sample.

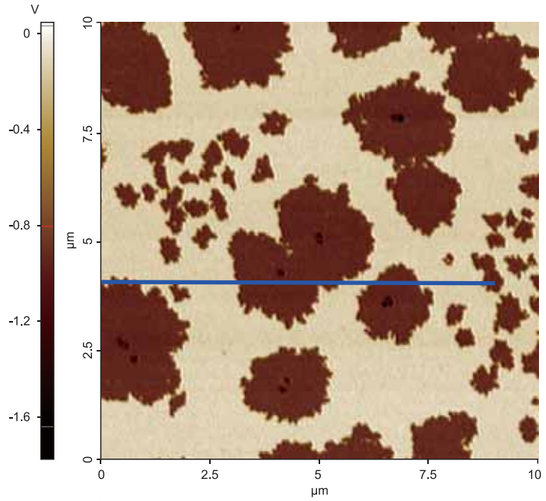
AM KPFM potential



Peak to valley: 795 mV
RMS Roughness: 210 mV

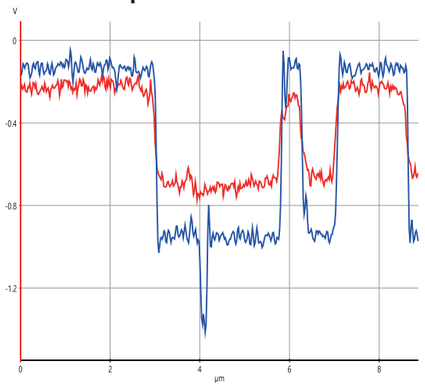
*AM KPFM: Amplitude modulation KPFM

Sideband KPFM potential



Peak to valley: 1879 mV
RMS Roughness: 392 mV

Multi-line profiles

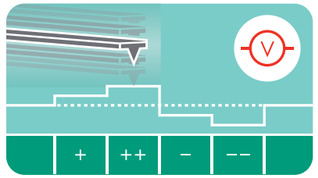


Potential image quality comparison by scan modes. Sideband KPFM shows the better image quality and quantitative results compared to AM KPFM.

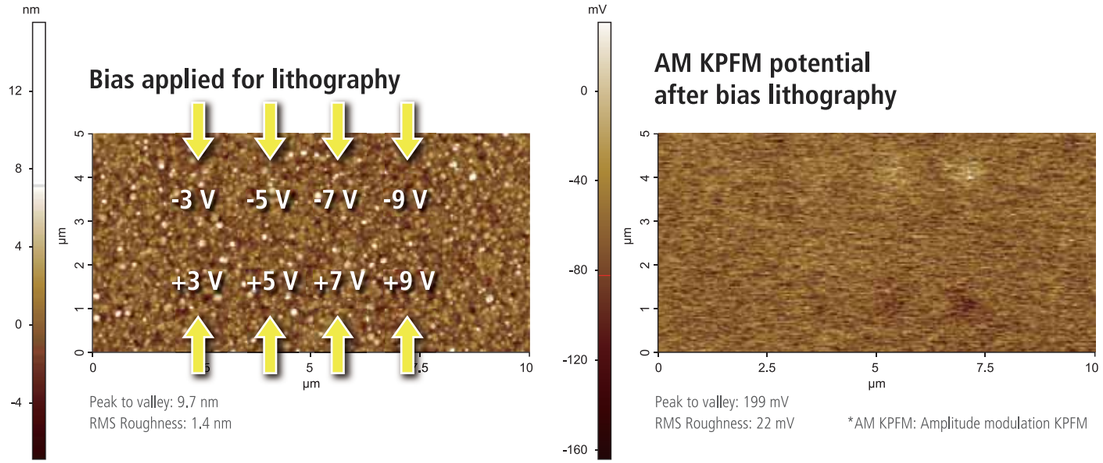
Scanning conditions

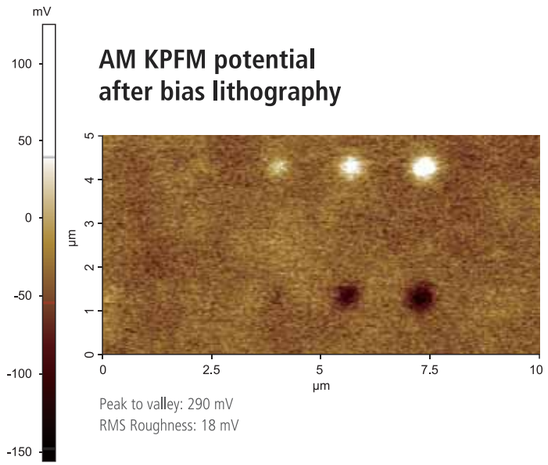
System: NX20
Scan Size: 10 µm × 10 µm
Scan Mode: KPFM
Scan Rate: 0.3 Hz
Cantilever: ElectriMulti75-G (k=3N/m, f=75kHz)
Pixel Size: 512 × 256

Dot lithography on PZT; Potential



Kelvin Probe Force Microscopy





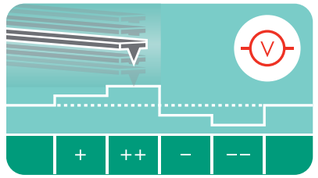
Surface potential was measured after "dots lithography" on PZT thin film. Applied tip bias for domain polling were 3V, 5V, 7V and 9V for both sign. Sideband KPFM distinguishes polarized domains on PZT surface well but the AM KPFM shows week surface potential signal.

Scanning conditions

System: NX10
Scan Size: 10 µm × 5 µm
Scan Mode: KPFM

Scan Rate: 0.3 Hz
Cantilever: ElectriMulti75-G (k=3N/m, f=75kHz)
Pixel Size: 512 × 256

Park logo lithography on PZT; Potential

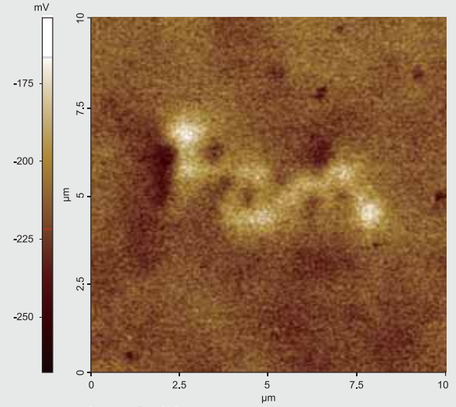


Kelvin Probe Force Microscopy

Design

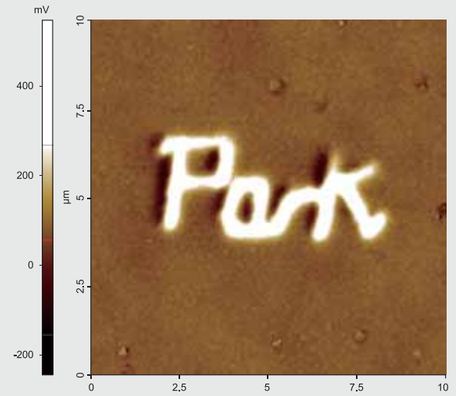
Peak to valley: 9.7 nm
RMS Roughness: 1.4 nm

AM KPFM potential after bias lithography



Peak to valley: 816 meV
RMS Roughness: 152 meV
*AM KPFM: Amplitude modulation KPFM

Sideband KPFM potential after bias lithography



Peak to valley: 1064 meV
RMS Roughness: 300 meV

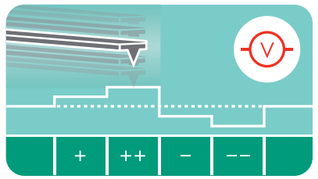
Surface potential was measured after "Park logo lithography" on PZT thin film. For domain polling, +9V was applied to tip and -9V was applied after moving 300nm to right. Sideband KPFM shows the better image quality compared to AM KPFM.

Scanning conditions

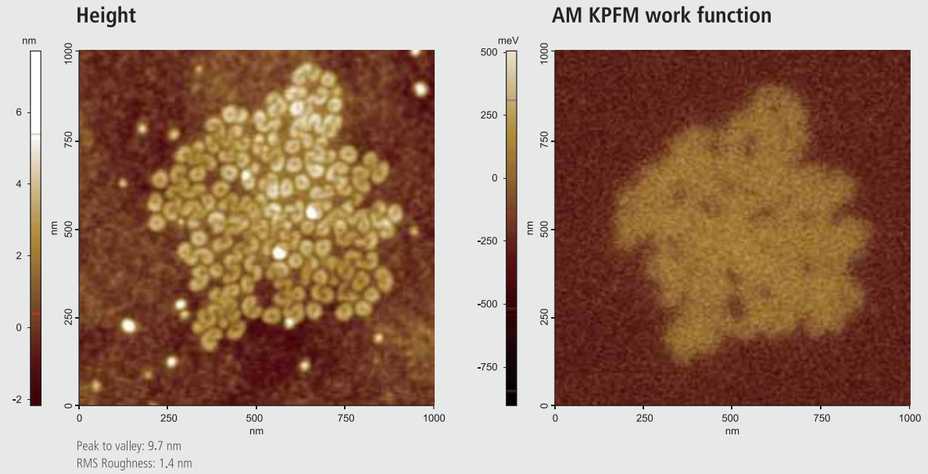
System: NX10
Scan Size: 10 µm × 5 µm
Scan Mode: KPFM

Scan Rate: 0.3 Hz
Cantilever: ElectriMulti75-G (k=3N/m, f=75kHz)
Pixel Size: 512 × 256

$F_{14}H_{20}$ on Si; Work function

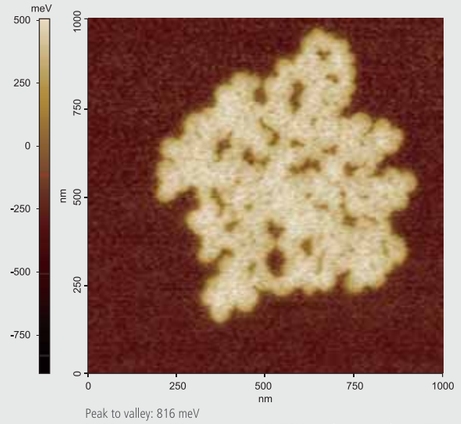


Kelvin Probe Force Microscopy



Peak to valley: 9.7 nm
RMS Roughness: 1.4 nm

Sideband KPFM work function



Peak to valley: 816 meV
RMS Roughness: 152 meV

*AM KPFM: Amplitude modulation KPFM

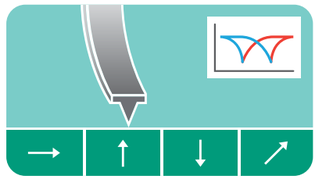
The same image color scale was used for work function image comparison. Sideband KPFM shows the better image quality and quantitative results compared to AM KPFM.

Scanning conditions

System: NX10
Scan Size: 1 μm × 1 μm
Scan Mode: KPFM

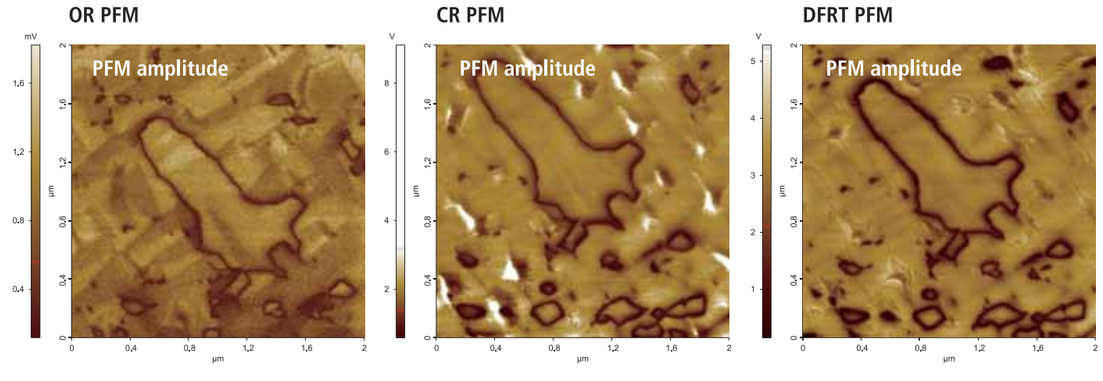
Scan Rate: 0.3 Hz
Cantilever: PPP-EFM (k=2.8N/m, f=75kHz)
Pixel Size: 512 × 256

BFO; PFM Images

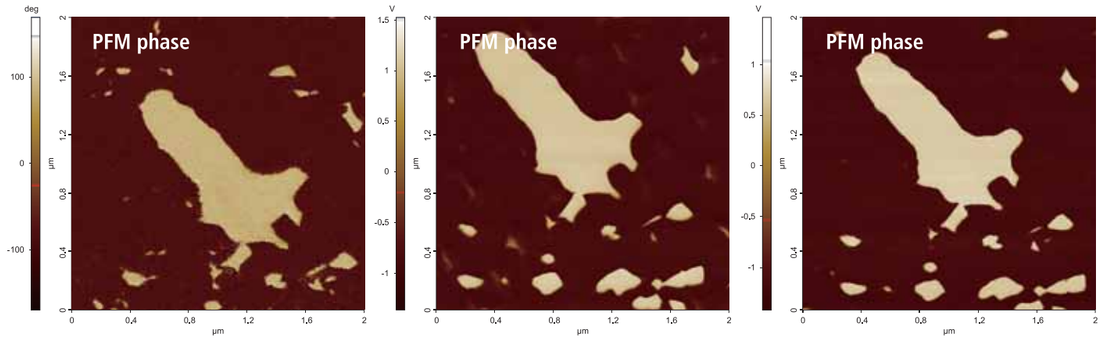


Piezoelectric Force Microscopy

PFM utilizes a lock-in amplifier to study the electrical properties and topography of a piezo sample surface in one single scan. Here, the AC voltage biased cantilever will introduce sample surface oscillation with same frequency. The oscillation component of the PSPD signal is extracted by the lock-in amplifier, resulting in the PFM signal.



- **Image comparison by three different PFM techniques**
- **DFRT PFM shows the best image quality without topography artifact.**



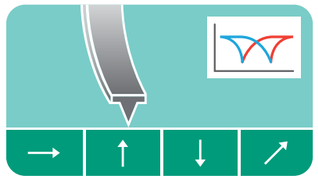
- **OR PFM: Off resonance PFM**
- **CR PFM: Contact resonance PFM**
- **DFRT PFM: Dual frequency resonance tracking PFM**

Scanning conditions

System: NX10
Scan Size: 2 μm × 2 μm
Scan Mode: PFM

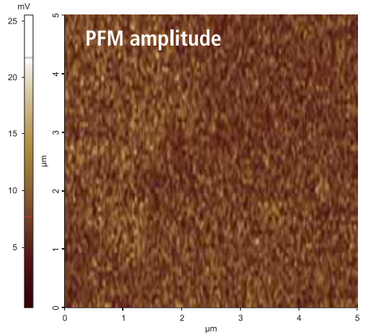
Scan Rate: 0.2 Hz
Cantilever: PPP-EFM (k=2.8N/m, f=75kHz)
Pixel Size: 512 x 512

PMN-PT; PFM Images

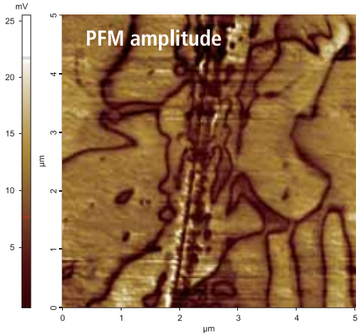


Piezoelectric Force Microscopy

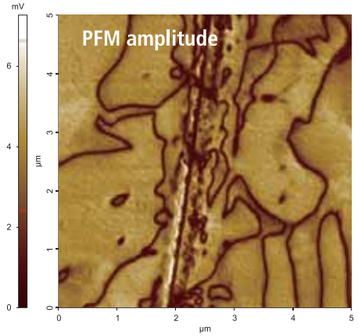
OR PFM



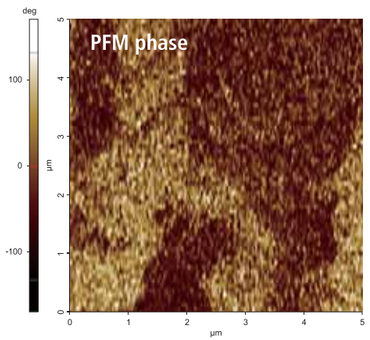
CR PFM

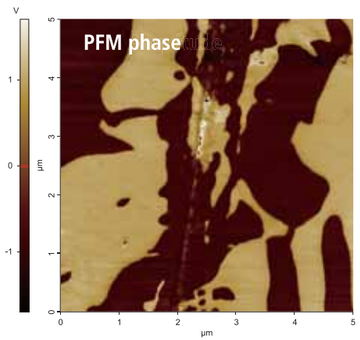


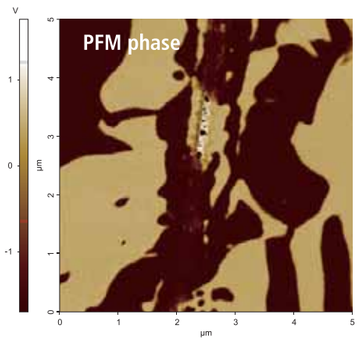
DFRT PFM



- Image comparison by three different PFM techniques
- DFRT PFM shows the best image quality without topography artifact.





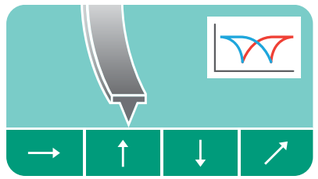


- OR PFM: Off resonance PFM
- CR PFM: Contact resonance PFM
- DFRT PFM: Dual frequency resonance tracking PFM

Scanning conditions

System: NX10
Scan Size: 5 μm × 5 μm
Scan Mode: PFM
Scan Rate: 0.5 Hz
Cantilever: NSC36Ti-Pt B (k=2N/m, f=130kHz)
Pixel Size: 512 x 256

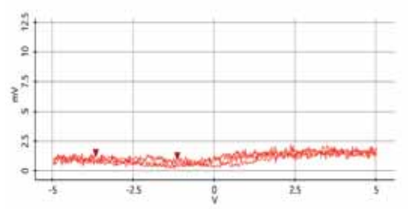
PMN-PT; PFM Images



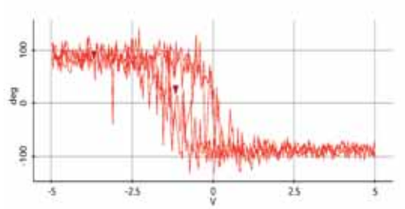
Piezoelectric Force Microscopy

OR PFM

PFM Amplitude-Sample bias curve

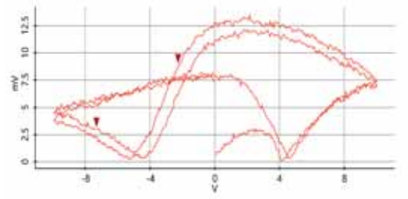


PFM Phase-Sample bias curve

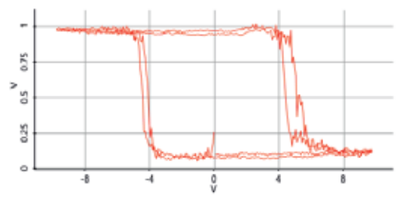


CR PFM

PFM Amplitude-Sample bias curve

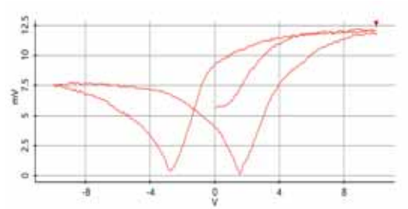


PFM Phase-Sample bias curve

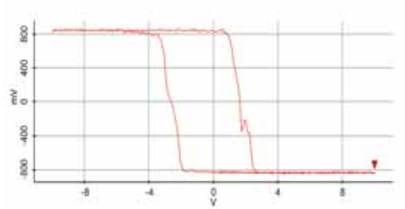


DFRT PFM

PFM Amplitude-Sample bias curve



PFM Phase-Sample bias curve

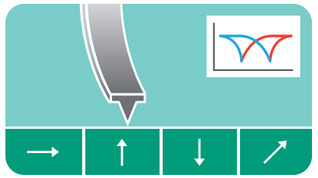


Scanning conditions

System: NX10
Sample bias sweep range: -5 V to +5 V for OR PFM
-10 V to -10 V for CR PFM, DFRT PFM
Scan Mode: PFM
Cantilever: NSC36Ti-Pt B (k=2N/m, f=130kHz)
Pixel Size: 1024 points

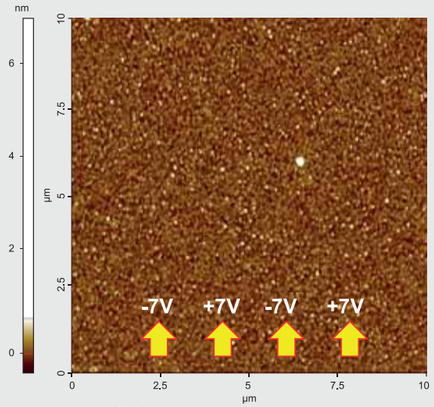
HfO_2 electrical property

Conductive AFM



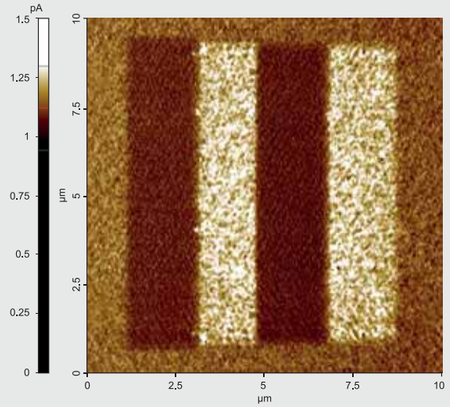
PFM

Height



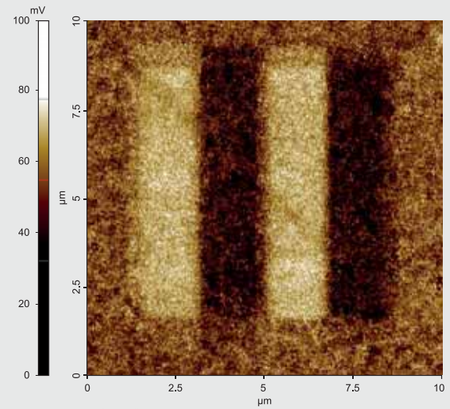
Peak to valley: 7.4 nm
RMS Roughness: 0.2 nm

Current after bias patterning



Peak to valley: 1.5 pA
Mean: 1.1 pA

PFM phase after bias patterning



Peak to valley: 100 mV
RMS Roughness: 11.6 mV

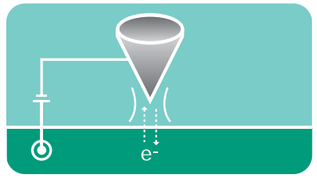
Ferroelectric domain on Hafnium oxide (HfO_2) thin film was switched by -7V and +7V. Low current in pA was observed at +4V bias after domain polling. PFM phase measured at 0V bias after domain polling using Contact resonance PFM.

Scanning conditions

System: NX10
Scan Size: 10 µm × 10 µm
Scan Mode: C-AFM, CR-PFM

Scan Rate: 0.5 Hz
Cantilever: PPP-CONTR (k=0.2N/m, f=13kHz)
Pixel Size: 512 × 256

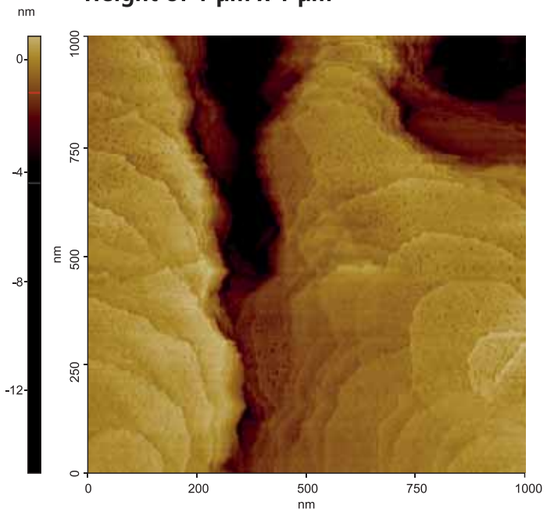
SAM on Au; STM



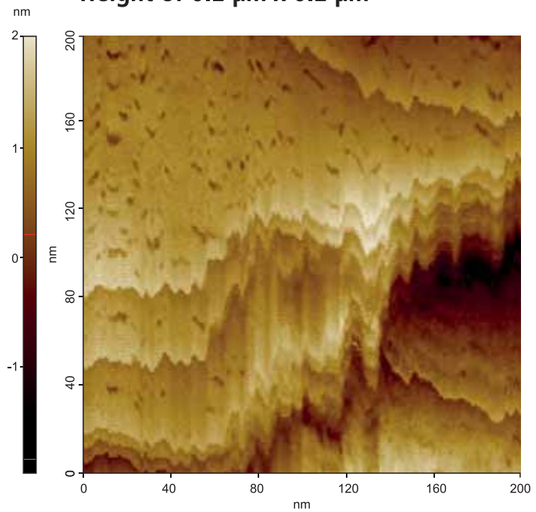
Scanning Tunneling Microscopy

Scanning Tunneling Microscopy (STM) is one of the application modes for Park AFM. STM is the ancestor of all atomic force microscopes. It was invented in 1981 by Gerd Binnig and Heinrich Rohrer at IBM Zurich. Five years later, they were awarded the Nobel Prize in physics for its invention. The STM was the first instrument to generate real-space images of surfaces with so-called "atomic resolution." This would later be known as atomic lattice resolution.

Height of 1 µm x 1 µm



Height of 0.2 µm x 0.2 µm



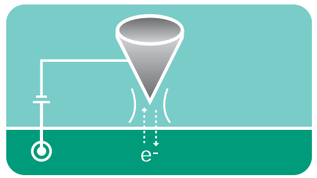
Self-assembled monolayer (SAM) on Au made from organothiols (C10) containing.

Scanning conditions

System: NX10
Scan Size: 1 µm × 1 µm, 0.2 µm × 0.2 µm
Scan Mode: STM

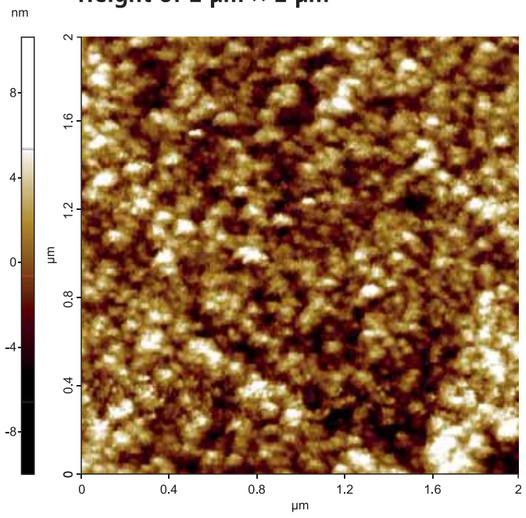
Scan Rate: 0.5 Hz, 1 Hz
Cantilever: Pt/Ir wire
Pixel Size: : 512×512, 512×512

Au patterned PET; STM

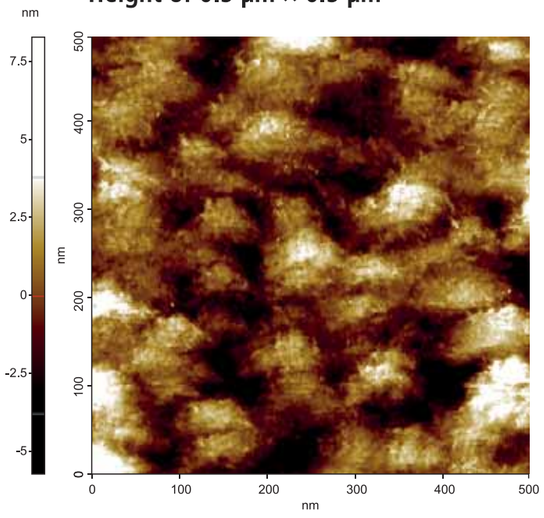


Scanning Tunneling Microscopy

Height of 2 μm × 2 μm



Height of 0.5 μm × 0.5 μm

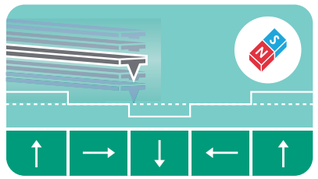


Scanning conditions

System: NX10
Scan Size: 2 μm × 2 μm, 0.5 μm × 0.5 μm
Scan Mode: STM

Scan Rate: 0.5 Hz, 0.3 Hz
Cantilever: STM wire
Pixel Size: 512 × 256, 512 × 256

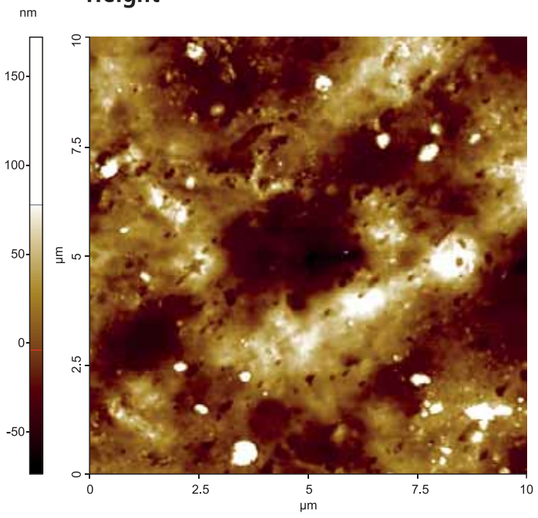
Iron/rubber composite; Magnetic property



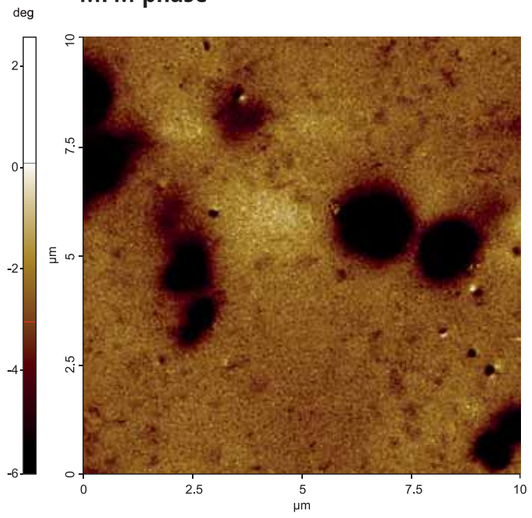
Magnetic Force Microscopy

As much as EFM couples a topography scan with a simultaneous scan for electrical properties, Magnetic Force Microscopy (MFM) combines a topography scan with a concurrent scan for magnetic properties. MFM features a non-contact AFM scan to obtain the topography, and a scan farther from the surface to probe long-range magnetic force. In this magnetic force domain, deflections of the magnetized cantilever correspond.

Height



MFM phase



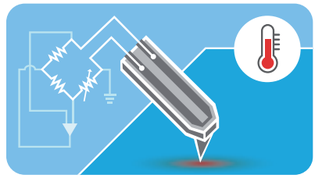
The iron particles are obviously distinguished from the rubber in MFM image.

Scanning conditions

System: NX12
Scan Size: 10 μm × 10 μm
Scan Mode: MFM

Scan Rate: 1 Hz
Cantilever: PPP-MFMR (k=2.8N/m, f=75kHz)
Pixel Size: 512 × 256

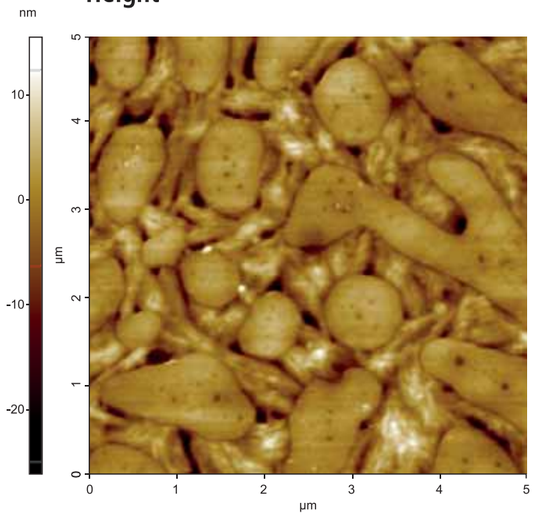
LDPS/PE; Thermal property



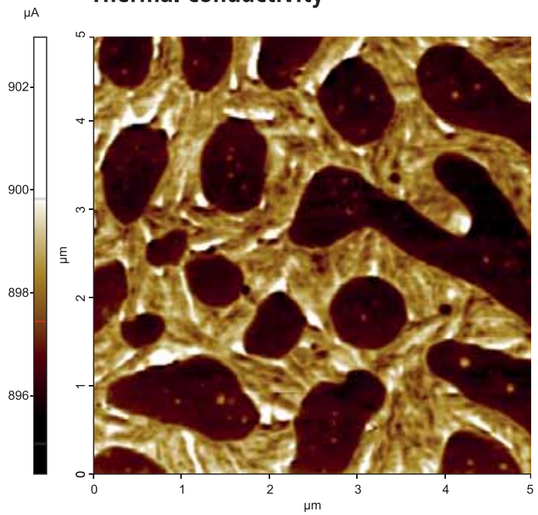
Scanning Thermal Microscopy

In order to measure the thermal property of a sample surface, a contact AFM scan is performed using a cantilever with temperature-dependent resistivity. Any changes in the tip resistance during scanning are recorded and correlated into a thermal image of the sample surface.

Height



Thermal conductivity



Peak to valley: 43.5 nm
RMS Roughness: 4.3 nm

Composite of LDPS and PE. Probe current shows different thermal conductivity by materials.

Scanning conditions

System: NX10
Scan Size: 5 µm × 5 µm
Scan Mode: SThM
Scan Rate: 0.2 Hz
Cantilever: Nanothermal probe (k=0.25N/m)
Pixel Size: 256 × 256

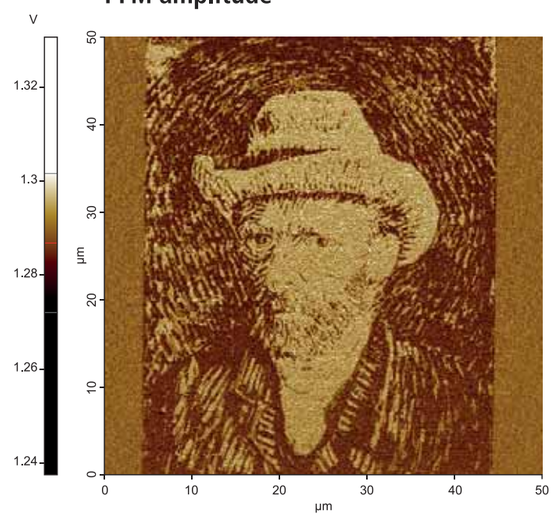
Vincent van Gogh

Nanolithography

Here, the cantilever is used to intentionally modify the sample surface via mechanical and/or electrical means. To mechanically alter a surface, a specialized, robust cantilever gouges the surface with excessive force. To electrically alter a surface, a cantilever with a high bias is used to oxidize local surface regions

Design

PFM amplitude



Re-arranged polling direction of PZT domains using bias lithography mode.

Scanning conditions

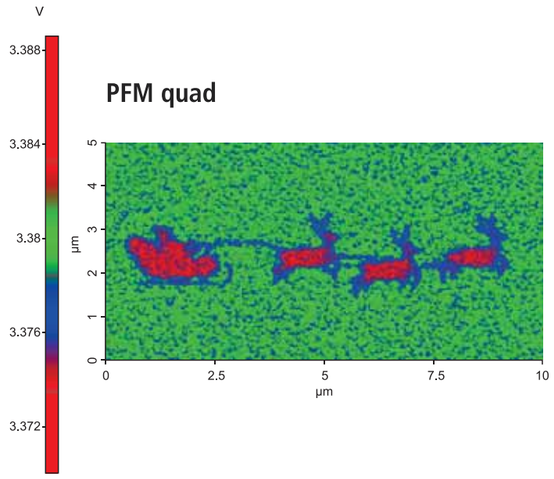
System: NX20
Scan Size: 50 µm × 50 µm
Scan Mode: Litho., DFRT-PFM
Tip Bias for lithography: -40 V for white area, +40 V for black area
Scan Rate: 0.5 Hz
Cantilever: PPP-EFM (k=2.8N/m, f=75kHz)
Pixel Size: 1024 x 1024

Santa with Rudolph on PZT film

Nanolithography

Design

PFM quad



Re-arranged polling direction of PZT domains using bias lithography mode.

Scanning conditions

System: NX10
Scan Size: 10 µm × 5 µm
Scan Mode: Litho., DFRT-PFM
Tip Bias for lithography: -10 V for white area, +10 V for black area

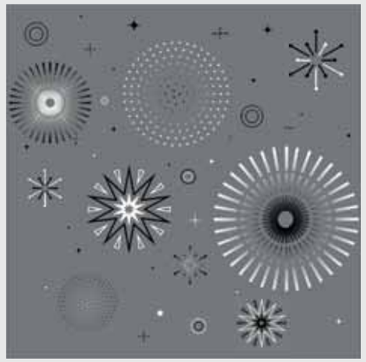
Scan Rate: 0.5 Hz
Cantilever: ElectriMulti75-G (k=3N/m, f=75kHz)
Pixel Size: 512 x 512

Christmas tree and firework on PZT film

Nanolithography

Design

Design



PFM quad

PFM quad

Re-arranged the domain pole direction on PZT surface using bias mode of lithography.

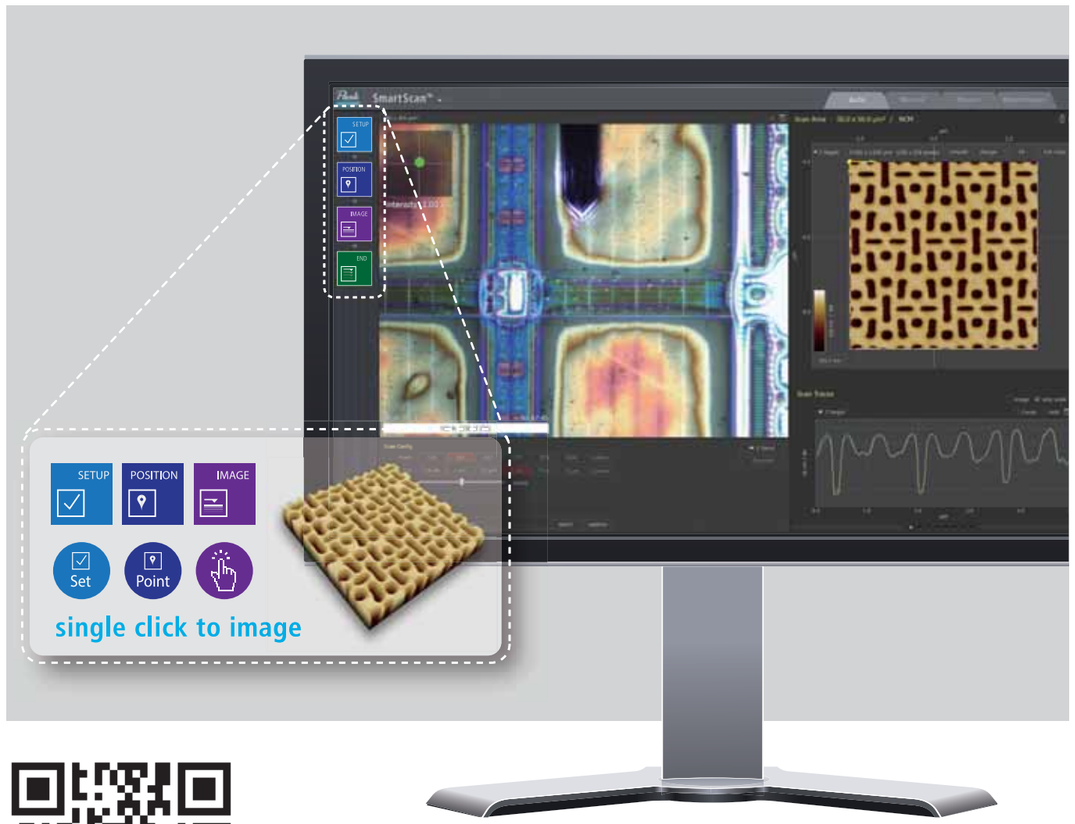
Scanning conditions

System: NX10
Scan Size: 10 µm × 5 µm
Scan Mode: Litho., DFRT-PFM
Tip Bias for lithography: -10 V for white area, +10 V for black area

Scan Rate: 0.5 Hz
Cantilever: ElectriMulti75-G (k=3N/m, f=75kHz)
Pixel Size: 512 x 512

Park SmartScan™

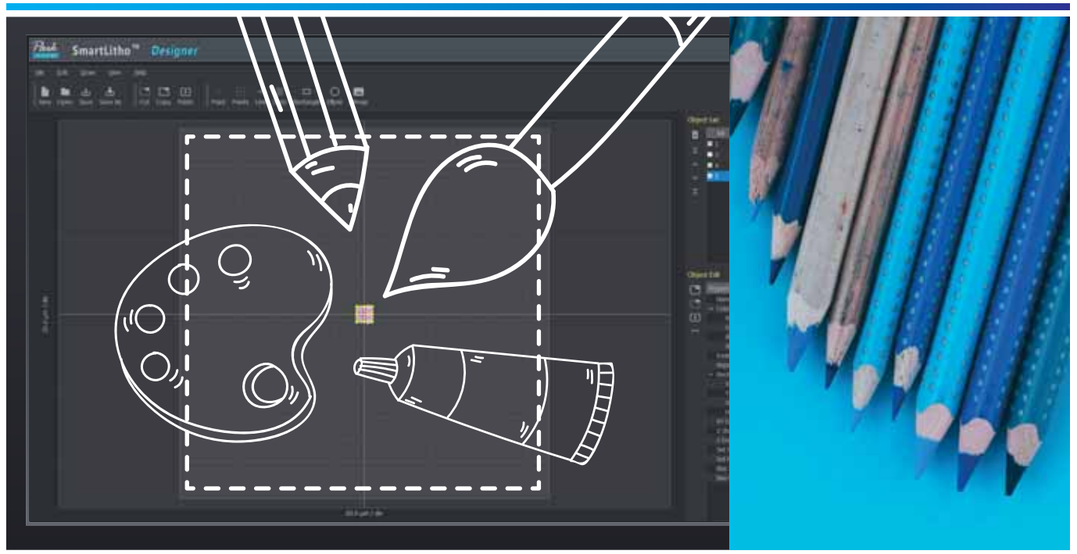
Bringing the power and versatility of AFM technology to everyone



Park SmartScan™ is a revolutionary operating software for Park AFMs that lets even inexperienced, untrained users produce high quality nanoscale imaging through three **simple clicks of a mouse in auto mode**, which rivals that made by experts using conventional techniques. SmartScan manual mode also provides all of the functions and tools necessary for more seasoned users to feel at home. This combination of extreme versatility, ease-of-use, and quality makes SmartScan the best AFM operating software available.

Park SmartLitho™

The next generation nanolithography and nanomanipulation software combining powerful tools with an easy user interface

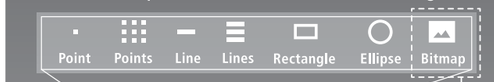


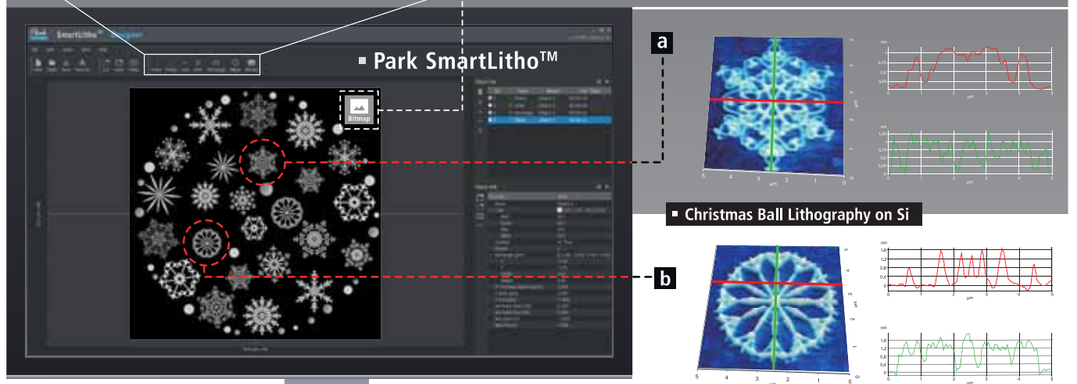
The easiest operating software available for nanolithography and nanomanipulation

Park SmartLitho, enabled by SmartScan is an AFM based platform that performs nanolithography and nanomanipulation on materials, electrical and electronics devices, nanotechnology and other areas of research.

Park SmartLitho software has a variety of lithography modes, supports both Vector mode and Raster mode and operates on the SmartScan platform, which has an easy user

Park SmartLitho provides a stand-alone convenient drawing editor.





Park Systems

Dedicated to producing the most accurate and easiest to use AFMs

General AFMs

Park Systems provides a range of popular AFMs for general research and industrial applications. Designed to be extremely versatile while still providing the accuracy and functionality necessary to do high quality work, our line of general AFMs offer researchers and engineers alike the ability to get extremely accurate results quickly and easily.

Applications:

- Materials Science
- Failure Analysis
- Semiconductor Analysis
- Hard Disk Media Analysis

Park FX40

A Groundbreaking New Class of Atomic Force Microscope for Nanoscientific Research: The AutonomousAFM

Park NX10

The premiere chioce for nanotechnology research

Park XE7

The most affordable research grade AFM with flexible sample handling

Park XE15

Power and versatility, brilliantly combined

Park NX20

The premiere choice for failure analysis

Park NX20 300 mm

The leading automated nanometrology tool for 300 mm wafer measurement and analysis

Park NX-Hivac

The most advanced high vacuum AFM for failure analysis and sensitive materials research

Park NX12

The most versatile AFM for analytical chemistry

Industrial AFMs

Park Systems is dedicated not just to advancing research, but industry as well. That's why our designers have worked to build a line of the most effective AFMs for FA engineers and industrial applications.

Applications:

- Failure Analysis
- Semiconductor Analysis
- Hard Disk Media Analysis

Park NX-Hybrid WLI

The AFM and WLI technologies built into one seamless system

Park NX-TSH

The automated Atomic Force Microscopy (AFM) system for ultra large and heavy flat panel displays at nanoscale

Park NX-3DM

Automated industrial AFM for high-resolution 3D metrology

Park NX-Wafer

Low noise, high throughput atomic force profiler with automatic defect review

Park NX-PTR

Fully automated AFM for accurate inline metrology of hard disk head sliders

Park NX-HDM

Simply the best AFM for media & substrate manufacturing