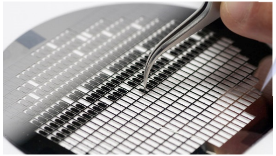
Adama
innovations

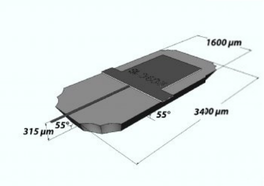
Sharp Conductive Commercial Diamond Probes

Adama innovations

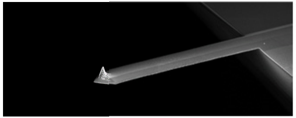
Diamond Probes



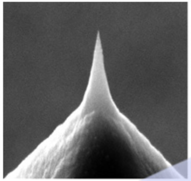
Wafer Scale Production



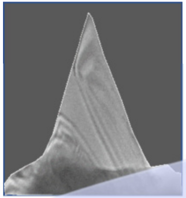
Standard Si chip with alignment groves on back



Diamond coated Si cantilever

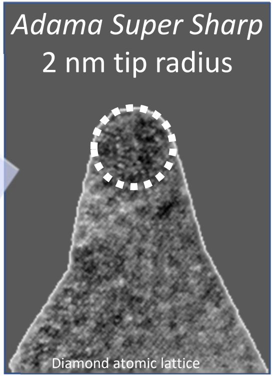


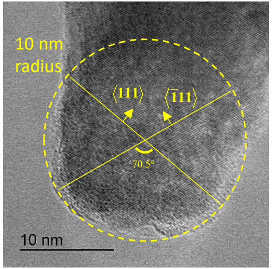
Diamond coated tip



Single crystal apex

Adama Super Sharp
2 nm tip radius



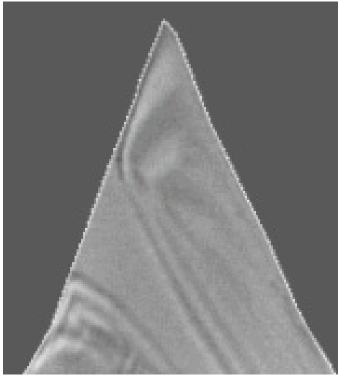


TEM: Rodrigo Bernal, Rob Carpick, U. Penn.

Sharp Conductive Diamond Probes

APEX SHARP

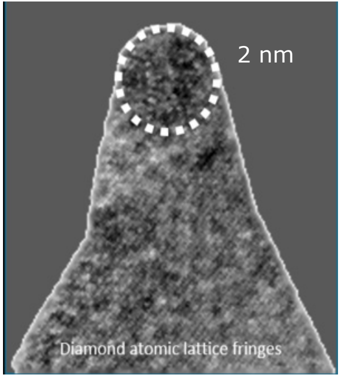
AD-2.8-AS, AD-40-AS



Radius = 10 ± 5 nm
k = 2.8, 40 N/m

SUPER SHARP

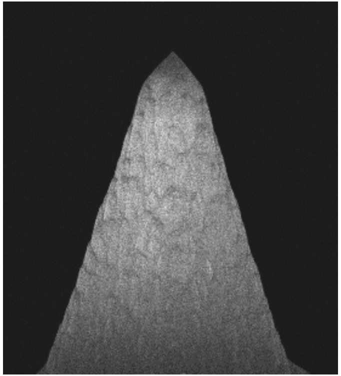
AD-2.8-SS, AD-40-SS



Radius < 5 nm
k = 2.8, 40 N/m

NANOMECHANICS

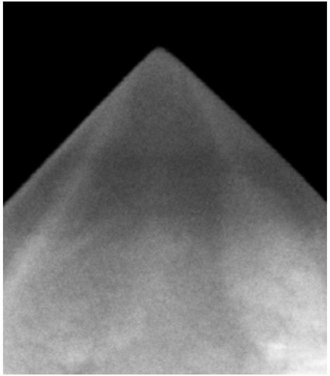
NM-RC, NM-TC



Radius = 10 ± 5, 25 ± 10 nm
k = 350 N/m

CONES

FM-LC, NC-LC

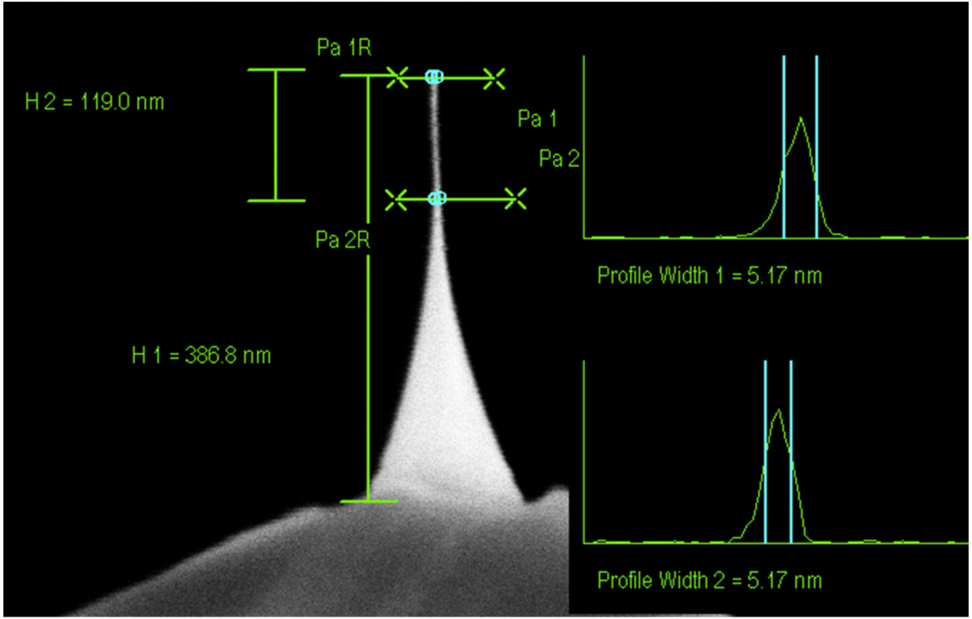


Radius = 20 ± 10 nm
k = 10, 100 N/m

Resistivity: ~ 0.005 Ohm·cm

Single Crystal Boron Doped Diamond

New Conductive High Aspect Ratio Probes



PILLAR

AD-2.8-P40, AD-2.8-P20
AD-40-P40, AD-40-P20

100nm tall cylindrical shape

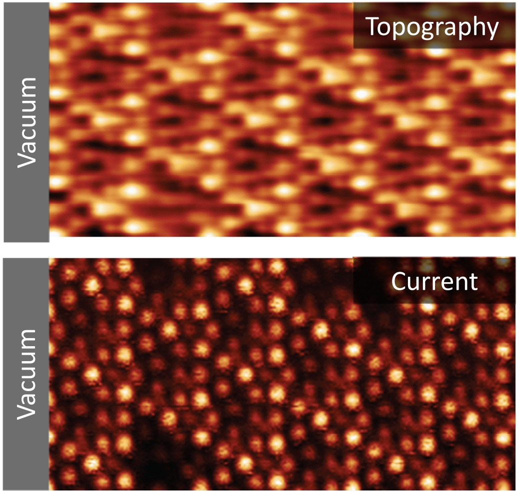
P40: < 40nm diam. *Available now*
P20: < 20nm diam. *Available now*
P10: < 10nm diam. *Preorder now*
P5: < 5nm diam. *Coming soon*

No tilt correction

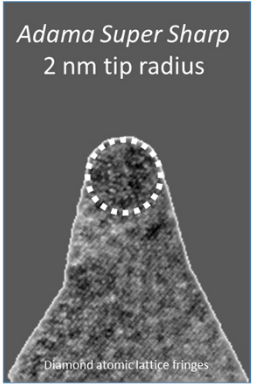
Resistivity: ~ 0.005 Ohm·cm

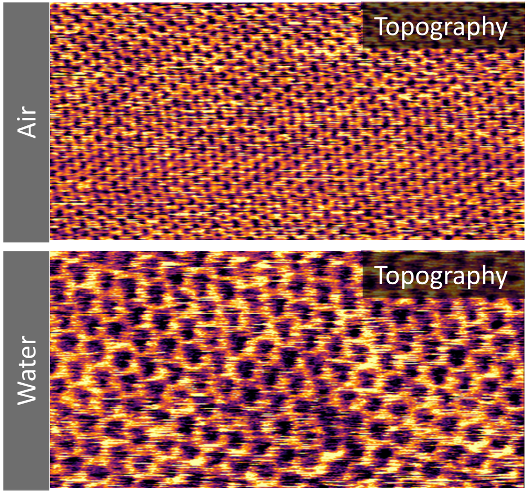
Single Crystal Boron Doped Diamond

Atomic Resolution - Topography and Electrical Data



14 x 7 nm Simultaneous AFM (Top) STM (Bottom) of 7x7 reconstructed silicon 111. Acquired using in FM mode using a **AD-40-SS** Adama Innovations probe. *Data courtesy of the John Boland Lab, CRANN, Trinity College Dublin.*



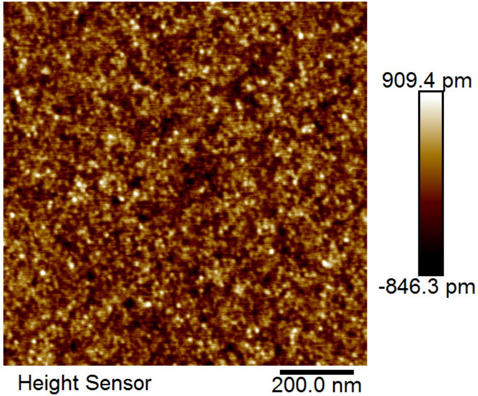


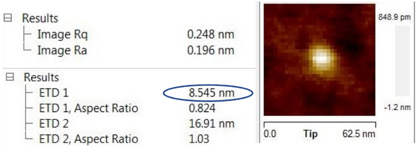
(Top) 10 x 5 nm Topography Image of HOPG. Acquired using an Asylum Research Cypher-S AFM in STM mode using a **80 N/m SS** Adama Innovations probe (Z Scale = 200 pm).
(Bottom) 10 x 5 nm Topography Image of Mica in MilliQ water in FM mode (Setpoint 320Hz Z Scale = 150pm) with **80 N/m SS** probe.

Atomic Resolution: Vacuum, Air, & Liquid

Probe Lifetime – Hard Disk Dynamic Repeatability Test

Scan 003

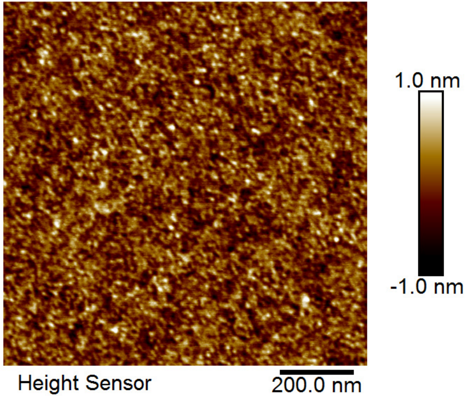


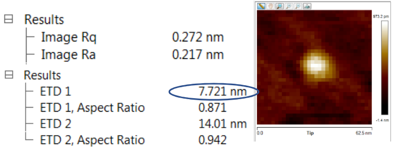


Results	
Image Rq	0.248 nm
Image Ra	0.196 nm

Results	
ETD 1	8.545 nm
ETD 1, Aspect Ratio	0.824
ETD 2	16.91 nm
ETD 2, Aspect Ratio	1.03

Scan 201

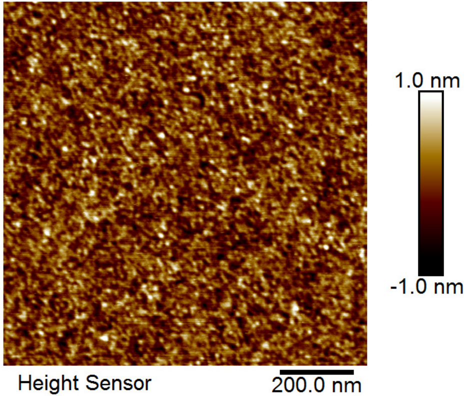


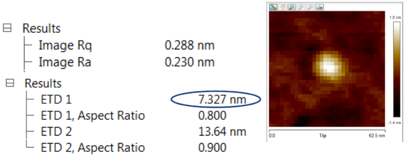


Results	
Image Rq	0.272 nm
Image Ra	0.217 nm

Results	
ETD 1	7.721 nm
ETD 1, Aspect Ratio	0.871
ETD 2	14.01 nm
ETD 2, Aspect Ratio	0.942

Scan 304



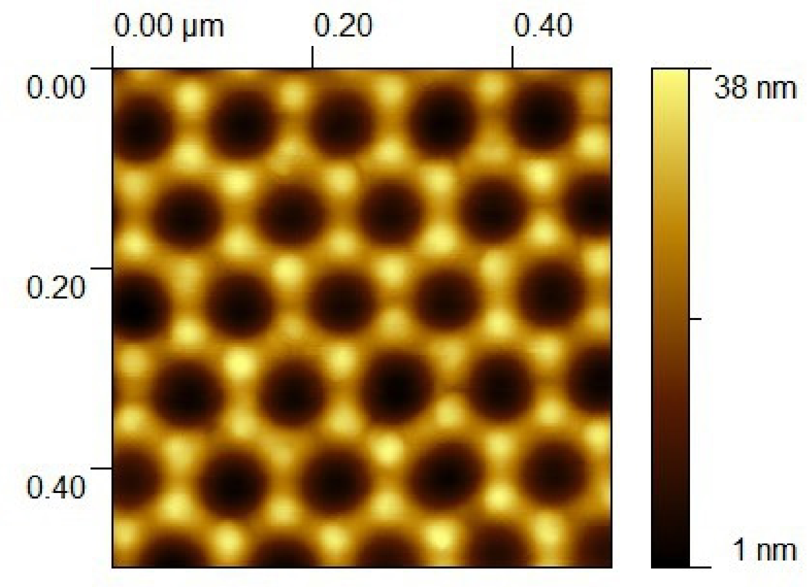


Results	
Image Rq	0.288 nm
Image Ra	0.230 nm

Results	
ETD 1	7.327 nm
ETD 1, Aspect Ratio	0.800
ETD 2	13.64 nm
ETD 2, Aspect Ratio	0.900

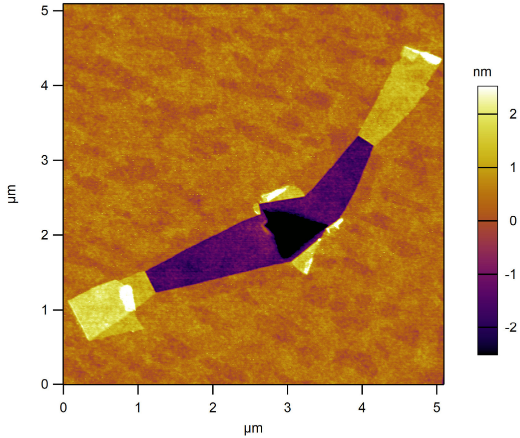
Hard Disk Dynamic Repeatability Test. The probe is withdrawn and engaged to the surface between each scan. Average roughness across all scans = 0.286 ± 0.006 nm. The probe actually gets slightly sharper during the test. Acquired using a Bruker Dimension Icon AFM in Tapping mode using a **AD-40-SS** Adama Innovations probe.

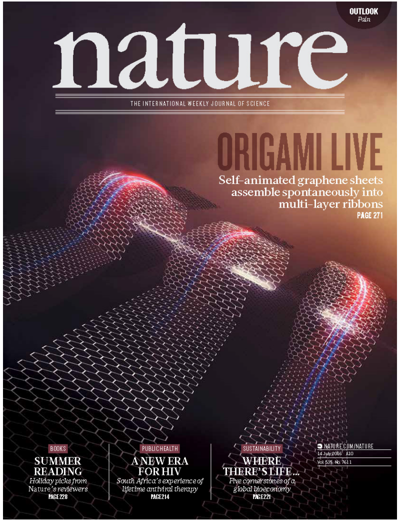
Resolution – Porous Anodized Aluminium



Data Courtesy of TipsNano. Acquired in Tapping mode using a **AD-40-SS** Adama Innovations probe.

Resolution – Graphene Folds on Silicon




OUTLOOK
Pain

nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

ORIGAMI LIVE
Self-animated graphene sheets
assemble spontaneously into
multi-layer ribbons
PAGE 271

BOOKS
SUMMER READING
Holiday picks from Nature's reviewers
PAGE 228

PUBLIC HEALTH
A NEW ERA FOR HIV
South Africa's experience of lifetime antiviral therapy
PAGE 214

SUSTAINABILITY
WHERE THERE'S LIFE...
Five cornerstones of a global bioeconomy
PAGE 221

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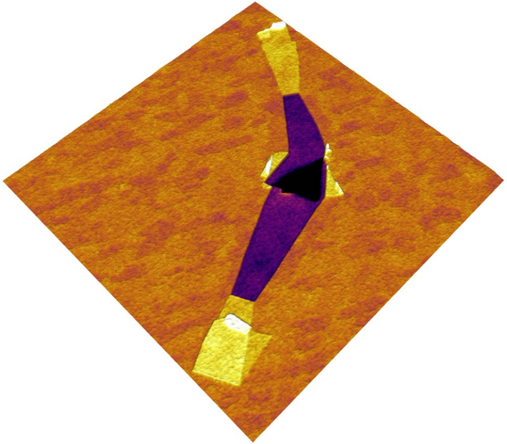
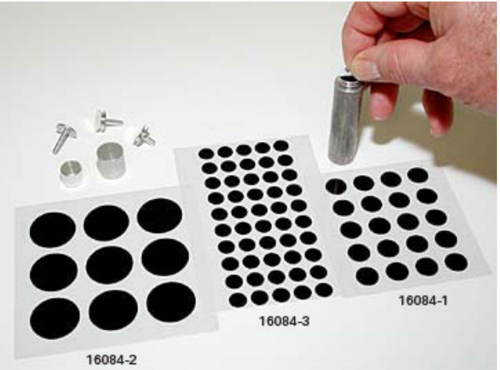
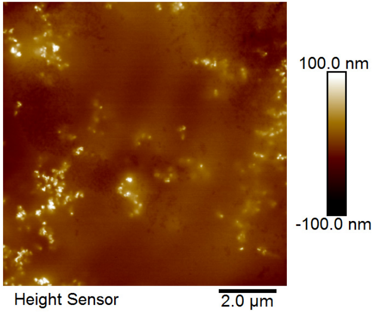
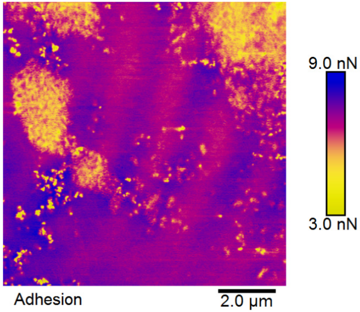


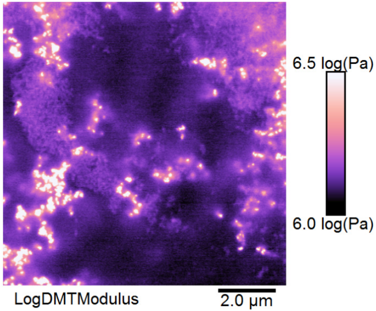
5 um scan of graphene folds on a silicon surface. The deep hole at the centre of the structure was made using an instrumented nanoindenter and the graphene spontaneously formed the observed folded structure.
Acquired using an Asylum Research MFP-3D AFM in AC mode using a **AD-40-AS** Adama Innovations probe.

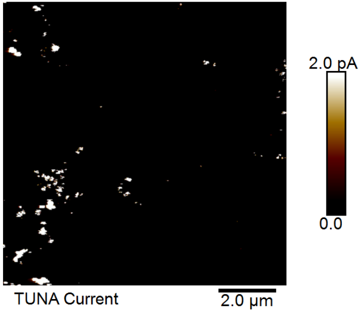
Electrical – Conductive AFM – Carbon Tape





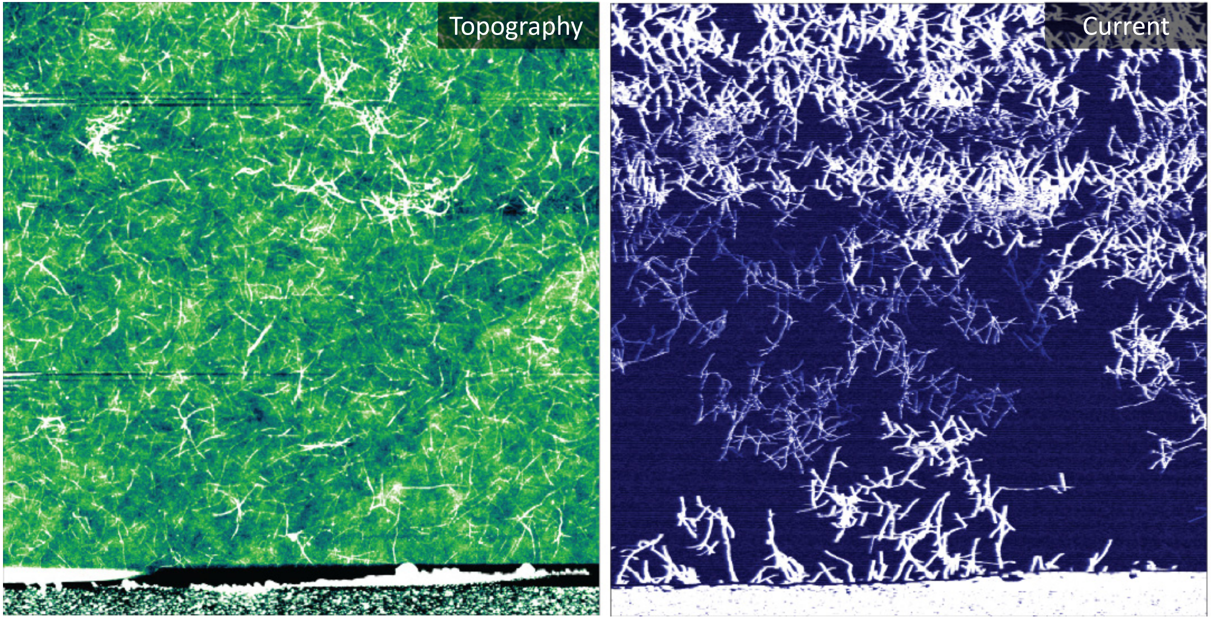






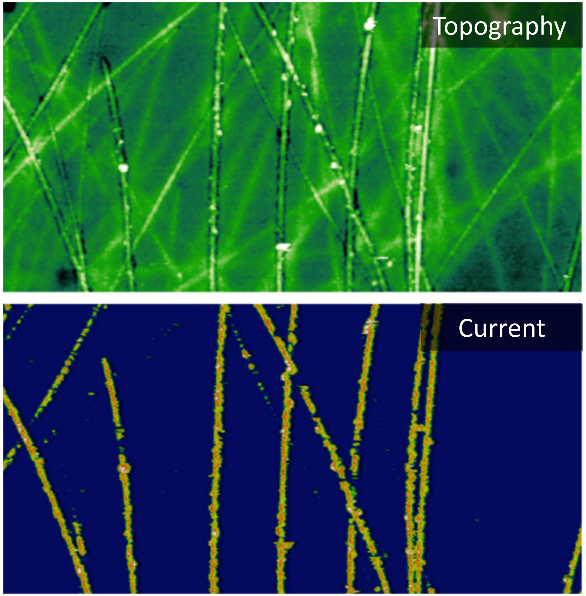
Conductive carbon tape (often used in SEM) is sticky and can pose challenges to image with AFM. Carbon nanoparticles are observed to be present in high concentration in the adhesion and modulus images but only a few small areas have a conducive pathway to the backside of the sample (bright spots in the current image). Acquired using a Bruker Dimension Icon AFM with PeakForce TUNA using an **AD-40-AS** Adama Innovations probe.

Electrical – Conductive AFM – Carbon Nanotubes



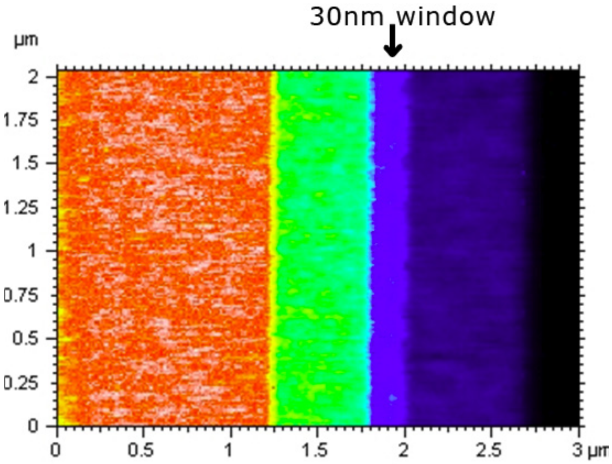
Carbon nanotubes are connected to a Au electrode (bottom of image). Adama conductive diamond probes enable imaging of this fragile sample with high resolution and excellent sensitivity.
Current image shows the electrical connectivity of the nanotube network to the electrode. Acquired using a Bruker Dimension Icon AFM in PeakForce TUNA mode using an **AD-40-AS** Adama Innovations probe.

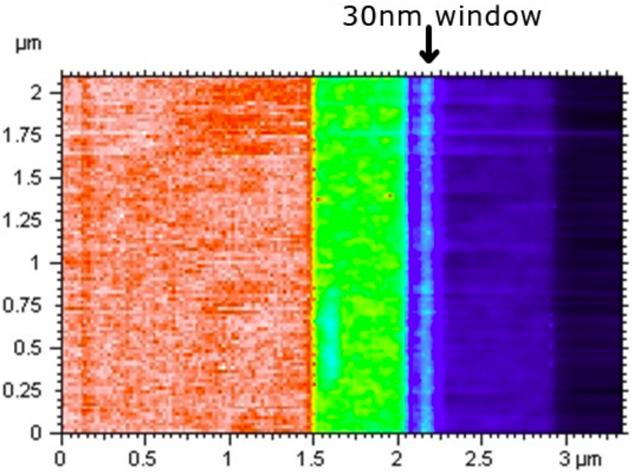
Electrical – Conductive AFM – Silver Nanowires



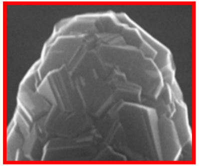
5 x 2.5 µm Conductivity map of a mixture of 20 - 40 nm silver nanowires on a silicon surface. Individual grain boundaries are visible in the current image. Acquired using a NT-MDT Spectrum Instruments Solver Nano AFM in Spreading Resistance Imaging mode using a **AD-2.8-SS** Adama Innovations probe.

Electrical – Conductive AFM – Back Surface Field Solar Cell

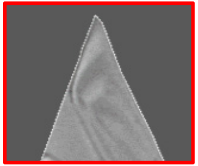




Regular Coated
Diamond Probe

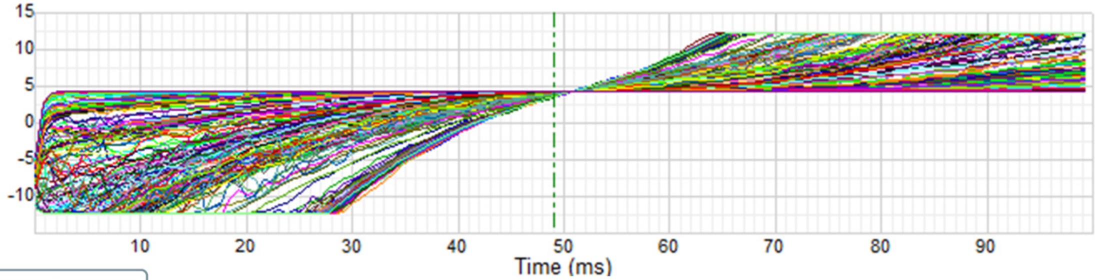


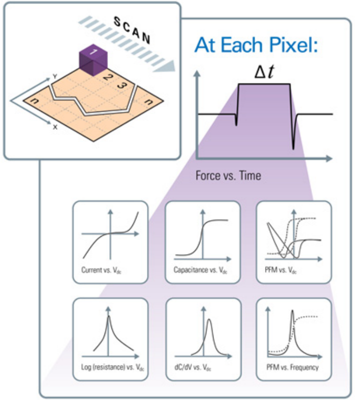
Adama Apex Sharp
Diamond Probe

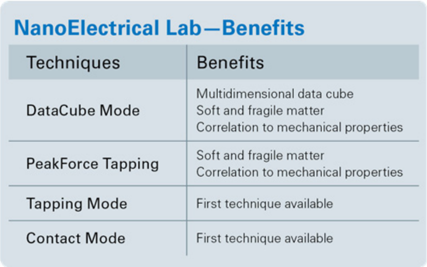


Conductive AFM imaging a back surface field (BSF) solar cell using regular diamond coated probes vs Adama Apex Sharp diamond probes. Note the 30 nm wide conductive band is only visible with Adama diamond probes. Acquired using a CSInstruments Nano-Observer AFM with a ResiScope using a **AD-2.8-AS** Adama Innovations probe.

Electrical – Conductive AFM Spectroscopy – Fe_2O_3

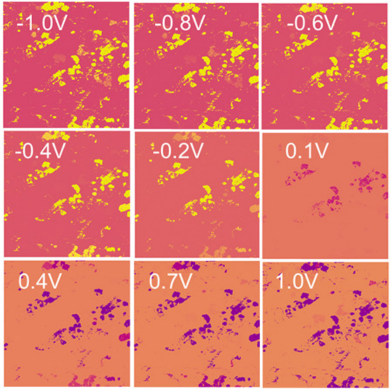






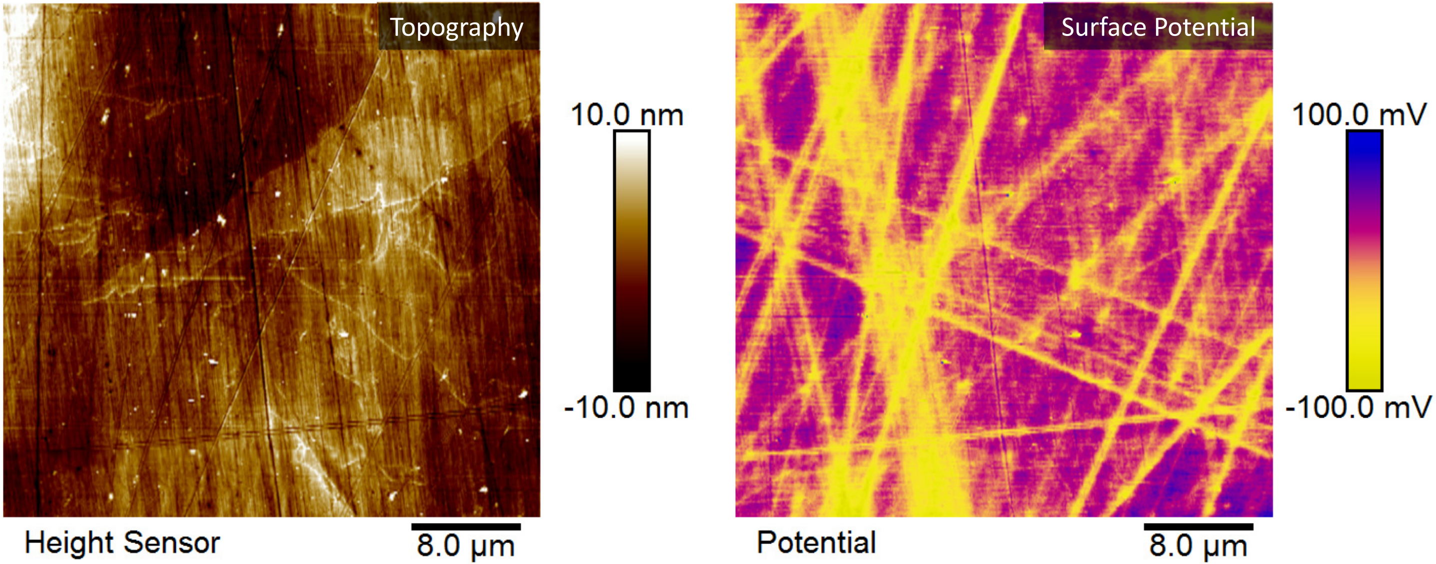
NanoElectrical Lab—Benefits

Techniques	Benefits
DataCube Mode	Multidimensional data cube Soft and fragile matter Correlation to mechanical properties
PeakForce Tapping	Soft and fragile matter Correlation to mechanical properties
Tapping Mode	First technique available
Contact Mode	First technique available



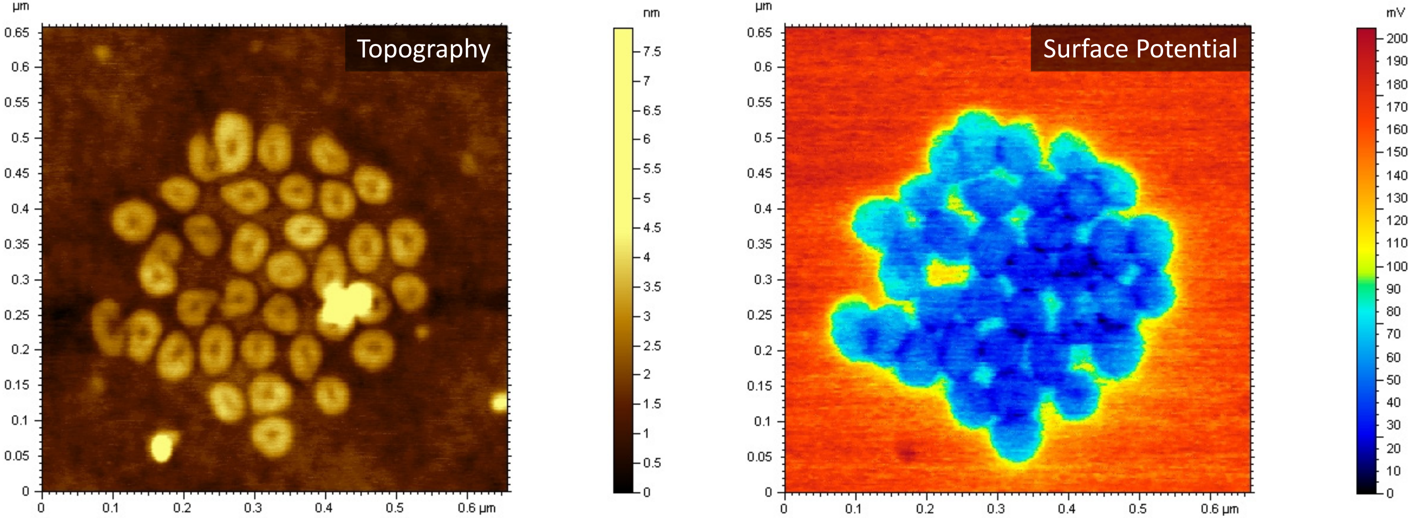
2 μm scan of Fe_2O_3 surface with DataCube TUNA spectroscopy (256 x 256 pixels).
I-V spectra is measured at every pixel (110 ms/pixel). Acquired using
a Bruker Dimension Icon AFM with DataCube TUNA using an **AD-2.8-AS** Adama Innovations probe.

Electrical – KPFM – Stainless Steel



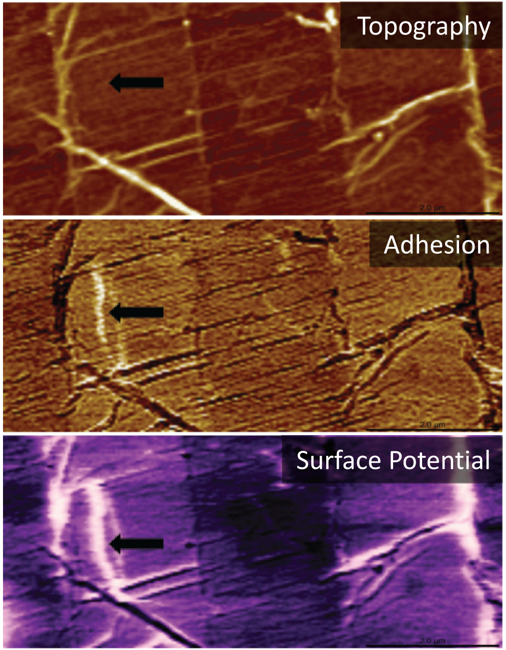
Imaging of a stainless steel sample showing polishing induced surface potential patterns not visible in topography. Acquired using a Bruker Dimension Icon AFM in PeakForce KPFM mode using an **AD-2.8-AS** Adama Innovations probe.

Electrical – KPFM – Fluoroalkanes



Imaging of fluoroalkanes on a graphite surface.
Acquired using a CSInstruments Nano-Observer AFM with
High Definition-KFM (HD-KFM) using a **AD-2.8-SS** Adama Innovations probe.

Electrical – PeakForce KPFM – 2D Materials (Graphene)



7.5 x 3.5 um PeakForce KPFM scan of graphene folds on a silicon substrate. A bright vertical band highlighted by the arrow is visible in both the adhesion (Middle) and surface potential (Bottom) images but not topography (Top). The higher surface potential may be attributed to weaker bonding between the graphene and the substrate in this region contributing to a change in dielectric constant.
(Sample: Georg Duesberg, Trinity College Dublin).

Acquired using a Bruker Multimode AFM
in PeakForce KPFM mode using an **AD-40-AS** Adama Innovations probe.

Electrical – KPFM – 2D Materials (Boron Nitride)

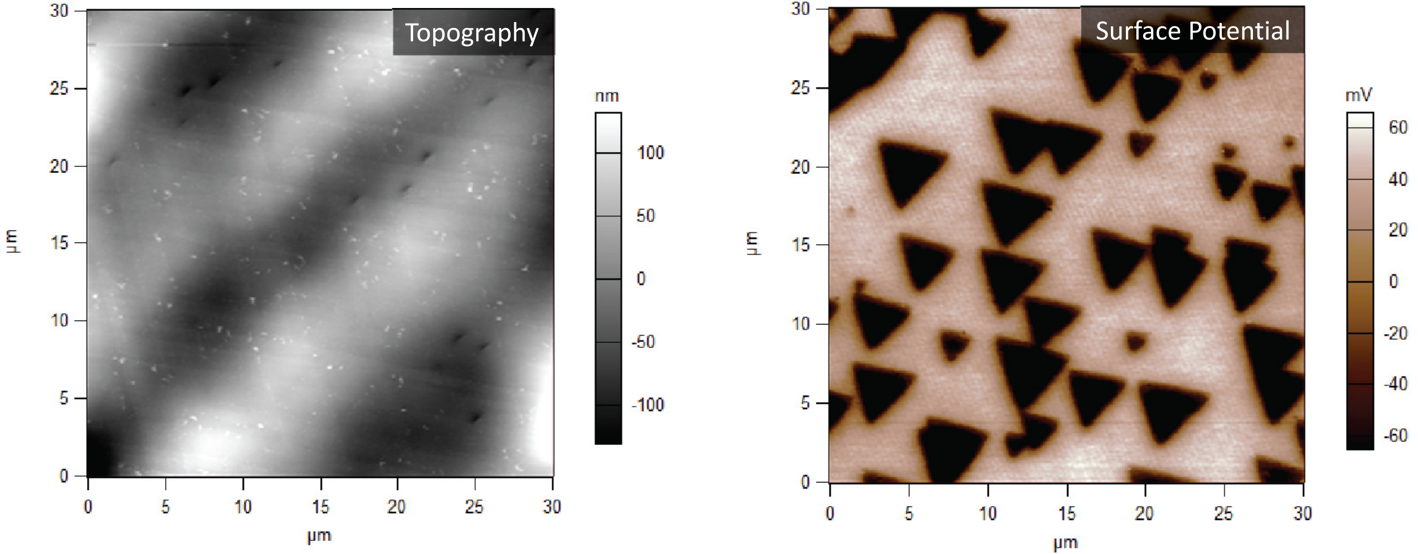
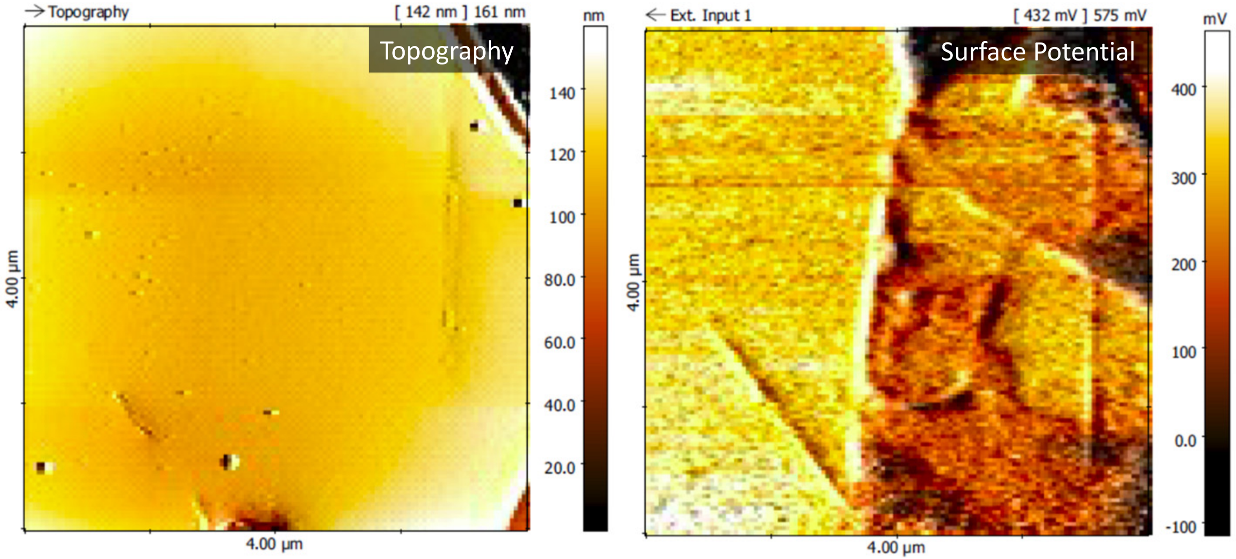


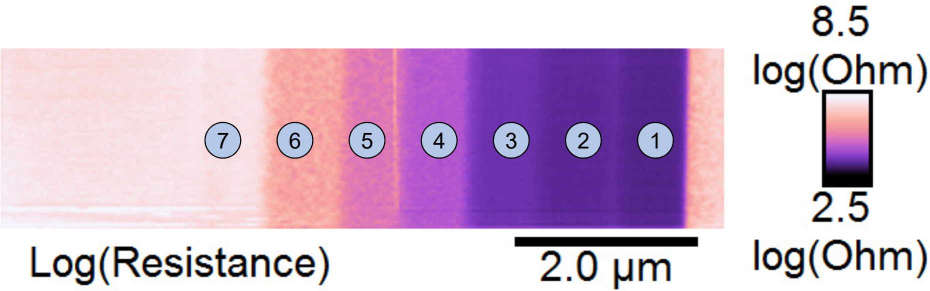
Image of boron nitride (BN) layers on a copper foil.
Strong contrast is observed in the surface potential (dark triangles, right) but not in topography (left).
This is due to the undulating copper foil surface making it difficult to image the topography of the thin BN layers.
Acquired using an Asylum Research Cypher-S AFM in KPFM mode using a **AD-2.8-AS** Adama Innovations probe.

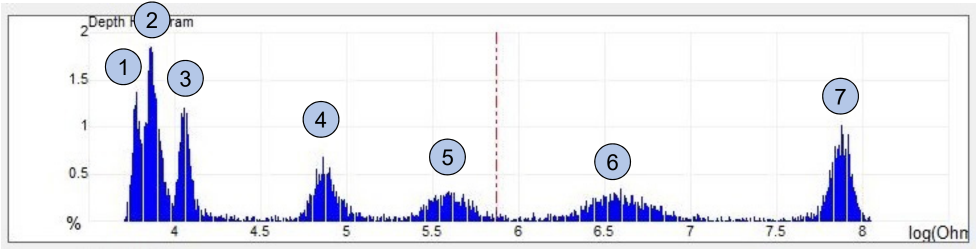
Electrical – KPFM – Silicon and Silicon Carbide

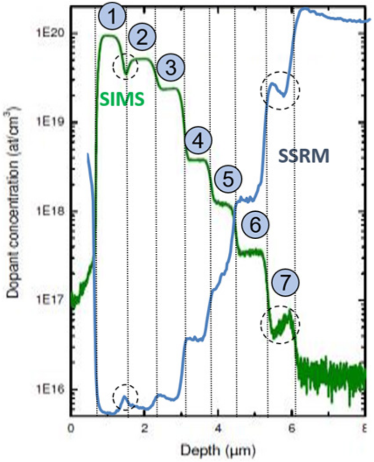


Data courtesy of DME-Semilab showing a clear surface potential contrast (right) between Si and SiC areas of the sample whereas topography (left) does not show any significant contrast. Acquired using a DME-Semilab BRR-SEM-AFM system in KPFM mode using a **AD-40-AS** Adama Innovations probe.

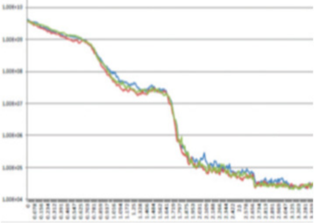
Electrical – SSRM – p-Si with a staircase dopant profile







Previous state of the art measurements on the same sample

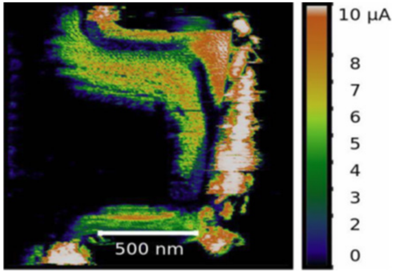


SSRM image of a p-type Si sample with staircase carrier profile. 7 stairs with carrier levels from 10^{16} to 10^{20} atoms/cm^3 are all observed with low noise, illustrating the large dynamic range and good conductivity. SSRM on Si requires high forces in order to penetrate through the native oxide and create a stable electrical contact. Adama diamond probes can withstand these high loads.

Acquired using a Bruker Dimension Icon AFM in SSRM mode using an **AD-40-AS** Adama Innovations probe.

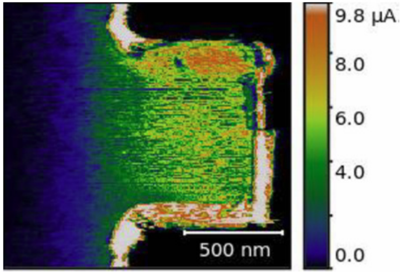
Electrical – SSRM – p-Si pillar and n-doped layer

Other Commercial Diamond Probe

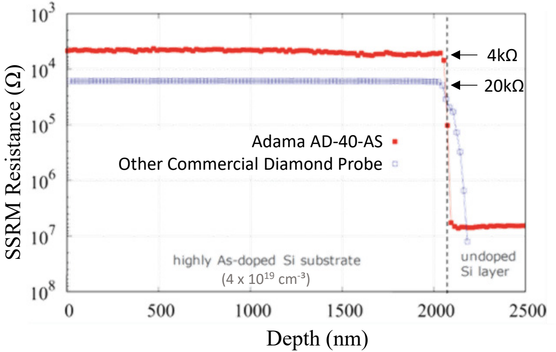


Imaging force = 12 uN, Bias = 200mV

Adama AD-40-AS



Imaging force = 1400nN, Bias = 50mV

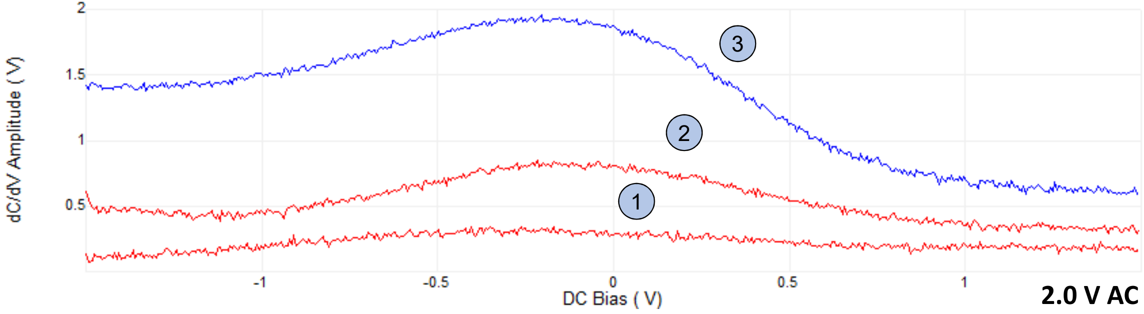


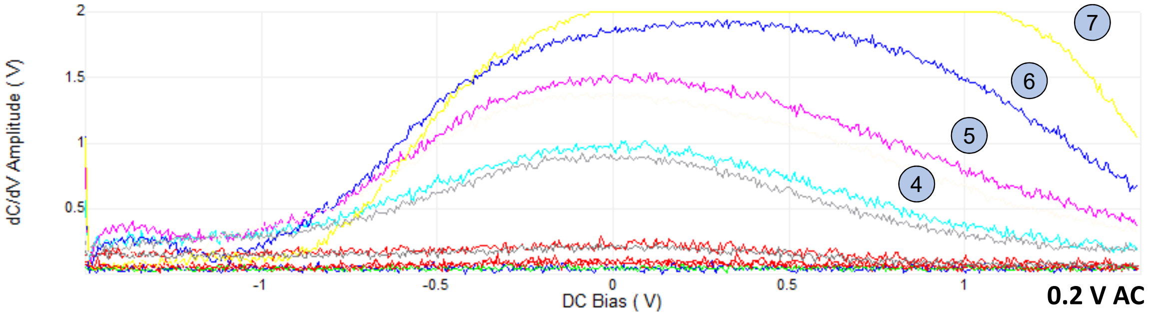
SSRM images of a cross section of a p-doped Si Nano-Pillar with a phosphorus doping profile and a gold outer layer. The Adama Innovations AD-40-AS probe shows excellent properties for SSRM analysis of doped silicon samples including low tip resistance and long-term stability. The dopant profile observed with the Adama probe is homogeneous whereas it is discontinuous and therefore misleading when using other commercial diamond probes. The Adama probe was used successfully for over 400 SSRM scans.

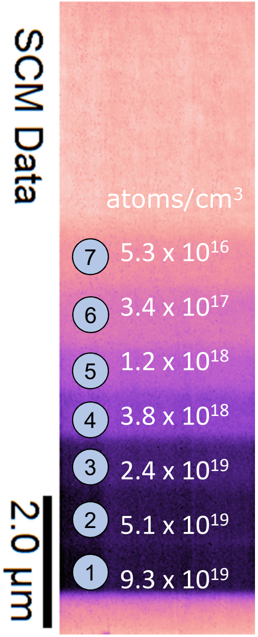
SSRM profile of the transition from highly n-doped region to an undoped Si layer. The Adama Innovations AD-40-AS probe exhibits a higher tip conductivity (< 4 kΩ) compared to other commercial diamond probes (20 kΩ). The AD-40-AS probe has a steep change in resistance at the highly doped / undoped interface leading to < 15 nm lateral resolution.

Data provided by Prof. Hartmut Bracht, Institute of Materials Physics, University of Muenster
using an **AD-40-AS** Adama Innovations probe.

Electrical – SCM – p-Si with a staircase dopant profile

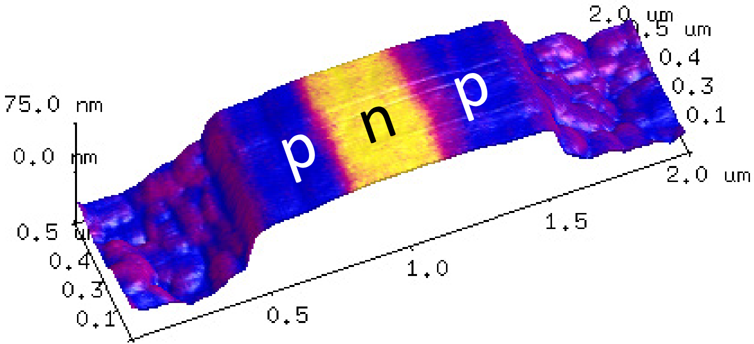




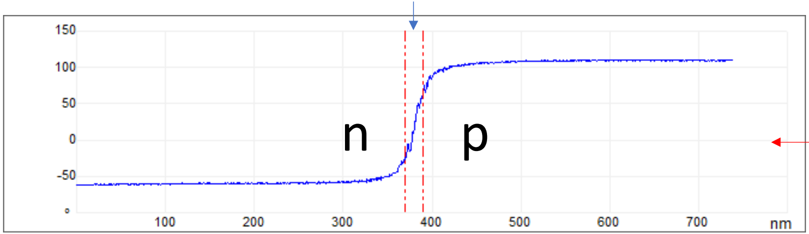


dC/dV–V spectroscopy shows textbook ‘MOS capacitor’ behavior, indicating metallic tip behavior.
Acquired using a Bruker Dimension Icon AFM in SCM mode using a **AD-2.8-AS** Adama Innovations probe.

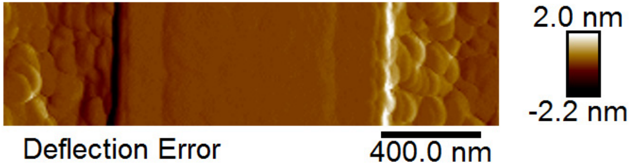
Electrical – SCM – SRAM Memory Transistor



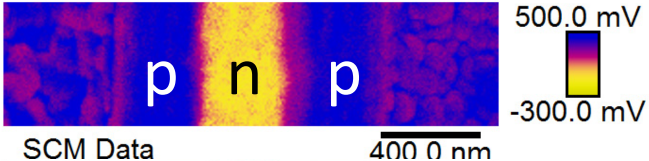
30 nm resolution



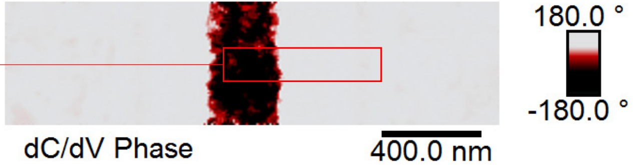
Height Sensor



Deflection Error



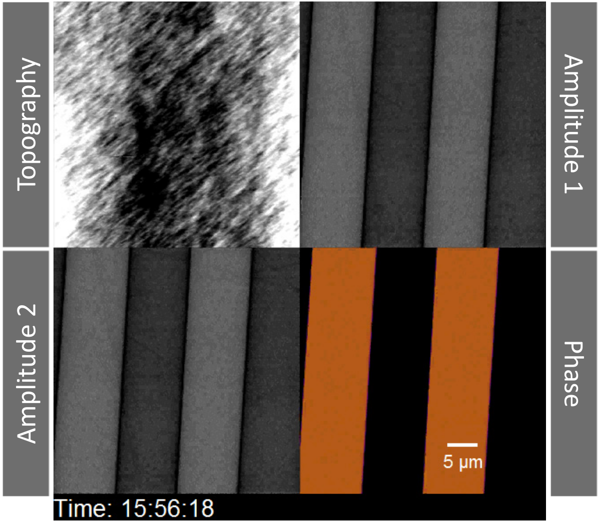
SCM Data

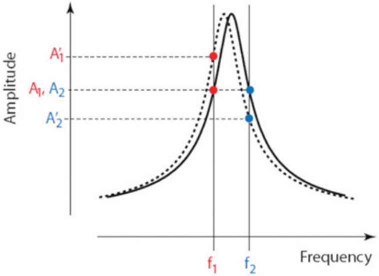


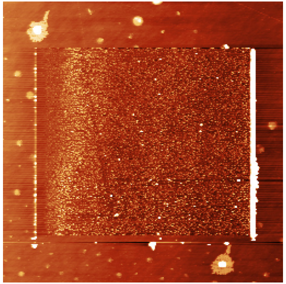
dC/dV Phase

SCM image of a transistor in a SRAM memory sample (top surface). The different doped regions (source/drain/gate) are all clearly observed with low noise and good spatial resolution.
Acquired using a Bruker Dimension Icon AFM in SSRM mode using an **AD-40-AS** Adama Innovations probe.

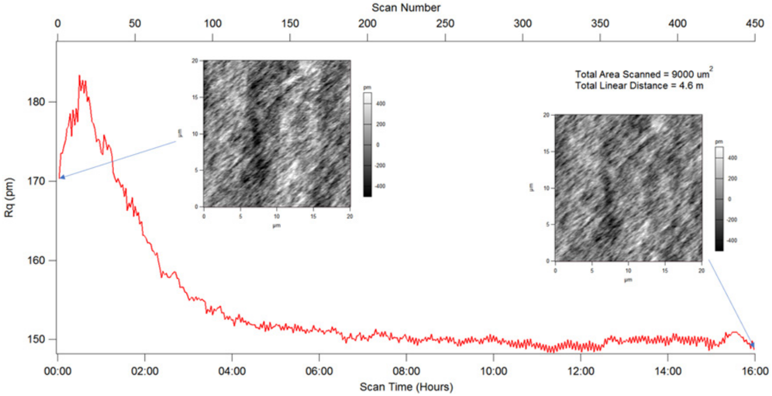
Electrical – PFM – Lithium Niobate (PPLN)







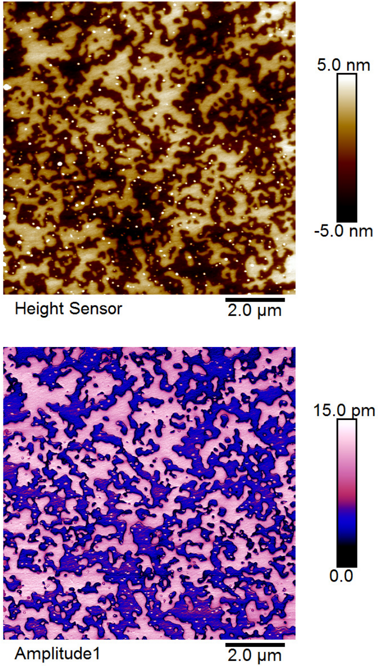
(left) 20 um image of Periodically Poled Lithium Niobate (PPLN) imaged continuously for 16 hours. The measured surface roughness (right) first increases as the probe gets slightly sharper followed by a decrease to a stable value as the surface is slightly milled by the probe. This slight milling results in improved PFM contrast during scanning. A tapping mode image showing the milled area is shown (top right).



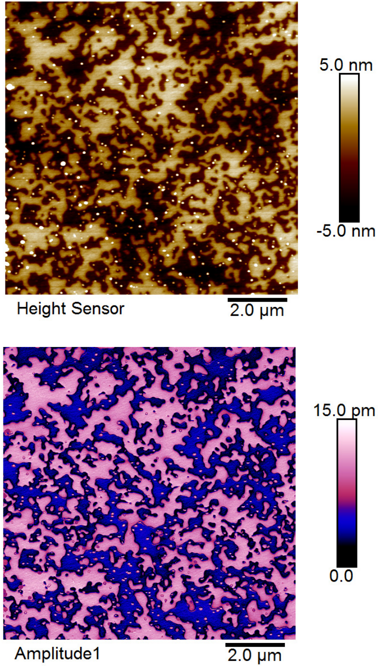
Acquired using an Asylum Research Cypher-S AFM
with DART-PFM using a **AD-2.8-AS** Adama Innovations probe.

Electrical – PFM – Lithium Tantalate ($LiTaO_3$)

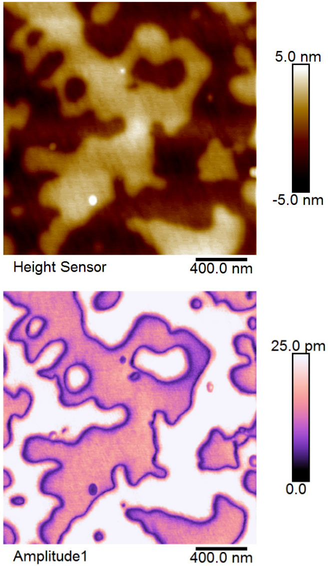
8th scan



30th scan



High Resolution Scans Next Day
Showing 10 nm Fidelity

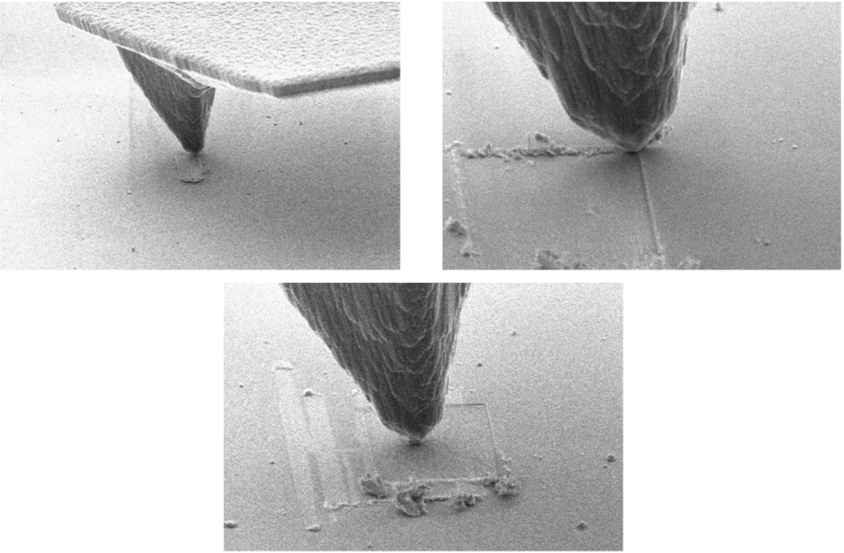


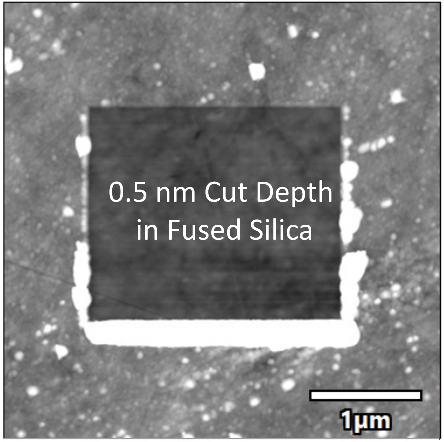
Total Travel = 61.5 cm
Scan Area = 3000 um^2

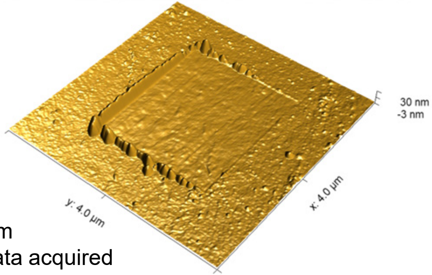
Acquired using a Bruker Dimension Icon AFM in PFM mode using an **AD-2.8-AS** Adama Innovations probe.

Tomography – Milling – Strontium Oxide and Fused Silica

AFM-SEM imaging of tomography of SrO

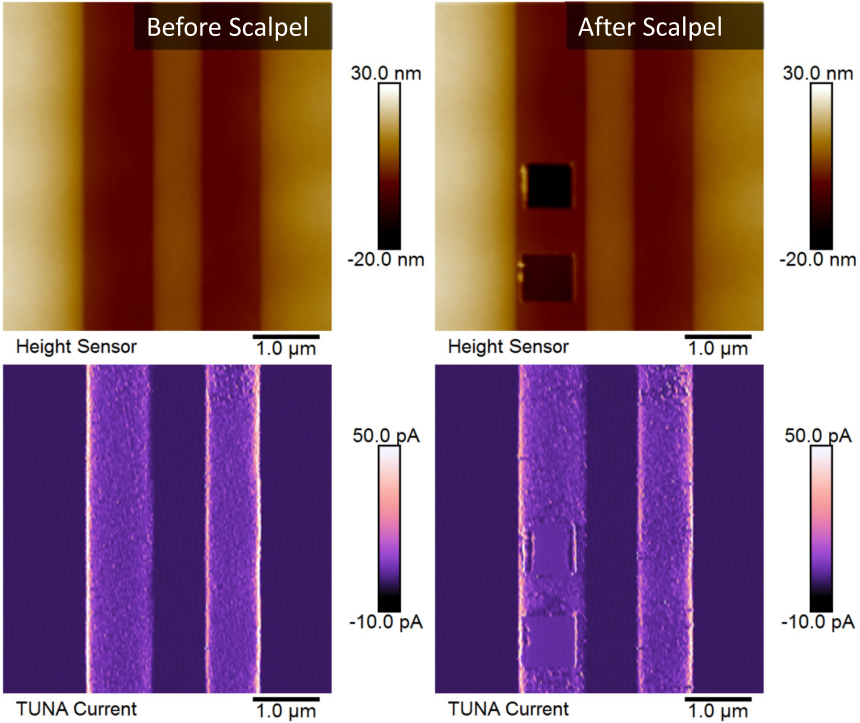


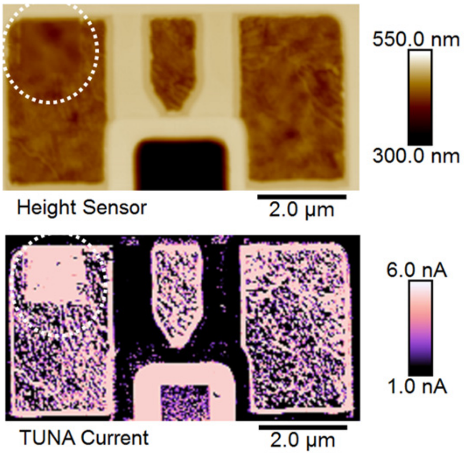




SrO data acquired using a DME Semilab BRR–SEM-AFM system
in contact mode using a **NM-RC** Adama Innovations probe. Fused Silica data acquired
using an Asylum Research Cypher-S AFM in contact mode (milling) and AC mode (inspection)
using a **NM-RC** Adama Innovation probe.

Tomography – Scalpel TUNA - Silicon

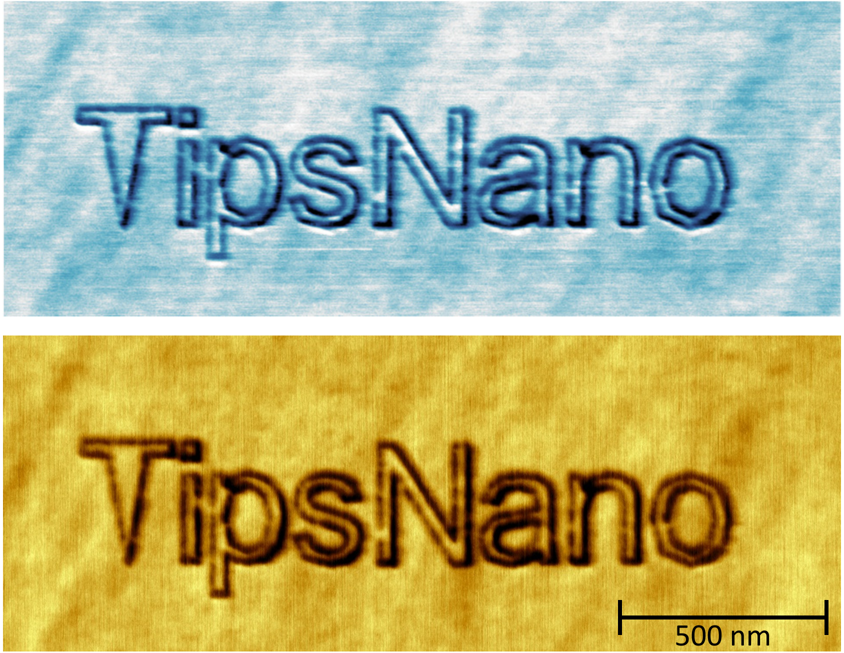




The scalpel method (Tomography) is used to remove the top layer (few nm only). The resulting TUNA current shows lower noise, as the electrical contact inside the crater is improved vs. virgin areas (reason: oxide & surface effects are removed, and possibly a phase transition of the Si results in improved electrical contact).

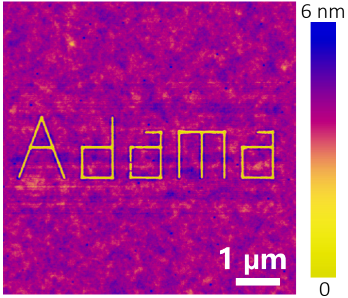
Acquired using a Bruker Dimension Icon AFM with Scalpel TUNA mode using a **NM-RC** Adama Innovations probe.

Lithography – Impulse Force Lithograph - GaAs

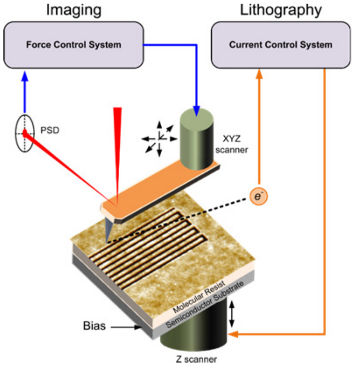


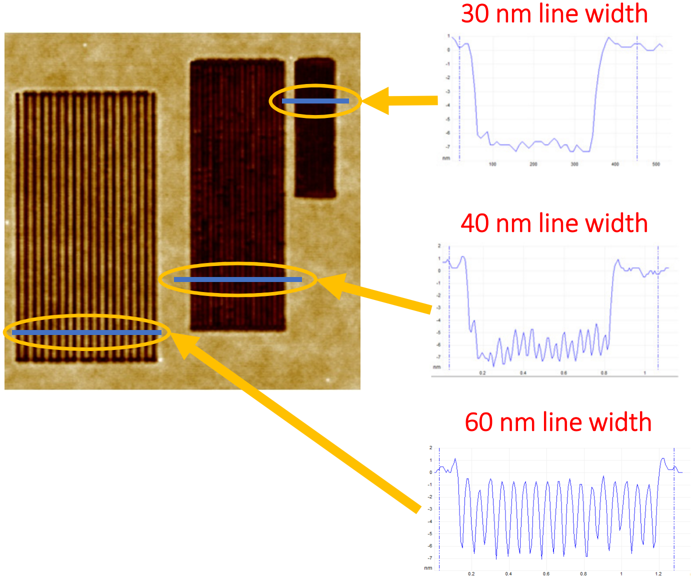
Data Courtesy of TipsNano. Impulse force lithography on gallium arsenide. Acquired during lithography (top) and inspected using contact mode (bottom) using a **AD-40-SS** Adama Innovations probe.

Lithography – Current Controlled (LE-CC) – Molecular Resist



Lithography on Molecular Resist

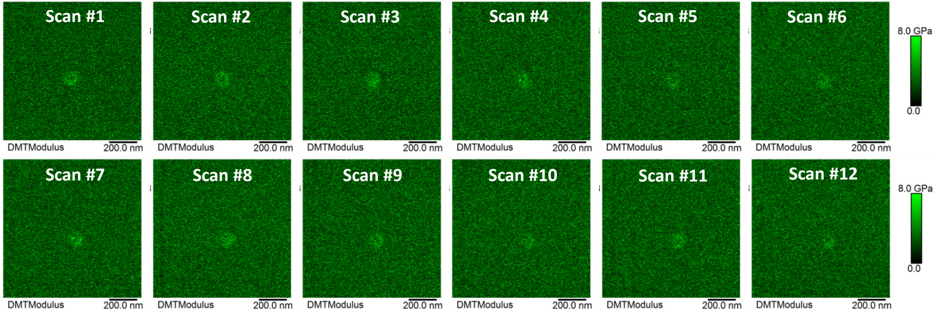




Parameters:
U_{bias}: 30-60V;
$I_{setpoint}$: 20-100pA;
Sample thickness: 10 - 40nm

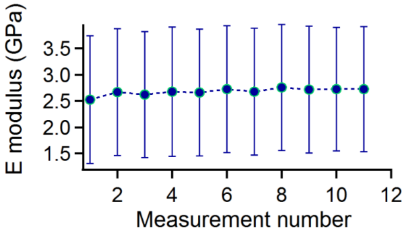
Data Courtesy of Peng Li, Xiaoyue He, and Xiaohui Qiu,
National Center for Nanoscience and Technology (NCNST), China.
Demonstration of repeatable lithography on molecular resist for 72 hours with ~40 nm fidelity.
Acquired using a **AD-40-AS** Adama Innovations probe.

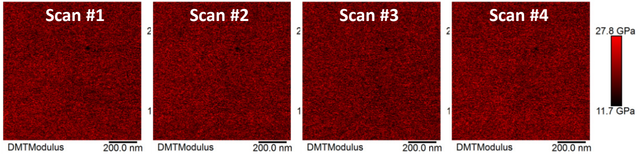
Nanomechanics – QNM – Polystyrene and HOPG

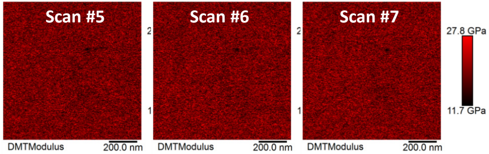


Polystyrene

Average = 2.68 ± 0.06 GPa



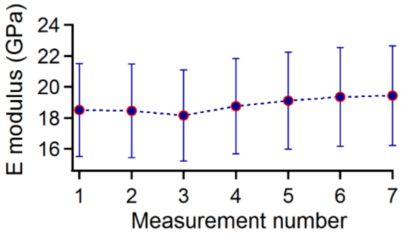




- Stable modulus mapping
- No jumps during imaging
- Repeatable modulus measurements
- Matching reference values

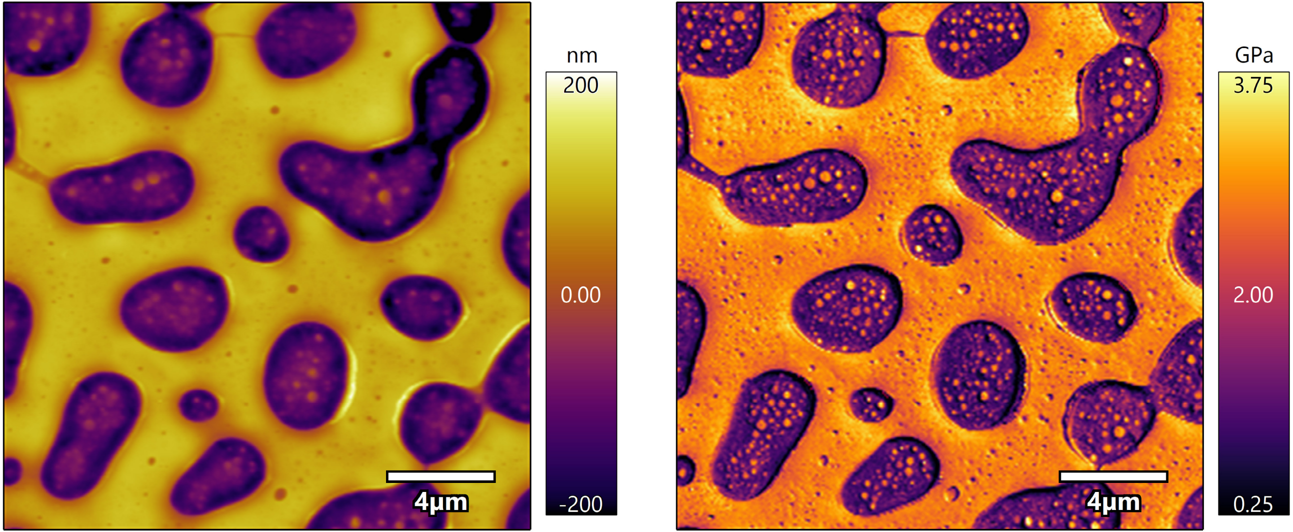
HOPG

Average = 18.82 ± 3.00 GPa



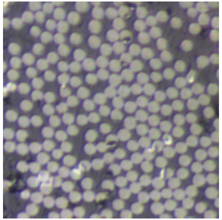
Acquired using a Bruker Dimension Icon AFM
with PeakForce QNM using an **AD-40-AS** Adama Innovations probe.

Nanomechanics – AMFM – Polystyrene / Polycaprolactone

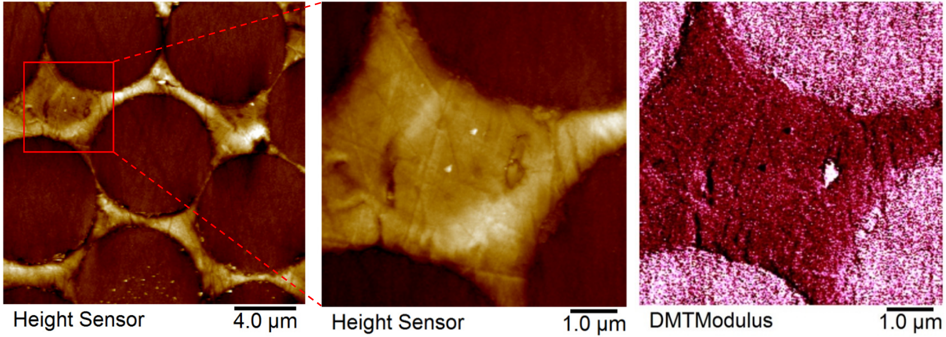


Imaging of a mixed Polystyrene (Modulus = 3 GPa) and Polycaprolactone (Modulus = 0.5 GPa) polymer film.
Modulus mapping enables clear chemical identification in this sample.
Acquired using an Asylum Research Cypher-S AFM in AMFM mode using a **AD-40-AS** Adama Innovations probe.

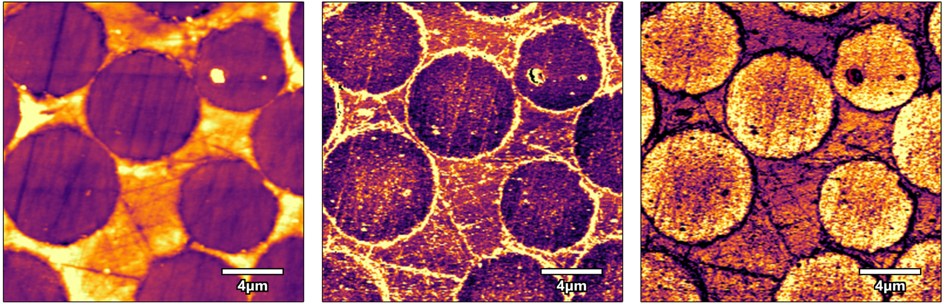
Nanomechanics – QNM & AMFM – Carbon Fibers in Epoxy



PeakForce QNM



AMFM-AFM



Height   Deformation   Modulus

BRUKER

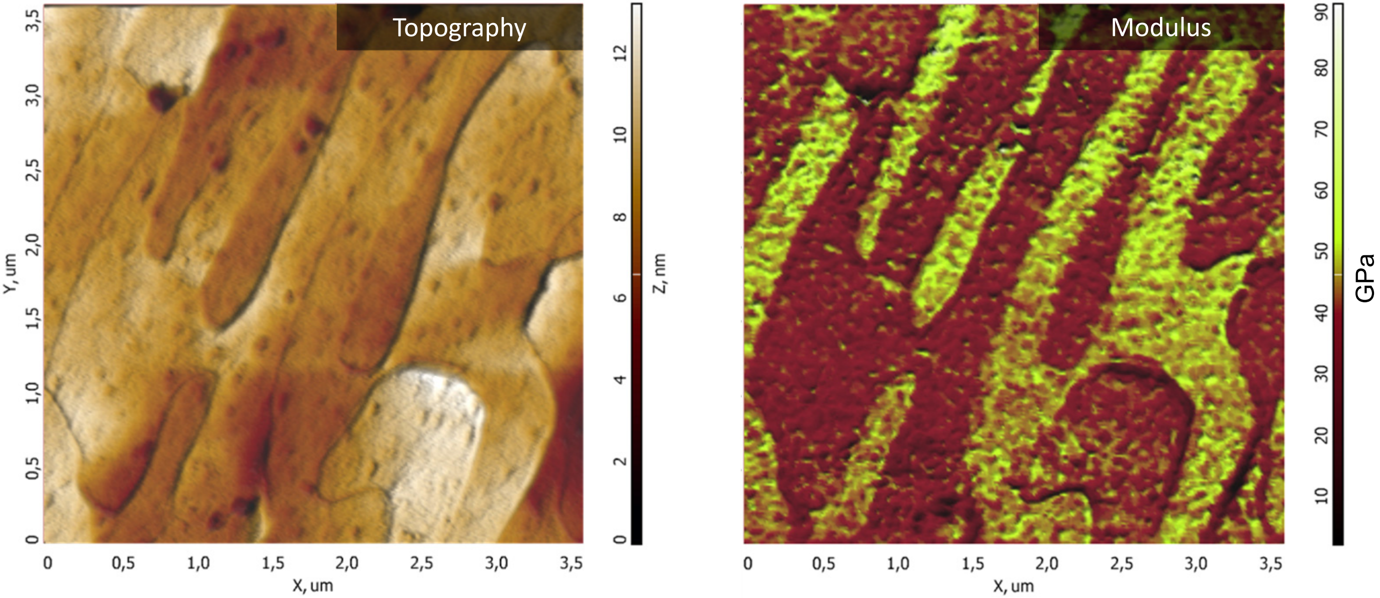
ASYLUM RESEARCH
an Oxford Instruments company

Imaging of a carbon fibers in an epoxy matrix using Bruker and Asylum Research nanomechanical mapping techniques.
Top - Acquired using a Bruker Dimension Icon AFM with PeakForce QNM using a **AD-40-AS** Adama Innovations probe.
Bottom - Acquired using an Asylum Research Cypher-S AFM with AMFM using a **80 N/m -AS** Adama Innovations probe.

Adama innovations

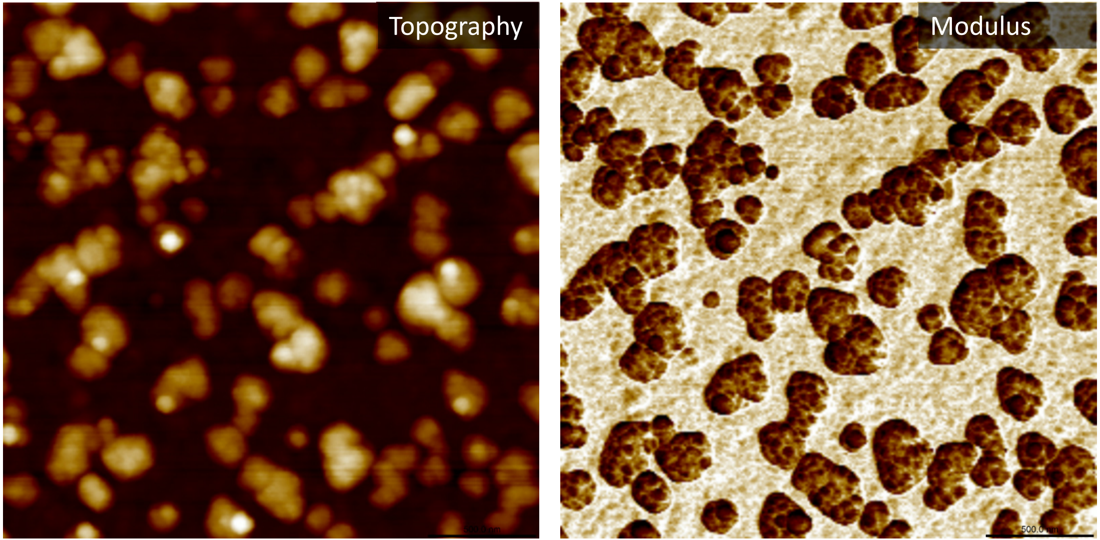
Adama innovations

Nanomechanics – AMFM – Bismuth / Tin Alloy



Data Courtesy: Dr. Stanislav Leesment (NT-MDT). Sample Courtesy: Dr. Sergei Magonov (NT-MDT).
Nanomechanical mapping of a Bismuth / Tin (Modulus: 35 GPa / 55 GPa) alloy
showing clear phase separation and species identification.
Acquired using a NT-MDT Titanium AFM in HybriD™ mode using a **80 N/m -AS** Adama Innovations probe.

Nanomechanics – QNM – Tungsten Diselenide (WSe2)

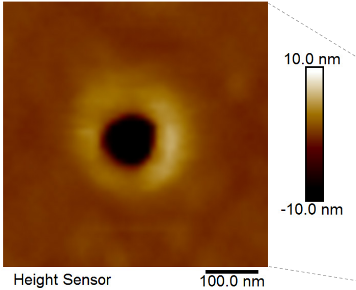


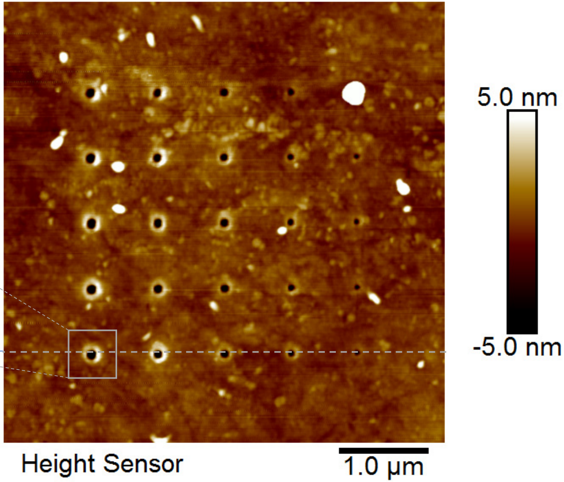
25 μm x 25 μm

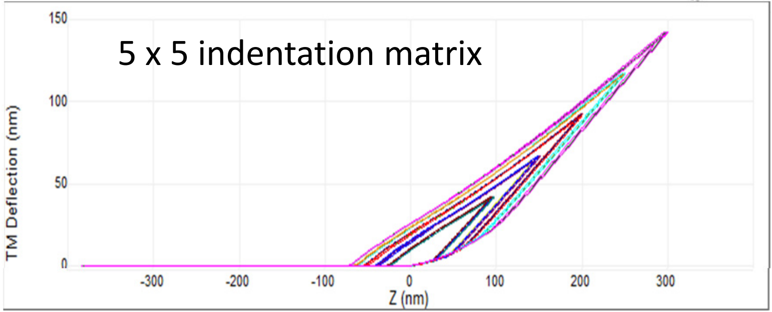
WSe$_2$ ~80 GPa

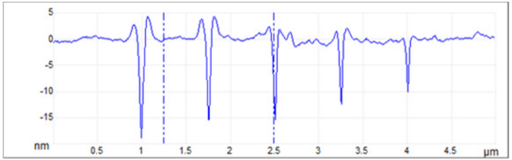
Mechanical mapping of the mechanical properties of Tungsten Diselenide (WSe2) nanoparticle clusters.
Here the modulus map shows variations in modulus within nanoparticle clusters.
Acquired using a Bruker Multimode AFM with PeakForce QNM using a **80 N/m -AS** Adama Innovations probe.

Nanomechanics – Nanoindentation – Fused Si



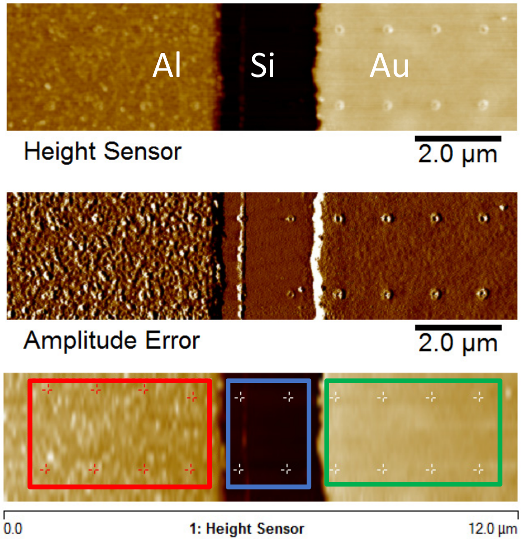


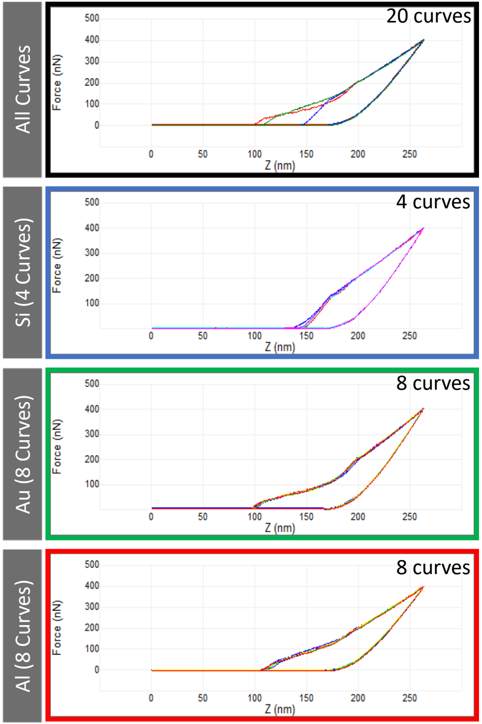




Nanoindentation curves on fused silica at 5 different loads at 5 locations per load. Indentation curves show excellent repeatability. Indents were imaged in Tapping Mode with the same probe. Acquired using a Bruker Dimension Icon AFM in Contact and Tapping modes using a **150 N/m -AS** Adama Innovations probe.

Nanomechanics – Nanoindentation – Thin Metal Films

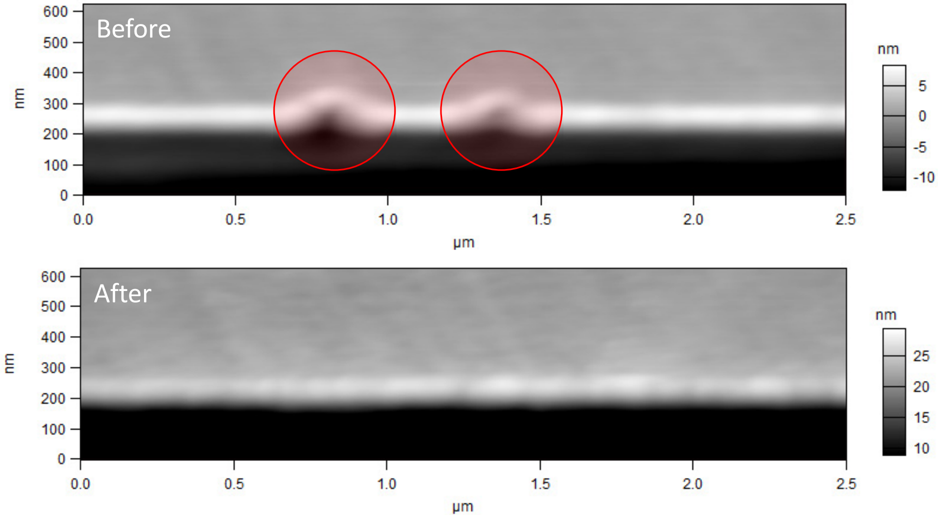


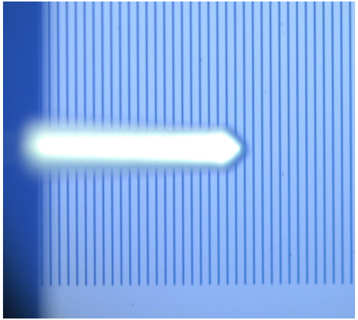


Nanoindentation array on thin metal films of gold and aluminum on silicon. This probe was used for 100 indentations on fused Si prior to these measurements. Force curves show excellent repeatability and allow for the accurate measurements of metal film thickness (Au = 50 nm and Al = 45 nm). Indents were imaged in Tapping mode with the same probe after indentation.

Acquired using a Bruker
Dimension Icon AFM in Contact and Tapping modes using a **150 N/m -AS** Adama Innovations probe.

Photomask Repair – Defect Repair

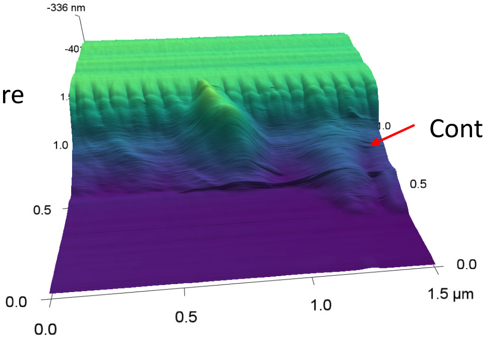




Repair of two photomask edge defects by machining the edge with a sharp robust diamond probe. Acquired using an Asylum Research Cypher-S AFM using an Adama Innovations Photo Mask probe.

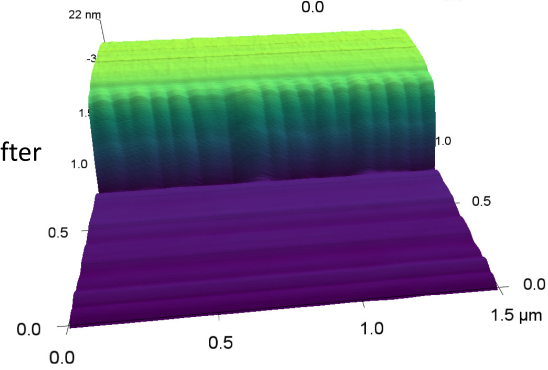
Photomask Repair – Cleaning

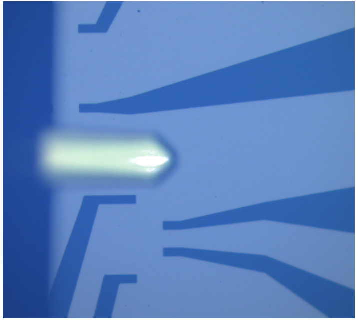
Before



Mask Contamination

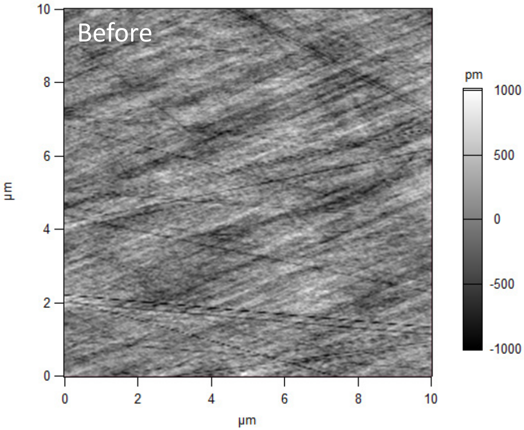
After

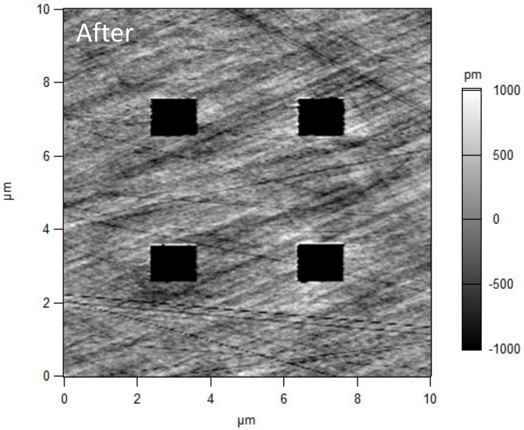


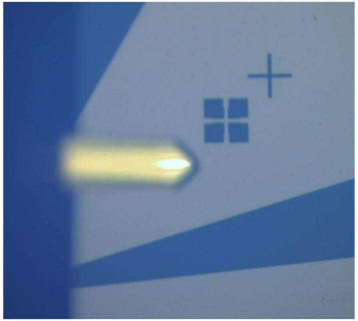


Cleaning of a photomask using a sharp robust diamond probe. A significant amount of debris is removed from the surface without damaging the photomask. Acquired using an Asylum Research Cypher-S AFM using an Adama Innovations Photo Mask probe.

Photomask Repair – Writing







Writing new photomask features using a sharp robust diamond probe. Here four new features are cut into the chrome of the photomask. Acquired using an Asylum Research Cypher-S AFM using an Adama Innovations Photo Mask probe.