# NP-AFM

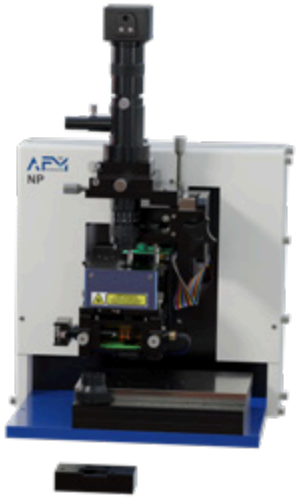
THE NP-AFM IS A **COMPLETE NANOPROFILER** TOOL INCLUDING EVERYTHING REQUIRED FOR SCANNING SAMPLES: MICROSCOPE STAGE, ELECTRONIC BOX, CONTROL COMPUTER, PROBES, MANUALS, AND A VIDEO MICROSCOPE. SAMPLES AS LARGE AS 200 x 200 x 20 MM ARE PROFILED BY THE **NP-AFM** SYSTEM, AND SEVERAL STAGE OPTIONS ARE AVAILABLE FOR MANY TYPES OF SAMPLES.

- Nanoprofiler AFM for:
  - Technical samples
  - Wafers and discs
- Two sample stage options to accommodate substrates up to 200 x 200 x 20 mm
- Integrated high resolution video microscope
- Linearized XY piezoelectric scanner
- Accommodates standard-sized AFM probes
- Includes vibrating and non-vibrating topography modes, plus lateral force and phase mode imaging
- Utilizes a direct drive motorized probe approach
- Captures images with intuitive LabVIEW™-based software

Using the industry-standard light lever force sensor, all of the standard scanning modes are included with the system. Vibrating mode is used for high resolution and soft samples, while non-vibrating mode can be used for routine scanning. Also included with the system are phase and lateral force modes.

Control software, written in LabVIEW™, is simple and intuitive to use. Differing windows walk users through the process: a pre-scan window helps align the AFM probe, a scanning window aids in acquiring images, a force position window is used for measuring F/D curves, and finally, a system window assists in altering system parameters.

Use the NP-AFM for routine scanning of technical samples such as wafers and disks or for nanotechnology research.



# NP-AFM CAPABILITIES

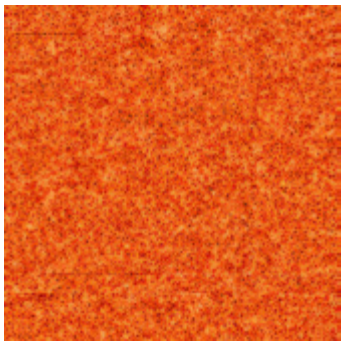
Polished and machined surfaces of semiconductors, glass, and metals are readily scanned with the **NP-AFM**. Due to its flexible stage design, fixtures can be created for holding almost any sample shape. Additionally, the stage can hold many smaller samples that may then be imaged in a specific order.

Once measured, the AFM images can be analyzed and standard surface texture parameters, such as Ra, are readily calculated.

Atomic force microscopes are capable of accurately measuring the dimensions of semiconductor and other micro-fabricated devices. Because the NP-AFM has been designed to accommodate commercially available AFM probes, users can easily install specialized probes for metrology measurements.

Step heights and pitch are among the dimensional measurements readily made with the NP-AFM. Either Gwyddion open source software, provided with the NP-AFM system, or alternate commercial analysis packages, can be used to
analyze the data.

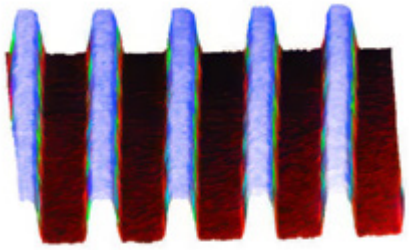
## MEASURE SURFACE TEXTURE AND ROUGHNESS



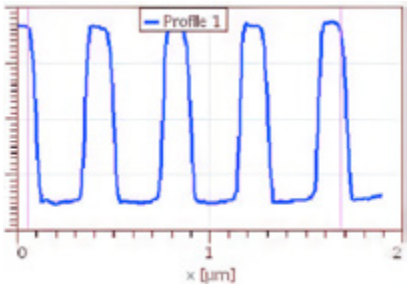
10 X 10 µm vibrating mode scan of a silicon surface showing a surface roughness (Ra) of 0.364 nm.

| Parameters | |
|---|---|
| Average value: | -0.000 |
| Minimum: | -2.097 |
| Maximum: | 1.826 |
| Median: | 0.001 |
| Ra (Sa): | 0.364 |
| Rms (Sq): | 0.456 |
| Skew: | -0.0198 |
| Kurtosis: | -0.000568 |

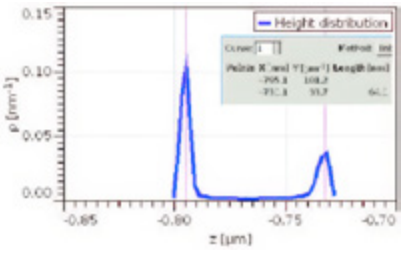
## MEASURE SURFACE TEXTURE AND ROUGHNESS



Three dimensional view: 2 x 2 µm scan, diffraction grating.




Line profile of diffraction grating showing pitch of the grating.




Histogram analysis showing height of features in the diffraction grating.

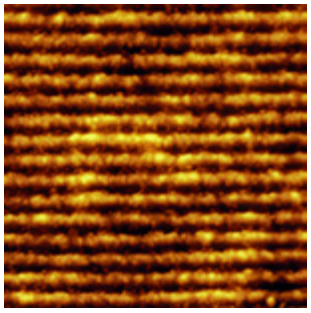
# NP-AFM CAPABILITIES CONTINUED...

One of the most powerful capabilities of the **NP-AFM** is visualizing surface structure. Although not easily quantified, the surface texture of the lines on the 2 µm grating (at right) is readily visualized. Features ranging in size from a few nm to a few µm are easily visualized by the **NP-AFM**.

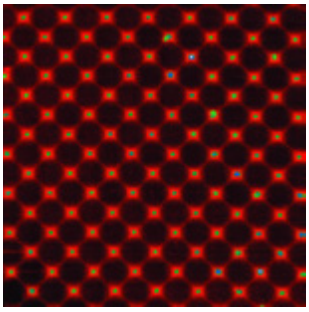
Atomic force microscopes are capable of accurately measuring the dimensions of semiconductor and other micro-fabricated devices. Because the NP-AFM has been designed to accommodate commercially available AFM probes, users can easily install specialized probes for metrology measurements.

Step heights and pitch are among the dimensional measurements readily made with the NP-AFM. Either Gwyddion open source software, provided with the NP-AFM system, or alternate commercial analysis packages, can be used to analyze the data.

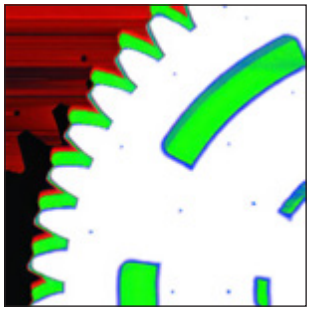
## VISUALIZATION



2 x 2 µm image of a grating.

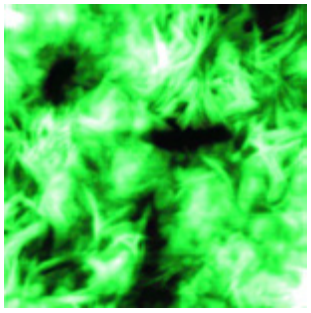


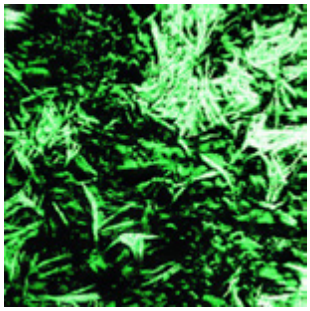
20 x 20 µm image of a silicon test pattern



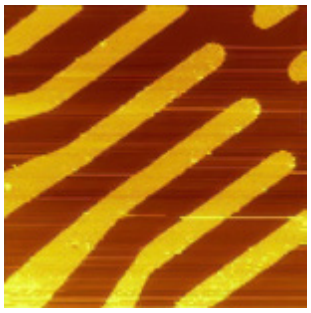
40 x 40 µm image of a gear fabricated with MEMS.

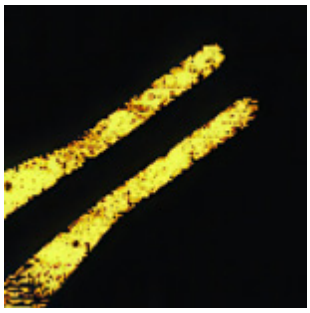
## MODES





20 x 20 µm image of a polymer sample. At the left is a topography image and at the right is a phase mode image





10 x 10 µm image of silicon sample with gold pattern. At the left is a topography image and at the right is a conductive AFM image. Two of the "fingers" on the test pattern are grounded and show contrast in the conductive AFM image.

# NP-AFM STAGE

The **NP-AFM** stage has excellent thermal and mechanical stability required for high resolution AFM profiling. Additionally, its open design facilitates user modification.

### HIGH RESOLUTION Z STAGE

The direct drive's Z stage controls motion down to 330 nm, assuring optimal tip approach. Software controls for the Z stage rapidly move the light lever up and down and regulate the automated probe approach.

### SAMPLE STAGE

The NP-AFM has multiple stage options, including a 2 x 3" manual stage with a resolution of 2 µm, and a sample stage for wafers and discs.

### LIGHT LEVER FORCE SENSOR

An industry-standard light lever force sensor is utilized in the NPAFM. Most commercially available AFM probes are accommodated in the probe holder. The light lever force sensor can make measurements in standard modes, including vibrating, non-vibrating, lateral force, and phase mode.

### VIDEO MICROSCOPE

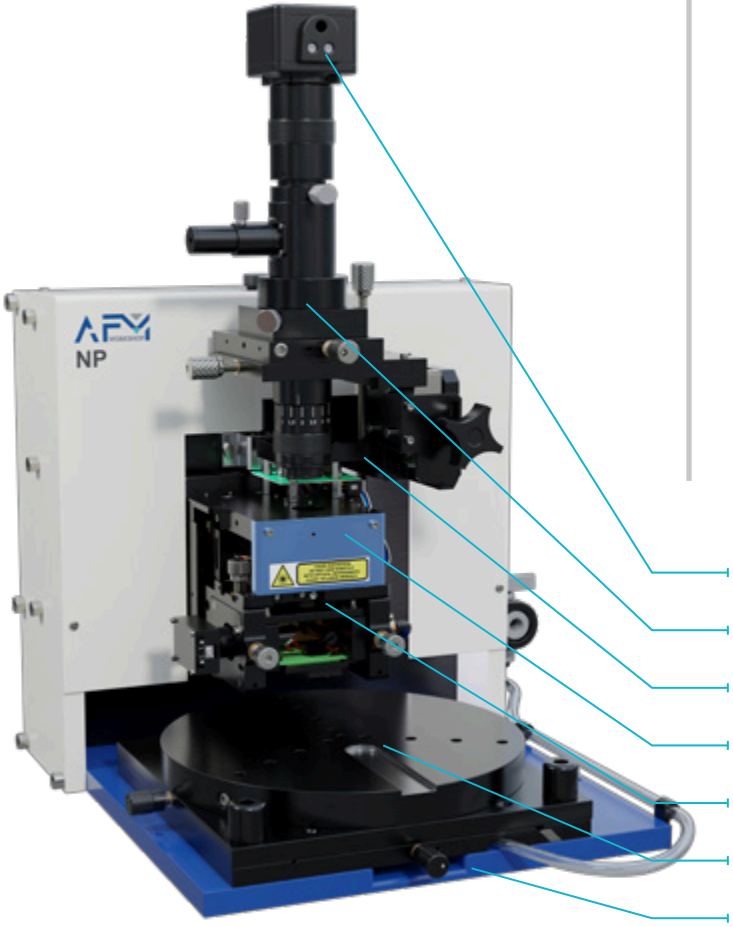
The high resolution video microscope has a zoom tube which allows a field of view between 2 x 2 mm and 0.3 x 0.3 mm. The video microscope is essential for aligning the light lever laser, locating features for scanning, and facilitating tip approach.

### XY PIEZO SCANNER

For XY scanning, linearized piezo electric ceramics utilize real-time feedback control to assure accurate measurements. The multiple modified tripod design (MMTD) of the XY scanner provides scans with minimal background bow.

### PROBE HOLDER

A modular probe holder is used in the light lever force sensor and held in place with a spring clip. Probes can be replaced in less than two minutes with the NP-AFM's probe exchange tool.




High resolution 3MP CCD color camera video microscope

XYZ video microscope positioning

High performance linear Z translator

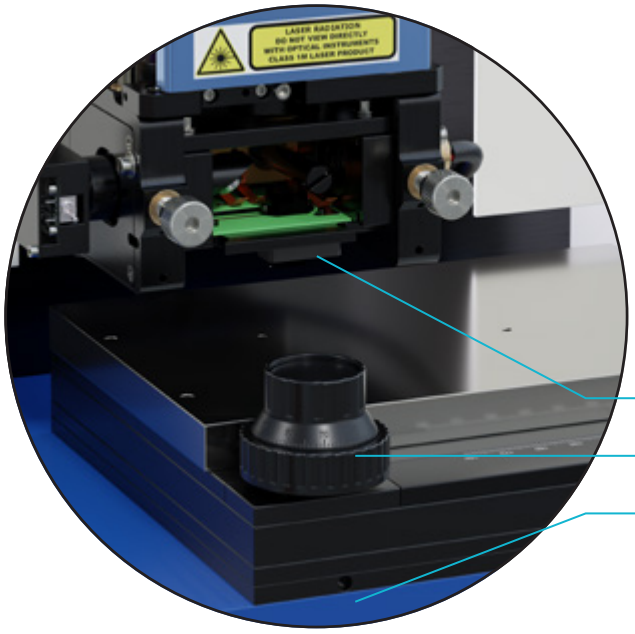
Linearized XY piezo scanner

Light lever force sensor

Sample stage - vacuum stage shown here

Small footprint, high stability stage structure

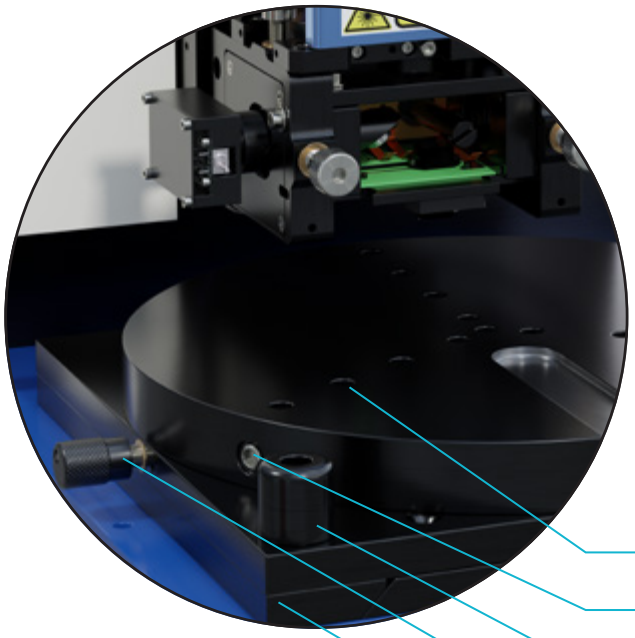
# NP-AFM 4012 STAGE



The NP-AFM-4012 Stage is designed to accommodate many sample shapes and sizes. The stage comes with a holder for 6 standard AFM magnetic disks. Custom sized sample holders may be readily designed and added to the stage.

- Sample holder with six magnets for standard AFM sample disks
- XY adjustment mechanism
- Sample platform with tapped holes for adding varying sample holding fixtures

# NP-AFM 4022 STAGE



Wafers and discs up to 8" in diameter are accommodated by the NP-AFM-4022 stage. The vacuum chuck has a unique design that holds the samples firmly while also enabling quick adjustments to accommodate varying diameters of sample sizes. There is a "two-tiered" translation system to locate features for AFM imaging.

- Vacuum ports at surface of vacuum chuck, configurable for 2, 4, 6, and 8" wafers
- Micrometer screws for precision motion of the vacuum chuck
- Stage lock screw
- Vacuum chuck rotates 360°
- 4" linear motion stage

Screws with o-ring seals are provided and allow selection of the correct vacuum chuck diameter.

# EBOX

Electronics in the **NP-AFM** are constructed around industry standard USB data acquisition electronics. The critical functions, such as XY scanning, are optimized with a 24 bit digital to analog converter combined with 4 bits of gain. With the analog Z feedback loop, the highest fidelity scanning is possible. Vibrating mode scanning is possible with both phase and amplitude feedback using the high sensitivity phase detection electronics.

### 28-BIT SCANNING

With 28-bit scanning, the highest resolution AFM images may be measured. Feedback control using the XY strain gauges assures accurate tracking of the probe over the surface.

### PHASE AND AMPLITUDE DETECTOR CIRCUIT

Phase and amplitude in the Ebox are measured with highly stable phase and amplitude chips. The system can display phase data while using amplitude for feedback when scanning in vibrating mode.

### SIGNAL ACCESSIBLE

At the rear of the Ebox is a 50 pin ribbon cable that gives access to all the primary electronic signals without having to open the Ebox.

### STATUS LIGHTS

At the front of the Ebox is a light panel that has seven lights. In the unlikely event of a circuit failure, these lights enable determination of Ebox power supply status.

### PRECISION ANALOG FEEDBACK

Feedback from the light lever force sensor to the Z piezoceramic is made using a precision analog feedback circuit. The position of the probe may be fixed in a vertical direction with a sample-and-hold circuit.

### VARIABLE GAIN HIGH VOLTAGE PIEZO DRIVERS

An improved signal to noise ratio as well as extremely small scan ranges are possible with the variable gain high voltage piezo drivers.

### FEATURES:

- Microprocessor for scan generation through 24-bit DACs
- Low-noise, variable gain high-voltage amplifiers with PID feedback for XY scanning
- Dimensions: Width 6" | Height 10" | Depth 14"
- High-fidelity, low noise Z feedback circuits for accurate probe tracking
- Phase and amplitude detection circuits for vibrating mode AFM
- Industry-standard National Instruments USB data acquisition board
- Internally accessible header for signal input/output
- Eight channels of ADC for monitoring and displaying data with LabVIEW™ software

# AFM CONTROL SOFTWARE

Software for acquiring images is designed with the industry standard LabVIEW™ programming visual interface instrument design environment. There are many standard functions, including setting scanning parameters, probe approach, frequency tuning, and displaying images in real time.

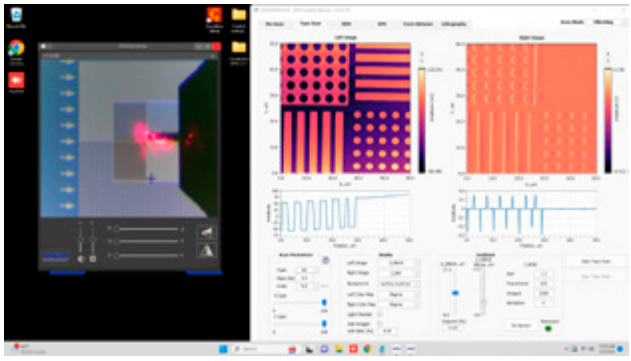
LabVIEW™ facilitates rapid development for those users seeking to enhance the software with additional special features. LabVIEW also enables the **NP-AFM** to be readily combined with any other instrument using LabVIEW.

### PRE-SCAN TAB

All of the functions required before making a scan are on the pre-scan tab. This includes selecting the scan mode, visual PLD alignment, frequency scan, and automatic tip approach.

### TOPO SCAN TAB

Images are acquired using the Topo Scan tab. Parameters selected on the scanning tab include the scan size, scan rate, GPID parameters, and the color scale used for displaying images. Included with the scanning tab is an image buffer capability that facilitates rapid zooming in and out.

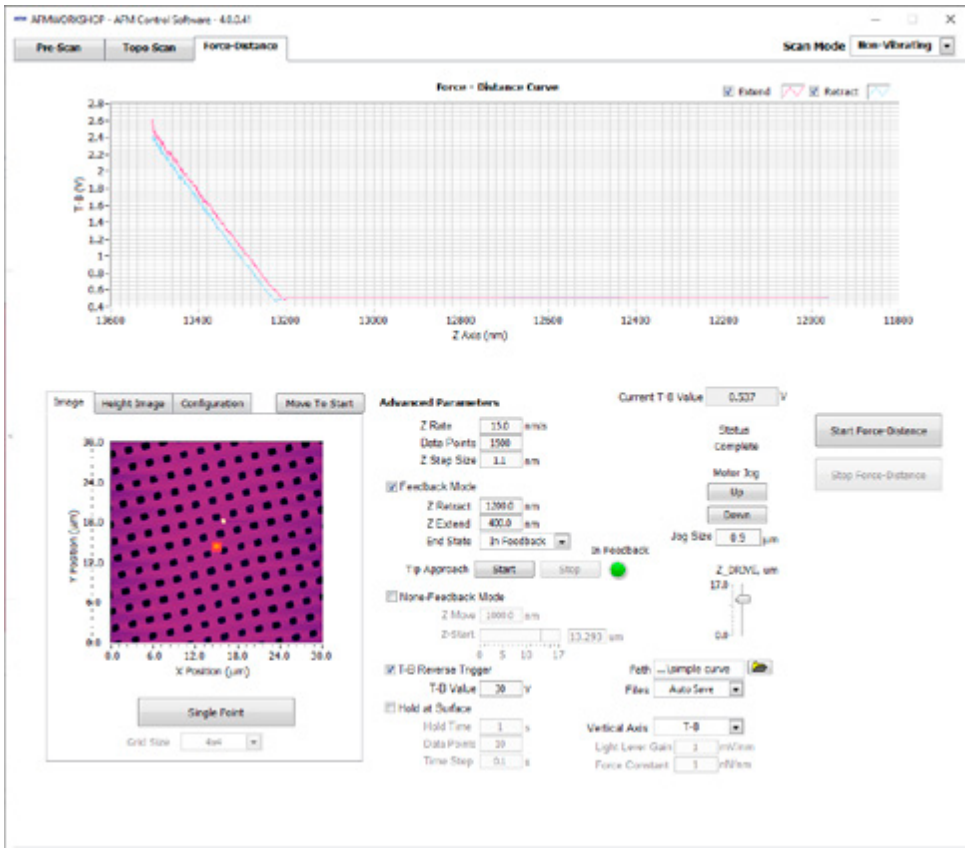


# AFM CONTROL SOFTWARE CONTINUED...

## MODES TABS

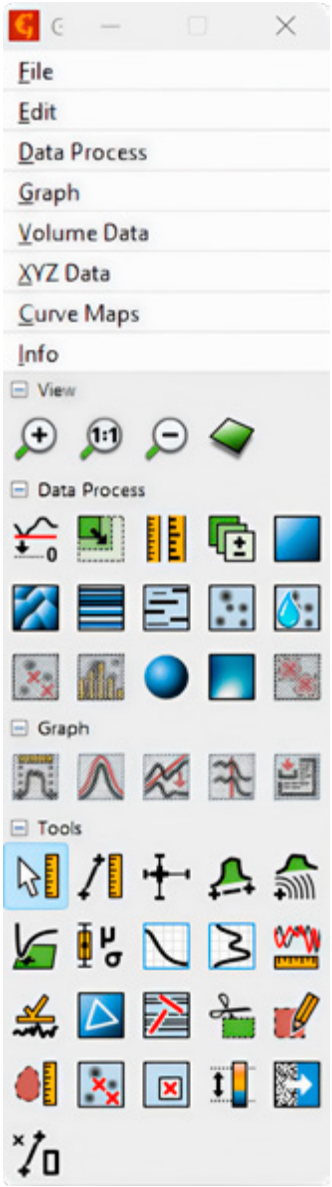
Software control for optional modes such as MFM, EFM, and advanced F/D are found in the modes tabs. The example shown here is of the advanced F/D mode tab. This allows fine control of all the parameters controlling acquisition of force-distance curves, as well as acquisition of F-D curve maps.

Mapping of curves in this way allows the user to locate and visualize regions of the sample with differing properties, such as presence of specific molecules, or mechanical properties.



# IMAGE ANALYSIS SOFTWARE

Included with the **NP-AFM** is Gwyddion open source SPM image analysis software. This complete image analysis package has all the software functions necessary to process, analyze, and display SPM images.

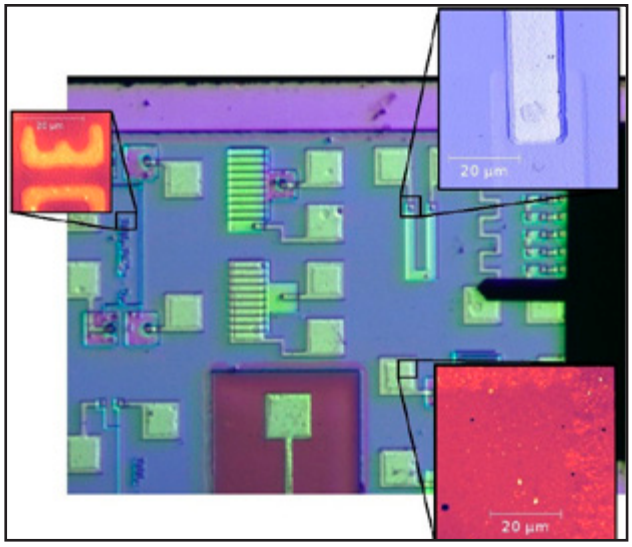



- Visualization: false color representation with different types of mapping
- Shaded, logarithmic, gradient- and edge-detected, local contrast representation, and Canny lines
- OpenGL 3D data display: false color or material representation
- Easily editable color maps and OpenGL materials
- Basic operations: rotation, flipping, inversion, data arithmetic, crop, and resampling
- Leveling: plane leveling, profiles leveling, three-point leveling, facet leveling, polynomial background removal, and leveling along user-defined lines
- Value reading, distance, and angle measurement
- Profiles: profile extraction, measuring distances in profile graph, and profile export
- Filtering: mean, median, conservative denoise, Kuwahara, minimum, maximum, and checker pattern removal
- General convolution filter with user-defined kernel
- Statistical functions: Ra, RMS, projected and surface area, inclination, histograms, 1D and 2D correlation functions, PSDF, 1D and 2D angular distributions, Minkowski functionals, and facet orientation analysis
- Statistical quantities calculated from area under arbitrary mask
- Row/column statistical quantities plots
- ISO roughness parameter evaluation
- Grains: threshold marking and un-marking, and watershed marking
- Grain statistics: overall and distributions of size, height, area, volume, boundary length, and bounding dimensions
- Integral transforms: 2D FFT, 2D continuous wavelet transform (CWT), 2D discrete wavelet transform (DWT), and wavelet anisotropy detection
- Fractal dimension analysis
- Data correction: spot remove, outlier marking, scar marking, and several line correction methods (median, modus)
- Removal of data under arbitrary mask using Laplace or fractal interpolation
- Automatic XY plane rotation correction
- Arbitrary polynomial deformation on XY plane
- 1D and 2D FFT filtering
- Fast scan axis drift correction
- Mask editing: adding, removing or intersecting with rectangles and ellipses, inversion, extraction, expansion, and shrinking
- Simple graph function fitting, and critical dimension determination
- Force-distance curve fitting
- Axes scale calibration
- Merging and immersion of images
- Tip modeling, blind estimation, dilation, and erosion

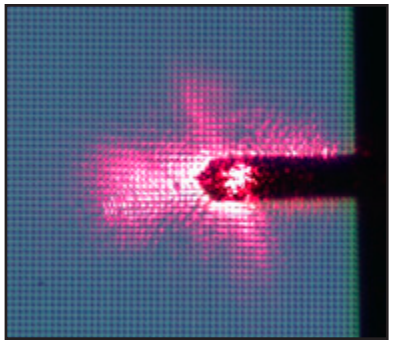
# VIDEO MICROSCOPE

A video optical microscope in an AFM serves three functions: aligning the PLD onto the cantilever in the light lever of the AFM, locating surface features for scanning, and facilitating probe approach.

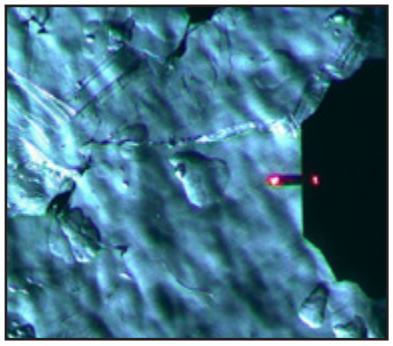
The **NP-AFM** includes a high performance video optical microscope along with a 5 megapixel camera, light source, microscope stand, and Windows software for displaying images.




Here the video optical microscope allows viewing features on a test structure. The AFM cantilever is on the right. Three images show results of areas selected for AFM scanning.



PLD alignment is greatly facilitated with the video optical microscope. This vibrating cantilever is 250 µm long. The red spot is from the PLD reflecting off the cantilever.



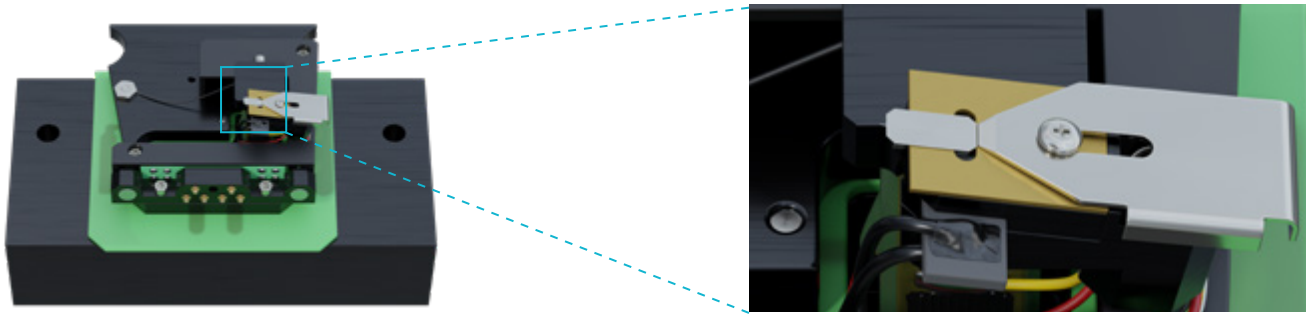
The video optical microscope zooms out to show an HOPG sample surface and the AFM cantilever.

# PROBE HOLDER/EXCHANGE

The **NP-AFM** utilizes a unique probe holder/exchange mechanism. Probes are held in place with a spring device that mates with a probe exchange tool.
This combination makes changing probes fast and easy on the **NP-AFM**.

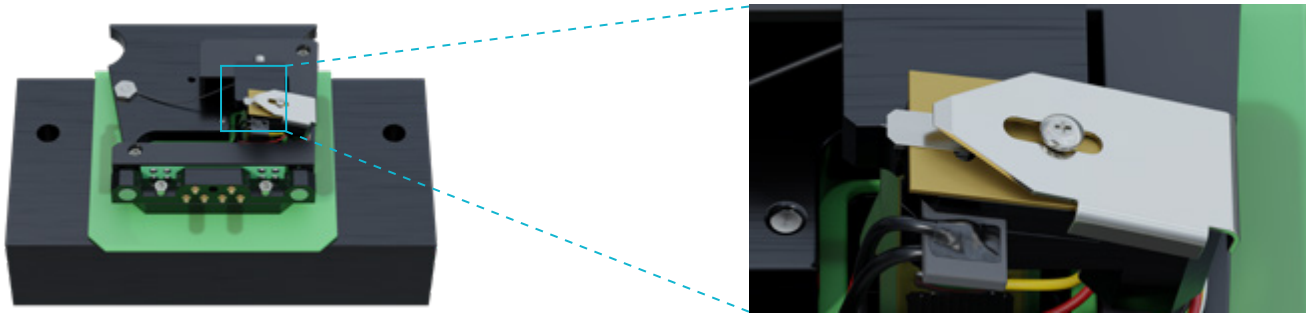
**STEP 1**

## Pull the probe clip back, place the probe on the probe holder



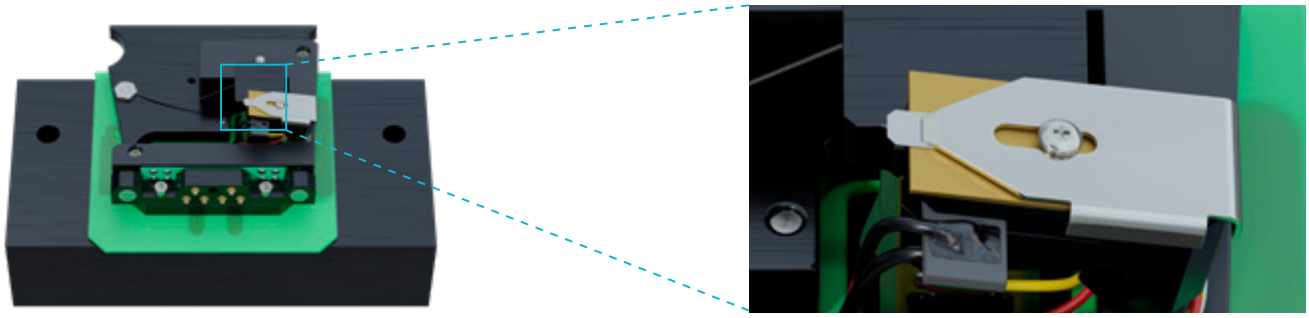
**STEP 2**

## Lift the clip up and move it forward over the probe chip



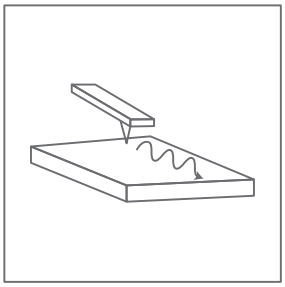
**STEP 3**

## Drop the probe clip onto the probe chip



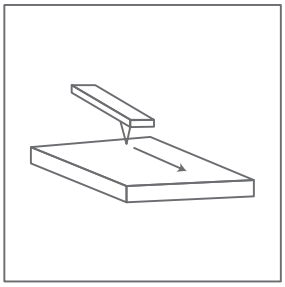
# SCANNING MODES

The **NP-AFM** includes the MOST COMMONLY USED AFM MODES.
They are:



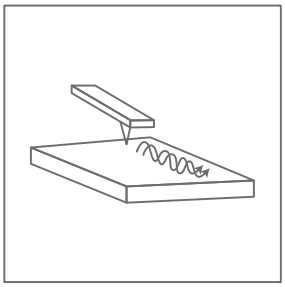
### VIBRATING (TAPPING)

Vibrating mode imaging is the most commonly used mode for measuring topography images with an AFM. In vibrating mode the vibration amplitude of the probe is held constant during a scan. Adjustable parameters include the vibrating frequency, amplitude of vibration, and the amount of dampening of the vibrating probe.



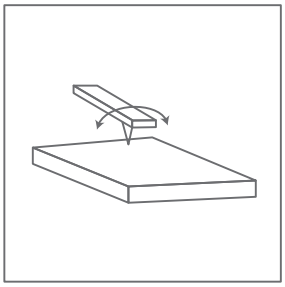
### NON-VIBRATING (CONTACT)

In non-vibrating mode, commonly called contact mode, the deflection of a cantilever is held constant during scanning. This mode is often used for scanning in liquids and is also used for measuring force-distance curves.



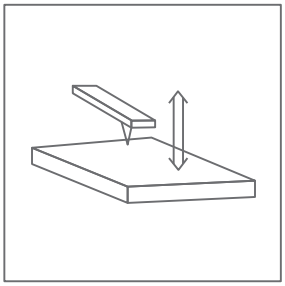
### PHASE

Phase mode images are measured in vibrating mode and are useful for identifying different areas of hardness on a surface. The technique operates by measuring the phase change caused by differing materials on a surface while scanning.



### LATERAL FORCE

Lateral force mode measures the local friction a probe senses as it is scanned across a surface. The friction can be caused by surface texture and differing chemical composition.

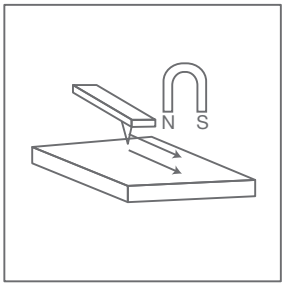


### BASIC FORCE/DISTANCE

Force-Distance curves measure the deflection of a cantilever as it interacts with a surface. Force-Distance measurements monitor such surface parameters as: Adhesion, Stiffness, Compliance, Hardness, and Contaminate Thickness. This simple AFM module allows measurements of force-distance curves. It can be upgraded to the Advanced Force-Distance module (see below).

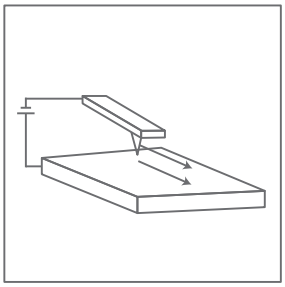
# SCANNING MODES CONTINUED...

OPTIONAL MODES that can be purchased with the **NP-AFM** include:



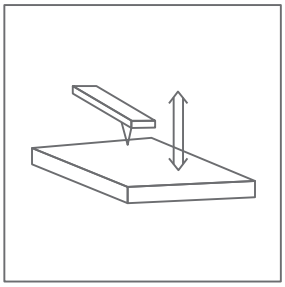

### MAGNETIC FORCE

Measures surface magnetic field by incorporating a magnetic probe into the AFM. MFM is used to generate images of magnetic fields on a surface, and is particularly useful in the development of magnetic recording technology. Magnetic fields associated with individual magnetic nanoparticles can also be revealed through MFM.



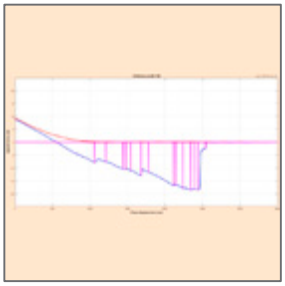
### ELECTRIC FORCE

Electrostatic Force Microscopy (EFM) is a type of dynamic non-contact atomic force microscopy where the electrostatic force is probed. "Dynamic" here means that the cantilever is oscillating and does not make contact with the sample. This force arises due to the attraction or repulsion of separated charges.



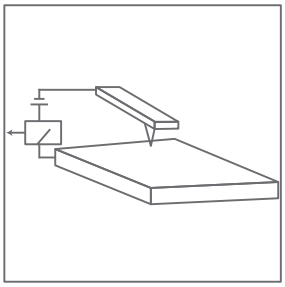
### ADVANCED F/D

Force-distance curves measure the deflection of a cantilever as it interacts with a surface. Force-Distance measurements monitor such surface parameters as: adhesion, stiffness, compliance, viscoelasticity, and surface layer thickness. This advanced AFM module is flexible and enables many types of experiments.



### FORCE DISTANCE CURVE ANALYSIS SOFTWARE

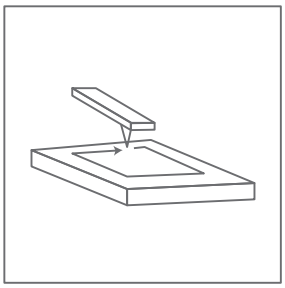
ISFVEM is a fast, intuitive software program for the analysis of a single force distance curve or a grid of curves generated with the AFMWorkshop advanced force distance acquisition software.



### CONDUCTIVE AFM

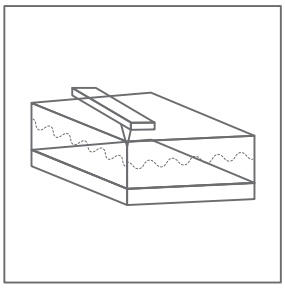
The C-AFM measures topography and conductivity images simultaneously. This option allows measuring current-voltage (I/V) curves at specific locations on a surface. This can be highly useful in development of microelectronics.

# SCANNING MODES CONTINUED...



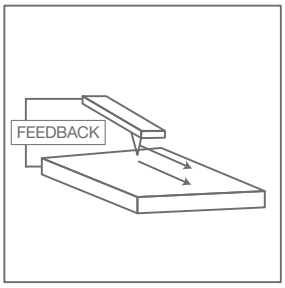
## LITHOGRAPHY

This NanoLithography software option enables the AFM probe to alter the physical or chemical properties of the surface. Created in LabVIEW and integrated with the AFM Control software. This software allows the customer to design their own nanolithographic patterns to be written to the sample surface. VI's are available to customers who want to modify the software and create new capabilities.



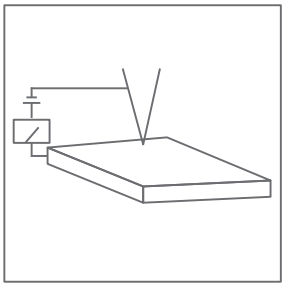
## OPEN LIQUID CELL

This option includes a special probe holder and open liquid cell for scanning samples submerged in liquids. The open liquid cell can directly replace the TT-2 AFM probe and sample holder.




## SCANNING KELVIN PROBE MICROSCOPY (SKPM)

SKPM measures the potential difference between a conductive probe and a conductive sample. The SKPM measurement is made by monitoring the output of a feedback loop that adjusts the potential on a probe so that the potential difference between the probe and surface is zero.



## SCANNING TUNNELING

In the STM, the current flow between a metal probe and a sample is used to control the distance between the conductive probe and conductive surface. When the probe is scanned across the surface, if the current between the probe and surface are held constant with a feedback control loop driving a piezo ceramic, the topography of the sample's surface is measured. This also allows measurement of localized I/V curves.

# SPECIFICATIONS

## 50 MICRON XY SCANNER

| | |
|---|---|
| Type | Modified Tripod |
| XY Linearity | < 1% |
| XY Range | > 50 µm |
| XY Resolution | < 3 nm closed loop<br>< 0.3 nm open loop |
| XY Actuator type | Piezo |
| XY Sensor type | Strain Gauge |

## 17 MICRON Z SCANNER / PROBE HOLDER

| | |
|---|---|
| Noise | < 0.2 nm |
| Strain Gauge Resolution | 1 nm |
| Tip Angle | 10° |
| Z Linearity | < 5% |
| Z Linearity-Sensor | < 1% |

## 7 MICRON Z SCANNER / PROBE HOLDER

| | |
|---|---|
| Noise | < 0.12 nm |
| Strain Gauge Resolution | na |
| Tip Angle | 10° |
| Z Linearity | < 5% |

## LIGHT LEVER AFM FORCE SENSOR

| | |
|---|---|
| Probe Types | Industry-standard |
| Probe Insertion | Manual |
| Probe Exchange | Tool |
| Probe Holding Mechanism | Clip<br>Vibrating Mode Piezo<br>Electrical Connector<br>to Probe |
| Laser/Detector Adjustment Range | +/- 1.5 mm |
| Adjustment Resolution | 1 µm |
| Minimum Probe to Objective | 25 mm |
| Laser Type | 670 nm Diode, < 3 mW |
| Laser Focus | < 25 µm |
| Detector | |
| Type | 4 Quadrant |
| Band Width | > 500 kHz |
| Signals Transmitted | TL, BL, TR, BR |
| Gain | Low, High Settings |
| Probe sample angle | 10° |

## DIGITAL DATA INPUT OUTPUT

| | |
|---|---|
| Connection | USB |
| Scanning | DAC |
| Number | 2 |
| Bits | 24 |
| Frequency | 7 kHz |
| Control DAC | |
| Number | 2 |
| Bits | 14 |
| Frequency | 2 kHz |
| ADC | |
| Number | 8 |
| Bits | 14 |
| Frequency | 48 kHz |

## Z MOTION

| | |
|---|---|
| Type | Direct Drive |
| Range | 25 mm |
| Drive Type | Stepper Motor |
| Min. Step Size | 330 nm |
| Slew Rate | 8 mm/minute |
| Limit Switch | Top, Bottom |
| Control | Software – Rate,<br>Step Size |

## ANALOG ELECTRONICS

| | |
|---|---|
| Vibrating Mode | |
| Freq Range | 2 kHz – 800 kHz |
| Output Voltage | 10 Vpp |
| Demod. Freq | TBD |
| Z Feedback | |
| Type | PID |
| Bandwidth | > 3 kHz |
| Sample Hold | Yes |
| Voltage | 0 – 150 V |
| XY Scan | |
| Voltage | 0 – 150 V |
| Bandwidth | > 200 Hz |
| Pan & Zoom | 22 Bits |
| Tip Approach Cutoff | < 20 µm sec. |

# SPECIFICATIONS CONTINUED . . .

## SOFTWARE

| | |
|---|---|
| Environment | LabVIEW™ |
| Operating System | Windows |
| Image Acquisition | Real Time Display (2 of 8 channels) |
| Control Parameters | |
| PID | Yes |
| Setpoint | Yes |
| Range | Yes |
| Scan Rate | Yes |
| Image Rotate | 0° and 90° |
| Laser Align | Yes |
| Vibrating Freq. Display | Yes |
| Force Distance | Yes |
| Tip Approach | Yes |
| Oscilloscope | Yes |
| Image Store Format | Industry-standard |
| Image Pixels | 16 x 16 to 1024 x 1024 |
| H.V. Gain Control | XY and Z |
| Real Time Display | Line Level, Light Shaded, Grey Color Palette |
| Calibration | System Window |
| Probe Center | Yes |

## VIDEO MICROSCOPE SPECIFICATION

| | Minimum Zoom | Maximum Zoom |
|---|---|---|
| **Field of View** | 2 x 2 mm | 300 × 300 µm |
| **Resolution** | 20 µm | 2 µm |
| **Working Distance** | 114 mm | 114 mm |
| **Magnification** | 45 × | 400 × |

## NP-AFM-4012

| | |
|---|---|
| Overall XY Range | 2″ x 3″ (5 mm x 7.6 mm) |
| Resolution | 3 µm |
| Max. Sample Size | 6″ x 6″ x 1/2″ (150 mm x 150 mm x 12 mm) |

## NP-AFM-4022

| | |
|---|---|
| 8″ (200 mm) Diameter Vacuum Chuck | |
| Linear Range | 4″ (100 mm) |
| Rotational Range | 360° |
| Secondary Manual | XY – 1/4″ (6 mm) |
| Vacuum | Required |

## SAMPLE HOLDER

| | |
|---|---|
| Type | Vacuum Chuck |
| Max. Lateral Dimensions | 200 mm |
| Max. Height | 25 mm |
| Rotational Range | 360° |

* Z Noise performance depends greatly on the environment the NP-AFM is used in. Best Z noise performance is obtained in a vibration free environment.

** Every effort is made to present accurate specifications, however, due to circumstances beyond AFMWorkshop's control, specifications are subject to change.