SA-AFM

USE THE **SA-AFM** FOR SCANNING LARGE SAMPLES, ROUTINE SCANNING OF TECHNICAL SAMPLES, AND FOR NANOTECHNOLOGY RESEARCH. THE **SA-AFM** IS A COMPLETE SYSTEM AND INCLUDES EVERYTHING REQUIRED FOR SCANNING ALL SIZES AND SHAPES OF SAMPLES.

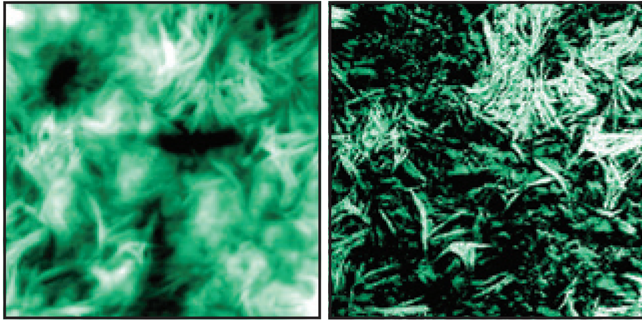
ADVANCED FEATURES

- **Flexible, stand alone design**
- **Scans any sample size**
- **Linearized XY piezoelectric scanner**
- **Accommodates widest range of standard AFM probes**
- **All standard modes, including vibrating, non-vibrating, and phase**
- **Direct drive motorized probe approach**
- **Intuitive LabVIEW™-based software for image capture**

Using the industry-standard light lever force sensor, all 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, lateral force, and basic force-distance 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 measures force distance curves, and finally, a system window assists in altering system parameters.

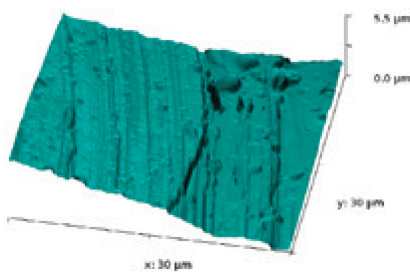
SA-AFM MEASUREMENTS



In addition to measuring surface structure, the **SA-AFM** is ideal for modes measurements. For example these images are of a polymer sample. The left image is the topography image and the right image is the phase image, measuring the relative hardness of the polymer sample.

SURFACE TEXTURE

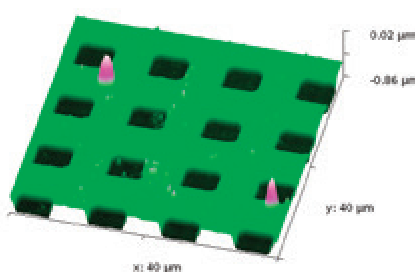
Surface texture on polished and machined surfaces is readily measured with the SA-AFM. With the SA's flexible stage design, fixtures for holding almost any sample shape can be created. Once measured, the AFM images can be analyzed and standard surface texture parameters such as Ra are readily calculated.



Polished Surface
30 x 30 x 5 µm

DIMENSIONAL

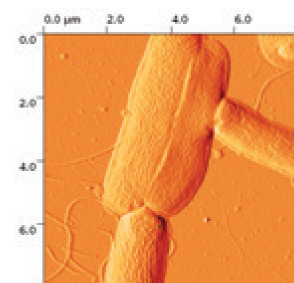
Atomic force microscopes are capable of accurately measuring the dimensions of semiconductor and other micro-fabricated devices. Because the SA-AFM accommodates most commercially available AFM probes, specialized probes for metrology measurements can be used.



Calibration Reference
40 x 40 x 1 µm

VISUALIZATION

One of the most powerful capabilities of the SA-AFM is the capability to visualize surface structure. Although not easily quantified, the surface texture of this cell structure is readily visualized. Features that may be easily visualized with the SA-AFM range in size from a few nm to a few µm.



Cells
8x8 µm

STAGE

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.

LIGHT LEVER FORCE SENSOR

An industry-standard light lever force sensor is utilized in the SA-AFM. The probe holder accommodates the widest range of commercially available AFM probes. The light lever force sensor can make measurements in standard modes, including vibrating, nonvibrating, 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.

UNIVERSAL 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 probe exchange tool. Additionally, the probe holder's spring clip can be used to supply voltages to the AFM probe for techniques such as conductive AFM.HR-AFM Light Lever Force Sensor.

SA AFM stage with XY sample translator for imaging small samples.

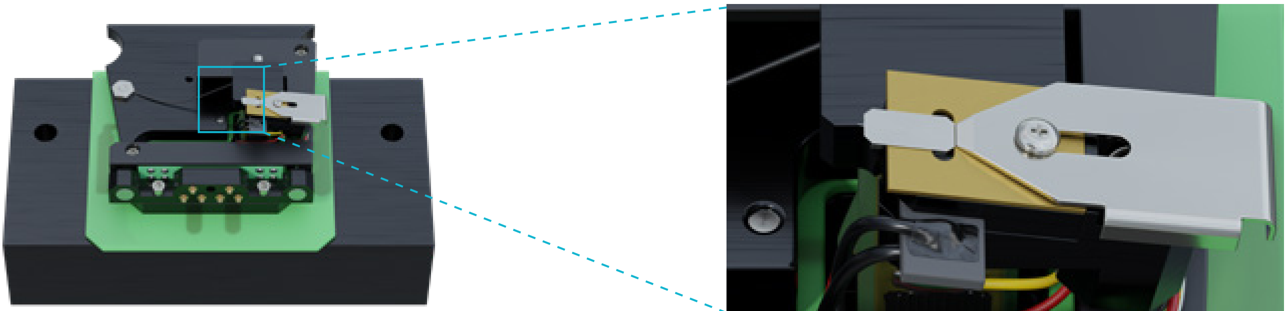
SA AFM stage without the XY sample stage is useful for looking at large samples such as a block of concrete.

PROBE HOLDER/EXCHANGE

The **SA-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 **SA-AFM**.

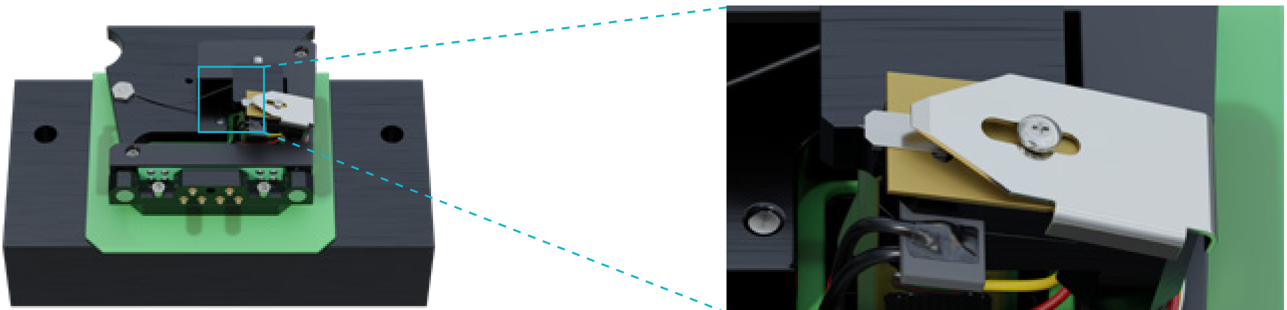
STEP 1

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



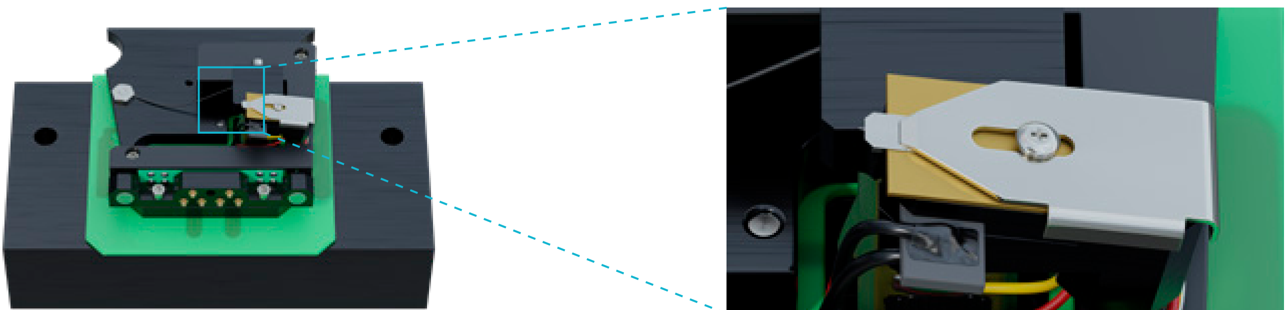
STEP 2

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



STEP 3

Drop the probe clip onto the probe chip



EBOX

Electronics in the **SA-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.

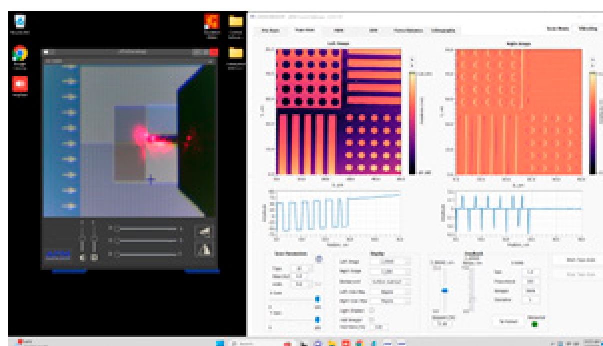
LabVIEW™ facilitates rapid development for those users seeking to enhance the software with additional special features. LabVIEW also enables the **HR-AFM** to be readily combined with any other instrument using LabVIEW.

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.



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.

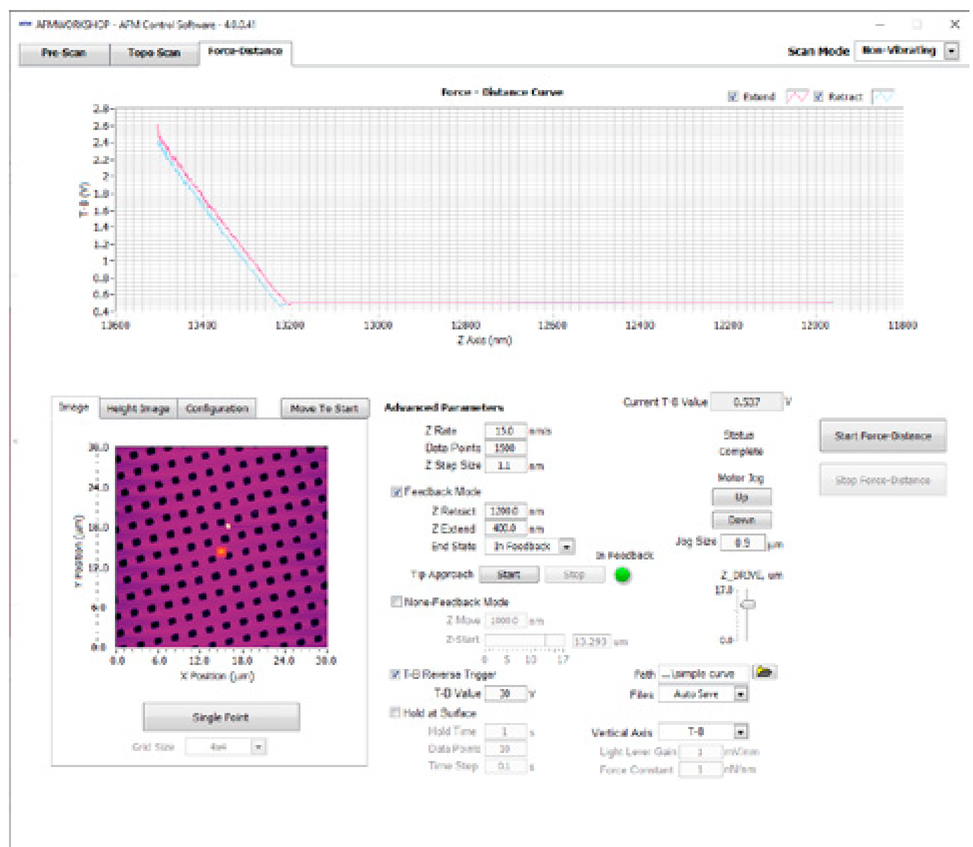
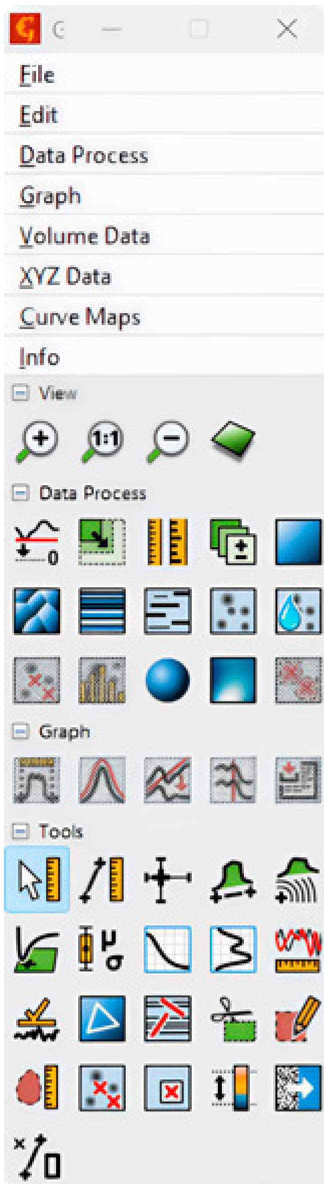


IMAGE ANALYSIS SOFTWARE

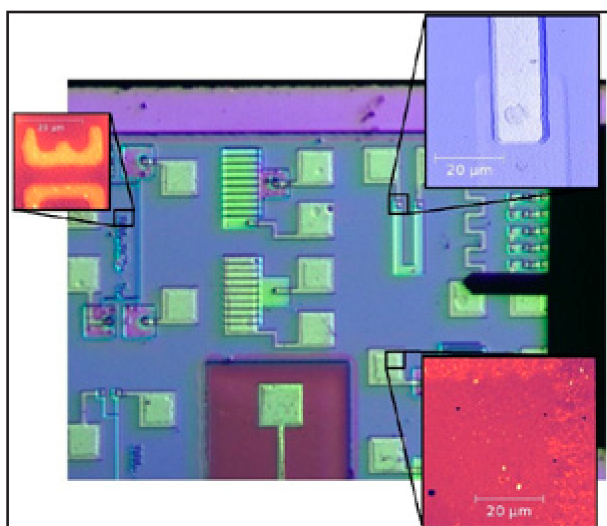
Included with the **HR-AFM** is Gwyddion open source SPM image analysis software. This complete image analysis package has all the software functions necessary to process, analyze, and display SPM images.



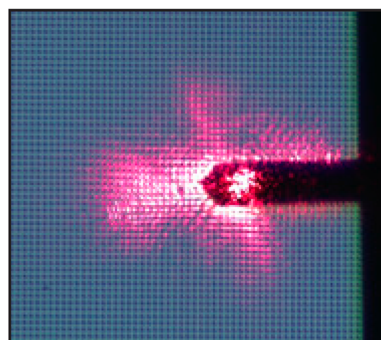
- Visualization: false color representation with different types of mapping
- Shaded, logarithmic, gradient- and edge-detected, local contrast representation, and Canny lines
- OpenGL 3D data display: false color or material representation
- Easily editable color maps and OpenGL materials
- Basic operations: 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

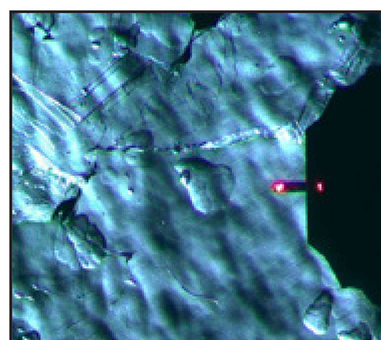
A video optical microscope in an AFM serves three functions: aligning the laser onto the cantilever in the light lever of the AFM, locating surface features for scanning, and facilitating probe approach.
The **SA-AFM** includes a high performance video optical microscope along with a 5 megapixel camera, 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.



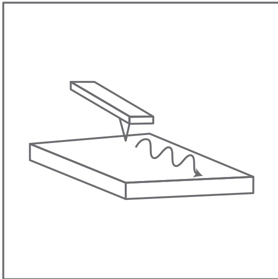
Laser alignment is greatly facilitated with the video optical microscope. This vibrating cantilever is 250 µm long. The red spot is from the laser reflecting off the cantilever.



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

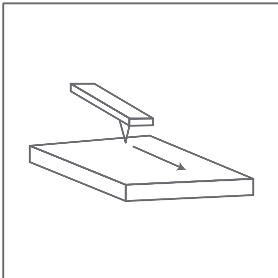
SCANNING MODES

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



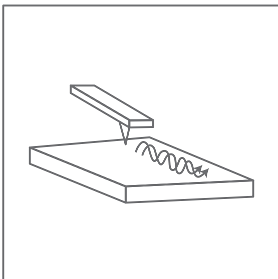
VIBRATING (TAPPING)

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.



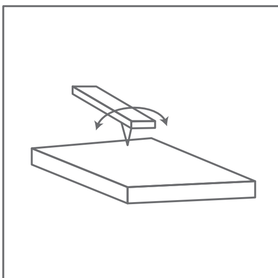
NON-VIBRATING (CONTACT)

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.



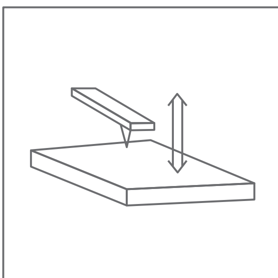
PHASE

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.

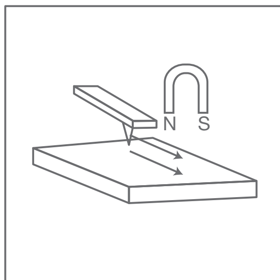


BASIC FORCE/DISTANCE

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).

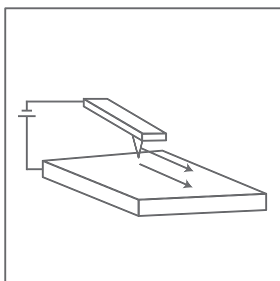
SCANNING MODES CONTINUED...

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



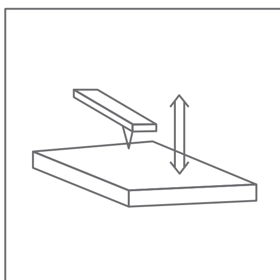
MAGNETIC FORCE

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.



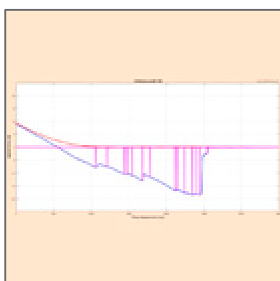
ELECTRIC FORCE

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.



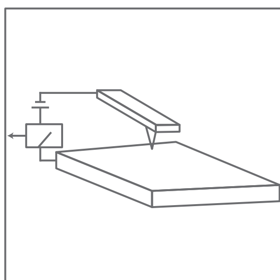
ADVANCED F/D

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.



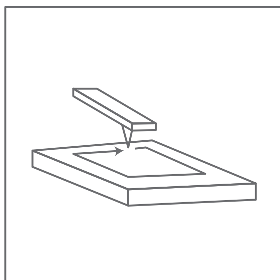
FORCE DISTANCE CURVE ANALYSIS SOFTWARE

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.



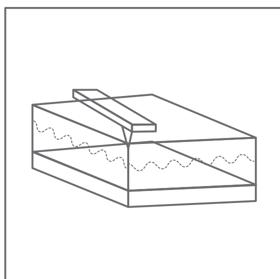
CONDUCTIVE AFM

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.



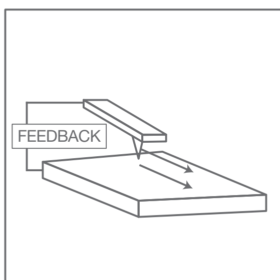
LITHOGRAPHY

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.



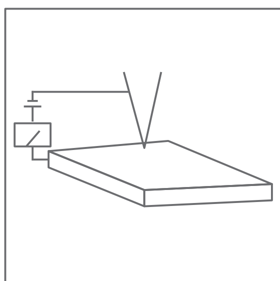
OPEN LIQUID CELL

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.

SA-AFM OPTIONS

Although the **SA-AFM** comes with everything you need to make AFM images, several additional options are available. AFMWorkshop regularly develops new options.

OPTIONAL MODES

Listed on Page 10 and 11 of this data sheet are the optional-modes available for the SA-AFM.

ELECTRICAL MODES

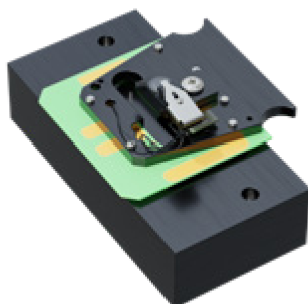
- Conductive AFM (C-AFM)
- Scanning Kelvin Probe (SKPM)
- Electric Force Microscopy EFM)
- Scanning Tunneling (STM)

LIQUID MODES

- Dunk and Scan - Open Liquid Cell

OTHER MODES

- Lithography
- Advanced Force/Distance
- Magnetic Force
- Force Distance Curve Analysis Software



OPTIONAL FEATURES

Image Logger

This option allows display of six channels in the forward and reverse direction. It has a spectrum function as well as a six channel data logger.

Break Out Box

BNC gives access to most of the signals in the Ebox.

Scanners

There are two scanners available for the SA-AFM. They are:

- Tip Scanning Z with Strain Gauge 17µm
- Tip Scanning Z 7µm

Q-Box/Q-Base

The Q-Box is a unique vibration solution that reduces both sound and structural vibrations. It features a unique adjustable elastomer suspension system which is optimal for atomic force microscopes.

SPECIFICATIONS

50 MICRON XY SCANNER

Type	Modified Tripod
XY Linearity	< 1%
XY Range	> 50 µm
XY Resolution	< 3 nm closed loop < 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 Vibrating Mode Piezo Electrical Connector to Probe
Laser/Detector Adjustment Range	+/- 1.5 mm
Adjustment Resolution	1 µm
Minimum Probe to Objective	25 mm
Laser Type mW	670 nm Diode, < 3
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, 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 1024	16 x 16 to 1024 x
H.V. Gain Control	XY and Z
Real Time Display	Line Level, Light Shaded, Grey Color Palette
Calibration	System Window
Probe Center	Yes

* *Z Noise performance depends greatly on the environment the SA-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.*

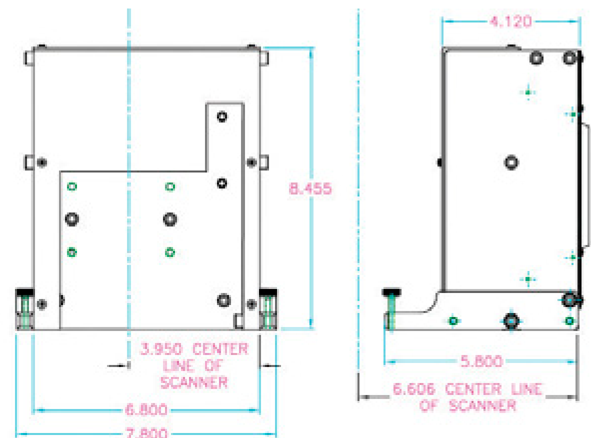
VIDEO OPTICAL MICROSCOPE SPECIFICATIONS

	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 ×

COMPUTER

- Industry-standard Computer & Monitor (laptop available upon request)
- Windows
- AFMWorkshop LabVIEW.exe installed

STAGE



- Back and side view of the SA-AFM stage without the AFM/video microscope. The feet at the bottom may be removed if the stage is rigidly mounted to a surface.