Hitachi High-Tech

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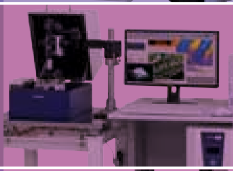
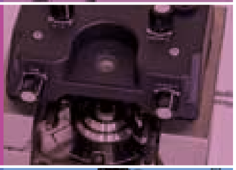





Scanning Probe Microscope Series

SPM Series

Hitachi High-Tech Science Corporation

WITH NANO NAVIGATOR

Bench-top

AFM5100N ●P.19
Multifunctional Small Unit

AFM5010 ●P.8~13

High-resolution

AFM5100N ●P.19
Multifunctional Samll Unit

AFM5000 ●P.8~13

AFM5300E ●P.20~21

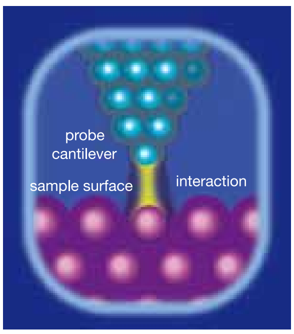
Environment Control Unit

AFM5000 ●P.8~13

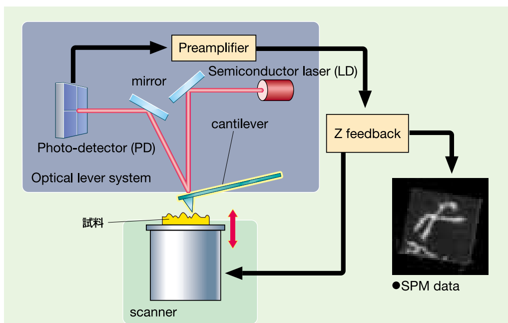
Principle of Scanning Probe Microscope

The scanning probe microscope is the generic name of a microscope that detects various physical quantities working between a probe and sample, and measures surface shape and physical properties of microscopic areas. Physical quantities detected include tunnel currents by a tunneling microscope (STM) and atomic force by an atomic force microscope. The figure to the right shows the operating principle of AFM.

Diagram of a probe microscope



Configuration of an Atomic Force Microscope



SPM for measuring and evaluating physical properties

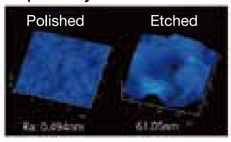
Nanoscale quality control

Surface roughness measurement, Pitch measurement, Step measurement
Angle measurement, Particle analysis

Organic and Inorganic thin films, Transparent electrode, Fine ceramics, Glass, Polymer, Wafer
Nanoimprint, Device, Microroughness

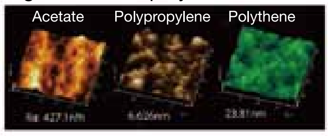
●Flowchart of surface roughness measurements

Liquid crystal surface finishing



Ceramic thin films

High molecular polymer

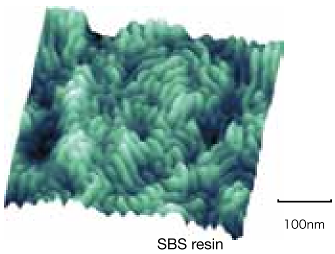


Metal film

Nanomaterial dispersion evaluation

Microphase separation structure, Polymer blends, Nanocomposite materials, Thin film, Fine particles
Surface, Interface

Microphase separation phase image



SBS resin

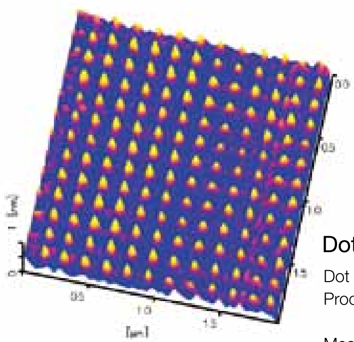
Polymer blend phase image

Polystyrene / Polybutadiene

Nanofabrication tool applications

Apply next generation nano-fabrication tools such as nanolithography and nanomanipulation.

●Example of scanning probe anodization



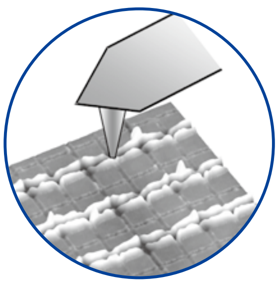
Example of a picture drawn by anodization on a silicon surface

Data courtesy:
National Institute of Advanced Industrial Science and Technology

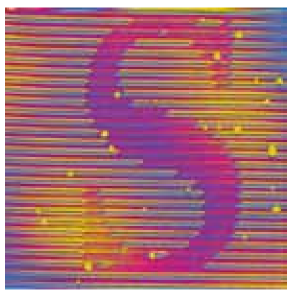
Dot array formation on silicon wafer

Dot radius: 25nm Dot gap: 150nm
Process conditions: Example of sample+5V
Pulse voltage application 5msec
Measuring range: 2μm

●Example of scratch processing



Example of the scratch process on a polymeric film surface by changing the probe load



Character pattern made by ridges that appear on each side of grooves and grooves made by scratching

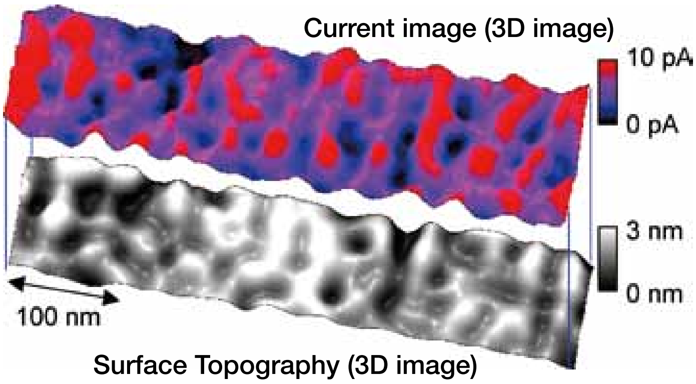
Measuring range: 10μm

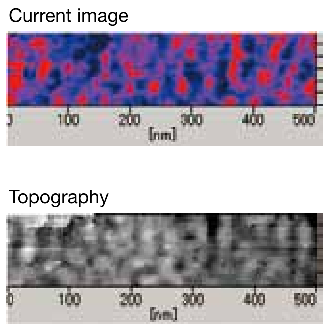
Nanoscale electrical property evaluation

Surface potential, Conductivity. Electrical resistance, Leakage current, Electrostatic capacity
Polarization, Dopant profiles, Mapping various electrical measurements

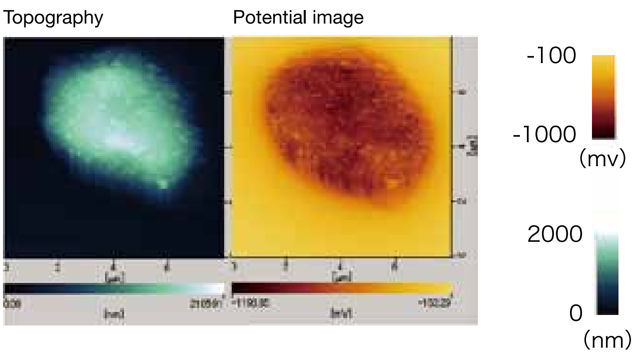
Composite materials, Conductive polymer, Organic EL, Soft material, Battery material
Electronic device, Organic semiconductor

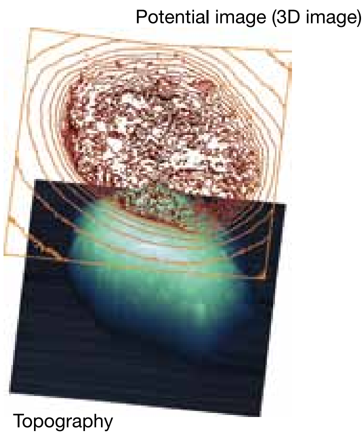
●Polymer film (for batteries) conductivity mapping evaluation



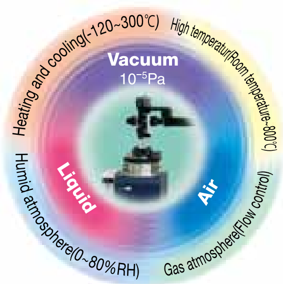


●Electromagnetic distribution evaluation on a charged toner surface



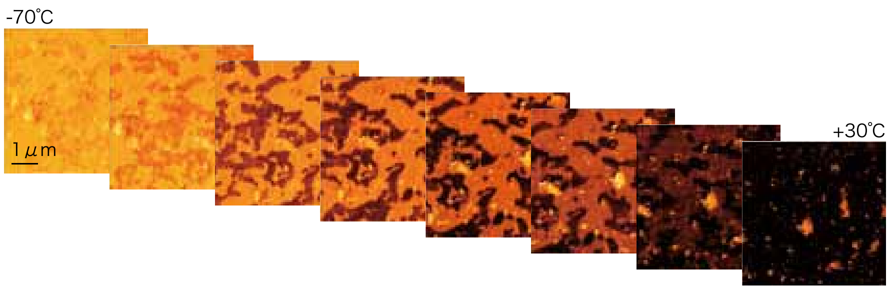


Topography and physical property evaluation under environment control



Not only can the environment be constantly controlled, the technology exists to automatically scan environment parameters and rapidly detect changes in the physical properties of sample.

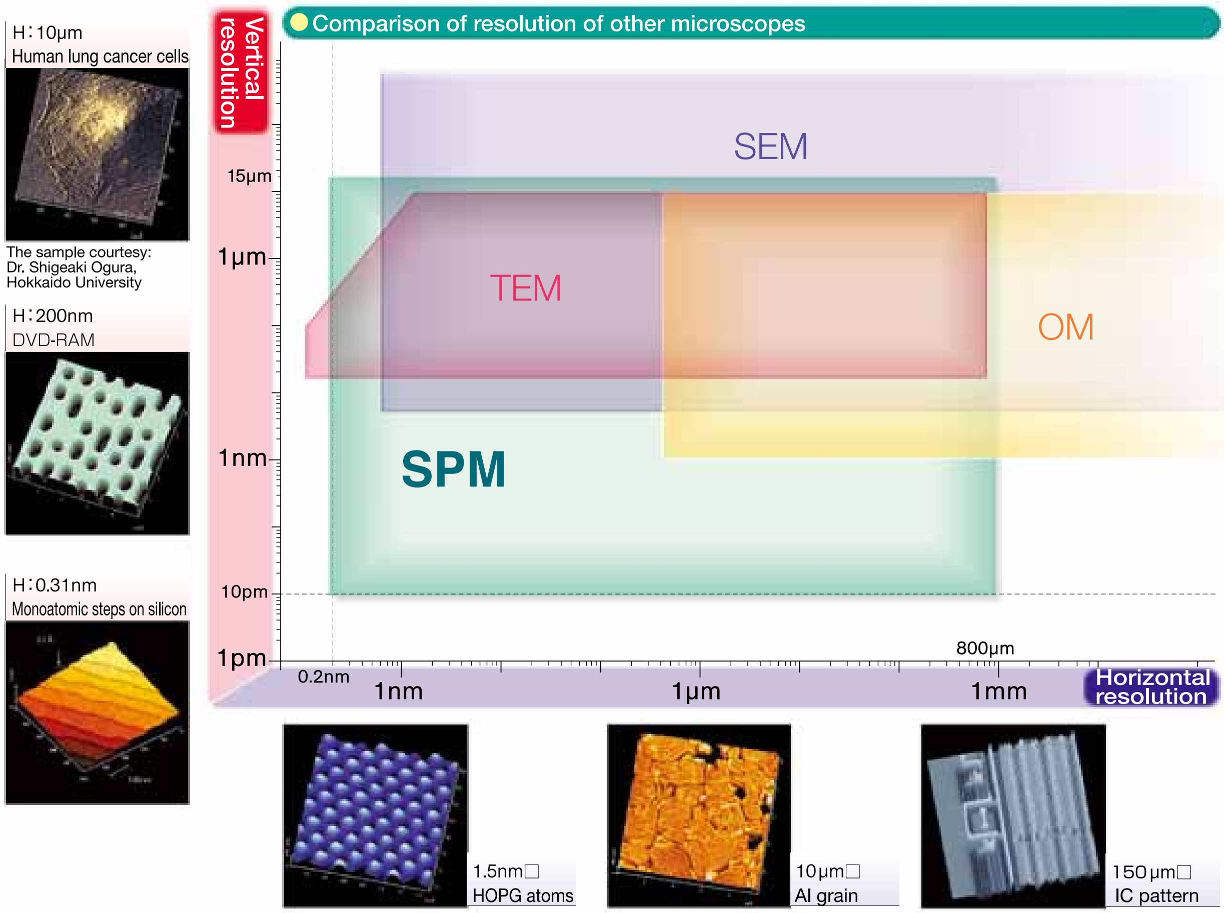
●Evaluate the mixed condition of natural rubber and butadiene rubber(-70℃~30℃)



Differences with other observational measuring devices

Merits of the scanning probe microscope (SPM)

SPM has a vertical resolution 0.01nm, and in-plane resolution 0.02nm; Resolution surpasses that of other observation devices.



Widening applications

SPM is used not only for surface measurement but in a wide range of fields including environmental control, mechanical, electrical, and magnetic.

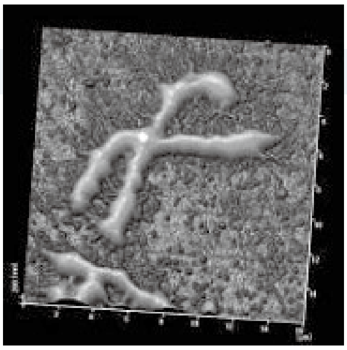
Organics and polymers	Semiconductor electronics	Inorganic	Metal, Dielectric, Magnetic substances	Living body
Plastic rubber	Si device Power semiconductors Organic EL	Glass Ceramics	Wiring, Memory, Storage	Protein Collagen Cell

Topography	Surface roughness, Particle analysis, Pitch measurement, Step measurement
Mechanical properties	Viscoelasticity, Friction force, Adhesion Force, Young's modulus
Thermal properties	Glass transition, Softening, Heat conduction
Electrical properties	Leakage current, Conductivity, Polarization characteristics, Dielectric constant, Surface potential
Magnetic properties	Magnetic force, Magnetic domain, Domain wall, Magnetic properties, Spin
Processing	Lithography, Manipulation, Anodization, Scratch

Solutions to problems in observation devices

Difficulties with the use of SEM/TEM

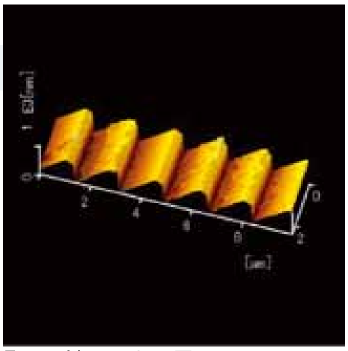
- Concern about damage from electron beam
- Charge-up in a vacuum and cannot be stably observed
- Pretreatment, such as a surface metal coating, is required to prevent charge-up
- No quantitative information such as height and roughness measurement



Human chromosome 16μm□

Difficulties when using a laser microscope

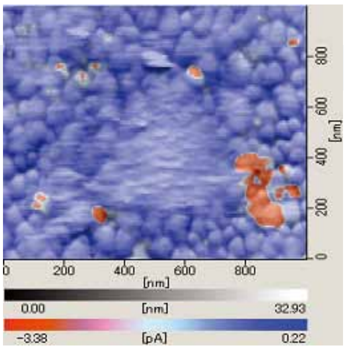
- Reliable nm level high resolution measurement not possible
- Unable to measure at the optical properties (angle and reflectance) of the sample surface
- Unable to do observational measurements in liquids or under environmental control
- Unable to measure mechanical properties, electrical properties, and magnetic properties



Fresnel lens 10μm□

Difficulties when using a stylus-based profilometer

- Tip is too thick so that high resolution measurements cannot be performed at nm microscopic areas
- Unable to position a point you want to measure
- Unable to measure viscous samples such as adhesives
- Unable to measure mechanical properties, electrical properties, and magnetic properties



Ferroelectric film leakage measurement 1μm□

	SEM/TEM	laser microscopes	Stylus-based profilometer	SPM
Pretreatment	×	○	○	○
nm Observation/ Measurement	△	×	×	○
Environment control observation	×	×	×	○
Measurement of physical properties	×	×	×	○
3D observation	×	○	×	○

SPM measurement is not difficult! Operating is simple.

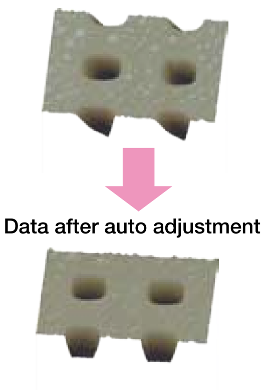
AFM5010
Controller

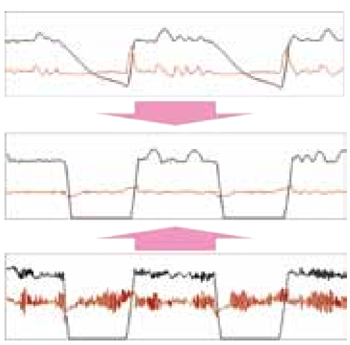
AFM5000

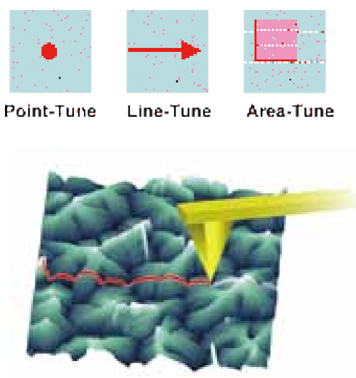
Setting measurement parameters for conventional SPM is difficult and requires an expert operator for reliable measurements. So what is wanted is the SPM that can be easily operated even by the novice. AFM5000 has a measurement parameter auto adjust function that lets you automatically set parameters to best match the sample.

Measurement Parameters Auto Tuning function

Parameters including the control gain, scan frequency, force and time of measurement are automatically adjusted while combining independently developed control algorithms to grasp conditions between sample and probe. Large uneven areas are automatically searched making optimal adjustments possible.

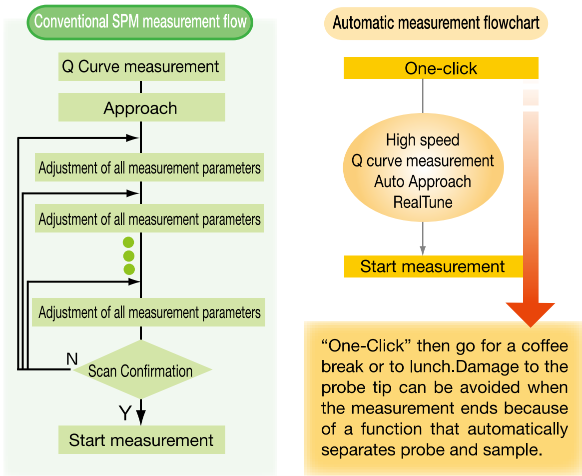






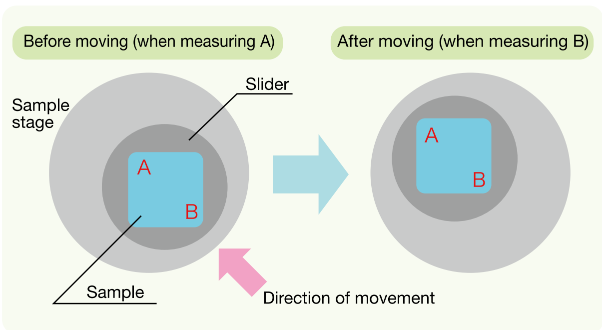
One-click automatic measurement

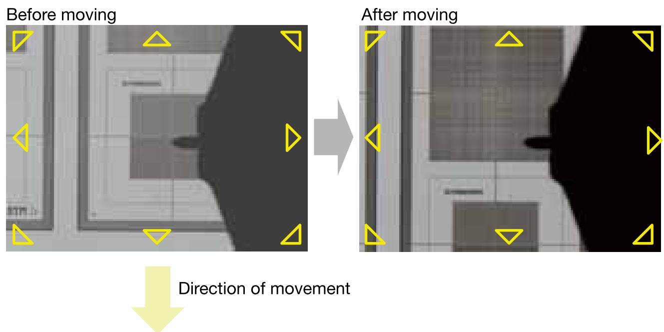
In the past, SPM operators needed to find the best combination of parameters to samples.
And wondering, stable image is finally retrieved but is it really okay? Has this happened to you?
With the AFM5000, prepare sample and cantilever, selecting measurement conditions, and simply click the button once. With one click operation, high speed Q curve measurement, auto approach, and auto parameter adjustment ends and measurement starts. Now, measuring is easy enough even for beginners.



Impact Stage (optional)

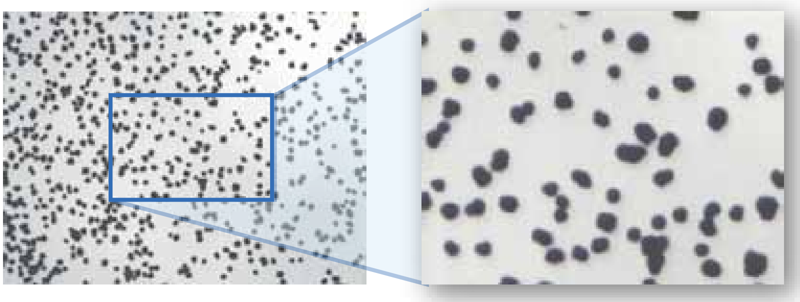
The impact stage is a function that can easily change measurement positions by moving a cursor in the CCD image.
This greatly improved operability for measuring multiple locations on the same sample.





Digital zoom

Image can be enlarged without changing optic lens magnification.Function convenient for easy, high precision positioning.



CCD Image　　3X Digital Zoom

● AFM5000/5010 Specifications

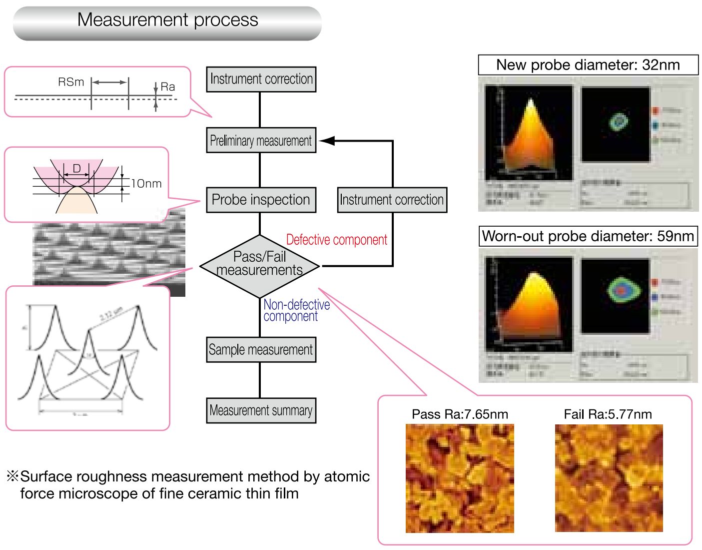
	AFM5000	AFM5010
OS	Windows7®	
Models	AFM5100N/AFM5300E	AFM5100N
RealTune Function	Auto tuning of contact force, scan speed, and feedback gain	
Option Function	Closed loop control, Q Control Function, Young’s Modulus Measurement Function	SIS, Young’s Modulus Measurement Function
Surface roughness	Probe Test Function, Arithmetic mean roughness (Ra:1~30nm), Average length of roughness curve element (Rsm:0.04~2.5μm)	
Operation window	Flowchart Navigation System, One-click Automatic Measurement System	
Measurement data points	8192×1024×4Screen, 8192×8192×4Screen (Option)	
Software	Data analysis batch process function, 3 dimension display function, Cross-sectional analysis Automatic Recipe Measurement Function, Image Overlap Function	
Size(W):(D):(H)	300×550×629mm	220×500×420mm

Aiming for high data reliability

Measurement technique suitable to nano-scale quality control.
Proposing technology that improves accuracy of observational data and point analysis.

Roughness measurement function

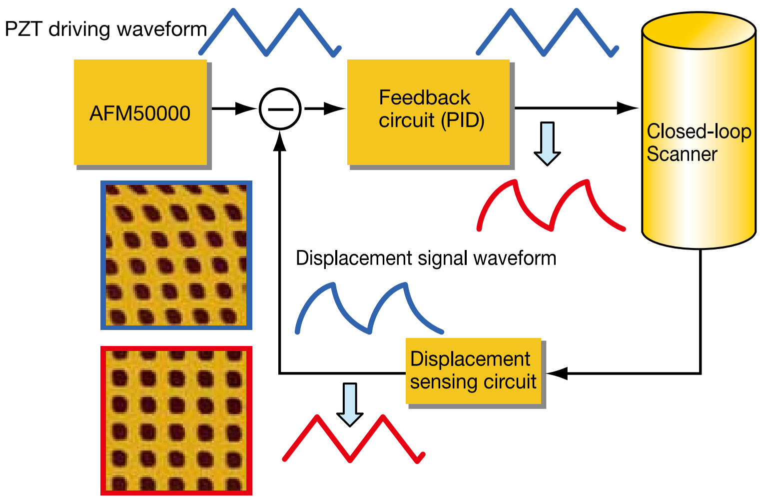
SPM has been used as a nano-meter roughness control tool; however, sharpness of a tip and friction are a challenge to acquire reliable data. The tip calibration function indispensable to nano-scale quality control enables objective judgments on reliability of obtained results.
The roughness measurement function that comes standard to the AFM5000 (controller) is suitable for nm level surface roughness control, such as information processing equipment display; transparent electrode thin films; coating of optical parts such as cameras and precision mechanical parts; and hard coating of tools.



※Surface roughness measurement method by atomic force microscope of fine ceramic thin film

Closed loop scanner (optional)

A drivable piezo-electric element is used at atomic level precision in order for the SPM to observe microscopic areas. However, there is distortion in the measurement image due to non-linear properties such as hysteresis and creep in the piezo-electric element. The closed-loop scanner accurately detects the amount of movement by sensor and drives the scanner during feed-back control so that the non-linear component of the piezo-electric is eliminated for exact line formation and orthogonal that enables scanning and movement. Accuracy improvement in measurement and processing of microscopic areas is achieved.
The effectiveness of a closed-loop scanner is not just imaging. SPM measurement should perform many point analyses including force curve measurement and current-voltage characteristics. Closed-loop scanner is very effective in accurately moving the probe exactly where aimed with pinpoint imaging from an image.



The closed-loop scanner is used to narrow down specific areas from a wide measurement image and remeasure the image. With conventional open-loop scanners, targeted locations are misaligned from scanner non-linearity by this type of positioning and remeasuring.

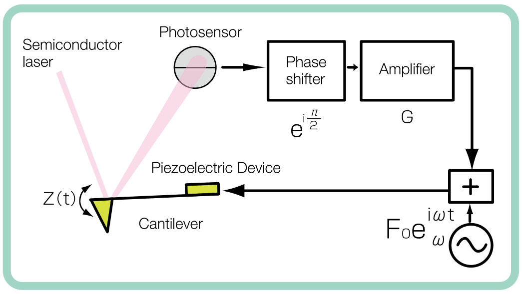
Advanced data acquisition

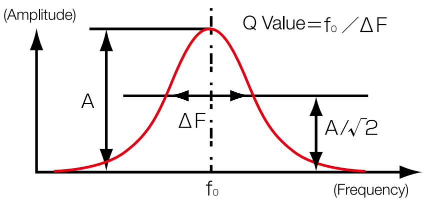
Optimum cantilever control by cutting edge technologies.

Q Control Function (Optional)

Sharpness of the frequency spectrum in cantilever oscillation is displayed by the Q value. A high sensitivity measurement can be achieved as the Q value increases because the Q value is proportional to the sensitivity of the force gradient detection.

This technology controls viscous resistance from gas molecules or liquid within air or solution by the action of an electronic circuit. It is able to improve sensitivity by Q value increase control within air or solution.

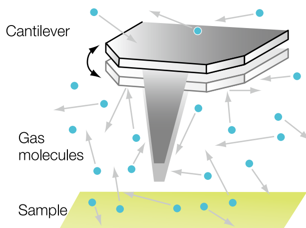


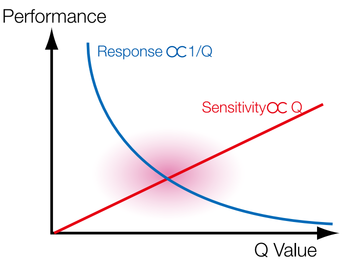


Frequency spectrum(Q Curve)

The Q Control transforms oscillation signals of the cantilever to speed signals through a phase shifter and controls the Q value by adding the amplified signal to the oscillation signal of the cantilever.

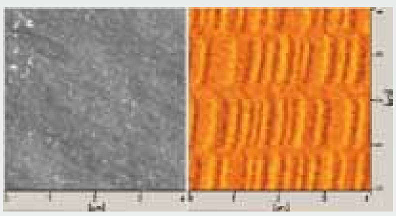
The amplification factor G polar plus supports increase control and minus supports suppression control.



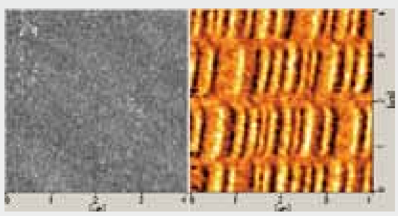


Vacuum measurements are best suited for avoiding the effects of adsorbed water on sample surfaces or high sensitivity measurements in the electro-magnetic mode that uses cantilever oscillation; however, the Q value becomes too large in a vacuum, reducing the responsiveness (stability) of the measurement. As a result, Q control is performed in a vacuum such that sensitivity and responsiveness become the best combination.

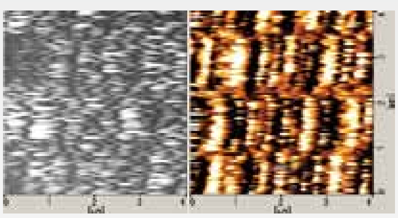
Observation by MFM of the magnetic recording state of a hard disk(In air, in a vacuum)



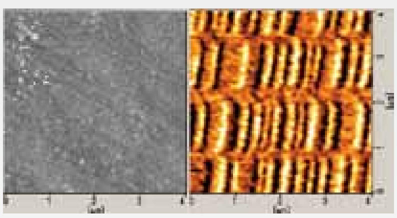
No Q value control in air(Q=400) for low sensitivity.



Increase control of Q value in air(Q=2000) for high sensitivity.



No Q value control in a vacuum (Q>15000) Low responsiveness

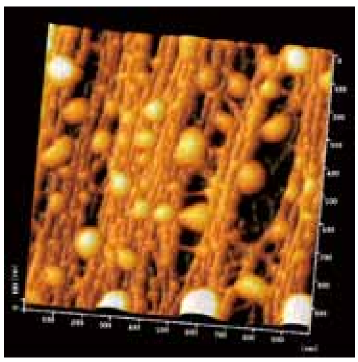


Inhibit Q value control (Q=4000) High responsiveness

Effects of Q Contro

- High sensitivity measurement in a vacuum
- High speed response in a vacuum
- High sensitivity measurement in air
- Micro force measurement in solution

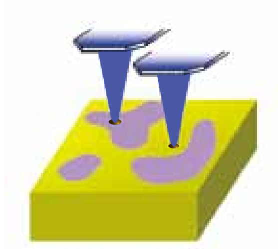
Viscous resistance increases in solution, Q value drops markedly, and micro force measurement of soft samples may be difficult.But even in this case, sensitivity improves and micro force measuring becomes possible when increasing the Q value by Q Control in solution.The right-hand image is of a hollow fiber membrane used in medical care. The surface of the hollow fiber membrane has a very soft hydrated film protrusion but is stably observed by Q Control.

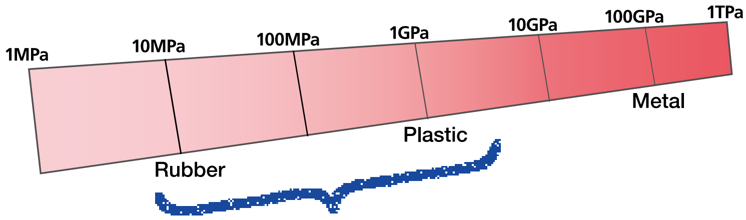


Measurement by DFM of hollow fiber membrane in a liquid(1 μm□)

Force Curve/Young's Modulus Measurement Function

Quantification of physical properties

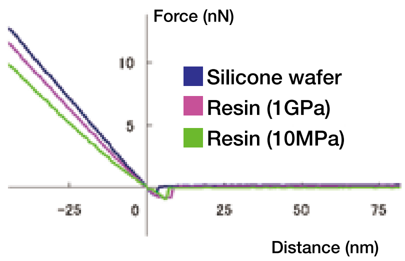


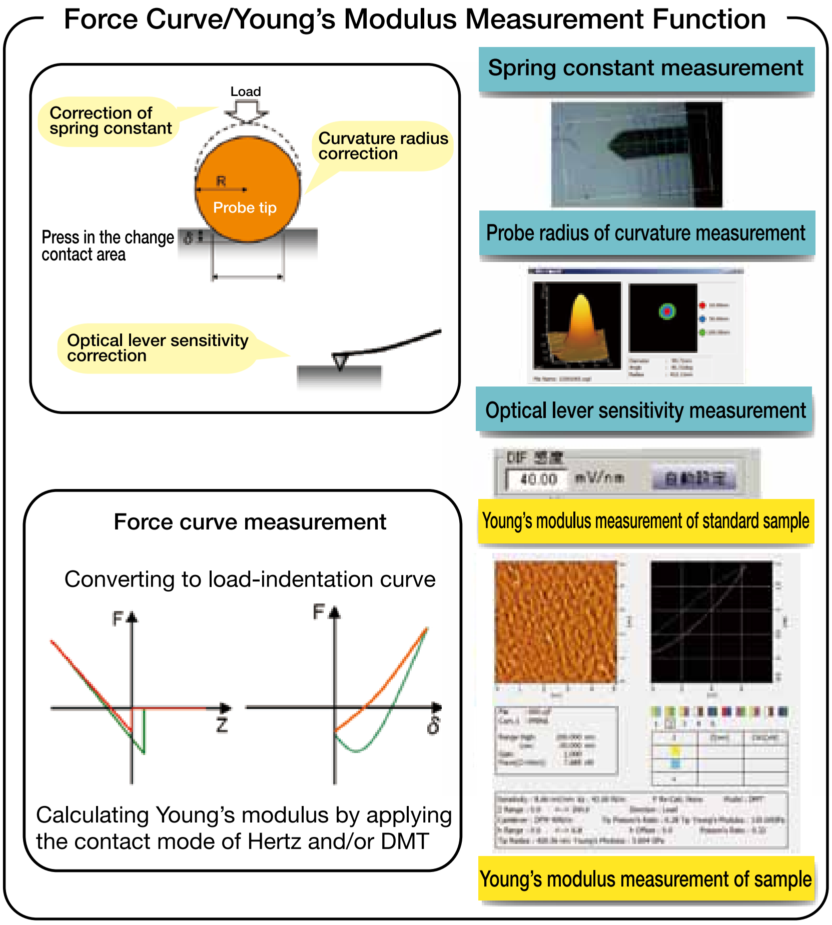


Realization of local Young's modulus measurement
Measurement range 10MPa~10GPa

High polymeric materials such as electronic material, separator, LCD protective film, tires, blend, rubber, plastic

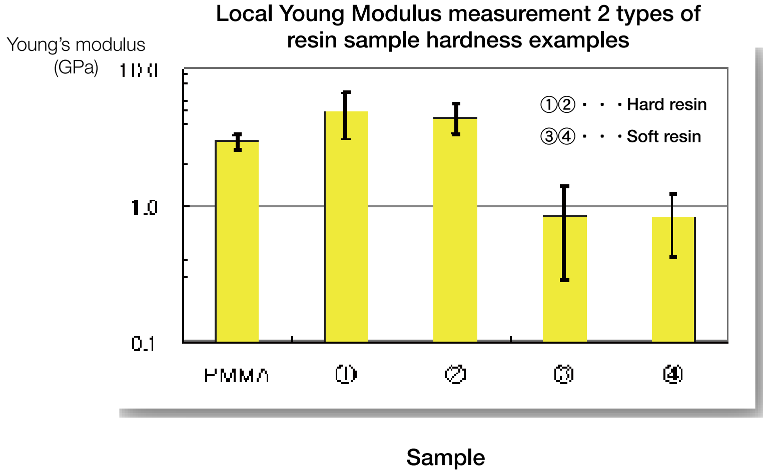
The force curve is transformed to a load push volume curve and the Young's modulus can be calculated by approximating the contact mode of Hertz or DMT. By force curve/Young modulus measurement software that combines functions such as cantilever spring constant correction and probe curvature radius calculation, the local Young's modulus of the sample surface can be calculated at a range of 10MPa～10GPa. PMMA is used in correction of the Young's modulus.





The AFM force curve has been used often in the past for evaluating hardness and adsorptive power of a sample. However, even evaluating differences of hardness of samples by the force curve, as in the figure above, the difference in the slope of the force curve is quite small and units are physical quantity unfamiliar with N/m. Young's Modulus can be found when a force curve is transformed to a load push volume curve by the Hertz or DMT contact model. The right hand figure is an example of measuring the local Young's modulus of hard and soft resins. More persuasive data will result in room to compare on the force curve.

Local Young Modulus measurement 2 types of resin sample hardness examples

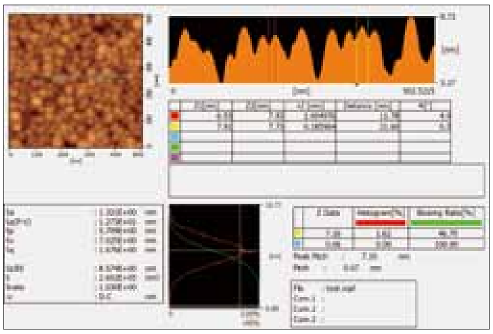


Various shape analysis functions

With all parameters required in analysis, specific numerical values give further persuasive power to data.

Example of the analysis function

- Line roughness analysis function
- Surface roughness analysis function
- Cross-section profile analysis function
- Step/ Width/ Pitch/ Angle Measurement Function
- Floor area ratio measurement function



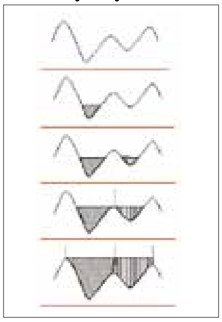
Roughness measurement of silicon wafer

Particle analysis function (optional)

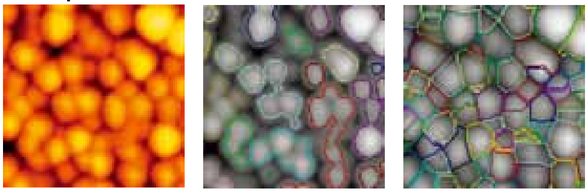
In addition to conventional particle analysis methods, filtering to eliminate board undulations, a particle extraction method by auto threshold value detection, and a watershed area division method by the flood principle are employed to support various analysis methods.

Separate information of particle extraction and segmented regions can be saved in the CSV format.

Watershed region segmentation method



Examples of the Threshold and Watershed methods



A: Topography data B: Threshold method C: Watershed methods

Watershed methods

L. Vincent, P. Soille: IEEE Trans. on Pattern Analysis and Machine Intelligence, 13, (1991) 583

Morphology filter function (optional)

Merits

- Able to reconstruct by calculating the true topography while taking into account the thickness of the probe.
- The morphological filter corrects the probe from raw data as the cylinder diameter or globe shape (any diameter).

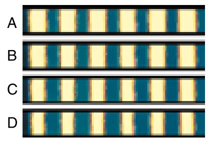
Example using morphology filter

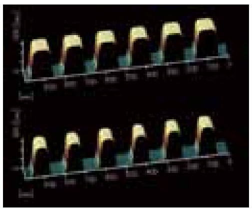
Sample : NTT-AT standard sample
Pitch: 160nm Step 340nm

Measurement method : use a SIS closed-loop scanner and carbon nano-probe.

Correction method : correct the probe from the raw data to the diameter of the cylinder.

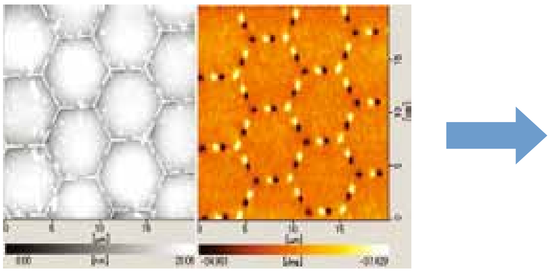
A : Raw data **B :** ϕ10nmCorrection
C : ϕ20nmCorrection **D :** ϕ30nmCorrection



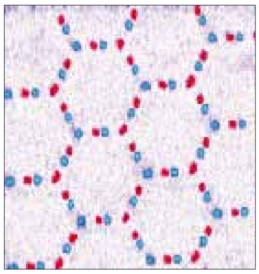


2 window overview

The cause and effect relationship between physical property and topography can be seen by overlaying of them.



Left: Topography+, Right: magnetism
Measurement area: 20μm



Y shaped Perm alloy regulation array magnetic structure

Q Control | In air | In liquid | In a vacuum | Temperature control

STM Tunnel current

Scanning Tunneling Microscope

A tunnel current flowing between probe and sample is detected (controlled so that the tunnel current is fixed and sample surface is scanned) by applying a bias voltage between a metallic probe and conductive sample as the distance between them approaches less than several nm. Shape as well as electronic state is observed.

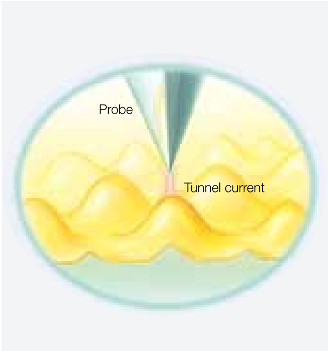
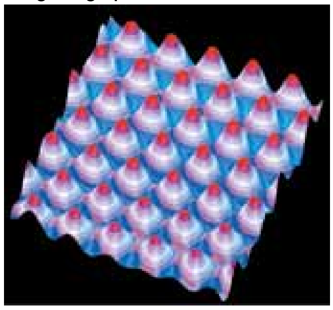


Image of graphite atoms

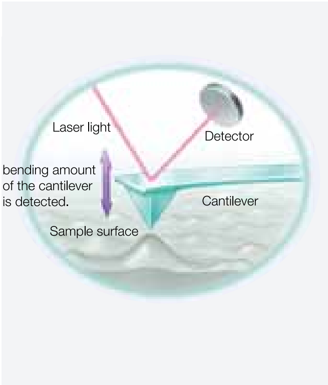


Measurement area: 3nm

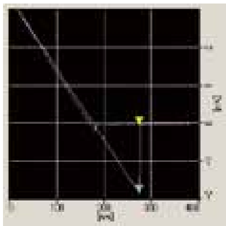
AFM contact

Atomic Force Microscope

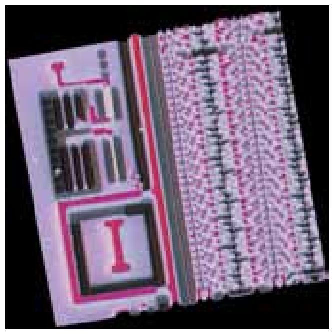
The working force between probe and sample is transformed to an amount of cantilever bending that is detected. The amount of bending is controlled, the sample surface is scanned, and the shape observed.



Example of AFM force curve



Semiconductor circuit

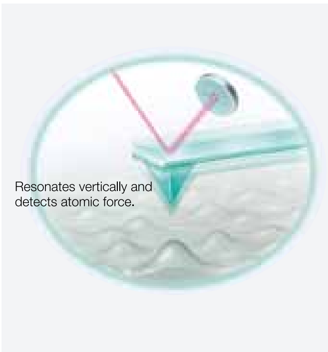


Measurement area: 100μm

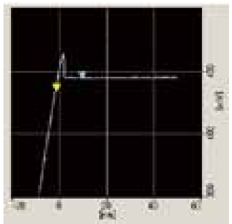
DFM Non-contact/Cyclic Contact

Dynamic Force Microscope

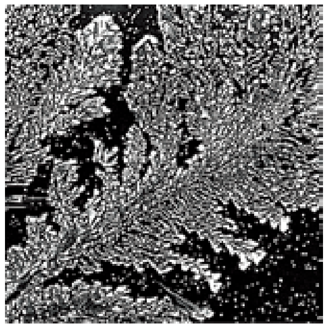
With the cantilever oscillating, the sample is approached, the force that moves between probe and sample is converted to cantilever amplitude change, detected, and controlled so that the amplitude is constant, the sample surface scanned, and shape observed.
A wide range of observations, such as soft samples and strongly absorptive samples, are possible.



Example of DFM force curve



Dendrite



Measurement area: 30μm

SIS

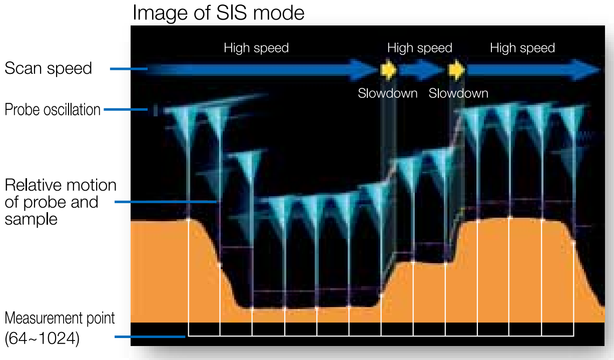
Sampling Intelligent Scan

SIS approaches the probe only at the measurement point, gets shape and physical property information except when retrieving data, receives the probe above the sample, and has an intelligent measurement mode that freely controls scan speed according to sample shape.
SIS solved problems in conventional SPM by reducing both effects of probe scan (such as drag and deformation) and interactions in the horizontal direction. This enables stabilized measurements, such as soft samples or samples that are largely uneven or adhesive.
In the Current Measure Mode, it is possible to measure the current image and stabilized shape image without breaking the sample when the sample is soft, and marking superior physical properties is possible without the effects (artifact) of shape from scanning in the Phase Mode.

SIS includes SIS-DFM based on the DFM mode and SIS-AFM based on the AFM mode.

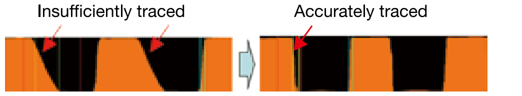
Conceptual diagram of the SIS-DFM scan method
Probe and sample make contact only when getting data. Aside from this, scanning speed drops when moving at high speeds in the horizontal direction while on stand by in mid-air and when in contact with the sample surface; and shelter motions that rise from the sample surface are automatically performed.

Image of SIS mode

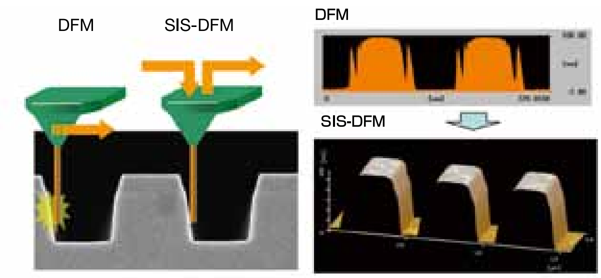


Advantages of high aspect topography measurements by SIS

In the case of DFM measurements, there may be uneven signals detected in the direction that the probe scans. Success is common when you can use automatic parameter adjustment with the measurement parameter auto adjustment function; however, for steep high aspect shapes, the DFM measurement itself may be difficult. When testing SIS in such cases, measuring can be successfully done as shown in the right-hand figure. When a carbon nano-probe (CNP) is applied to high aspect shapes, operation becomes unstable by absorbing the side of the sample. This results in noise because the CNT itself is very soft. SIS-DFM applies in this case also and high aspect shapes can be stably observed.



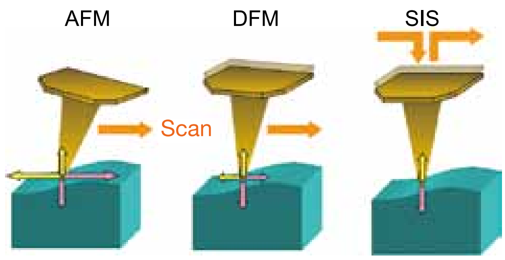
High-aspect topography measurement (by using conventional DFM cantilever)



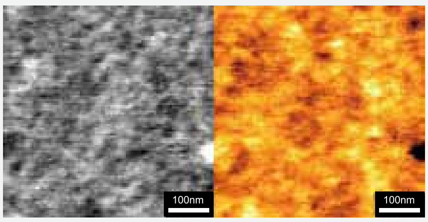
High-aspect topography measurement by CNP

Advantages of physical property measurement by SIS

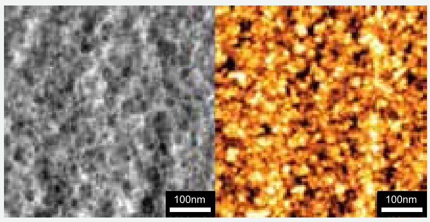
SIS achieves measurements that are not subject to action in the horizontal direction by scanning.Thus, SIS enables precise force detection by vertical direction movements in SPM physical property measurement modes, allowing you to get measurement data without artifact.



Comparison of Shape/Phase measurements of adhesives (DFM, SIS-DFM)



DFM/Phase Measurement (Left: shape, Right: phase) of adhesives

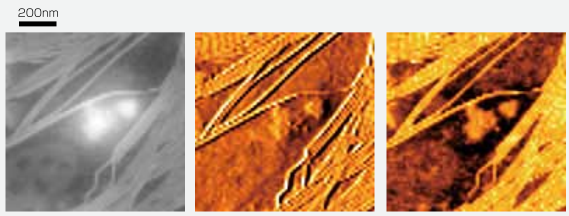


SIS/Phase Measurement (Left: shape, Right: phase) of adhesives

DFM cannot get a clear image of the phase the same as with the shape on soft surfaces with strong adhesiveness; however, SIS-DFM clearly observes both shape images and phase images. In this way, SIS can accurately perform stabilized measurements not only by shape measurement but also by phase measurement.

Phase measurement comparison of high polymer film

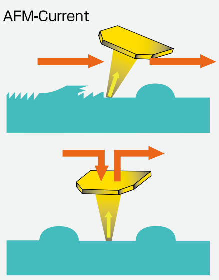
Lamella crystals on PET sheets result from phase measurements by DFM and SIS-DIF modes. The shape image shows only images measured by the SIS-DFM mode. The left side of the Lamella crystal tends to be brighter and the right side darker in the DFM phase image. This is thought to be due to action by the force of the probe in the horizontal direction, or feedback error. On the other hand, the Lamella crystal is bright in contrast and can be accurately observed without the effects of shape and scanning in the phase image of SIS-DFM.

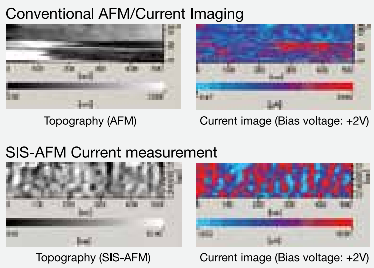


<Topography image: SIS-DFM mode> <Phase image: DFM> <Phase image: SIS-DFM>

Current measurement comparison of soft conductive material

The conventional current simultaneous AFM mode deforms samples resulting in an unstable image reflected in the scan direction for current distribution. On the other hand, the SIS-AFM current measurements perform stabilized measurements for both current images and shape images without deforming the sample. Thus, stabilized current measurements are possible in the SIS-AFM mode.



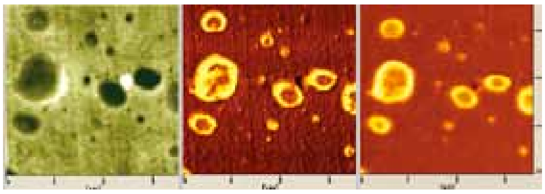


PM

Phase Mode

The DFM measurement detects phase lag in oscillation of the cantilever depending on the size of adsorptive power or hardness and softness, and observes differences of physical properties of the sample surface.

Polypropylene block polymer phase measurement



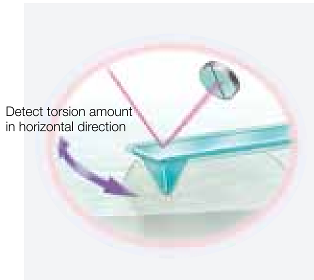
A: Topography B: Phase image C: Adhesion image

This example shows results that resemble the measurement image from the phase image adhesion mode. Measurement area: About 3.5μm

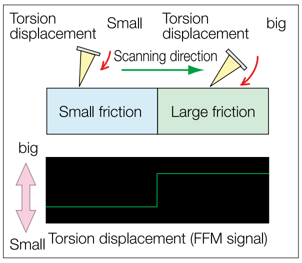
FFM

Friction Force Microscope

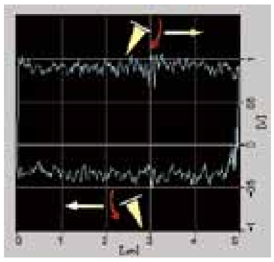
Scan the sample is scanned in the direction in which the measurement area (in AFM measurements) cantilever is bent, convert and detect the frictional force between probe and sample to the torsion amount of the cantilever, and observe simultaneously work between the probe and sample.



Cantilever movement and FFM signal



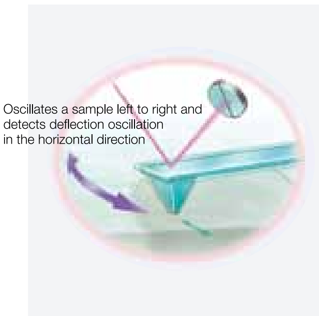
Friction curve



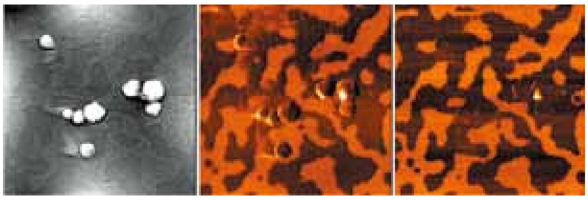
LM-FFM

Lateral Modulation FFM

Friction image that do not rely on surface unevenness or scan direction by adding micro oscillations in the horizontal direction (direction of cantilever deflection) to the sample is observed and the deflection oscillation of the cantilever is detected.



Friction distribution measurement of silicon oil film on polystyrene



A: Topography B: FFM image C: LM-FFM image

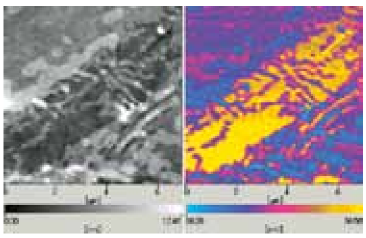
Friction of oil film is less, resulting in dark contrast in FFM and LM-FFM images. Measurement area: About 2.5μm

VE-AFM/DFM

Viscoelastic AFM/DFM

Observes viscoelasticity image by adding vertical micro-oscillations in a sample and detects deflection oscillations (oscillation in the vertical direction) of the cantilever that change by differences in surface viscoelasticity.

Viscoelasticity distribution measurement of a polyethylene film dispersed by coating



A: Topography B: VE-AFM image

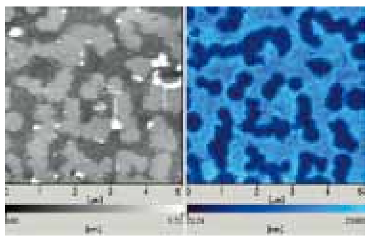
It can be observed that a polystyrene base is harder than a coating film.

Measurement area: About 7μm

Adhesion

Micro-oscillates the sample in the vertical direction, detects the amount of deflection of the collimator the moment the probe separates from the sample, and observes adsorption power distribution.

Adsorption force distribution measurement of Langmuir-Brodgett film



A: Topography B: Adhesion image

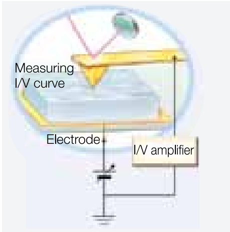
It can be observed that adsorption of fluorine series film is less on Si boards.

Measurement area: About 5μm

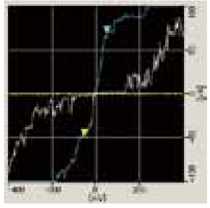
Current/Pico-current/CITS

Current Imaging Tunneling Spectroscopy

Scans in the horizontal direction with a bias voltage applied to the sample, detects the current that flows between probe and sample, and observes current distribution.
Able to observe current distribution at any voltage value by measuring an I/V curve at all points within the sample plane.

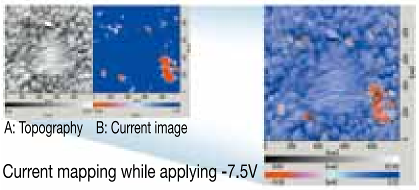


I/V curve



I/V curve can be obtained at any points on the sample.

Find leakage spots of ferroelectric thin films



A: Topography B: Current image

Current mapping while applying -7.5V

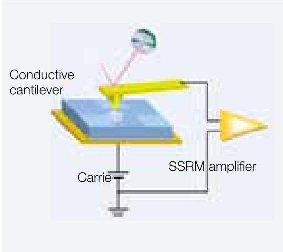
The image on the left is an overlay of its topography and current images.The leakage point can be easily identified.

Measurement area: 1μm

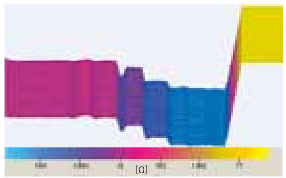
SSRM

Scanning Spread Resistance Microscope

Local resistance distribution on the sample surface at the wide range amp greater than 6 figures is observed by using a hard cantilever of high conductivity and measuring the micro-current at the contact position with the probe by applying a device voltage to the sample. The practical semiconductor dopant concentration range is sufficiently covered.



P type dope test pattern on Si board

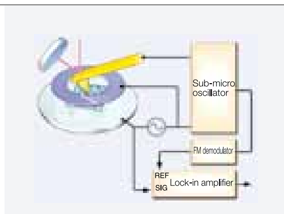


Concentration distribution
10^{14}~10^{20}atom/cm^3

SNDM

Scanning Nonlinear Dielectric Microscope

Apply an AC voltage between probe and sample, and by detecting changes in non-linear dielectric constant directly below the probe, observe ferroelectric polarization and semiconductor dopant concentration distribution.

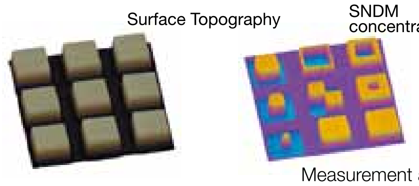


PN dope test pattern

Sample courtesy:
Dr. Hiroyuki Sugimura, Kyoto University

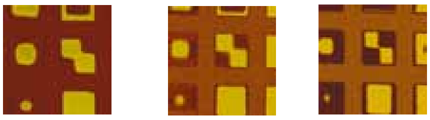
Surface Topography

SNDM
concentration image



Measurement area: 20μm

Environment control SNDM (Example using environment control unit)



In air (high humidity) In air (low humidity) In a vacuum

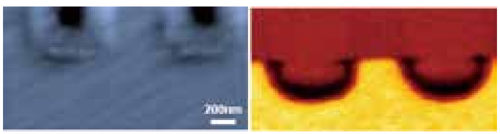
Effects of surface adsorbed water (humidity) on PN dope test pattern SNDM measurements

A joint research of NEDO and AIST

HS SNDM

High-Sensitivity SNDM

Detection sensitivity of SNDM is upon the performance of detectors, FM modulators, and Lock-in amps. In search of the ultimate performance of this hardware compared to conventional SNDM, drastic improvements of approximately 50 times detection sensitivity were made.



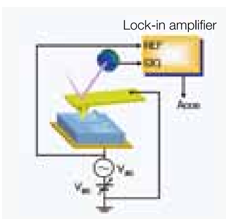
(A) Topography (B) Acos image

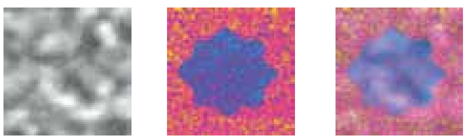
Carrier distribution measurement of commercial transistors(20μm)

PRM

Piezo-Response Microscope

Apply an AC current between the probe and sample, and by scanning, observed strain distribution of the sample while detecting the ferroelectric strain component.





A: Topography B: PRM image C: Overlapped images

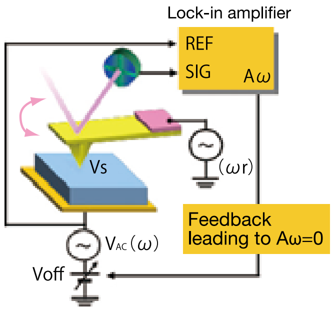
Example of applying a DC voltage of a coercive electric field on a PZT thin film, setting a star shaped mark, and observing the recorded mark by PPM measurements with a DC voltage below the coercive electric field.
Measurement area: 6μm

KFM

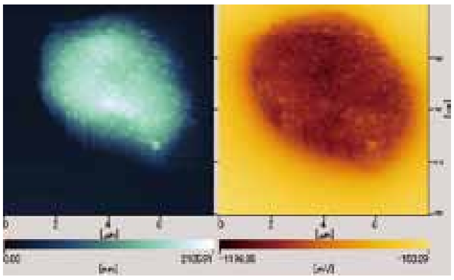
Kelvin Probe Force Microscope

Measured and imaged the surface potential by the feedback DC voltage by applying AC as well as DC voltages between a conductive cantilever and sample so that the amplitude of the static force component from the AC voltage is zero.

・NC-KFM(Non-contact KFM)
・CC-KFM(Cyclic contact KFM)



Charged toner potential measurementr
(Scanner: XY 100μm/ Z 15μm)



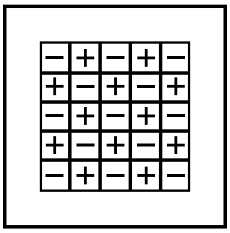
EFM

Electric Force Microscope

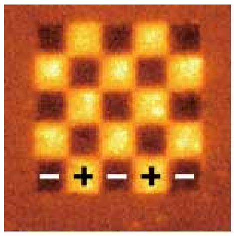
Applied an AC or DC voltage between a conductive cantilever and sample and created an image of the static electricity force components (amplitude component and phase component) by an AC voltage.

・EFM(AC)…AC field response
・EFM(DC)…DC field response

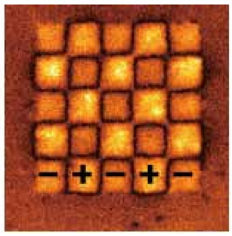
KFM directly detects potential of sample surfaces.
EFM does not directly detect surface potential but has better responsiveness than KFM and is convenient for imaging qualitative electrical properties.



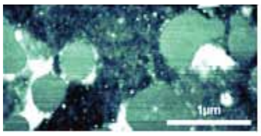
EFM(AC) measurement of ferroelectric polarization patterns



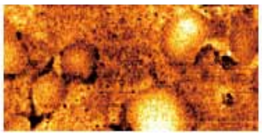
Acos image



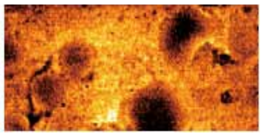
Amplitude image



Topography



EFM(DC) V=+5[V]

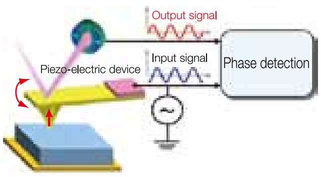


EFM(DC) V=+5[V]

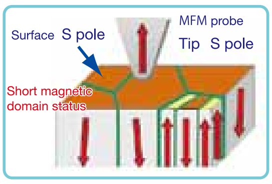
MFM Received the Magnetic Society of Japan Best Paper Award (2003)

Magnetic Force Microscope

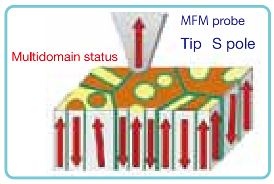
A magnetic action between magnetic probe and sample is produced and imaged as potential changes in cantilever oscillation. High sensitivity and high resolution magnetic domain imaging is possible by measuring in a vacuum.

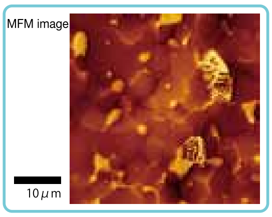


Magnetized Neodymium magnet

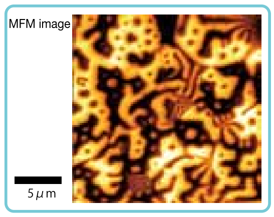


Thermal demagnetized Neodymium magnet





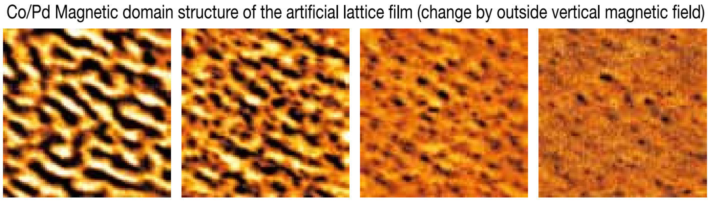
Nd-Fe-B system sintered magne domain observation



(Q value control in a vacuum, SI-MF40-Hc)

Example using the magnetic field application option

Co/Pd Magnetic domain structure of the artificial lattice film (change by outside vertical magnetic field)



H=0 500 1000 3000

A joint research with Isiho Laboratory, Akita University.

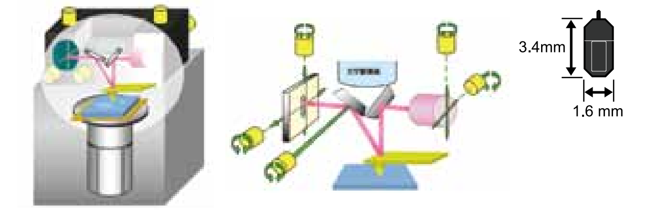
AFM5100N

Multifunctional Small Unit

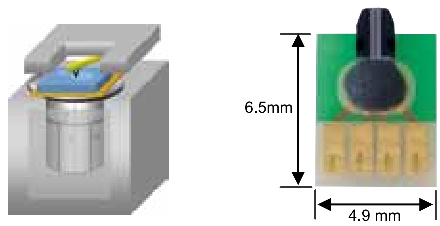
AFM5100N is a compact, multi-functional SPM equipped with self-sensing cantilevers. Laser adjustment is not required. Simply place the sample and the self-detecting holder. Operation is simple due to AFM5000's Measurement Parameter Auto Adjust function and One-click Auto measurement.

The ultimate in simple measuring is realized by self-detecting style

Conventional SPM device (optical lever method)

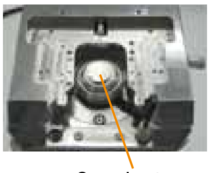


AFM5100N (Self-detection method)



● Measurement flow

Place sample on stage



Sample stage

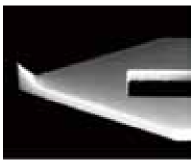
Sensor built-in cantilever one-touch device

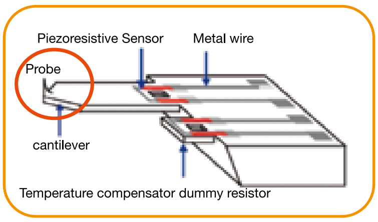
Place self-detecting holder on the sample

Afterward, simply press button

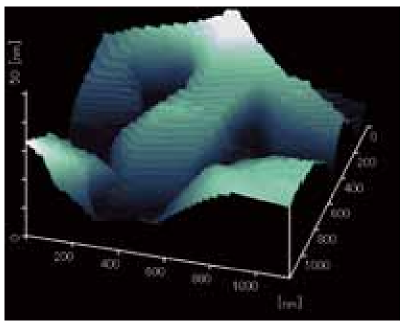
Sensor built-in lever…Element technology by SPM even at low costs applies top level MEMS technology

The self-detecting lever with built-in sensor is a cantilever piezo-resistance sensor combined through MEMS technology. The cantilever uses components mounted on boards combined with wiring. Replacement of a cantilever can be easily performed by the novice for each board. The cantilever bends from a force that acts on the probe, changing the resistance of the piezo-resistance sensor in the narrow part of the cantilever. Bending of the cantilever changes the resistance, which is detected by the bridge circuit together with the resistance of the temperature compensator dummy resistor.





Crystal steps (approximately 1.5nm) of organic film can be clearly observed. (parameter auto tuning result)



● AFM5100N Specifications

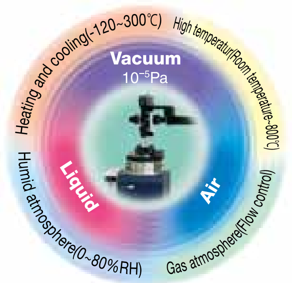
Detection	Optical lever method or Self-detection method
Sample size	35mmφ, 10mm thick / 50mm², 20mm thick (optional)
Scan range	20/1.5μm, 100/15μm, 150/5μm, 110/6μm (Closed-loop control)(optional)
Optical microscope	Combination microscope, Desk-top zoom microscope, Zoom microscope, Metallurgical microscope
Sample movement mechanism	XY stage (±2.5mm), Impact stage (Optional)
environment control	Air, Liquid, Heating (RT~250℃), and Humidity control

AFM5300E

Environment Control Unit

Simple operation (stress free) of the environmental control SPM supports various environmental needs, including vacuum, liquid, gas, temperature, and humidity.
It is equipped with a new temperature sweep function. By this new function, quantitative surface property changes can be evaluated while continuously changing temperature.

Improved resolution in a high vacuum…Advantages to electrical property measurements due to no adsorbed water



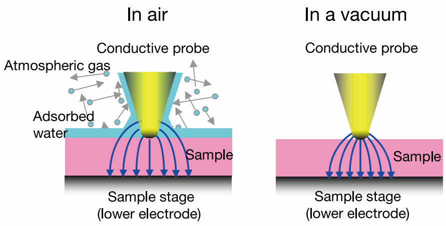
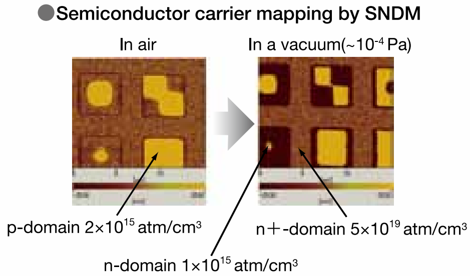
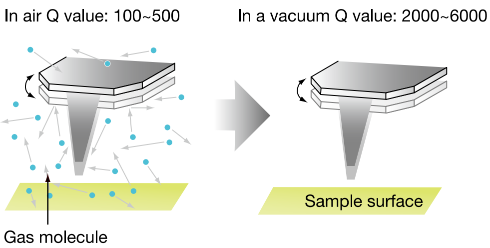


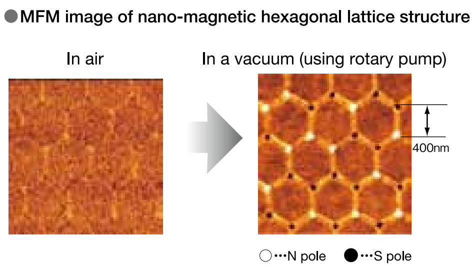
Figure 11. Schematic diagram of electric flux and resolution of electric measurement in air and in a vacuum



Because the dielectric constant of water is approximately 80, measurement conditions in atmosphere where adsorbed water (moisture) exist would affect electrical properties measurements. For example, resolution may decrease by increasing the effective area of electrical contact of the probe by adsorbed water. As an example of semiconductor carrier distribution measurements by SNDM, the doped region as designed for P type and N type has an observed resolution higher in vacuum than in air, and concentration differences in the N+region are clearly observed.

Improved measurement sensitivity in a vacuum…Eliminate molecular movement of atmospheric gas molecules and the effects of viscous resistance



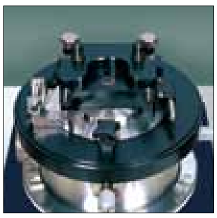


In the type of SPM measurement that vibrates the cantilever, viscous resistance by gas molecules affects the sensitivity of output detection. High sensitivity measurements can be performed by combining Q value control in a vacuum.

See page 11 for more information about the Q Control function.

Simple operation realized (comprehensive holder flange)

A tool-free open close mechanism is employed so that there is no need to adjust the optic axis after sample and holder are replaced when switching measure modes, thus providing high operability.



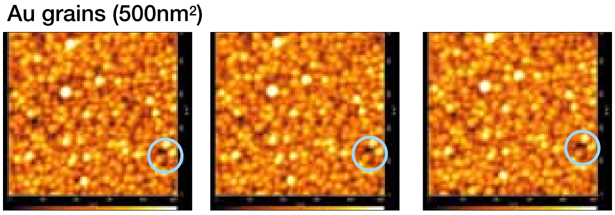
Optical head

Upper flange

Established excellent high performance

Success in thorough drift reduction by swing cancellation mechanism.
Polished basic performance indispensible to nano-order structure analysis and improved reliability.

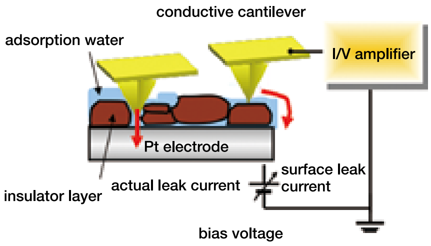
Au grains (500nm²)



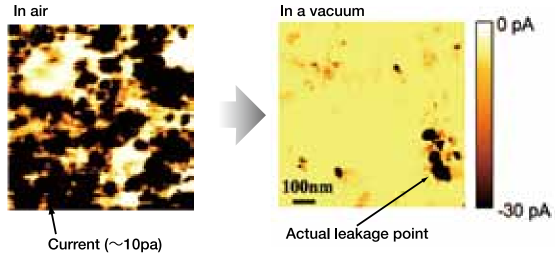
Right after approaching / After 20 minutes / After 40 minutes

Elimination of surface leakage current from adsorbed water for proper physical property analysis
(measurement of electrical properties in a high vacuum)

● Current measurements in air SPM(Conductive-AFM, SSRM)



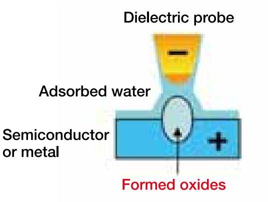
● Measurement of locations of ferroelectric membrane leakage



Leakage current of a large ferroelectric device results in various problems including an increase in power consumption and changes or gradation of physical properties near leakage locations. In order to properly comprehend the mechanism of this degradation, an evaluation that locally identifies the leakage spots is essential; however, the surface leakage current that transmits surface adsorbed water by measuring in air is disturbed. On the other hand, measuring in a vacuum can eliminate such effects.

Scanning probe anodization advantages and disadvantages…Advantages of high vacuum electrical property measurements

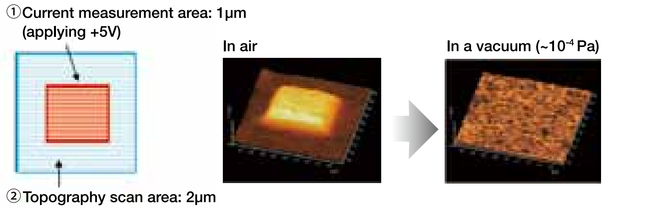
● Theory of scanning probe anodization



Example of AFM lithography

Data courtesy: AIST

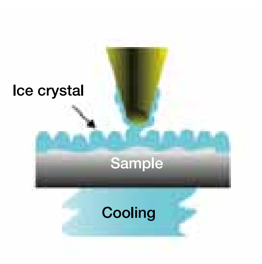
● Example of anodization that hinders electrical property measurements



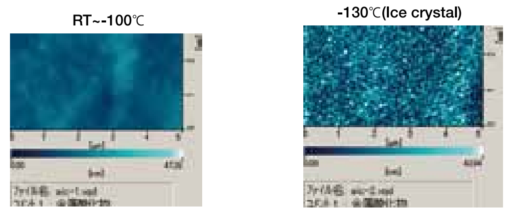
Scanning probe anodization is often used as an easy method for making nano-structures. The treble clef is an anodized pattern drawn by performing a voltage applied raster scan to a Si substrate. Problems do not occur in making nano-structures but sometimes occur in the nano-regions of electrical property measurements. As in the example above, an anodized film is created by the first scan area. When this type of surface is oxidized when reevaluating electrical properties at the same location, for example, it is not done correctly.On the other hand, this type of phenomenon does not occur in a high vacuum.

In order to observe under low temperature, avoid the accretion of ice crystals by a high vacuum.

● Problem of ice accretion in air



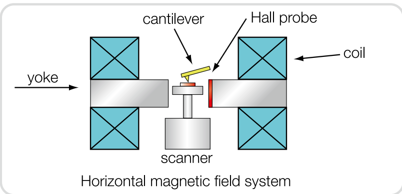
There is no ice accretion until -100°C in a high vacuum



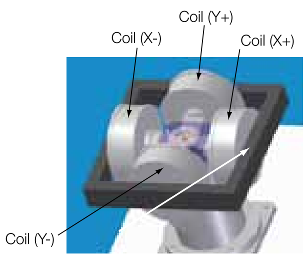
When the temperature in air falls below the dew point, ice will form on the surface. Normally, condensation begins near 0°C. Even with a dried gas that has as little water vapor as possible, ice gradually forms when cooled below 0°C. In a vacuum environment created by the AFM5300E turbo molecular pump, the shape and physical change can be investigated when cooling by the SPM because the ice forming temperature can be set at a low temperature of -100°C.

Applied magnetic field option (horizontal, vertical, in-plane rotation and magnetic field sweep)

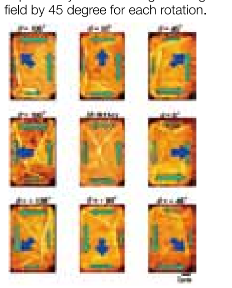
Able to install a magnetic field application device to an environmental control unit by an electromagnet.
• Maximum 5000 oersted (Oe)
• Magnetic flux density feedback mechanism by the Hall Effect



Horizontal magnetic field system



MFM measurement on closure domain of permalloy when rotating the magnetic field by 45 degree for each rotation.

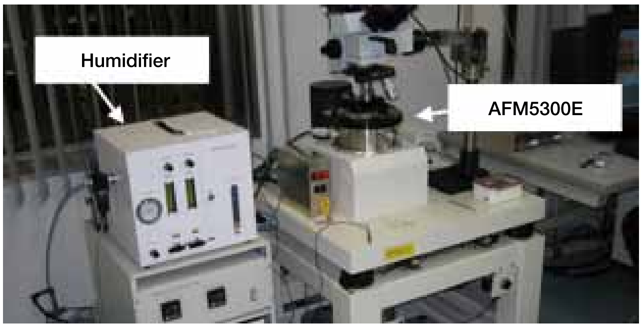


● AFM5300E Specifications

Detection	Optical lever Method (Low-coherent optical system)
Sample size	25mmφ, 10mm thickness
Scan area	20/1.5μm, 100/15μm, 150/5μm, 15μm (XY Closed-loop control)
Optical microscope	Zoom microscope, Metallurgical microscope
Sample moving system	XY stage (+2.5mm)
Pressure	TMP+RP (up to 9.9×10^{-5} Pa), RP (up to 9.9Pa)
Environment control	Air, Liquid, Temperature Control (-120～300℃ or RT～800℃), and Humidity Control (20～80%RH)

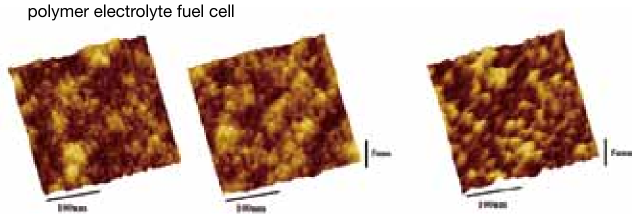
Option lineup

Humidity introduction unit



The AFM5300E can be equipped with a humidity sensor in the service port and humidity controlled nitrogen gas introduced into the camber.
Adjustable range: 20~80%RH

● Observation by humidity control of electrolyte membrane for polymer electrolyte fuel cell

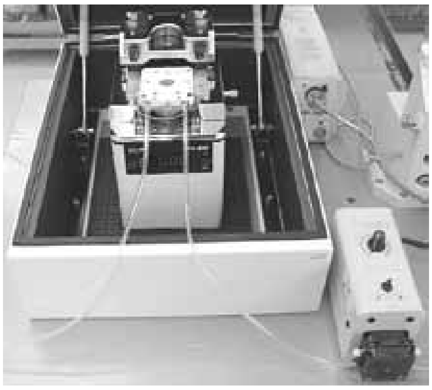


Dry conditions (Humidity10%)

High temperature state (Humidity80%)

Comparison: measurement in pure water

Portable and sealable environment control cell



● Sealed environment control cell
Sealed cell supports electro-chemical AFM, liquid AFM that realizes gas and liquid flow
(Adjustable to humidity control)

When making a sample, set it in a sealed cell. Observation is possible with the effects of air exposure and humidity eliminated if it is brought to where the SPM instrument is located.

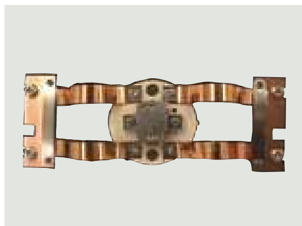
Compatible in a vacuum and in air Temperature control option

●For AFM5300E

Combined heating and cooling sample stage -120°C~+300°C

Cooling Dewar

Cantilever heating option (up to 200°C)



High temperature sample stage up to 800°C

●For AFM5100N

Atmosphere heating option (up to 250°C)

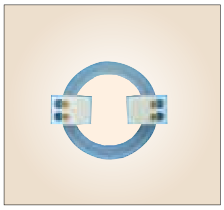
Liquid Temperature Control Module (up to 60°C)

Options for AFM5100N

Exceptional expandability is among the features of the AFM5100N. There is a complete optional lineup for supporting all measurement modes, such as in-solution measurements and gas environment measurements by cell replacement.

Observation holder in solution
DFM holder in solution
Probe holder

Petri Dish Cell



Sample Fixable Petri Dish Cell

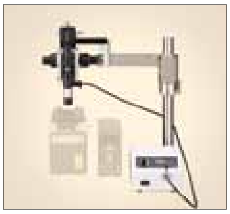
Electrochemical Cell

Positioning microscope

Metallurgical Microscope

Objective lens ×5, ×20, ×50
With differential interference function
Monitor magnification: 2800
(on a 19 inch monitor)

Zoom microscope



Monitor magnification 200~1420
(on a 19 inch monitor)
Non-step switching zoom

Simple microscope

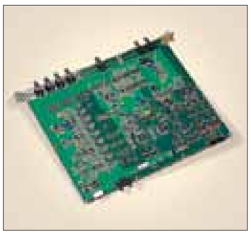
lens ×4
Monitor magnification 220
(on a 19 inch monitor)

Desktop Zoom Microscope

Monitor magnification 220~1420
(on a 19 inch monitor)
Non-step switching zoom

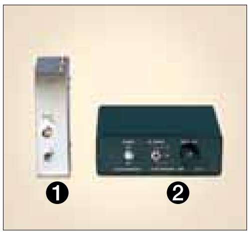
Probe station expansion

Modulation board



SPM lock-in detection circuit
LM-FFM, VE-AFM/DFM,
KFM, PRM, SNDM

I/V Amplifier



❶ Pico AMP(10^{11})
pA order (~100pA)

❷ Nano AMP(10^{8})
nA order (~100nA)

Bias Voltage 100V Box

Scanner

Standard/Wide field scanner

Standard
XY 20μm/ Z 1.5μm

Wide area
XY 150μm/ Z 5μm

Wide area
XY 100μm/ Z 15μm

Charge Neutralizer

Static blower

Ion bombardment
static eliminator

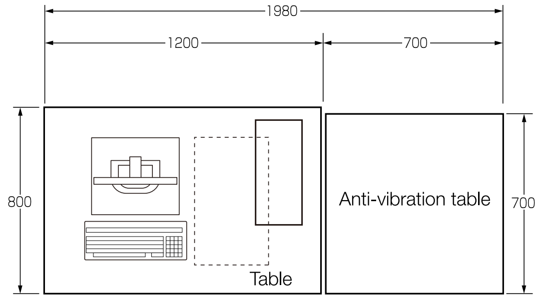
Soft X-ray Charge Neutralizer

Soft X-ray Charge Neutralizer
(X-ray leakage protective cover attached)

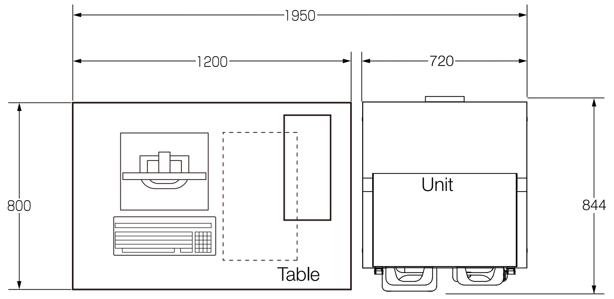
● Dimensions

(Units:mm)

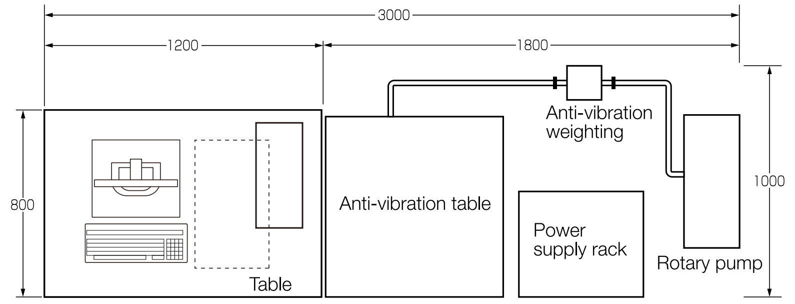
●AFM5100N(High resolution)



●AMF5400L



●AFM5300E



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