C147-E021

SHIMADZU
Excellence in Science

Scanning Probe Microscope / Atomic Force Microscope

SPM-9700HT Plus

Making the Unknown Visible

Scanning Probe Microscope/Atomic Force Microscope

SPM-9700HT Plus

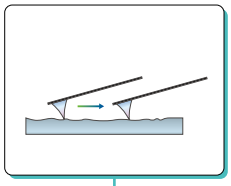
Scanning probe microscope (SPM) is a generic term for microscopes that scan sample surfaces with an extremely sharp probe to observe their three-dimensional image or local properties at high magnifications. The SPM-9700HT Plus takes high-throughput observations to the next level.

Functionality and Expandability to Meet a Wide Variety of Requirements

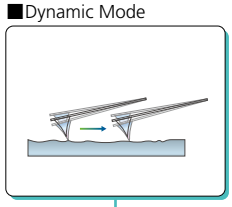
■ indicates standard specification. □ indicates optional specification.

Other special orders are also accepted. For more information, contact your Shimadzu representative.

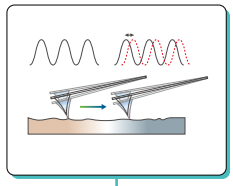
■Contact Mode



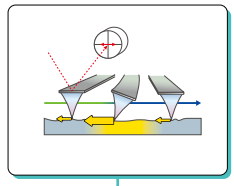
■Dynamic Mode



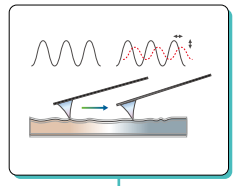
■Phase Mode



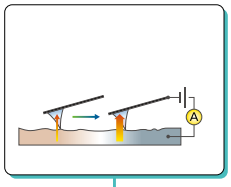
■Lateral Force Mode (LFM)



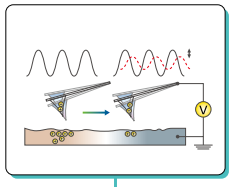
■Force Modulation Mode



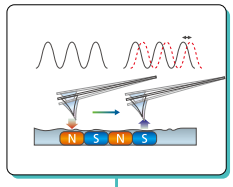
□Current Mode, I/V



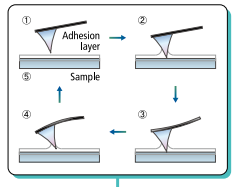
□Surface Potential Mode (KPFM)



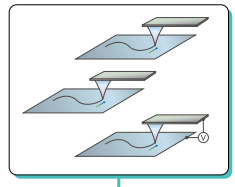
□Magnetic Force Mode (MFM)



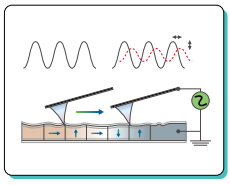
■Force Curve
□Nano 3D Mapping Fast



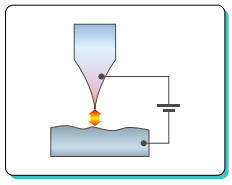
□Vector Scanning
<special order>



□Piezoresponse Force Mode (PFM) <Special order>



□STM
<Special order>



■HT Scanner (10μm)

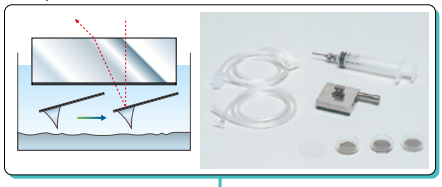
☐Middle Range Scanner (30μm)

☐Wide Range Scanner (125μm)

☐Deep-Type Scanner (55μm)

☐Narrow Range Scanner (2.5μm)

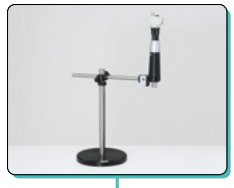
☐Petri Dish Type Solution Cell <Special order>



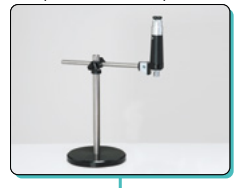
☐Electrochemical Solution Cell

☐High Magnification Optical Microscope Unit

☐Optical Microscope Unit with Camera



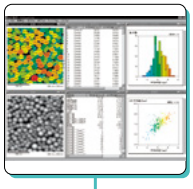
☐Optical Microscope Unit



☐Fiber Light

☐Sample holder for cross-sectional observation <Special order>

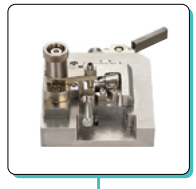
☐Particle Analysis Software



☐Desk-Type Air-Spring Vibration Damper

☐Active Vibration Damper
☐Active Vibration Damper with a Stand

☐Cantilever Mounting Jig



☐Static Eliminator

☐Computer Table

☐Sample Heating Unit

☐Light Irradiation Unit

☐LED Transmitted Illumination Kit, Model S
☐LED Transmitted Illumination Kit, Model L

Observations Independent of the Operator

ANALYTICAL INTELLIGENCE

The system and software are equipped with Analytical Intelligence, our user support technology that provides maximum support for the overall workflow, from data acquisition to analysis.

ANALYTICAL INTELLIGENCE

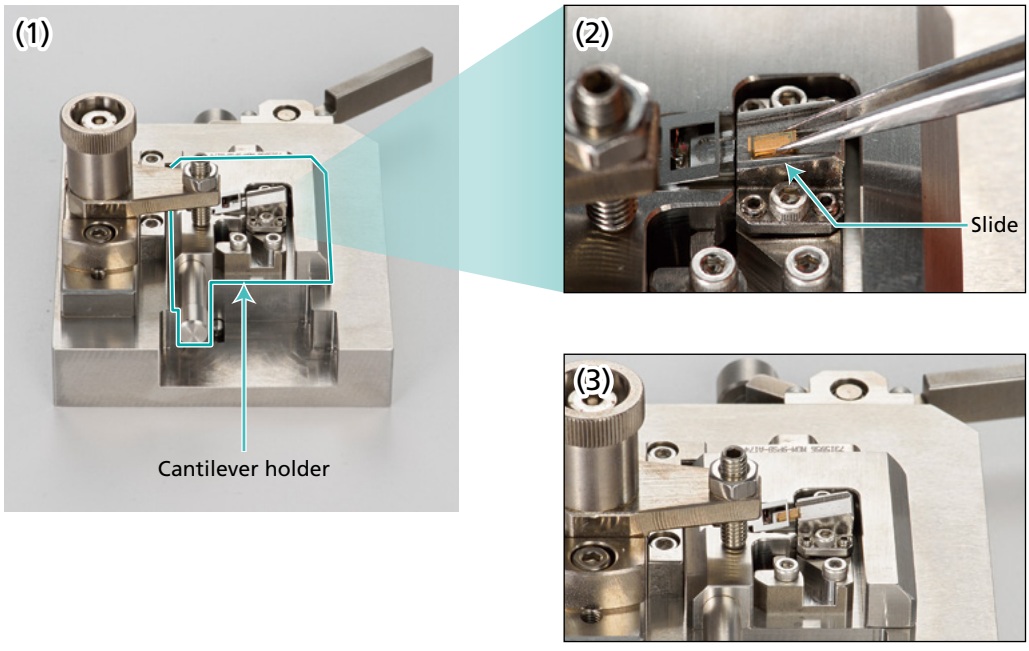
- Automated support functions utilizing digital technology, such as M2M, IoT, and Artificial Intelligence (AI), that enable higher productivity and maximum reliability.
- Allows a system to monitor and diagnose itself, handle any issues during data acquisition without user input, and automatically behave as if it were operated by an expert.
- Supports the acquisition of high quality, reproducible data regardless of an operator's skill level for both routine and demanding applications.

1 Instrument preparation

Cantilever Mounting Jig
Cantilever Master (Optional)

This jig ensures easy and secure mounting of the cantilever.

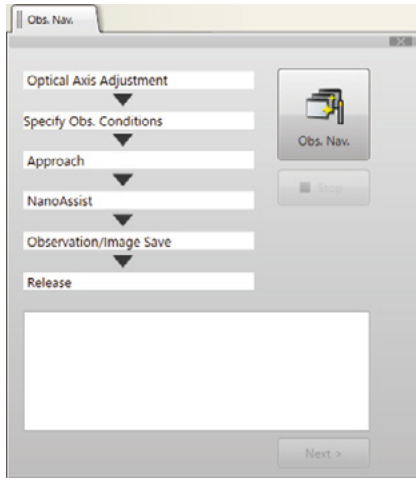
Mounting procedure:
(1) Set the cantilever holder in the cantilever mounting jig.
(2) Place the cantilever on the slide.
(3) Slide the the cantilever onto the cantilever holder, and secure it.



2 Startup

Observation Navigation

The entire sequence from startup to measurement is supported by observation navigation. Everything up to observation can be implemented by anyone without consulting the instruction manual.



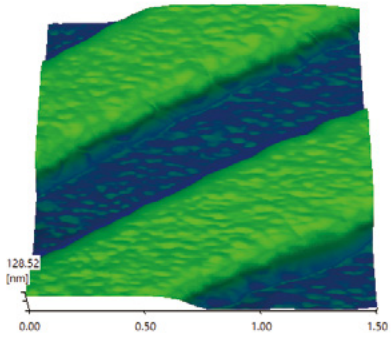
3 Optimization of observation conditions

NanoAssist

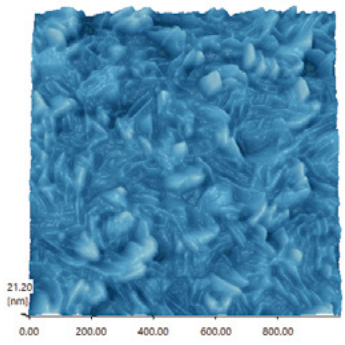
ANALYTICAL INTELLIGENCE

With the SPM-9700HT Plus, the observation conditions, including the operating points and gain values, are configured automatically.

- Shape Images Obtained with NanoAssist



Diffraction Grating



Vapor-Deposited Nb Coating

4 Observation

High-Throughput Observations
Fast Physical Property Mapping

Ultra-fast observations have been achieved by improving the processing speed of the control system and optimizing the drive unit.
The time needed for observations has been significantly reduced while maintaining optimal performance.

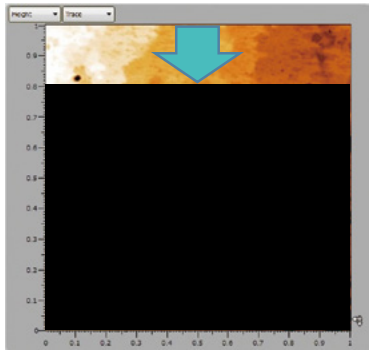


Image Observed Using Previous Instrument (SPM-9700)
(During acquisition)

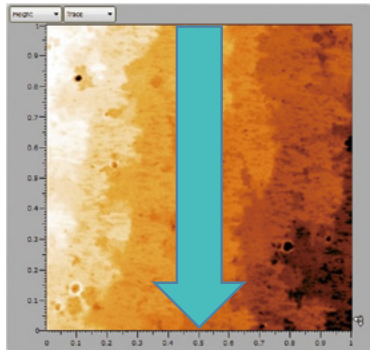
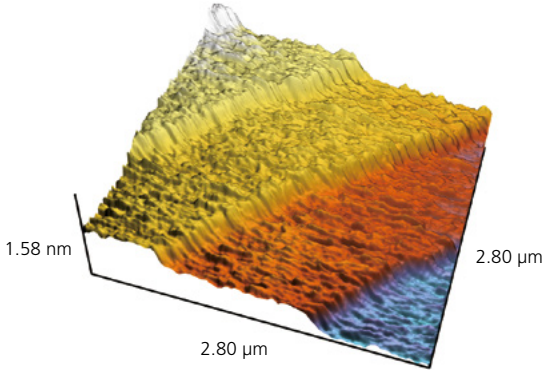


Image Observed Using SPM-9700HT Plus
(Measurement completed)

Observation time

About **25** sec*

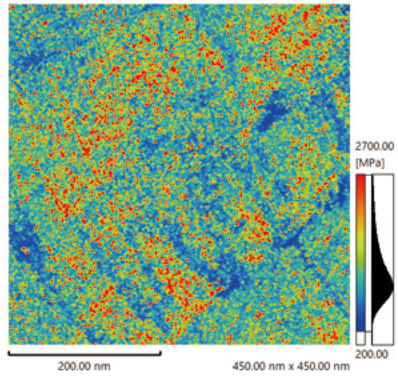
• Observation of TiO_2 Atomic Steps



Observation time

About **27** min*

• Mapping Elastic Modulus of High-Density Polyethylene



* Actual observation times will vary depending on parameter settings.

Watch the video to experience the speed!

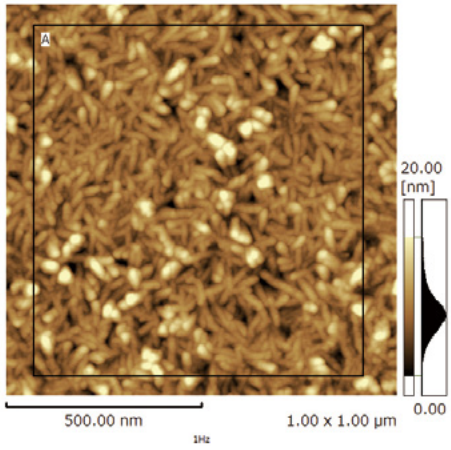
Application

5 Data analysis

Assortment of Data Analysis Functions

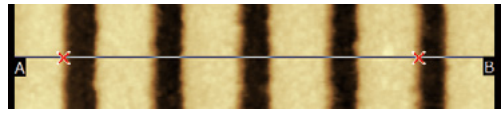
Multiple data analysis tools accommodate a variety of samples and applications, including surface roughness, particle data analysis, and morphological analysis.

- Analysis of Surface Roughness of Vapor-Deposited Metal Film

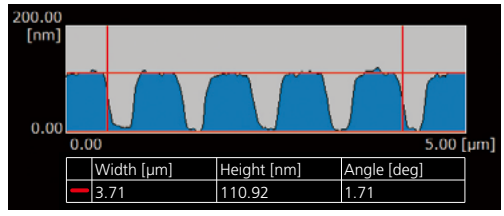


Surface Shape

- Measurement of Grating Step



Surface Shape



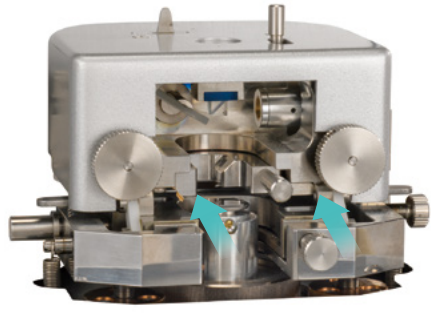
Cross-Section Shape

6 To the next sample

Head Slide Mechanism

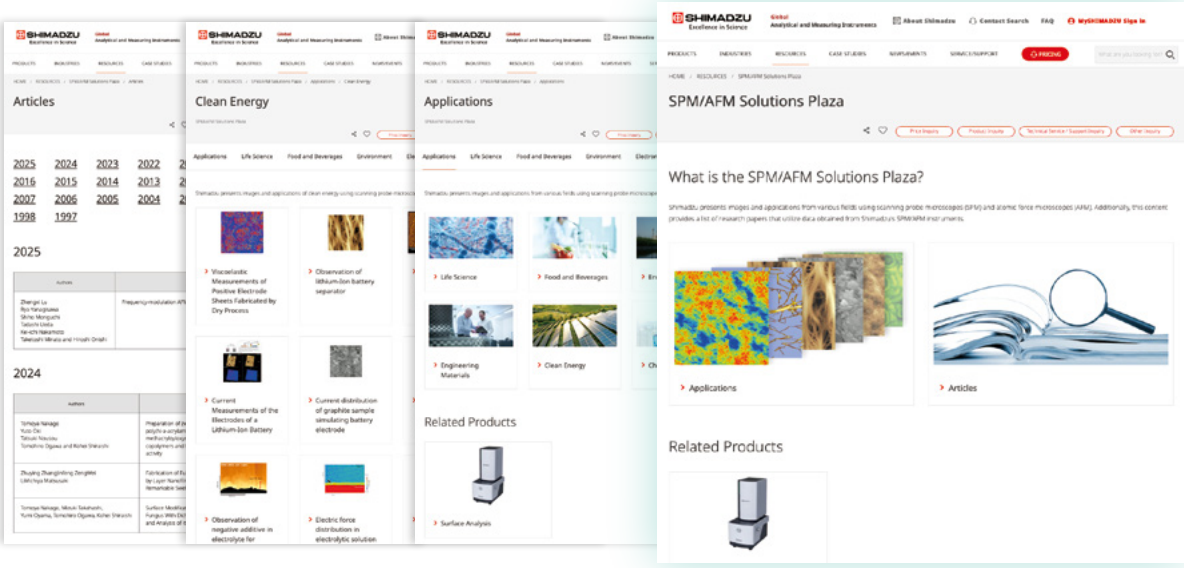
The design allows space around the sample, while maintaining a high level of rigidity.

- Samples can be replaced without removing the cantilever holder.
- Samples can be accessed even during SPM observations.
- Samples are approached automatically, regardless of the sample thickness.



SPM/AFM Solutions Plaza Website

Information, such as more recent examples of observation data, applications, and a list of scientific articles, is also available on the SPM/AFM Solutions Plaza website.

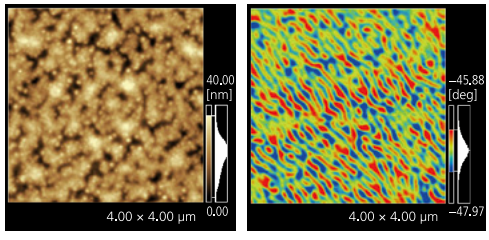


List of Scientific Articles | List of Fields | Observation Data | Top

SPM/AFM Solutions Plaza Search

Electronics

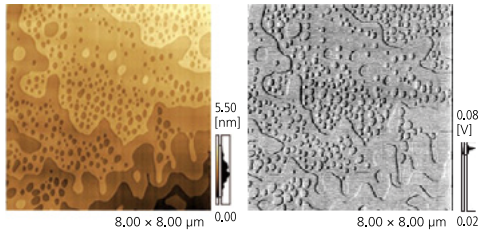
Magnetic Thin Film



Surface Shape | Magnetic Force (MFM)

From magnetic force (MFM) images, fingerprint-like magnetic domain and domain wall structures with a width of approximately 100 nm can be obtained.

Ferroelectric (TGS)

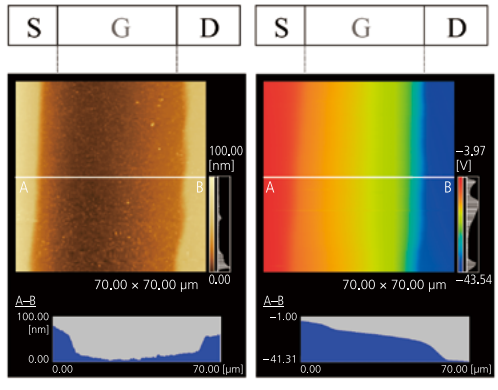


Surface Shape | Friction (LFM)

The cleavage surface of a TGS (ferroelectric tri-glycine sulfate) single crystal sample was observed in which the spontaneous polarization direction was aligned by applying a DC electric field. It was confirmed that when the polarization was aligned, no contrast (except the outline) appeared in the friction image. This result is consistent with the contrast on a friction image reflecting the direction of spontaneous polarization.

(Sample source: Professor Makoto Iwata, Graduate School of Engineering, Nagoya Institute of Technology)

Analysis of the Electric Potential of Organic Thin-Film Transistors (OFETs)



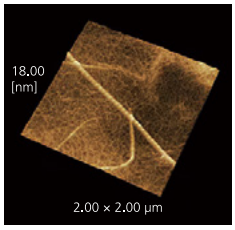
Surface Shape | Surface Potential (KPFM)

This is an example of analysis of the shape and potential of an organic thin-film transistor. The material was 3-hexylthiophene (P3HT), which can provide high mobility. In actual measurements using SPM, the source electrode is grounded, potentials are applied independently to the gate and drain electrodes, and correlated with the change in the surface potential (KPFM) at the top of the gate.

(Sample source: Professor Fukuda, School of Electrical and Electronic Engineering, Faculty of Engineering, Muroran Institute of Technology)

Life Sciences

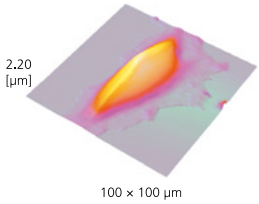
Collagen



Collagen is a main component of skin, bones, tendons, and connective tissues, and is the most plentiful protein in mammals. Collagen fibers with a striated structure and the collagen molecules that form them are observed throughout the whole surface.

(Sample source: Professor Nagai, Associate Professor Tajima, Hokkaido University)

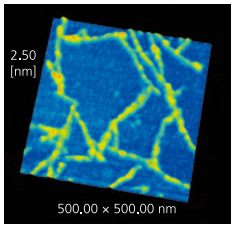
Human Umbilical Vein Endothelial Cell (HUVEC)



Human umbilical vein endothelial cells (HUVECs) were observed in a culture medium. It can be clearly seen that the cell surface is smooth and the nucleus is raised.

(Sample source: Professor Sugimoto, Professor Takemasa, Department of Anatomy (1), Nippon Medical School)

Fibroin Protein



Fibroin protein from silk thread was extracted and observed. Fibrous proteins and periodic internal structures were observed.

(Sample source: Professor Nagashima, Tokyo University of Agriculture)

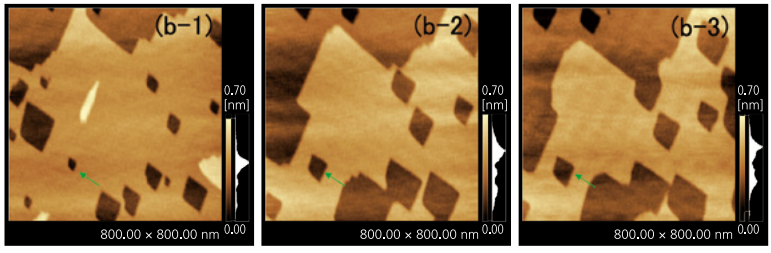
Long-Chain DNA

Long-chain DNA molecules were observed in air. This DNA is derived from a bacteriophage, and has a length of 20 µm. The characteristic string-like structure of long-chain DNA molecules and both ends of the molecule can be observed.

(Sample source: Akira Muramatsu, Yoshikawa Laboratory, Faculty of Life and Medical Sciences, Doshisha University)

Industrial Materials

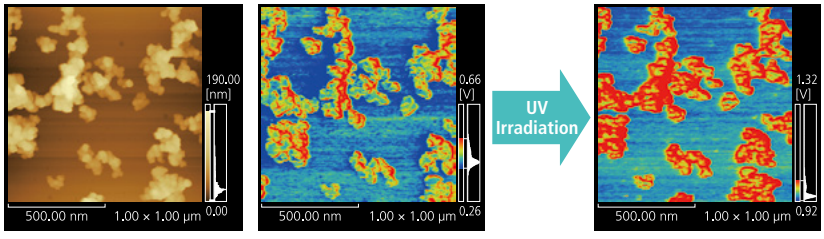
Calcite in Solution



The process of calcite crystal dissolution in a solution was observed. The spread of steps of about 0.3 nm due to dissolution was observed. From (b-1) to (b-3) took about 10 minutes.

(Sample source: Professor Kagi, School of Science, The University of Tokyo)

Surface Potential of Pt-loaded TiO_2 Photocatalyst under UV Irradiation

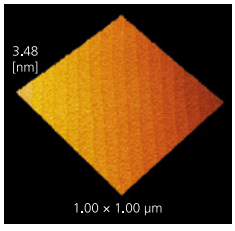


Surface Shape | Surface Potential (KPFM) | Surface Potential (KPFM)

An increase of the surface potential of the catalyst particles by an average of 130 mV after exposure to UV light was measured.

(Sample source: Associate Professor Kazuhiko Maeda, Department of Chemistry, Graduate School of Science, Institute of Science Tokyo)

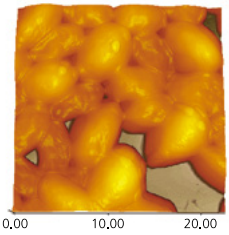
Sapphire Atomic Steps



Atomic steps can be clearly observed on the surface of a sapphire substrate.

Food and Beverages

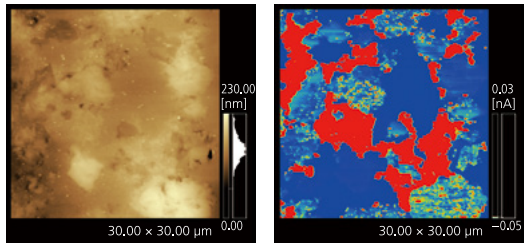
Beer Yeast



Many round or lemon-shaped fungus bodies and disc-like structures on the surface of the fungus bodies were clearly observed. This disk-like structure is called a bud scar, and indicates the number of times the yeast has budded, in other words, the age of the yeast.

Clean Energy

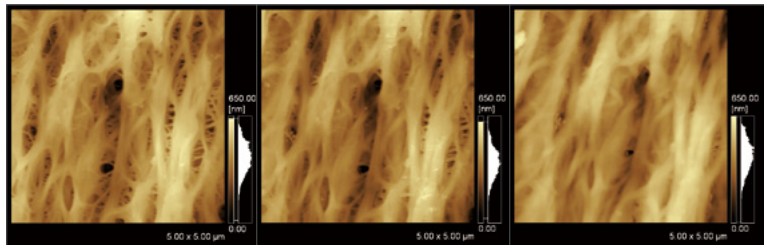
Lithium-Ion Battery, Cathode Material



Surface Shape Current

This is a cross-section of a cathode sheet made of ternary NCM (lithium nickel cobalt manganese oxide ($Li(Ni\text{-}Co\text{-}Mn)O_2$)), which is the main LIB cathode material. It can be inferred from the current image that conductive additive is distributed in the red area, active material with many conductive paths is distributed in the yellow-green area, and active material and binder with few conductive paths are distributed in the blue area.

Lithium-Ion Battery, Separator

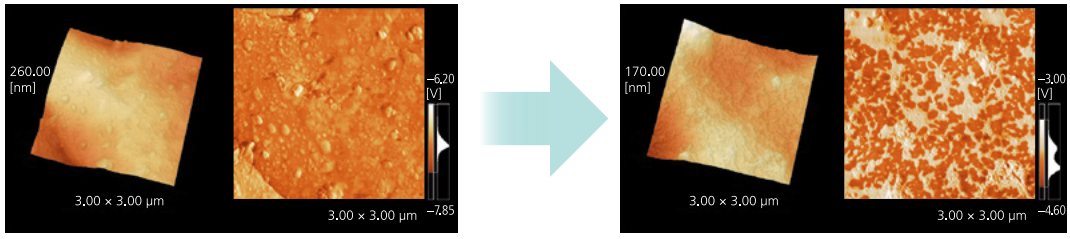


Room Temperature 125 °C 140 °C

The surface of a separator extracted from a lithium-ion battery was observed. By observing the heating, it can be seen that as the temperature increases, the fibers swell and fill the fine holes.

Chemistry

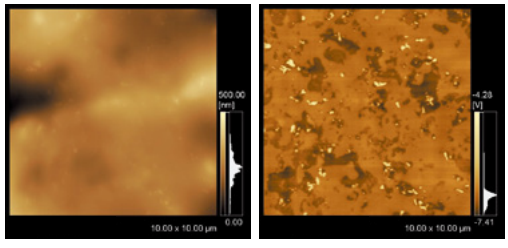
Polymer Film



Surface Shape Phase Surface Shape Phase

A special film was observed while being heated at 30 °C and 50 °C and compared. The left side shows a surface shape image and the right side shows a phase image. Changes that cannot be seen on the surface shape images can be clearly seen in the phase images. This means that the heating caused a change in the physical properties of the film, producing a difference in viscoelasticity.

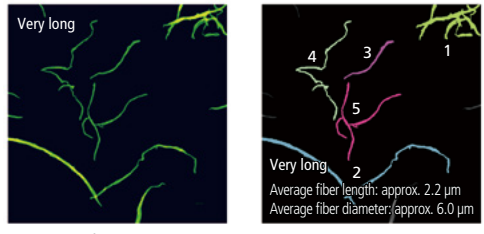
Polymer Blend



Surface Shape Phase

This is a sample that is a mixture of three types of polymer. The three phases cannot be clearly seen on the surface shape image (left), but can be clearly seen in the phase image (right).

Cellulose Nanofiber (CNF)



Surface Shape Particle Analysis

CNFs dispersed in water were observed, and the length and diameter of each fiber were measured.

No.	Boundary Length (µm)	Mean Z-Value (µm)
1	4.6	8.4
2	6.5	8.2
3	1.6	4.6
4	4.3	4.2
5	4.4	4.3
Mean	4.3	6.0

Particle Analysis Software (option)

The particle analysis software extracts particles from SPM-9700HT Plus images. It calculates feature values for each particle and displays the results. The software is useful for statistical data processing, and a wide range of feature values and statistics can be tabulated, sorted, or graphed. Numerical data can also be exported.

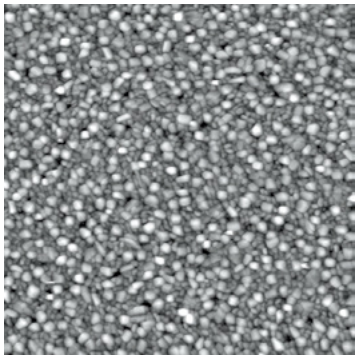
Feature Parameters

1 Center X
2 Center Y
3 Maximum Diameter
4 Pattern Width
5 Horizontal Feret Length
6 Vertical Feret Length
7 Radius as Circle excluding Hole
8 Radius as Circle including Hole
9 Mean Radius
10 Mean Radius Variance
11 Nearest Distance
12 Perimeter
13 C Perimeter
14 Maximum Z
15 Minimum Z
16 Average Z
17 Average Round Z
18 Area excluding Holes
19 Area including Holes
20 Surface Area
21 Volume
22 Pattern Direction
23 2nd Moment Direction
24 Area / Feret Area
25 Particle Area / All Area
26 Distortion
27 Circular Degree
28 Roughness
29 Thin Degree

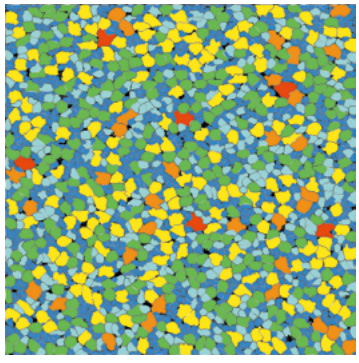
Statistical Values

1 Average
2 Standard Deviation
3 Line Average
4 Square Average
5 Cubic Average
6 Sum
7 Maximum
8 Minimum
9 Maximum Label
10 Minimum Label
11 Range
12 Samples

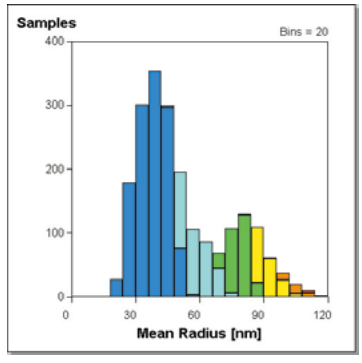
Analysis Example



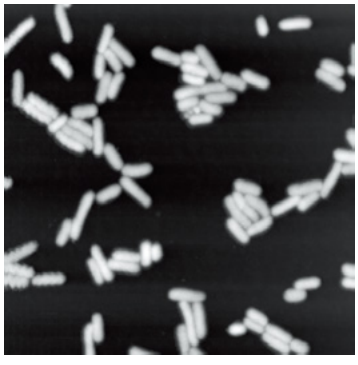
Thin Film (5 µm square)



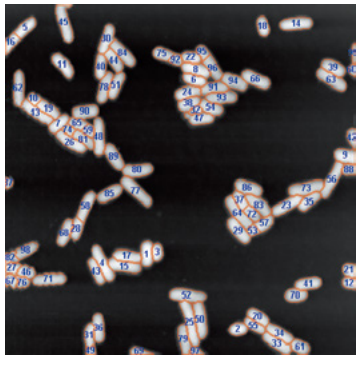
Particle Extraction and Classification Results



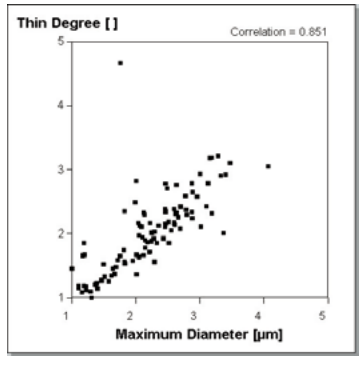
Histogram of Mean Radius



E. Coli Bacteria (30 µm square)



Particle Extraction and Labeling Results

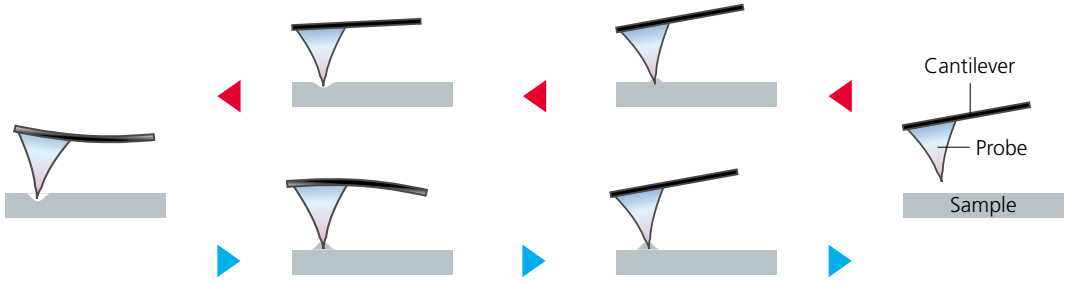


Graph of Correlation Between Maximum Diameter and Thin Degree

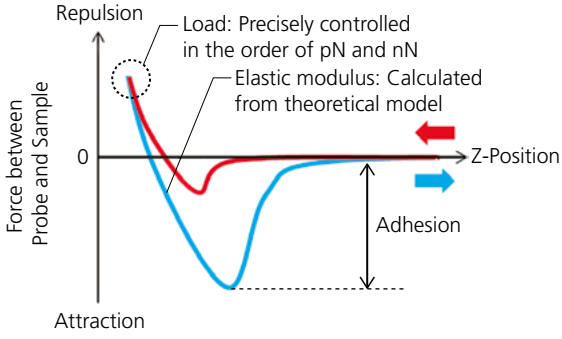
Nano 3D Mapping Fast (option)

By changing the distance between the cantilever probe of the scanning probe microscope and the sample, and measuring the force acting on the probe (force curve measurement), it is possible to evaluate the physical properties of surfaces and interfaces.

Force Curve Measurement



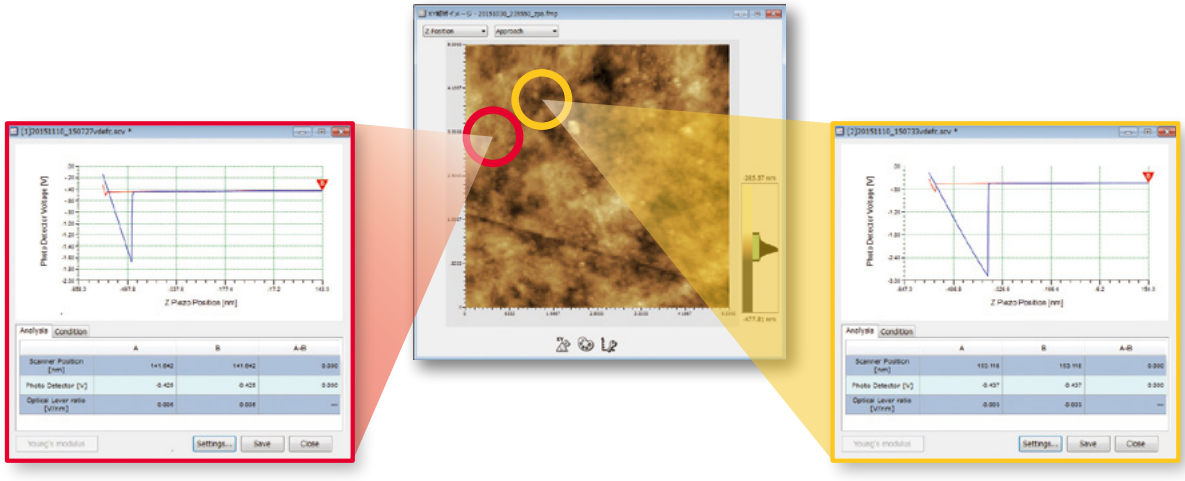
Cantilever Responses to Forces During Force Curve Measurements



Force Curve

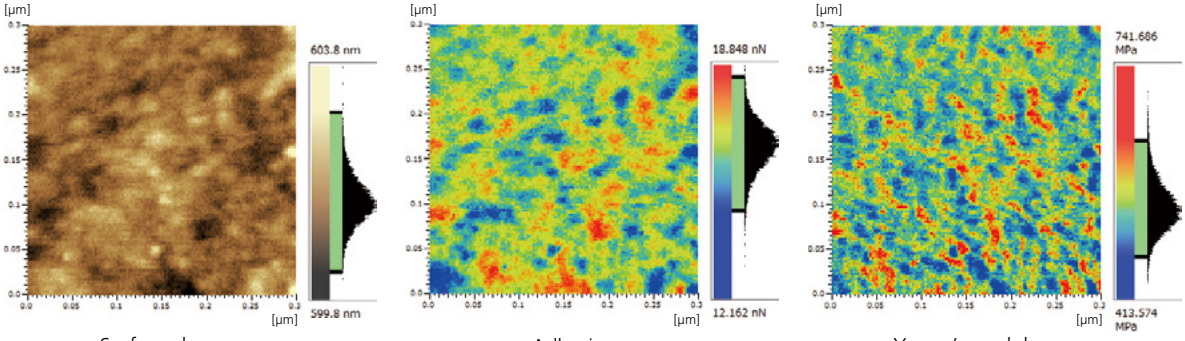
By acquiring a force curve at various points on the sample surface, the physical properties in the XY-plane can be mapped.
This is especially useful for evaluating the mechanical properties of thin films that are difficult to measure even with a nanoindenter or soft materials with a hardness between about a few kPa and 1 GPa.

Evaluating Physical Properties at Any Point on a Film



Force curves were measured at arbitrary points on a lm surface. The results show that the adhesive force is different at the respective points. Similarly, physical properties can also be evaluated on small soft samples, such as biopolymers.

Mapping the Physical Properties of Plastic Films

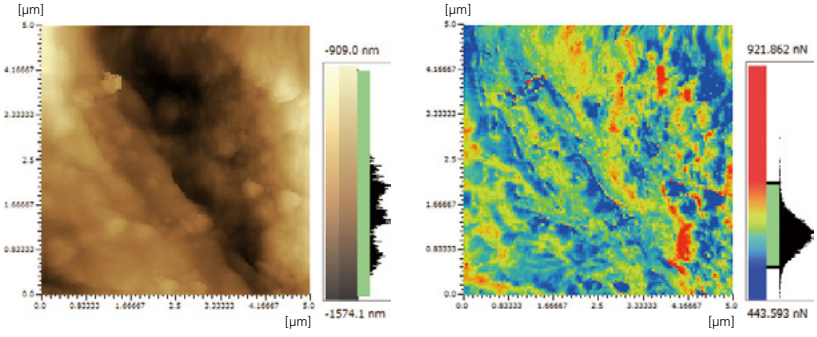


Surface shape | Adhesive | Young's modulus

Mapping analysis can be used to measure adhesive force and Young's modulus as well as surface topography. The figure shows a quantitative visualization of the Young's modulus within a localized area only 300 nm wide on a plastic film surface. (Sample source: MORESCO Cooperation)

Application example Evaluating the uniformity of a polymer material surface

Adhesive Part of an Adhesive Tape

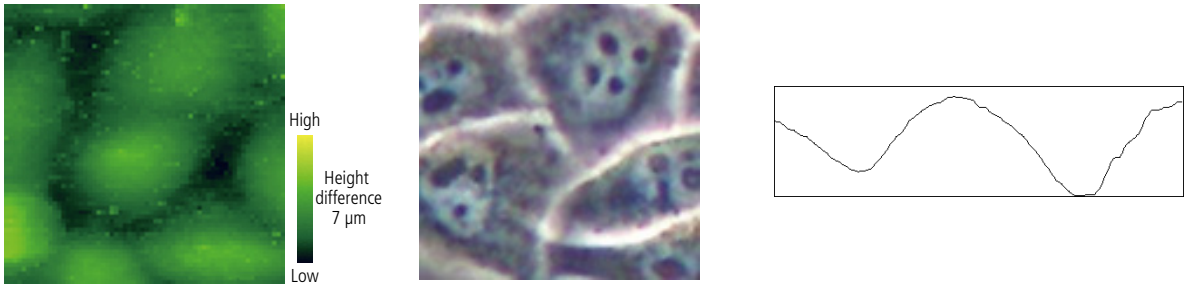


Surface shape | Adhesive

These images are from an evaluation of the adhesive part of an adhesive tape. They show that the adhesive force is distributed non-uniformly. This demonstrates how the system can be used to evaluate adhesive properties, which were difficult to evaluate using conventional methods.

Application example Evaluating the localized adhesive properties of thin films.

HeLa Cell



Surface Shape | Optical Microscope Phase Contrast Image | Cross-Section Shape

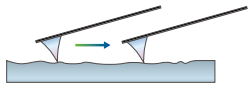
HeLa cells were observed while in the living state. It can be seen that each individual cell is dome-shaped. This suggests that the adhesion force between cells is weak.

Wide Assortment of Expansion Functionality

Shape

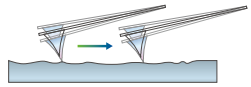
■ Contact Mode

This mode creates an image of displacement in the sample height direction by scanning the sample surface with the repulsive force acting between the cantilever tip and sample kept constant. Force curves can be measured as well.



■ Dynamic Mode

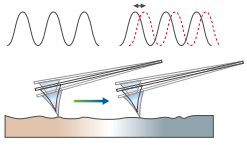
This mode vibrates the cantilever near its resonant frequency. Since the amplitude changes as the cantilever approaches the sample, a sample height displacement image can be created by moving the probe to keep the amplitude constant. Force curves can be measured as well.



Physical Properties

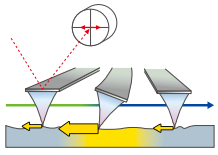
■ Phase Mode

This mode detects the phase shift delay in the cantilever vibration during dynamic mode scanning. This allows creating an image of differences in sample surface properties.



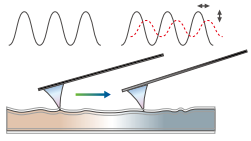
■ Lateral Force Mode (LFM)

By detecting the amount of twist in the cantilever during contact mode scanning, an image can be created from information corresponding to lateral forces (friction) acting between the sample and cantilever.



■ Force Modulation Mode

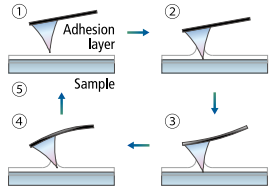
This mode vibrates the sample at constant amplitude and frequency during contact mode scanning. The cantilever response is detected by separating it into its amplitude and phase components. This allows creating an image of differences in sample surface properties.



■ Nano 3D Mapping Fast

Option

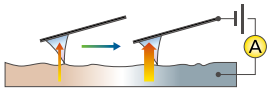
A force curve can be measured for each point in observed image data to observe a distribution of sample mechanical properties or adhesive strength.



Electromagnetivity Option

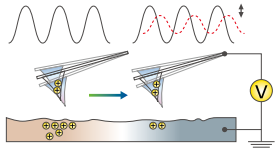
■ Current Mode

This mode applies a voltage between a conductive cantilever and sample during contact mode scanning and creates an image from the distribution of current flows.
I/V measurement is also possible.



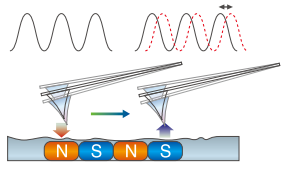
■ Surface Potential Mode (KPFM)

An image can be created from the electric potential of the sample surface by applying an alternating current electrical signal to a conductive cantilever and detecting the static electric force acting between the sample surface and cantilever.



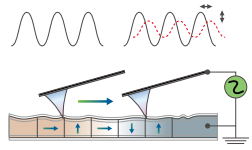
■ Magnetic Force Mode (MFM)

This mode scans the sample with a magnetic tipped cantilever kept at a constant distance from the sample. An image can be created from magnetic information of the sample surface obtained by detecting the magnetic force from the magnetic leakage field.



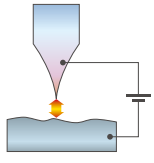
■ Piezoresponse Force Mode (PFM)

Surface polarity distribution is observed by detecting the piezoelectric response to electrical signals.



■ STM

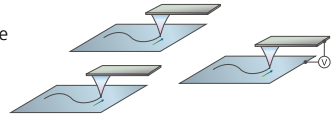
Surface shape is observed by scanning the metal probe with the tunneling current kept constant.



Machining Option

■ Vector Scanning (special order)

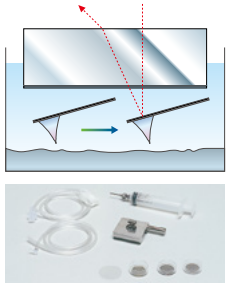
The scanning direction, force between the probe and sample, or the applied voltage can be programmed to allow scanning according to a program.



Atmospheric Control Option

Petri Dish Type Solution Cell (special order)

The sample is attached to the bottom of a small petri dish, which is then filled with solution. By scanning with the cantilever immersed in solution, AFM observations can be performed in solutions.



Sample Heating Unit

The sample can be loaded into the unit and heated.

Light Irradiation Unit

This unit enables the use of a fiber optic light to irradiate sample surfaces. It does not include the light source or the optical fiber.

Electrochemical Solution Cell

This cell is used for AFM observations of sample surface changes while an electrochemical reaction occurs in an electrolytic solution. The cell includes three standard electrodes (working, counter, and reference) and includes a petri dish type solution cell.

(Does not include the separately-ordered electrochemical controller (potentiostat).)

Lineup of Related Products

Scanning Probe Microscope

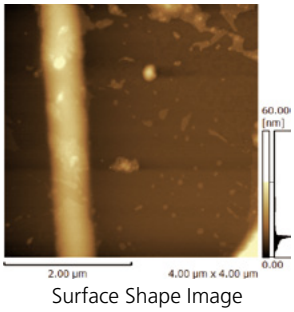
SPM-Nanoa™

Features

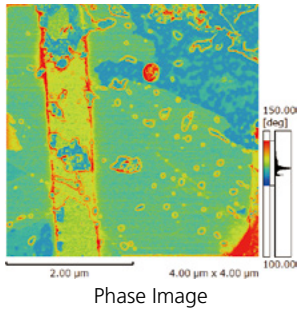
- Laser optical axis and detector adjustment, and observation condition settings are automated.
- Sharp images are captured with all modes from optical to SPM microscopy modes.
- Various support functionality achieves fast observation.

Observation of Polymer Materials

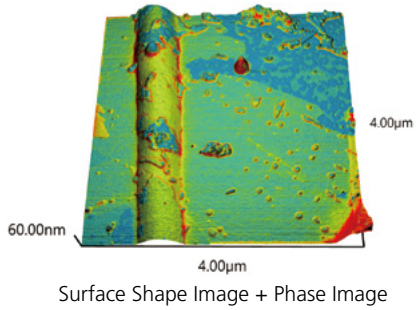
A water mixture of cellulose nanofiber (CNF) and polyvinylpyrrolidone (PVP) was observed electrospun onto a silicon substrate.
The surface shape image shows the cylindrical shape of the fibers and the phase image shows physical property differences of CNF and PVP fibers as differences in contrast.
(Sample source: Professor Nakai, Graduate School & Faculty of Bioresources, Mie University)



Surface Shape Image

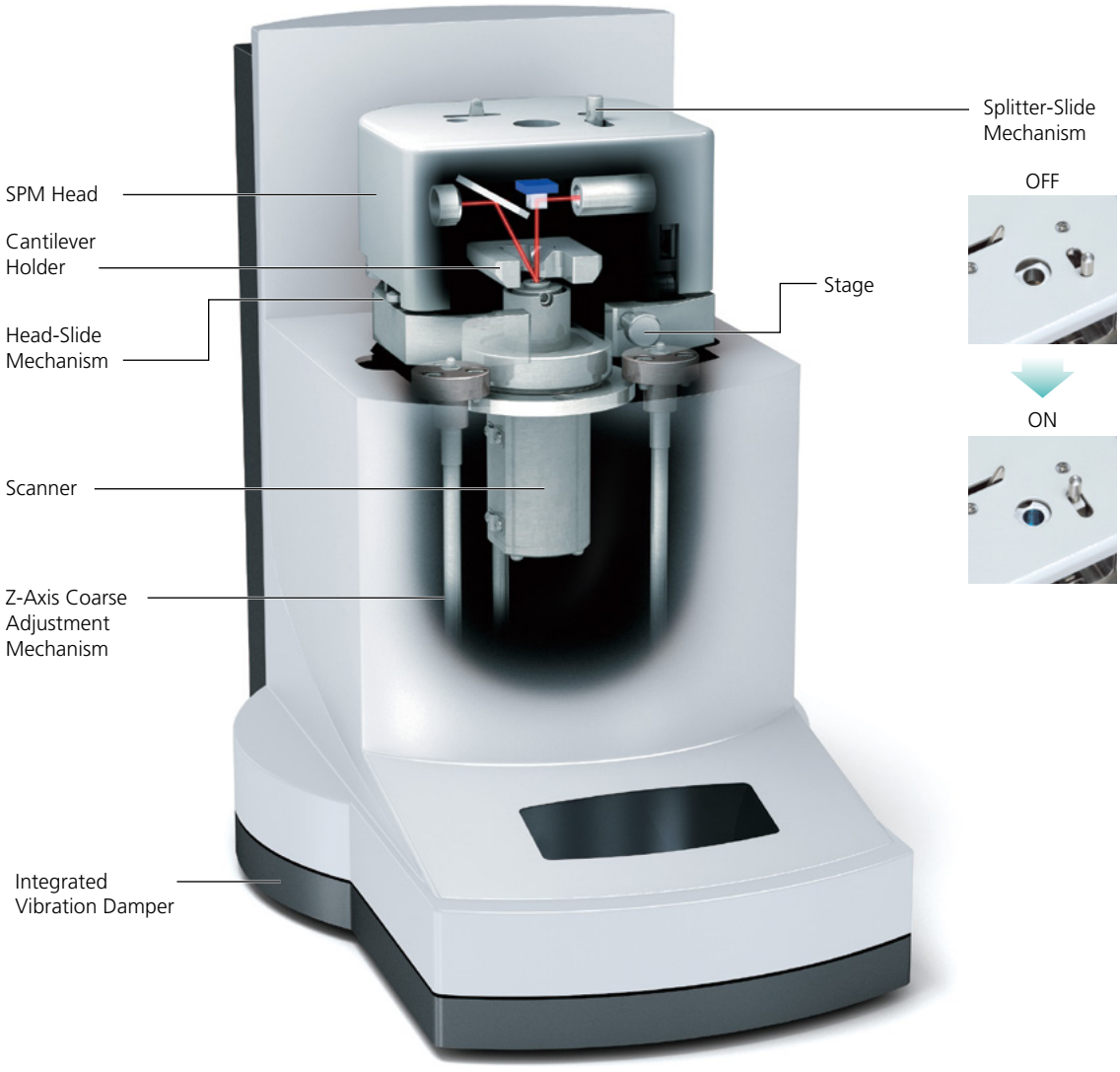


Phase Image



Surface Shape Image + Phase Image

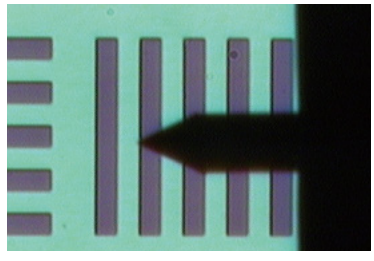
SPM Unit



Example of Optical Microscope Setups

- High Magnification Optical Microscope Unit (with Camera)
  Magnification of Display Monitor:
  48× to 900× zoom (14-inch display mode)
  including coaxial epi-illumination
- Optical Microscope Unit (with Camera)
  Magnification of Display Monitor:
  100× (14-inch display mode)
- Optical Microscope Unit (without Camera)
  Magnification: 40× (20× ocular and 2× objective)

Example of Observing a Sample and Cantilever Using the High Magnification Optical Microscope Unit



The splitter slide mechanism enables obtaining a bright optical microscope image.
Field-of-View: 270 µm × 180 µm
Cantilever: NCH

Specifications

SPM Unit

Resolution	XY	0.2 nm
	Z	0.01 nm
Scanner	Max scanning size (X·Y·Z)	10 µm × 10 µm × 1 µm (standard)
		30 µm × 30 µm × 5 µm (optional)
		125 µm × 125 µm × 7 µm (optional)
		55 µm × 55 µm × 13 µm (optional)
		2.5 µm × 2.5 µm × 0.3 µm (optional)
Sample Stage	Max sample size	ø24 mm × 8 mm (optional)
	Sample securing method	Securing by magnet
Vibration Damping Mechanism	Method	Mounted on SPM unit

Control Unit

Scan Controller	X/Y-axis control	±211 V Always 16-bit resolution
	Z-axis control	±211 V Maximum 26-bit resolution

Installation Specifications

- Installation Environment

  The following conditions are preferable for the installation environment.

  Temperature: 23 °C ± 5 °C

  Humidity: 60 % max. (no condensation)

- Power Supply

  The power supply listed is required for operating this instrument.

  SPM-9700HT Plus

  Single-phase: 100 to 120 V, 50/60 Hz, 15 A, 2 circuits

  Grounding: Type D grounding (maximum resistance 100 Ω)

  - The above-mentioned is the power supply for the basic SPM-9700HT Plus specifications. This will change depending on the optional configuration. For details, refer to the specifications.

- Size and Weight

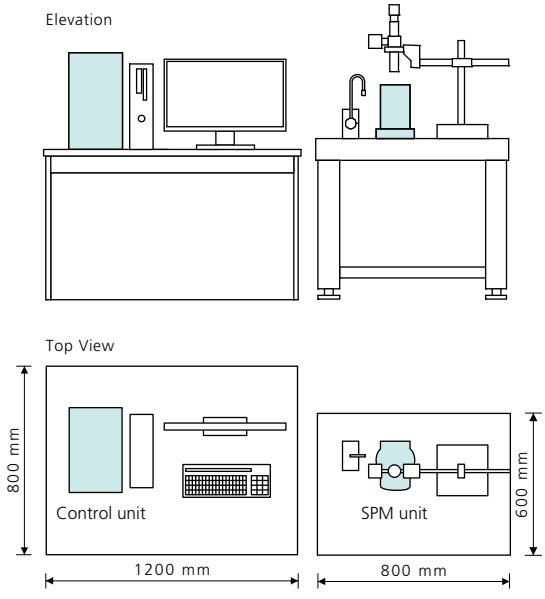
  SPM unit: W180 × D255 × H260 mm, 5.5 kg

  Control unit: W250 × D420 × H454 mm, 18.5 kg

- Laser product classification

  Class 1 Laser product (IEC 60825-1:2014)

SPM-9700HT Plus



- This figure is one example of a configuration.
- The sizes of the OA table and desk-type air-spring vibration damper are for reference.

Shimadzu Corporation

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