

Keysight 7500 AFM

Data Sheet



System Overview

The Keysight 7500 AFM establishes new performance, functionality, and ease-of-use benchmarks for nanoscale measurement, characterization, and manipulation. This next-generation system extends the forefront of atomic force microscopy, offering a large, closed-loop AFM scanner with atomic resolution, industry-leading environmental control, ultra-high-precision temperature control, an unrivaled range of electrochemistry capabilities, and much more.

The clever, compact design of the 7500 gives researchers quick, convenient access to their samples. A half-dozen of the most used AFM imaging modes are supported by the system's standard nose cone, which can easily be interchanged with specialized nose cones as needed, extending the 7500's capabilities effortlessly.

Furthermore, a newly introduced 7500 STM scanner now provides guaranteed atomic-resolution imaging of various conducting surfaces, and a new inverted light microscope (ILM) system combines the power of the high-resolution 7500 atomic force microscope with the direct optical viewing capability of an inverted optical microscope.

Whether serving academia or industry, the Keysight 7500 is the new gold standard for advanced AFM applications in the fields of electrochemistry, life science, materials science, polymer science, electrical characterization, and nanolithography.

Features and Benefits

- Atomic-resolution imaging with closed-loop 90 μ m AFM scanner
- Exceptional environmental and temperature control
- Standard nose cone supports expanded set of imaging modes
- Superior scanning in fluids, gases, and ambient conditions
- Single-pass nanoscale electrical characterization
- Unprecedented electrochemistry (EC) capabilities
- New STM scanner for studies of conducting materials
- New ILM system for simultaneous AFM/optical imaging

Additional Capabilities

- Materials science
- Life science
- Polymer science
- Electrochemistry
- Electrical characterization
- Nanolithography

New Design Advantages: AFM and STM

The 7500 offers stable AFM imaging combined with exceptionally flat, easily reproducible displacement over the entire scan range to deliver high resolution and very low distortion. Keysight’s patented top-down tip scanner technology is ideal for imaging in fluids and in air as well as under controlled temperature and environmental conditions.

The AFM scanner’s standard nose cone enables the use of contact mode, AAC mode, current-sensing AFM (CS-AFM), EFM, KFM, MFM, and MAC Mode in fluids and in air. Easy-to-load nose cones for additional AFM techniques, such as Top MAC Mode and DLFM, can be interchanged quickly and conveniently. Agilent nose cones are made from PEEK polymers, have low chemical reactivity, and can be used in a wide range of solvents. A stainless steel nose cone is available for fluorescence work.

The system’s video optics include a color camera and can resolve details to less than 1.7µm. Open access to the scanner and easy alignment of the optics help simplify use of the 7500. The user-friendly scanner has a built-in detector, no cables to plug-in, and is easy to calibrate.

A new STM scanner is also now available for use with the 7500 AFM platform. Scanning tunneling microscopy is a technique that takes advantage of the extreme distance sensitivity of the tunneling current between two conducting electrodes to measure tunnel-current variations as a probe is scanned over a sample’s surface.

The 7500 STM scanner delivers outstanding results on a variety of conducting materials in ambient, controlled gas, and fluid environments. Preamplifier modules extend its effective range; the low-current and ultra-low-current STM scanner provides stable imaging at pico-ampere and sub-pico-ampere currents to resolve individual atoms and molecules.



The 7500 scanner.

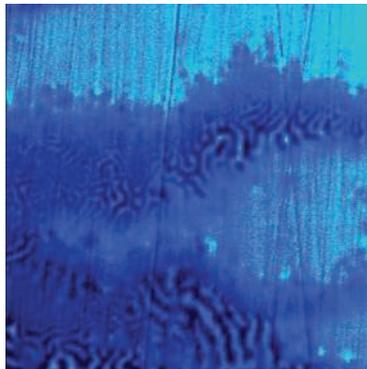
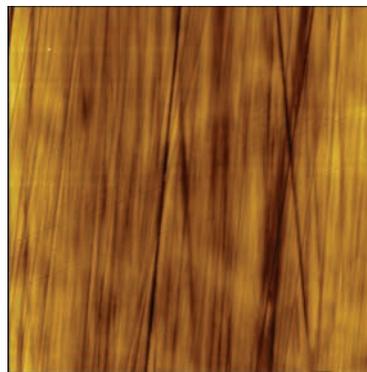


Figure 1. Topography image (top) of polished duplex stainless steel. MFM image (bottom) showing ferrite and Austenite domains of the duplex stainless steel. Scan size: 10µm.

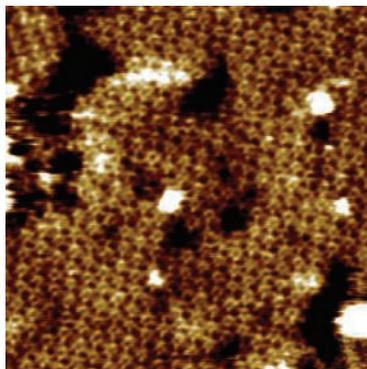


Figure 2. High resolution closed-loop MAC mode image of bacteriorhodopsin, revealing the donut-like structure of bacteriorhodopsin trimers, and the connecting fibrous arms in between. Scan size: 120nm.

Environmental and Temperature Control

The 7500 AFM system includes a built-in environmental chamber engineered to meet the many requirements of intricate, demanding nanoscience applications. The chamber provides an easily accessible, sealed sample compartment that is completely isolated from the rest of the system. Six inlet/outlet ports permit the flow of different gases into or out of the sample area.

The system's scanner resides outside the environmental chamber, so it is protected from contamination, harsh gases, solvents, caustic liquids, and other potentially damaging environments. Humidity levels are monitored by sensors built into the chamber. Oxygen and reactive gases can be introduced into and purged from the sample chamber.

Robust, easy-to-handle sample plates designed specifically for use with the 7500 are offered to facilitate studies in air, in fluids, or with electrochemistry. The system's standard sample plate can be utilized for many imaging modes and is configurable with a fluid cell. Special heating and cooling plates offer a total range of -40°C up to 250°C . Sample plates for Top MAC Mode are also available

Keysight's temperature control system employs a patented thermal insulation and compensation design to deliver the industry's most precise temperature control. This highly versatile option allows imaging during temperature changes and is fully compatible with all imaging modes, including those utilized in fluids. The temperature controller's unique design isolates the sample plate from the rest of the system, improving stability and performance. Temperatures can be controlled from -40°C up to 250°C , with suitable resolution and control to match any experimental requirements.

MAC Mode

Keysight's patented MAC Mode is a gentle, nondestructive AFM imaging technique that employs a magnetic field to drive a paramagnetically coated cantilever, yielding precise control over oscillation amplitude (thus providing excellent force regulation). Since only the tip is driven, the signal-to-noise ratio is greatly enhanced, yielding a significant improvement while imaging in fluids.

MAC Mode has allowed researchers to resolve sub-molecular structures that could not be resolved with any other AFM technique. It is particularly useful for imaging delicate samples in application areas that require high resolution and force sensitivity, such as life science, polymer science, and surface science. AAC mode is included with MAC Mode.

The MAC Mode III controller is optimized for single-pass Kelvin force microscopy (KFM) and electrostatic force microscopy (EFM), a technique that enables simultaneous collection of topography and surface potential data by using a servo-on-height cantilever approach that is insensitive to scanner drift. These modes are especially useful for measuring dielectric films, metal surfaces, piezoelectric materials, and conductor-insulator transitions. In addition to KFM/EFM and piezo force microscopy

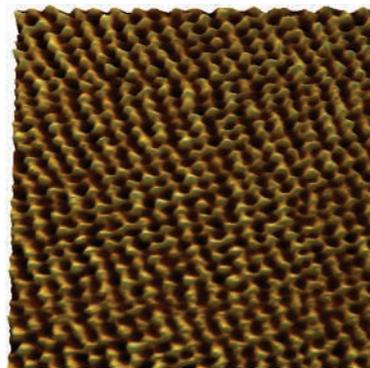


Figure 3. Closed-loop contact mode, topography image of atoms on mica. Scan size: 10 nm.

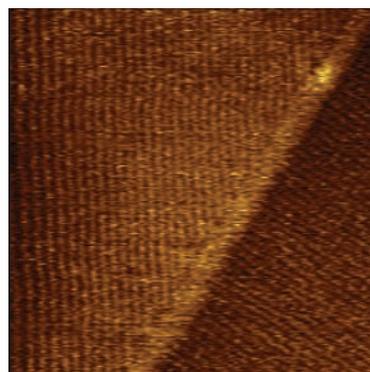


Figure 4. Closed-loop topography image of $\text{C}_{36}\text{H}_{74}$. Scan size: 162 nm.

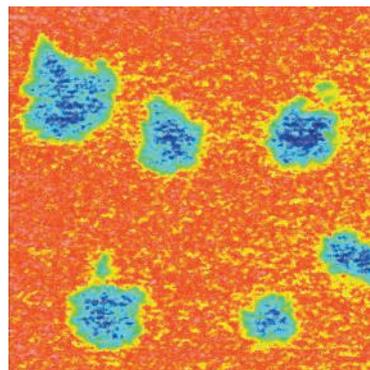
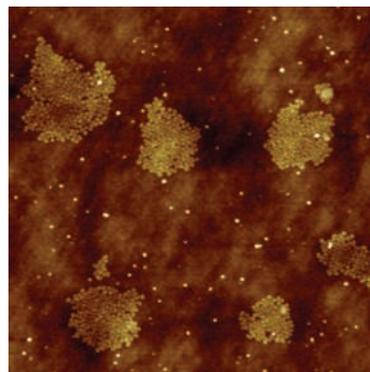


Figure 5. KFM topography (top) and surface potential (bottom) images of fluoroalkane $\text{F}_{14}\text{H}_{20}$ self-assembly on Si. Scan size: $4\mu\text{m}$.

(PFM), MAC Mode III allows the use of higher resonance modes of the cantilever. Higher resonance modes can be utilized to collect additional information about mechanical properties of the sample surface.

In addition, a newly available Keysight ILM system lets researchers fully leverage many key 7500 AFM capabilities, including MAC Mode, for life science studies whose results depend on the simultaneous acquisition of atomic force and optical (or fluorescence) microscopy data. The patented mounting design of the ILM system incorporates a rigid structure that provides the low noise floor needed to obtain sub-nanometer resolution. The advanced design also allows the AFM to sit on top of an inverted microscope and under the illumination pillar, resulting in better optical contrast. The ILM system is compatible with many popular inverted microscope and camera models.

Electrochemistry

The Keysight 7500 can be equipped with electrochemistry accessories that include a fluid cell, a salt bridge, improved software, and a built-in, low-noise potentiostat/galvanostat for *in situ* EC-AFM studies. When combined with precise temperature control, it is possible to obtain information about electrochemical processes that would otherwise be inaccessible. Furthermore, the 7500 AFM system’s environmental control allows imaging with no dissolved oxygen in either aqueous or non-aqueous solutions. The optional EC glove box features a smaller chamber that allows the glove box and AFM to be placed inside the Pico IC isolation chamber for uncompromising results.

The 7500 can also be utilized with SECM mode, a seamlessly integrated technology package that enables scanning electrochemical microscopy (SECM) on conductive and insulating samples. This new Agilent mode of AFM operation has been designed to provide ultimate performance as well as supreme ease of use. SECM can be performed quickly and reliably with nanoscale resolution. It is very useful for myriad applications, including the investigation of homogeneous and heterogeneous electron transfer reactions, the imaging of biologically active processes, surface modification, analysis of thin films, screening of catalytic materials, and corrosion process studies.

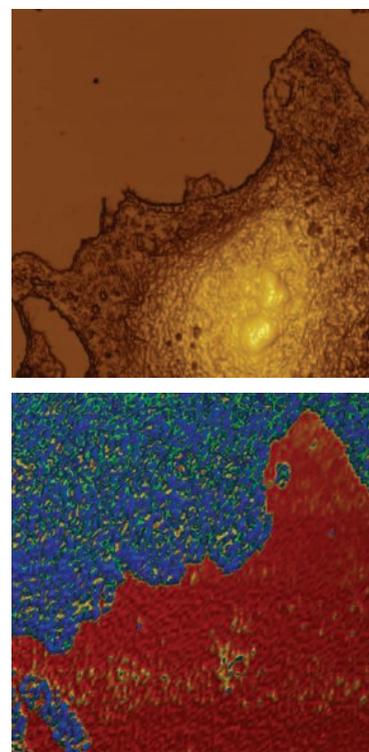
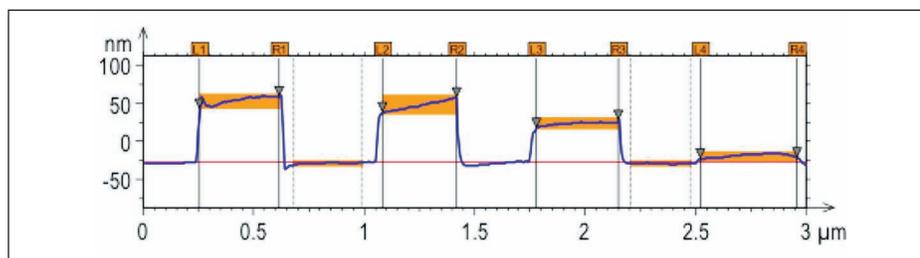


Figure 6. Contact mode, topography image (top) of a cell were made to characterize cell morphology including nucleus lower right. Scan size 50 μm. Elasticity map (bottom) of a fixed cell. An array of force distance curves were measured at the same position as shown in the top figure. A map of elasticity modulus was constructed by analyzing the individual force distance curves.



| Cu/Au | Voltage | 0.4 V | -0.1 V | -0.2 V | -0.3 V | -0.4 V |
|----------------|---------|-------|--------|--------|--------|--------|
| Thickness (nm) | | 0 | 10.4 | 53.0 | 77.2 | 84.2 |
| Roughness (nm) | | 2.78 | 3.29 | 3.81 | 5.79 | 10.3 |

Figure 7. (top) Averaged topography line profile from the AFM image. (bottom) The estimated thickness and surface roughness of the Cu films deposited at different overpotentials.

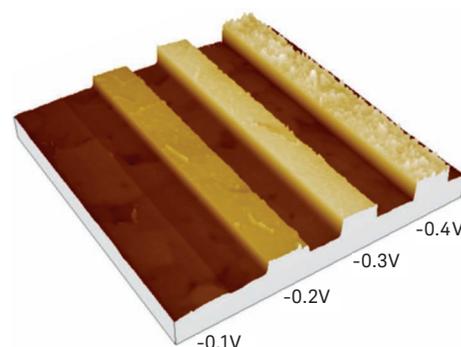


Figure 8. Three-dimensional EC-AFM topography image of Cu films deposited at different overpotentials.

PicoTREC

Keysight’s exclusive PicoTREC molecular recognition toolkit is designed for use with MAC Mode. With PicoTREC, researchers can quickly distinguish between species that are engaged in molecular binding events and those that are not binding events, thus eliminating the need to perform slow and tedious force-volume spectroscopy experiments to get the same results.

Scientists can use PicoTREC with the 7500 AFM to explore dynamic properties of biological systems (antibody-antigen, ligand-receptor, drug-receptor, DNA-protein, DNA-DNA, and so forth) by imaging patterns of molecular binding and adhesion on surfaces.

Software

The 7500 AFM system utilizes Keysight’s PicoView, an imaging and analysis software package that allows complete control of all scanning parameters and provides the flexibility required for more complex experiments. Improved electrochemistry capabilities, such as cyclic voltammetry (CV) using either the AFM tip or the sample, enable the software to deliver superior control for EC-AFM and EC-STM experiments.

PicoView also affords researchers new, customizable math plug-ins that return values to facilitate quantitative mapping of sample properties at the nanoscale. The new version of PicoView fully supports Keysight’s unique PicoScript (automation/customization) and PicoLITH (lithography/nanomanipulation) options as well.

For additional interactive post-processing capabilities, Keysight’s easy-to-use Pico Image imaging and analysis software package provides all of the features and functions required to build a surface analysis report on multi-layer measurement data.

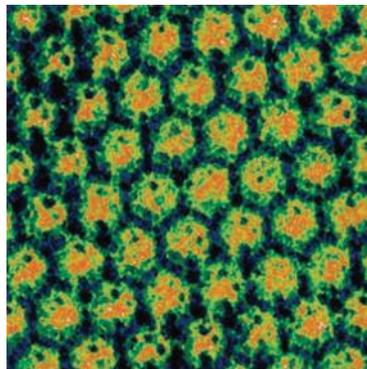
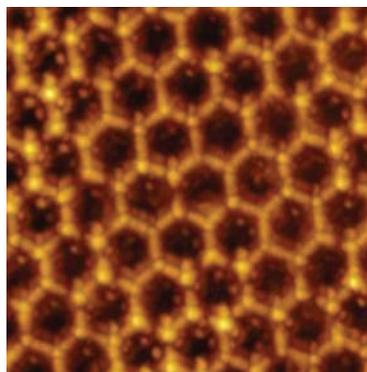


Figure 10. Topography (top) and capacitance gradient dC/dZ (bottom) images of a conducting polymer on an Au substrate. Scan size: $3\mu\text{m}$.

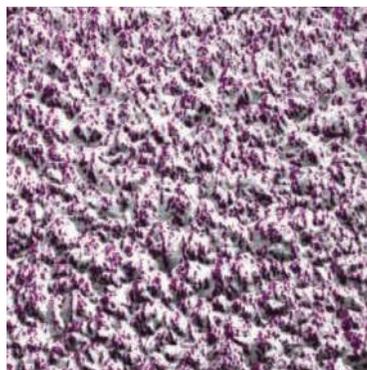
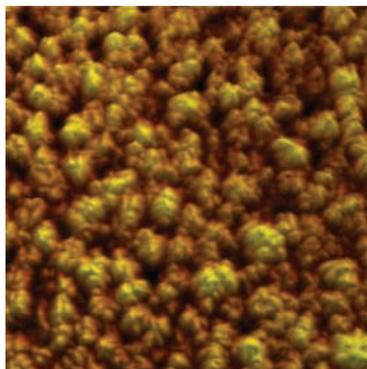


Figure 11. 3-D CS-AFM images of a positive biased sample W/Ti alloy. Topography (top) and current image overlaid on topography image (bottom). Scan size: $2\mu\text{m}$.

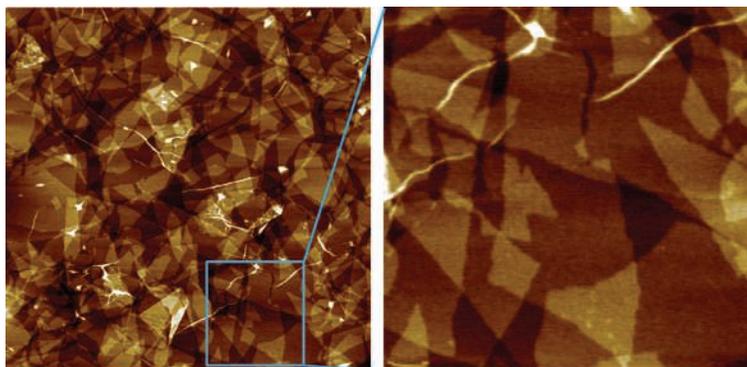


Figure 9. Topography images in closed loop of graphene oxide (GO) on mica. Scan size: left $5\mu\text{m}$ and $1.5\mu\text{m}$ right.

7500 System Specifications

Scanner

| | |
|-----------------------------|-----------------------|
| Scan range: | 90µm in XY, 12µm in Z |
| X/Y positioning noise (CL): | < 0.15nm typical |
| XY linearity: | < 0.5% |
| Noise level: | < 0.3nm in Z |
| Out of plane travel: | < 0.1% Full range |
| Laser: | 670nm |

System Controller

| | |
|----|--|
| PC | Quad core Xeon, 8G ram, 1TB disk, Win7 x 74 2ea 23" FPD, 1920 x 1080 pix resolution |
|----|--|

Video Microscope

| |
|---------------------------|
| Top down video microscope |
| Manual focus and zoom |
| 2M pixel color USB camera |
| 1.7µm resolution |

Sample Size

| | |
|----------------------|---------------|
| Manual X/Y stage: | ~ 10mm travel |
| Motorized Z stage: | ~ 10mm travel |
| Max sample diameter: | ~ 25mm |
| Max sample height: | ~ 8mm |

Standard Modes

Contact, LFM, AAC, Phase, CS-AFM, MFM, EFM, KFM, Liftmode, F-d Spectroscopy, F-V Spectroscopy, Force Plugins, Force Modulation (FMM), Q-Control, LV PFM

Optional Modes

MAC, STM, PicoTREC, DLFM, Nanolithography, Electrochemistry, Heating/Cooling, Thermal K, PicoScript

Microscope Dimensions

| | |
|------------|--------------------|
| L x W x H: | 191 x 191 x 201 mm |
| Weight: | 7.5Kg |

Potentiostat (Option)

| | |
|----------------------|-------------------------------|
| Scan rate: | 0.1mV/s – 10V/s |
| Current range: | 5pA – 100mA |
| Current sensitivity: | 0.01, 0.1, 1, 100, 10,000uA/V |
| Max. sample rate: | 16bit@25kHz |

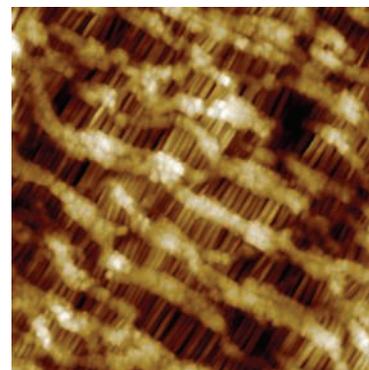


Figure 12. Closed-loop topographic image of polymer isotactic polypropylene. Scan size: 2µm.

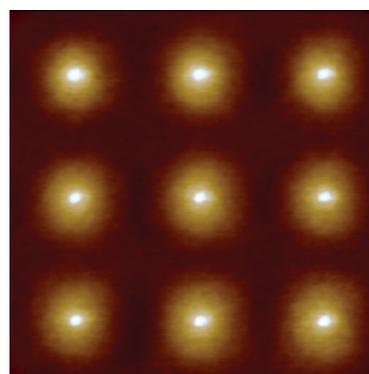
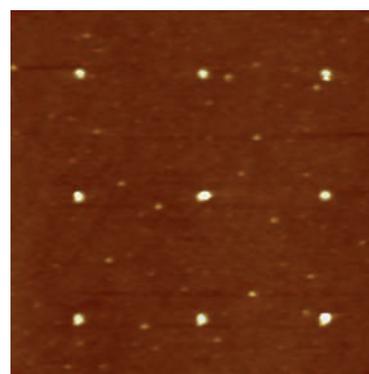


Figure 13. Humidity-dependent anodic oxidation of a silicon surface. Side-by-side AFM topographic images of the resulting surface after the tip-directed oxidation under a RH of 20% (top) and a RH of 90% (bottom), respectively. Scan size: 6µm.

AFM Instrumentation from Keysight Technologies

Keysight Technologies offers high precision, modular AFM solutions for research, industry, and education. Exceptional worldwide support is provided by experienced application scientists and technical service personnel. Keysight's leading-edge R&D laboratories are dedicated to the timely introduction and optimization of innovative, easy-to-use AFM technologies.

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Published in USA, August 26, 2014
5991-3639EN

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