Keysight Technologies
5500 AFM

Data Sheet

KEYSIGHT
TECHNOLOGIES
Unlocking Measurement Insights

Overview

The Keysight Technologies, Inc. 5500 is the ideal multiple-user research system for atomic force microscopy. As the high-performance flagship of Keysight's AFM instrument line, the 5500 provides atomic-scale resolution and a wealth of unique technological features, including patented top-down scanning, ultra-precision temperature control, and industry leading environmental control. It is well suited for life science, materials science, polymer science, electrical characterization, and nanolithography applications.

The intelligent, modular design of the 5500 permits the simple integration of an inverted optical microscope, numerous imaging modes, customizable sample-handling plates, an electrochemistry kit, and a video microscope. In short, the versatile 5500 has been engineered to support almost every scientific AFM capability offered by Keysight.

Scanners

Keysight's open- and closed-loop scanners (two ranges available: 90 µm x 90 µm, or 9 µm x 9 µm) offer outstanding linearity, accuracy, versatility, and ease of use. These multipurpose, top-down scanners are ideal for imaging in fluids or air and under controlled temperature and environmental conditions. To deliver high-resolution imaging results, a balanced-pendulum design is utilized that eliminates artifacts in the image by keeping the relative position of the laser spot fixed in relation to the cantilever throughout the scan cycle.

STM scanners (10 µm x 10 µm, or 1µm x 1µm) are also available for use with the 5500. Keysight's STM scanners deliver excellent results on a variety of conducting materials. These low-current and ultra-low-current STM scanners provide stable imaging at pico-ampere and sub-pico-ampere currents to resolve individual atoms and molecules. STM scanners take advantage of the extreme distance sensitivity of the tunneling current between two conducting electrodes. By measuring the tunnel-current variations as a probe is scanned over a sample's surface, STM is able to deliver the highest-resolution SPM images.

Open access to the scanner and easy alignment of optics help simplify use of the 5500. In addition, easy-to-load scanner nose cones make switching imaging modes quick and convenient. The nose cones are made from PEEK polymers, have low chemical reactivity, and can be used in a wide range of solvents. Their easy interchangeability provides tremendous flexibility.

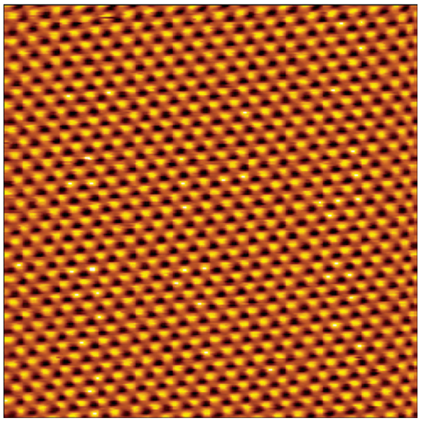

Figure 1. STM image of HOPG showing atomic structure. Scan size: 4 nm.

Key Features

- Exceptional environmental and temperature control
- Superior scanning in fluids, gases, or ambient conditions
- High precision AFM delivers atomic resolution
- The utmost flexibility from a highly modular system
- Convenient vertical sample approach

Applications

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

MAC Mode

Keysight's patented MAC Mode provides the industry's best performance for imaging in fluids and imaging soft samples, allowing researchers to image submolecular structures that cannot be resolved with any other AFM technique. MAC Mode is particularly useful in application areas that require high resolution and force sensitivity, such as biology, polymers, and surface science. AAC mode is included with MAC Mode.

MAC Mode III

Patented MAC Mode III provides three user-configurable lock-in amplifiers, affording researchers virtually limitless application possibilities and unprecedented speed. It also provides two expansion slots. MAC Mode III has been designed to allow single-pass imaging concurrent with KFM/ EFM. Simultaneous, high-accuracy topography and surface potential measurements are enabled by a servo-on-height cantilever approach that is not susceptible to scanner drift. KFM/ EFM is especially useful for measuring dielectric films, metal surfaces, piezoelectrics, and conductor-insulator transitions.

MAC Mode III also lets researchers perform vertical or lateral modulation studies and delivers a unique plot of the oscillating amplitude vs. frequency in contact. This capability allows easy optimization of the detection sensitivity for a broad range of cantilever spring constants.

In addition to KFM/EFM and piezo force, MAC Mode III allows the use of higher resonance modes of the cantilever. Higher harmonic imaging provides contrast different from that seen with fundamental amplitude and phase signals. This technique can be utilized to collect additional information about mechanical properties of the sample surface.

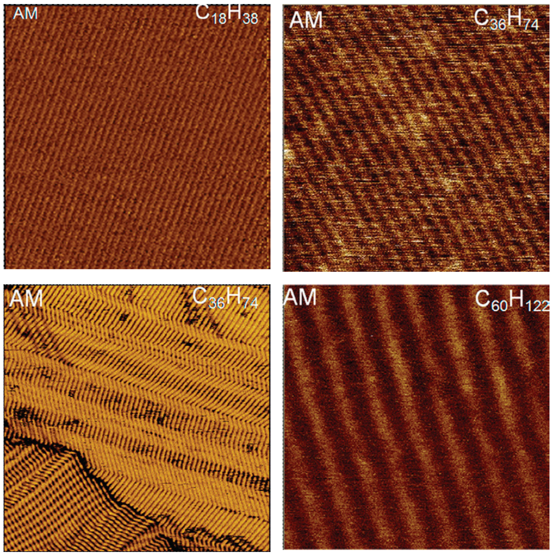

Figure 2. AFM images of normal alkanes on graphite obtained in amplitude modulation mode.

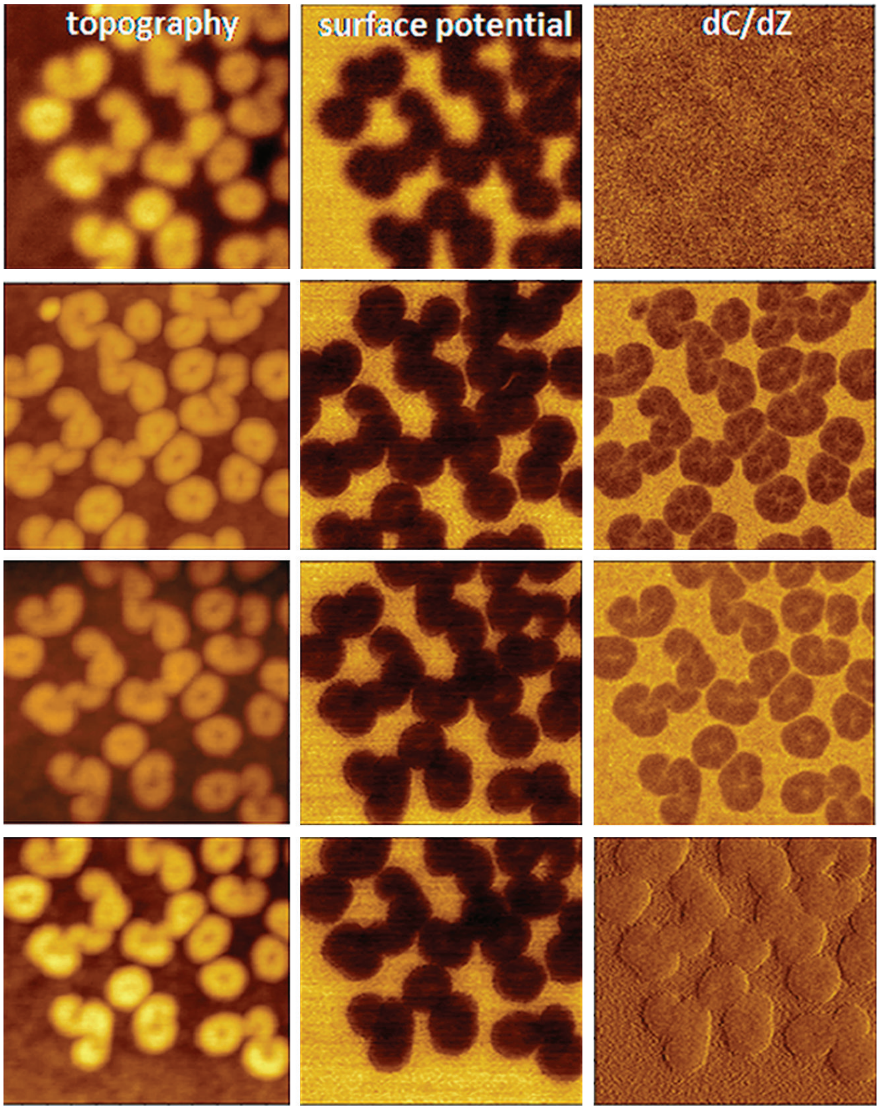

Figure 3. Topography, surface potential and, dC/dZ and dC/dV images of $F_{12}H_{20}$ adsorbates on Si. The images were obtained in the AM-FM mode. Scan area 300nm. The contrast covers the height and potential changes in the 0–200 nm and 0–1 V ranges. The contrast of dC/dZ maps is in relative units. The images in the columns from top to bottom were obtained respectively at the probe-sample distances of 1 nm, 7 nm, 15 nm, and 30 nm.

Temperature Control

Keysight's temperature controller uses a patented thermal insulation and compensation design to deliver the industry's most precise temperature control. It allows imaging during temperature changes and is fully compatible with all imaging modes, including those utilized in fluid. The temperature controller's design isolates the sample plate from the rest of the 5500 system. An insulated ceramic fixture protects the surrounding apparatus from the effects of heating or cooling, thus providing the most precise, stable temperature control available. Temperature control is offered with heating up to 250°C and cooling down to -30°C.

Environmental Control

Keysight's industry-leading environmental isolation chamber (EIC) has been specifically designed to meet the many requirements of intricate, demanding atomic force microscopy and scanning probe microscopy research. The EIC mounts directly to the 5500 and provides a sealed sample compartment that is completely isolated from the rest of the system. Eight inlet/outlet ports permit the flow of many different gases into or out of the sample area.

Keysight scanners reside outside the EIC, so they are protected from contamination, harsh gases, solvents, caustic liquids, and other damaging experimental conditions. With the EIC, humidity levels can be controlled, oxygen levels monitored and controlled, and reactive gases easily introduced into and purged from the sample chamber.

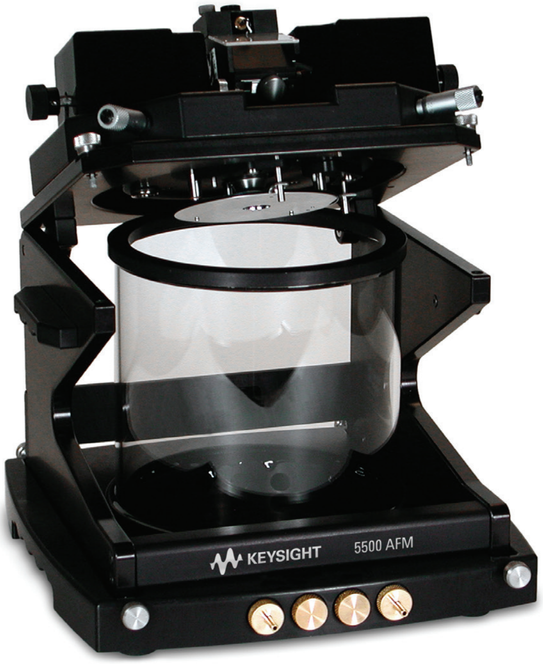

Figure 4. 5500 AFM with environmental chamber.

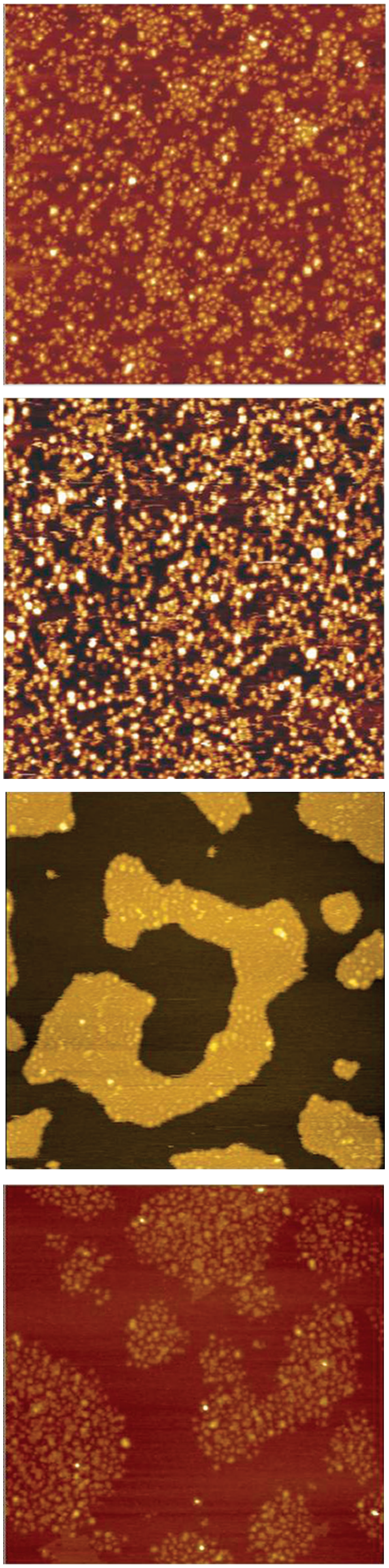

Figure 5. Topography images of multiarm star block copolymer macromolecules at low humidity (a), at high humidity (b), at high humidity after 12 hours (c), and at low humidity again (d). Scans are 2 µm.

Sample Plates

The unique design of Keysight's sample plates delivers superior sample stability and ease of use. Magnetic suspension provides easy loading and eliminates mechanical drift. The stand-alone plates permit simple sample mounting and application-specific plate customization. A modular design allows the plates to be used with an unparalleled number of options, such as open liquid cells, flow-through cells, salt-bridge cells (electrochemistry), Petri dishes (live-cell imaging), and glass microscope slides.

Electrochemical SPM

Keysight's electrochemical SPM option includes a complete kit for high-resolution in situ EC-SPM experiments. Electrochemical SPM offers a low-noise potentiostat/galvanostat for in situ EC-STM and EC-AFM. When combined with temperature control, it is possible to obtain valuable information about electrochemical processes that would otherwise be inaccessible. The addition of environmental control allows imaging with no dissolved oxygen in either aqueous or non-aqueous solutions.

The new SECM mode combined with the AFM is a seamlessly integrated technology package that enables scientists to perform scanning electrochemical microscopy (SEM) on conductive and insulating samples with a state-of-the-art atomic force microscope from Keysight Technologies. This new Keysight mode of AFM operation has been designed to provide ultimate performance as well as supreme ease of use.

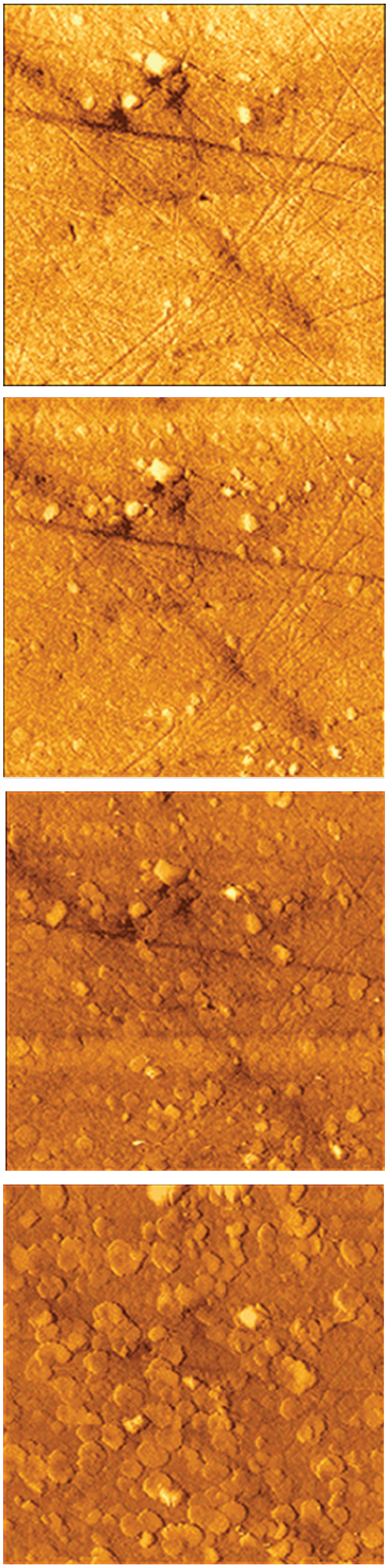

Figure 7. Corrosion study of a polished metal surface: rest potential (a), after two cycles (b), after three cycles (c), and after six cycles (d).

PicoTREC

Keysight’s exclusive PicoTREC molecular recognition tool kit is designed for use with MAC Mode. The option includes specialized hardware, electronics, consumables, and accessories. With PicoTREC, researchers can quickly distinguish between species that are engaged in molecular binding events and those that are not engaged in molecular 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 5500 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.

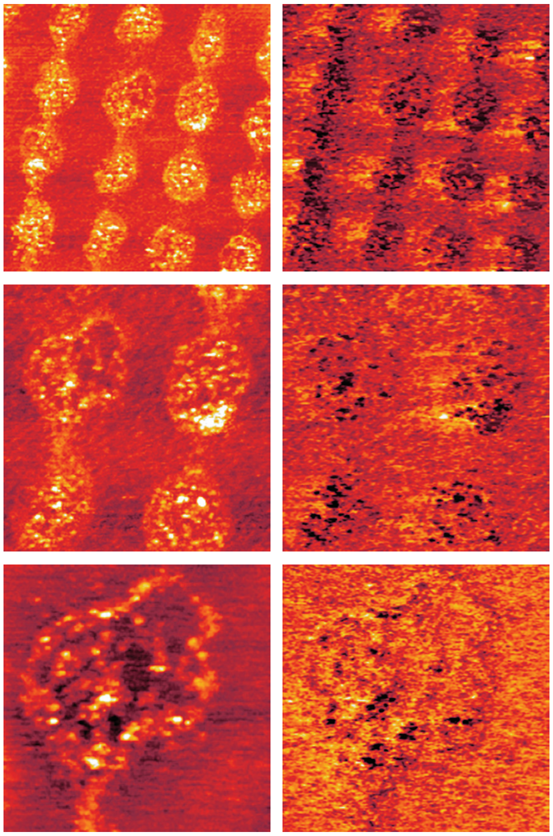

Figure 8. PicoTREC imaging of the micropatterned avidin molecules. Topographic images (left), and corresponding recognition images (right).

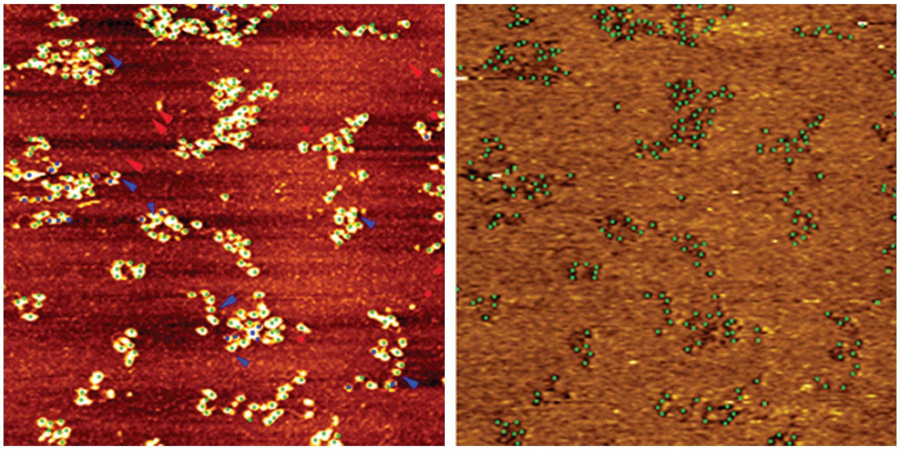

Figure 9. Accuracy and reproducibility using PiocTREC anti-His3 on AFM and chromatin on glutaraldehyde mica. PicoTREC can repeat an experiment in a matter of minutes. In the left image blue indicates misses and red indicates false hits. In the right image green indicates hits. There was five minutes between scans and number of hits went down on the rescan (96% to 92%) and the false positive rate was 2.8%. Images courtesy of Dr. Stuart Lindsay based on results generated in his lab by Dr. Hongda Wang at ASU.

Software

The 5500 utilizes Keysight's PicoView, an imaging and analysis software package that offers 3D rendering capabilities. PicoView allows complete control of all scanning parameters and provides the flexibility required for more complex experiments. An integrated script editor and sample scripts are also included.

For additional interactive post-processing capabilities, Keysight's easy-to-use Pico Image Basic imaging and analysis software package includes all of the features and functions required to build a basic surface analysis report on multi-layer measurement data that is input from the 5500. The document consists of a set of frames containing surfaces, profiles extracted from surfaces, the results of applying filters and other operators, analytical studies, and 2D and 3D parameters. A measurement identity card, screen notes, and illustrations can be added to each document. Pico Image Advanced and Expert packages are also available.

Ultra High Resolution Imaging on the 5500

The Keysight 5500 not only provides the researcher flexibility and modularity but also the highest imaging resolution. The 5500 has excellent signal-to-noise characteristics, low thermal drift and excellent control of the tip-sample forces. Figures 9–11 are just a few of the sub-100 nm features seen in a variety of polymers

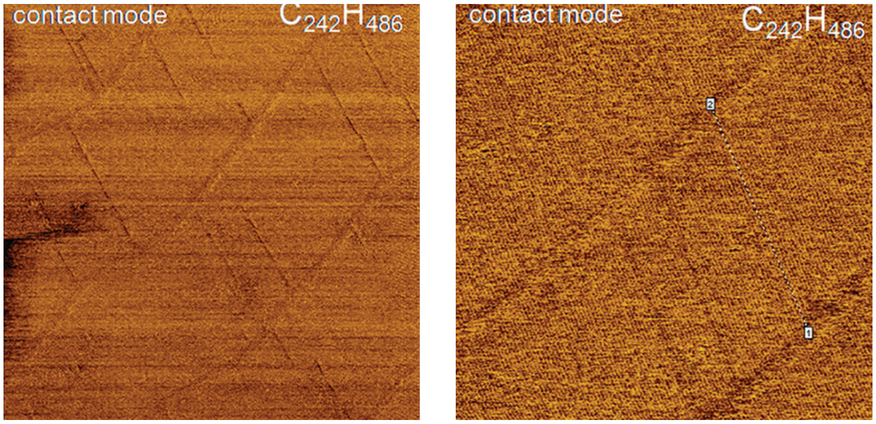

Figure 10. AFM images of $C_{242}H_{486}$ lamellae on graphite obtained in the contact mode. Several slightly twisted lamellae were detected in the images of $C_{242}H_{486}$. A number of linear defects caused by the missing chains or their parts are also distinguished in the 100 nm image (left). The individual alkane chains, which are extended between the edges of the lamellae, are also noticed in the 55 nm image (right).

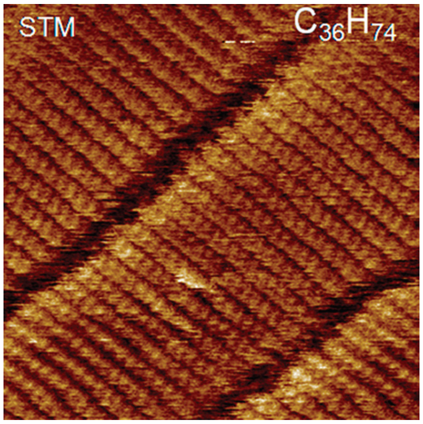

Figure 11. STM image of $C_{36}H_{74}$ alkanes on graphite. Scan size: 8 nm.

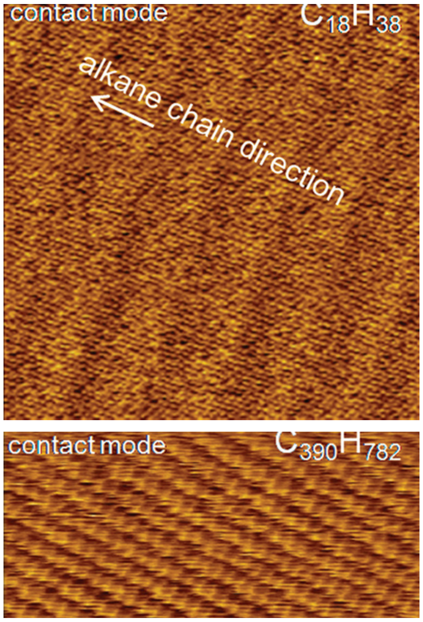

Figure 12. AFM images of $C_{18}H_{38}$ and $C_{390}H_{782}$ lamellae on graphite obtained in the contact mode. The spacings, which are related to the lamellae and individual chains, are distinguished in the image of $C_{18}H_{38}$ lamellae (top). The zigzag pattern along the closely packed alkane chains is seen in the image of the ultra long alkane – $C_{390}H_{782}$ (bottom).

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.

www.keysight.com/find/afm

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5500 AFM Specifications

Large Multi-Purpose Scanner	
Scan range	90 µm in XY, 7 µm in Z
Noise level	<5Å in XY, ≤0.3 Å (RMS) in Z
Small Scanner	
Scan range	9 µm in XY, 2 µm in Z
Noise level	<1 Å in XY, <0.2Å in Z
Sample Plate Sizes	Kinematic mount translatable plate
Optics	Navitar video camera
Vibration Isolation	Available
Controller	
Input	Ten 16-bit channels
Drive	5 channels ± 215 V, 24-bit
Output	Four 24-bit channels, ± 10 V
Interface	USB
Power	100 – 120 V AC or 220 – 240 V AC 1A; 50 – 60 Hz
Facilities Specifications	
Acoustic noise	< 75dBc
Temperature variation	Does not exceed ± 2°F
Humidity variation	Does not exceed ± 20% RH

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