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Central Research Facility

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Scanning Probe Microscopy

With STM, AFM, LFM, MFM, EFM, Nanoindentation

Scanning Probe Microscope Laboratory has two SPM systems (Dimension Icon and MultiMode 8) with one controller (Nanoscope V) from Bruker Corporation. Hence, only one system is operated at a time. The SPM system has a number of modes to explore surface properties of materials. At present only the following modes are operational upon payment basis.

- Scanning Tunneling Microscopy (STM)
- Atomic Force Microscopy (AFM)
- Lateral Force Microscopy (LFM) or Frictional Force Microscopy (FFM)
- Magnetic Force Microscopy (MFM)
- Electric Force Microscopy (EFM)
- Nanoindentation

Typical Specifications of SPM System

		Dimension Icon	Multimode 8
Scan area		≤ 90 μm × 90 μm	≤ 10 μm × 10 μm
Roughness (Z scale) variation		≤ 10 μm	≤ 2.5 μm
Scanner nonlinearity		<0.5%	<0.5%
Sample size:	Diameter Thickness	≤ 210 mm (with vacuum chuck) ≤ 15 mm	≤ 15 mm ≤ 5 mm
Resolution (AFM):	Lateral Spatial	1 Å 0.5 Å	1 Å 0.3 Å
Nanoindentation:	Tip Load	Berkovich type, Diamond ≤ 260 μN	
Image size		≤ 5120 pixel × 5120 pixel	
View Optics: Display and capture		180 μm to 1465 μm, 5 Mega-pixel	

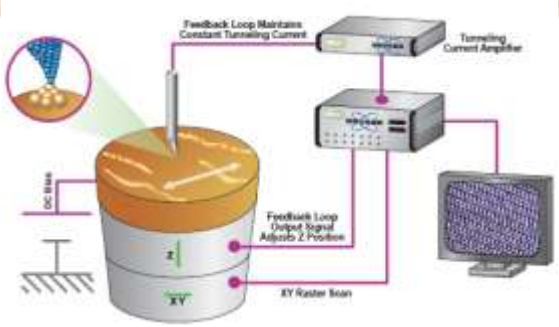
SPM Operations

Scanning Probe Microscopy (SPM) is a technique to provide spatially localized three-dimensional information by raster scanning a sharp probe (tip) across a surface of interest while monitoring the tunneling current or cantilever deflection from the probe sample interaction. Depending on the interaction, in addition to topographic information, a variety of surface properties can be measured (such as electrical, magnetic, and mechanical). The main SPM scan modes are contact mode and TappingMode™, and these build the foundation of all advanced scanning techniques. SPMs can also be used to measure material properties at a single point on the sample surface. This is accomplished through SPM spectroscopy.

STM Probes Cantilever Probes

Scanning Tunneling Microscopy (STM)

STM is the original embodiment of SPM. Here the probe is a metal needle, held perpendicular to the sample. The contrast mechanism is the tunneling current between the density of states of tip and a conducting or semiconducting sample when an electrical bias is applied. In feedback mode, the tip-sample tunneling gap is adjusted in order to maintain a predetermined constant current.

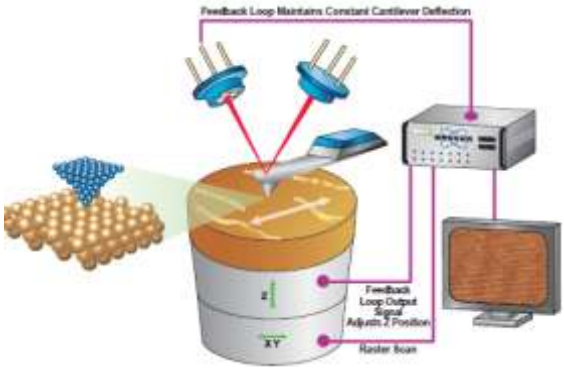


***Scanning Tunneling Spectroscopy (STS)*:** STM is used to acquire tunneling current vs. bias voltage characteristics to probe the electronic properties of a sample surface.

Applications: Studies of surface morphology, micro and nanostructures, surface reconstructions, molecular self-assembly, nanomanipulation, molecular interactions, electronic structure.

Atomic Force Microscopy (AFM)

Contrast mechanism in AFM is based on the van der Waals force on interaction between a microcantilever probe and sample surface.



In *Contact Mode*, the probe and sample are in direct contact throughout the raster-scan. The detector measures the deflection of the cantilever in response to the sample topography. During imaging, the sample is either held at a fixed height (Constant Height Mode) or modulated via a feedback loop to adjust the position of the sample to hold the cantilever deflection constant (Constant Force Mode).

In *Tapping Mode* of operation, a “tapping piezo” mechanically oscillates the probe at or near its fundamental resonance frequency. The oscillating probe is brought into intermittent contact with the sample to be imaged until the "tapping" between

the tip and the sample reduces the cantilever oscillation to a predetermined level. The controller records the cantilever's oscillation amplitude and its phase relative to the drive signal. A feedback loop is employed to adjust the Z position of the sample to maintain a constant tapping amplitude.

***Force Spectroscopy*:** AFM is used as a spectroscopy tool to acquire force vs. distance curve to probe tip and sample interaction at a given location on the sample surface. For example, contaminants and lubricants affect force spectroscopy measurements, as do thin layers of adsorbates on the sample surface.

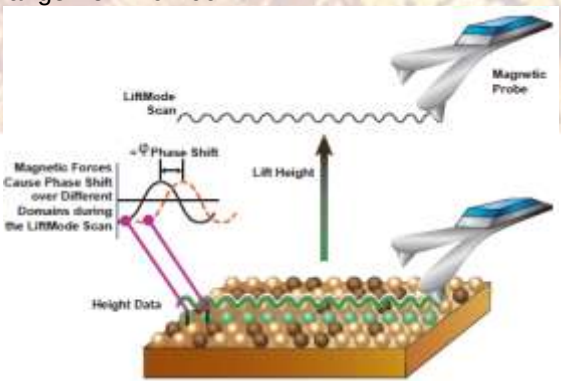
Applications: Studies of surface morphology, micro and nanostructures, surface reconstructions, molecular configurations.

Lateral Force Microscopy (LFM) or Frictional Force Microscopy (FFM)

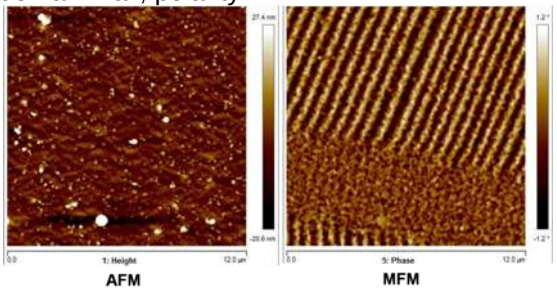
LFM is a contact AFM mode that identifies and maps relative differences in the frictional forces between the probe tip and the sample surface. In LFM, the scanning is always perpendicular to the long axis of the cantilever. Forces on the cantilever that are parallel to the plane of the sample surface cause twisting of the cantilever around its long axis. This twisting is measured by the quad-cell PSPD.
Applications: Identification of transition between different components in, e.g. polymer blends, composites, contaminants; delineating coverage by coatings; determination of frictional coefficient.

Magnetic Force Microscopy (MFM)

A ferromagnetic probe interacts with the magnetic field above a ferromagnetic sample. The sample is first scanned in Tapping Mode to obtain the sample topography. The topographic information is stored and retraced with a user-selectable height offset in LiftMode. During the lift-trace, the magnetic data is collected by measuring the variations in the phase signal. Typical lift heights in MFM range from 20-100 nm.

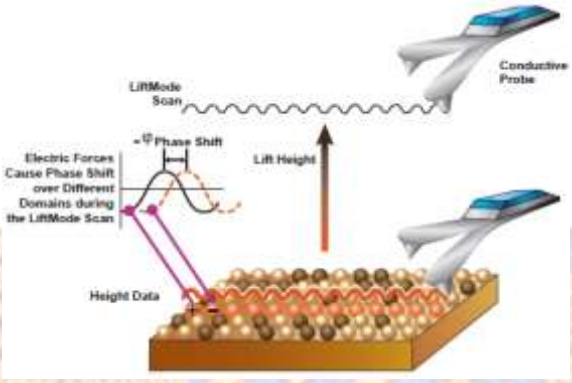


Applications: Imaging and identification of magnetic phase, magnetic domain structure, domain wall, polarity.



Electric Force Microscopy (EFM)

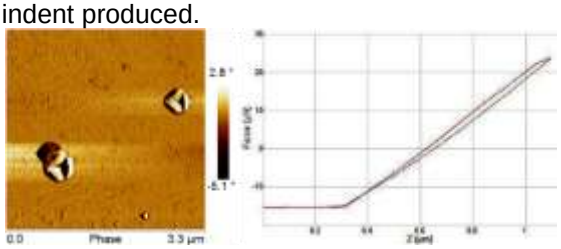
EFM uses a conductive tip to gather information about the electric field above a sample, e.g. made of a ferroelectric material. A topographic image is acquired and the same is retraced with a user-selectable height offset in LiftMode in the same manner as in MFM. During the lift-trace, the electrostatic force data is collected by measuring the variations in the phase signal. Alternatively, phase shift can be used as a feedback signal moving the imaging contrast to frequency shift making this mode useful for quantitative interpretations. Typical lift heights in EFM range from 20-80 nm.



Applications: Imaging and identification of electronic phase, structure of charge distribution or electronic polarization domain, polarity.

Nanoindentation

AFM can be used to deliberately modify a surface. This modification is accomplished with specialized SPM software that provides additional ways to control the motion of the scanner and thus the probe or the sample. A sharp diamond tip is pressed down on the sample surface to produce an indent. A *Force-distance* characteristic curve is also generated. Surface mechanical properties are correlated with the depth and area of the indent produced.



Applications: This mode is used to quantify mechanical and tribological properties of the sample surface like hardness, stiffness, Young's modulus, fatigue, yield, creep, adhesion, elasticity, elastic or plastic deformation energies etc.

Outreach

- SPM is an indispensable microscopy and spectroscopy equipment in educational and research institutes for the use of the faculty members and research scholars of the science and engineering disciplines like Applied Physics, Applied Chemistry, Applied Geology, Applied Geophysics, Electronics engineering, Fuel and Mineral Engineering, Mechanical engineering, Electrical engineering, Mining engineering, Petroleum engineering, Chemical engineering, Civil engineering etc.
- Outside users of the same and many interdisciplinary fields like Materials Science, Nanoscience and Technology, Surface Science, Metrology, Electrochemistry, Polymer Science, Bioscience, Biotechnology, Biomedicine, etc. are benefitted from this facility.
- The system is also expected to be extensively used by the relevant sectors of industry and national research laboratories for quality maintenance, research and development activities.

SPM Services

- SPM services are provided on payment basis to both internal and external users. Requisition form of service, instructions and service charges can be downloaded from the link: http://iitism.ac.in/pdfs/research/SPM-Form-n-Information.pdf
- Internal users should directly get in contact with the SPM Laboratory to book a work slot. External users may contact with the System in Charge, SPM, CRF.
- All payments must be made prior to booking the slot. Original of the payment slip (carbon copy for deposit in ISM cash counter in the head of CRF-SPM) or original Demand Draft [drawn in favour of Registrar, IIT (ISM)] must be provided with the booking form.
- To avail the concessional rates for academic and research institutes, as mentioned in the requisition form and information sheet, an external user should also send a documentary evidence (i.e. a letter of request from an authorized signatory in his / her institute's / department's original letter head) for the same along with the filled up registration form and Demand Draft. Schedule of work slot will be informed by email.

Guidelines on Sample Requirement and Study

(i) Samples should be prepared by the users and brought to the facility on the date and time of appointment for analysis. Services through mail are also provided to external users at their own risk. In the latter case one may send the samples, payment in prescribed form and other documents to the official address of the system in charge.
(ii) Samples should be dry, moisture free, clean and dust free (no loose particles on the sample surface).
(iii) Sample size and its roughness height variation should be maintained within the limits as mentioned on the front page of this brochure. If one has no idea about the roughness of the sample, it has to be polished and should look shiny.
(iv) Users should have a primary idea of the intrinsic property of the material with respect to the features they wish to explore specially in LFM, MFM & EFM.
(v) Observation of atomic features is not a usual matter except certain extremely favorable conditions. So generally it is a “No”.
(vi) If one has any doubt about the availability of any service or needs further clarification regarding any aspect, please discuss with the system in charge before making payment for the service.
(vii) The operator will not be responsible for any damage to the sample during operational procedure.

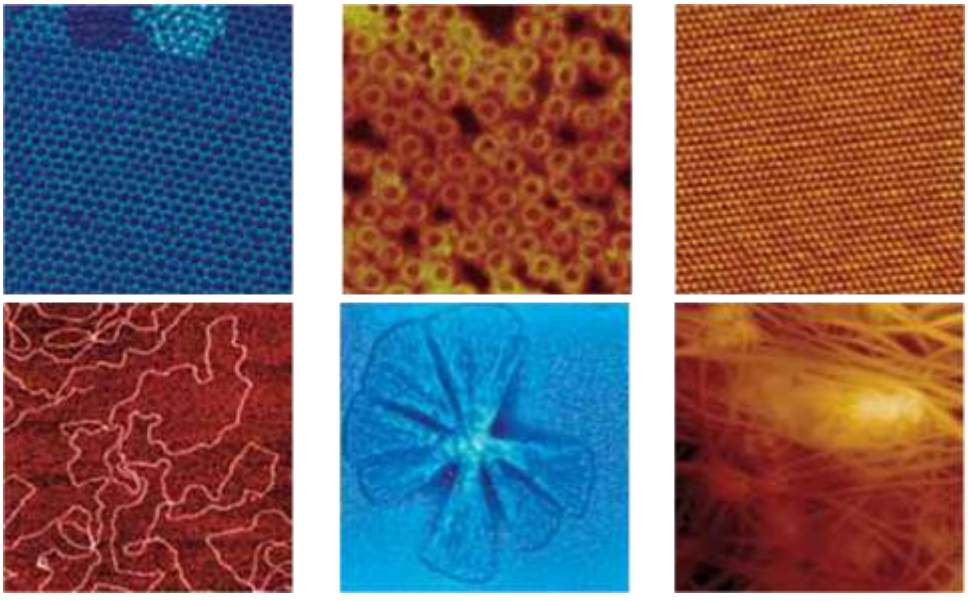


Image courtesy: Bruker Corporation