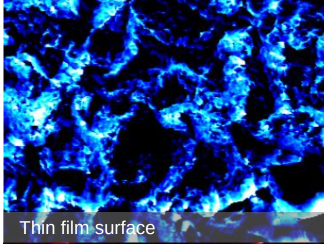
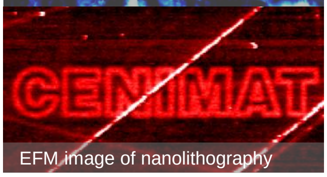
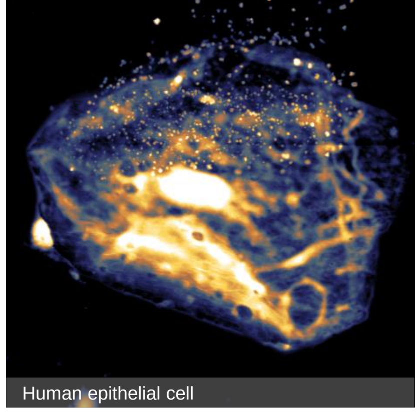
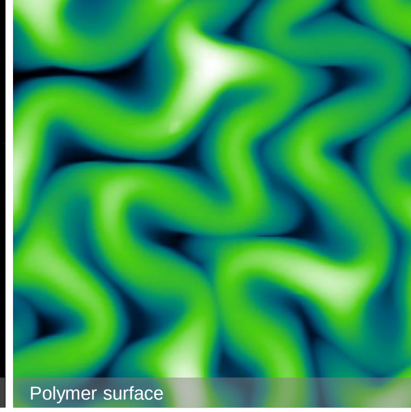
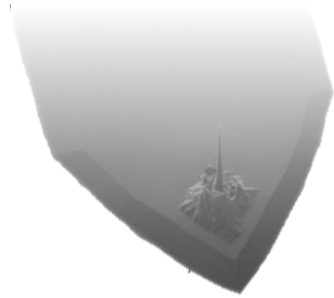

Thin film surface


EFM image of nanolithography


Human epithelial cell


Polymer surface

Atomic Force Microscopy



Nanofabrication Laboratory

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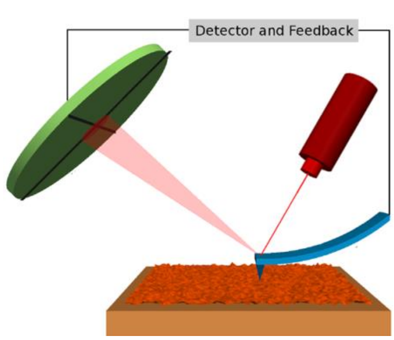


Adapted from Filipovic, L; Topography Simulation of Novel Processing Techniques; PhD Dissertation, Wien 2012

The principle

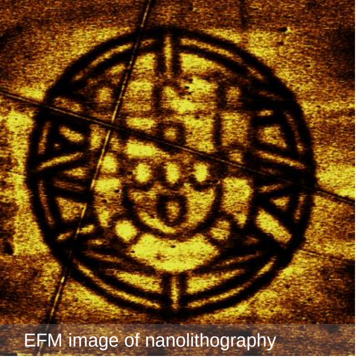
Atomic force microscopy, or AFM, is a high resolution imaging technique that can, under some conditions, achieve atomic resolution. With a principle different from many other microscope techniques, in AFM, a nano-metric probe is approached to a surface and used to scan it. The position of the probe is monitored using a detection system (commonly, a beam of light reflected by the probe to a position sensitive photodiode) and forwarded to a feedback system, which can raise or lower the probe in order to assure that the distance probe-sample is constant. Each time the probe encounters an obstacle – a change in topography – its behaviour or position is affected, and the AFM will record that change, allowing to map a surface. In fact, the majority of AFMs function in a 'tapping' mode, a mode in which the probe, instead of being deflected against a surface, is oscillated above it, with the alterations in the oscillation generated by the surface, helping to create surface images of an object of study.

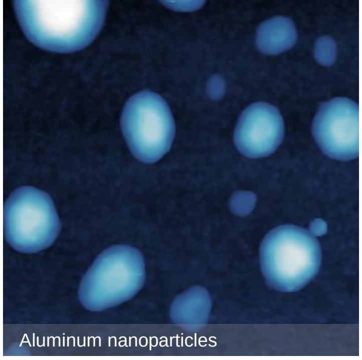
AFM's unique range of possibilities

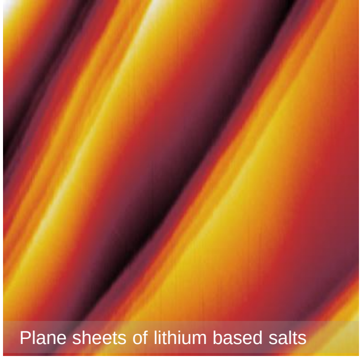
AFM's unique way to interact with the sample opens doors to types of data that cannot be acquired in other microscopes. For example, it is possible to apply a bias between tip and sample and map the conductivity together with topography. Or the same way the oscillation of the probe can be used to map the topography, it can be used to detect electrostatic or magnetic phenomena. The probe can also be used to study properties of the sample, by studying its behaviour when the probe approaches or contacts against it.

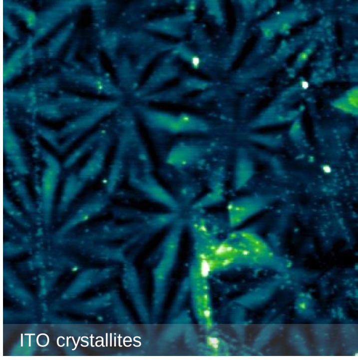
Applications

From point by point to 4D image generation for morphological, structural, mechanic and electrical sample study. Z-axis picometre resolution sensors allow for precise topography acquisition and roughness analysis. Few to none sample preparation coupled with no need for controlled conditions means that virtually any sample can be imaged with AFM - biologic elements can even be imaged in liquid media.


EFM image of nanolithography


Aluminum nanoparticles

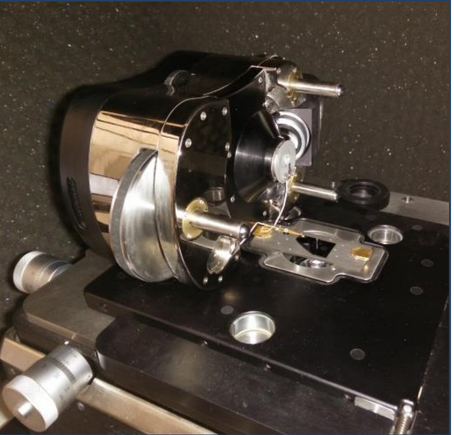

Plane sheets of lithium based salts


ITO crystallites

Technical specifications

Asylum Research MFP-3D Stand Alone

- Maximum scan range:
  - XY axis - 90x90 µm
  - Z axis - 14 µm
- Max resolution (SNR limit)
  - XY axis – 500 picometres
  - Z axis – 60 picometres
- 100 kHz feedback loop locked to deflection (contact) or amplitude (tapping) signal
- Measurable signals include (but not limited to):
  - Contact mode - height, deflection and lateral force
  - Tapping mode – height, amplitude and phase
- Spectroscopy acquisition for over 30 signals (10 of which are user customizable) allows complex point by point generation of single spectra or map spectra

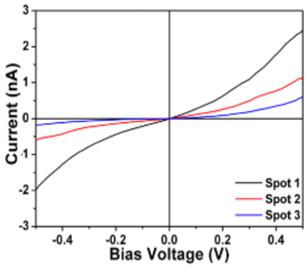


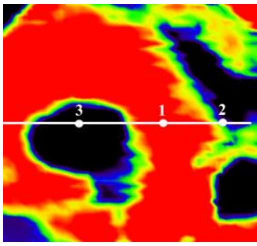
Additional features

- Current mapping supported by an ORCA module (sensitivity of 2 nA/V) able to bias the sample with a ±10 V range and compatible with a probe station system
- Lift mode and probe biasing circuit allow for on-demand electrostatic (EFM), magnetic (MFM) and kelvin probe force (KPFM) microscopy measurements
- Piezoresponse force microscopy (PFM) permits imaging and manipulation of ferro/piezoelectric responsive domains in samples
- Liquid operation is supported, both using a fluid cell and in room conditions
- Surface modification/analysis cab be achieved by local oxidation or indentation
- Complex spectroscopy analysis – both point by point and mapping supported

Conductive AFM (CAFM) – Current mapping and I-V curves

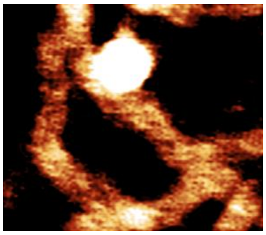
Conductive AFM allows to map the conductivity of a surface at the micro and nanoscale, at same time as the surface. It is also possible to plot highly precise I/V curves on selected areas, like on the nanostructures to the right. The distance between points is ~20 nm.

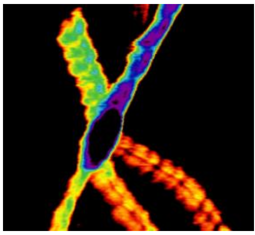




Liquid media operation – biology in its native habitat

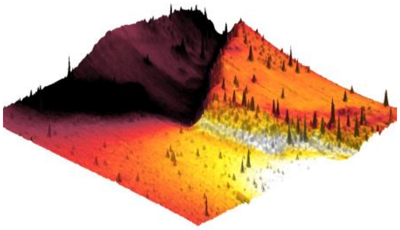
The possibility of operating an AFM in liquid, allows for high magnification images of bio-molecule structures in their native media to be recorded, like the DNA-nuclease interaction on the near-right or the amyloid fibrils on the far-right.





4 dimension rendering

Z-axis picometre precision acquisition allows precise production and manipulation of 4D images, plotting several data at the same time. In the image on the right, the surface potential of the insulator-contact-semiconductor boundary of a transistor channel is plotted over the topography, highlighting the different work functions of each step of deposited material.



Spectroscopy measurements

Spectroscopy consists in measuring the probe's behaviour, point by point, when it is approached to the surface. The approach behaviour, like changes in deflection or amplitude, can shed light on surface properties like Young modulus, adhesion, long range forces, etc.
For example, on the right it is possible to see the effect on a cantilever's oscillation amplitude as it approaches a surface under different bias.