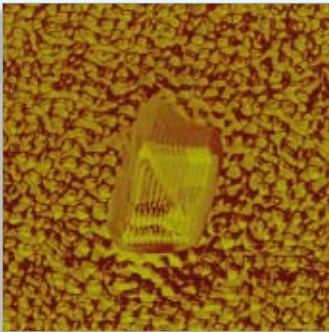


a cantilever tip with a reflected laser beam



Scanning Probe Microscopy (SPM)

- topography
- magnetic domains
- electrical behaviour
- non-destructive
- surface properties
- chemical interactions

Scanning probe microscopy (SPM) provides information on the nanometer scale. Using a very sharp tip, height profiles can be measured with a resolution better than 1 nm. Measurements can be performed in an inert atmosphere, at elevated temperatures and even in liquids such as water. Beyond height information, SPM offers the possibility to study mechanical properties as well as electrical and magnetic behaviour of materials. Attaching functional groups to the sharp tip even allows imaging of chemical and biological interactions on a nanometer scale.

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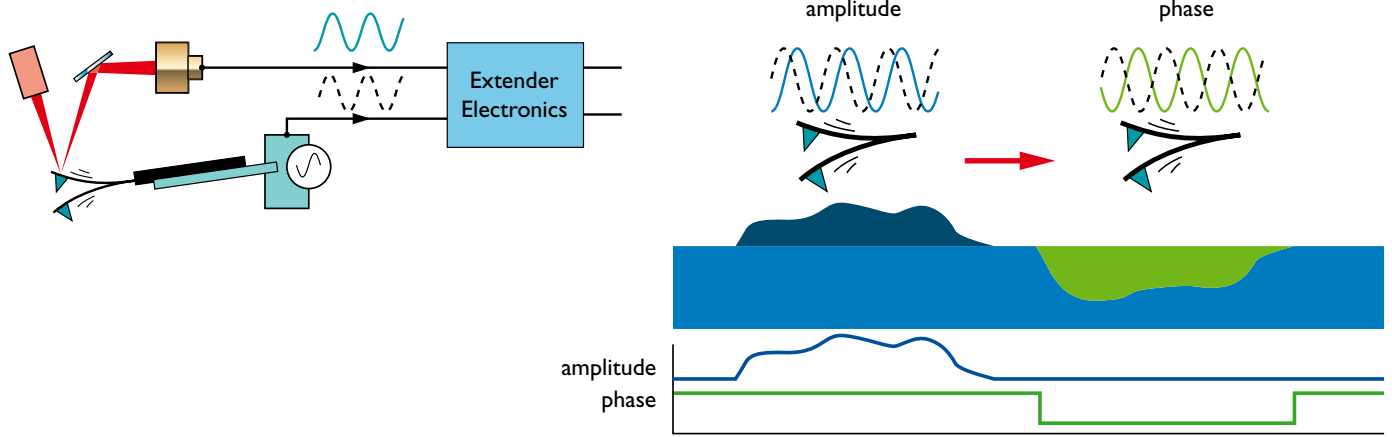


Fig.1: Visualisation of height and phase imaging using AFM. When the vibrating tip hits the sample, the feedback loop makes it move upwards to track the topography. During the contact, the phase of the vibration can change as a result of visco-elastic behaviour of the material. Using a combination of height and phase information, both topography and other material properties can be studied.

Scanning Probe Microscopy (SPM) comprises a family of techniques in which a sharp probe (cover) on a cantilever is precisely scanned across a surface. The force between the tip and sample results in motion of the cantilever. The motion is followed with a laser beam that is reflected by the cantilever. In this way a small change in the tip position is translated to a larger movement of a laser spot. When the reflected beam changes position, the output of a photodetector changes proportional to the motion of the cantilever. Motions smaller than 1 nanometer are routinely measured with this method. As a result, a surface can be imaged by scanning the tip and maintaining the force between the probe tip and the sample surface. Using different probes it is possible to examine a variety of forces - i.e. van der Waals, friction, magnetic or electrical.

Atomic Force Microscopy (AFM) – The basics

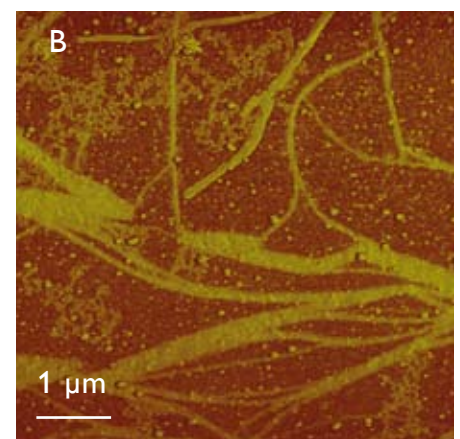
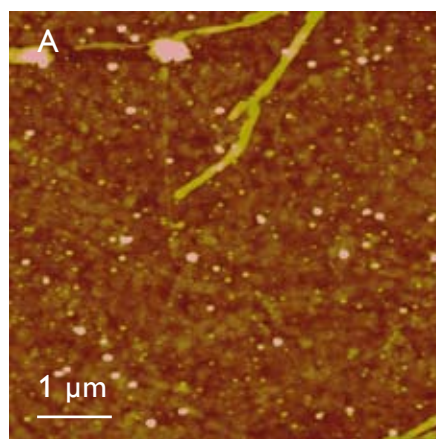
AFM is the most basic of scanning probe techniques, providing topographic information. As it produces height images with nanometer scale resolution, it is used to solve processing and material related problems in a wide range of technologies. The tips of AFM probes are normally very sharp (1-10 nm tip diameter) to ensure high-resolution tracking of the surface. Contrary to other techniques used to characterize topography, a feedback loop adjusts the probe up or down to restore the level of interaction. A computer stores the vertical position at each point and assembles an image.

Tapping mode and phase imaging

When the probe is kept in contact with the sample while 'dragging' it for imaging

purposes, the shear forces can be large and it is possible to damage soft materials. As an alternative, tapping mode AFM can be used (Figure 1). First the cantilever with the probe tip at its distal end is made to resonate. At the frequency at which this occurs (10-400 kHz range), the amplitude and phase of the vibration is measured. The probe tip is then scanned at some distance from the surface so as to touch it only when the maximum amplitude is reached. This is a gentle approach, allowing even the imaging of single DNA molecules on surfaces. Besides an amplitude change as a result of topographical variations, the phase of the vibration can change. This effect is indicative of a variation in material properties, rather than height. When height and phase data are combined, it is possible to determine whether measured features are the result of chemical differences or height differences on a surface (Figure 2).

Fig. 2: Height (A) and phase (B) image for a sensor material. In the height image, various particles and line structures are visible on the substrate. Only in the phase image, the presence of an organic self-assembled monolayer is visible as a result of its different mechanical properties.



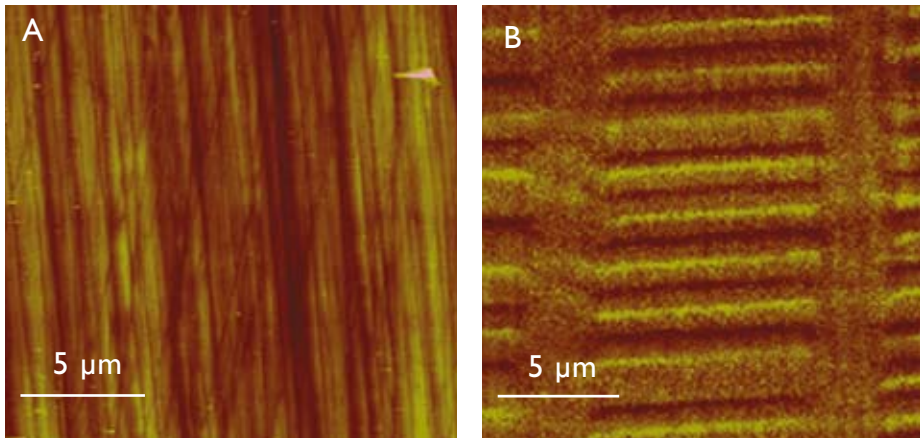


Fig. 3: Magnetic Force Microscopy (MFM) image of overwritten tracks on a textured hard disk. The written data is not visible in the topographic image as the roughness of the material is high (A). However, during a second pass above the surface only the magnetic forces are active and the written information becomes visible (B). The topography (A) was imaged using tapping mode; the magnetic force image of the same area (B) was captured with lift mode (at 35 nm from the surface).

Probing a range of surface properties

Several forces can be used to provide information about surface properties other than topography. Using different probe tips, images can be made that represent mechanical, electrical and magnetic properties, hydrophobicity, tribology and other material properties.

This more general approach of the same technology also includes the study of biological and chemical interactions between activated tips and surfaces of interest. Some analytical tools require direct contact between the tip and the surface (such as conduction, friction or hardness measurements). Other methods rely on a second pass measurement. First a height image is measured, after which a second pass is made at about 20 nm above the surface. Several long-range forces (such as magnetism or surface potential) can be measured specifically using this so-called lift mode.

Three standard lift modes

Magnetic Force Microscopy shows the fine details of bit and domain structure on hard disks, as well as the magnetic fields emanating from operating recording heads. It also shows the domain structure in magnetic materials (Figure 3). For such measurements a tip is used that is coated with a ferromagnetic thin film, i.e. cobalt-chromium.

Electric Force Microscopy distinguishes fixed charges, conductive and insulating regions and identifies short and open circuits. Obviously, the tips used for these

measurements require a conductive coating like platinum-iridium.

Scanning Surface Potential Microscopy (or Kelvin Probe Microscopy) distinguishes materials based on the work function and related electronic properties. For example, injection barriers in organic semiconductors or trapped charges in a thin film transistor can be studied with this method. Because of the high resolution of SPM methods, even the electrical behaviour of nanowires can be imaged (Figure 4).

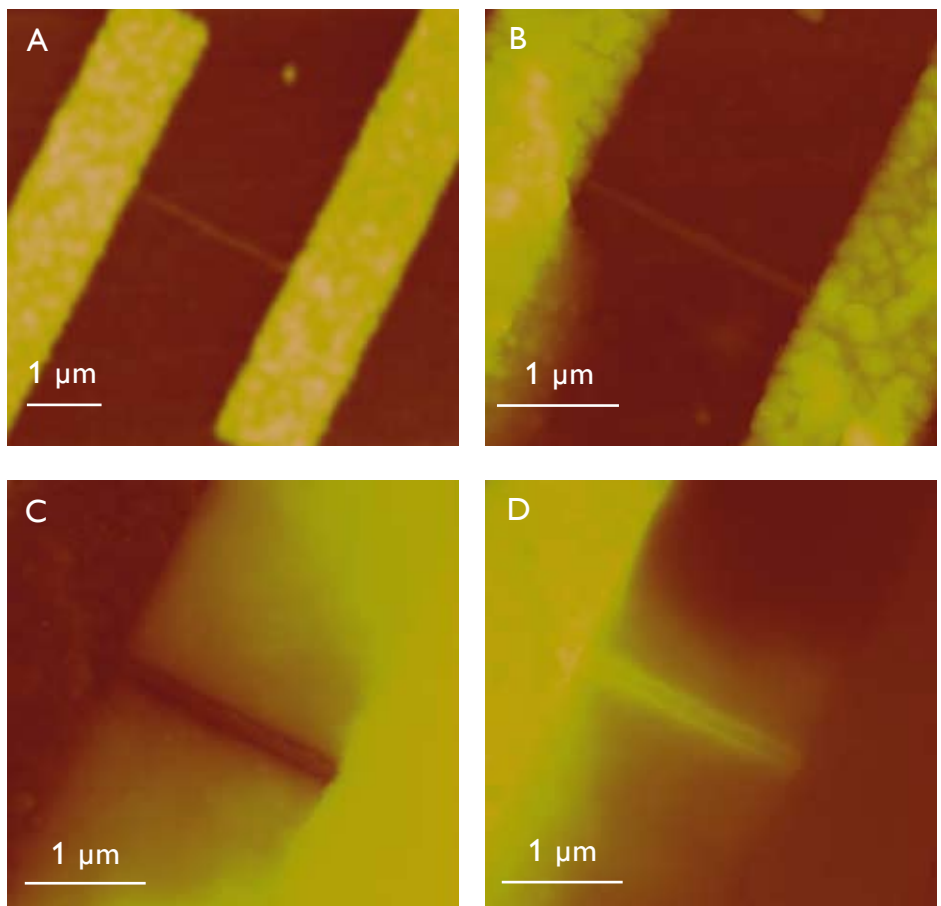
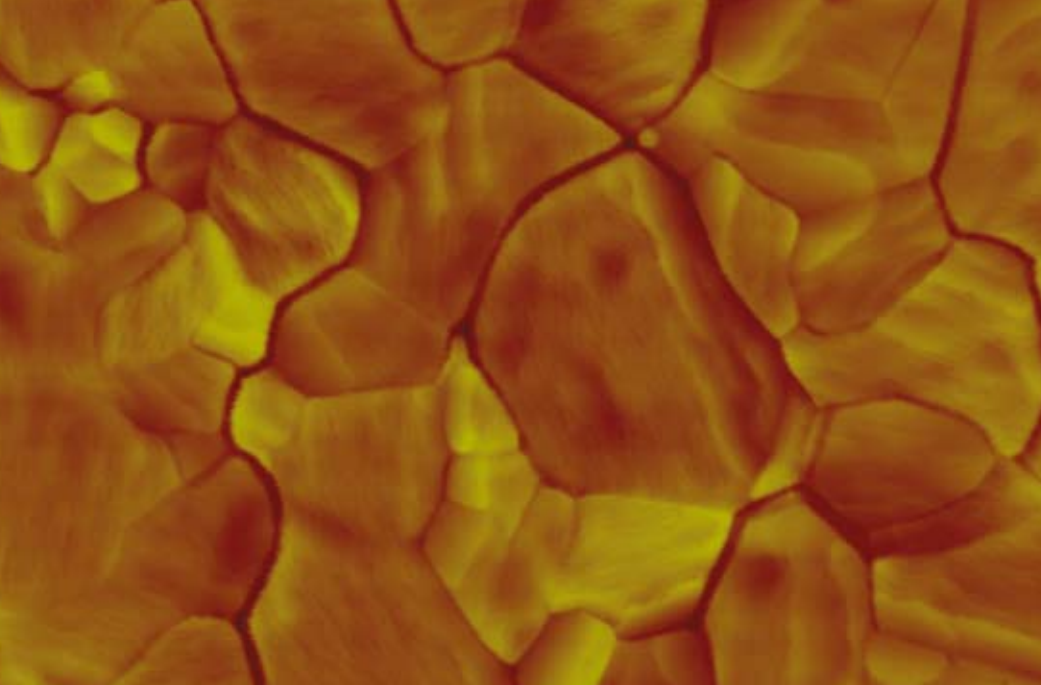


Fig. 4: SPM images of a nanowire between two electrical contacts. (A)-(B) AFM images of the 50 nm thick nanowire. (C)-(D) Surface potential images obtained at 20 nm above the surface using 3V and -3V respectively. Figure C shows that there is an injection barrier at the right electrode, but only for one direction of current flow, as Figure D does not show a sharp potential change at an electrode.



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Applications

- Structural characterization of liquid crystalline materials
- Fault identification in microscopic structures
- Surface potential measurements on active polymer TFTs and in nanowires
- Stability and reactivity studies for various thin layers
- Detection of (biological) interactions at the nanometer scale
- Study of phenomena and processes, such as abrasion, adhesion, cleaning, corrosion, etching, friction, lubrication, microlithography, moulding, plating and polishing

Characteristics

Obtained information

- Topographic (< 1 nm details)
- High-resolution magnetic, electrical and chemical information

Techniques used

- Force Modulation
- Lateral Force Microscopy (LFM)
- Magnetic Force Microscopy (MFM)
- Electrical Force Microscopy (EFM)
- Conductive AFM
- Kelvin probe microscopy/ Scanning Surface Potential Microscopy (SSPM)
- and other interaction modes

Sample type

- Solids
- Thin films
- Both organic and inorganic materials

Atmosphere

- In air, nitrogen or in liquid; Temperature between 10-250°C

Sample requirements

- No size requirements

Lateral and depth resolution

- For relatively flat samples < 1 nm in Z and 1-4 nm in XY

Quantification

- Only for topography; otherwise dependent on the force used for mapping

Routine analysis

- Only for topography



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