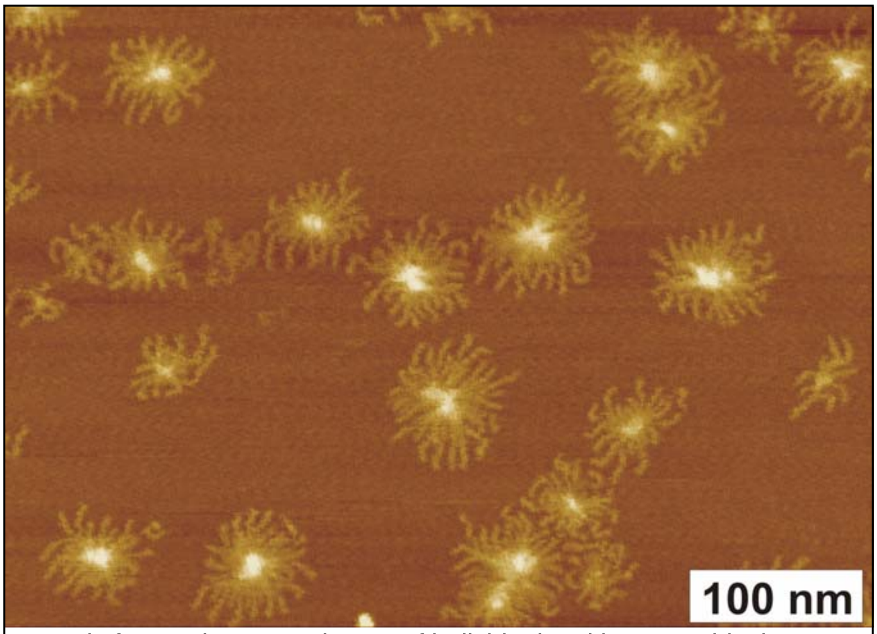
Atomic Force Microscopy Facility

Institute of Materials



Atomic force microscopy image of individual multiarm star block copolymer molecules.
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1. Introduction

Atomic force microscopy (AFM) has become a standard technique, both to visualize surface topography and microstructure as well as to probe materials properties. The technique is based on the principle that when a tip, which is integrated to the end of a spring cantilever, is brought within the interatomic separations of a surface, interatomic potentials will be developed between the atoms of the tip and the atoms of the surface. As the tip travels across the surface, the interatomic potentials will then force the cantilever to bounce up and down with the contours of the surface (Figure 1). Therefore, by measuring the deflection of the cantilever, the topographical features of the surface can be mapped out. The advantage of AFM compared to, for example, electron microscopy are the ease of sample preparation and the possibility not only to visualize surface microstructure and topography, but also to probe a broad range of materials properties.

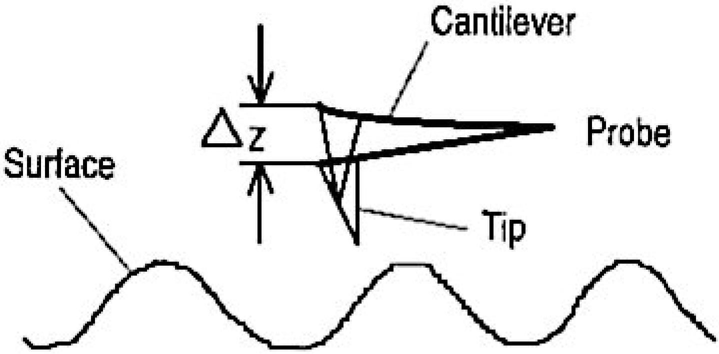

Figure 1: *Schematic illustration of the interaction of an AFM cantilever with the sample surface. (Source: http://www.pace.leeds.ac.uk/labs)*

A schematic diagram showing some of the essential elements of an atomic force microscope is given in Figure 2. The forces between the sample and the tip are measured using a laser and detector, which monitors the cantilever motion. The negative feedback loop moves the sample up and down via a piezoelectric scanning tube (PZT) so as to maintain the interaction force to a preselected level (Reference Force). A three dimension image can finally be constructed by recording the cantilever motion in Z direction as a function of the sample's X and Y position. Theoretically, for any material which has a certain rigidity, surface images with atomic resolution can be produced as the latest development in laser technology has allowed the deflection of the cantilever to be detected down to the Angstrom scale.

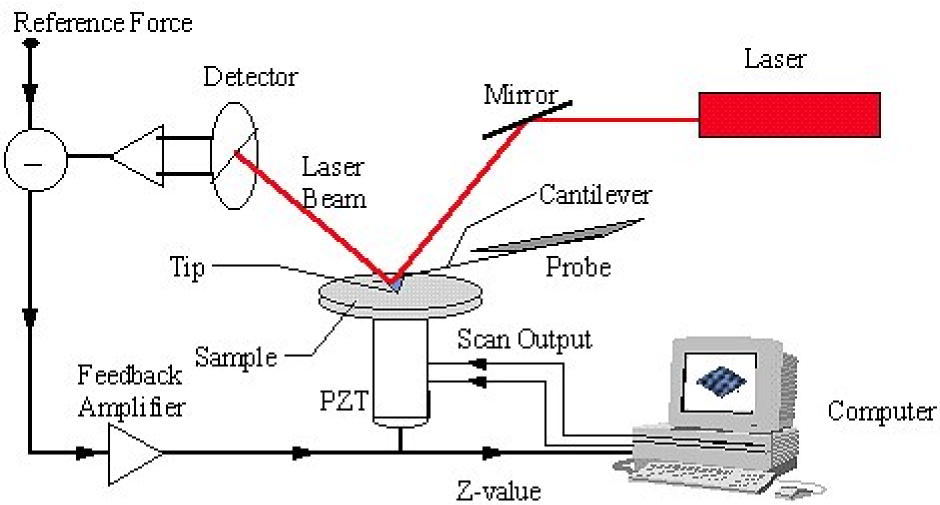

Figure 2: *Diagram showing the essential elements of an AFM. (Source: http://www.pace.leeds.ac.uk/labs)*

2. Equipment

The Atomic Force Microscopy (AFM) Facility at the Institute of Materials at EPFL is located in rooms MXG 922 and MXG 923 and consists of two instruments, a Veeco CP-II and a NanoScope IIIa microscope. In the following two paragraphs, a brief description of the main features of these two instruments will be given.

2.1 The CP-II AFM

The CP-II is a user-friendly instrument that is particularly suited for routine experiments.

Specifications:

- Lateral range of scanning area: ~ 90 μm x 90 μm.
- Maximum sample size: 50 mm x 50 mm x 20 mm.
- Resolution: μm to Angstrom.

Modes:

- **Contact AFM:** Measures topography by sliding the probe's tip across the sample surface.
- **TappingMode AFM:** Measures topography by tapping the surface with an oscillating tip. This eliminates shear forces, which can damage soft samples and reduce image resolution. TappingMode is available in air and fluids. This is the technique of choice for most AFM work
- **Scanning Tunneling Microscopy (STM):** Measures the topography of the sample surface using a tunneling current, which is dependent on the separation between the probe tip and a conductive sample surface.

2.2 The NanoScope IIIA AFM

The NanoScope IIIa is a more advanced instrument, which offers a wide range of possibilities to visualize surfaces and probe materials properties. In contrast to the CPII microscope, the NanoScope IIIa also can be operated at temperatures between - 35 °C and 250 °C and also allows experiments to be carried out in liquids.

Specifications:

- Lateral range of scanning area: ~110 μm x 110 μm or 10 μm x10 μm (depending on the scanner).
- Maximum sample size:15 mm diameter, 5mm thickness.
- Resolution: μm to Angstrom.
- Liquid cell: experiments can be carried out in water, solvents and buffers
- Temperature range = - 35 °C – 250 °C.

Modes:

- **Contact AFM:** Measures topography by sliding the probe's tip across the sample surface.
- **TappingMode AFM:** Measures topography by tapping the surface with an oscillating tip. This eliminates shear forces, which can damage soft samples and reduce image resolution. TappingMode is available in air and fluids. The technique of choice for most AFM work.
- **Phase Imaging:** Provides image contrast caused by differences in surface adhesion and viscoelasticity.
- **Non-contact AFM:** Measures topography by sensing Van der Waals attractive forces between the surface and the probe tip held above the surface. Provides lower resolution than either contact or TappingMode AFM.
- **Electric Force Microscopy (EFM):** Measures electric field gradient distributions above sample surfaces. Performed using LiftMode to track topography.
- **Surface Potential Microscopy:** Measures differences in local surface potential across the sample surface. Performed using LiftMode to track topography.
- **LiftMode:** A combined, two-pass technique that separately measures topography (using TappingMode) and another selected property (e.g., magnetic or electric force), using the topographical information to track the probe tip at a constant height above the surface.
- **Force Modulation:** Measures relative elasticity/stiffness of surface features.
- **Lateral Force Microscopy (LFM):** Measures frictional forces between the probe tip and sample

surface.

- **Scanning Tunneling Microscopy (STM):** Measures topography of the sample surface using a tunneling current, which is dependent on the separation between the probe tip and a conductive sample surface.
- **Lithography:** Use of a probe tipe to mechanically scratch or indent a sample surface. May be used to generate patterns, test surfaces for microhardness, etc. Performed using AFM and STM.

3. Organization and Rules

Introduction and training:
New users should contact Philippe Charpilloz for an introduction and training.

Number of users:
The number of users is restricted to two per laboratory. Exceptions may be possible but need to be discussed with the Director.

Costs:

- The AFM facility does not provide cantilevers, substrates or other consumables that are needed for sample preparation or microscopy. Users are responsible for purchasing these materials themselves.
- Fixed costs (maintenance, maintenance contracts) will be billed annually to the user laboratories. By using the AFM facility, the user laboratories agree to contribute to the fixed costs proportional to the time they have used the AFM facility. User time is defined as the time a user is logged-on on the PC that operates the AFM. This time is monitored automatically.
- Any costs due to damages to the AFM instruments that are directly related to the users' operation of the instrument will be fully charged to the user's laboratory.
- Special conditions apply for users from outside EPFL. Interested parties should contact Philippe Charpilloz or Harm-Anton Klok.

Instrument booking and use:

- Reservation forms are placed on the doors of the AFM lab. This system will be replaced by an internet booking system in the near future.
- Between 8 am and 8 pm, the microscopes can be booked at most 4 hours per day per user.
- Prior to starting their experiments, users should inspect the microscope for any damages and sign the log-on sheet. With their signature, the users accept the microscope for their use. After completion of their work, users sign the log-out sheet to certify that the microscopes are left behind in good order.