Consulting
Service measurements
Project collaboration
Training & Education

SUL

Swiss Scanning Probe Microscopy User Laboratory

CCMX
Competence Centre for
Materials Science and Technology

EMPA
Materials Science & Technology

Prof. Dr Hans Josef Hug

Welcome to SUL, the Swiss Scanning Probe Microscopy User Laboratory @ Empa!

Your company wants to develop a new plasma-coating process for a specific fiber material and you need to understand the adhesive properties of the components involved. Or you are developing tools and you want to make them «corrosion-proof». Or you want to assess the critical dimensions of your semiconductor devices. Or the coarseness of a surface that had just been treated by your novel polishing method. At SUL, your problems can be solved. The SUL is a newly established user laboratory that offers a wide range of services and opportunities for industrial and academic partners alike. This is an invitation to explore the SUL and its facilities – and maybe the first step to a fruitful and successful collaboration with us.

Many state-of-the-art technical applications critically depend on structural, physical or chemical properties of surfaces or coatings on a nano- or microscale level. These properties include corrosion resistance, wear behaviour and mechanical strength, which are all determined by their surface (structure). Hence, local analysis of surfaces and their properties will, in many cases, be of crucial importance for the performance and reliability of modern materials and devices. These analytical methods became reality with the advent of nanotechnology.

Nanoscience and nanotechnology saw the light of day with the development of a new family of analytical instruments based on the Scanning Tunneling Microscope (STM), first developed in 1982 at IBM Research Laboratory Zurich. The most prominent and versatile member of the growing family of scanning probe microscopes is certainly the Atomic or Scanning Force Microscope (AFM or SFM).

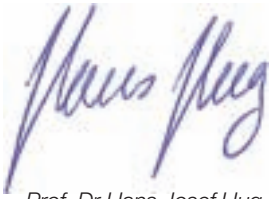
The SFM is used to image surfaces with up to atomic resolution but also to determine or even modify local material properties with a lateral resolution in the nanometer range. Among the material properties that can be assayed with the SFM are local mechanical properties such as the sample's topography, local stiffness, electrical properties such as local resistivity, charge density and contact potential, as well as chemical properties such as local contact potential and adhesion. Local magnetic properties, piezo response and corrosion properties can be mapped with high spatial resolution.

By further functionalizing the SFM probe it is possible to selectively investigate the local chemical or biological structure of the sample. But the SFM is not only able to image a sample it can also selectively modify it by nanolithographing in a so called "bottom-up" approach.

However, as with most highly specialized analytical equipment, the reproducible acquisition of data is only the first step towards an in-depth understanding or the solution of a problem. In many cases data interpretation or the detailed choice of the specific instrument or operational mode is crucial for success.

At the Swiss Scanning Probe Microscopy User Laboratory (SUL) at Empa in Dübendorf, a number of SFMs are installed to tackle a wide range of surface analytical problems. Professional staff with decades of fore-front research experience in scanning probe microscopy is looking forward to meeting your challenges – be it through providing service measurements, consulting on technical questions or data interpretation or training/education on the SFM. With the SUL we extend one of Empa's crucial traditional roles – namely to provide highest-level services and training to industrial and academic partners in the field of nanotechnology.

See you soon at the SUL, your service lab for materials analysis on the nanoscale!



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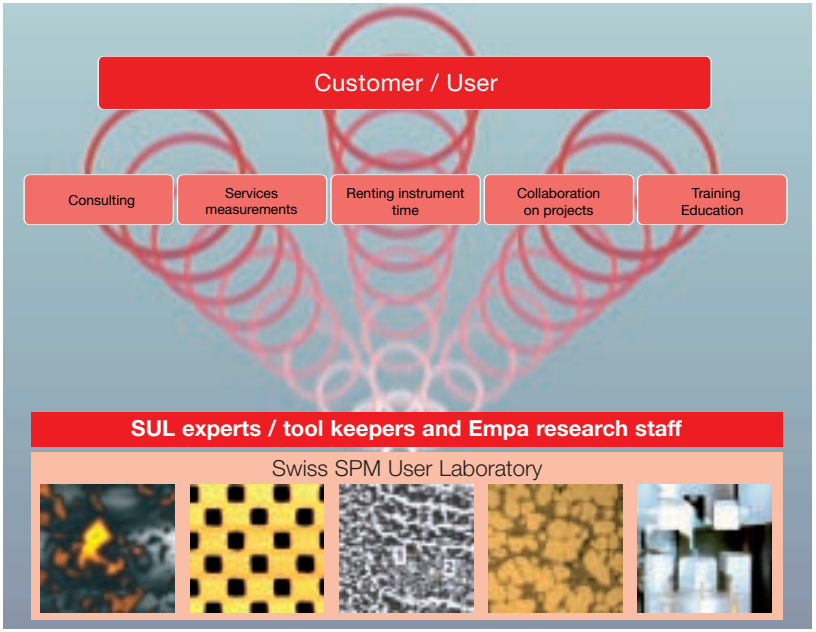
Services: What the Swiss Scanning Probe Microscopy User Laboratory (SUL) has to offer

The SUL provides analytical services and fast and simple access to sophisticated analytical equipment for partners and customers from both industry and academia. Moreover, the SUL acts as a platform for collaborative R&D projects at the forefront of scanning probe microscopy. Several multi-purpose and highly specialized scanning probe microscopes are installed in newly established user laboratories at Empa. The instruments are supervised and maintained by Empa's expert operation staff.



Your services at the SUL:

Consulting: Experts will assist and advice you in solving your specific surface analytical problems.

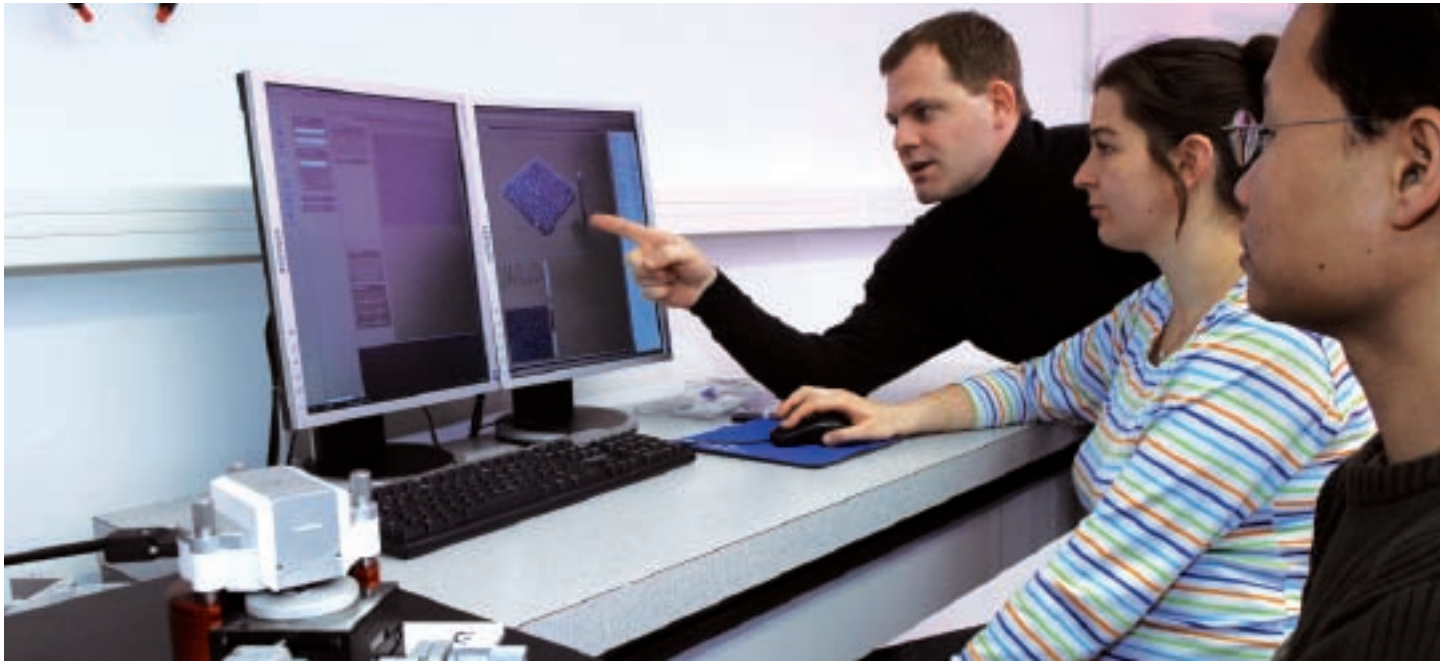
Measurement services: You provide the sample under investigation, and Empa experts will deliver measurements with high reproducibility and quality. SUL staff will also provide you with an in-depth analysis of the acquired data.

Renting measurement time: You can book time slots on specific SUL instruments to analyze your samples in whatever way you consider necessary to solve your problems.

Collaboration on R&D projects: If you are looking for a partner to realize scientific and development projects in the field of (surface) material analysis, the SUL is your collaborator of choice. We are eager to team up with both industrial and academic partners.

Training, education: Last but not least, to deepen your understanding of SFM technology, SUL experts are offering advanced education and training courses for their industrial and academic customers and partners.

Service Packages at SUL – from «rent-a-microscope» to «all-inclusive», tailored to your needs

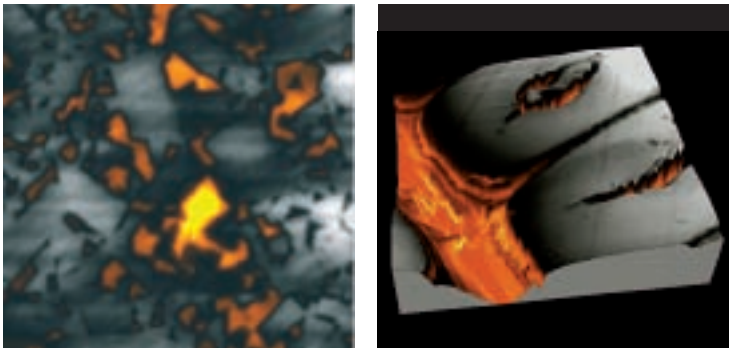


We offer different measurement service packages depending on your specific requirements and wishes:

- The **«Full measurement service package»** includes sample preparation, scanning probe microscopy measurements performed by SUL experts, data analysis/interpretation and a detailed final report of the analysi s.
- The **«Basic measurement service package»** includes scanning probe microscopy measurements performed by SUL experts, basic data analysis and a short report. The sample preparation is carried out by the customer.
- The **«Simplified measurement service package»** only includes scanning probe microscopy measurements performed by SUL experts, together with the customer. Sample preparation, data analysis and a report are not provided.
- **Renting measurement time on a microscope:** After an appropriate training course, customers/users can book time slots on a specific microscope and perform measurements by themselves.

Applications: Surface Topography and «Roughness»

Topography measurements of surfaces are preferably carried out using the «Mobile S» AFM. Crucial surface parameters like roughness, shape and orientation distribution of (particle) adhesives can thereby rapidly be assessed. There is no size restriction on the samples as the microscope can be non-destructively positioned on top of any surface – sample preparation can thus be kept to a minimum. The «Mobile S» is, literally, your «AFM-to-go», which can be utilized wherever your samples are.
The AFM is also suited for imaging of compound samples and soft surfaces like polymer thin films or biological tissue. In addition, a special scan mode allows for the measurement of the local resistivity of the sample surface, making it possible to assess the conductivity of e.g. composite samples on a Sub-micron scale.



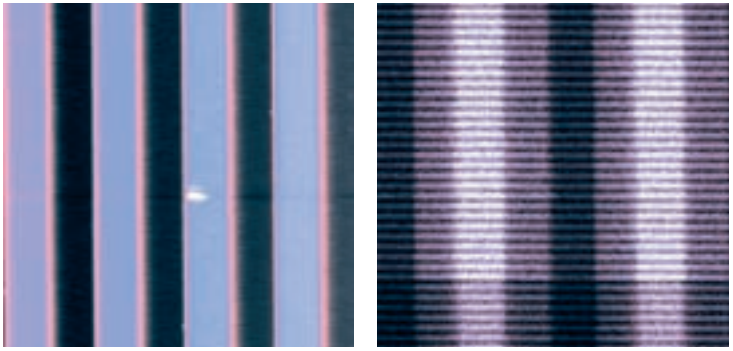
The «Mobile S» AFM is an extremely small and handy atomic force microscope, which can be used anywhere. Topography image of a W:Co composite sample (left). Close-up on two beech wood cells: The cell walls as well as the nuclei are clearly visible (right).

System & Performance

- Highly mobile «field-measurement capable» AFM due to small size and no restriction on sample size; laboratory sample stage features an x-y micrometer stage for smaller samples.
- Operation in ambient environmental conditions.
- Two linearized, orthogonal scan stages:
  - overview scanner with x/y/z = 110µm/110µm/12µm range and 1.7nm/0.15nm lateral/vertical precision.
  - high resolution scanner with x/y/z = 10µm/10µm/1.8µm range and 0.34nm/0.03nm lateral/vertical precision.
- Diverse spectroscopy modes.
- Analysis software with automated reporting system.

Applications: Electronic Properties of Material Surfaces

The «XE-100» AFM is especially suited for the measurement of electronic properties of sample surfaces. It features several advanced so called «electrostatic force» scan modes that allow the analysis of the resistivity and conductance at the sample surface – or at structures lying underneath – on a nanometer scale. Such measurements are extremely important in electrical failure analysis of micro- and nanostructured samples but are also useful to distinguish different phases in composite materials. A two pass type scan mode allows for the simultaneous acquisition of sample properties (e.g. topography and electrostatic potential).
The AFM is also able to perform a chemical surface analysis by measuring the local stiffness, adhesion or surface potential. By further functionalizing the probe it is possible to assess the local chemical and biological structure of the sample. The results can be compared with XPS or TOF-SIMS measurements which can be done on in-house instruments.



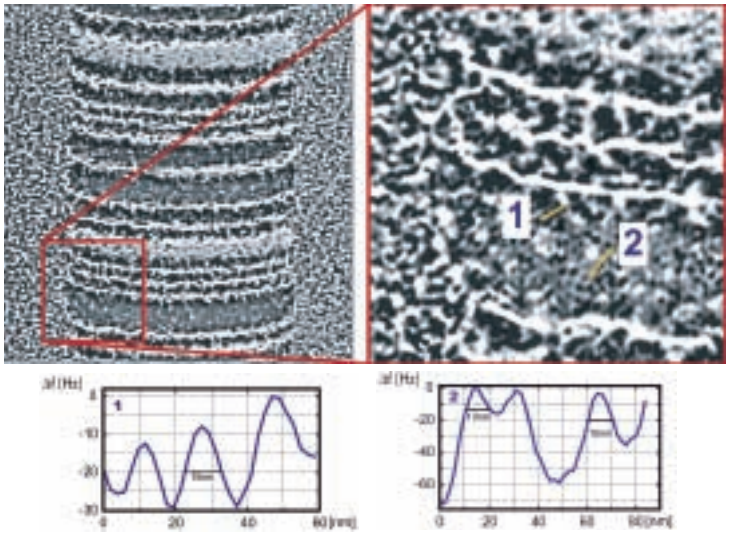
Topography (left) and electrostatic force microscopy (EFM) signal (right) of a microfabricated grating. The EFM image reveals that the vertical bars are differently charged. All images are 10µm x 10µm.

System & Performance

- Highly flexible non-contact scan mode (allowing fast image acquisition) and two pass modes (e.g.: topography and electrostatic potential).
- Two linearized, orthogonal scan stages:
  - overview scanner with x/y/z = 50µm/50µm/12µm range and 0.1nm/0.05nm lateral/vertical precision.
  - high resolution scanner with x/y/z = 5µm/5µm/1.7µm range and 0.02nm/0.01nm lateral/vertical precision.
- Active damping system and AFM enclosure guarantee a high thermal stability and minimal disturbance by external vibration.
- Direct on-axes view to the tip and sample by a high resolution optical camera system (resolution 1.5µm).
- Optimized for sample dimensions of up to 10cm x 10cm x 2cm.

Applications: Magnetism and Ferroelectric Properties

The «hrMFM» is a scanning force microscope optimized for high-resolution measurements of magnetic and ferroelectric samples. With the true non-contact operation mode, a lateral magnetic resolution of 10nm can routinely be achieved. The microscope is housed in a vacuum chamber, which allows for measurements under clean, reproducible conditions.
The flexible electronics and scan software makes it possible to run general one- or two-dimensional scans – any signal can be used as x (and y), and an arbitrary measurement signal can be plotted on the z-axis. For example, the electrostatic force along a scan line can be plotted over the applied tip-sample voltage in order to assess the ferroelectric response of the sample.



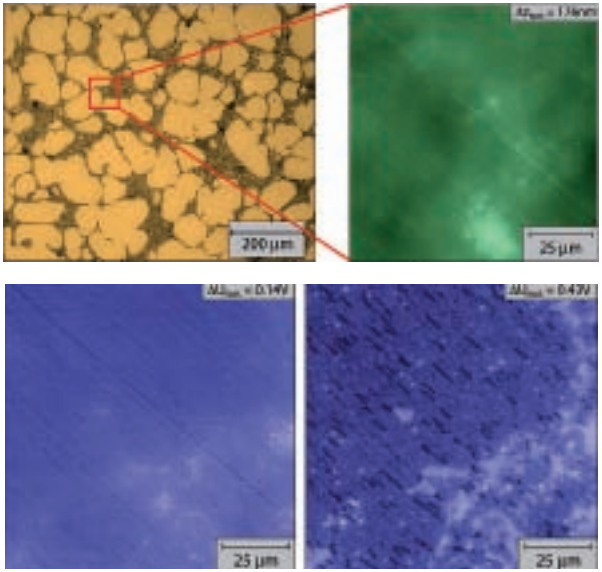
High-resolution MFM images of a perpendicular high disk media track. The line sections 1 and 2 in the zoomed image on the right demonstrate that magnetic features on the order of 10nm can be resolved. (courtesy of NanoScan)

System & Performance

- Highly flexible general one- or two-dimensional non-contact scan mode.
- Advanced general spectroscopy.
- Clean, temperature-controlled high-vacuum system presenting reproducible environmental conditions.
- Linearized, orthogonal scan stage with x/y/z = 40µm/40µm/6µm range and 0.2nm/0.03nm lateral/vertical resolution; lateral magnetic resolution of 10nm.
- Sample stage can hold samples up to 12cm in diameter.
- Fully motorized radial 100 nm/step, 0.2m°/step with a reproducibility of < 250nm, 0.5m°.

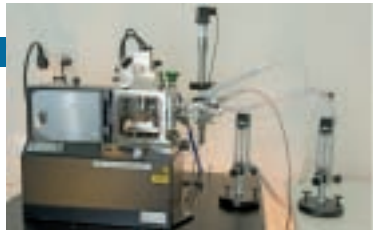
Applications: Extreme Environments – Gases, Humidity

The measurement environment of the «EScope» is extremely variable – according to measurement requirements – and is hence the microscope of choice for AFM studies under non-ambient conditions. For instance, temperature and humidity can be varied over a large range. The microscope can also be operated under various gases – even corrosive ones –, which enables failure analysis of various materials. Moreover, the precise control of the measurement environment makes it possible to study the development and progression of the failure or damage over time. This can be achieved by continuously imaging the surface's topography and/or the electrostatic potential, both of which are often subject to change during corrosion or degradation.



Images top to bottom, left to right: The «EScope» AFM can analyze samples under extreme conditions. Optical and AFM topography image of a Mg-Al-Zn film. When plasma cleaned, the AFM image shows a homogeneous oxidation of the surface. After exposure to 70% relative humidity, strong surface corrosion (light blue and black features) becomes visible. In collaboration with Leichtmetallkompetenzzentrum Ranshofen, Austria.

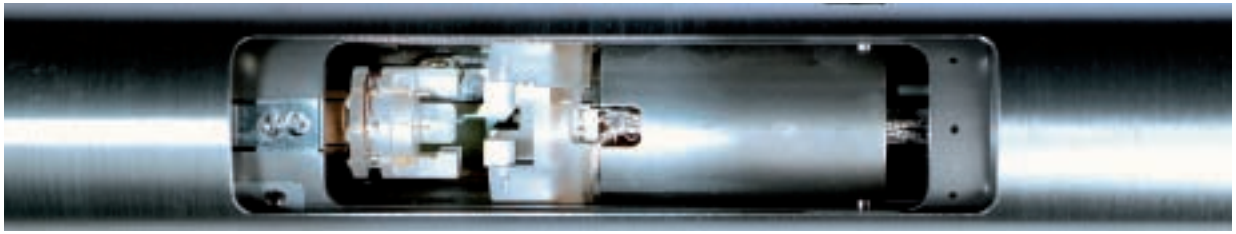
System & Performance



- Extremely flexible measurement environment: various gases, temperatures of up to 185°C, humidity of up to 60%, measurements in fluids possible.
- Thermal, pressure and humidity enclosure.
- Operates in ambient air or under near high-vacuum.
- Linearized, orthogonal scan stage with x/y/z = 90µm/90µm/5µm range and <1nm/<0.1nm lateral/vertical resolution.
- Optimized for sample dimensions of up to 30mm x 30mm x 12mm.
- Motorized coarse positioning: 6mm x 6mm x 14mm.

Applications: Extreme Environments – Temperature, Magnetic Field (available from July 2007)

The «PPMS-AFM» is a high-resolution AFM integrated into a Physical Properties Measurement System enabling it to operate at temperatures between -270°C and +100°C and in magnetic fields of up to 7T. These conditions make it possible to study the change of material dependent properties, for example phase transitions, related phenomena and other aspects, which are crucial for developing new engineering materials and compounds. The «PPMS-AFM» will, therefore, mainly be an instrument used for R&D-type projects. The microscope operates in high-vacuum, thus ensuring clean and reproducible environmental conditions.



System & Performance

- Flexible measurement environment: temperatures from -270°C to +100°C with a stability of 0.02K, magnetic fields of up to 7T with a stability of 0.2Oe.
- Linearized, orthogonal scan stage with x/y/z = 50µm/50µm/5µm at room temperature and 10µm/10µm/1µm at low temperatures and 0.75nm/0.075nm lateral/vertical resolution at low temperatures; lateral magnetic resolution of 15nm.
- Fully motorized x-y coarse positioning system with 2mm x 2mm travel range.
- Sample size restricted to 5mm x 5mm x 3mm.
- Highly flexible general one- or two-dimensional non-contact scan mode plus advanced general spectroscopy.

The SUL – your Training and Education Center for Scanning Probe Microscopy

Upon request we offer education and training courses on the following topics:

- Introduction to the basics of scanning probe microscopy
- How to successfully plan a scanning probe microscopy measurement
- Analysis and interpretation of scanning probe microscopy measurements/data
- Training on specific scanning probe microscopes at the SUL

Duration and level of the courses will be adapted to customer demand.

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The ETH Domain's Competence Centre for Materials Science and Technology (CCMX) was established to promote collaboration on promising technologies and their applications. It combines the strengths of several ETH Domain institutions (EPFL, ETHZ, Empa and PSI) and of CSEM, and involves the active participation of partners from industry, industrial associations and Swiss universities. With EPFL as the Leading House, the CCMX has already initiated activities in various areas. The SUL is jointly financed by both CCMX and Empa.

Empa is a transdisciplinary research and service institution within the ETH Domain covering selected fields of materials science and technology development including important environmental aspects. Empa's R&D activities focus on the requirements of industry and the needs of society, therefore bridging the gap from science to engineering and from research to industry and society. As a result, Empa is capable of providing its partners with customized services and solutions that not only enhance their innovative edge, but also help to improve the quality of life for the public at large. Safety, reliability and sustainability of materials and systems are cross-sectional topics permeating all Empa activities. As such, Empa plays a key role in Switzerland's research and innovation landscape.

Empa also brings its competencies to bear in the areas of knowledge dissemination, technology transfer, different levels of teaching and continuing formation, thus transforming knowledge and inventions into marketable innovations. The newly established PORTAL is the «one-stop shopping» access point for potential customers and partners looking for innovative solutions and collaborative research efforts in materials science and technology.

Materials Science & Technology