Scanning Probe Microscopy

The Aarhus SPM
State-of-the-Art AFM and STM Technology for Advanced SPM Research

- Extreme Stability
- Highest Productivity
Advanced Heat Flow Management

Symmetry in the mechanical design as well as highly defined heat flows in the physical arrangement of the Aarhus SPM systems allows variable temperature measurements with the highest thermal and mechanical stability. As a result of this design, thermal equilibrium is reached within minutes even after changing temperatures of several hundred Kelvin. This advanced heat flow management allows measurements from cryogenic temperatures to temperatures exceeding 1000K with a thermal stability well below one Kelvin.

With scanning probe microscopy (SPM) being a powerful tool for nanotechnology on the atomic scale, SPECS licensed the STM (scanning tunneling microscopy) system from University of Aarhus. Up until then, commercial SPM systems were approaching the needs of scientists with a wide variety of SPM techniques, yet neglecting fundamental problems arising from the lack of mechanical stability and from time-consuming operational requirements from its users.

The STM 150 Aarhus, a direct copy of the University’s system, entered the market showing ultimate stability and ease of use at the very same time. In doing so SPECS managed to offer STM systems that operate on a daily basis, thereby allowing scientists to spend more time thinking about possible experiments rather than investing valuable time operating the instrument itself.

“I had beautiful results with my systems at home as well – with the main difference being that my best results required months of operation whereas the STM 150 Aarhus showed even better results within hours, without having operated the instrument before!”

Leading Scientist in STM Research

Mechanical Loop

One of the key features of the Aarhus SPM family members is the smallest possible mechanical loop between sensor and surface using the miniaturized approach mechanism. With most other instruments not having such a feature, the Aarhus SPM gains its fundamental stability from this miniaturized mechanical loop.

Tip Replacement

Another key feature for all Aarhus SPM family members is not having to replace probing sensors, e.g. a tunneling tip. The lack of instrumental stability, i.e. from sensor damaging contact with the surface (‘tip crashes’) along with the lack of cleaning possibilities, i.e. removing contaminants and sensor sharpening, made ‘in-situ’ tip replacement necessary for most other instruments. Within the Aarhus SPM family a different approach is used. By using a protection shield all sensors are left within the instrument and are bombarded with a parallel ion beam. The sensors are not just cleaned but also sharpened in a very reproducible and time-efficient manner.
Most commercial AFM systems have to be modified after market and required highly skilled experts on a 24/7 basis to operate them. SPECS took on the challenge of reaching the highest productivity by developing the **SPM 150** Aarhus with **KolibriSensor™** and **NANONIS** control systems.

**NANONIS**

The lack of appropriate control systems has always been a challenge for all AFM applications. With **NANONIS** having found a way to develop extremely advanced and user-friendly control electronics, a new era in SPM technology began, thus letting the users develop mechanical hardware whilst being able to depend on a reliable and powerful control system in their hands. What began as a collaboration between SPECS and NANONIS resulted in the creation of SPECS Zurich. Along with this and the development of **KolibriSensor™**, SPECS SPM systems now include all the mechanical advantages of the Aarhus base system, and the effectiveness and reliability of SPECS Zurich components.

**The Aarhus SPM Family**

To demonstrate the unique capabilities of the Aarhus SPM family members, a most bold approach was taken: to run all Aarhus SPM Family members at a conference within the exhibition area. Without any consideration of appropriate location, and without any measures to avoid disruptive vibrations, all systems were put to task under this harsh testing environment. To the surprise and delight of many, the Aarhus SPM systems working during the whole exhibition produced the highest quality results that could barely be superceded even under the best of experimental conditions.

**Live Performances, SPM in Vibrant Environments**

In the past few years, SPECS has managed to further develop the instrument with the highest priority on stability and ease of user operation, resulting in an Aarhus SPM family with unique capabilities being available never before.
STM 150 Aarhus / Release 2
Through the modification of the suspension mechanism of the SPM head and adding permanent cooling wires, the STM 150 Aarhus sets a new standard by showing the highest thermal stability at variable temperatures between 90 and 400K without compromising its original mechanical stability.

STM 150 Aarhus HT
By adding a radiative heater element with a high stability power supply, the STM 150 Aarhus allows imaging of all kinds of samples at temperatures exceeding 1300K. Using improved heat flow management it is possible to suppress thermal drift with ultimate mechanical and thermal stability regardless of temperature and duration of the experiment.

LEEM Edition
With SPECS offering the low electron energy microscope FE-LEEM P90 with unique lateral resolution, its dedicated sample holder was implemented into the STM 150 Aarhus. Including the HT option, all LEEM/PEEM experiments can also be performed within the STM 150 Aarhus, thereby allowing users the LEEM/PEEM view with atomic resolution.

MBE Edition
The need for ‘in-situ’ molecular beam epitaxy (MBE) and SPM studies resulted in the development of a dedicated 1” MBE sample holder. Together with the HT option, studies can now be performed investigating the results of MBE growth process, even at elevated temperatures.

All of these Aarhus STM Family members come with control electronics developed by the University of Aarhus. The SPC 260 now equips these family members with control electronics with video frame recording speeds over a USB2.0 Interface. Its acquisition and analysis software is based on the proven concept from University of Aarhus.

HOPG Imaging with SPC 260 - High-speed Imaging
Scanner Mount and Approach Motor

- Sample Holder Clamps
- Stage for Plate-shaped Holder
- Sensor Holder
- Scanner Tube
- Approach Motor
- Motor Mount
- Approach Motor Rod
- Access for in-situ Evaporation or (specular) Light

Sample Holder Options

- Standard
- Hat-shaped Crystals
- Direct Current
- High Temperature
- FE-LEEM P90
- MBE

...and customized solutions

Turn-key UHV System

- Load Lock System with Turbo Pump
- In-situ Sensor Sputtering
- Main Chamber with Aarhus SPM (all versions)
- Transfer Rod / Wobble stick for loading and operating the Aarhus SPM
- Space for additional sources (Evaporation and light in/out)

...and easy integration into complex systems
**The SPM 150 Aarhus**

**ULTIMATE AFM AND STM PERFORMANCE**

**With KolibriSensor™ and NANONIS Control Package**

Using Nanonis’ state-of-the-art control in atomic force microscopy (AFM), the Aarhus SPM family allows imaging of non-conductive samples in non-contact AFM (nc-AFM) mode. In combination with SPECS’ development of the KolibriSensor™, a quartz oscillator-based sensor, atomically resolved imaging is possible. Furthermore, considering the significantly more demanding AFM technology, this Aarhus SPM family member makes atomically resolved imaging of conductive and non-conductive samples possible on a daily basis. By separating the tungsten tip from the resonator, force and tunneling signals can be recorded simultaneously and completely independently of one another with uncompromised STM and AFM resolution. The SPM 150 Aarhus represents a new generation of UHV systems to examine every possible surface at the atomic scale.

**UNSURPASSED IMAGING**

Unique features of the KolibriSensor™ compared to conventional tuning fork-based sensors allow for high-quality images that can also display tunneling and force signals completely independently of one another (and yet simultaneously) at the highest speeds and the smallest oscillation amplitudes.

**Highest Imaging Stability**

The high stability during operation of the KolibriSensor™ during nc-AFM imaging gives you the possibility to go beyond characterization of clean surfaces. Even defects or step edges can be imaged routinely.

**Imaging at Extremely Small Oscillation Amplitudes**

Application of small oscillation amplitudes in nc-AFM imaging results in enhanced detection of the short range chemical bonding forces. The high stiffness of the KolibriSensor and its excellent signal to noise ratio allows for atomic resolution imaging at extremely small oscillation amplitudes even at room temperature. These low amplitudes have so far been only applicable when working at cryogenic temperatures.
**KolibriSensor™ Design**

The design of the KolibriSensor™ provides purely electrical excitation and read out of the force signals. For a clear separation of oscillation current $I_{osc}$ and tunneling current $I_{tunn}$, the metallic tip is separately connected to a third electrode by a wire. A sputter shield enables in-situ tip cleaning and sharpening within the microscope.

**Force Mapping and Spectroscopy**

The highly symmetric geometry of the electrically actuated quartz rod ensures that only the rod is excited during oscillation while the sensors’ base remains at rest. This allows for precise and stable spectroscopy experiments. Characterize your sample beyond imaging on a quantitative level by combination of force/tunneling current vs. distance or bias voltage in spectroscopic experiments.

**High-speed nc-AFM Atomic Resolution Imaging**

Get to know more about surface dynamics. The extraordinary high resonance frequency of 1 MHz allows for fast nc-AFM atomic resolution imaging at extremely fast scanning speeds. These imaging speeds are not accessible with other piezoelectric force sensors like tuning forks due to their low resonance frequencies.

At SPECS in Berlin and at SPECS in Zurich, great care is taken to maintain the state-of-the-art performance of SPM Aarhus systems by increasing the versatility of the instrument without compromising any mechanical or thermal stability. With this well defined concept, the Aarhus SPM family sets new standards in commercial SPM technology for scientific applications.
**TECHNICAL DATA**

**AARHUS SPM HEAD**

Temperature Range: 90 - 400K (1300K optional)
In-situ Access: Specular and Evaporation
Approach Speed: ≤ 1mm / minute
Scan Range: 150mm x 1500nm
Sensitive Z Range: ± 175 nm
Stability (z noise): < 1 pm rms
Thermal Stability: < 0.1K / hour @ T > 115K
Lateral Drift: < 0.15 nm/min
Vertical Drift: < 0.05 nm/min
Temperature Control: 2 Zener Diodes and 2 Thermocouples near sample & scanner

Separate analog heater for STM head and sample, manual or automated, temperature displays, alarm control for both temperatures and external interlock.

**KOLIBRISENSOR™**

Resonance Frequency: 1 MHz
Q-Factor: > 10,000
Spring Constant: 540 kN/m
Noise Floor: < 10 fm/√Hz
Oscillation Amplitudes: 10 pm - 1 nm

**NANONIS CONTROL SYSTEM**

Consisting of:
- SPM Control System Base Package SPMCS-BP4-3
- Oscillation Controller Module SPMCS-OC4
- Atom Tracking Module SPMCS-AT4
- Kelvin Probe Controller Module SPMCS-KC4

Includes:
- High Voltage Amplifier, Femto Preamp, and Aarhus Adaptation Kit.

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**SPC 260 SCAN ELECTRONICS & DATA ACQUISITION**

- Tunneling Current: 0.001 - 50 nA
- Scan Speed: 1,000,000 pixels / sec.
- Direct Monitoring of Iₜ:
- Remote Headphones (included)
- Operating System: Windows 2000/XP
- PC Interface: USB2.0
- Diagnostic Features: z(t), I(t) with Fourier transform
- Drift Compensation: Fully automated (with feature selection or template matching)
- Z-Travel Centering: In-situ, fully automated
- Video Recording Mode: 260 images/sec. at 64x64 pixels
dl/dV, dl/dz, dz/dV, dz/dl, ...
- Spectroscopy Modes:
  - Multi-channel Data Acquisition for various tunneling parameters.
  - Multi-scan Mode for forward and backward scans.
  - Multiple Manipulation and Lithography features.

**NANONIS**

**KOLIBRISSENSOR™**

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ISO 9001 Certificate