



Materials Science & Microscopy

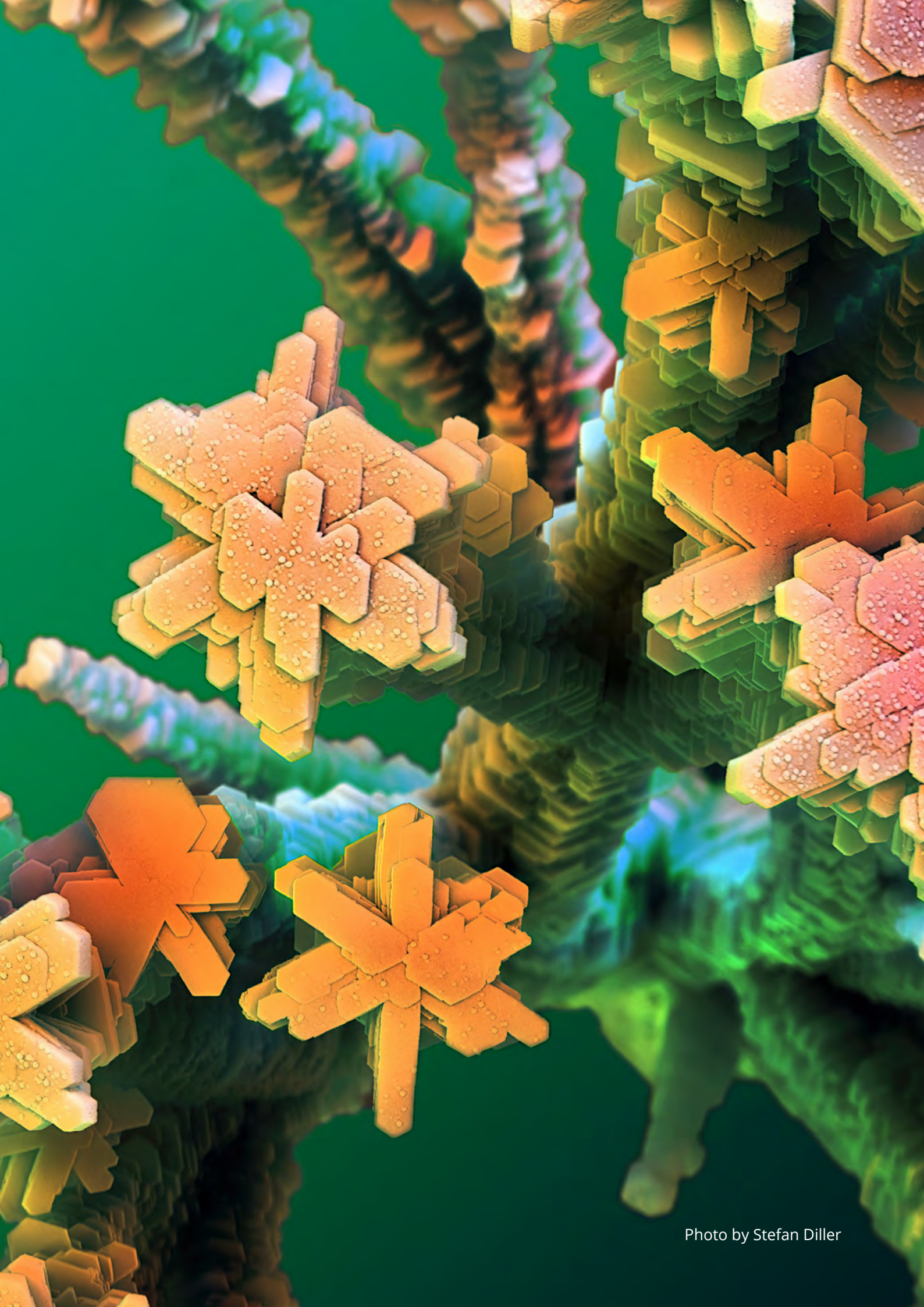


Photo by Stefan Diller

Materials Science and Electron Microscopy

The modification of material properties such as surface characteristics, manipulating electronic and magnetic behavior, and optical attributes has reached sub-atomic scales. Quantum mechanical systems and quantum effects are at the forefront of research and development, finding pathways into a wide range of applications, unlocking vast new markets.

Suitable analysis methods are under development, while established techniques are continuously improved and adapted to meet the growing demands for precision and stability. At the same time, they must accommodate increasing complexity while remaining compact and available for use in extreme environments, such as high magnetic fields, ultra-high vacuum, cryogenic conditions, and high-intensity radiation fields. These advancements enable deeper exploration of the Nano, Pico, and Quantum world, ensuring that new effects can be reliably detected and harnessed.

This is precisely where SmarAct comes into play. With a broad product portfolio, comprehensive in-house manufacturing depth, intrinsic innovative strength, and extensive development expertise, nearly all use cases, and highly specialized applications can be addressed. OEM solutions can be conceived, implemented and realized with all technical aspects considered.

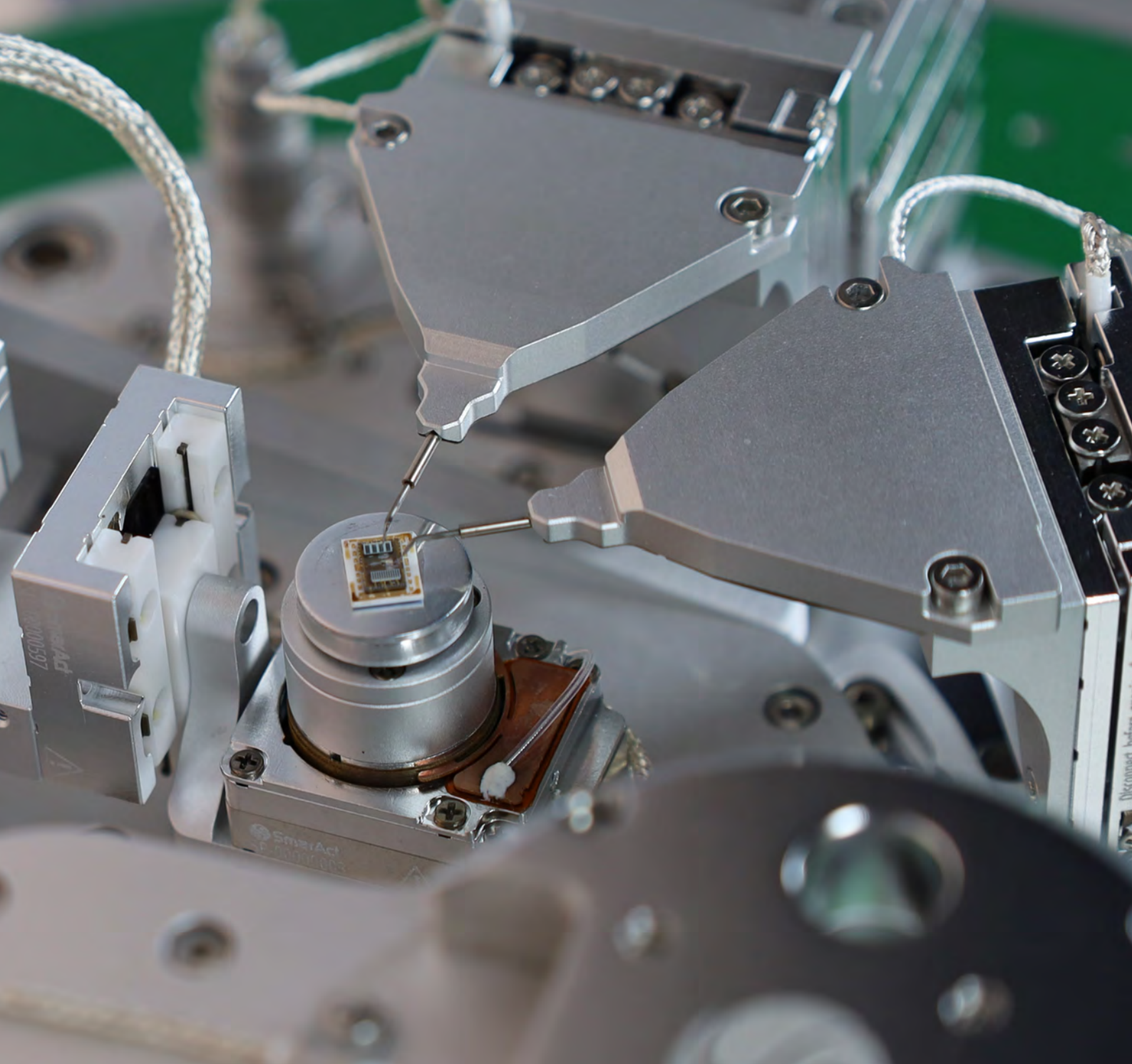
Whether it is high-resolution 3D printing, ultra-precise sample handling, electron or scanning probe microscopy, nanoindentation, nanoprobng, spectroscopy, diffractometry or quantum computing and sensing, or nanometer-resolution metrology, industrial and OEM customers as well as research facilities rely on SmarAct's expertise.



Ultra-Compact Precision for SEM Applications 6-Axis Sample Positioning – Flexible & Future-Proof

SmarAct sets new standards in ultra-compact, high-precision positioning for electron microscopy. Whether to integrate into a new SEM or to upgrade an existing system, the fully customizable 6-axis sample stage offers seamless integration

and a wide range of configuration options. Despite its minimal footprint, the sample stage enables full 6-axis positioning, allowing unrestricted access to the sample with nanometer and micro-degree precision. The stage is therefore suitable



for a wide range of analysis and processing methods as well as sample preparation, like FIB.

For extended functionality, the system can be equipped with an automated sample exchange or up to four independent probing towers - minimizing the need for system modifications or downtimes.

The modular design allows for subsequent expansion or fully customized modules. The 6-axis sample stage and add-on

modules can operate independently from the electron microscope opening up new possibilities for even older microscopes by simply adding state of the art functionality and features.

All stages can optionally be equipped with a closed-loop control system, enabling impressive possibilities for data acquisition, analysis, and visualization.



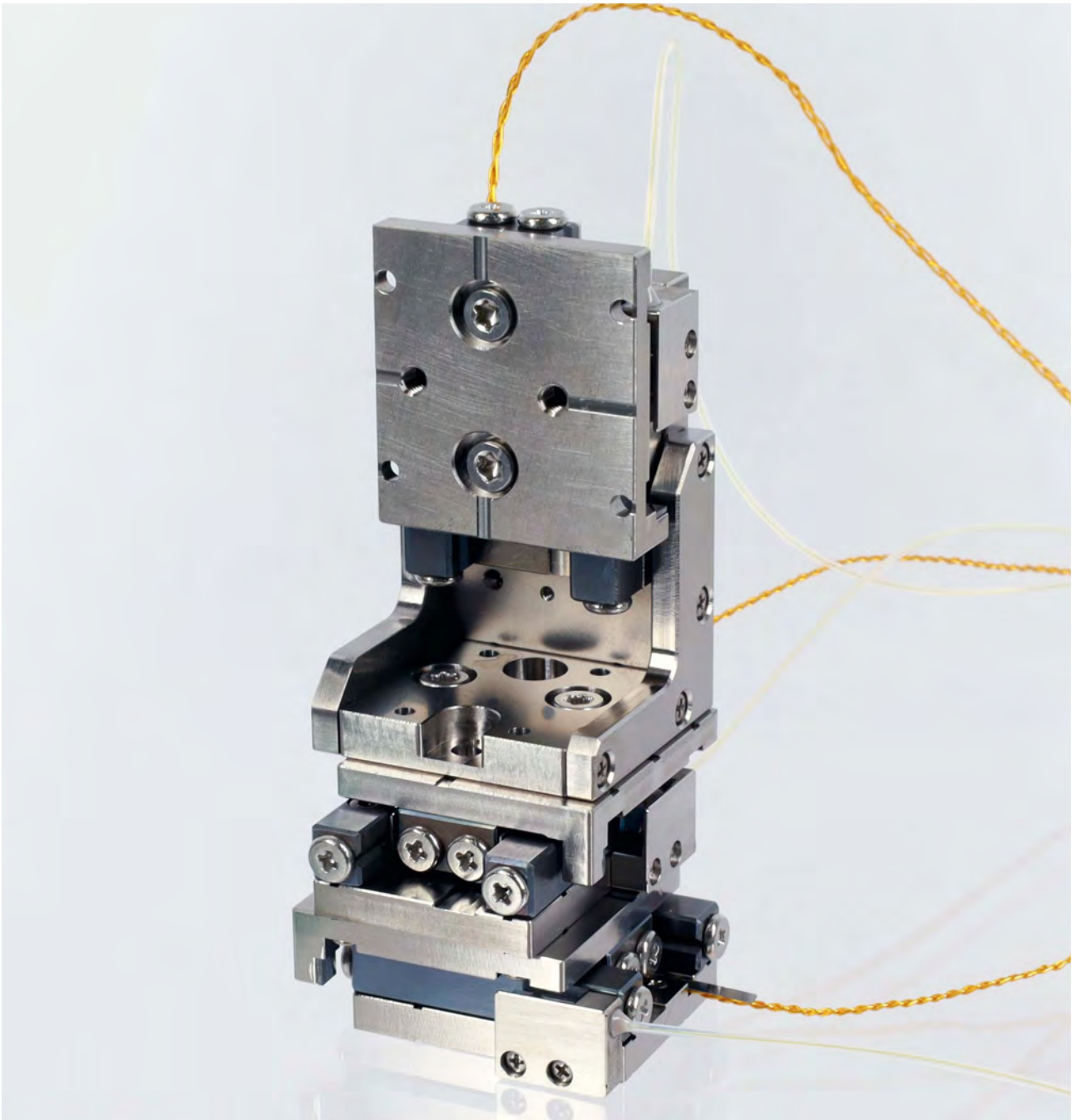
Computer Tomography

Functional properties of novel materials and material systems are based on complex internal, geometric structures. Non-destructive analysis methods, such as computer tomography, can make these nanometer-sized structures accessible at highest resolution and in multiple dimensions. The high information depth of the measurement data allows not only a structural but also a chemical analysis of the material system. Only the use of short-wave X-ray light in combination with nanometer-precise positioning technology enables access to details in the nanometer range. SmarAct positioning systems offer compact, highly customizable solutions that fully meet the requirements in terms of complexity, precision, operating environment, and controllability as well as user-friendliness and experience.

The smallest of such systems integrate seamlessly into all types of EM-environments providing access to novel measurements, e.g. Cryo-EM, as well as probing techniques unlocking new functions even for older EM-devices.

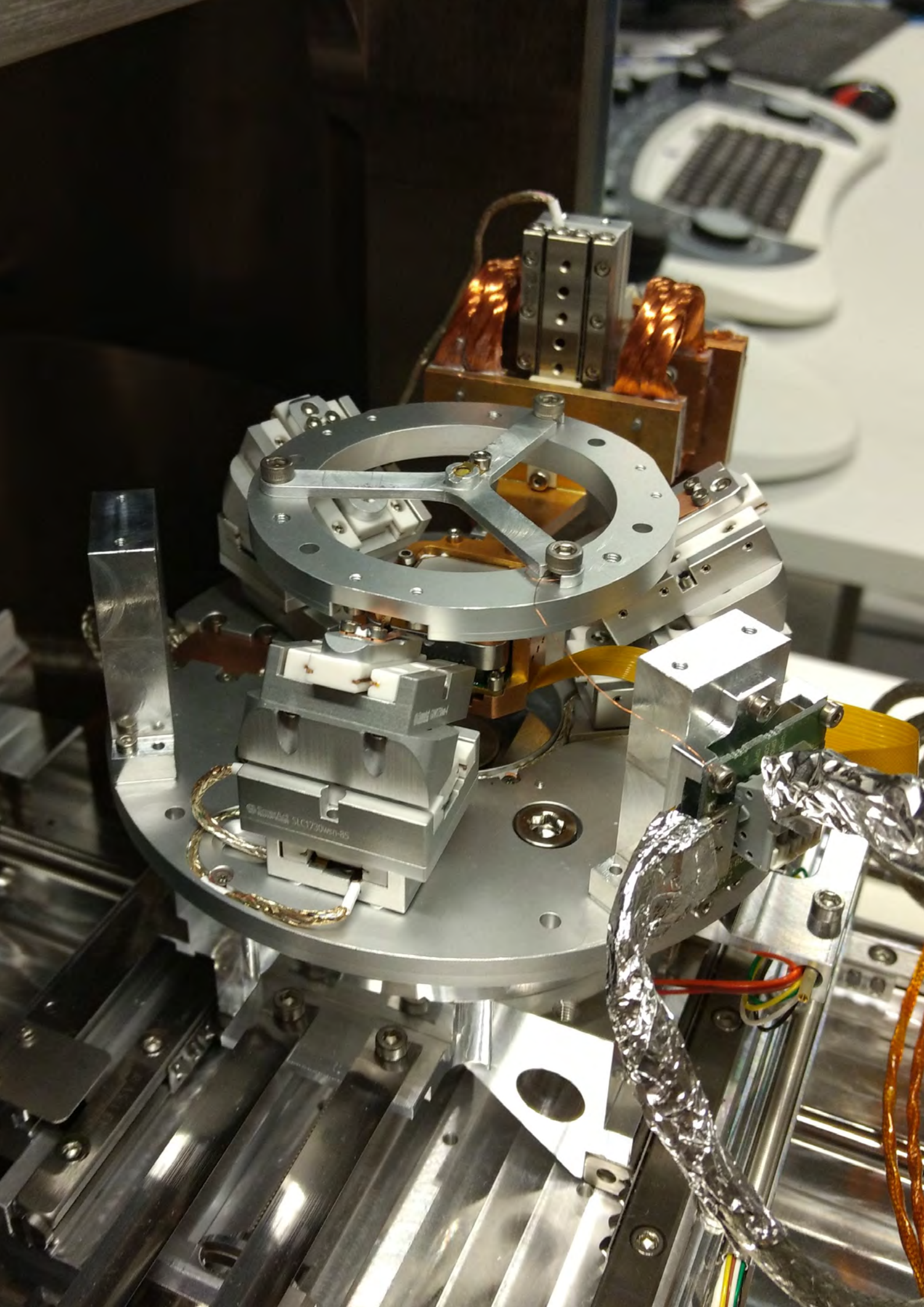
A high-load vertical stage accommodates an ultra-high precision air bearing that is utilized for the sample manipulation. Adding for example a hexapod like motion system allows the alignment of the specimen in up to six degrees of freedom. Furthermore, kinematic calculation systems can be solely designed for specific applications, facilitating access to the systems and improving user-experience.

Closed-Loop Stages for Operation in Cryogenic Environment



SmarAct XYZ cryogenic positioning systems, composed of three easily combined titanium linear stages, holders and adapter plates, are compact, modular and highly precise multi-axis setups that can be the perfect match for quantum computing and sensing applications. It can optionally be equipped with cold plates

and copper braids to ensure optimal heat transfer from the payload to the mounting base plate. Integrated interferometric position feedback allows nanometer-precise positioning even at extreme cryogenic conditions.



4D Scanning Transmission Electron Microscopy

4D Scanning Transmission Electron Microscopy (4D-STEM) is a powerful tool for characterizing material properties.

A focused electron beam sequentially scans an electron-transparent sample area. The transmitted electrons form a diffraction pattern and are recorded with an electron-sensitive camera at each scan point mapping properties such as crystal symmetry, lattice parameters, and strain. Adaptable to standard scanning electron microscopes making it ideal for characterization of 2D-materials and suspended 2D-like Van der Waals heterostructures due to its sub-nm spatial resolution and large scan area of up to several square millimeters.

In this specific experiment, an in-house developed system collected 4D-STEM datasets in an SEM. The transmission diffraction stage (TDS) comprises a sample stage based on a SmarAct **SMARPOD** 110.45 moving the specimen in six degrees of freedom with single nanometer- and micro degree precision. An electron-sensitive camera inside the **SMARPOD**, a detachable sample holder for TEM grids, and additional components, including a linear stage and copper-based heat management system.

SMARPOD and linear stage are essential to accurately position the sample and adjust the camera length (the distance between the sample and the camera) to ensure optimal sample alignment and movement relative to the camera resulting in high electron yields, allowing fast data acquisition and unmatched image quality.

Spectroscopy

Spectroscopy and spectro-microscopy are the most important methods for characterization of materials' surfaces with a focus on electronic structure and transport properties of charge carriers. For this the electron binding energies and emission angles have to be measured with ultimate precision as a function of the wavelength or frequency of the probing radiation.

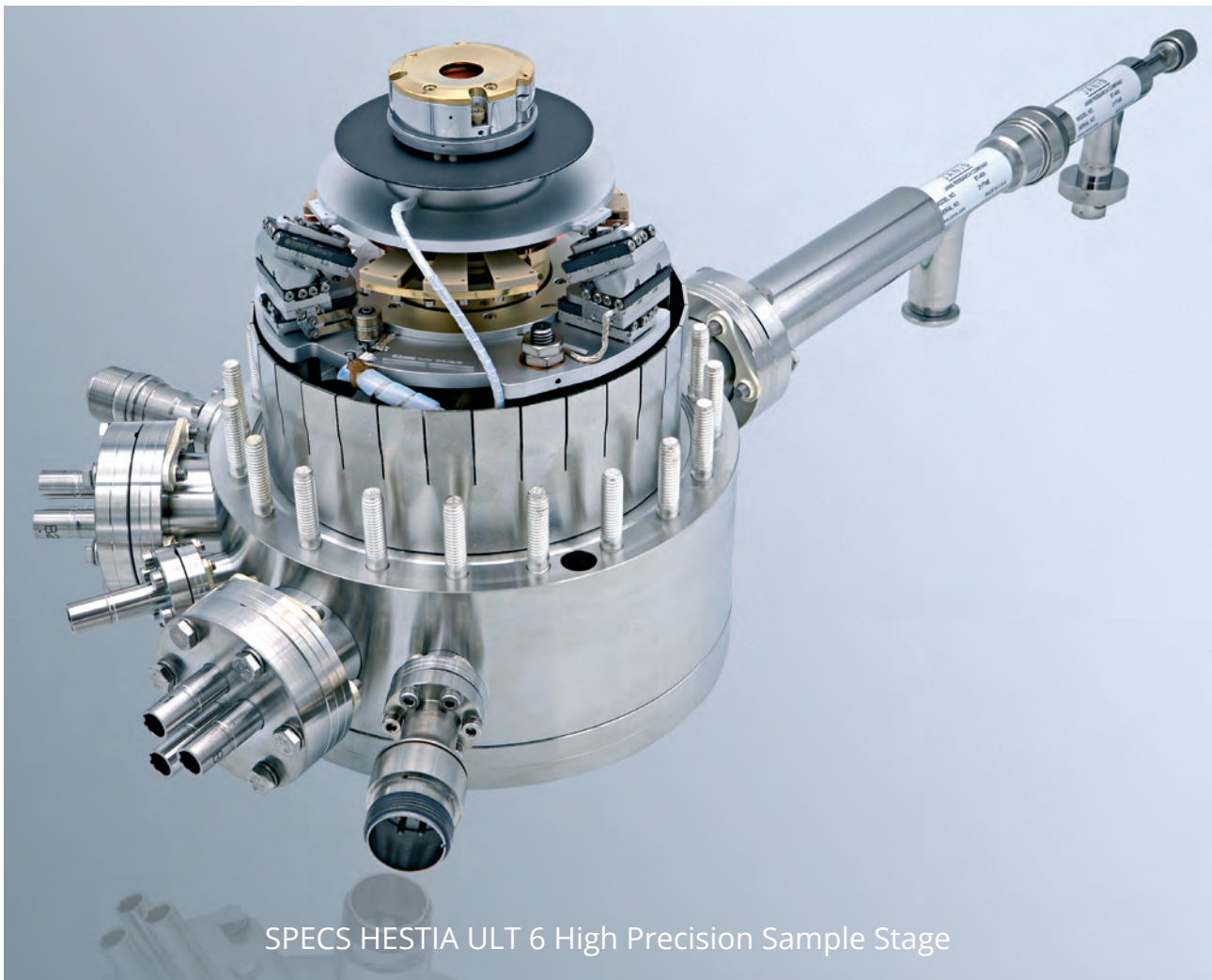
Since the investigated structures of materials become smaller and more complex, the analyzed areas have to be in the μm to nm regime. Thus, the request for high

precision positioning systems increase in the field of spectroscopy.

SmarAct provides a variety of different nano-positioning systems with resolution down to 1 nm for linear and rotational motions well suited for these tasks.

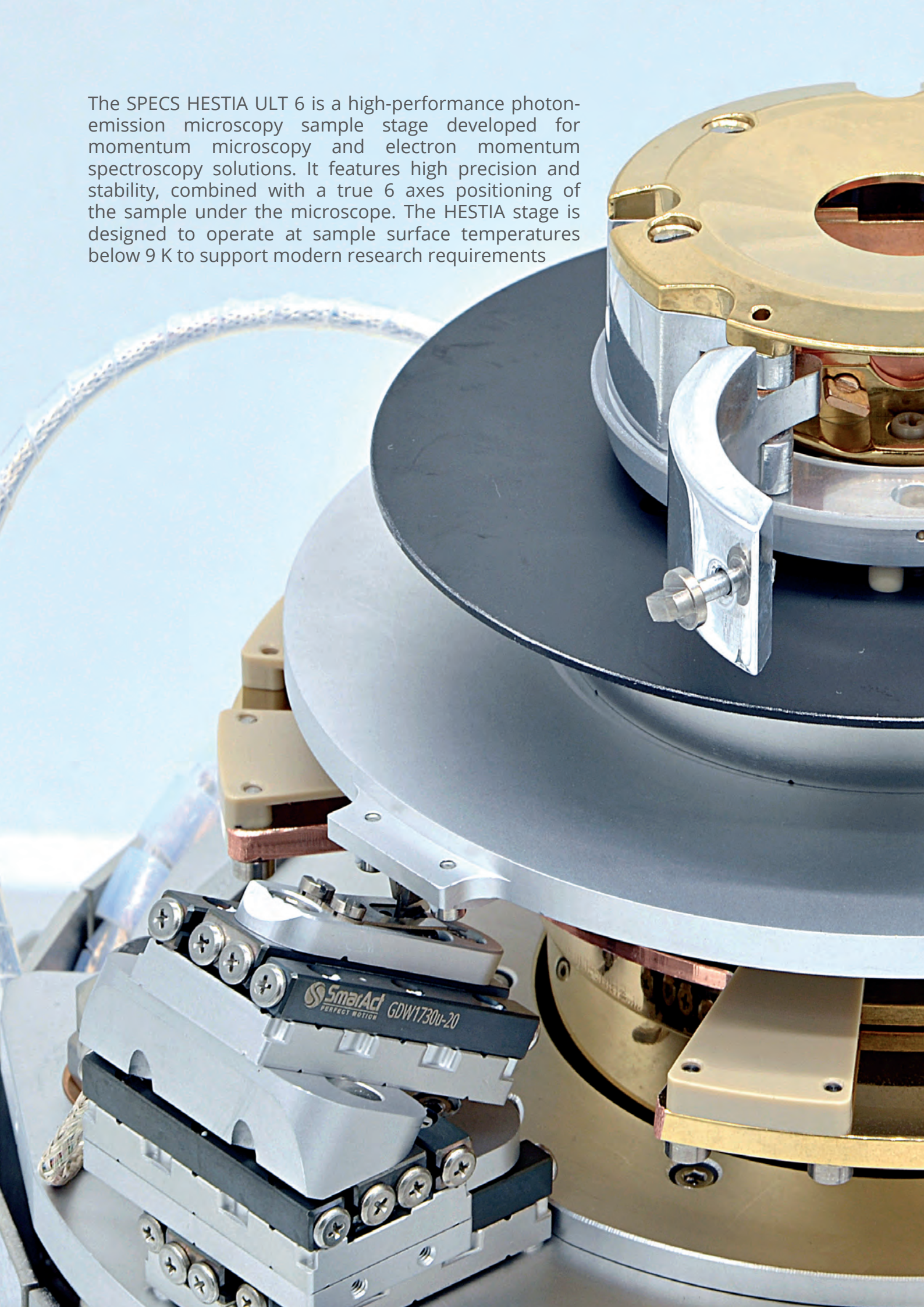
SmarAct is specialized on providing the perfect fit of the positioning system to your application and positioning task by individual customizations.

Smaract has developed a special version of the **SMARPOD** based on which SPECS was able to develop a high precision microscopy stage for momentum microscopy:



SPECS HESTIA ULT 6 High Precision Sample Stage

The SPECS HESTIA ULT 6 is a high-performance photon-emission microscopy sample stage developed for momentum microscopy and electron momentum spectroscopy solutions. It features high precision and stability, combined with a true 6 axes positioning of the sample under the microscope. The HESTIA stage is designed to operate at sample surface temperatures below 9 K to support modern research requirements





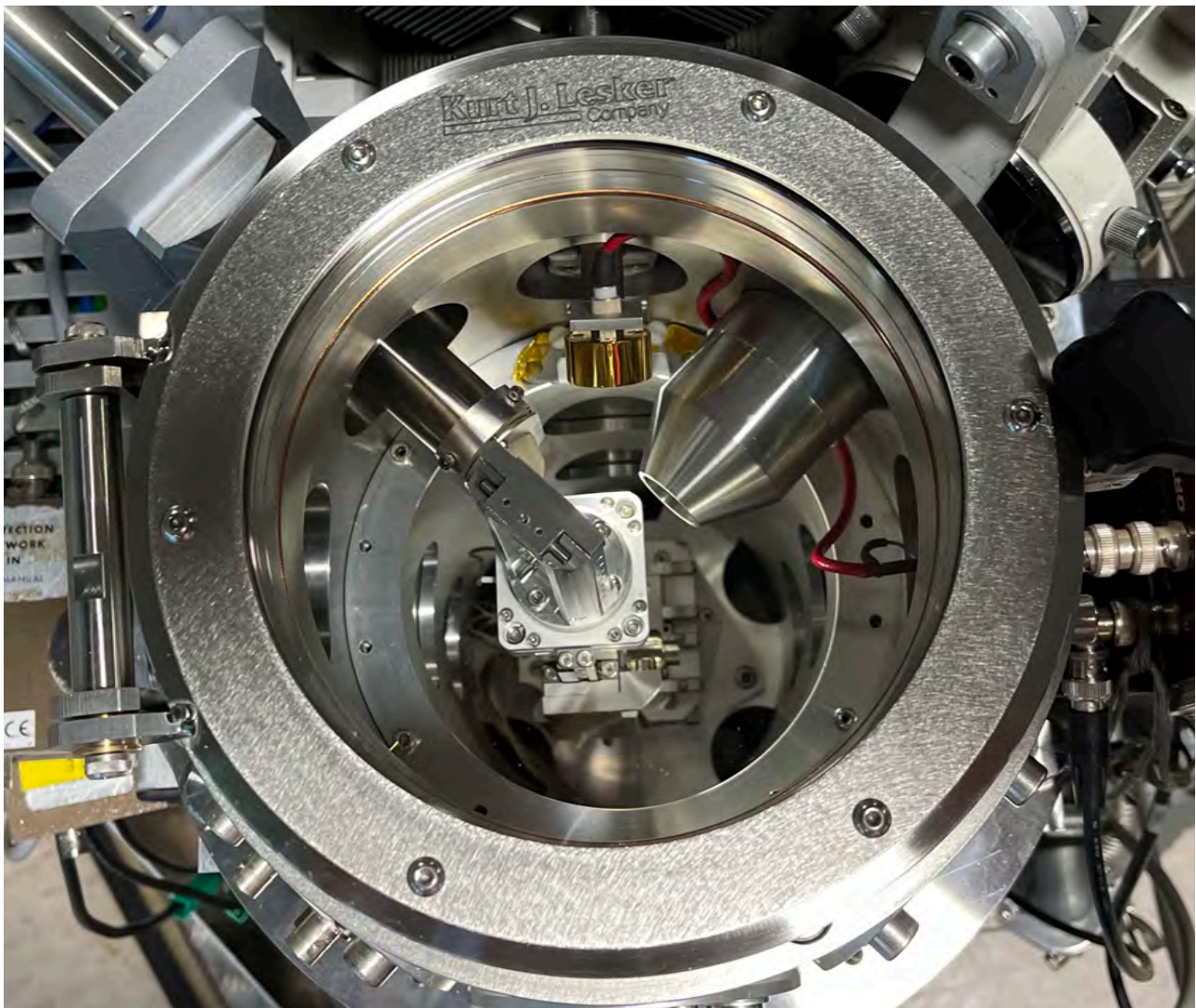


nanoARPES

For the most demanding nanoARPES measurements, SmarAct has developed an ultra-compact, fully customized multi-axis positioning system that enables direct measurement of the electronic structure of crystalline samples with unmatched precision. Designed and built according to specific customer requirements in terms of precision; compactness and available degrees of freedom, this one-of-a-kind system ensures stability and accuracy for sample alignment while performing beam shaping as well as beam alignment simultaneously.

At its core is a 13-axis positioning system, providing full control over sample alignment with nanometer precision. The system is built from non-magnetic materials only ensuring minimal interference in the sensitive measurements. Integrated optical position of two **PICOSCALE** interferometric sensor heads guarantees ultra-stable sample positioning, making it ideal for high-resolution angular resolved spectroscopic experiments.

This advanced solution is a testament to SmarAct's expertise in high-precision motion systems. By combining cutting-edge technology with tailor-made engineering, we provide researchers with the tools they need to push the boundaries of material science – precision meets possibility.



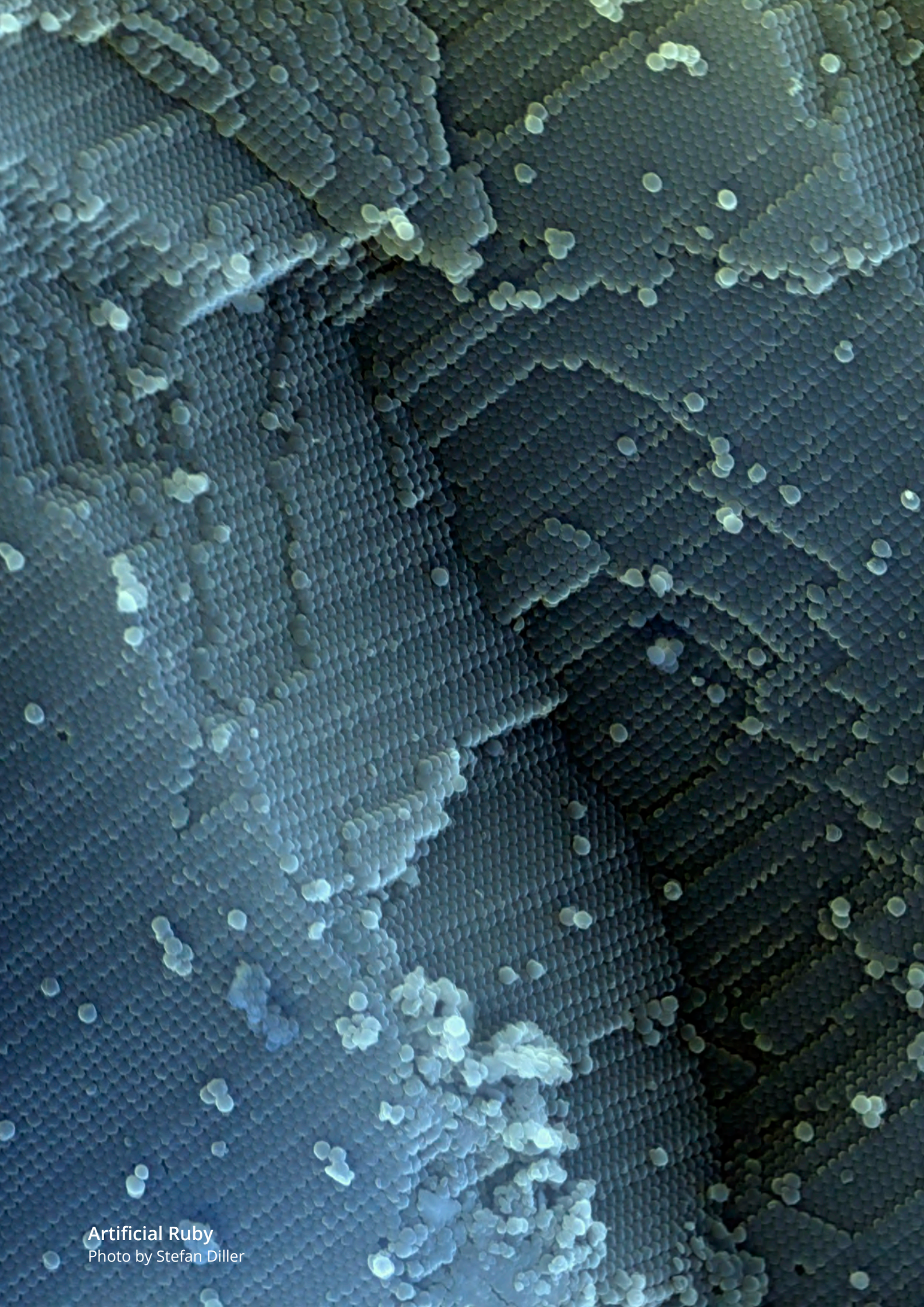
Sample Manipulators for Microbeams

The interaction of matter gives the user many options to study new materials and their properties. The investigation methods often include a fixed microbeam and an adjustable sample stage. In materials science the composition or mapping of samples is an interesting field that requires movements of a sample with high precision and stability and a repeatable process.

SmarAct designs and assembles motion systems that are optimized for the requested degree of freedom. The example shown is a sample manipulator system designed for movements in four degrees of freedom with three linear

stages and one rotational stage based on the stick-slip principle of our piezo stages.

The positioning system is inserted to a sample chamber from Oxford Microbeams for angle-resolved IBA (Ion-Beam-Applications), 3D imaging or grazing incidence PIXE (Particle-Induced X-ray Emission) allowing reliable automated operation with programmed sample positioning.



Artificial Ruby
Photo by Stefan Diller

With the development and production of market-leading solutions in the field of high-precision positioning, automation and metrology, the SmarAct Group reliably accompanies their customers in achieving their goals. The broad product portfolio – from single positioning stages to complex parallel kinematics, miniaturized robots, control systems and measurement technology – is complemented by automated microassembly solutions. Even the most challenging customer requirements can be met by maximum adaptability and complete in-house production.

Since its founding in 2005, SmarAct has steadily grown from a small team of engineers to a group of companies with three independent business units and over 270 highly skilled members. Today, SmarAct relies on years of experience and, above all, on a very passionate team with unconditional customer focus.

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