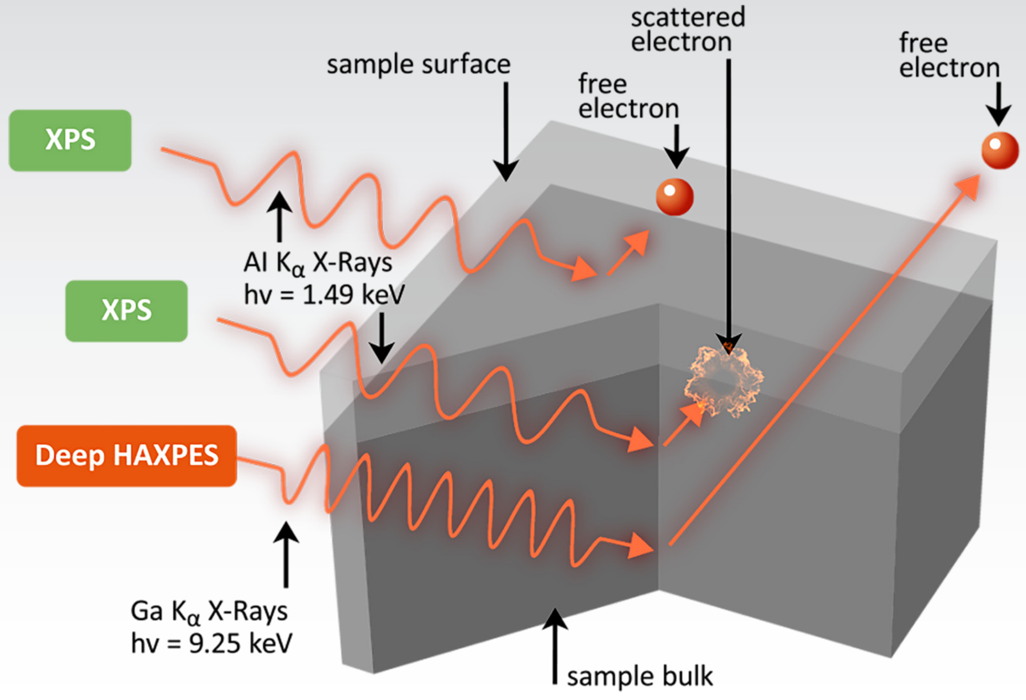
DeepCore-X

Investigate surface to interface, without sputtering, without compromise

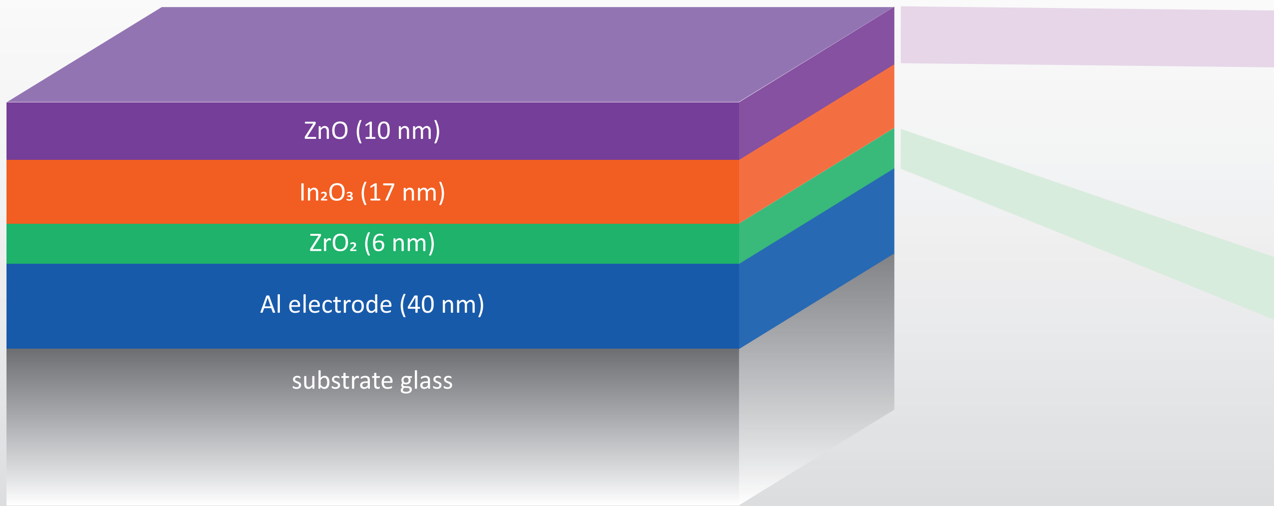
Pushing the boundaries of material characterization with XPS and Deep HAXPES

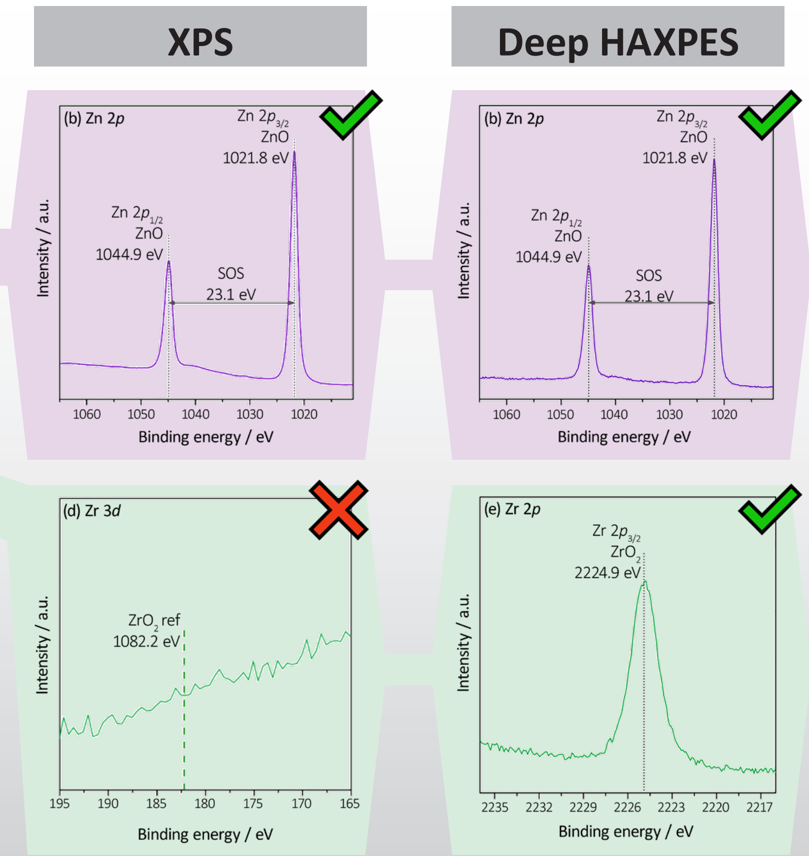
The DeepCore-X is a next-generation instrument that combines **soft and hard X-ray photoelectron spectroscopy (XPS & HAXPES)** in one instrument and integrates smart modular solutions within a proven design, delivering a robust, high-performance system tailored to individual experimental needs.

- **Synchrotron-like Deep HAXPES in lab** enabled by the small spot Ga Kα MetalJet Source (9.25 keV) with 1000 W continuous operation and a 3.5× intensity boost.
- **High-fidelity XPS measurements** achieved with the monochromated Al Kα Source (1.5 keV), delivering <250 meV linewidth.
- **High efficiency through high-resolution** PES with more data per run – powered by the scynchrotron proven EW4000 Hemispherical Analyser (200 mm radius, 60° acceptance).
- **Streamlined workflows and faster insights** through integrated control and acquisition software with automation, live visualization, and intuitive operation.
- **Hands-off productivity** for busy labs with automated alignments, sample queues, and long unattended measurement series to ensure maximum uptime.



XPS and Deep HAXPES analysis of a complex multilayer MOSFET gate test structure





From Surface to Depth: XPS and HAXPES

Standard XPS provides clear insight into the top ZnO layer of complex multilayer devices, but signals from deeper oxides such as In_2O_3 and ZrO_2 become weak or undetectable. HAXPES at 9.25 keV extends the analytical reach, delivering strong, high-quality spectra from every layer – including buried oxides and even the Al electrode. Together, XPS and HAXPES give a complete picture of surface and subsurface chemistry, essential for optimizing advanced transistor performance.

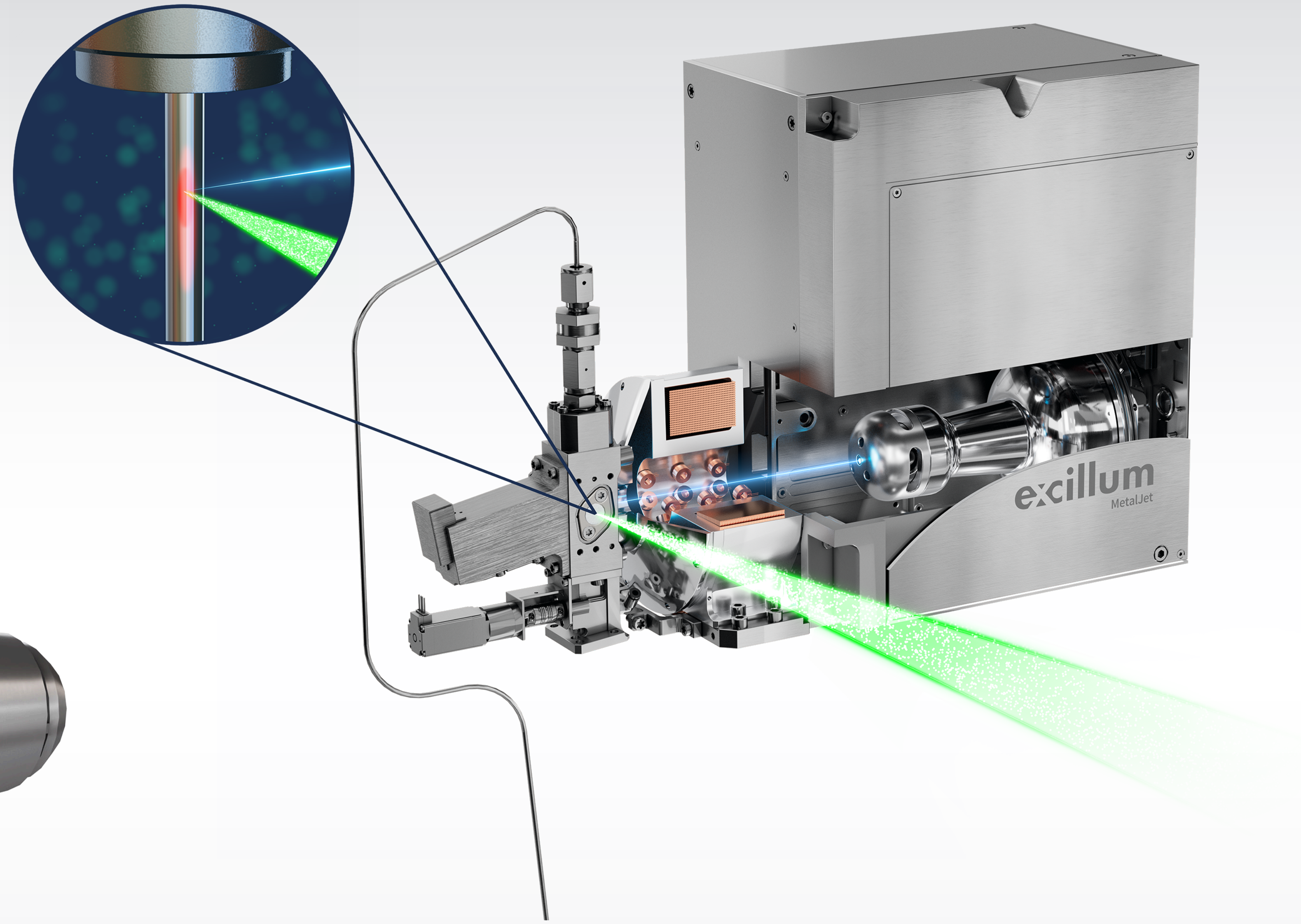
Yu, M., Cai, T., 2018. Review of Scientific Instruments 89, 109902.

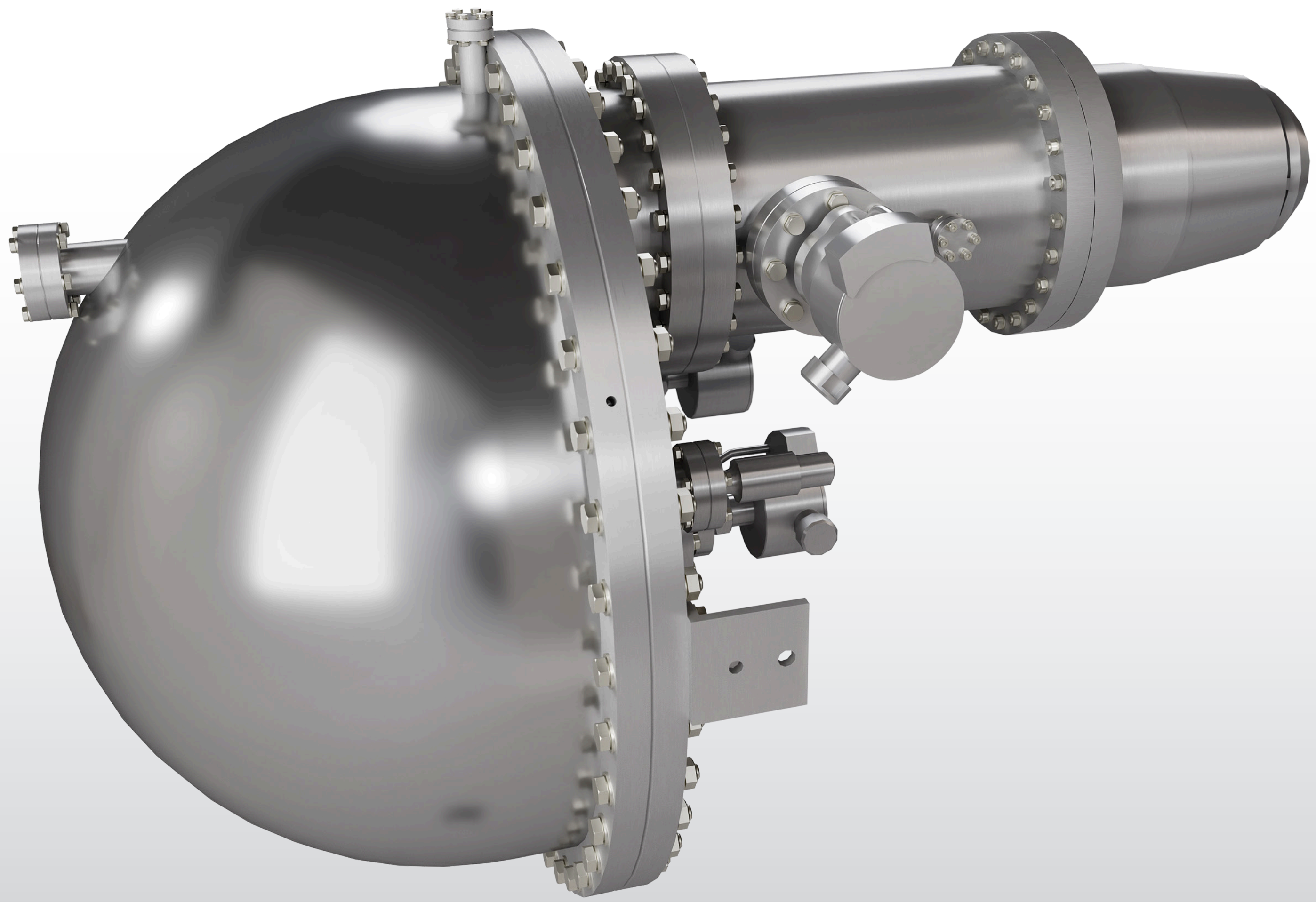
High-energy illumination meets high-acceptance detection

MetalJet X-rays and EW4000 analyser – designed to work together

9.25 KeV Ga Kα source from Excillum

- Deep, non-destructive access to buried interfaces and bulk – enabled by Ga Kα (9.25 keV) hard X-rays.
- High flux for fast HAXPES – 1000 W continuous operation with ~3.5× intensity boost (F vs D-series) accelerates data collection.
- Sharp spectra on small features – ~50 µm spot enabling grazing incidence synchrotron beamline geometry.
- F-series, engineered for uptime – liquid-metal jet with electromagnetic pump (no moving parts), jet shield and exit-window protection for stable, reliable operation



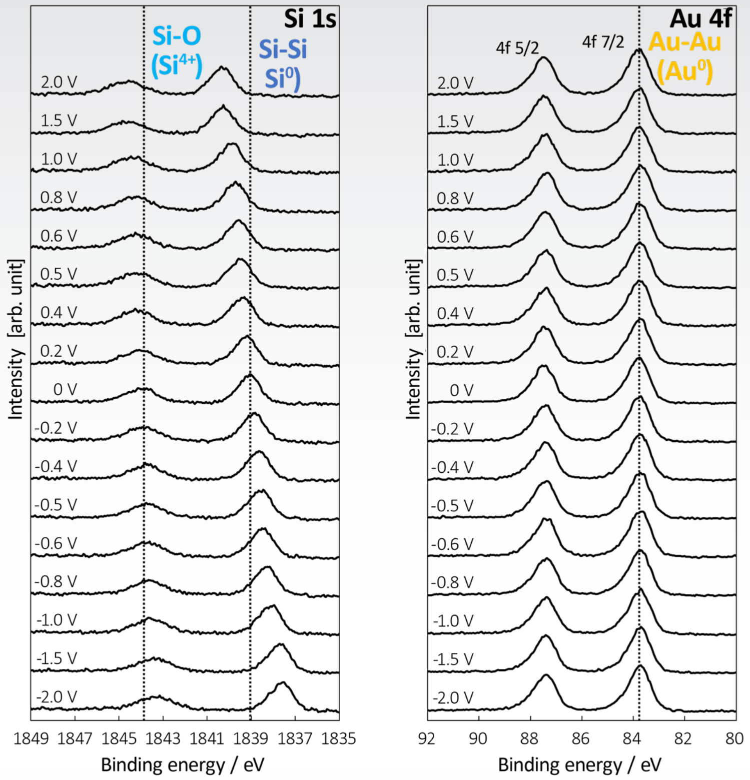


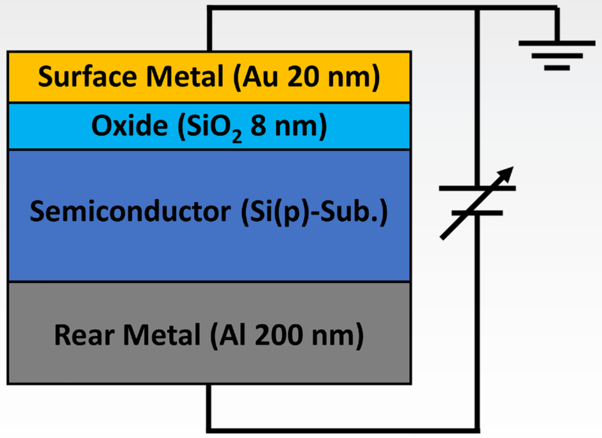
EW4000 High-Energy Electron Analyser

- More data per run, less stage motion – 60° extreme wide angular acceptance and 200 mm radius, for highest transmission and efficient depth profiling.
- Resolution and flexibility for any task – variable pass energy (20–500 eV), swept and snapshot modes, and software-controlled entrance slits optimize count rate vs. resolution.
- Clean signals and reproducibility – low-noise 2D MCP/digital camera detector and ultra-stable HV electronics deliver consistent, publication-grade, high signal-to-noise XPS and HAXPES.
- Accurate acquisitions with minimal distortion – built-in image-correction software ensures reliable energy and emission-angle imaging, even at wide acceptance, for all combinations of settings.

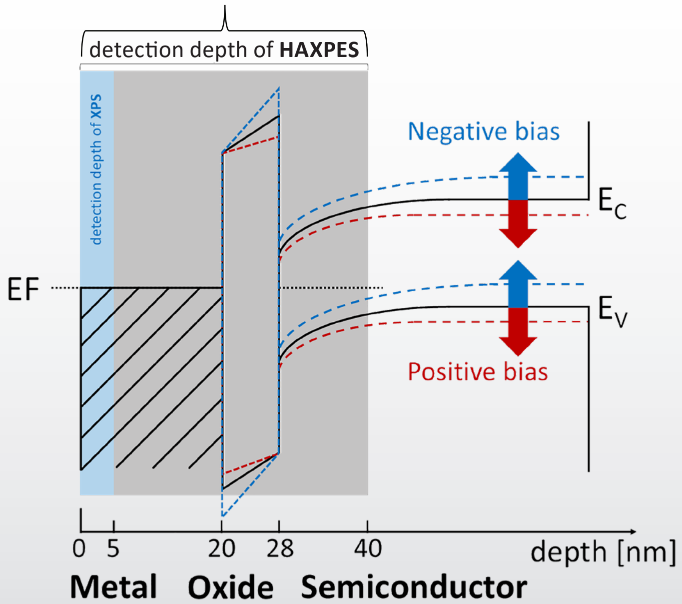
Applications that drive Discovery

Direct observation of band structure variation during device operation

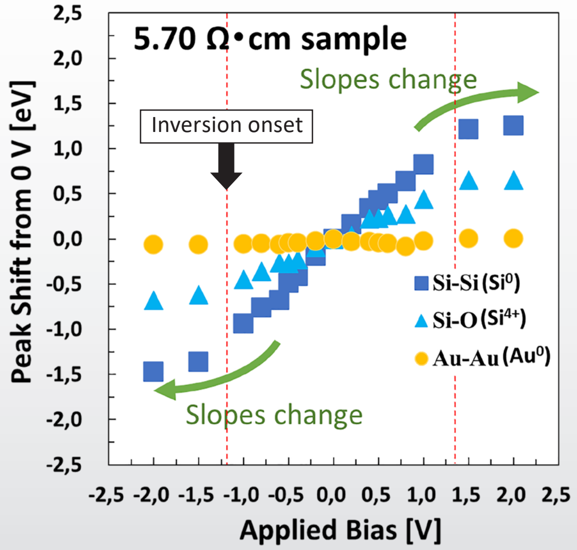




The applied bias from -2 V to 2 V gives no binding energy shift of the grounded Au top electrode. The signal from the buried Si substate, however, exhibits a bias dependent shift.



Comparison of detection depth of XPS (blue) and HAXPES (grey) along with an illustration of the band bending induced by positive and negative bias.



The change in binding energy shift - from linear to nonlinear - marks the transition from depletion to accumulation or inversion, which are the working principles of a MOS.

Minowa, T., Usuda, K., Yokogawa, R., Ogura, A., 2025. Applied Physics Letters 126, 072103.

Understanding how buried interfaces respond under electrical bias is critical for evaluating advanced MOS structures and multilayer devices. Traditional surface-sensitive XPS cannot probe through the top electrode and thin film stacks to provide insight of the chemistry in buried layers. Further, lower energies are sensitive to electric fields from sample bias application.

HAXPES provides non-destructive access to buried interfaces even under applied bias. Excitation with the Ga Kα MetalJet Source generates high-energy photoelectrons that can escape through metal electrodes and oxide layers, while the EW4000 analyser with image-corrected wide-angle detection captures data unveiling band-bending and trap-state formation with high resolution.

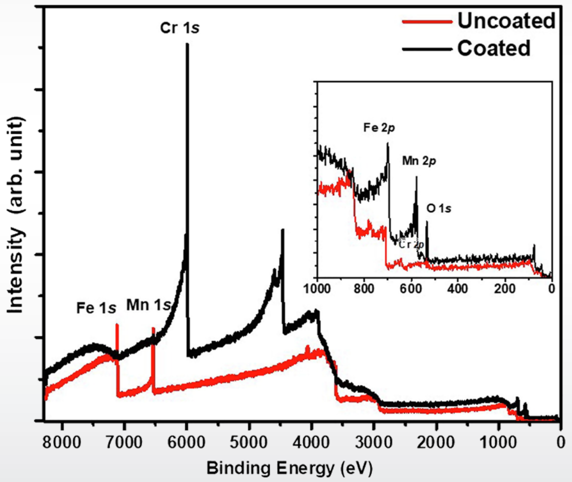
In their study, Prof Ogura's group demonstrate how bias-applied measurements reveal shifts in core-level binding energies that correspond directly to band bending at buried semiconductor/oxide interfaces. This enables a clear view of charge distribution in fully encapsulated device stacks. HAXPES makes it possible to perform operando electronic structure analysis of real-world device architectures in the laboratory, providing insights previously only achievable at synchrotron beamlines.

While the experiment is performed on a proof-of-principle semiconductor stack rather than a modern complex structure, the method relies on the binding energy shift of the Si 1s signal in the substrate. This makes it largely independent of the overlayer oxide stack.

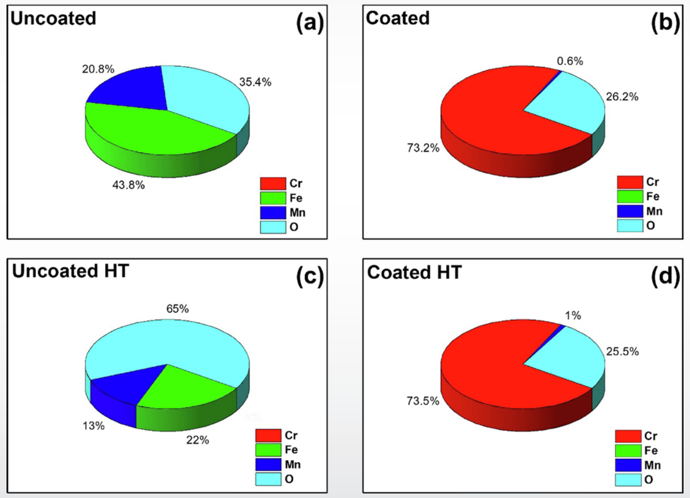
– Bias-applied operando measurements using Lab HAXPES with Ga x-ray source is a powerful, nondestructive method for evaluating buried interfaces in multilayer films of actual MOS devices.

Professor Atsushi Ogura
Meiji University, School of Science and Technology, Department of Electronics and Biomaterials, Semiconductor Nanotechnologies, Japan

Stabilizing metal powders for additive manufacturing



HAXPES survey spectra from uncoated (red lines) and Cr-coated (black lines) powder. Information depth with Ga source: Fe 2p, Cr 2s, Mn 2p ≈ 30 nm and Fe 1s, Cr 1s, Mn 1s ≈ 9 nm



HAXPES was used to confirm that continuous Cr films had formed, and to investigate oxygen pick-up in accelerated oxidation studies. Relative concentrations of Fe, Mn, Cr, and O, using the 1s orbitals for uncoated and Cr coated powder before and after heat treatment (HT).

Metallic powders are the foundation of powder metallurgy and additive manufacturing, but their performance can be limited by oxidation and poor flowability. For steels in particular, surface oxidation compromises both handling and final part quality. In this work, SA508 Grade 3 steel powders were coated with chromium using magnetron sputtering to provide a protective surface layer without altering the bulk properties of the material.

XPS and bulk-sensitive HAXPES confirmed that the Cr coating strongly suppresses surface oxidation, clearly separating the stable metallic core from reactive surface layers. The results show how thin, engineered coatings can extend powder stability and processability, providing a straightforward route to higher-quality inputs for advanced manufacturing.

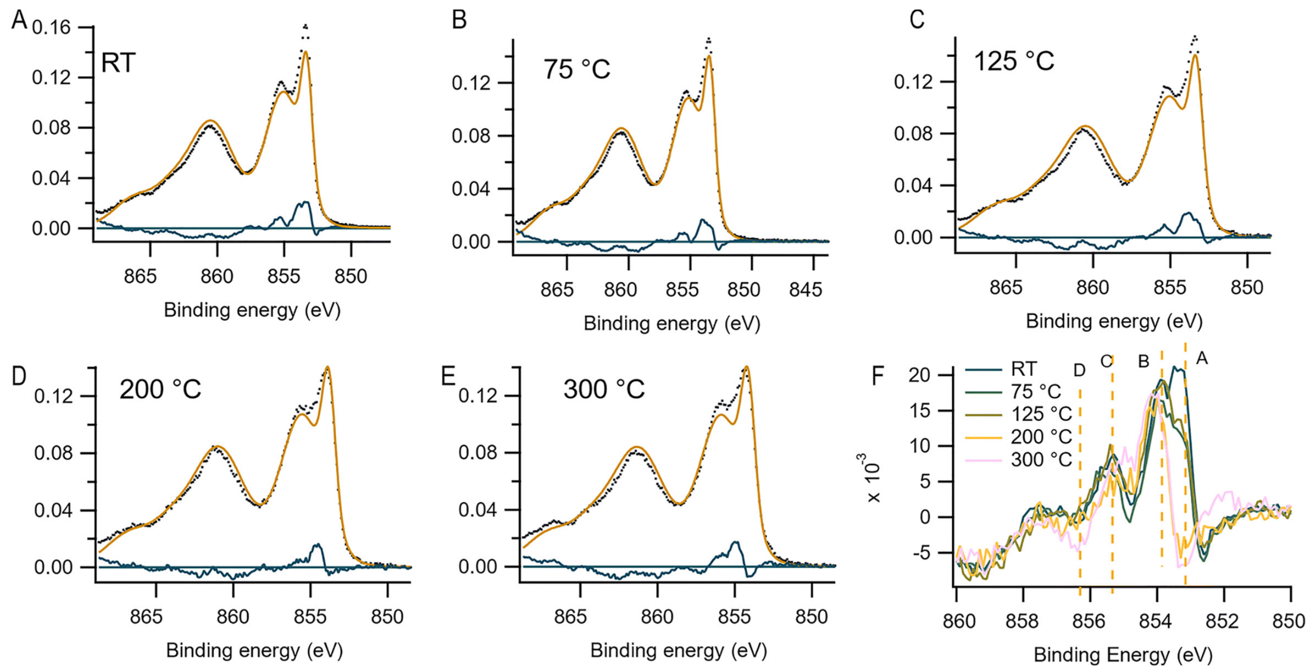
Unnikrishnan, R., Preuss, M., et al. 2022. Materials & Design 221, 110900.

Isolating surface fingerprints of nickel oxide using XPS and HAXPES

Nickel oxide is a versatile transition-metal oxide, widely studied for applications in catalysis, energy storage, and electrochemistry, where surface states and their interaction with gases critically determine functionality. Disentangling bulk and surface contributions, however, remains challenging with conventional spectroscopic tools.

By combining surface sensitive, synchrotron, ambient-pressure XPS with lab-based, bulk-sensitive Ga HAXPES, this work disentangles the two. The authors show that mesoporous NiO surfaces are a dynamic mix of hydroxides and reactive oxygen species dependent on temperature, atmospheric oxygen and water. HAXPES provides the bulk reference needed to isolate subtle surface fingerprints, offering a powerful route to track how NiO surfaces respond under realistic conditions.

Wrede, S., Tian, H., et al. 2025. Phys. Chem. Chem. Phys. 27, 12762–12773.



(A)–(E) Area normalized Ni 2p spectra of mesoporous NiOx films (black dots) from synchrotron XPS, the bulk NiO from HAXPES with Ga source (orange) and the residue of the bulk spectra from HAXPES to the data from synchrotron XPS (blue line) with increasing temperatures.
(F) Direct comparison of the subtracted spectra to the surface contribution at increasing temperatures.

Non-destructive Depth Profiling and Semiconductor Device Interfaces

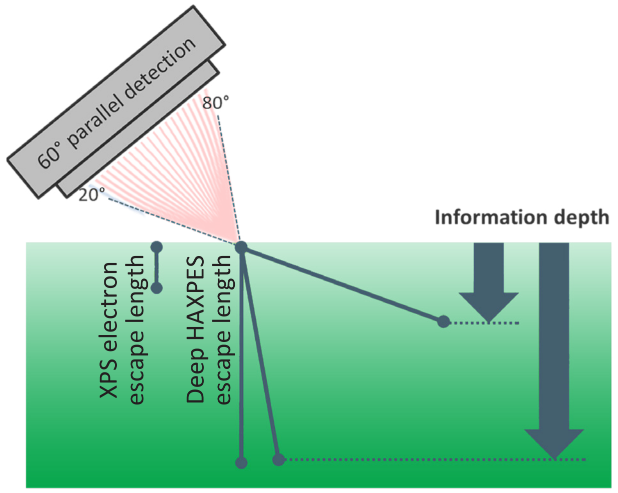
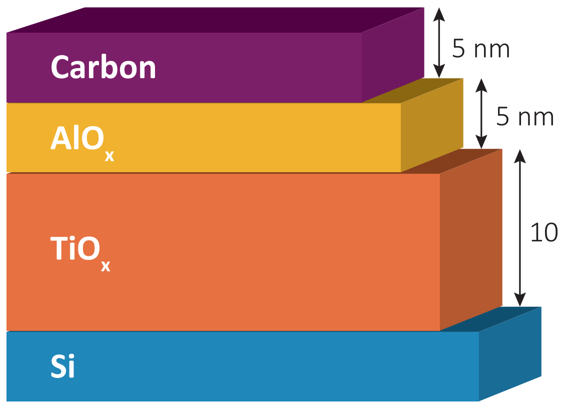


Illustration of how electron emission angles are used to access information from varying depths within the sample. The angular-resolved mode of the EW4000 analyser captures a 60° range for depth profiling - without requiring sample rotation.

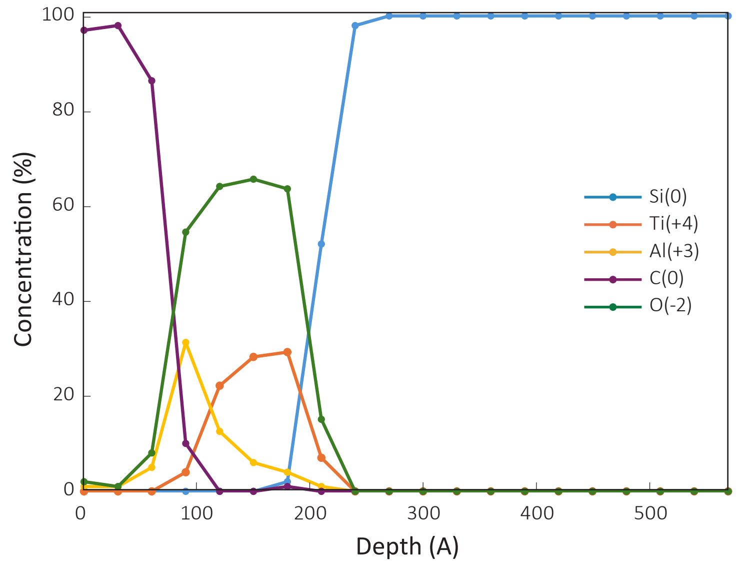
Modern semiconductor devices depend on complex multilayer architectures, where buried interfaces critically influence performance. Deep HAXPES enables direct investigation of the structural and chemical properties of these subsurface layers within the actual device stack, without the need for sputtering, thereby avoiding potential artifacts or chemical alterations.

The high photon energy of the Ga Kα MetalJet source (9.25 keV) allows probing depths of up to 50 nm, making it possible to perform non-destructive depth profiling. By analyzing angular intensity distributions and chemical states, layer thicknesses and elemental distributions can be accurately determined, providing valuable insights into device composition and integrity.



Multilayer stacked film

Non-destructive artefact free depth profile of multilayer stacked film



Non-destructive depth profile (no sputtering) obtained from angular-resolved Deep HAXPES measurements at 9.25 keV, showing elemental concentrations as a function of depth. The results align well with the expected composition of the grown sample.

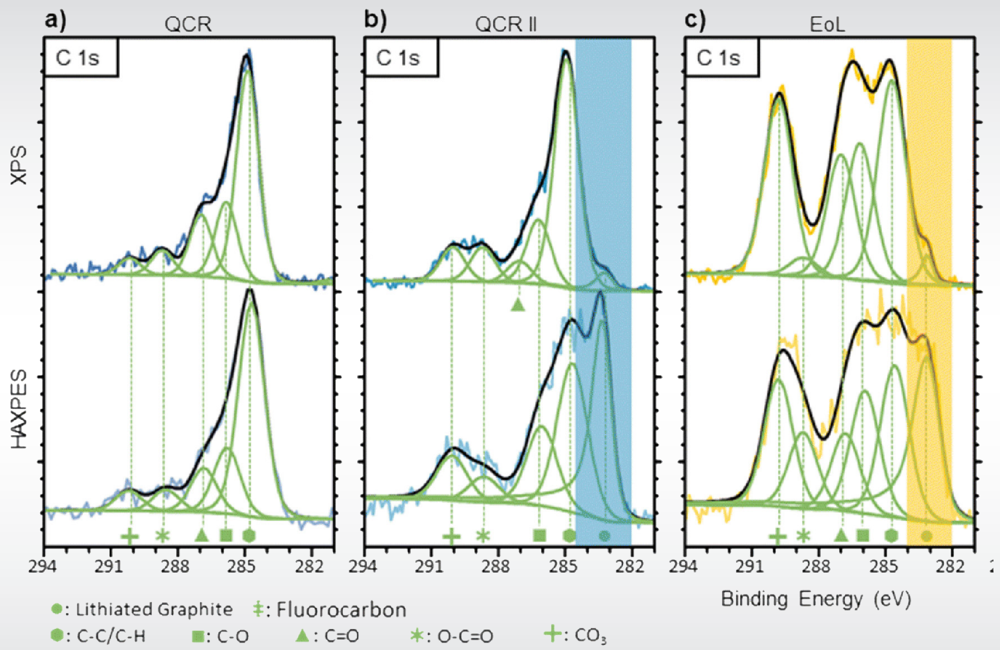
Sample by NTT-AT. Data courtesy: Dr S. Toyoda, Scienta Omicron

Surface chemistry and recycling insights from aged EV anodes

Early electric vehicle anodes, such as those used in first-generation Nissan Leaf cells, employed poly (vinylidene difluoride) (PVDF) binders, which pose challenges for recycling due to their poor solubility in environmentally friendly solvents. This study demonstrates that PVDF-bound anode material can be effectively separated from the copper current collector through simple immersion in water—enabled by the chemical reactivity of residual lithiated graphite.

HAXPES played a central role in identifying this residual lithiated graphite (~283 eV) deep within the anode structure, beyond the reach of conventional XPS. The high photon energy of HAXPES allowed non-destructive probing through thick SEI layers, revealing active material that remains even after discharge. This graphite reacts with water during recycling, generating hydrogen gas and localized pressure that promote delamination – eliminating the need for harmful solvents.

These findings support low-cost, sustainable recycling methods that reclaim high-performance graphite for reuse, helping reduce battery waste and secure critical material supply.



Carbon 1s XPS (top row) and HAXPES (bottom row) of anodes before wash and air exposure. All anodes were electronically discharged to a SOC 0 % before the experiment. The lithiated graphite region is highlighted with a transparent band.

Sargent, A.T., Allan, P.K., et al. 2023. J. Mater. Chem. A 11, 9579–9596.

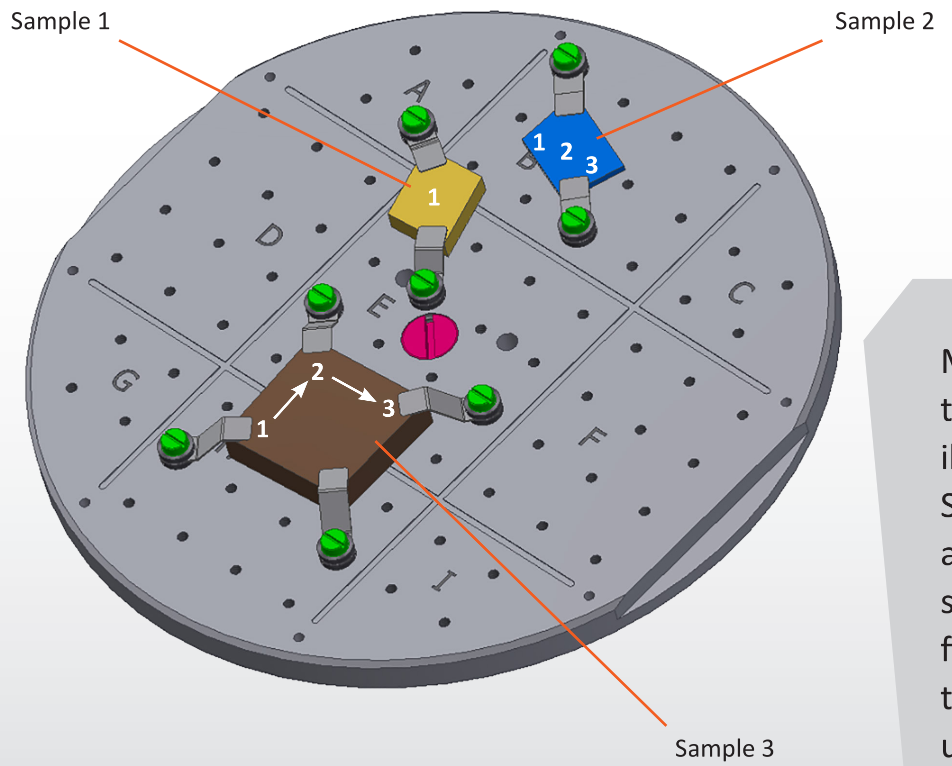
Enhanced sample accessibility

Flexible Sample Handling

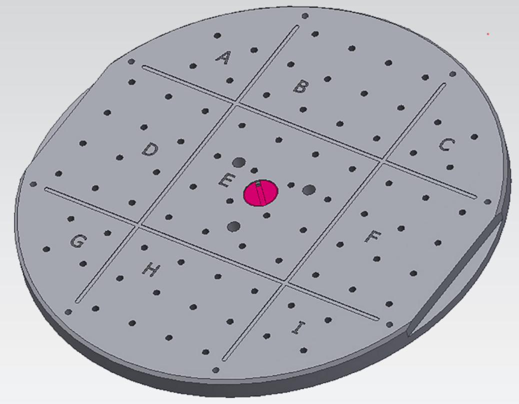
- 100 mm diameter breadboard sample carriers accommodate samples of various shapes and sizes
- Sample carrier options:
  - Sample carrier 100: Versatile, plain breadboard sample carrier
  - Operando 100: 6 electrical contacts for in-operando measurements
  - Wafer-4: Carrier for 4" wafers
  - Flag-style sample holder adaptors for connecting and sharing samples
    with other Scienta Omicron analysis and growth and sample preparation equipment

Scientific Sample Stage

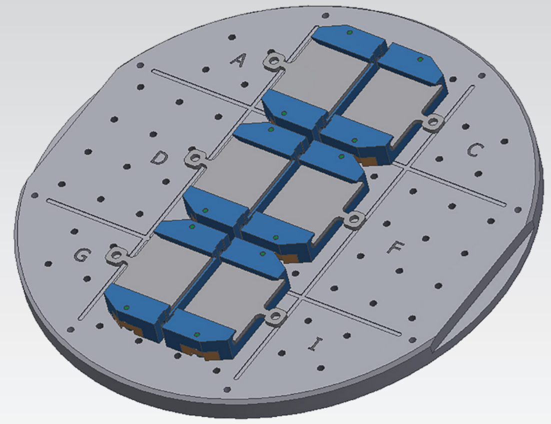
- Dedicated stage for flag-style sample holders with cooling and heating from 160 K to 1100 K.



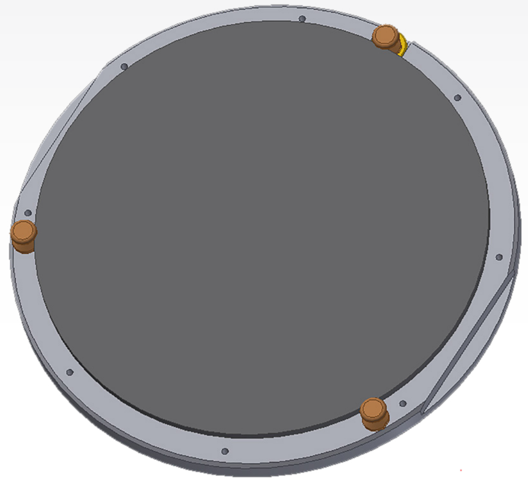
Measurement sequences for the three samples shown in the illustration.
Sample 2 includes multi-point acquisition, while sample 3 is scanned along two paths – first from point 1 to point 2, then from point 2 to point 3, using five measurement points for each segment.



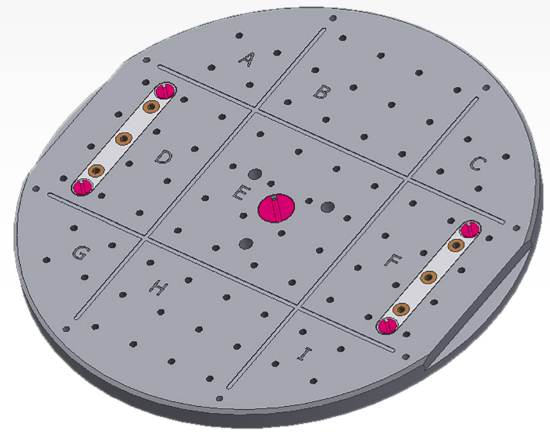
Sample carrier 100



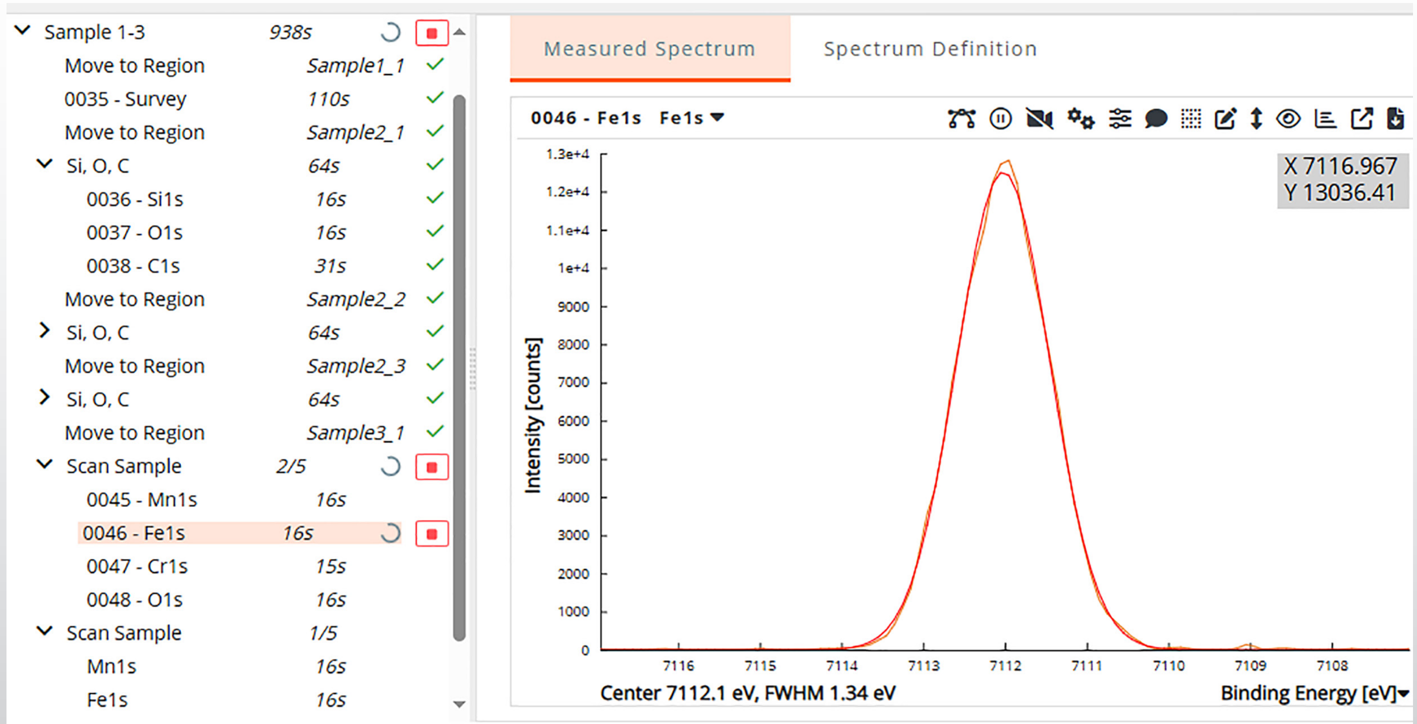
Sample carrier 100 with flag-style sample holders



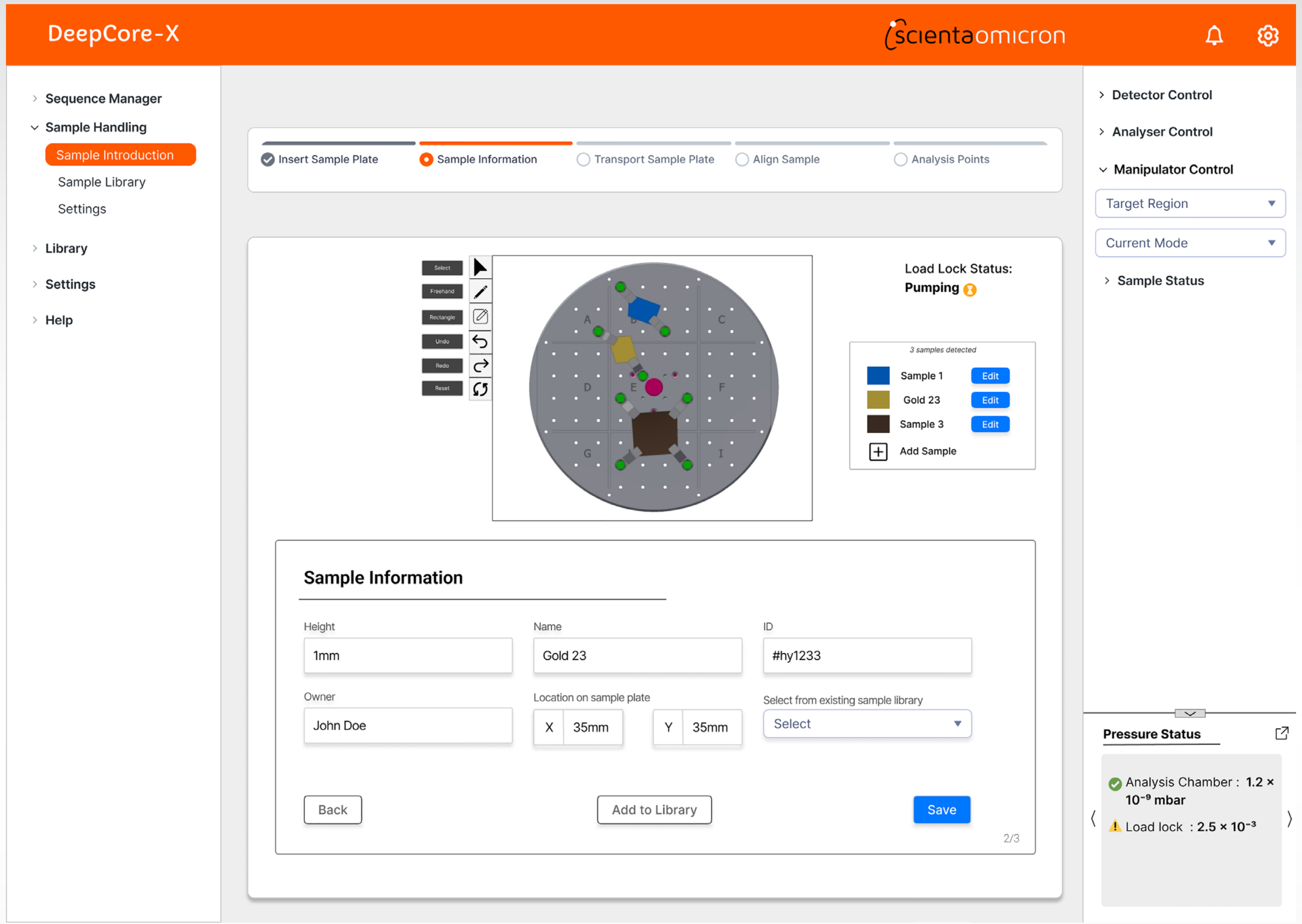
Wafer 4: 4" wafer holder



Operando 100 with 6 contacts (2x3)



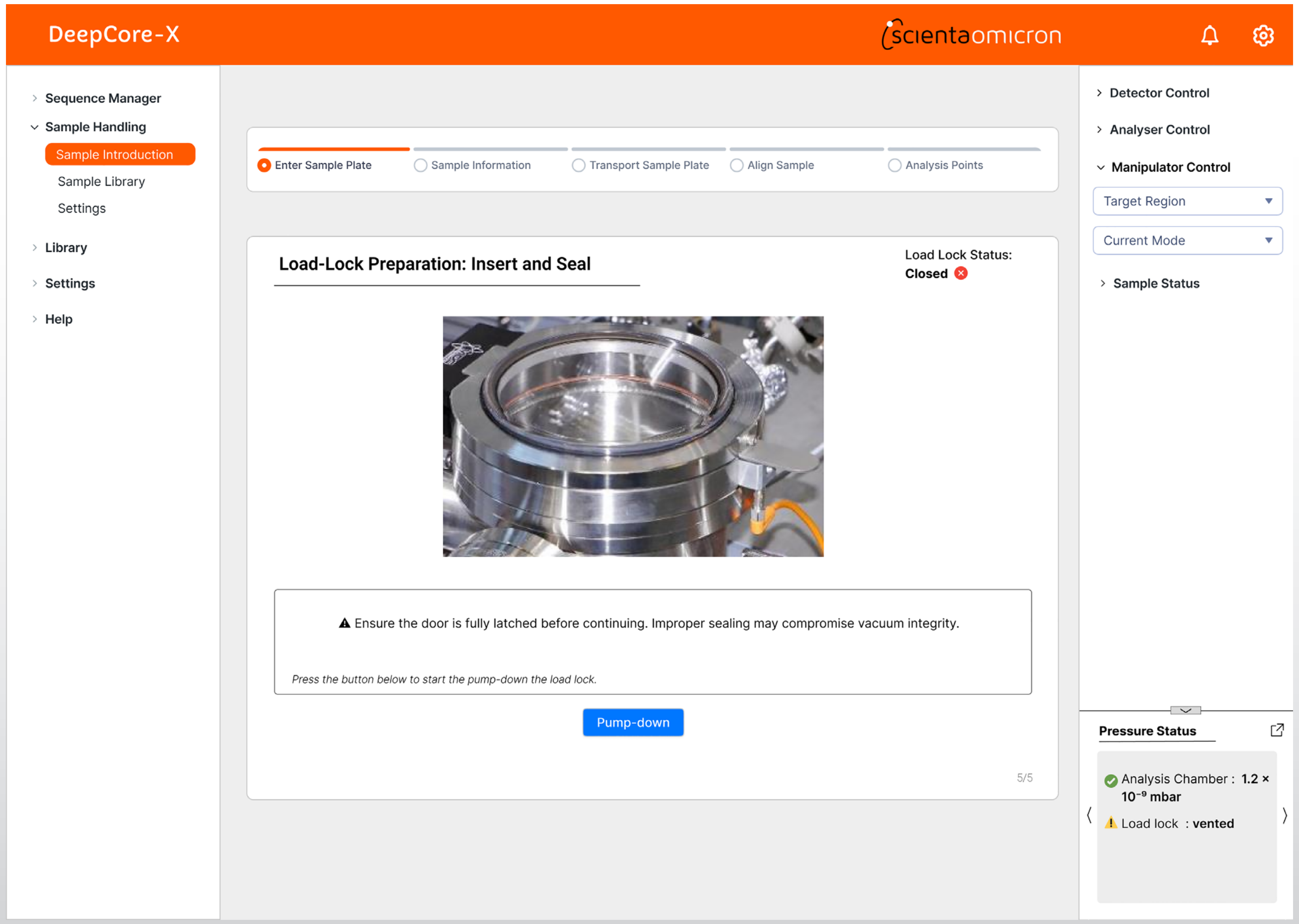
Integrated control and acquisition software



Guided sample introduction

The control and acquisition software has been designed with a user-friendly interface for guided sample introduction and load lock handling. Operators can follow a step follow step-by-step visual instructions, with real-time progress bars and safety prompts to ensure smooth venting, sample loading and transfer.

- Customizable control menus for flexible workflows
- Automatic sample plate detection for reduced setup time
- Always-on system status with clear pressure and load lock indicators
- Camera-assisted navigation and measurement point selection
- Easy definition of measurement sequences to streamline recurring tasks and reduce operator workload

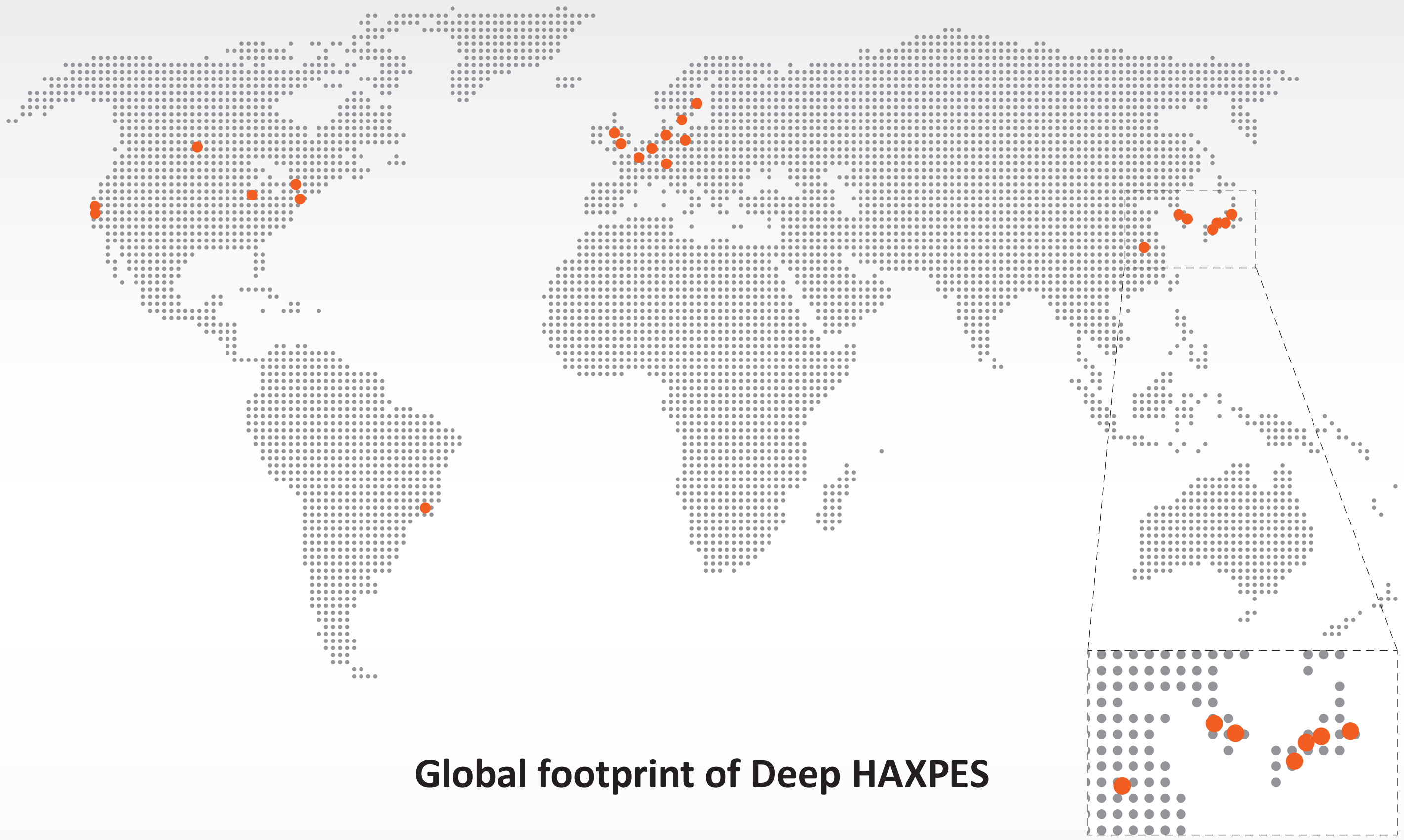


Smart sample management

To support multi-user facilities and long projects, the control and acquisition software is developed with smart sample management tools that make organization and tracking effortless.

- Smart sample detection to confirm positions and quickly set measurement points
- Sample library to store metadata, locations, and user information for each sample
- Integrated mapping of X–Y coordinates, height, and orientation
- Live camera view for navigation, allowing quick verification of sample identity and position inside the chamber
- Sequence automation integrated with the sample library, enabling scheduled multi-sample runs with minimal supervision

Our Deep HAXPES technology trusted by leading scientists and institutions around the world



Global footprint of Deep HAXPES

– HAXPES with Ga Kα is transforming characterisation in advanced materials research. We already routinely measure through passivation layer interfaces and detecting deeply buried layers. The upgraded throughput and sample accessibility of the next generation HAXPES-Lab will enhance this capability significantly.

Dr. Ben Spencer, Surface Characterization Facility lead, Henry Royce Institute

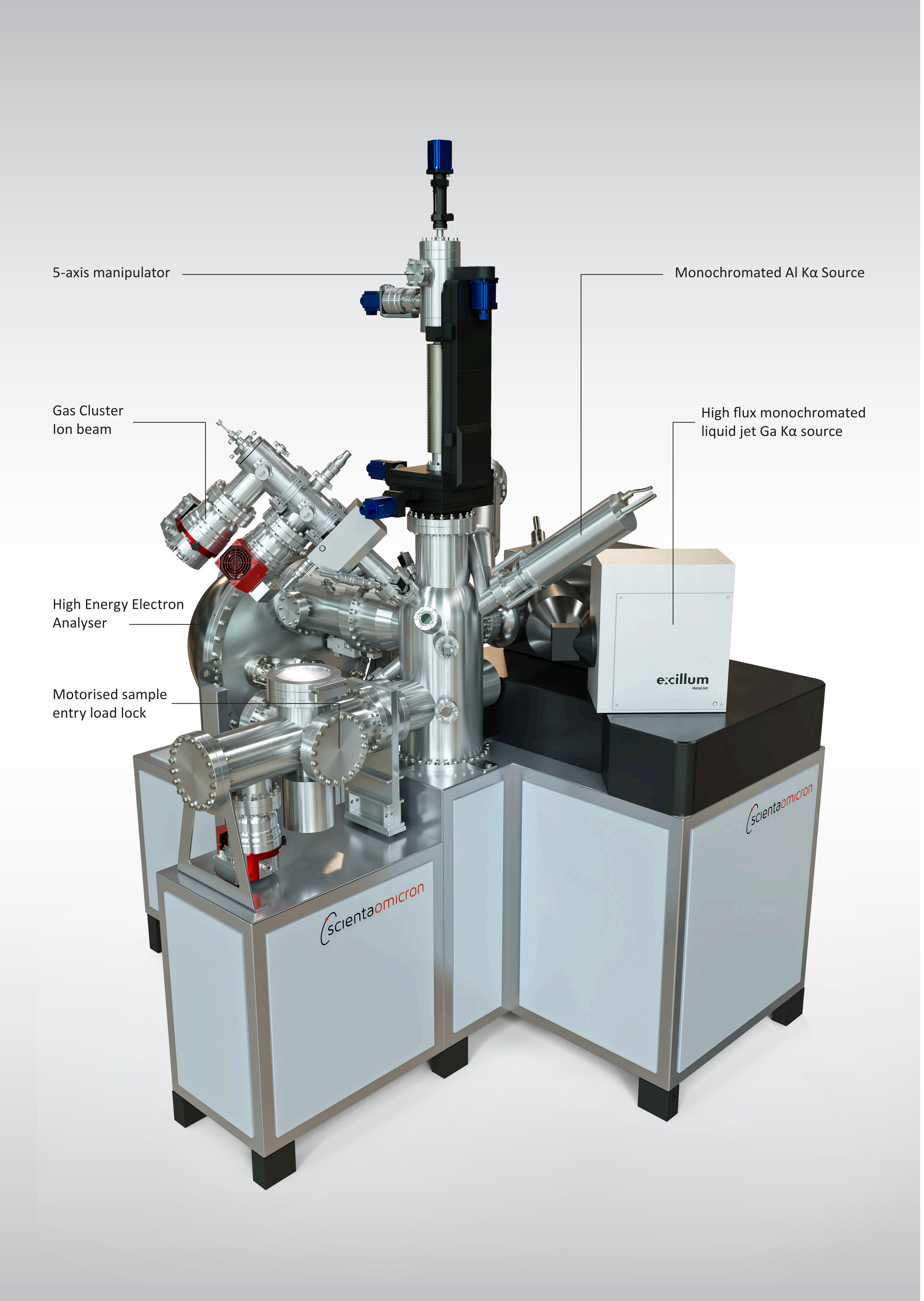
Designed for sustainability and the environment

At Scienta Omicron, sustainable product design is our priority, and we believe all research should be carried out with sustainability in mind.

That's why the Scienta Omicron DeepCore-X has been engineered not only for cutting-edge performance but also for energy efficiency, reduced waste, and long-term reliability.

- Smart automation minimizes operator time and system idling, ensuring efficient use of resources.
- Long component lifetime and modular design extend service cycles, reducing waste and the need for frequent replacements.
- Compact laboratory footprint with dramatically reduced travel and facility energy costs compared to synchrotron beamline access.

As a proud participant in the United Nations Global Compact, Scienta Omicron aligns with international principles on environmental responsibility, human rights, and sustainable development. Our commitment ensures that groundbreaking science can be achieved while contributing to a more sustainable future.



Technical Highlights

Sample transfer and navigation	100 mm diameter sample carriers with advanced options for 4” wafers electrical contacts bias application Automatic workflow from entry to measurement position Camera assisted sample navigation and measurement sequence set-up Scientific sample stage for heating and cooling
Electron spectrometer: EW4000 analyser	High transmission analyser including angular modes for depth profiling Optimal resolution and intensity balance with software-controlled entrance slits and variable pass energy More than 1000 simultaneous energy and 750 angular channels supporting overview and snapshot spectra
Monochromatic HAXPES x-ray source for deep probing	Excitation energy: 9.25 keV Excillum Ga Kα MetalJet F Spot size: 50 µm Maximum power: 1000 W Total system HAXPES resolution: <0.55 eV
Monochromatic XPS x-ray source for surface sensitivity	Excitation energy: 1.49 keV Al Kα Spot size: 1 mm Maximum power: 300 W Photon linewidth: 0.25 eV
Flood source	Electron flood gun for charge neutralization during X-ray photoelectron spectroscopy experiments on insulators and semiconductors
Ion sputtering source	Scanning, fine focus Ar+ ion source for high performance sputter etching, depth profiling and charge neutralization
System features	Base pressure: 5 x 10^{-10} mbar 5 axis sample manipulator with azimuth rotation Integrated system control and acquisition software
Options	Gas Cluster Ion Beam source Sample carriers for Bias applications, 4” wafers, flag style adaptors etc.