NEW PRODUCT RELEASE

EnviroESCA II

FULLY INTEGRATED NEAR-AMBIENT PRESSURE XPS/HAXPES-PLATFORM
FOR IN SITU AND OPERANDO SURFACE SCIENCE

KEY FEATURES

- XPS and HAXPES at pressures up to 100 mbar
- Multiple photon energies, Al K_α, Ag L_α, Ti K_α and Cr K_α
- Fully autonomous exchangeable experiment modules
- Loading-to-measurement < 2 min
- High throughput analysis



Enviro™

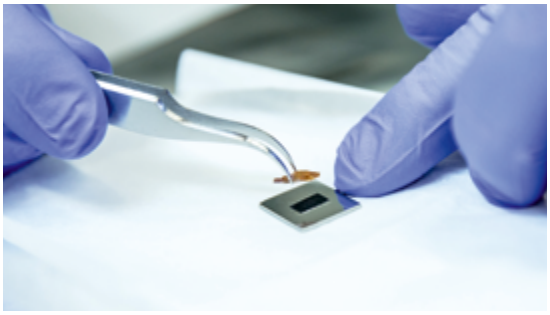
A member of SPECSGROUP

EnviroESCA II

SURFACE CHEMISTRY UNDER REALISTIC CONDITIONS

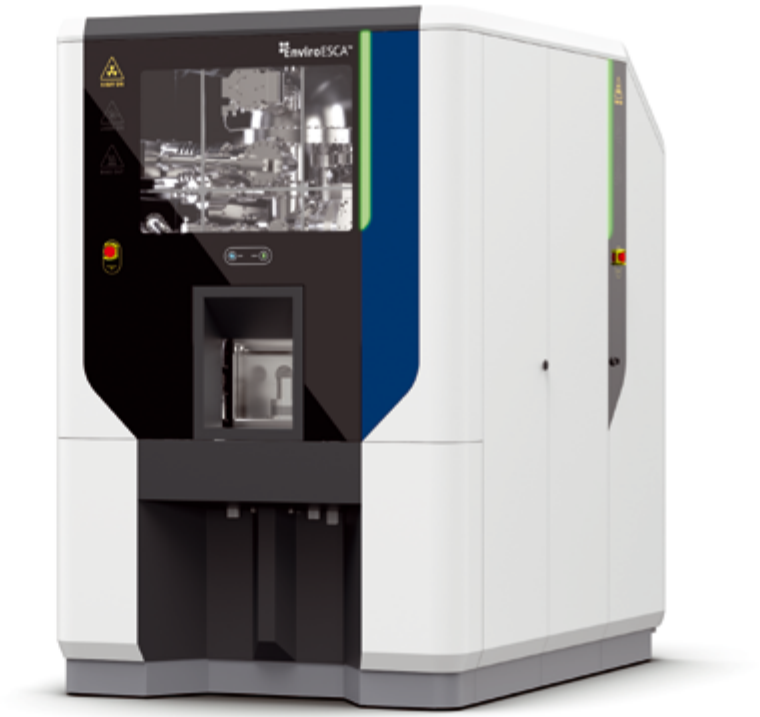
Exploring real-world processes

Many materials behave differently under ultra-high vacuum than in their actual working environment. Near Ambient Pressure-XPS and HAXPES bridge the material and pressure gaps by enabling samples to be studied in the presence of gases, vapours and liquids. In situ and operando measurements reveal surface composition, chemical states and reaction processes as materials interact, transform and perform under real-world conditions.





Engineered for experiments under real conditions



The concept

EnviroESCA is a dedicated NAP-XPS/HAXPES platform that complements conventional UHV-XPS by extending photoelectron spectroscopy into controlled gas, vapour and liquid-containing environments. A differentially pumped electron analyzer captures photoelectrons close to the sample surface, reducing scattering losses along the electron path. Combined with multi-line, monochromated X-ray excitation, the system provides quantitative information on elemental composition, chemical states and electronic structure across a pressure range up to near-ambient conditions.

The integrated system layout combines the analysis chamber, electron analyzer, X-ray source, differential pumping stages, vacuum and gas-management systems, sample positioning and optical navigation in one coordinated platform. Exchangeable sample environments support controlled gas dosing, water vapor exposure, thermal treatment, electrochemical operation, and liquid or solid-liquid-gas interface studies. The modules can be prepared and validated independently before transfer into EnviroESCA II for in situ or operando analysis. Optional complementary techniques can monitor reaction products or provide additional information from the same experiment and measurement spot.

This measurement concept provides surface analysis in application-relevant environments. In situ and operando measurements reveal real-time insights into surface reactions, transient chemical states, reaction intermediates, and surface transformations.

System capabilities

- Near Ambient Pressure Photoelectron Spectroscopy (NAP-XPS/HAXPES)
- Near Ambient Pressure Angle Resolved X-ray Photoelectron Spectroscopy (NAP-ARXPS)
- Near Ambient Pressure Ultraviolet Photoelectron Spectroscopy (NAP-UPS)
- Pressure range 10^{-7} to 100 mbar
- Infrared Reflection Adsorption Spectroscopy (IRRAS)
- RAMAN Spectroscopy
- Solar simulator
- UHV and environmental charge compensation
- Exchangeable sample environments for variable or high temperature treatments and electrochemical cells
- Glovebox extension for all sample environment
- High sample throughput capacity

Core Components

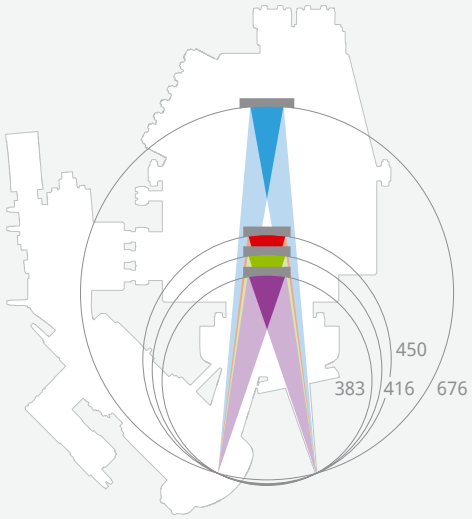


Advanced, multi-line X-ray source

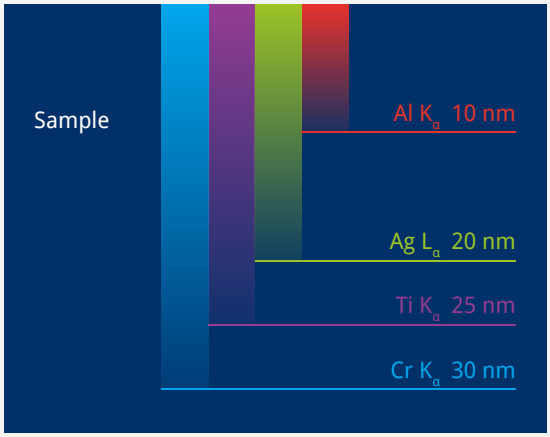
The quality of a measurement begins with the excitation beam. The µFOCUS 450 X-ray source series offers flexible combinations of X-ray excitation lines, from conventional Al K_α to Ag L_α, Cr K_α and the recently introduced Ti K_α. The different excitation energies provide various information depths, allowing the excitation to be matched to the analytical problem.

Each line uses a dedicated anode and individually optimized monochromator crystal.

- Excitation Lines: Al K_α (1487 eV), Ag L_α (2984 eV), Ti K_α (4511 eV), Cr K_α (5414 eV)
- Dedicated optics for every selected X-ray line
- Spot size: < 100 µm to 500 µm (for Al K_α)
- Optimized photon flux density



Monochromator layout with Rowland Circles; in mm



Available information depth by four X-ray lines.

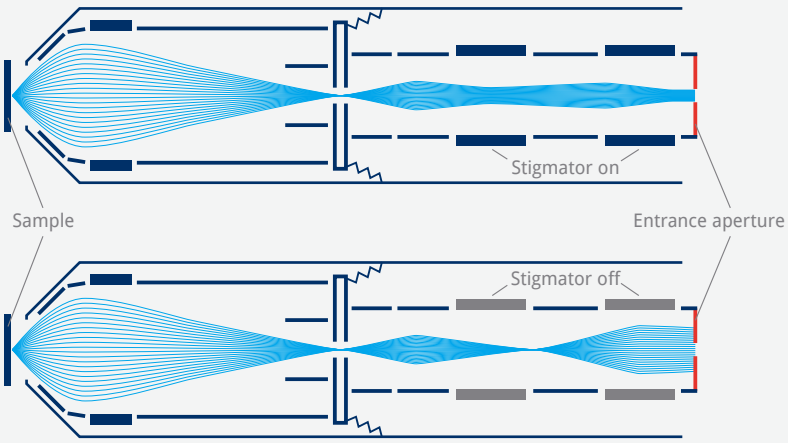
High-transmission electron analyzer

The high-transmission hemispherical electron energy analyzer AEOLOS 150 is a true 180° hemispherical energy analyzer with 150 mm mean radius. Its design is especially optimized for highest transmission and small excitation spots. It was developed for demanding XPS, HAXPES, and angle-resolved measurements.

Combined with the AD-CMOS true pulse counting detector, it delivers high count rate performance and excellent linearity.

- Optimal spectral performance for XPS, HAXPES and ARXPS
- Beam forming lens for maximum signal intensity
- Non-destructive depth profiling with 44° acceptance angle
- True pulse counting CMOS detector





Patented beam forming lens for up to 2× count rate at constant resolution.

Main System

System base and core architecture

The EnviroESCA II system base enables non-destructive XPS surface analysis at pressures up to 100 mbar and offers a reduced sample loading-to-measurement turnaround of under two minutes. The system is fully software controlled in a compact all-in-one interface featuring integrated safety interlocks, automated gas and pressure management, and multi-user safety controls.



High-transmission analyzer

Hemispherical Electron Analyzer equipped with a high-transmission lens offers optimal photoelectron collection efficiency across UHV and NAP regimes. Paired with a true pulse-counting ADCMOS detector the analyzer delivers high sensitivity and rapid spectrum acquisition.

Multi-line, small-spot X-ray source

Micro-focused and monochromated X-ray source features a tunable spot size and up to four individual monochromated X-ray excitation lines Al K_α, Ag L_α, Ti K_α and Cr K_α.

UV source

Dedicated UV source adds the capability of Ultraviolet Photoelectron Spectroscopy (UPS) for valence band and work-function studies under near ambient gas pressures.

Pumping and vacuum system

Corrosion-resistant, multi-stage pumping system with chemical-resistant turbomolecular pumps and oil-free dry backing pumps enable a wide pressure dynamic range.



Charge compensation

UHV charge compensation uses a low-energy electron source for conventional sample charge suppression. The intrinsic environmental neutralization features gas photoionization at elevated pressures (> 1 mbar) for homogeneous, artifact-free charge neutralization on complex insulators, ceramics and polymers. The system contains integrated gas inlet lines to introduce inert compensation or process gases.

Ion sources and sputter depth profiling

Fine-focused monoatomic ion source enables sample surface cleaning, Ion Scattering Spectroscopy (ISS/LEIS), and precision sputter depth profiling. Gas Cluster Ion Beam Source (GCIB) for gentle, damage-free depth profiling of delicate organic polymers, biomaterials, and thin films is optionally available.

Optical spectroscopy and combined techniques

Through specialized optical ports simultaneous optical spectroscopy (e.g., in situ Raman or IRRAS) can be integrated and coupled to photoelectron measurements.

Gas diagnostics and in situ processing

Differentially pumped quadrupole mass spectrometer (RGA) provides real-time gas tracking and purity monitoring during the experiments.

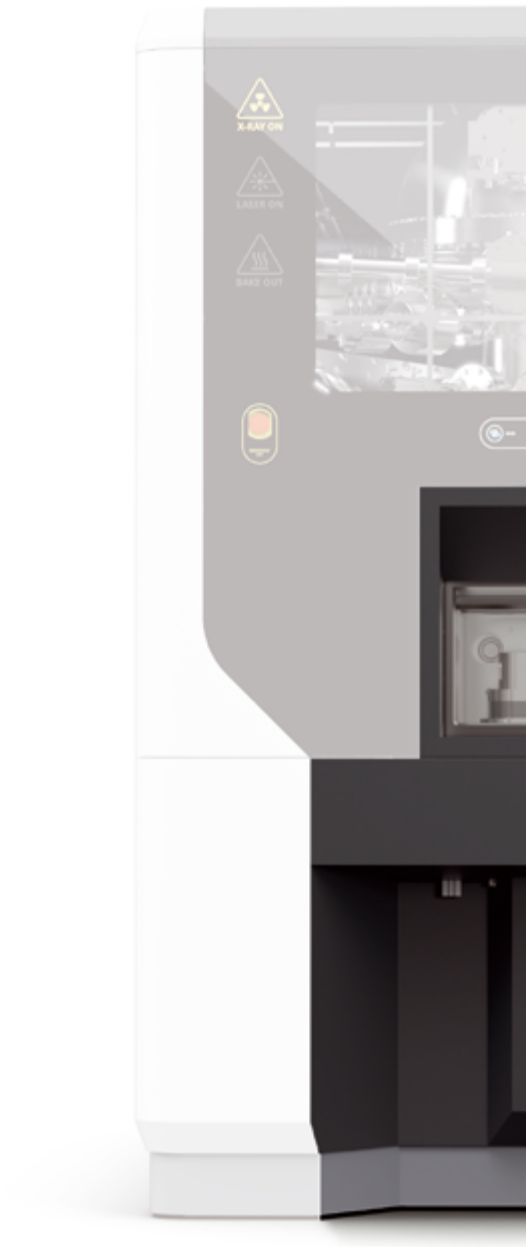
Experiment Sample Environment

From sample environment to experiment sample environment

The new autonomous experiment module advances the EnviroESCA II sample environment concept into a self-contained experimental platform. Each module integrates its own gas-dosing system, control computer, power supply, and dedicated electrical, fluidic, and process interfaces. This allows experimental parameters and peripheral equipment to be used independently of the EnviroESCA II.

Experiments can be assembled, commissioned and tested outside EnviroESCA II. Users first validate the setup on the bench, whether it involves gas or liquid flows, heating, illumination, electrical or electrochemical contacts, or a defined measurement sequence. The complete module is then transferred into the analysis system for in situ or operando characterization under the same conditions. Standardized mechanical, electrical and fluidic interfaces keep the configuration intact during transfer and ensure the module integrates reliably with the spectrometer. Instrument time is spent on measurements, not on setup.

This modular architecture separates experiment development from valuable analysis time. Users can prepare one module while another measurement is running, test complex configurations before installation, and reproduce experimental conditions more reliably. It also provides greater flexibility for developing dedicated cells for catalysis, electrochemistry, thermal processes, gas-solid reactions, and other application-specific workflows.





Various types of experiment sample environments

All modules incorporate a digital camera for experiment observation, integrated PC for experiment control and a downstream RF plasma cleaner for non-destructive, in situ hydrocarbon removal and surface activation prior to analysis and process/purge gas dosing. An integrated glovebox coupling is available.

Standard configuration
High-precision 3-axis (X, Y, Z) manipulator handles samples up to 90 mm in diameter and 40 mm in height (50 mm² addressable region), up to 6 electrical contacts/feedthroughs.

High-temperature configuration
Integrated IR laser heating module reaching sample temperatures up to 1000 °C under 10 mbar atmosphere (10 mm² addressable area).

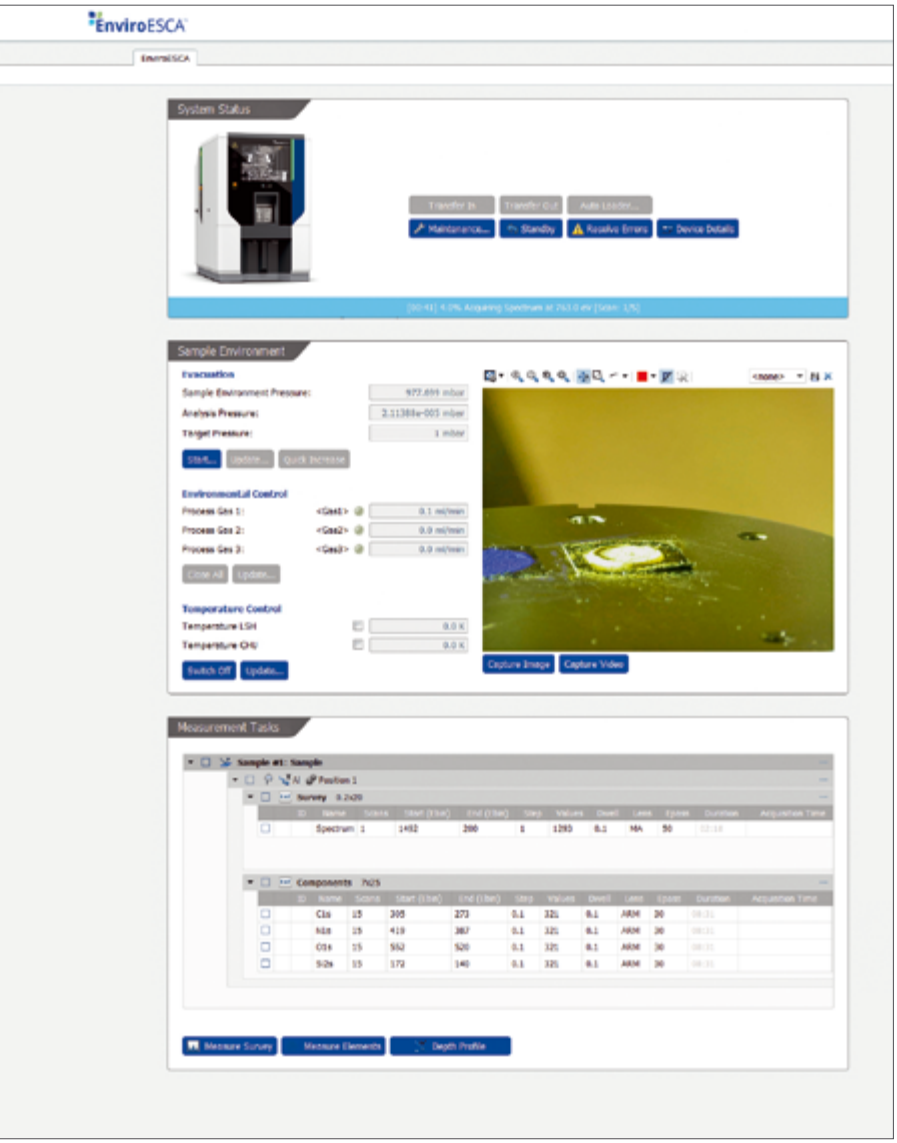
Variable-temperature configuration
Button heater (up to 600 °C) and precision power supply for controlled sample heating. Temperature-controlled Peltier cooling (down to –10 °C) for thermally sensitive, volatile, or biological samples. Both with a 10 mm² addressable area.

Electrochemical configuration
Refillable 3-electrode electrochemical cell for solid-liquid interface studies, and liquid dosing lines.

Software

Software

Keystone E is the integrated control and automation software for EnviroESCA II. It provides centralized control of instrument hardware, including vacuum, gas dosing, and sample handling components, while managing experiment execution, data acquisition, and system monitoring. Its modular architecture enables automated workflows, reproducible measurements, and seamless integration of standalone experiment modules with the EnviroESCA II analytical platform.



Recipes

Advanced measurement recipes automate the experimental workflow, ensuring reproducible results while reducing operator effort and measurement time. A suite of integrated experiment features, including periodic table and spectroscopic reference libraries, supports efficient experiment planning and data interpretation. This simplifies the daily operation and enhances user confidence across a wide range of applications.

Data processing

Advanced curve-fitting routines used for automated peak identification and quantification are just one example of the advanced software package. Specific data sets are easily retrieved from the central database by using advanced search routines. Each entry can be tagged and grouped for batch data analysis.

Data logging

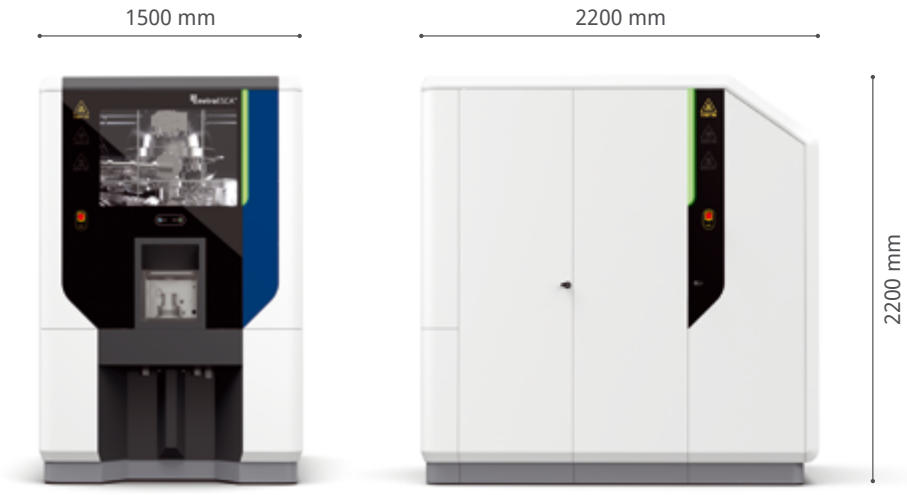
All system parameters including temperature of system components, pressure readings, and equipment health status are permanently recorded. Availability of this database makes for time-efficient service and maintenance.

Technical data

EnviroESCA II	
Electron Spectrometer	• High-transmission hemispherical electron analyzer with 150 mm mean radius • Differentially pumped lens system • Ultra-linear adaptive dimensions true-pulse counting AD-CMOS detector
Multi-line X-ray Source	• Standard: Al K_α micro-focused monochromator • Optional: Ag L_α, Ti K_α and Cr K_α lines for extended excitation energies • Spot size < 100 µm to 500 µm (for Al K_α)
Charge Neutralization	• Environmental charge compensation • Floodgun
Ion Source (optional)	• Scannable small spot ion source (200 eV – 5 keV) • Gas cluster ion source
Pumping System	• Turbomolecular pumps • Oil-free backing pumps
Pressure Range	• Defined by analyzer aperture (up to 100 mbar with an aperture of 300 µm; other aperture sizes on request)
Gas Dosing System	• 5 separate gas dosers at analysis position • H_2O vapour • Mass flow controllers
Cameras	• 3 digital microscopes for sample navigation and documentation
Automation and Software	• Keystone E software package • Fully automated vacuum and gas dosing system • Integrated data recording and reporting

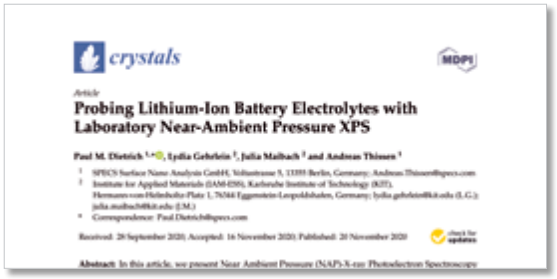
Technical alterations reserved.

Dimensions



We invite you to discuss your experiments and demo measurements with EnviroESCA II.

Publication Examples



Energy storage / Battery electrolytes Liquid electrolytes at work

Conventional XPS forces liquid electrolytes into vacuum-compatible states that no longer resemble their working chemistry. EnviroESCA keeps them liquid.

The challenge

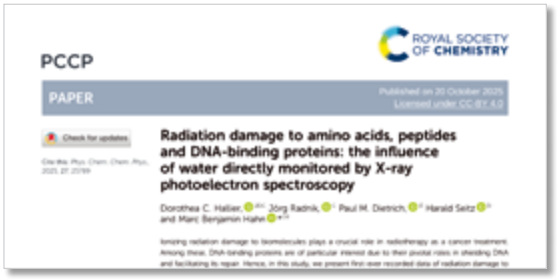
Commercial Li-ion electrolytes such as LiPF6 in EC/DMC are volatile and easily damaged under standard UHV-XPS, masking exactly the solid-liquid interface chemistry that governs battery performance. Researchers from SPECS and the Karlsruhe Institute of Technology recorded NAP-XPS spectra of the commercial LP30 electrolyte in both its vapor and liquid phase, then immersed a V_2O_5 single crystal – a model cathode material – directly into the electrolyte at pressures of 2–10 mbar. The resulting core-level spectra revealed clear chemical differences between the LiPF6-based commercial electrolyte and a LiTFSI model system, showing that solid-liquid interfaces in energy-storage systems can be probed with a compact laboratory instrument rather than a synchrotron beamline.

The insights

- Analyze commercial battery electrolytes in their native liquid state
- Immerse solid electrode materials directly into the electrolyte for interface studies
- Compare model and commercial electrolyte chemistries side by side

Publication basis

P. M. Dietrich, L. Gehrlein, J. Maibach, A. Thissen,
Crystals 10 (2020) 1056
DOI: 10.3390/cryst10111056



Medicine / Radiation biology Protein radiation damage, under water

DNA-binding proteins shield DNA and help repair it after radiotherapy. Until now, nobody had watched radiation damage a protein while it was hydrated.

The challenge

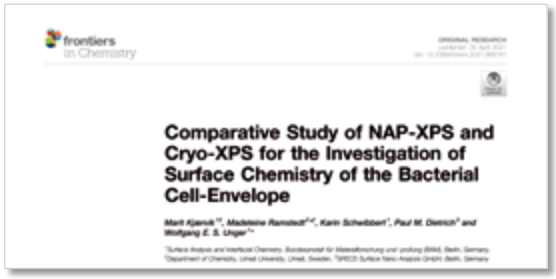
In cells, proteins bound to DNA can protect it from radiation, or make the damage worse. Conventional XPS can only irradiate these proteins dry, in vacuum. Researchers from the University of Potsdam, Fraunhofer IZI-BB, BAM and SPECS used NAP-XPS to record the first data of radiation damage to a protein under a water atmosphere. In EnviroESCA, the model DNA-binding protein gene-V (G5P), amino acids and peptides were irradiated and probed at 4–5 mbar water for about 13 hours and compared with dry samples in vacuum. In dry samples, X-rays mainly broke peptide bonds and split off side groups. Under water, the overall damage decreased despite extra damage routes from water radiolysis – the opposite of what the same setup showed for DNA.

The insights

- Irradiate and monitor proteins and peptides while they are hydrated
- Compare the radiation response of different biomolecules (DNA vs. proteins) under the same conditions
- Generate data for cancer radiotherapy and astrobiology research

Publication basis

D. C. Hallier, J. Radnik, P. M. Dietrich, H. Seitz, M. B. Hahn,
Phys. Chem. Chem. Phys. 27 (2025) 25789
DOI: 10.1039/d5cp01887k



Microbiology / Bacterial cell envelopes
Bacteria, without the freeze-dryer

For decades, XPS of bacteria has meant freeze-drying or cryo-preparation first – steps that risk altering the very cell-envelope chemistry under investigation.

The challenge

Standard XPS requires a vacuum incompatible with living, hydrated bacterial samples, so researchers have relied on freeze-dried or cryogenically frozen specimens – convenient for the instrument, questionable for biology. A joint team from BAM, Umeå University and SPECS directly compared NAP-XPS on hydrated, near-native Pseudomonas fluorescens with cryo-XPS on frozen equivalents. The study established C 1s and other reference spectra for this bacterial strain and proposed planktonic P. fluorescens cells as a reference material for future bacterial surface-chemistry work – a benchmark independent of any single preparation method.

The insights

- Analyze bacterial surfaces close to their native, hydrated state
- Directly compare hydrated NAP-XPS and frozen cryo-XPS data on the same strain
- Establish reference spectra for future bacterial surface-chemistry studies

Publication basis

M. Kjærvik, M. Ramstedt, K. Schwibbert, P. M. Dietrich, W. E. S. Unger,
Frontiers in Chemistry 9 (2021) 666161
DOI: 10.3389/fchem.2021.666161



Food science / Nutritional biotechnology
Zinc, baked into yeast

Trace-element-enriched yeasts are a growing category of nutritional supplement, but before zinc-enriched yeast can be authorized as a food ingredient in the EU, regulators need to know exactly what chemical form the zinc takes.

The challenge

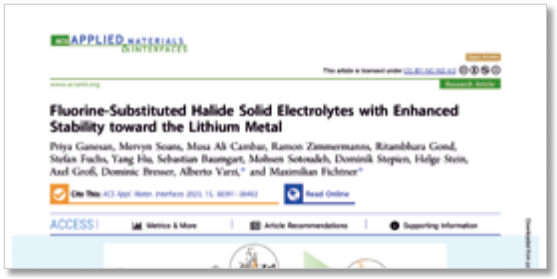
Zinc-enriched yeast has not yet been approved for food use in the EU because comprehensive data on the actual zinc species present – as opposed to simply total zinc content – has been missing. Researchers from the University of Potsdam, TU Berlin, Charité and SPECS screened ten industrial yeast strains, finding zinc levels spanning 0.06 to 51 picograms per cell, then combined surface-sensitive spectroscopy with proteomics on the two most promising strains. The results showed that part of the accumulated zinc sits at the cell surface, coordinated to phosphate and amino-acid ligands, while proteomic analysis revealed that zinc-excess cells shift from a Zap1-regulated zinc balance into an intracellular excess response.

The insights

- Screen yeast strains for zinc-enrichment potential at picogram-per-cell resolution
- Locate accumulated zinc at the cell surface versus intracellular compartments
- Combine surface spectroscopy with proteomics to explain a regulatory response

Publication basis

G. Grimmer, J. Muenzner, M. Schmacht et al.,
Applied Microbiology and Biotechnology (2026)
DOI: 10.1007/s00253-025-13692-y





Energy storage / Solid-state batteries
Halide electrolytes meet lithium metal

The interphase between a solid electrolyte and a lithium anode decides whether a cell lasts. EnviroESCA lets you analyze that interphase without the sample ever touching air.

The challenge

Halide solid electrolytes such as Li_2ZrCl_6 have high ionic conductivity and good oxidation stability, but decompose in contact with lithium metal and form a growing, electronically conducting interphase. Researchers from the Helmholtz Institute Ulm and KIT replaced part of the chlorine with fluorine ($Li_2ZrCl_{6-x}F_x$) and cycled symmetric Li|SE|Li cells for 800 h. The cycled cells were transferred without air exposure into an EnviroESCA attached to a glovebox. Li 1s, F 1s and Zr 3d spectra showed that the fluorine-free electrolyte is reduced to metallic Zr, while $Li_2ZrCl_{5.5}F_{0.5}$ forms a protective LiF-containing layer with only slight Zr reduction. This explains its much lower polarization and stable cycling up to 0.7 mA cm^{-2}, where the unmodified electrolyte short-circuits.

The insights

- Analyze air- and moisture-sensitive battery materials transferred directly from a glovebox
- Identify the species that form at buried Li|electrolyte interfaces, such as LiF, LiCl and metallic Zr
- Link surface chemistry to cycling performance and to DFT predictions

Publication basis

P. Ganesan, M. Soans, M. A. Cambaz, ..., A. Varzi, M. Fichtner,
ACS Appl. Mater. Interfaces 15 (2023) 38391–38402
DOI: 10.1021/acsami.3c03513

Energy conversion /
Perovskite solar cells
Light, oxygen and self-healing

Perovskite solar cells degrade when light and air act on them together. EnviroESCA measures how fast that happens, and how the material recovers.

The challenge

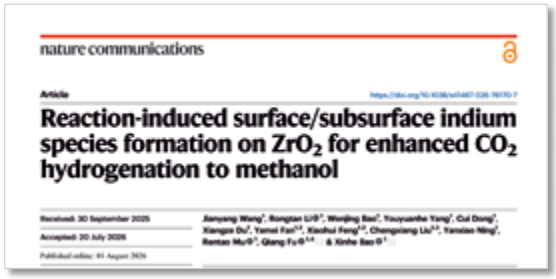
Mixed-halide perovskites are the basis of today's best solution-processed solar cells, but they lose stability under real operating conditions. Most XPS studies only show the surface before and after degradation, in vacuum. Researchers from Georgia Tech, the University of Arizona, the University of Liverpool and SPECS used dynamic NAP-XPS to follow the corrosion of triple-cation $CsFAMAPb(IBr)_3$ films live, under 2 mbar O_2 and white-light illumination. Corrosion occurred only when oxygen and light acted together: iodide was oxidized to I_3^- and about half of the lead sites were reduced, at a rate of about 3×10^{-4} at.% per second. Without oxygen and light, the original composition slowly recovered as iodide diffused back from below the surface. Composition changes below 2 % altered the rates or even the degradation pathway, linking surface chemistry to defects.

The insights

- Track light- and gas-driven surface reactions as they happen, at mbar pressures
- Measure reaction rates for degradation and recovery, not just end states
- Screen perovskite compositions and interface treatments for photochemical stability

Publication basis

M. De Keersmaecker, P. Dietrich, M. Bahri, N. D. Browning, N. R. Armstrong, E. L. Ratcliff,
J. Am. Chem. Soc. 147 (2025) 8881–8892
DOI: 10.1021/jacs.5c00668





Catalysis / CO_2 conversion
Watching a catalyst rebuild itself

Oxide catalysts change their structure while they work. EnviroESCA follows those changes under realistic gas treatments, from start to finish.

The challenge

In_2O_3–ZrO_2 catalysts turn CO_2 and green hydrogen into methanol without precious-metal promoters, but their structure keeps changing under reaction conditions. Researchers at the Dalian Institute of Chemical Physics found that the reaction itself rebuilds the catalyst: indium oxide particles spread into thin InOx surface layers and also move below the ZrO_2 surface, forming an In–Zr–O solid solution. The team then treated samples at 400 °C and 1 bar in the reactor chamber of an EnviroESCA, switching between CO_2 and CO_2/H_2, and measured them by quasi in situ XPS. Under CO_2 alone, the Zr 3d spectra revealed low-melting zirconium carbonate. When hydrogen was added, the carbonate signal dropped as indium and zirconium mixed into the solid solution. The optimized catalyst reached a methanol space-time yield of 1.1 g per g of catalyst per hour and stayed stable for 600 hours at 300 °C.

The insights

- Treat catalysts in reactive gases at up to 1 bar and analyze them directly in the same system
- Identify short-lived intermediates such as carbonates that drive the catalyst's restructuring
- Turn restructuring under reaction conditions into a strategy for designing catalysts

Publication basis

J. Wang, R. Li, W. Bao, ..., Q. Fu, X. Bao,
Nature Communications 17 (2026) 9300
DOI: 10.1038/s41467-026-76170-7

Photocatalysis / Climate and energy
Sunlight, CO_2 and no sacrifice

Photocatalytic CO_2 reduction offers a route to store solar energy as a liquid fuel, but most demonstrations depend on sacrificial reagents that undermine the technology's real-world sustainability case.

The challenge

Achieving efficient, selective photocatalytic conversion of CO_2 to methanol using only water as the proton source – without any sacrificial agent – has been limited by low quantum efficiency and rapid recombination of photogenerated charges. Researchers developed a bimetallic AuCu alloy supported on TiO_2 nanoparticles and correlated its photocatalytic performance with in-situ FTIR spectroscopy. The AuCu/TiO_2 catalyst achieved a methanol production rate of 63.31 μmol g^{-1} h^{-1} with 85.6% selectivity, with the Au-Cu synergy specifically promoting hydrogenation of a COOH* intermediate toward CHO* and ultimately methanol.

The insights

- Achieve CO_2-to-methanol conversion without a sacrificial reagent
- Reach 85.6% methanol selectivity through bimetallic AuCu–TiO_2 design
- Link catalyst surface chemistry to mechanistic intermediates via combined surface and IR analysis

Publication basis

G. Cen, W. Chu, J. Lu, J. Ding, Y. Hu, W. Wang,
Journal of Environmental Chemical Engineering 14 (2026) 121314
DOI: 10.1016/j.jece.2026.121314

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