NEW PRODUCT RELEASE

EnviroESCA

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

KEY FEATURES

- XPS and HAXPES at pressures up to 50 mbar
- Four X-ray lines Al, Ag, Ti and Cr
- Fully autonomous exchangeable experiment modules
- Loading-to-measurement < 1 min
- High throughput analysis

Enviro™

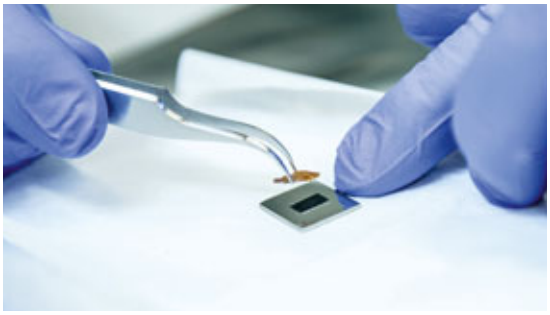
A member of SPECSGROUP

EnviroESCA

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.

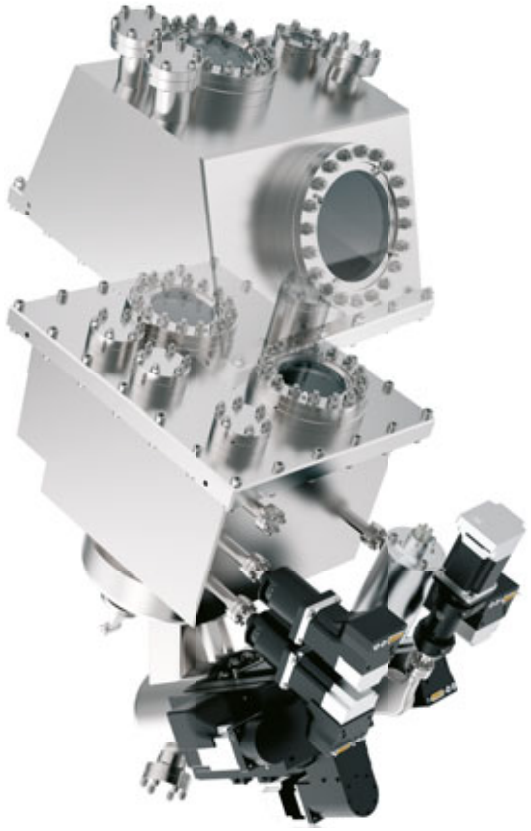
The integrated system layout combines the analysis chamber, electron analyzer, X-ray source, differential pumping stages, vacuum and gas-management systems, sample positioning and optical navigation in one coordinated platform. Exchangeable experiment sample environments support controlled gas dosing, 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 for in situ or operando analysis. Optional complementary techniques can monitor reaction products or provide additional information from the same experiment.

This measurement concept provides surface analysis in application-relevant environments. In situ and operando measurements reveal real-time insight 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 50 mbar
- Infrared Reflection Adsorption Spectroscopy (IRRAS)
- RAMAN Spectroscopy
- Solar Simulator
- Dual Beam and Environmental Charge Compensation
- Exchangeable Experiment Sample Environment for Variable or High Temperature Treatments and Electrochemical Cells
- Glovebox Extension for all Experiment Sample Environment
- High Sample Throughput Capacity

Core Components

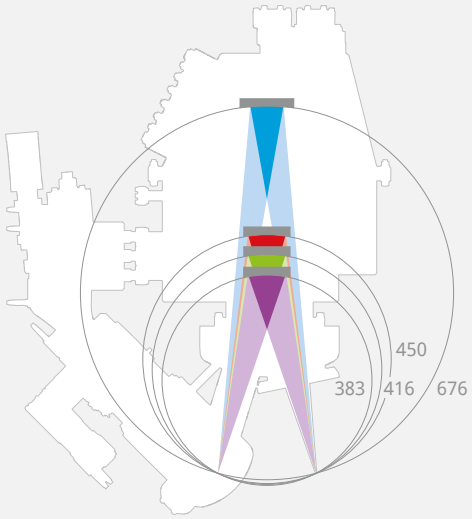


Advanced, multi-line X-ray source

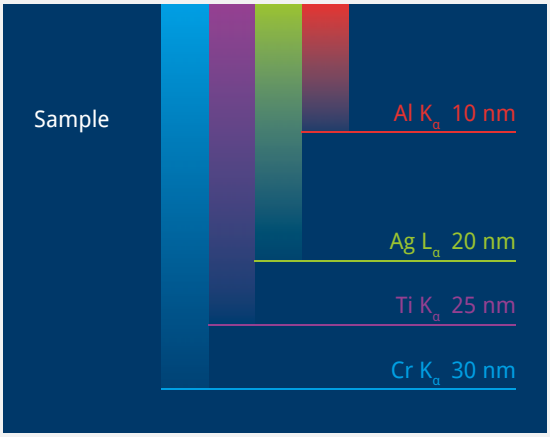
The quality of a measurement begins with the excitation beam. The µFOCUS X-ray source series offers flexible combinations of X-ray excitation lines, from conventional Al K_α to Ag L_α, Cr K_α and the recently introduced Ti K_α. The different excitation energies provide various information depths, allowing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



Monochromator layout with Rowland Circles; in mm



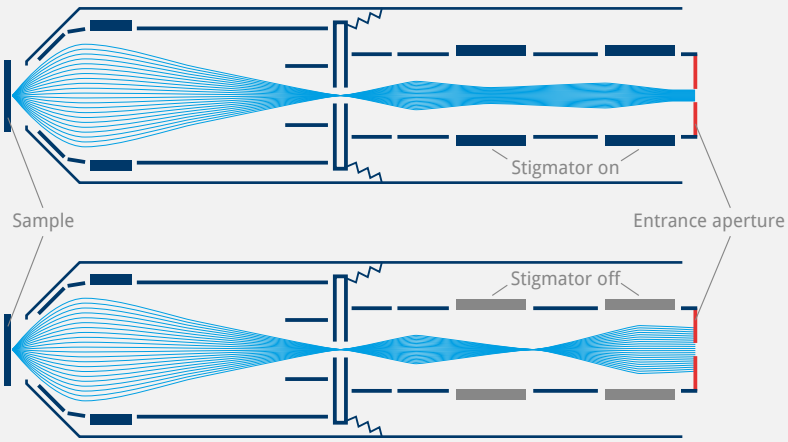
Available information depth by four X-ray lines.

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 best signal intensity
- Depth profiling with 44° acceptance angle
- True pulse counting CMOS detector



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

Main System

System base and core architecture

Near-ambient pressure system base enables non-destructive XPS surface analysis at pressures up to 50 mbar and offers a reduced sample loading-to-measurement turnaround of under one minute. The system is fully software controlled in a compact all-in-one enclosure 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 AD-CMOS 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 capabilty 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 upgraded 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.

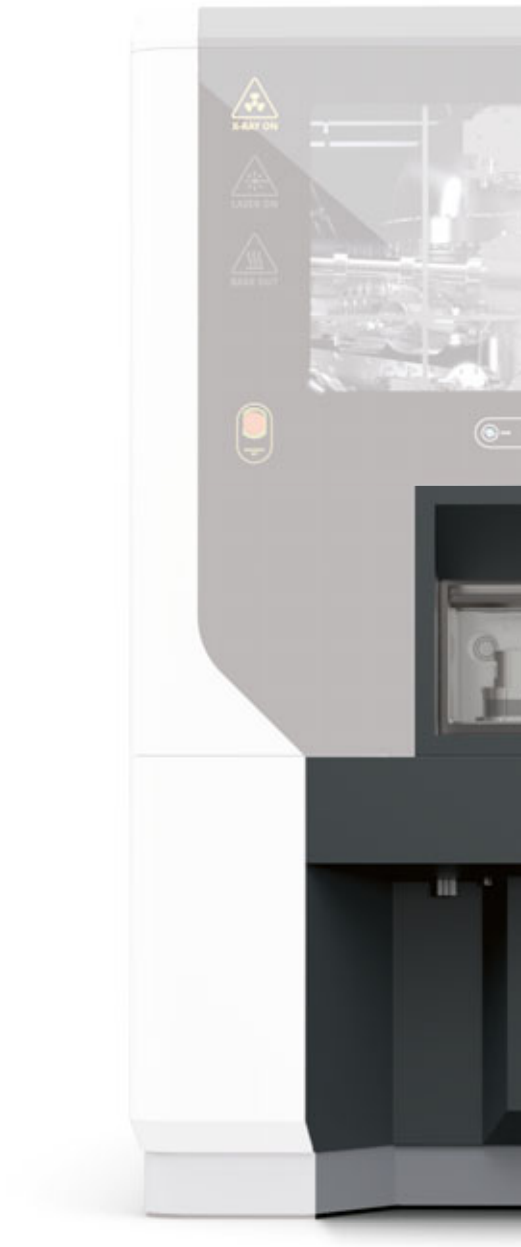
Experiment Sample Environment

From sample environment to experiment sample environment

The new autonomous experiment module advances the EnviroESCA 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.

Experiments can now be assembled, commissioned, and operated outside EnviroESCA. After validating the gas flows, operating parameters, and experimental sequence, the complete module is transferred into the analysis system for in situ or operando characterization stable under the applied conditions. The defined mechanical and technical interfaces preserve the experimental configuration during transfer and ensure reliable integration with the spectrometer.

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.

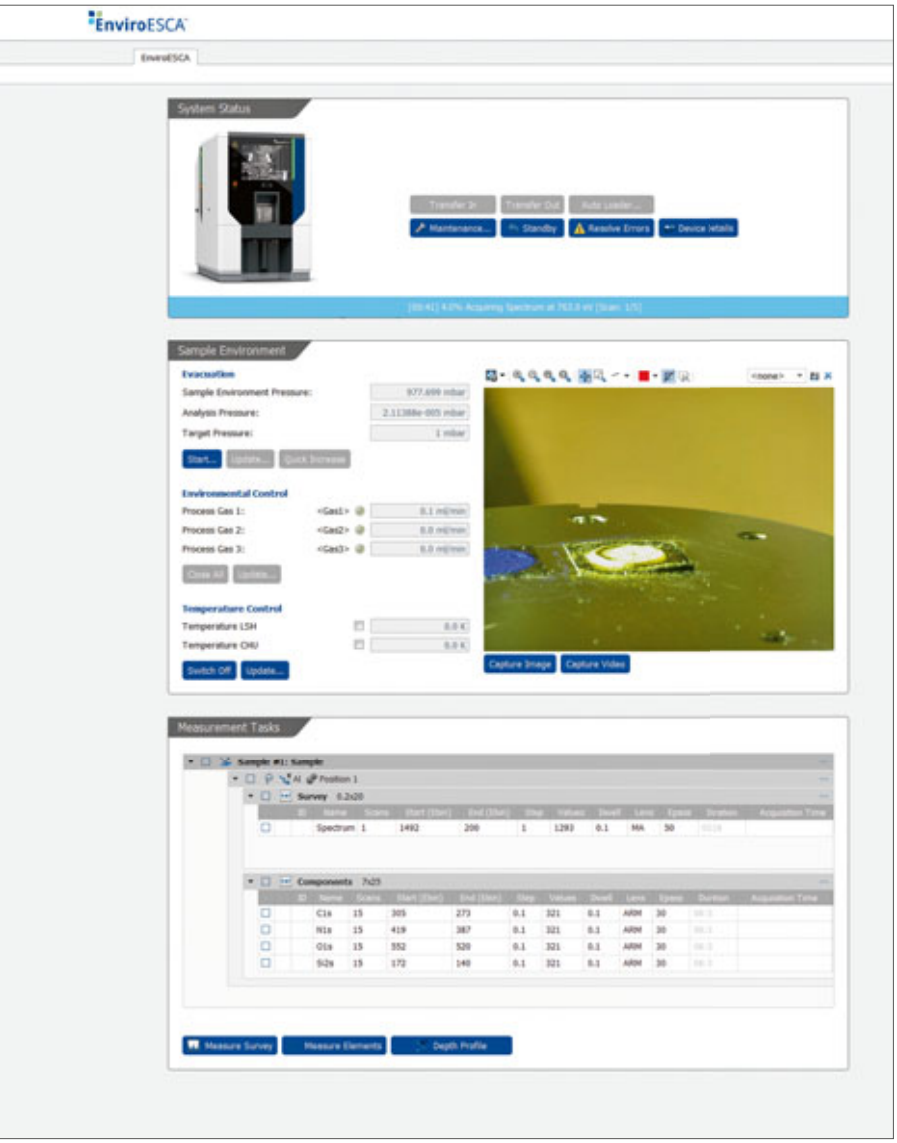
Standard configuration
High-precision 3-axis (X, Y, Z) manipulator handles samples up to 100 mm diameter and 40 mm height (50 mm² addressable region), up to 6 electrical contacts/feedthroughs.

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 and precision power supply for controlled sample heating. Temperature-controlled Peltier cooling for thermally sensitive, volatile, or biological samples.

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

Software



Software

Keystone is the integrated control and automation software for EnviroESCA. 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 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

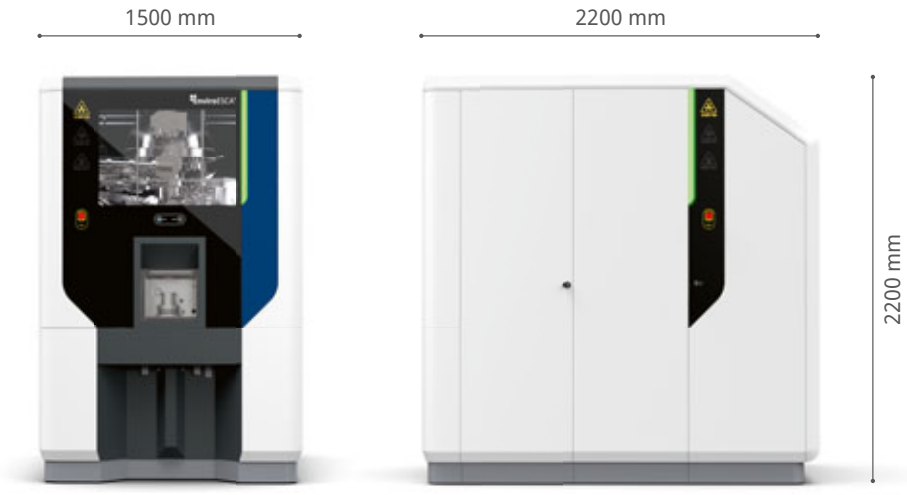
All system parameters including temperature of system components, pressure readings, and equipment health status are permanently recorded. Availability of this database makes for time-efficient service and maintenance.

Technical data

EnviroESCA	
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
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 separated gas dosers at analysis position • H_2O vapour • Mass flow controllers
Cameras	• 3 digital microscopes for sample navigation and documentation
Automation and Software	• Keystone Software package • Fully automated vacuum and gas dosing system • Integrated Data Recording and Reporting

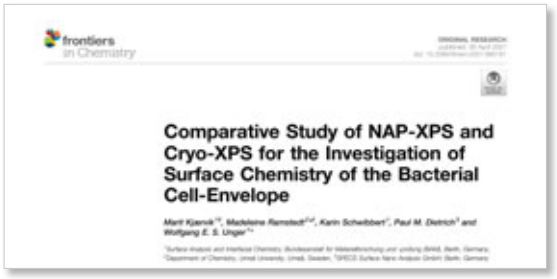
Technical alterations reserved.

Dimensions



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

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
Radiation Damage, Caught in Water

Radiotherapy relies on radiation damaging DNA, but the underlying chemistry has almost always been studied dry, under vacuum – the opposite of the cellular environment.

The challenge

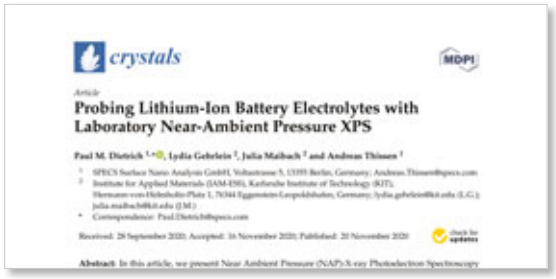
Water radiolysis is central to how ionizing radiation damages DNA in the body, yet conventional XPS cannot keep DNA hydrated during irradiation, so all earlier XPS studies were confined to a dry, vacuum-only regime. Using NAP-XPS, researchers from Freie Universität Berlin, BAM and SPECS irradiated double-stranded DNA directly under a water atmosphere and compared the outcome to dry, vacuum-based irradiation. In dry DNA, X-rays predominantly broke the sugar-phosphate backbone. Under water, hydroxyl radicals generated by radiolysis shifted the damage pattern: base damage and base release became the dominant outcome, even as the number of strand breaks increased further – a distinction invisible to conventional vacuum-based XPS.

The insights

- Irradiate and monitor biomolecules while keeping them fully hydrated
- Separate direct radiation damage from indirect, water-radical-driven damage
- Generate data directly relevant to cancer radiotherapy research

Publication basis

M. B. Hahn, P. M. Dietrich, J. Radnik, Communications Chemistry 4 (2021) 50
DOI: 10.1038/s42004-021-00487-1


crystals

Probing Lithium-Ion Battery Electrolytes with Laboratory Near-Ambient Pressure XPS


RESEARCH

Unlocking the Zn-enriching potential of industrial yeast strains—an experimental journey from metal analysis to proteomics

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

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

Energy Storage / Reference Data A Reference Spectrum for the Next Battery

Reference spectra are the quiet infrastructure of surface science – unglamorous, but every subsequent study of a similar material leans on them for calibration.

The challenge

The model battery electrolyte LiTFSI in propylene carbonate is difficult to analyze by conventional XPS, since it would evaporate or degrade under standard vacuum conditions. Researchers recorded a full set of survey, Li 1s, S 2p, C 1s, N 1s, O 1s and F 1s NAP-XPS spectra of the electrolyte at 200 Pa in ambient gas atmosphere, using the residual gas itself for charge compensation. Peak-fitted C 1s, O 1s and F 1s narrow scans provide a citable chemical fingerprint that future battery-electrolyte studies can calibrate against.

The insights

- Provide a full multi-element reference spectrum for a widely used model electrolyte
- Demonstrate charge compensation via residual gas rather than dedicated hardware
- Supply peak-fitted narrow-scan data ready for direct comparison

Publication basis

P. M. Dietrich et al.,
"Near ambient pressure–x-ray photoelectron spectroscopy spectra of lithium bis(trifluoromethane-sulfonyl) imide in propylene carbonate", Journal of Applied Physics (2023)

Pharmaceutical Surfaces Tracking an Antiseptic Through a Biofilm

Povidone-iodine is a widely used antiseptic, but understanding how it distributes through a biofilm-like matrix at the nanometer scale requires depth information conventional XPS alone cannot provide.

The challenge

Confirming the in-depth distribution of an active agent within a nanometer-thin organic film demands a method that can remove material layer by layer without destroying the very chemistry being measured. Researchers at BAM and SPECS used agarose thin films doped with povidone-iodine as a model for the biofilm exopolysaccharide matrix, then combined variable-excitation-energy XPS with argon gas cluster ion beam sputtering to profile iodine depth-wise. Both independent methods agreed: iodine was depleted at the outermost surface layer, attributed to loss of molecular iodine under vacuum exposure, but homogeneously distributed through the rest of the film down to the substrate interface.

The insights

- Depth-profile an active pharmaceutical ingredient through an organic film with minimal damage
- Cross-validate two independent depth-profiling methods on the same sample
- Reveal a surface-specific depletion effect invisible to bulk measurements

Publication basis

M. Kjærvik, P. M. Dietrich et al.,
BAM/SPECS study; Enviro-Application Note #220801 (“Sputter Depth Profiling of Iodine in Organic Thin Films”)

Sustainable Food Production Cold Plasma Meets Machine Learning

Seed priming can dramatically improve germination and crop resilience, and cold plasma offers a chemical-free way to do it – if its many process parameters can be brought under control.

The challenge

Cold-plasma seed priming involves a large number of interacting parameters, making it hard to design reliable, reproducible protocols by trial and error alone. A review co-authored by researchers from Savitribai Phule Pune University, the German Federal Institute for Risk Assessment and SPECS surveyed the state of cold-plasma seed priming and proposed machine learning as a way to model and optimize plasma treatment parameters across seed types – aiming to replace ad-hoc experimentation with data-driven protocol design.

The insights

- Replace synthetic chemical seed treatments with a plasma-based alternative
- Frame plasma-parameter optimization as a machine-learning problem
- Connect surface-analysis expertise to sustainable-agriculture research

Publication basis

A. Shelar, A. V. Singh, P. Dietrich et al.,
RSC Advances 12 (2022) 10467–10488
DOI: 10.1039/d2ra00809b

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Version 09.26

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