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Tailored Compound Specific Carbon Isotopes Analysis in Heritage Science

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Radiocarbon dating has long been a cornerstone of archaeological science, providing a reliable means to determine the age of organic materials. Yet when applied to cultural heritage objects, traditional bulk analytical approaches often reach their limits due to complex material histories, mixed carbon sources, conservation treatments, and the limited amount of material available for sampling.

Supported by an SNSF Ambizione program, our research seeks to overcome these limitations by shifting the focus from bulk materials to individual molecules. We aim to untangle the mixed carbon sources encountered in heritage materials through compound specific approaches and further target the color of an object, namely natural organic dyes and pigments. The implementation of compound-specific radiocarbon analysis (CSRA) and compound-specific isotope analysis (CSIA) in heritage science requires not only high analytical precision, but also rigorous control of exogenous carbon contamination. This presentation will highlight our current efforts toward the development of colour-specific carbon isotopic methodologies, with preliminary results focusing on protocol development, including purification strategies, blank assessment, and contamination modelling.

More broadly, this work illustrates how analytical chemistry can contribute to new methodological frameworks in heritage science. By targeting the molecules responsible for an object's colour, compound-specific carbon isotope analysis opens new possibilities for investigating not only chronology, but also the provenance, material history, and broader cultural narratives embedded within heritage objects.

Rumpf, L.; Sandström, E.; Iacconi, C.; Sandmeier, V.; Hendriks, L. *CHIMIA* **2025**, 79 (11), 784–791.

Depth-Resolved Investigation of Elemental Fractionation in Zircon and Glass Matrices using Single-Pulse-Resolved LA-ICP-TOFMS

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Uranium-lead (U-Pb) dating of zircon (ZrSiO₄) is a cornerstone of modern geochronology. Due to its high analytical throughput and low sample consumption, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) has become a widely applied technique for U-Pb and Pb isotope ratio analysis. However, accurate U-Pb ratio determination is frequently compromised by non-stoichiometric effects, commonly referred to as elemental fractionation, which cause measured elemental signals to deviate from the true sample composition. These effects are matrix-dependent and may arise during laser ablation, aerosol transport, and/or within the ICP.

To mitigate elemental fractionation, quantitative analyses commonly rely on external calibration using matrix-matched zircon reference materials of known composition and age. Nevertheless, variations in ablation behaviour among different zircon reference materials continue to limit analytical accuracy and inter-laboratory comparability.^{1,2} The use of well-characterized glass reference materials, such as NIST SRM 610, for external calibration has proven unsuccessful, indicating fundamental differences in the ablation and fractionation behaviour of zircon and glass matrices.³

In this study, single-pulse-resolved LA-ICP-TOFMS was employed to investigate the zircon-specific ablation behaviour of matrix elements, Pb, and U. The high temporal resolution enabled the detailed characterization of the depth-dependent ablation behaviour and corresponding transient signals. Zircon reference materials of different ages were analysed in hole-drilling mode and each cross-validated by calibrating against the other zircon reference materials. Crater depths and diameters were determined and the resulting ablation rates assessed. In addition, the external calibration strategy was extended through the use of monodisperse microdroplets as a secondary normalization standard.⁴ Being directly introduced into the plasma, microdroplets can correct for ICP-induced fractionation and provide additional insight into the contribution of plasma-related processes to the overall quantification accuracy.

Identical measurements were performed using the NIST SRM 610 glass to directly compare zircon and glass ablation behaviour. The results provide new insight into matrix-dependent fractionation processes and highlight the limitations of glass reference materials for accurate zircon U-Pb ratio determination.

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Protein Identification by Nanopore-Based Amino Acid Profiling

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Proteins perform most cellular functions and are key biomarkers of health and disease, yet proteomic analysis lags far behind genomics due to the complexity and diversity of proteoforms. Recent advances in nanopore technology are transforming protein analysis. One promising strategy for protein identification is peptide profiling; however, its applicability remains limited to the identification of specific proteins, and discriminating among the vast variety of proteins is still challenging. Here, we propose a nanopore-based single amino acids (AAs) profiling method for protein identification. Combined with controlled enzymatic digestion, selected regions of the target proteins are hydrolyzed into individual AAs. We then conjugate a molecular tag to each released AAs to enhance its interactions with the nanopore interface, thereby amplifying the signal readouts, and improving the capture frequency. By reading corresponding electrical current signals of those AAs in a nanopore system, we thereby enable the robust construction of protein profiles. Our *in silico* prediction showed that with this method, it is sufficient to identify 91% of human proteins in the UniPort database. With future optimization, our results point to a new route for nanopore-based protein identification beyond peptide profiling.

Keywords: Protein identification; Amino acid profiling; Enzymatic digestion; Nanopore sensing

Fingerprinting materials oxidation using laser-induced XUV spectroscopy (LIXS)**D. Bleiner^{1,2}, S. Rameshbabu¹, J. von Ballmos³**

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Laser-induced XUV spectroscopy (LIXS) is an emerging plasma-based microanalytical technique that offers access to the early, “background-uncontaminated” (pristine) stages of laser-induced plasma evolution [1]. In this study, the capability of LIXS to resolve not only the elemental composition but also the oxidation state of complex materials is investigated, i.e., by exploiting radiative recombination dynamics. Using a spatial-filtered detection scheme, the evolution of plasma emission was tracked, revealing characteristic spectral features associated with electron recombination into unoccupied s or d atomic orbitals. The latter retain a distinct fingerprint of the parent material’s oxidation state. Preliminary experiments on LiF, Al, and Ni served to calibrate the relationship between expansion kinetics, emission time delay, and atomic structure. Reference samples, including lithium manganese oxides with well-defined stoichiometries, were used to correlate LIXS spectral fingerprints to manganese oxidation levels. The results indicate that, contrary to the observations for the thermalized LIBS plasma, the LIXS laser plasma does not erase information on the material’s stoichiometry. Instead, the recombination features in the XUV region directly reflect the electronic configuration of the parent material. This work introduces LIXS as a novel route for rapid, stoichiometry-sensitive mapping of oxidation states, with immediate applications in the quality control of energy materials and battery components. The approach lays the foundation for the development of oxidation-specific plasma spectroscopy, extending the analytical power of laser ablation far beyond elemental analysis.

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Origin Determination of Sapphire using High-resolution Femtosecond Laser Ablation Ionisation Mass Spectrometry

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Geographic origin determination of gemstones relies on the quantitative measurement of trace-element abundances linked to specific geological environments. For gem corundum, including sapphire, origin determination remains challenging because many deposits formed under similar geological conditions and therefore exhibit similar trace-element compositions [1, 2]. As a result, robust geographic discrimination requires analytical techniques capable of providing sufficient trace-element data while maintaining high sensitivity and mass resolution to reliably detect and distinguish low-abundance elemental signatures.

This contribution presents the applicability of femtosecond laser ablation ionisation mass spectrometry (fs-LIMS) for trace-element chemical composition analysis relevant to sapphire origin determination using the Laser Mass Spectrometer – Gran Turismo (LMS-GT), a high-mass-resolution ($m/\Delta m$ of up to 20,000) time-of-flight LIMS instrument with micro-metre spatial resolution [3]. The analysed sample was a beryllium-diffusion-treated yellow sapphire provided by the Swiss Gemmological Institute SSEF. The sample surface was gold coated to reduce surface charging upon laser irradiation [4]. Measurements were performed using spot-by-spot fs-LIMS chemical analysis combined with mass-selective beam blanking to improve detection limits [5].

LMS-GT resolves atomic ions from polyatomic species interferences, allowing detection of trace elements relevant for sapphire origin determination, including Mg, Ti, V, Cr, Fe, and Ga, with high mass accuracy. Relative element abundances derived from spot-wise-averaged fs-LIMS spectra show good agreement with published LA-ICP-MS datasets for sapphires from major geographic deposits. This demonstrates that fs-LIMS can quantitatively reproduce compositional patterns in corundum even without the application of matrix-matched relative sensitivity coefficients (RSC) [6], while maintaining minimal sample consumption. These results highlight the potential of high-resolution fs-LIMS as an analytical technique for gemstone chemical analysis applicable for origin determination. The combination of micrometre-scale spatial resolution, high mass resolving power, and high trace-element sensitivity for more elements than used in analysis so far provides new opportunities for chemical characterisation of gem materials.

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The Bounty Rule: Analytical Dimensionality Outperforms Precision in Non-Target High-Resolution Mass Spectrometry

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High-resolution mass spectrometry (HRMS) has become the cornerstone of non-target analysis (NTA) workflows, enabling molecular formula assignment from accurate mass and isotopic patterns. Yet even sub-ppm mass accuracy and tandem MS/MS fragmentation remain fundamentally one-dimensional constraints, insufficient to resolve structural isomers or eliminate candidate ambiguity in complex matrices. We draw an analogy to the history of maritime navigation to demonstrate that increasing measurement *dimensionality* — not marginal precision gains — is the decisive factor for unambiguous molecular identification. A formal mathematical framework is developed in which the identification uncertainty volume in N -dimensional observable space scales multiplicatively with each added dimension, while precision improvements yield only linear reductions in candidate count. This principle is formalised as the "Bounty Rule": analytical identification confidence scales with the number of independent measurement dimensions, not with precision within any single dimension alone. Ion mobility spectrometry (IMS), which provides collision cross section (CCS) values encoding molecular size and shape, is introduced as the orthogonal "longitude" to the mass spectrometric "latitude." Using cyclic IMS-HRMS data on structurally challenging isomeric flavonoids in *Passiflora* extracts, we demonstrate resolution enhancement from a resolving power of ≈ 65 to ≈ 145 over five cyclic passes, enabling complete isomer separation at identical exact mass. We further discuss the instrument acquisition paradox in which continued investment in ever-higher mass resolution yields diminishing analytical returns compared with adoption of IMS as a complementary dimension. The term *heterohyperspectral* is proposed to describe this class of physically heterogeneous, high-dimensional molecular datasets.

Information Session about the SCS Division Analytical Sciences

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Broadband Characterization of the α -Relaxation Near the Glass Transition: Limitations of Time–Temperature Superposition and Advantages of CHIRP Rheometry

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Time–Temperature Superposition (TTS) is widely used to construct viscoelastic master curves under the assumption of thermorheological simplicity. However, amorphous polymers frequently violate this assumption in the temperature interval immediately above the glass transition temperature, T_g , where multiple relaxation mechanisms with distinct temperature sensitivities may coexist. In this work, the breakdown of TTS near T_g is investigated in a broad molecular weight distribution polystyrene using small-amplitude oscillatory shear measurements.

Conventional frequency sweeps performed between 110 °C and 160 °C fail to superpose in the onset region of the α -relaxation, particularly in the storage modulus G' , as revealed by Gurr-Palmen representations. This behavior reflects temperature-dependent distortions of the relaxation spectrum rather than simple horizontal or vertical shifts.

To overcome these limitations, broadband CHIRP excitation was performed using an ARES-G3 rotational rheometer, whose strain-controlled architecture, high dynamic precision, and sensitive torque measurement make it particularly well suited for rapid broadband oscillatory testing. This approach enabled the viscoelastic response near T_g to be probed over more than five decades in frequency within a significantly reduced measurement time. The CHIRP-derived spectra provide a cleaner and more continuous description of the α -relaxation, allowing reliable analysis using the Havriliak–Negami model. These results demonstrate that CHIRP rheometry, implemented on a high-performance platform such as the ARES-G3, offers an effective alternative to conventional TTS for characterizing polymer dynamics near the glass transition.

On-line Elemental Analysis using Nitrogen for LA-ICPMS

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The combination of solid sample analysis by Laser Ablation with argon-based Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS) for trace element analysis was introduced over 40 years ago.[1] Over these years, significant improvements were achieved ranging from the use of helium as carrier gas[2] to the measurement in 3-dimensions of elemental distributions using state-of-the-art fast washout ablation cells.[3] Yet, not every sample can be placed inside an air-tight ablation cell. Open ablation cells were developed to allow analysis of samples independent of their size and shape. However, these designs suffered from sample contamination due to the use of sealants or required a gas exchange device for online ICPMS measurement,[4] increasing the total gas consumption and the required hardware. Sampling methods for laser generated aerosol on filters was also developed using a portable setup, but its applications were restricted to off-line analysis,[5] requiring additional sample preparation and increasing the risk of contamination. Most of these drawbacks can now be circumvented with the recently introduced nitrogen-based high-power plasma source for ICPMS, which provides similar figures of merit as conventional argon-based ICPs, while reducing the operating costs significantly.[6]

Therefore, detailed characterization of nitrogen as an alternative carrier gas and its comparison to helium has been carried out[7] and will be presented including quantitative insights into the laser-induced fractionation. These fundamental considerations will be discussed in combination with the new possibilities offered by the nitrogen plasma source, including the current development of a novel portable laser ablation setup. These new applications will be described along with the evaluation of the operating conditions required for such on-line analyses in the field.

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Researching Backwards: Root-Cause Reconstruction in Industrial Failure AnalysisD. C. Cortes Gomez^{1,2}¹OST-Otschweizer Fachhochschule, ²IWK-Institute for Material Technologies and Plastics Processing

Most contributions present forward-directed research — from hypothesis through controlled experiment to replication. This contribution turns that direction around and focuses on industrial failure analysis. Here the starting point is not a research question but a failed component whose history is unknown. The problem is an inverse one: to reconstruct a defensible, actionable root cause from a single, non-repeatable event, with incomplete information and under time pressure.

Drawing on anonymized cases reduced to the materials level, this contribution shows how familiar analytical methods (FT-IR, DSC, SEM/EDX, and others) are used for targeted diagnosis rather than exhaustive characterization: converging lines of evidence instead of completeness, and only as much data as a decision requires. Each case takes a different failure in a plastic or composite component and works back to its cause.

This focus on how materials actually behave in service, rather than as idealized laboratory specimens, is what makes the topic valuable for an analytically minded audience. Behind every macroscopic failure lies a chemical story — chain scission or crosslinking, oxidation, the loss of functional additives, the intrusion of contaminants, or the weakening of interfaces — that links the visible damage to changes at the molecular level. Reading these molecular signatures from a degraded part offers insight into universal failure mechanisms, into the limits of individual methods under real-world loading, and into the logic of an analytical approach that reaches defensible conclusions despite uncertainty.

Identification of glycosaminoglycans with different sulfation degrees through magnesium-mediated interaction with a biological nanopore

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Glycosaminoglycans (GAGs) are acidic polysaccharides that play crucial roles in various physiological and pathological processes¹. However, their high structural complexity has made comprehensive characterization difficult, often limiting analyses to short fragments². Nanopore technology offers a powerful single-molecule approach and has shown promise for monosaccharide and glycan analysis, yet distinguishing GAGs in complex mixtures remains challenging. In addition, the rapid translocation of GAGs through nanopores limits temporal resolution and hampers sequencing efforts. Here, we present a strategy that utilizes electrolyte-mediated, GAG-specific interactions within biological nanopores to overcome these limitations. The sulfate and carboxyl groups of GAGs interact with acidic residues within the aerolysin channel via divalent cations bridging like Mg^{2+} , thereby slowing GAG translocation by more than 100-fold. Mutating the interacting residues abolishes these effects, confirming their specificity. The interaction mechanism was further validated using all-atom molecular dynamics simulations and cryo-electron microscopy. Notably, similar sulfate-specific signatures were also observed in commonly used biological nanopores, including α -HL and MspA. Leveraging this mechanism, we successfully distinguished different GAG species within a mixed GAG sample, including long GAG polymers over 20 kDa. Furthermore, machine-learning analysis enabled high-accuracy identification of the regioselective desulfated heparin variants. Together, these results represent a valuable step toward GAG identification and sequencing at the single-molecule level.

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Technetium-99 - A new tracer for nuclear forensics

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Technetium-99 (^{99}Tc) is a radioisotope of mainly anthropogenic origin formed by nuclear fission¹. In reprocessed uranium fuel an industrial threshold of 10'000 Bq ^{99}Tc per kg uranium (U) is recommended². Chemically, the element Tc shows similar properties as the actinides U and plutonium, which allows it to bypass the separation steps during reprocessing, fluorination and enrichment³. This leads to varying ^{99}Tc contamination in U material and allows the differentiation between material of natural origin, as well as mixed and reprocessed material. Our studies cover 32 samples of the most relevant U materials within the U fuel cycle, including natural uranium ore concentrate (Yellow Cake), UO_2 powder, different forms of U fuel, and waste samples from enrichment. Our investigations revealed ^{99}Tc concentrations from 0.1080 ± 0.0345 to 1463 ± 239 Bq per kg U and demonstrate that the careful analysis of ^{99}Tc can give valuable insights of the materials origin. More specifically, if the material originates from a natural feed stock (Yellow Cake) or if it has been already irradiated and reprocessed. Therefore, the method is a powerful signature to classify otherwise chemically identical U materials.

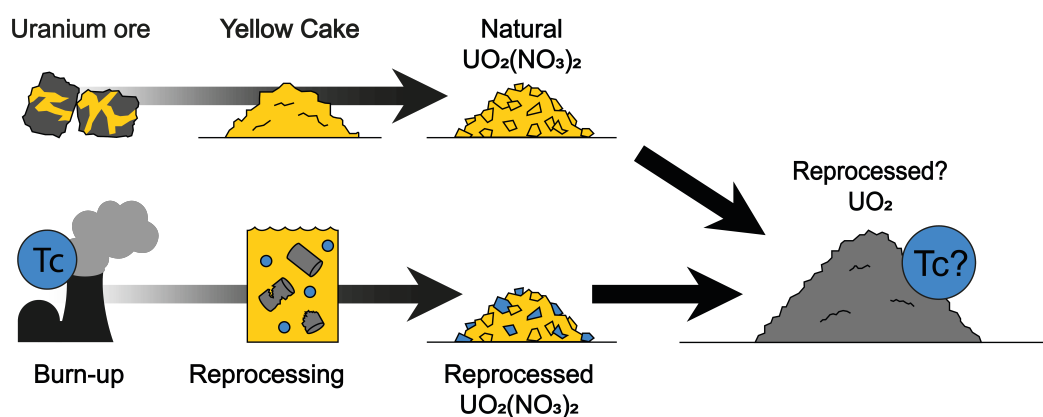


Figure 1: Reactor-grade UO_2 can be obtained from natural uranium ore concentrate (Yellow Cake) or from uranium that has been previously irradiated and reprocessed. The compounds of Tc show similar chemical and physical properties as the corresponding U compounds, thus its separation from U during reprocessing and enrichment is challenging. This renders it as a valuable forensic tracer for previously irradiated U material.

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Multiple-Quantum-Edited Heteronuclear Single-Quantum Correlation ExperimentsC. N. Baumann¹, J. Furrer^{1*}¹Department of Chemistry, Biochemistry and Pharmaceutical Sciences, University of Bern, Bern, Switzerland

Two-dimensional heteronuclear nuclear magnetic resonance (NMR) experiments, particularly heteronuclear single quantum coherence (HSQC) experiments [1], are essential tools for assigning carbon resonances in organic molecules. HSQC spectra can provide more structural information through multiplicity editing. Multiplicity editing is an NMR technique that modifies the signal phases based on the number of directly bonded hydrogens [2].

This poster presents a new multiplicity-edited HSQC experiment with improved sensitivity to CH and CH₃ groups exhibiting atypical $^1J_{CH}$ coupling constants. In this implementation the editing is performed while the magnetization of interest is in a double quantum state instead of in a single quantum state. Performing the multiplicity editing in a double quantum state reduces the dependence of XH_n signal intensities on the editing delay. This results in improved sensitivity for groups with atypical $^1J_{CH}$ coupling constants.

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Towards Protein Sequencing: Single Amino Acid Discrimination and Quantification by Aerolysin Nanopore.

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Many diseases, including cancer and neurodegenerative disorders, are driven by protein dysfunction. Understanding proteins at the molecular level requires accurate sequencing methods, yet unlike DNA, proteins remain extremely challenging to sequence due to their chemical diversity and structural complexity. Nanopore-based sensing has already revolutionized DNA sequencing, but its application to proteins and their building blocks is still in its early stages. Here, we explore the use of the engineered aerolysin nanopore to detect, discriminate and quantify individual amino acids at nanomolar concentrations. By analyzing ionic current signatures generated upon amino acid translocation, we demonstrate the ability to distinguish structurally similar amino acids. This work represents a step towards nanopore-based single-molecule protein sequencing, opening new avenues for disease biomarker detection.

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Cracking the sugar code: Towards nanopore-based glycan sequencing

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Heparan sulfate (HS) and heparin (HP) are closely related, negatively charged glycosaminoglycans that appear as post-translational modifications on proteoglycans. HS/HP feature unique and dynamic sulfation patterns that underscore binding interactions with hundreds of extracellular partners to regulate crucial cellular processes such as mitogenesis and blood coagulation. Therefore, identifying these sulfation sequences is paramount to understanding HS/HP-mediated signaling. Current methods to resolve HS/HP sequence reveal oligomer composition and sulfation types, but do not enable direct analysis of intact chains. Nanopore-based DNA sequencing is a single-molecule technique that detects ionic current changes as DNA moves across a nanometer-scale pore, with processive enzymes enabling controlled translocation. While this framework is broadly applicable to other biopolymers, current studies show that HS/HP translocate rapidly, precluding sequence information. Realizing nanopore-based HS/HP sequencing will require overcoming two major challenges: controlling polymer translocation through the pore and distinguishing individual monosaccharides as they translocate. Here, I will discuss some approaches aimed at addressing these problems, followed by preliminary studies on a native processive glycan enzyme, Sulf, in imparting translocation control. In parallel, I will also assess the ability of biological nanopores to distinguish sulfation and desulfation states using immobilized HP chains. These results represent important initial steps towards decoding HS/HP sulfation patterns at a single-molecule level.

Development of a Py-GC/MS Method to Quantify Tire and Road Wear Particles in Aquatic and Terrestrial Organisms

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Tire and road wear particles (TRWPs) are ubiquitous contaminants detected across all environmental compartments, including aquatic, terrestrial, and atmospheric systems. As a result, organisms inhabiting these environments are continuously exposed to TRWPs and their associated chemical additives, which have been shown to induce toxic effects, notably in coho salmon. Moreover, TRWPs can be transferred through the trophic chain, raising concerns about their bioavailability and potential ecological impacts. Despite this, methods to reliably quantify TRWP exposure in living organisms remain limited. The present study aims to develop and validate a robust sample preparation and analytical method based on pyrolysis-gas chromatography-mass spectrometry (Py-GC/MS) for the quantification of TRWPs in complex biological matrices. Three model organisms representing different environmental compartments were investigated: two aquatic species, *Gammarus fossarum* and *Chironomus riparius*, and one terrestrial species, *Eisenia fetida*. To account for increasing environmental matrix complexity, experiments were conducted on (i) lyophilized organisms spiked with cryo-milled tire tread (CMTT) particles, (ii) organisms exposed to CMTTs under controlled laboratory conditions, and (iii) organisms collected directly from the environment. Various chemical (H₂O₂) and enzymatic (chitinase) digestion protocols were systematically evaluated to identify optimal conditions (i.e. temperature, incubation time, concentration) enabling maximal removal of organic matter while preserving the integrity of TRWPs. In parallel, several rubber-specific chemical markers (i.e. 4-vinylcyclohexene, 2,4-dimethyl-4-vinylcyclohexene, α -methylstyrene, dipentene and 4-phenylcyclohexene) were assessed to enhance detection specificity, minimize potential analytical interferences, and optimize method sensitivity. The resulting methodological framework provides essential tools for the accurate quantification of TRWPs in complex biological matrices and represents a critical step toward improving exposure assessment and ecological risk evaluation of TRWPs in aquatic and terrestrial ecosystems.

Assessment of Laser-based Infrared - Imaging for Microplastic Analysis

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The analysis of microplastic particles (MPs) in environmental matrices is highly time-consuming, making their integration into routine monitoring programs challenging. Consequently, spatial and temporal patterns of MPs in the environment are difficult to assess. Until recently, two types of detection systems targeting particles were most popular: i) Fourier transform – infrared (FT-IR) systems connected to focal-plane array (FPA) detectors, which acquire hyperspectral data from entire sample areas with a pixel resolution of $\sim 5\ \mu\text{m}$, and ii) laser systems, either tunable quantum cascade lasers (IR laser) or lasers with a fixed wavelength (Raman microspectroscopy), in combination with a single-point detector for individual particle analysis based on visible light images or IR absorption images recorded at a specific wavenumber. While both approaches have distinct advantages and limitations, the analysis of thousands of particles extracted from various environmental matrices and deposited on suitable substrates (e.g., 25 mm aluminum oxide filters (Anodisc)) typically requires several hours to days.

Most recent technological advances have enabled the development of instruments that combine large-area detectors ($\sim 500 \times 500$ pixels) with tunable IR laser sources. Due to the enormous power of the IR lasers systems, hyperspectral data can be recorded at very short exposure times. Compared to the systems described previously, IR laser-based imaging (ILIM) systems enable the acquisition of hyperspectral data from an entire 25 mm filter at a spatial resolution of $4.25\ \mu\text{m}$ in less than 30 min.

In this presentation, we demonstrate the potential of the LUMOS II ILIM (Bruker) system by quantifying ten polymer types in prepared polymer mixtures deposited on Anodisc filters. The results are compared with those obtained using a state-of-the-art FT-IR imaging system (Bruker LUMOS II equipped with a 32×32 pixels FPA detector, spatial resolution of $5\ \mu\text{m}$). To assess the influence of matrix constituents on the quality of the spectra and to evaluate to what extent matrix-induced spectral alterations affect polymer identification, additional experiments were conducted using spiked sewage sludge extracts. Furthermore, the distinctive IR absorption spectrum of red polyethylene (PE) spheres allowed an unambiguous identification of these particles. Red PE spheres were therefore added to the sewage sludge extracts as surrogate standards, allowing an ‘automatic’ assessment of the experimental recoveries in each experiment.

The secrets of the ink behind the iconic “Basel Dove” stamp

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Despite their small size, postage stamps are culturally significant artefacts that reflect the artistic, technological, and political contexts of their production. Nowadays, they are an integral part of the world's cultural heritage due to their historical and social significance. Although usually measuring just a few square centimetres and often worth only a few Swiss francs, rare issues are highly sought after by collectors and can reach prices of several hundred thousand francs, conferring on some of them the status of miniature works of art. Among them, the Basel Dove remains one of the most iconic examples, as it is the very first tricolour postage stamp ever issued. Despite their historical and artistic significance, their material composition has rarely been the subject of scientific study. Recently, our work on the first systematic characterization of the materials of 98 Swiss stamps issued between 1850 and 1908, using a combination of non-invasive analytical techniques, including Raman Spectroscopy, Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR) together with Scanning Electron Microscopy with Energy Dispersive X-ray spectroscopy (SEM-EDX), provided new insights into their ink composition [1].



Building on this previous research, the present study focuses on 29 specimens of the iconic Basel Dove preserved in the archives of the Museum für Kommunikation, was conducted with the same non-invasive methodological approach. Our findings reveal distinct pigment choices between the issues of 1845 and 1847 and shed new light on the material history of Swiss postage stamps in the 19th century, uncovering the manufacture of the world's very first tricolour stamp. This work highlights the value of combining spectroscopy and imaging techniques in philatelic research and, more broadly, in heritage science.

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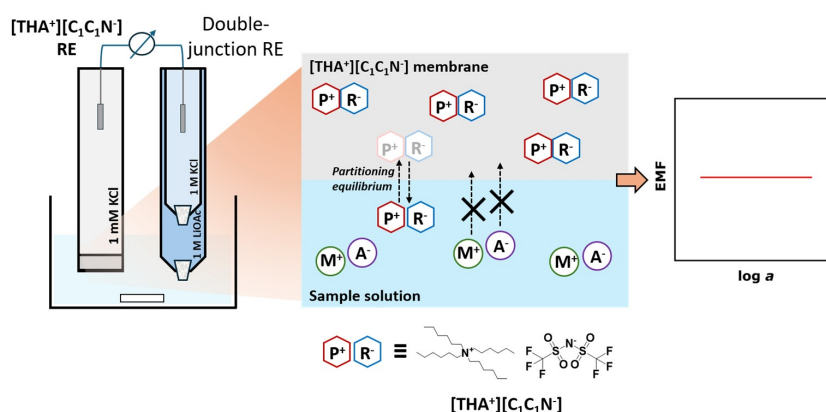
Optimization of Lipophilic Organic Electrolytes for Reference Electrode Development

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Reference electrodes (REs) based on polymeric membranes doped with organic electrolytes represent a promising approach toward miniaturized, maintenance-free [1], and all-solid-state electrochemical sensing systems. However, achieving long-term potential stability remains challenging due to the trade-off between electrolyte partitioning and membrane retention. Electrolytes with insufficient lipophilicity tend to leach rapidly into the sample, shortening electrode lifetime and potentially contaminating the measurement environment [2,3]. Conversely, highly lipophilic electrolytes can exhibit undesirable sensitivity to sample composition when deviations from ideal stoichiometry occur [3]. Consequently, identifying an optimal electrolyte lipophilicity range is essential for the development of reliable membrane-based REs.

In this work, a series of organic electrolytes based on the bis(trifluoromethanesulfonyl)imide ($[C_1C_1N\Box]$) anion was investigated by systematically varying the lipophilicity of tetraalkylammonium counter cations. The influence of electrolyte lipophilicity on ion partitioning, potential stability, and membrane lifetime was evaluated under both static and flow conditions. Among the investigated compositions, tetrahexylammonium bis(trifluoromethanesulfonyl)imide ($[THA\Box][C_1C_1N\Box]$) demonstrated the most favorable performance, yielding highly reproducible reference potentials with a low variation across solutions spanning the physiological electrolyte range. Quartz crystal microbalance measurements further confirmed significantly reduced electrolyte leaching, while no evidence of chemical interference with ion-selective membranes placed in their vicinity was observed. These findings establish practical design principles for selecting organic electrolytes with optimized lipophilicity and demonstrate the potential of $[THA\Box][C_1C_1N\Box]$ -based membrane REs for integration into robust all-solid-state sensing platforms requiring high stability, extended operational lifetime, and reliable analytical performance.



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Classifying Quantum Dot Systems in a Commercial Quantum Dot Enhancement Film by LA-ICP-TOFMS Imaging and PCA

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Quantum dot (QD) displays made their commercial debut in 2013, and QD technologies have since become widely implemented in consumer products. [1] In QD enhancement films (QDEFs), red- and green-emitting semiconductor nanocrystals are embedded in a resin to form mechanically stable composites. QDs are typically stabilized using surface ligands and/or particulate encapsulates, whereas the final QDF properties can be tuned using (in)organic additives. [2] Commercial display technologies currently employ InP-based, CdSe-based and lead-halide perovskite-based QDs. [3] Since Cd and Pb are toxic and regulated under the EU restriction of hazardous substances (RoHS), legal limits apply to their average concentration in each homogeneous component. [4] However, micro-encapsulated QD domains may contain substantially higher local concentrations than indicated by these bulk averages. Consequently, spatially resolved analytical strategies are necessary to assess local Cd/Pb levels in QD microdomains, which are masked when reported as homogeneous-material averages.

In this work, we characterize a QDF obtained from a TV intended for a non-EU market, with respect to emitter type, matrix composition and layer structure. Photoluminescence spectroscopy, including steady-state and time-resolved measurements, was employed to identify possible QD emitters. Laser ablation inductively coupled plasma time-of-flight mass spectrometry (LA-ICP-TOFMS) imaging was performed to map spatial distributions across the cured-resin composite. Correlative pixel analysis supported the interpretation of elemental distribution maps, revealing two distinct QD systems within the film. Principal component analysis (PCA) combined with k-means clustering enabled classification of pixel populations and discrimination between different QD systems and the surrounding polymer matrix. This approach demonstrates how LA-ICP-TOFMS imaging combined with multivariate analysis can provide additional information for the characterization of commercial QDEFs through spatially resolved classification of distinct QD populations.

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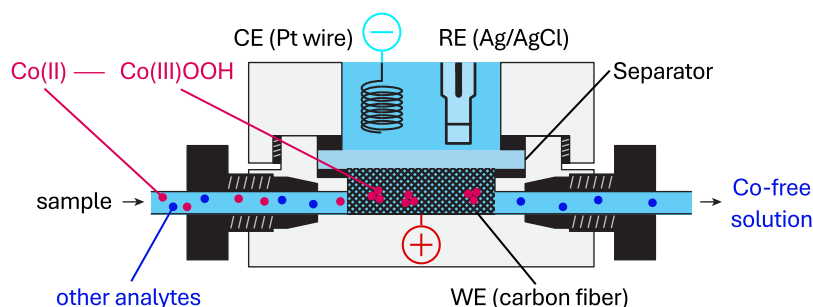
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Anodic Electrodeposition for the Separation of Co-60 for Background Suppression in γ -Spectrometric Analysis

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The precise identification and quantification of radionuclides is essential for monitoring emissions from nuclear installations, environmental radioactivity measurements and the decommissioning of nuclear facilities. As one of the main activation products in nuclear power plants (NPP), Co-60 complicates γ -spectrometric analyses through the introduction of a pronounced Compton background, potentially obscuring less intense signals from other radionuclides. Consequently, radionuclides may require separation prior to their identification and quantification, by using well-established radioanalytical methods such as ion-exchange or extraction chromatography. Less explored electrochemical separation methods using inexpensive carbon-based electrode materials may provide an alternative or complementary approach with distinct chemical selectivity. In previous studies, cathodic electrodeposition was used to separate radionuclides of Ag, Sn, Sb, and Te from Co-60 containing samples [1]. Even more efficient would be the direct separation of Co-60 in a single step. A possible approach to achieve this might be found in the tendency of a few metals to form poorly soluble oxidic species at high oxidation states. Hence, this work explores anodic electrodeposition in a standard three-electrode flow-through electrolysis setup (see Figure below) as a method for the fast and selective separation of Co and other transition metals from aqueous solutions. Optimized model experiments with stable Co(II) in an acetate-sulfate electrolyte resulted in separation efficiencies of > 95%. Here the latest results and the applicability of the developed approach for background suppression in γ -spectrometric measurements will be presented.



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Minimally invasive elemental fingerprinting of historical colored sheet glass by open ablation LA-ICP-MS

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Stained glass constitutes an important category of cultural heritage. The elemental composition of colored sheet glass used in the making of stained glass provides insight into the raw materials and technologies used in its production, while also illuminating historical trade networks linking glasshouses and artists. [1] Within the SNSF project *Stained Glass in Islamic Lands* [2], Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) is employed to generate elemental fingerprints of 19th- to early 20th-century glass samples from collections with known provenance and production dates.

Open ablation LA-ICP-MS has previously been shown to enable direct analysis of cultural heritage objects that are too large, irregular, or sensitive for conventional closed ablation cells. [3] In this study, the approach is applied to the glass samples and adapted to the requirements of this specific project. A key challenge is to obtain reliable compositional data while minimizing material removal from valuable objects. Sampling will therefore be restricted to unobtrusive areas, such as glass edges, and the required ablated volume will be optimized to ensure sufficient sensitivity, limits of detection, and reproducibility.

The open ablation setup [4] will be compared with a conventional closed-cell configuration to evaluate whether the resulting elemental data are suitable for statistical classification. The Corning Archaeological Reference Glasses [5] will be measured to assess accuracy and reproducibility across different historical glass compositions. This work aims to establish open ablation LA-ICP-MS as a minimally invasive workflow for generating classification-ready compositional data from historical glass sample collections.

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Forensic Trace Element Analysis of Bullets**F. Weigand¹, C. Saxer², D. Günther^{1*}**

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Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is a tool used in forensic science, with which the trace elemental composition of a sample can be quantified with low limits of detection.¹ Comparative analysis of the trace elemental fingerprints of different samples allows to corroborate or exclude evidence from a crime scene. As forensic samples are unique, sample preparation methods such as digestion which alter or destroy a sample should be avoided and methods such as Laser Ablation (LA) coupled to ICP-MS preferred.²

While LA-ICP-MS has been successfully applied to samples such as glass, ink and paper, elemental analysis of bullets with ICP-MS has traditionally been performed using acid digestion.³ This approach destroys valuable evidence on the surface of a bullet in the form of rifling marks engraved by the rifling of the gun from which it was fired. Preservation of these rifling marks is crucial as they allow to match a bullet to a firearm.⁴ With LA-ICP-MS a bullet's trace elemental fingerprint can be obtained while causing minimal or no alteration to these rifling marks.

In this study the distinguishability of bullets based on their trace elemental fingerprint using LA-ICP-MS is investigated.

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Compatibility with Media, Accelerated Aging, and Lifetime Estimation in the Polymer Lifecycle

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Polymeric materials are exposed to a variety of thermal, mechanical, chemical, and environmental stresses throughout their service life, which can significantly affect their performance, reliability, and durability. Understanding these aging mechanisms is essential for predicting long-term behavior and ensuring the safety and functionality of polymer-based products. This work presents a comprehensive overview of laboratory methods used to evaluate media compatibility, accelerated aging, and lifetime estimation of polymers and polymer assemblies.

Lifetime prediction approaches are discussed with a focus on thermal degradation models, including the Arrhenius method, which enables estimation of service life based on temperature-dependent degradation kinetics. Thermogravimetric analysis (TGA), following ASTM E1641 and E1877 standards, is employed to determine the relationship between thermal lifetime and operating temperature. Experimental validation is achieved through accelerated aging studies at elevated temperatures.

The influence of environmental factors such as humidity, ultraviolet radiation, and chemical exposure is further investigated. High-temperature/high-humidity aging is assessed through controlled storage conditions followed by tensile testing according to DIN ISO 527 to quantify changes in mechanical properties. UV resistance is evaluated using accelerated weathering tests that simulate outdoor exposure, while surface color changes are measured visually and instrumentally. Media compatibility is determined through environmental stress cracking tests according to EN ISO 22088-3, examining the effects of solvents, chemicals, and disinfectants under mechanical load.

In addition, methods for evaluating the aging resistance of disposable polymer products are presented. Surface and material changes resulting from aging are characterized through contact angle measurements, tensile testing, and FTIR spectroscopy. The combination of these accelerated aging and characterization techniques provides valuable insights into degradation mechanisms and enables reliable prediction of long-term polymer performance in demanding applications.

Keywords: polymers, accelerated aging, lifetime estimation, media compatibility, environmental stress cracking, UV aging, durability testing, polymer degradation.