BP 27: Focus Session Chemical Imaging for the Elucidation of Molecular Structure I (joint session O/BP)

Unravelling the multiscale molecular heterogeneity at interfaces is one of the main challenges in modern biophysics and surface science due to the major role specific structural properties play in determining their macroscopic function and behavior. In the last few decades, several specialized chemical imaging techniques have been developed that can reveal many of these crucial structural details, representing an enormous advance in our elucidative capabilities. Clear examples of this range from super-resolution and 3D tomography to tag-free characterization down to the single-molecule level. This focus session will explore the vast range of methods and possibilities for characterizing the different structural aspects in heterogeneous molecular systems and specifically highlight the potential complementarity of the different techniques through multi-modal approaches. Overall, by bringing together different communities, this session aims to foster scientific exchanges that could spark the next major developments in chemical imaging.

Organized by
Martin Thämer (FHI Berlin), Alexander Fellows (FHI Berlin), and Kerstin Blank (University Linz)

Time: Thursday 15:00–17:30 Location: H24

Invited Talk BP 27.1 Thu 15:00 H24

Infrared Nanoscopy and Tomography of Intracellular Structures — Joachim Heberle[1], Katerina Kanevche[1], •Emmanuel Pfitzner[1], David Burr[2], Janina Drauschke[2], Andreas Elsaesser[2], and Jacek Kozuch[1] — [1]Freie Universität Berlin, Department of Physics, Experimental Molecular Biophysics, — [2]Experimental Biophysics and Space Sciences, Arnimallee 14, 14195, Berlin, Germany

Although techniques such as fluorescence-based super-resolution imaging or confocal microscopy simultaneously gather morphological and chemical data, these techniques often rely on localized and chemically specific markers. To eliminate this flaw, we have developed a method of examining cellular cross-sections using the imaging power of scattering-type scanning near-field optical microscopy (sSNOM) and Fourier-transform infrared spectroscopy at a spatial resolution far beyond the diffraction limit (nanoFTIR). Herewith, nanoscale surface and volumetric chemical imaging are performed using the intrinsic contrast generated by the characteristic absorption of mid-infrared radiation by the covalent bonds. We employ infrared nanoscopy to study the subcellular structures of eukaryotic (C. reinhardtii) and prokaryotic (E. coli) species, revealing chemically distinct regions within each cell. Serial 100 nm-thick cellular cross-sections were compiled into a tomogram, yielding a three-dimensional infrared image of subcellular structure distribution at 20 nm spatial resolution. The presented methodology can image biological samples with less interference due to the low energy of infrared radiation and the absence of labeling.

Invited Talk BP 27.2 Thu 15:30 H24

Coherent Raman Imaging — •Michael Schmitt[1] and Juergen Popp[1,2] — [1]Institute of Physical Chemistry and Abbe Center of Photonics, Friedrich-Schiller-University Jena, Helmholtzweg 4, 07743 Jena, Germany — [2]Leibniz Institute of Photonic Technology, Member of Leibniz Health Technologies, Albert-Einstein-Straße 9, 07745 Jena, Germany

Raman-based technologies have profoundly impacted life sciences and biomedical research. Despite their unmatched molecular specificity, traditional Raman spectroscopy suffers from limited sensitivity, making it less suitable for rapid imaging. This limitation is addressed by coherent Raman scattering (CRS) microscopy, primarily through coherent anti-Stokes Raman scattering (CARS) and stimulated Raman scattering (SRS). This talk examines the potential of CARS and SRS imaging for biological and biomedical analysis, offering detailed insights into the molecular composition of biomedical specimens, such as cells or tissue. The presentation will focus on the applications of these techniques in molecular and functional diagnostics in the fields of medicine and life sciences. Furthermore, recent developments in translating CRS into compact, clinically viable systems, such as handheld probes, will be presented, focusing on intraoperative tumour diagnostics for early detection and improved improved therapeutic outcomes.

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Invited Talk BP 27.3 Thu 16:00 H24

Sum Frequency Generation Microscopy of Electrochemical Interfaces — •Steven Baldelli — University of Houston, Houston, Texas

Sum frequency generation spectroscopy (SFG) is a valuable technique to study the molecular properties of surfaces. As a second-order technique, it is uniquely sensitive to the average organization of molecules at the surface. However, as most surfaces are spatially heterogeneous, it isn't easy to interpret the spectrum as a single domain. The development of SFG into microscopy has allowed a more detailed and accurate analysis of the spatio-spectro-temporal evolution of surface chemistry. The SFG microscope development will be presented, and compressive sensing and the application toward electrocatalysis will be used.

BP 27.4 Thu 16:30 H24

Elucidating the Composition, Order, and 3D Molecular Orientation of Thin Films with Phase-Resolved Sum-Frequency Generation Microscopy — •Alexander Fellows, Ben John, Martin Wolf, and Martin Thämer — Fritz-Haber-Institute, Berlin, Germany

The vast majority of molecular interfaces have highly heterogeneous structures, ranging across all length-scales. These manifest as variations in density, composition, and molecular packing structure, all of which are critical in controlling the macroscopic properties and functional behaviour of the films. While various chemical imaging techniques can access many of these important structural details, characterising their relative order and specific packing arrangements represents a formidable challenge.

Here, we present a chemical imaging approach based on phase-resolved sum-frequency generation (SFG) microscopy. By probing molecular vibrations, this technique achieves molecular recognition and thus is sensitive to the local composition and density. Furthermore, through its symmetry selection rules, output SFG signals are dependent on absolute molecular orientations. This hence allows it to distinguish different molecular conformations and characterise the amount of orientational order in the system. Finally, with an azimuthal-scanning approach, the in-plane and out-of-plane signal contributions can be separated, allowing the 3D molecular orientations to be elucidated. By applying SFG imaging to model lipid monolayers, we gain an unprecedented overview of their hierarchical packing structures.

BP 27.5 Thu 16:45 H24

Low temperature multimode atomic force microscopy using an active MEMS cantilever — Michael G. Ruppert[1], Miguel Wiche[2], André Schirmeisen[2], and •Daniel Ebeling[2] — [1]University of Technology Sydney, Australia — [2]Justus Liebig University Giessen, Germany

Low-temperature atomic force microscopy (AFM) is one of the most powerful tools in surface science. With the chemical bond imaging technique, i.e., by using CO functionalized AFM tips, it became possible to visualize the chemical structure of individual organic molecules, which is essential for studying on-surface reactions and molecular manipulation processes. Routinely, such measurements are performed

with qPlus sensors. Here, we present a proof of concept for an active microelectromechanical systems (MEMS) microcantilever with integrated piezoelectric sensing and demonstrate its capability to obtain scanning tunneling microscopy as well as high-resolution non-contact atomic force microscopy images on an atomically flat Au(111) surface. Equipped with a focused ion beam deposited tungsten tip, the active MEMS cantilever is able to obtain high contrast scanning tunneling and frequency shift images at the fundamental and a higher eigenmode of the cantilever. This is interesting for the application of multifrequency AFM operation modes that could enhance the capabilities of the bond imaging technique.

BP 27.6 Thu 17:00 H24

Instrumentation for high-resolution biomolecule imaging enabled by electrospray ion beam deposition (ES-IBD) — •Lukas Eriksson[1], Tim Esser[1,2], and Stephan Rauschenbach[1] — [1]University of Oxford, Oxford, UK — [2]Thermo Fisher Scientific, Eindhoven, Netherlands

Direct imaging of (bio-)molecules with cryogenic electron microscopy (cryo-EM) or scanning probe microscopy (SPM) is a powerful approach for elucidating molecular structure. However, sample preparation can be a major challenge: either very time- and resource-intensive or incompatible with the vacuum environment required by the imaging method.

Here, we explore preparative mass spectrometry as an alternative workflow towards structural elucidation of biomolecules. A novel, custom-built deposition stage extending a commercial mass spectrometer (Thermo Fisher Scientific Orbitrap UHMR) allows for the mass-filtered, soft-landed deposition of a wide mass range of target molecules (m = 100 to 10^6 Da) onto various surfaces, including cryo-EM grids and metal crystals for SPM. Successful deposition and subsequent imaging requires extensive control over conditions such as pressure, temperature, ion trajectories, sample surfaces, and sample transfer to obtain clean, chemically pure samples of the desired species in the right (i.e. native) configuration. The sample holder also enables controlled growth of ice layers for embedding deposited molecules, allowing high-resolution reconstructions of proteins from cryo-EM.

BP 27.7 Thu 17:15 H24

LFM study of copper oxide — •Sophia Schweiss, Alfred J. Weymouth, and Franz J. Giessibl — Universität Regensburg, Regensburg, Deutschland

Small-amplitude FM-AFM is a method to study surfaces and adsorbates with atomic resolution. At low temperature, the tip apex can be prepared so that it ends in a single O-atom, making the tip inert and enhancing imaging [1, 2]. With a laterally oscillating tip, i.e. lateral force microscopy (LFM), the conservative (frequency shift, Δf) and non-conservative (dissipated energy, E_{diss}) components of the tip-sample interaction can also be independently measured. Here too, inert tip apices are commonly used. One measurement of E_{diss} relies on the cocking and snapping of the tip over a single chemical bond, for which the current state of the art utilizes CO-terminated tips. In this work, a CO-terminated tip [1] is used to investigate the (2×1)O reconstruction of Cu(110) with LFM. Simulations are performed to guide interpretation. In this larger ongoing study, these LFM measurements will be repeated for a CuOx tip [2] to evaluate it as a tool for measuring E_{diss}.

[1] Gross et al., Science, **325**, 1110 (2009)
[2] Mönig et al., Nat. Nano., **13**, 371 (2018)