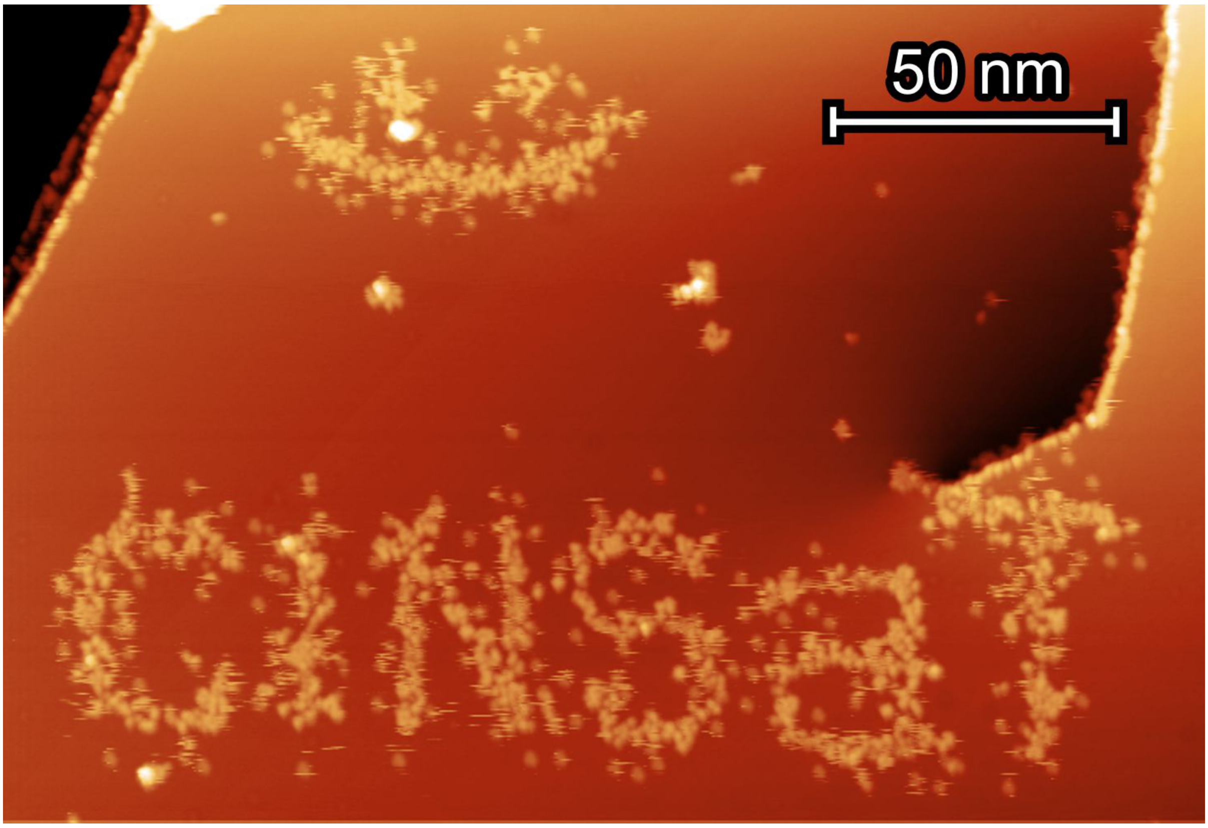
CINSaT Center for Interdisciplinary Nanostructure Science and Technology

Newsletter No. 19 (January 2026)



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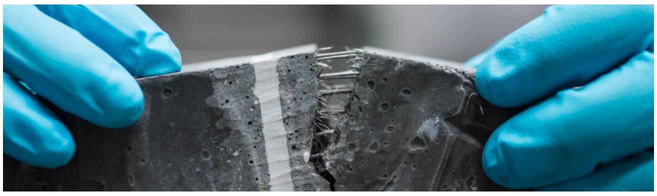

Cover Image:
STM tip-induced Writing with single molecules. A two-dimensional molecular gas consisting of physisorbed molecules serves as the ink. Voltage pulses applied with the tip convert individual molecules from a mobile, physisorbed state into an immobile, chemisorbed state. In this way, the tip selectively “fixes” single molecules to the surface, enabling molecular writing with nanometer precision (image taken by Nico Kubetschek, AG Matzdorf).

Preface

Dear Readers of the CINSaT Newsletter,

Welcome to the second issue of the CINSaT newsletter for 2025. This issue provides an overview of the vibrant scientific activities and achievements of our community over the past year. CINSaT continues to serve as a platform for innovative research, interdisciplinary collaboration, and the exchange of ideas in nanoscience.

In this issue, we highlight the DFG-funded initiative WARP – The Wave Riding Particles Instrument initiated by our member Prof. Arno Ehresmann and Dr. Rico Huhnstock, a collaboration between experimental physics and computer science. This project aims to overcome limitations of conventional AFM measurements in liquids by using magnetic microparticles as probes for high-throughput, precise characterization of liquid-mediated surface interactions. AI-assisted 3D particle tracking and optical imaging will allow the WARP instrument to measure hundreds of particles simultaneously, paving the way for versatile investigations of surfaces under various conditions. More information in the New Projects section.

We also present the Surface Physics group of our member Prof. René Matzdorf in the Members section, which investigates strongly correlated electronic systems, low-dimensional nanostructures, and chiral molecular assemblies. Their work employs advanced techniques such as low-temperature scanning tunneling microscopy and spectroscopy, LEED, and Auger electron spectroscopy to explore exotic electronic states, supramolecular chirality, and light-switchable conductive molecules.

This issue features two significant research highlights. Researchers from the SFB-1319 ELCH have demonstrated that high-energy photo- and Compton electrons can be used to determine the absolute configuration of chiral molecules in the gas phase. Their work, presented by Prof. Philipp Demekhin, expands the concept of light-driven chiral recognition into intermediate and hard x-ray regimes, providing new opportunities for molecular diffraction imaging. On behalf of all members of CINSaT, I congratulate the members involved in SFB-ELCH on the recently achieved extension. In addition, Prof. Schaffrath and colleagues have uncovered that the dual roles of Urm1 in tRNA thiolation and protein urmylation can be separated. Expression of Sulfolobus acidocaldarius Urm1 in Saccharomyces cerevisiae revealed that protein urmylation is evolutionarily conserved, while tRNA thiolation is not. This finding provides insights into the evolution of protein modification pathways and enables targeted investigations of urmylation mechanisms. More information in the Research Highlights section.

Finally, the annual CINSaT Autumn Colloquium took place on November 5, 2025, attracting strong participation and presenting exciting scientific talks and posters. For more details on speakers, posters, and awardees, please refer to the full article in the Latest Reports section.

We hope you enjoy reading this issue and find inspiration in the exciting research presented by our CINSaT community. We wish you good health and continued success in your scientific endeavors.

Research Highlights

Chiral Recognition with High-Energy Photo- and Compton Electrons

We demonstrate that high-energy photo- and Compton electrons can be employed to determine the absolute configuration of chiral molecules via diffraction imaging and extend the concept of light-driven chiral recognition in the gas phase toward intermediate and hard x-ray domains.

Low-energy photoelectrons escape a molecular ion slowly and have sufficient time to respond to every and each detail of its potential. Thereby, low-energy electrons can discriminate between two handednesses of a chiral molecule, allowing for a chiral recognition in the gas phase via photoelectron circular dichroism. While there are no doubts about the enantio-sensitivity of low-energy electrons, high-energy electrons are commonly assumed to be enantio-insensitive. This is because a high-energy photoelectron wave packet leaves the molecular ion rather quickly and has no time to adopt its chiral asymmetry. Nevertheless, high-kinetic-energy electrons allow to access structural and dynamical information via photoelectron diffraction imaging. In particular, their molecular-frame angular distributions exhibit forward-scattering lobes pointing (away from the emitter site) in the directions of heavy neighbors, whose nuclei act as lenses for the emerging electron wave. Moreover, a superposition of the directly-emitted and on-the-neighbor-scattered photoelectron waves creates rich double-slit interference patterns that can directly be related with a distance between the emitter and the scatterer. Typical molecular-frame emission distributions of high-energy electrons are depicted in panels (I) and (II) on the left-hand side of the figure below.

In the currently running DFG collaborative research center SFB-1319 ELCH, we demonstrated theoretically that high-energy electrons can be used for a chiral recognition in the gas phase. The discrimination between two enantiomers can be achieved via electron diffraction imaging of a chiral molecule, especially when its absolute configuration cannot be deduced by Coulomb explosion imaging. Our findings are exemplified in the figure below on the example of the ionization of O 1s inner-shell electron of methyloxirane (C3H6O, MOx) molecules by two different light-driven mechanisms. Specifically, we consider photoionization and ionization by Compton scattering of high-energy photons. Momenta of ionic fragments, determined via Coulomb explosion imaging, build a plane, which is however identical for both enantiomers (see turquoise arrows and green plane in the insets atop). Here, we made use of the forward-scattering lobes in the molecular-frame electron emission distributions, which point toward the heavy neighbors and survive averaging over the light polarization for the photoionization and over the photon momentum transfer for the Compton ionization. As one can see, the main lobe in the two-dimensional emission distributions (as encoded in the color-coded map), pointing from the oxygen atom (emitter) toward the carbon atom in the chiral center (scatterer), allows for the identification of the molecular handedness. In particular, it appears in these distributions above or below the plane determined by charged molecular fragments (black horizontal line at $\cos\theta=0$), respectively, for S-MOx in panels (a) and (c) or R-MOx in panels (b) and (d).

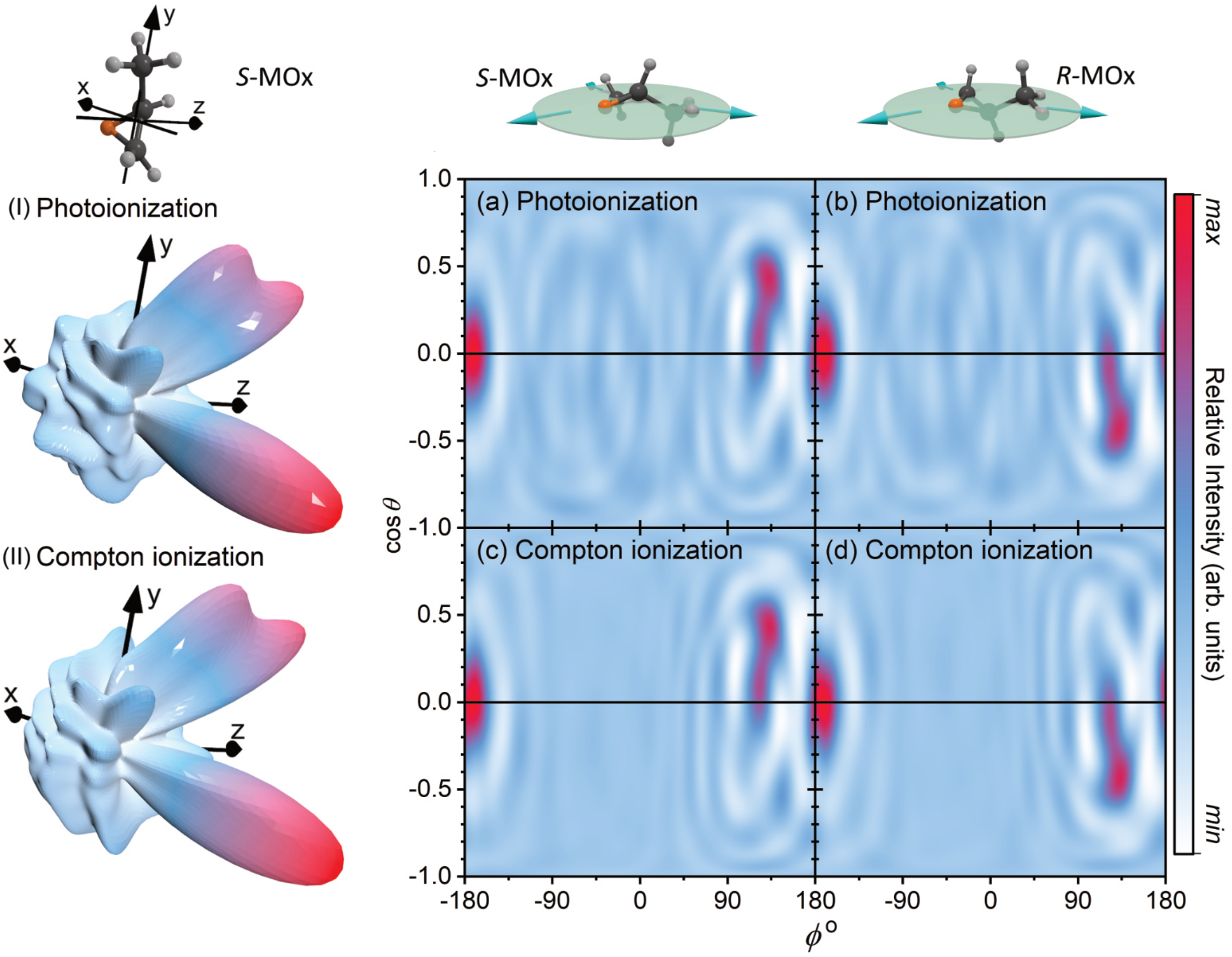

Figure 1: Polarization-averaged molecular-frame photoelectron angular distributions (upper panels) and photon-momentum-transfer-averaged molecular-frame Compton electron angular distributions (lower panels) for the O 1s ionization of S- (I),(II),(a),(c) and R- (b),(d) enantiomers of methyloxirane (see insets atop) for an electron kinetic energy of 200 eV. The electron angular distributions of the two enantiomers are mirror images of each other with respect to the black horizontal line (the green plane in the insets). The main lobe pointing toward the chiral center appears above (for S-MOx) or below (for R-MOx) the black horizontal line and, thus, unambiguously identifies the molecular handedness. (I) and (II) depict the three-dimensional representations of respectively, (a) and (c), where the distance from the origin indicates the emission probability. The respective molecular orientation is visualized atop.

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Further Information

Haubenreißer et al., Phys. Rev. Lett. 135, 213203 (2025);
doi: 10.1103/4fnf-wkfd

Ubiquitin-like protein urmylation is conserved from archaea to yeast

URM1 gene shuffle from *Sulfolobus acidocaldarius* to *Saccharomyces cerevisiae* has uncovered that dual-function sulfur carrier roles for Urm1 in tRNA thiolation and protein urmylation can be separated from one another by expressing an archaeal Urm1 homolog in yeast.

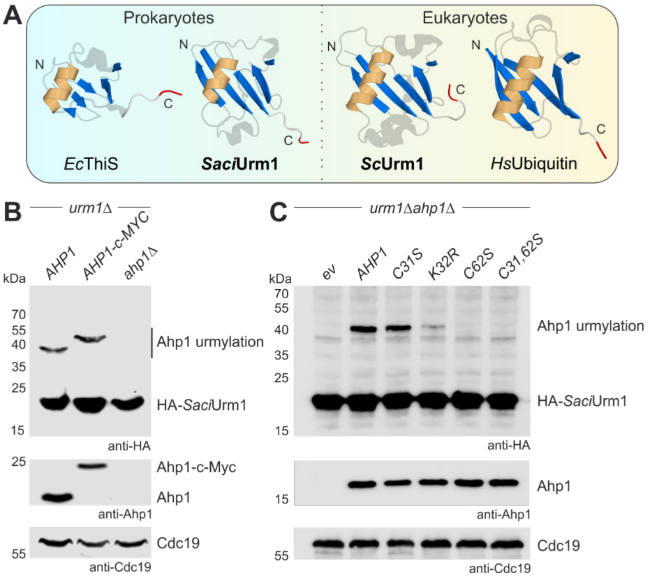

Figure 1. SaciUrm1 conjugates to yeast Ahp1 in an urmylation-like fashion. (A) Ribbon diagrams of ThiS from E. coli (PDB: 1f0z), Urm1 from S. acidocaldarius (AlphaFold) and S. cerevisiae (PDB: 2qjl), and human ubiquitin (PDB: 1ubq). Conserved β-grasp fold structures with a typical sheet of five antiparallel β-strands (marine), a central α-helix (orange), and C-terminal di-glycine motifs (red) are highlighted. (B) Protein extracts from urm1Δ, urm1ΔAHP1-c-MYC or urm1Δahp1Δ strains expressing HA-SaciURM1 were subjected to anti-HA Western blots (top panel) to detect free HA-SaciUrm1 (~20 kDa) and urmylated Ahp1 (~40 kDa) or Ahp1-c-Myc (~50 kDa). Unconjugated Ahp1 (~20 kDa) or Ahp1-c-Myc (~25 kDa) is monitored in anti-Ahp1 Western blots (middle panel). (C) Protein extracts from urm1Δahp1Δ strains co-expressing HA-SaciURM1 and indicated AHP1 substitutions or an empty vector (ev) were subjected to anti-HA Western blots (top panel). Free forms of HA-SaciUrm1 (~20 kDa) and urmylated Ahp1 (~40 kDa) are marked. Free Ahp1 (~20 kDa) is detected by anti-Ahp1 blots (middle panel). Protein loading was controlled with anti-Cdc19 Western blots (bottom panels in B-C).

Urm1 represents a ubiquitin-like protein (Ubl) with dual functionality as a sulfur carrier for tRNA thiolation and a modifier for protein urmylation. Its structural and functional similarities to both bacterial sulfur carriers (e.g., ThiS, MoaD) and eukaryotic Ubls (e.g., SUMO, NEDD8) (Fig. 1A) position Urm1 as a molecular fossil that may trace back the evolutionary transition from prokaryotic sulfur transfer to eukaryotic protein conjugation pathways. In our recently published study in Nature Portfolio's journal Communications Biology, we show Urm1 from *S. acidocaldarius* (SaciUrm1) conserves urmylation function, but not tRNA thiolation, when expressed in *S. cerevisiae*, revealing a functional separation of the dual roles for Urm1.

Alignment of archaeal and yeast Urm1 sequences confirms shared structural features, including conserved β-grasp folds and C-terminal di-glycine motifs (Fig. 1A). Functional analysis has shown that SaciUrm1 attaches to yeast peroxiredoxin Ahp1 in a manner indistinguishable from *S. cerevisiae* Urm1 (ScUrm1), with SaciUrm1 forming a ~40 kDa conjugate similar in size to ScUrm1–Ahp1 complexes (Fig. 1B). The modification requires Lys-32 of Ahp1 as the primary urmylation site and redox-active Cys-62 as evidenced by electrophoretic mobility shift assays (Fig. 1C). The requirement for the catalytic Cys-62 of Ahp1 is significant, as this residue is essential for peroxiredoxin activity and yeast Urm1 attachment, while a Cys-31 substitution (C31S) retains partial Ahp1 activity and urmylation capability. The conservation of Ahp1 recognition by SaciUrm1 implies that mechanistically, the urmylation reaction is evolutionarily preserved from archaea to yeast and predates the Archaea–Eukarya divergence.

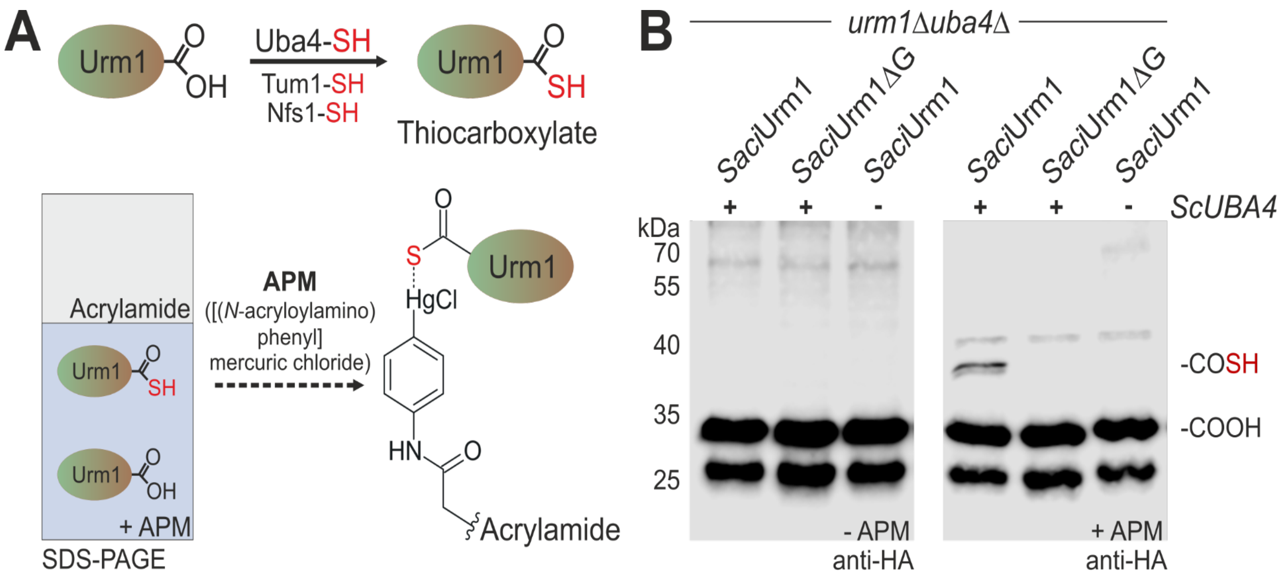

Figure 2. Identification of thiocarboxylated SaciUrm1 by APM gels. (A) Scheme illustrating APM usage in SDS-PAGE to diagnose Urm1 thiocarboxylation. Urm1–COOH is thio-activated at its C-terminal glycine by Uba4 resulting in Urm1–COSH. Adduct formation with thiocarboxylated Urm1 through the thiophilic character of APM results in retarded migration indicating the presence of sulfur in the thiocarboxylate (–COSH). (B) EMSA diagnostic for thiocarboxylation of SaciUrm1 by Uba4. Protein extracts from urm1Δuba4Δ strains coexpressing ScUBA4 (+) or not (-), with HA-tagged SaciUrm1 or its glycine deletion (ΔG), were separated by SDS-PAGE containing a layer of APM, as specified (+/-). APM dependent retardation of anti-HA signals (right panel) distinguishes sulfur-free (–COOH) from thiocarboxylated (–COSH) HA-SaciUrm1.

Sulfur-incorporation into the C-terminal di-glycine motif of Urm1, also known as thiocarboxylation (–COSH), is essential for tRNA thiolation and protein urmylation functions. It is catalyzed by the E1-like enzyme Uba4 through a well-defined sulfur relay (Fig. 2A). Here, desulfurase Nfs1 extracts sulfur from cysteine and transfers it to S-transferase Tum1 and the catalytic cysteine of Uba4 for ultimate thiocarboxylation of Urm1. The latter is confirmed by APM [(N-acryloylamino)phenyl]mercuric chloride, which triggers mobility shifts in SDS-PAGE through adduct formation with thiocarboxylated Urm1 (Fig. 2A). Using APM assays, we verified that SaciUrm1 undergoes thioactivation on its C-terminus by yeast Uba4 (Fig. 2B). However, despite thiocarboxylation, SaciUrm1 fails to support tRNA anticodon thiolation in yeast, as evidenced by mass spectrometry (LC-MS/MS) analysis that showed absence of sulfur-dependent wobble uridine modifications (mcm^5s^2U34) and accumulation of sulfur-free (mcm^5U34) intermediates. The thiolation defect also manifests phenotypically as SaciUrm1 expression failed to rescue the sensitivity of urm1Δ yeast mutants to elevated cultivation temperatures.

The separation of urmylation from tRNA thiolation upon expression of SaciUrm1 in yeast, suggests that the dual roles of Urm1 may have evolved independently. While archaeal Urm1 likely functions in tRNA thiolation within *S. acidocaldarius*, the yeast thiolation machinery (Ncs2–Ncs6 heterodimer) may not recognize the archaeal Urm1 homolog. This incompatibility aligns with prior findings that archaeal tRNA thiolation enzymes form homodimers, whereas eukaryotic ones are heterodimeric. Thus, the incompatibility of SaciUrm1 with the yeast thiolation machinery suggests the eukaryotic tRNA thiolation complex co-evolved with Urm1, while protein urmylation remained unchanged in eukaryotes. This functional separation could enable targeted investigation of urmylation mechanisms and allow for direct analysis of urmylation-specific functions. Future work will investigate whether in the context of its native archaeal host, SaciUrm1 functions in tRNA thiolation and aim to identify the specific protein–protein interactions that might prevent SaciUrm1 from engaging with the thiolation enzyme complex in yeast.

Further Information

Zupfer, K., Kaduhr, L., Bessler, L., Helm, M., & Schaffrath, R. (2025). Evolutionary conservation of ubiquitin-like protein urmylation as revealed by URM1 gene shuffle from archaea to yeast. Communications biology, 8(1), 1637. https://doi.org/10.1038/s42003-025-09212-3

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New Projects

New DFG-funded Project: WARP – The Wave Riding Particles Instrument

A joint effort of researchers from experimental physics and computer science led to the successful application for a project in the DFG program "New instrumentation for research". A novel measurement apparatus can now be set up, with the aim of innovating the analysis of liquid-mediated surface properties on the nano- and microscale.

For probing surface structures and properties at the nano- and microscale, Atomic Force Microscopy (AFM) has been an established tool for some time. Performing measurements in a liquid, however, imposes limitations on the method, rendering the characterization less straightforward in this case. For instance, AFM scans are typically carried out in the dynamic mode, making use of a vibrating tip interacting with the surface of interest. Here, damping caused by the surrounding liquid lowers the measurement resolution. In addition, scanning typically only a single tip across the surface limits the measurement area and leads to a low measurement throughput.

Precise characterization of wetted surfaces/structures plays an important role in a lot of scientific fields, from material science to cell biology. "WARP – The Wave Riding Particles Instrument" is an approach to overcome these restrictions, opening the door for precise analysis of liquid-mediated surface-to-surface interactions with a large throughput. Its basic idea is visualized in Figure 1: Magnetic microparticles are utilized as surface interaction probes, replacing the cantilever-mounted tip from AFM measurements. These particles will be arranged in a well-defined pattern close to the sample surface of interest via trapping in tailored magnetic stray fields located above the surface. These stray fields emerge from a magnetic domain pattern imprinted into a magnetic thin film substrate sitting below the sample to be investigated. Having the particles positioned close to the sample surface due to the attraction exerted by the stray fields, their surfaces will interact with the sample surface below via liquid-mediated forces, e.g., electrostatic forces. The height of the particles above the sample surface will give us insights into the strength of these interactions; it is therefore crucial to determine it with sufficient precision. Here, we will establish an AI-based evaluation technique for measuring particle heights using an all-optical 3D tracking approach. Imaging the particles with a high-resolution camera, their relative vertical position with respect to the focal plane of the utilized microscope can be determined by analyzing their sharpness, as demonstrated in Huhnstock et al., Scientific Reports 12, 20890, 2022. This 3D tracking method will lay the foundation to simultaneously infer the heights of hundreds of particles above the sample surface and thereby characterize the liquid-mediated surface properties. By using a neural network-based algorithm, our goal is to achieve this characterization in near real-time, similar to AFM scans. Applying external magnetic fields, we are able to induce directed motion of the particles across the surface, initializing an effective surface scanning. As all the particles are freely movable and can be evaluated in parallel, the limitations of cantilever-based measurements regarding damping and low throughput do not apply here. Our goal is to make the WARP instrument adaptable to all kinds of different measurement scenarios via an intelligent calibration routine, increasing its flexibility with regard to the type of sample to be measured.

For the realization of this project, we will combine unique expertise from experimental physics (Arno Ehresmann, Rico Huhnstock – Functional Thin Films) and computer science (Bernhard Sick – Intelligent Embedded Systems). We will build on our extensive experience in magnetic domain engineering, directed close-to-surface magnetic particle transport, and machine learning-assisted 3D particle tracking to construct the proposed research apparatus and verify its functionality with a series of proof-of-principle experiments. After this initial project (funded by the DFG for 3 years under project number 566304473), our aspiration is a follow-up initiative where the basic functionality of the setup is transferred to a ready-to-use measurement apparatus. The idea is that it will be usable for answering interdisciplinary research questions revolving around liquid-covered surfaces/structures and their liquid-mediated characteristics.

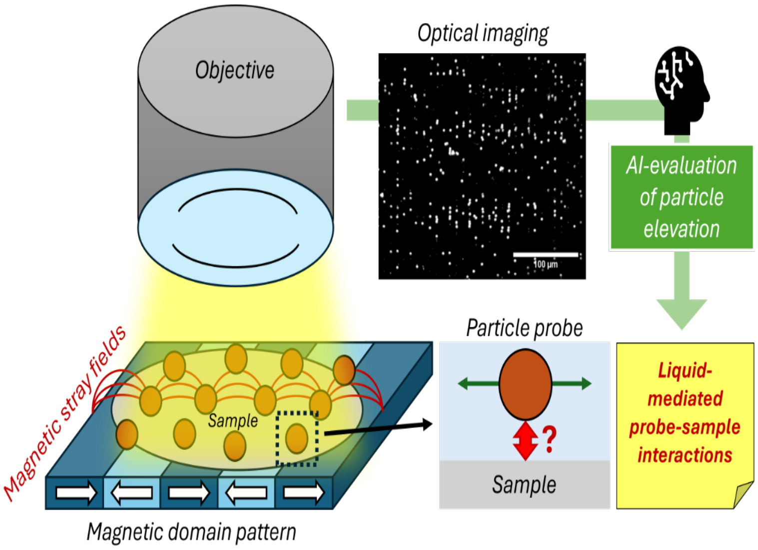

Figure 1: Schematic principle of WARP – The Wave Riding Particles Instrument. Liquid-immersed magnetic microparticles are assembled in a regular pattern close to the sample surface of interest. The assembly is promoted by magnetic stray fields emerging from an engineered magnetic domain pattern positioned below the sample. Interactions between particles (probes) and the underlying sample surface are screened by analyzing their vertical separation distance. Optical brightfield/ darkfield imaging of the particles in combination with a machine learning-based 3D tracking algorithm is planned to shed light on liquid-mediated surface-to-surface interactions via measurement of the particle height above the sample surface.

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New Members
Prof. Dr. Jost Adam

Prof. Jost Adam was appointed Chair of Computational Materials and Photonics (CMP) at Kassel University in September 2023 and became a member of CINSaT in spring 2024.

The Computational Materials and Photonics (CMP) Section at the University of Kassel is part of Department FB 16 – Electrical Engineering and Computer Science and has, since 2024, also been co-allocated to FB 10 with the Institute of Physics.

A mathematician by training, Jost completed his Ph.D. thesis in computational electromagnetics, developing algorithms for multipole-based near-to-far field transformations. During earlier research phases with the Computational Electromagnetics Group and the Chair for Integrated Systems and Photonics at Kiel University (CAU) and the Photonics Laboratory at the University of California, Los Angeles (UCLA), he worked independently across various areas of mathematical and computational modeling of multiphysical phenomena. Before joining the University of Kassel, he led the Computational Materials Group in the Department of Mechanical and Electrical Engineering at the University of Southern Denmark (SDU), where he and his team focused on multiphysical computational modeling of novel materials and devices from the atomistic level to the mesoscale.

Jost's research lies at the interface of computational solid-state physics, physical chemistry, materials science, and photonics engineering. At CMP, Jost and his team work on the computational modeling of novel materials and devices from the molecular (atomistic, quantum) level to the mesoscale. They investigate the photonic, plasmonic, electronic, quantum spin-related, magnetic, and mechanical properties of materials and nanostructures, employing ab initio quantum-mechanical methods as well as classical electromagnetic, variational, and artificial-intelligence-based approaches. To enable realistic simulation and optimization, they develop and apply numerical and analytical tools under technologically and fabrication-relevant constraints. Current applications include optoelectronic and MEMS-based sensing, photovoltaics, nanoscale electronics, catalysis, surface–molecule interactions, and thermoelectricity.

Jost and his team are currently focusing on two-dimensional materials, perovskite materials, and their interfacial behavior. Two-dimensional materials beyond graphene are a major research focus because they offer intrinsic bandgaps and diverse electronic, optical, magnetic, and chemical properties, enabling atomically thin, flexible, and highly tunable devices. Unlike graphene, these materials already support practical applications in electronics, optoelectronics, energy, sensing, and quantum technologies, while also providing platforms for exploring new physical phenomena and designing advanced heterostructures. Janus (broken-symmetry) two-dimensional materials play a critical role in next-generation energy conversion, particularly thermoelectrics, by combining structural asymmetry with strong coupling between charge, heat, and lattice degrees of freedom. The intrinsic out-of-plane dipole moment and built-in electric field in Janus monolayers enhance charge-carrier separation, modify phonon transport, and enable simultaneous optimization of electrical conductivity and Seebeck coefficient while suppressing thermal conductivity. These features break conventional trade-offs that limit thermoelectric efficiency, positioning Janus 2D materials as a promising platform for high-performance, ultrathin, and flexible thermoelectric devices. Double perovskite materials are an important research focus for photovoltaics and magnetic applications because they offer tunable electronic structures, improved stability, and reduced toxicity compared with lead-based perovskites, making them promising for durable and environmentally safer solar cells. At the same time, their flexible crystal chemistry enables the design of materials with controlled magnetic ordering, spintronic functionality, and strong coupling between electronic and magnetic properties, supporting both next-generation energy technologies and advanced magnetic devices.

A long-term research goal is to establish a predictive, multifunctional materials platform based on two-dimensional materials—including Janus (broken-symmetry) systems—and engineered double perovskites to enable efficient, stable, and sustainable energy and information technologies. By integrating semiconducting, magnetic, and polar 2D materials with tunable perovskite architectures, this effort aims to realize high-performance photovoltaics, thermoelectrics, spintronic devices, and quantum technologies, while advancing fundamental understanding of symmetry breaking, interfacial phenomena, and coupled electronic–thermal–magnetic processes at the atomic scale. Computational modeling plays a central role in this research endeavor by enabling predictive design and accelerated discovery of novel two-dimensional and double perovskite materials with targeted electronic, optical, and magnetic properties. First-principles simulations, multiscale modeling, and data-driven approaches allow researchers to screen vast chemical spaces, understand structure–property relationships, and optimize interfaces and heterostructures before experimental synthesis.

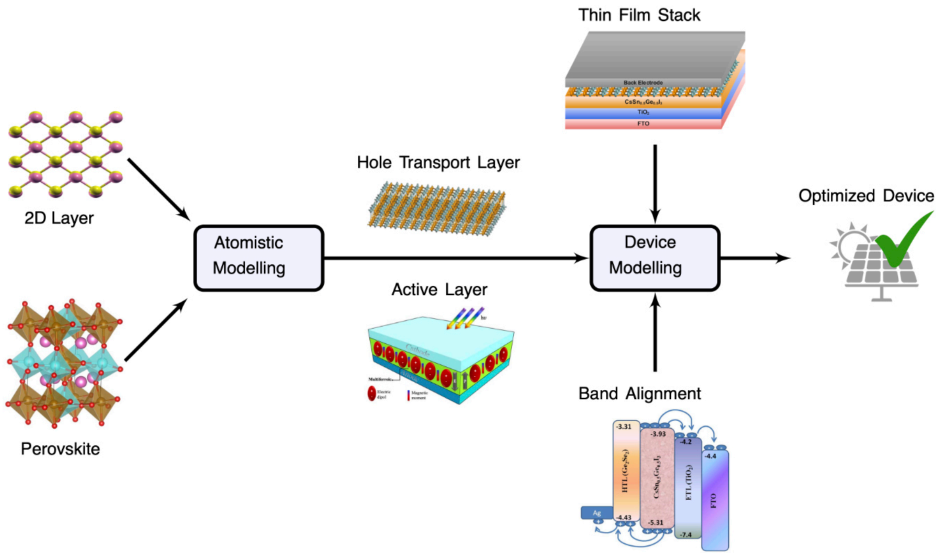

Figure 1: Sketch of a typical framework for atomistic-to-mesoscale modeling at CMP (here: for energy conversion). A computational ab initio step to design and test novel materials is followed by the extraction of device-relevant parameters and a final proof-of-principle device or interface simulation.

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Research Groups

Research Group: Surface Physics

In the Surface Physics group, we investigate the structural and electronic properties of nanostructured surfaces, novel materials, and molecules adsorbed on surfaces. We are particularly interested in systems in which electron correlations give rise to unconventional physical phenomena, especially in low-dimensional environments, for example, the emergence of Luttinger liquids in one-dimensional structures.

In most materials, electrons can be treated as nearly free and are therefore well described either as non-interacting particles embedded in a gas of electrons or within the framework of a Fermi liquid, in which electron-electron interactions are weak, as visible on the uncorrelated trajectories shown in (Fig. 1a). However, in strongly correlated systems these simple pictures break down, as electrons are forced to interact strongly with one another (Fig. 1b). Because the physics of such strongly correlated systems is still not fully understood, we are motivated to identify and study experimental model systems that may host correlated electronic states.

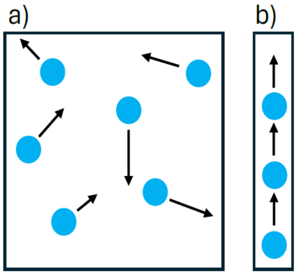

Fig. 1 Weakly interacting electrons in a 2D Fermi-Liquid (a) and strongly correlated electrons in a one-dimensional system (b).

Our primary tools are low-temperature scanning tunneling microscopy (LT-STM) and scanning tunneling spectroscopy (LT-STS) at 5 K and 77 K, which provide atomic spatial resolution and a good energy resolution in density of states spectroscopy. These methods are complemented by low-energy electron diffraction (LEED), Auger electron spectroscopy (AES), and gas-phase mass spectrometry. To achieve optimal measurement and synthesis conditions, all experiments are carried out under ultrahigh vacuum (UHV) of 1-10 mbar and under cryogenic conditions. For sample preparation, we employ argon-ion sputtering, electron-beam evaporators, and thermal molecular evaporators, which allow us to deposit atoms and molecules at extremely low rates (submonolayers per minute).

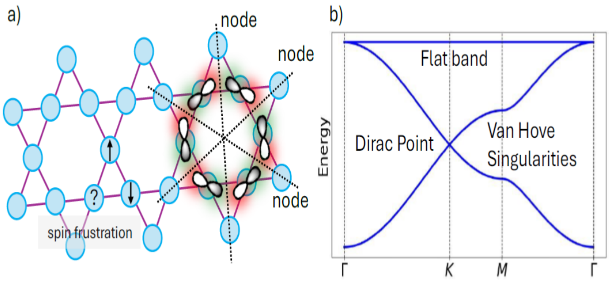

Fig. 2 Real-space representation of a Kagome lattice (left). Nearest-neighbor antiferromagnetic coupling leads to geometric frustration, giving rise to highly degenerate magnetic ground states. In tight-binding models, destructive interference between hopping paths produces a flat band in the dispersion relation. A localized eigenstate of this flat band can be constructed from an alternating-phase (antibonding) combination of orbitals around a hexagonal plaquette. The resulting wavefunction has nodes on the connecting sites, preventing hopping to neighboring sites and confining the state to a single pore.

To synthesize model systems that exhibit potentially correlated electronic behavior, we follow two approaches. First, we employ anisotropic reconstructed semiconductor surfaces and deposit transition metals to fabricate one-dimensional nanostructures. Another approach for the synthesis of systems to study correlated electronic behavior is the design of two-dimensional metal-organic materials whose lattice geometries make them promising candidates for the emergence of exotic electronic states. An example is the 2D-Kagomé lattice (Fig. 2a), where "orbital" phase frustration led to a flat band in the electron dispersion relation, as already visible in tight binding calculations (Fig. 2 b). Furthermore, systems with this lattice can host a spin glass and other exotic phases.

Another part of our research focuses on chirality on the surface. STM enables us to directly determine the absolute configuration of molecular adsorbates (Fig. 3).

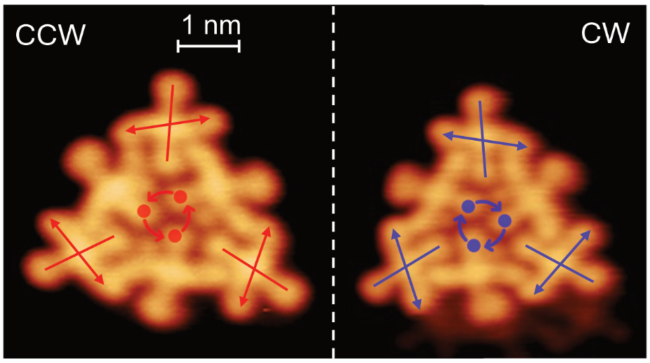

Fig. 3 The STM image shows pro-chiral molecules, assembled in chiral nano islands. The left island has a counterclockwise rotational sense, the right island clockwise. The absolute configuration of the chiral adsorbates, as well as the chiral adsorption motifs, can be determined using STM measurements.

We investigate how intermolecular interactions influence chiral amplification and enantiomeric separation. Additionally, we explore supramolecular global chirality that can arise from chiral binding or adsorption motifs, even from intrinsically achiral molecules.

In collaboration with the group of Prof. Faust (Chemistry of Mesoscopic Systems), we study switchable, conductive molecules. The goal is to synthesize molecules that can be switched between different conductivity states using visible light. These systems are examined through statistical STM break-junction measurements in our group (Fig.4).

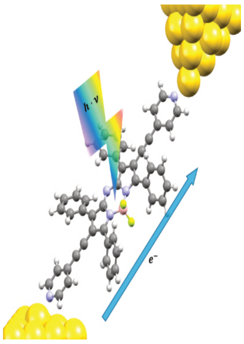

Fig. 4 An organic dye is bound on two electrodes. The conductivity is measured while the dye is excited by visible light.

Finally, we are interested in chemical reactions on surfaces. We take advantage of the catalytic properties of various substrates to study thermally or light-induced reactions in ensembles, as well as field-induced reactions in single molecules or small molecular assemblies.

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Latest Reports

Annual CINSaT Autumn Colloquium Attracts Over 120 Participants

The annual CINSaT Autumn Colloquium took place on November 5, 2025, in Lecture Hall 282 at the Heinrich-Plett-Straße campus of the University of Kassel. The event featured three external speakers and attracted more than 120 registered participants, along with additional interested students. Open to all researchers interested in nanoscience, the colloquium offered a platform for scientific exchange through lectures, discussions, and a poster session showcasing current CINSaT research.

The colloquium was opened by Prof. Claudia Backes, spokesperson of CINSaT. The first lecture was delivered by Prof. Gonzalo Abellán (University of Valencia, Spain), who presented “Two-dimensional Layered Hydroxides: From Molecular Control to Scalable Applications,” highlighting the potential of two-dimensional materials and his experience in translating research into a start-up. After a networking coffee break, Prof. Benjamin Butz (University of Siegen) gave a talk entitled “Enable the Impossible – The New INCYTE Research Center Siegen,” providing insights into the establishment of an interdisciplinary research center, a topic of particular relevance to CINSaT’s future plans. The final lecture was presented by Dr. Jörn Bonse (Federal Institute for Materials Research and Testing, BAM), who discussed “Ultrafast Optical Probing of Laser-Induced Formation of Periodic Surface Nanostructures,” focusing on research into laser-induced periodic surface structures (LIPSS).

The subsequent poster session featured 60 contributions from CINSaT research groups and enabled lively scientific discussions in the foyer of Lecture Hall 282. Catering was provided by the Studierendenwerk Kassel. Poster prizes were awarded by a jury consisting of Prof. Rudolf Pietschnig, Prof. Florian Baron, Prof. Ulrich Siemeling, Prof. Martin Garcia, and Dr. Andreas Hans. The jury emphasized the exceptionally high scientific quality of the submissions, which made the selection process particularly challenging. First prize (€150) went to Jana Dietrich (Experimental Physics II), second prize (€100) to Sina Dörr (Physical Chemistry of Nanomaterials), and third prize (€50) to Nikolai Weidt (Experimental Physics IV).

For the first time, CINSaT also honored outstanding bachelor’s or master’s theses from the previous year. Two bachelor’s theses were recognized with a prize of 250 € each: Jana Dietrich (Experimental Physics II) received the award for the best bachelor’s thesis in the natural sciences for her work “Untersuchung der Selbstassemblierung prochiraler Moleküle auf der Au(111)-Oberfläche zur Synthese zweidimensionaler metallorganischer Netzwerke,” while Mick Trachsel was honored for the best bachelor’s thesis in engineering for “Analysis of Optical Properties of Single and Multi-Layered Anti-Reflective Coatings for MEMS Micromirror-Based Reflective Displays Using a Self-Developed Spectral Simulation Software.” Both theses were praised by their respective supervisors, Prof. René Matzdorf and Prof. Hartmut Hillmer, as excellent achievements that far exceeded the expectations for bachelor-level work.

With strong attendance and a well-balanced program, the CINSaT Autumn Colloquium was once again a great success. CINSaT congratulates all awardees and looks forward to next year’s event.

Audience of the 2025 CINSaT Autumn Colloquium.

The guest speakers from left to right - Prof. Gonzalo Abellán, Prof. Benjamin Butz and Dr. Jörn Bonse.

Winners of the 2025 best poster prizes with jury from left to right - Jana Dietrich, Sina Dörr, Nikolai Weidt, Prof. Garcia, Prof. Pietschnig, Dr. Hans, Prof. Backes and Prof. Florian Baron.

Winners of the 2025 best theses prizes with their supervisors from left to right - Prof. René Matzdorf, Jana Dietrich, Mick Trachsel and Prof. Hartmut Hillmer.

CRC 1319 “Extreme light for sensing and driving molecular chirality” secures further funding period

19 researchers from 5 institutions under the coordination of the University of Kassel applied for the DFG funding and convinced the review board in the on-site evaluation. The collaborative research center (CRC) will be funded with a total of 10.3 million euros for the next four years.

Molecular chirality – the fact that a molecule’s left- and right-handed versions share almost all of their physical properties but differ dramatically in their chemical and biological behavior – poses intellectual challenges across the natural sciences and is relevant to the building blocks of life, playing a vital role in medicine and health. The Collaborative Research Centre (CRC) 1319 ELCH started on January 1, 2018 at the University of Kassel and three other research locations in Germany, the Goethe-University in Frankfurt am Main, the Philipps-University in Marburg and the Deutsche Elektronen-Synchrotron DESY in Hamburg. Two years later, the consortium was expanded to include Freie Universität Berlin. We focused on a very fundamental aspect of chirality. With ELCH, a research center targeting a microscopic and quantum mechanical understanding of chiral molecules in the gas phase has been established. The most advanced tools of experimental and theoretical atomic and molecular physics, and quantum optics (AMO) are used to control and drive chirality at a single-molecule level. Using electromagnetic radiation, we address the entire molecular system consisting of electrons and nuclei and provide a unique light-driven gas-phase laboratory for chiral molecular physics.

In funding periods 1 and 2, our continuously increasing number of internal collaborations has resulted in important progress towards the original four long-term goals: (i) Combination of partial Coulomb explosion with PECD is a breakthrough towards the determination of absolute configuration, allowing to target larger molecules and to correlate PECD with the molecule’s configuration. (ii) A high-resolution laser-based method has been realized as part of a set of advanced instruments for the determination of enantiomeric excess which applies to mixtures and conformers. (iii) Enantiomer-selective excitation of a racemate is a key to chiral purification, and a seminal experimental demonstration combined with theory took a big step toward complete selectivity. (iv) The demonstration of laser spectroscopy of short-lived radioactive molecules and the large increase in spectral resolution opens new perspectives for fundamental physics experiments since parity-violating interactions in chiral molecules increase steeply in strength with the atomic number.

In preparing for the third funding period, we have paved the way for the next generation by welcoming seven new PIs, most of whom are in the early stages of their careers, to the consortium. After a very successful on-site evaluation in June 2025, the DFG senate decided to grant a third and last funding period, offering us four more years of research.

With new project leads, we will now extend the investigations to molecules in defined environments, where new chirality-sensitive observables are expected and where the modifications of observables by environments are addressed. We are in the unique position to compare results on individual molecules with results on the same molecules embedded in an environment. Altogether, there will be 19 investigators from 14 research groups hosting 18 scientific research projects and one administration project in the third funding period starting from 01.01.2026. Nine groups will be carrying out research at the University of Kassel.

Group picture of the SFB-ELCH members.

Further Information

https://goto.uni-kassel.de/go/sfb-elch

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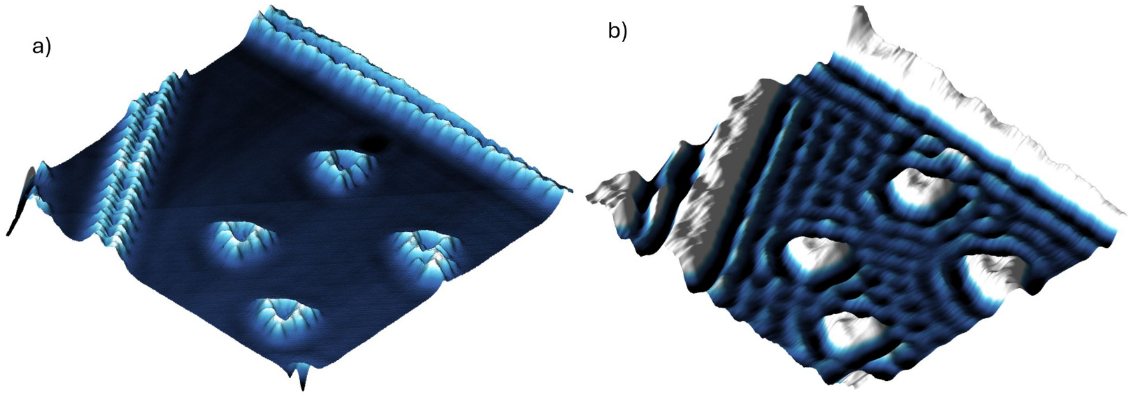
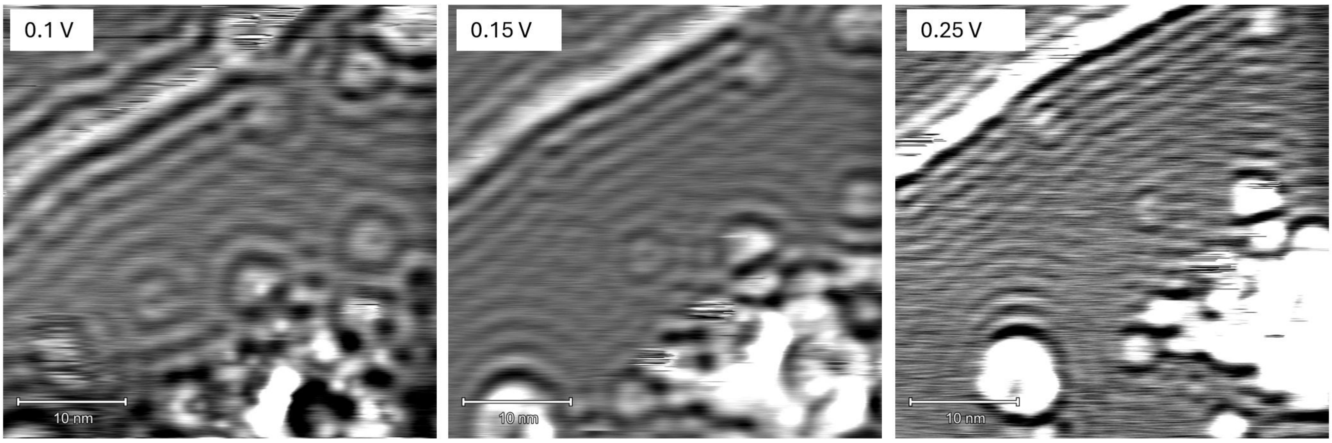
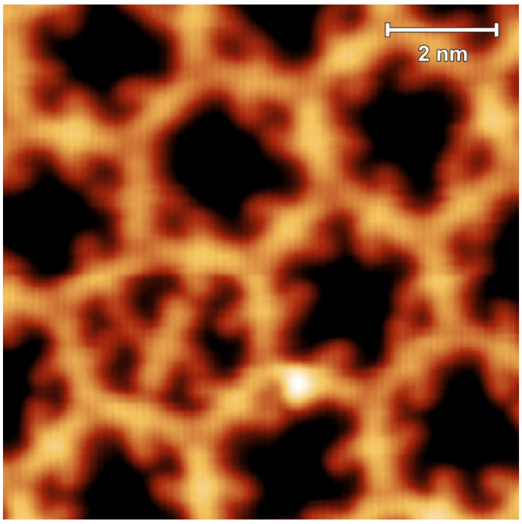
Nano Arts



STM topography of 1D and 0D self-assembled molecular nanostructures on Ag(111) and (b) the Interference pattern of the 2D electron gas of the Ag(111) surface state scattered from the nanostructures (images taken by Jannik Sauerland and Nico Kubetschek, AG Matzdorf).



Wave nature of electrons visualized by mapping the local density of states of an Ag(111) surface with defects (image taken by Jana Dietrich and Nico Kubetschek, AG Matzdorf)



2D-metal organic framework with a guest molecule (image taken by Jana Dietrich and Nico Kubetschek, AG Matzdorf).

Announcements

CINSaT Alumni Database

CINSaT has launched an alumni database to stay in touch with former members of CINSaT-related research groups.

For more than 20 years, young researchers in CINSaT groups have worked toward earning their diplomas or PhDs. We previously reported on a meeting of the first cohort of nanoscience students, which showed that many former students are now well-established members of the scientific community, both in academia and in industry. This initial impression now needs to be substantiated, which is why we have created the alumni database.

Through this database, former students and group members can enter their contact information to remain connected with CINSaT.

We therefore ask all members of CINSaT and CINSaT research groups to forward this information to any graduates of CINSaT research groups at the University of Kassel whom they know. Please share this information.

uni-kassel.de/forschung/cinsat/alumnidatenbank.html

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