O 34: Poster Tuesday: Scanning Probe Techniques 2

Time: Tuesday 11:00–13:00 Location: P3

O 34.1 Tue 11:00 P3

Implementation of a Scanning Tunneling Microscope for Measurements in Electrochemical Environment — •Fabian Schröfel, Matthias Greve, Karsten Tarhouni, and Olaf Magnussen — Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany

The atomic-scale understanding of processes at the interface between solid electrodes and liquid electrolytes is of high importance for electrochemical energy storage and conversion. Electrochemical scanning tunneling microscopy (ECSTM) is a key technique for the investigation of such interfaces. Operating an STM in an electrochemical environment requires special measures, as the potentials of both STM tip and sample need to be controlled and electrochemical currents at the tip need to be kept way below the tunneling current.

Here, we report details on a new ECSTM built in our group. It consists of a newly developed STM head that is optimized for studies in electrochemical environment, high scanning frequencies, and low thermal drift. The instrument is based on a commercial SPECS Nanonis STM controller that we equipped with a custom-build bipotentiostat and coarse-approach. A suitable control software for electrochemical studies, which we integrated into the Nanonis software, allows to perform cyclic voltammetry parallel and separate from the STM measurements. Characterization of the mechanical stability of the STM and first STM images and electrochemical data will be presented.

O 34.2 Tue 11:00 P3

Determining the phase transfer function of an STM for coherent spin operations — •Evert Stolte — TU Delft

Coherent control of single spin transitions in atoms on a surface has been achieved with electron spin resonance scanning tunnelling microscopy (ESR-STM).[1] Extending that control to a series of sequential gates on different transitions and developing more complex gates requires radio frequency (RF) pulses at different frequencies with controlled relative amplitudes and phases, which are both affected by the transfer function of the power line to the tunnel junction. While the amplitude transfer function can be determined through a well-described rectification procedure [2], characterizing the phase transfer function remains challenging. Straightforward transmission or reflection measurements are excluded as it is not possible to separate phase rotations incurred on the way into the STM from those happening on the outward journey.

Here we report on the development of an in-situ method to determine the phase transfer function at radio frequencies that can be readily implemented to standard ESR-STM setups. The method is based on the envelope detection of the beat signal that is generated by adding two continuous wave RF signals separated by an audio frequency. The effectivity of the procedure is tested through pump-probe autocorrelation measurements with square pulses, which should show a reduced minimum width if the phase correction is successful.

[1] Yang, K. (2019). Science, 366(6464), 509-512.
[2] Paul, W. (2016). Review of Scientific Instruments, 87(7).

O 34.3 Tue 11:00 P3

Performance of an electrically driven q-plus sensor in a commercial Joule Thomson STM — •Hester Vennema, Laëtitia Farinacci, and Sander Otte — Delft University of Technology, Delft, The Netherlands

The q-plus sensor is a wide-spread tool for performing combined STM-AFM measurements in ultra-high vacuum at cryogenic temperatures. Here, we implement the use of q-plus sensors in a JT-STM. Contrary to other set-ups in which q-plus sensors are used, we do not drive our sensor mechanically, via an excitation of the Z-piezo, but electrically, with the excitation signal directly sent to the tuning fork.

In order to characterize the performance of our homemade q-plus sensors we develop a set-up to test their response to an electrical drive in ambient conditions. Following M. Lee et al. [1], we can disentangle the mechanical and electrical response of the sensors to the driving signal. After transfer into the JT-STM, we demonstrate the possibility to use electrically driven q-plus sensors for combined STM-AFM measurements: with a Q factor around 20000 we can control the amplitude of the oscillation to be as low as 70 pm. Our first principle measurements are performed on a CuCl2/Cu(100) surface [2]. We investigate with local contact potential difference measurements the local change of work function that leads to the confinement of field emission resonances above such vacancy patches.

[1] M. Lee et al., Appl. Phys. Lett. 91, 023117 (2007)
[2] R. Rejali et al., arXiv:2204.10559 (2022)

O 34.4 Tue 11:00 P3

Development of a compact millikelvin STM for single spin resonance — •Daria Sostina[1], David Collomb[2], Wantong Huang[2], Mate Stark[2], Christoph Sürgers[2], Philip Willke[2], and Wolfgang Wernsdorfer[2] — [1]Institute for Quantum Materials and Technologies (IQMT), Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Physikalisches Institut (PHI), Karlsruhe Institute of Technology, Karlsruhe, Germany

In the last decade detection and manipulation of spins at the atomic scale has been achieved by combining techniques like electron spin resonance (ESR) with scanning tunneling microscopy (STM) [S. Baumann et al., Science 350 (6259), 417-420 (2015)]. However crucial properties of potential quantum spins such as the spin relaxation time T1 and the phase coherence time T2 remain short. Both T1 and T2 are affected by the proximity to the tip and substrate, which provide thermally excited electrons [P. Willke et al., Science Advances 4(2), 1543 (2018)]. A potential solution lies in lowering the temperatures utilizing dilution refrigerators (DR). Here, we present the design and implementation of a unique DR-STM optimized for ESR reaching millikelvin temperatures. Since the ground state population scales with the resonance frequency, better RF transmission at high frequencies is also desired for ESR-STM. In the compact dilution fridge, the RF line is optimized by a short total length of cables as well as using high-frequency cabling up until the tip. As a result, we believe that our compact DR-STM will help to improve ESR-STM paving the way for quantum information processing using single spin centers on surfaces.

O 34.5 Tue 11:00 P3

Design of a high-stability miniaturized scanning tunneling microscope for small-bore cryostats — •Felix Huber, Stephan Spieker, and Sebastian Loth — University of Stuttgart, Institute for Functional Matter and Quantum Technologies, Stuttgart, Germany

Low-temperature scanning tunneling microscopy (STM) setups are typically housed in large cryostats and require proportionally large vacuum chambers, as well as extensively shielded custom-built laboratories to reach the signal-to-noise ratios (SNR) desired for cutting-edge reasearch. Yet, by miniaturizing the STM-head, the SNR can be significantly improved, due to the favorable scaling of resonance frequencies [1], thermal characteristics and the cryostat hold time. The STM design presented here, is optimized to work in noisy environments, provides optical access to the tunnel junction, and can be used in a standard-bore cryogenic dewar due to its small volume and dimensions [2]. This design could be used for experiments requiring long averaging times, and may serve as an easy upgrade to existing room-temperature setups.

[1] C.R. Ast, et al. Rev. Sci. Instrum. 79, 093704 (2008).
[2] R. Schlegel, et al. Rev. Sci. Instrum. 85, 013706 (2014).

O 34.6 Tue 11:00 P3

Functionalized Tips in low-temperature AFM/STM - Fabrication and Application — •Lorenz Brill, Marco Grünewald, Roman Forker und Torsten Fritz — Friedrich-Schiller-Universität, Jena, Germany

AFM with functionalized tips has been an emergent and fast growing field in the last couple of years. The chemical passivation of the metal tip achieved via functionalization allows for images with atomic or intramolecular resolution to be recorded.

In our contribution, we detail the fabrication of CO-functionalized tips with a commercial low-temperature STM/AFM by Specs Surface Nano Analysis GmbH and demonstrate atomic resolution on a Cu(111)-surface. Furthermore, we show structure elucidation of organic molecular islands on the Cu(111)-substrate via atomic resolution images.

This technique shows great promise for further investigations, especially in areas not accessible via conventional STM, e.g. detailed structure analysis of 1,4-benzoquinone on metal substrates.

O 34.7 Tue 11:00 P3

Inspecting non-linearities in scanning force microscopy — •Lukas Böttcher[1], Anna Dittus[2], Jens Starke[2], Ingo Barke[1], and Sylvia Speller[1] — [1]Institute of Physics, University of Rostock — [2]Institute of Mathematics, University of Rostock

In dynamic force microscopy bistable states are often encountered. This includes two stable states at small and large amplitude flanking one unstable state at intermediate amplitude, separating two attracting regions. Our aim is to investigate the behavior of oscillating cantilevers in dynamic force microscopy [1,2]. We acquired distance dependent frequency sweeps of amplitude and phase. From this we determined saddle-node branches with cusps and compare the behavior with simulations.

[1] A.C. Boccara et al., Applied Physics Letters 58 (1991).
[2] Robert W. Stark, Materials Today 13 (2010)

O 34.8 Tue 11:00 P3

Setup for laser-based time-resolved momentum microscopy — •Felix Passlack, Stefano Ponzoni, Giovanni Zamborlini, and Mirko Cinchetti — Department of Physics, TU Dortmund University, Otto-Hahn-Straße 4, Dortmund, Germany

In this work, we characterize the performance of a recently installed time-resolved angular-resolved photoemission spectroscopy (trARPES) system. trARPES is performed by coupling an optical beamline for pump-probe spectroscopy[1] to a state-of-the-art momentum-microscopy photoemission spectrometer (KREIOS MM, SPECS GmbH). This allows for an almost continuous tunability of the pump photon energy between $0.5eV$ and $3.8eV$ while capturing the full photoemission horizon of the $6eV$ probe. The performance of the system is characterized through a set of measurements on the topological insulator Bi_2Se_3, for which both the static electronic structure and the out of equilibrium electron dynamics are already extensively studied in literature following the evolution of the electronic structure with an energy resolution in the order of $50meV$, a momentum resolution of $0.005A^{-1}$and a time resolution below $500fs$ throughout the whole photoemission horizon. In particular, thanks to the ultimate angular acceptance of the photoemission microscope, we are able to track the dispersion of the photoexcited states in Bi_2Se_3 up to $\pm 0.48A^{-1}$ and $1eV$ above the Dirac point, beyond the practical limitations of conventional high-resolution ARPES spectroscopy with $6eV$ photons.

[1] F. Mertens et al., Review of Scientific Instruments **91** (2020)

O 34.9 Tue 11:00 P3

Development and characterization of a Herriott-type multipass cell compression-setup for fs-pulses and variable repetition rates — •Lasse Sternemann[1], Karl Schiller[1], Alan Omar[2], Matija Stupar[1], Mirko Cinchetti[1], and Clara Saraceno[2] — [1]Department of Physics, TU Dortmund University, Otto-Hahn-Straße 4, 44227 Dortmund, Germany — [2]Ruhr-Universitaet Bochum, Germany

We present developement and characterization of a Herriott-style multipass cell aimed at achieving ultrashort pulses with high peak power. The setup is used as a driving laser for a high repetition rate HHG (High Harmonic Generation) source for time-resolved momentum microscopy.

The setup compresses the pulses generated by a commercial Ytterbium-based laser (Carbide, Light Conversion) with an average power of 50 W and a variable repetition rate between 100 kHz and 1 MHz. The pulses are first spectrally broadened by self-phase-modulation by passing through a non-linear $\chi^{(3)}$ medium multiple times. Then, a pair of negative group-dispersion-delay coated mirrors compress the pulse by dispersion correction. By moving the non-linear medium within the mulitpass cell we were able to compress the pulses from 242 fs to around 45 fs for different high repetition rates while keeping a transmission of over 90 % and peak powers between 1 GW and 2 GW [1].

[1] A. Omar, et al. *Advanced Solid State Lasers*, OSA Technical Digest (Optical Society of America, 2021), paper JM3A.55

O 34.10 Tue 11:00 P3

Multispectral time-resolved energy-momentum microscopy using high-harmonic extreme ultraviolet radiation — •Nils Wind[1,2], Michael Heber[3], Dmytro Kutnyakhov[3], Federico Pressacco[3], and Kai Rossnagel[2,4] — [1]Institut für Experimentalphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]Ruprecht-Haensel-Labor, Deutsches Elektronen-Synchrotron DESY, 22607 Hamburg, Germany — [3]Deutsches Elektronen-Synchrotron DESY, 22607 Hamburg, Germany — [4]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany

A 790-nm-driven high-harmonic generation source with a repetition rate of 6 kHz is combined with a toroidal-grating monochromator and a high-detection-efficiency photoelectron time-of-flight momentum microscope to enable time- and momentum-resolved photoemission spectroscopy over a spectral range of 23.6–45.5 eV with sub-100-fs time resolution. Three-dimensional (3D) Fermi surface mapping is demonstrated on graphene-covered Ir(111) with energy and momentum resolutions of $\lesssim$100 meV and $\lesssim$0.1 Å^{-1}, respectively. The table-top experiment sets the stage for measuring the k_z-dependent ultrafast dynamics of 3D electronic structure, including band structure, Fermi surface, and carrier dynamics in 3D materials as well as 3D orbital dynamics in molecular layers.