O 28: Poster Session - Scanning Probe techniques: Method Development

Time: Monday 18:15–20:00 Location: P1A

O 28.1 Mon 18:15 P1A

Understanding lateral force microscopy data of organic molecules — •Elisabeth Riegel, Oliver Gretz, Alfred J. Weymouth, and Franz J. Giessibl — Universität Regensburg, Regensburg, Germany

Frequency-modulation lateral force microscopy (LFM) is a variant of the highly-successful frequency-modulation atomic force microscopy in which the direction of the tip oscillation is along the surface. In this geometry, the setup is not sensitive to long-range background forces in the direction of the surface normal, but only to the short-range interactions. To achieve high spatial resolution, we oscillate our tip at sub-Angstrom amplitudes. We applied this technique to study islands of PTCDA on Cu(111). On Cu(111), PTCDA forms roughly a herringbone pattern. In this contribution, we discuss the interpretation and understanding of the frequency shift and dissipation data with a model of the tip-sample interaction including CO bending.

O 28.2 Mon 18:15 P1A

Probing relaxations of atomic-scale junctions in the Pauli repulsion range — Jonathan Brand, •Nicolas Néel, and Jörg Kröger — Institut für Physik, Technische Universität Ilmenau, D-98693 Ilmenau, Germany

Clean metal as well as C_{60}-terminated tips of an atomic force microscope probe the interaction with C_{60} molecules adsorbed on Cu(111) and Pb(111). The force measurements unveil a monotonic shift of the point of maximum attraction with the bias voltage. The conventional superposition of long-range van der Waals and electrostatic forces with short-range Pauli repulsion does not reproduce the shift. By phenomenologically including bias-dependent relaxations of the electrode geometry in the analytical expression for the short-range force the experimental data can qualitatively be described.

O 28.3 Mon 18:15 P1A

Fast low-noise transimpedance amplifier for scanning tunneling microscopy — Martin Štubian[1,2], Juraj Bobek[1,2], Martin Setvin[1], and •Michael Schmid[1] — [1]Institute of Applied Physics, TU Wien, Austria — [2]Brno University of Technology, Brno, CZ

Scanning tunneling microscopy is one of the most versatile techniques in surface physics. One of the factors limiting its performance is the bandwidth and noise of the preamplifier. Higher bandwidth enables faster scanning, and also implies low phase shifts, which reduces the susceptibility to feedback loop oscillations. STM preamplifiers are current-voltage converters (transimpedance amplifiers, TIAs), usually with a high feedback resistor. Increasing its resistance leads to lower current noise (Johnson noise of the resistor), but at the same time usually results in lower bandwidth. Using a multi-stage amplifier design, we could achieve an input noise of $\approx 5\,\mathrm{fA}/\sqrt{\mathrm{Hz}}$ at room temperature and low frequencies, but nevertheless a large bandwidth of 50–200 kHz and large dynamic range (sub-pA to 50 nA). We also demonstrate that minimizing the input capacitance is of paramount importance for low noise. This means that connecting the STM tip to the preamplifier via a long coaxial cable is unfavorable, and the performance can be substantially improved by placing the first amplifier stage into vacuum. Additionally, for low-temperature STMs, the Johnson noise is reduced by placing the feedback resistor in thermal contact with the cryostat. We also discuss a source of noise in operational amplifiers usually not considered, but important for TIAs.

O 28.4 Mon 18:15 P1A

Simultaneous length extensional- and flexural operation of a qPlus sensor for biaxial force detection. — •Jinglan Qiu[1,2], Dominik Kirpal[1], and Franz J. Giessibl[1] — [1]University of Regensburg, Germany — [2]Hebei Normal University, Shijiazhuang, China

In dynamic atomic force microscopy, the tip of the cantilever usually is oscillating in the z-direction perpendicular to the surface. By adding a second oscillation in the x-direction, parallel to the surface, lateral forces can be directly investigated. In the case of a silicon cantilever this can be realized by using a torsional mode [1]. In the case of the qPlus sensor, the length extensional mode (LE-mode) can be used, analogous to a needle sensor. However, this requires an adjustment of the electrode configuration. We have prepared a qPlus sensor for the length extensional mode, characterized the properties of the mode and showed the capability of atomic resolution in both, the LE-mode and the lateral 1st flexural mode.

[1] O. Pfeiffer, R. Bennewitz, A. Baratoff, E. Meyer, P. Grütter, Phys. Rev. B, 65, 161403 (2002).

O 28.5 Mon 18:15 P1A

Setup of a THz-STM for pump-probe experiments using a commercial THz-source — •Philip Kapitza, Hüseyin Azazoglu, and Rolf Möller — Fakultät für Physik/Cenide, Universität Duisburg-Essen, Germany

To study the excitations of single atoms or molecules on their intrinsic timescales ultrafast temporal and atomic-scale spatial resolution is essential. This can be achieved by combining the very high spatial resolution of a scanning tunneling microscope (STM) with picosecond duration terahertz (THz) pulses. When coupled to the tip of a STM the THz pulses can modulate the bias voltage in the tunneling junction [1,2,3]. The setup presented on this poster consists of a homebuilt low-temperature STM (LT-STM) and a commercial THz-pulse source for time domain spectroscopy (THz-TDS). The THz-emitter of this THz-TDS system is a photoconducting antenna irradiated by a fs-IR laser. For pump-probe experiments using the THz-pulses two THz-emitters will be used with both terahertz beams focused onto the tip. The time delay between the pump and the probe pulse will be created by splitting the beam of the fs-IR laser with one part of the beam going through an optical delay line.

[1] Cocker, T. L. et al., Nat. Photon. 7, 620-625 (2013).
[2] Cocker, T. L. et al., Nature 539, 263-267 (2016).
[3] Yoshioka, K. et al., Nat. Photon. 10, 762-765 (2016).

O 28.6 Mon 18:15 P1A

Atom manipulation capabilities of MnNi Tips in STM — •Nicolaj Betz[1], Max Hanze[1,2], Luigi Malavolty[1,2], Fabian D. Natterer[3], Susanne Baumann[1], and Sebastian Loth[1,2] — [1]University of Stuttgart, Institute for Functional Matter and Quantum Technologies, Stuttgart, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany. — [3]University of Zurich, CH-8057 Zurich, Switzerland.

Scanning tunneling microscopy (STM) with spin-polarized tips can combine the ability to manipulate individual atoms with the ability to gain fundamental insights into magnetic interactions via the spin-sensitivity in the current [1]. In this work, we investigate the performance and the manipulation capabilities of antiferromagnetic MnNi tips. Antiferromagnetic tips are promising candidates for spin-polarized STM because of their robust microscopic magnetization, that defines spin contrast, and their small stray field, which reduces perturbations on the probed magnetic structures. We etch our tips using a HCl solution [2] and characterize them with scanning electron microscopy. The tips require intense in-vacuum cleaning. We find that self-sputtering using field emission in an Ar atmosphere yields clean and sharp tips. We perform STM measurements at different magnetic fields on Cobalt islands evaporated on Au(111). And we investigate the atom manipulation capabilities by dropping individual atoms from the tip.

[1] Toskovic, R. et al., Nature Phys 12, 656-660 (2016)
[4] Forrester et al., Rev. Sci. Instrum. 89, 123706 (2018)

O 28.7 Mon 18:15 P1A

Design of low temperature ESR-STM — •Denis Krylov, Won-jun Jang, Yujeong Bae, and Andreas J. Heinrich — Center for Quantum Nanoscience, Institute for Basic Science, Seoul, Republic of Korea

A combination of electron spin resonance (ESR) and scanning tunneling microscopy (STM) enables a time-domain control over electron and nuclear spins with atomic-scale resolution. This technique provides a great potential for chemical structure analysis, quantum coherent manipulation and quantum sensing. The critical points of the ESR-STM system design are low loss RF wiring with sufficient coupling to the cooling stage and a vibration free environment.

We report about the progress in developing of the home-built system with two-dimensional vector magnetic field and sub Kelvin temperatures.

O 28.8 Mon 18:15 P1A

How to Resolve Dynamic Surface Processes by High-Speed Scanning Tunneling Microscopy — •Zechao Yang, Leonard Gura, Jens Hartmann, Heinz Junkes, William Kirstädter, Patrik Marschalik, Markus Heyde, and Hans-Joachim Freund — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

Here we present the concept of a new high-speed scanning tunneling microscope (STM) for resolving dynamic processes in amorphous network structures at the atomic scale.

The design of the microscope body is compact, rigid, and highly symmetric to ensure vibrational stability and low drift characteristics. The scanner unit in this microscope consists of two independent tube piezos for slow and fast scanning, respectively. A commercial scanning probe microscopy (SPM) controller is used for the slow scanner unit, while a high-speed Versa Module Eurocard bus (VMEbus) system controls the fast scanning. The data acquisition of the tunneling signal, x-, y-, and z-position is realized by a high-speed digitizer. Scan control and data acquisition has been programmed in an EPICS framework.

Another important feature in our approach is the implementation of a spiral scan option for avoiding internal resonance frequencies of the microscope body. The tip scans in a quasi-constant height mode, where the logarithm of the tunneling current signal can be regarded as roughly proportional to the surface topography.

In first test measurements at room temperature, diffusion processes within an O(2x2) coverage on Ru(0001) have been atomically resolved with a time resolution of 25 milliseconds per frame.

O 28.9 Mon 18:15 P1A

Design of a high-stability miniaturized STM — •Felix Huber[1], Stephan Spieker[1], and Sebastian Loth[1,2] — [1]University of Stuttgart, Institute for Functional Matter and Quantum Technologies, Stuttgart, Germany. — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany.

State-of-the-art low-temperature scanning tunneling microscopy setups are typically housed in large cryostats, require proportionally large vacuum chambers, as well as extensively shielded custom built laboratories to reach the signal-to-noise ratios (SNR) required for cutting-edge experiments. However, by miniaturizing the STM-head, the SNR can be significantly improved, due to the favorable scaling of resonant frequency [1], thermal characteristics, and measurement time. The STM design presented here is optimized to work in noisy environments, and due to its small volume and dimensions can be used in a standard bore cryogenic dewar [2]. The setup is designed for long hold times, as well as for a short turn-around, allowing for rapid sample preparation and characterization. This design could be used for extended averaging experiments, or it could be utilized as an easy upgrade to existing UHV setups.

[1] Ast, C. R., Assig, M., Ast, A. & Kern, K. Design criteria for scanning tunneling microscopes to reduce the response to external mechanical disturbances. Rev. Sci. Instrum. 79, 093704 (2008).

[2] Schlegel, R. et al. Design and properties of a cryogenic dip-stick scanning tunneling microscope with capacitive coarse approach control. Review of Scientific Instruments 85, 013706 (2014).

O 28.10 Mon 18:15 P1A

Single-atom electron paramagnetic resonance in a scanning tunneling microscope driven by a radiofrequency antenna at 4K — •Stepan Kovarik, Tom S. Seifert, Corneliu Nistor, Luca Persichetti, Sebastian Stepanow, and Pietro Gambardella — Department of Materials, ETH Zurich, Switzerland

Combining electron paramagnetic resonance (EPR) with scanning tunneling microscopy (STM) enables detailed insight into the interactions and magnetic properties of single atoms on surfaces [1]. A requirement for EPR-STM is the efficient coupling of microwave excitations to the tunnel junction. Here, we present a coupling efficiency of the order of unity by using a radiofrequency antenna placed parallel to the STM tip, which we interpret using a simple capacitive-coupling model [2]. We further demonstrate the possibility to perform EPR-STM routinely above 4 K using amplitude as well as frequency modulation of the radiofrequency excitation. We directly compare different acquisition modes on hydrogenated Ti atoms on bilayer MgO on Ag and highlight the advantages of frequency and magnetic field sweeps as well as amplitude and frequency modulation in order to maximize the EPR signal. The possibility to tune the microwave-excitation scheme and to perform EPR-STM at relatively high temperature and high power opens this technique to a broad range of experiments.

[1] S. Baumann *et al.*, *Science* **350**, 417 (2015)
[2] T. S. Seifert *et al.*, arXiv:1908.03379 (2019)

O 28.11 Mon 18:15 P1A

Control of broadband THz near fields in an STM junction — •Natalia Martín Sabanés[1,2], Sarojini Mahajan[1], Martin Wolf[1], and Melanie Müller[1] — [1]Fritz Haber Institute, Berlin, Germany — [2]Freie Universität Berlin, Berlin, Germany

In THz-gated Scanning Tunneling Microscopy (THz-STM),[1] the electric field of a single-cycle THz pulse acts as a transient bias modulating the STM-junction, enabling control of the tunneling current on femtosecond time scales. Optimal operation of a THz-STM requires exact knowledge and precise control of the THz near field waveform. In this regard, we demonstrate THz near field sampling via THz-induced modulation of ultrafast photocurrents in a metal-metal junction,[2] and characterize in detail the coupling of broadband (1-30 THz) single-cycle THz pulses generated from a spintronic emitter to the STM tip. Specifically, we show that employing NIR laser pulses with a curved wavefront for THz generation allows for precise control of the phase, amplitude and bandwidth of the THz near field. Depending on the excitation conditions, THz near fields with frequencies up to 10 THz and peak voltages of several volts (up to 4 V) can be achieved at 1 MHz repetition rate. We further discuss the influence of non-instantaneous effects such as THz-streaking, space charge dynamics and hot carriers in the metals on the bandwidth and shape of the measured near field waveforms, and define operation regimes for reliable near field characterization. References: [1] Cocker T., el at, Nature 539, 263-267 (2016); [2] Yoshida S., et al, ACS Phot. 6, 1356-1364 (2019)