O 91: Poster Session VII: Scanning probe techniques: Method development II

Time: Thursday 10:30–12:30 Location: P

O 91.1 Thu 10:30 P

Fast low-noise transimpedance amplifier for scanning tunneling microscopy — Martin Štubian[1], Juraj Bobek[1,2], Martin Setvin[1,3], Ulrike Diebold[1], and •Michael Schmid[1] — [1]Institute of Applied Physics, TU Wien, Austria — [2]Brno University of Technology, Brno, CZ — [3]Charles University, Praha, 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 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 up to 200 kHz and large dynamic range (<0.1 pA to 50 nA). For low noise, it is important to minimize the input capacitance. Connecting the STM tip to the preamplifier via a long coaxial cable should be avoided, 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.

[1] M. Štubian et al., Rev. Sci. Instrum. 91, 074701 (2020).

O 91.2 Thu 10:30 P

Theoretical models for KPFM with flexible tip apexes — •Ondrej Krejci[1] and Adam S. Foster[1,2,3] — [1]Department of Applied Physics, Aalto University, FI-00076 Aalto, Finland — [2]Graduate School Materials Science in Mainz, Staudinger Weg 9, 55128, Germany — [3]WPI-NanoLSI, Kanazawa University, Kakuma-machi, Kanazawa 920-1192, Japan

Kelvin Probe Force Microscopy (KPFM) started as a technique with the possibility to determine areas of a sample with different work functions [1], but as lateral resolution moved towards (sub)angstrom precision, it found its place also in identifying differently charged parts of molecules (e.g. [2]). This ability was in specific cases used in KPFM to obtain chemical resolution using SPM [3,4,5]. On the other hand, the exact interpretation of KPFM data with flexible tip apices (e.g. CO-tip) remains unknown. In this work, we will summarise up-to-date knowledge about KPFM [1,4,6] focusing mainly on measurements with FM-AFM/STM. Based upon this, we will present a new model for electrostatic field, which is describing the experiments with CO-metal tips [5] and metal substrates. This new electrostatic model is applied in a DFT calculations simulating the full tip-sample system. These calculations will be compared with simple mechanistic models capturing various sources of achieved signal. With this, we aim to recover the physics behind KPFM with flexible tip apices.

Ref: [1] APL 58, 2921 (1991). [2] Nat. Nanotechnol. 7, 227-231 (2012). [3] Nano Lett. 14, 3342-3346 (2014) [4] PRB, 90, 155455 (2014). [5] ACS Nano 12, 5274-5283 (2018) [6] PRB 86, 075407 (2012).

O 91.3 Thu 10:30 P

Radio-frequency transmission to the junction of a scanning tunneling microscope — •Nafise Kalantari, Thomas Jürgens, Rene Woltmann, Manuel Gruber, Alexander Weismann, and Richard Berndt — Institut fur Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany

Electron spin resonance scanning tunneling microscopy (ESR-STM), as implemented by Baumann et al. [1], requires the application of a constant-amplitude radio frequency (RF) voltage at the tunnel junction over a wide range of frequencies. To achieve constant amplitude the RF input power is adjusted to compensate for frequency dependent variations of the cable transmission. This approach relies on a precise determination of the RF transmission function. Here, we discuss the upgrade of a low-temperature STM with high-frequency cables and a superconducting magnet. In particular, we present the RF transmission achieved with 40 dB attenuation at maximum.

[1] S. Baumann, W. Paul, T. Choi, C. P. Lutz, A. Ardavan, A. J. Heinrich, Science 350, 417-420 (2015).

O 91.4 Thu 10:30 P

Single Asperity Sliding Friction across the Superconducting Phase Transition — •Wen Wang[1,2], Dirk Dietzel[1], and Andre Schirmeisen[1] — [1]Institute of Applied Physics, University of Giessen, 35392 Giessen, Germany — [2]School of Mechanical Engineering, Southwest Jiaotong University, 610031 Chengdu, China

In sliding friction, different energy dissipation channels have been proposed, including phonon and electron systems, plastic deformation, and crack formation. However, the details of how energy is coupled into these channels is heavily debated, and especially the relevance of the electron system for energy dissipation often remains elusive. Here, we present contact mode AFM friction experiments of a single asperity sliding on a high-T_C BSCCO-superconductor in a wide temperature range from 40 K to 300 K [1]. Overall, friction decreases with temperature as expected based on thermally activated friction models, but we find an unexpected large peak around T_C of 95 K. We model these results by a superposition of different energy dissipation channels, where the influence of electronic contributions vanishes when cooling below the superconducting phase transition temperature. Our experiments thereby unambiguously link electronic friction effects to the number of normal state electrons in the superconducting phase below T_C, allowing us to quantify the relative importance of the electron system to overall friction.

[1] W. Wang, D. Dietzel, A. Schirmeisen, Science Advances, eaay0165 (2020)

O 91.5 Thu 10:30 P

Microwave-assisted tunnelling and interference effects in superconducting junctions under fast driving signals — •Robert Drost[1], Pitor Kot[1], Maximilian Uhl[1], Juan Carlos Cuevas[2], Joachim Ankerhold[3], and Christian R. Ast[1] — [1]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany — [2]Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, 28049 Madrid, Spain — [3]Institut für Komplexe Quantensysteme and IQST, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany

As scanning tunnelling microscopy is pushed towards fast local dynamics, a quantitative understanding of tunnel junctions under the influence of a fast AC driving signal is required, especially at the ultra-low temperatures relevant to spin dynamics and correlated electron states. We subject a superconductor-insulator-superconductor junction to a microwave signal from an antenna mounted in situ and examine the DC response of the contact to this driving signal. Basic quasi-particle tunnelling can be interpreted using a modified density of states in the electrodes. The situation is more complex when it comes to higher order effects such as multiple Andreev reflections. Microwave assisted tunnelling unravel these complex processes, providing deeper insights into tunnelling than are available in a pure DC measurement.

O 91.6 Thu 10:30 P

Development of a Variable-Temperature High-Speed Scanning Tunneling Microscope — •Zechao Yang, Leonard Gura, Jens Hartmann, Heinz Junkes, Florian Kalass, Matthias Brinker, William Kirstaedter, Markus Heyde, and Hans-Joachim Freund — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

To understand the crystalline to vitreous transition in oxide films as a function of temperature in real space and at real time, we developed a variable-temperature high-speed scanning tunneling microscope.

The scanner consists of two independent tube piezos for slow and fast scanning, respectively. For fast scans, we use spiral geometries to avoid image distortions. The spiral geometry and the tip velocity are adjustable.

The STM tip scans in quasi-constant height mode with a predefined tilt correction. The surface topography can then be deduced from the logarithm of the tunneling current. We implemented the scan control into the EPICS framework [1] and developed highly customizable, purely python based software for the image analysis.

With these tools, we atomically resolved diffusion processes within an O(2x2) structure on Ru(0001) with a time resolution of 25 milliseconds per frame. The measurements prove the vibrational stability and low thermal drift characteristics of our microscope.

For future high temperature measurements we will use a continuous flow cryostat to counter-cool the piezo material of the scanner.

[1] Junkes, H. et al. (2018). ICALEPCS2017, pp. 1762-1766.

O 91.7 Thu 10:30 P

Combined AFM and STM with high optical access achieving atomic resolution in ambient conditions — •Korbinian Pürckhauer, Simon Maier, Anja Merkel, Dominik Kirpal, and Franz J. Giessibl — University of Regensburg, Regensburg, Germany

Performing atomic force microscopy (AFM) and scanning tunneling microscopy (STM) with atomic resolution under ambient conditions is challenging due to enhanced noise and thermal drift. We show the design of a compact combined atomic force and scanning tunneling microscope that uses qPlus sensors and discuss the stability and thermal drift. By using a material with a low thermal expansion coefficient, we can perform constant height measurements and achieve atomic resolution in both AFM and STM on various samples. Moreover, the design allows a wide angle optical access to the sensor and the sample that is of interest for combining with optical microscopes or focusing optics with a high numerical aperture.

[1] Pürckhauer et al., Rev. Sci. Instrum. 91, 083701 (2020)