O 72: Poster Wednesday: Scanning Probe Techniques

Time: Wednesday 17:45–20:00 Location: Poster B2

O 72.1 Wed 17:45 Poster B2

The Use of Spherical Particles for Cantilevers in an Atomic Force Microscope — •Katja Stommel, Hsiao-Ching Tsai, and Mathias Getzlaff — Institut für Angewandte Physik, Heinrich-Heine Universität Düsseldorf, Germany

The elasticity of cells is an important property and mainly influenced by the cell's cytoskeleton. With an AFM it is possible to measure the elasticity of soft materials. It is necessary to use a probe tip with a known, well-defined shape to determine the Young Modulus of, e.g., cells using the Hertz model. Hence, the goal of this project is to test and document a reproducible method of attaching a spherical particle to a cantilever.

A combined system including an AFM and a transmitted light-microscope is used for the process, during which a spherical particle of silica is glued at a tipless cantilever. To control the quality of the modified cantilever, another transmitted light-microscope is used. Images showing the side and the top view are acquired and used to determine the size and shape of the attached particles. The quality check shows that the method to modify cantilevers cannot be reproduced easily. Because the imaging is not precise enough, the conditions of the Hertz model are not necessarily fulfilled.

O 72.2 Wed 17:45 Poster B2

Upgrade of a low-temperature STM for single atom electron spin resonance — •Fabian D. Natterer[1,2], François Patthey[1], Tobias Bilgeri[1], Patrick R. Forrester[1,2], Nicolas Weiss[1], and Harald Brune[1] — [1]Institute of Physics, EPFL, Lausanne, Switzerland — [2]Physik-Institut, University of Zurich, Switzerland

Electron spin resonance with a scanning tunneling microscope (ESR-STM) combines temperature independent energy resolution in the nano-electron range and control of the atomic dimensions. We describe here the transformation of a low-temperature STM to an ESR-STM. The system is capable of delivering RF power to the tunnel junction at frequencies up to 30 GHz. We perform ESR on the model system TiH/MgO/Ag(100) by sweeping the magnetic field and find a magnetic moment of $(1.004 \pm 0.001)\ \mu_B$. Our upgrade enables to toggle between a DC mode, where the STM is operated with the regular control electronics, and an ultrafast-pulsed mode that uses an arbitrary waveform generator for pump-probe spectroscopy or reading of spin-states. Both modes allow for simultaneous radiofrequency excitation, which we add via a resistive pick-off tee to the bias voltage path. The RF cabling from room temperature to the 350 mK stage has an average attenuation of 18 dB between 5 and 25 GHz. Additional losses occur at the flexible cable segment connecting the STM tip. We discuss our transmission losses and indicate ways to reduce attenuation. We finally demonstrate how to synchronize the arrival times of RF and DC pulses coming from different paths to the STM junction, a prerequisite for future pulsed ESR experiments.

O 72.3 Wed 17:45 Poster B2

Analysis and quantification of electrochemical strain in contact resonance atomic force microscopy — •Sebastian Badur, Thomas Göddenhenrich, and André Schirmeisen — Institut für Angewandte Physik, Justus-Liebig-Universität Gießen, D-35392

Contact resonance atomic force microscopy can be used to measure the electrochemical strain caused by ionic movement (Vegard strain).

These potential-induced local surface deformations strongly depend on ionic concentration, electric field distribution and diffusion time. Besides that, local electrochemical strain response is mostly superimposed by other local tip-sample contact mechanics from local and non-local electrostatic forces that contribute to the image contrast formation.

For measuring and quantifying electrochemical strain, we developed a method to eliminate these parasitic contributions by using band excitation in a low and high frequency regime of the cantilever excitation.

As sample, we use Li_xCoO_2 as a typical battery cathode material. Contact resonance measurements and additional current measurements were done with conductive cantilevers and tips under UHV condition.

O 72.4 Wed 17:45 Poster B2

Design of a New Photon Collecting STM — •Mike Stummvoll[1], Markus Etzkorn[1], and Uta Schlickum[1,2] — [1]Technische Universität Braunschweig, Institut für Angewandte Physik, Mendelssohnstr. 2, 38106 Braunschweig — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart

To access dynamical properties of single photon sources on surfaces, atomic scale control is mandatory. For the improved characterisation of charge carrier and exciton dynamics, we design a new scanning-tunnelling microscope (STM).

The tunnel current in an STM tunnel junction can be used to excite photons locally on atomic scale objects. To collect the emitted photons we will employ a parabolic mirror, which will be aligned *in-situ* using piezo-driven actuators. An external optical set-up will be used for optical analysis. A spectrometer will yield information on the photon wavelength while avalanche photo-diodes (APDs) will be used for single-photon detection and high time resolution.

O 72.5 Wed 17:45 Poster B2

The Kondo resonance line shape in scanning tunnelling spectroscopy: instrumental aspects — •Manuel Gruber, Alexander Weismann, and Richard Berndt — Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany

The differential-conductance spectrum of magnetic adsorbates on surfaces can exhibit a zero-bias feature originating from the many-body Kondo effect. The intrinsic line shape of this Kondo resonance and its temperature dependence contain, in principle, valuable information. In the present study, using low-temperature scanning tunneling microscopy along with model calculations, we investigate the influence of instrumental broadening on the Kondo line shape of a model molecular Kondo system (all-*trans* retinoic acid on Au(111)). The modulation voltage used for the lock-in detection, noise on the sample voltage, and the temperature of the microscope tip are considered [1].

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[1] M. Gruber, A. Weismann, R. Berndt, J. Phys. Condens. Matter **30**, 424001 (2018)

O 72.6 Wed 17:45 Poster B2

Apparent tunneling barrier height and local work function of atomic arrays — Neda Noei, Alexander Weismann, and •Richard Berndt — IEAP, CAU Kiel, D-24098 Kiel

Spatially resolved measurements of the apparent tunneling barrier height Φ_{app} in scanning tunneling microscopy have been used to estimate variations of the local work function Φ of surface structures. We experimentally show that Φ_{app} can fail as a measure of Φ. The discrepancies are attributed to a kinetic energy contribution to Φ_{app}. This contribution depends on the lateral extent of the tunneling current filament and, consequently, on the local surface structure. Support by DFG via SFB 677 is acknowledged.

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Design of a low-temperature scanning tunneling microscope for detection of single-molecule light emission — •Tzu-Chao Hung, Brian Kiraly, Alexander A. Khajetoorians, and Daniel Wegner — Radboud University, Institute for Molecules and Materials (IMM), 6500 GL Nijmegen, The Netherlands

Phosphorescent triplet-emitter molecules are promising candidates for highly efficient OLEDs, but it is not well understood how the opto-electronic properties are altered when they are embedded in a device environment. In order to fundamentally study such dependences with atomic-scale resolution, we upgraded a low-temperature STM (T= 4K) to detect tip-induced light emission from the tunnel junction. An in-situ lens is placed close to the tunnel junction to collimate the light out of the ultrahigh vacuum system into a fiber coupler. The end of the fiber is either guided to a spectrometer with an LN2-cooled CCD detector or to a single photon counting module. This way, we are able to simultaneously study the structure, electronic properties and light-emission spectra of single molecules down to submolecular resolution and with photon yields down to few counts per second. We will present the design and performance of the setup and show preliminary results on single-molecule light emission of ZnPc molecules.

O 72.8 Wed 17:45 Poster B2

Contrast mechanism in Scanning Field Emission Microscopy

— •Gabriele Bertolini[1], Robin Pröbsting[1], Hugo Cabrera[1], Urs Ramsperger[1], Danilo Pescia[1], and Oguzhan Gürlü[1,2] — [1]Laboratory for Solid State Physics, ETH Zurich, 8093 Zurich, Switzerland — [2]Istanbul Technical University, Department of Physics, 34469 Istanbul, Turkey

We perform Scanning Tunneling Microscopy in the field emission regime by retracting the tip few nanometers away from the sample, out of the tunneling condition. By applying a higher negative potential to the tip with respect to the sample, field emission of electrons is achieved. Formally this technique is named as Scanning Field Emission Microscopy (SFEM) and it is based on STM in combination with Topografiner technology. SFEM can provide chemical and magnetic information of surfaces with nanometer level spatial resolution due to the high sharpness of the tip. During experiments we simultaneously measure the amount of emitted electrons from the tip, the absorbed electrons by the sample, as well as the electrons escaping the tip-sample junction. In our setup we also have an electron energy analyzer. In this work we present our results on the chemical contrast observed in different metal and semiconductor surfaces as well as metal/semiconductor interfaces using SFEM. We show how the contrast mechanism observed on the current and electron maps of the surface can be interpreted and can be enhanced.

O 72.9 Wed 17:45 Poster B2

Collection and Detection Mechanisms for Photons Emerging from Tunnel Junctions

— •Berk Zengin[1,2], Hugo Cabrera[2], Dilek Yildiz[2,3], Danilo Pescia[2], and Oguzhan Gürlü[1,2] — [1]Istanbul Technical University, Department of Physics, 34460, Istanbul, Turkey — [2]ETH Zurich, 8093, Zurich, Switzerland — [3]University of Basel, Basel, Switzerland

Even though photon emission from planar tunneling junctions were studied long before the invention of Scanning Tunneling Microscope (STM), studies on such photon generation mechanisms are gaining more interest in recent years. Several photon collection and detection mechanisms with high efficiencies were reported. We constructed several photon collection mechanisms on a commercial STM system. In one, emitted photons were collected using a fiber that was placed in proximity of tunneling junction, mounted on a manual positioner. Based on simulations carried out by finite element methods, a ball lens was placed in between fiber and the junction to increase coupling efficiency and results were compared accordingly. Furthermore, a bundle of two fiber cores were used to detect photons in order to perform two channel photon detection from the tunnel junction. Two types of detectors were utilized for photon collection process. Our results indicate that photon maps acquired simultaneously with topography and tunneling current maps can show contrast between neighboring data points, demonstrating a resolution with several Angstroms. In general, we address the challenges of interpretation of photon maps obtained under ambient conditions due to changes at the tip apex.

O 72.10 Wed 17:45 Poster B2

A Time and Spatially Resolved Study of the Thermal Response of the Tip of a Scanning Tunneling Microscope on Pulsed Optical Excitation

— •Georg Alexander Traeger[1,3], Taner Esat[1,2], Martin Wenderoth[3], and Jungseok Chae[1,2] — [1]Center for Quantum Nanoscience (QNS), Institute for Basic Science (IBS), Seoul, Republic of Korea — [2]Department of Physics, Ewha Womans University, Seoul, Republic of Korea — [3]IV. Physics Institute, Georg- August-University, Göttingen, Germany

Combining Scanning Tunneling Microscopy (STM) and pulsed optical excitation was already envisioned in the early 1990s. [1] In this approach, disentangling thermal effects due to heating of the tip from optically induced dynamics of the sample has always been a major issue. Grafström et al. [2] sytematically investigated the thermal response on sinusoidal stimulus up to 100 kHz. Only recently, Kloth et al. [3] estimated thermal effect of pulsed optical excitation based on the shaken pulse pair excitation up to several nanoseconds. Using an electro-optical modulator, we investigate the thermal response of a W tip/Cu(111) surface from the low up to the high frequency regime. In combination with the raster-scanned laser focus, we have access to both time and spatially thermal response of the tip under optical excitation. [1] Weiss et al. APL. 63, 18 (1993) [2] Grafstrbm et al. J. of Vac. Sci. & Tech. B 9, 568 (1991) [3] Kloth et al. Rev. Sci. Instr. 87, (2016).

O 72.11 Wed 17:45 Poster B2

Microsecond Heat Pulses to Induce Phase Changes by Thermal Scanning Probe Lithography

— •Samuel Zimmermann and Jürgen Brugger — Microsystems Laboratory, EPFL, Switzerland

Thermal scanning probe lithography (t-SPL) is an advanced lithography technique to create nanoscale surface structures by means of a heated atomic force microscopy tip. We use the fast heating and cooling rates accessible by t-SPL ($\sim 10^8$ K/s) to locally induce phase changes in two organic materials, which are not attainable at the macroscale.

The first material is a fluorescent supramolecular polymer, which exhibits thermoresponsive luminescent behavior with two distinct fluorescence colors due to reversible aggregation of excimer forming moieties. Fast heating and cooling of small volumes on the order of attoliter with the thermal probe permits to quench the green fluorescent high-temperature state and to fabricate nanoscale structures with a fluorescence contrast below the optical diffraction limit.

The second material is silk fibroin, a protein extracted from the cocoons of the *Bombyx mori* moth, which exhibits a polymorphic structure with a difference in water solubility depending on its molecular arrangement. Applying microsecond heat pulses with a heated probe locally renders the material water-soluble by melting β-sheet crystallites, which act as crosslinks between the fibroin stands. Nanoscale patterns were fabricated with the heated probe, the contrast formation mechanism analyzed and a dry-etching transfer is demonstrated.

O 72.12 Wed 17:45 Poster B2

homemade nv-based scanning probe microscopy

— •Ke Bian — College of Physics, Peking University, China

NV center host in diamond crystal is suitable for magnetic detection at nanoscale because of its high magnetic sensitivity and atomic size. We established a NV-based scanning probe microscopy (NVSPM) system aiming for scanning magnetometry and nanoscale nuclear magnetic resonance (NMR). Our home-built Pan-type scanner is rigid against both acoustic and electronic noise from ambient environment. We can obtain atomic resolution in STM mode and nanometer resolution in AFM mode. The high NA objective, microwave coplanar waveguide and kilo-gauss vector magnetic field are integrated inside the scanner. We also established confocal imaging and pulse sequence system for addressing single NV and coherent manipulation. By dynamical decoupling technique we can easily detect internal C13 nuclear spins with shallow NVs. The stable and accurate positioning ability paves the way for direct imaging of nanoscale magnetic particles or nuclear spin clusters on diamond surface.