O 73: Scanning Probe Methods II

Time: Thursday 10:30–13:15 Location: WIL A317

O 73.1 Thu 10:30 WIL A317

Friction contrast in Dynamic Friction Force Microscopy — •Felix Mertens, Thomas Göddenhenrich, and André Schirmeisen — Institut für Angewandte Physik, Justus-Liebig-Universität Gießen, D-35392 Gießen

Dynamic Friction Force Microscopy is a measuring technique for the investigation of friction properties on the nanometer scale. The off-resonance modulation of the sample excites bending oscillations of the cantilever if the tip is in contact with the sample surface. Contrast at surface steps and grain boundaries on HOPG demonstrate, that the third-harmonic lock-in detection is a selective method for the investigation of different tip-sample interactions. Furthermore, the signal on antimony nanoparticles shows the dependence on modulation amplitude and frequency for different materials as well as the influence caused by the particle topography.

O 73.2 Thu 10:45 WIL A317

Artifacts in combined STM/AFM due to non-ideal ground in an STM pre-amplifier — •Nirmalesh Kumar Sampath Kumar, Alfred John Weymouth, and Franz Josef Giessibl — Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

In AFM, it is normal to apply a bias voltage between the tip and the sample, most often to compensate for the contact potential difference. In order to perform simultaneous STM, the tunneling current must be measured. This usually involves a pre-amplifier that holds its current input terminal at a virtual ground that is ideally equal to real ground. Limitations of amplifier bandwidth, gain and slew rate lead to time-dependent deviations of virtual ground from zero, causing a time-dependent variation of the electrostatic force between tip and sample. These time-dependent deviations can lead to artifacts in apparent dissipation and even to an apparent "self" excitation of the cantilever. Here, we monitor virtual ground and discuss the effect of virtual ground deviations to apparent dissipation.

O 73.3 Thu 11:00 WIL A317

Dynamic local work function measurement and the role of topography — •Ferdinand Huber[1], Sonia Matencio[2], Alfred J. Weymouth[1], and Franz J. Giessibl[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Institute of Material Science of Barcelona (ICMAB-CSIC), Campus UAB, 08193 Bellaterra, Spain

Performing simultaneous STM/AFM allows the electronic structure of the surface to be investigated. Two common methods are Kelvin Probe Force Microscopy (KPFM) and current-distance (I-z) spectroscopy. With KPFM, the tunneling current channel is difficult to interpret because the applied bias is not constant. I-z spectroscopy is usually performed at low temperature in order to minimize drift and creep. We propose an alternate technique called *dynamic κ measurement* based on Refs. [1] and [2], in which we measure the decay constant of the tunneling current taking advantage of the oscillating conducting tip. We explain this technique and compare it to measurements at low temperature. Furthermore we discuss the influence of topography on the local work function.

[1] G. Binnig, H. Rohrer, Surf. Sci. **126**, 236 (1983)
[2] M. Herz, Ch. Schiller, F. Giessibl and J. Mannhart, Appl. Phys. Lett. **86**, 153101 (2005)

O 73.4 Thu 11:15 WIL A317

The STM as Microwave resonator: Josephson currents interacting with the environment — •Berthold Jäck[1], Matthias Eltschka[1], Maximilian Assig[1], Markus Etzkorn[1], Christian R. Ast[1], and Klaus Kern[1,2] — [1]Max-Planck-Institute for Solid State Research, D-70569 Stuttgart — [2]École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne

We investigated the Josephson Effect in Vanadium tunnel junctions by using an STM operating at a temperature of 15 mK [1]. As the STM junction geometry is of very small capacitance our measured current-voltage characteristics exhibit clear indications for Coulomb blockade dominated tunneling in the overdamped regime. Next to the supercurrent we observe harmonic sub-gap features at energies of about 100 *eV. By varying the STM tip length and the tip-sample geometry we are able to tune both resonance energy as well as its intensity. We explain these findings with photon-assisted tunneling of Cooper pairs driven by an electro-magnetic mode localized on the STM tip. The mode is excited by GHz radiation which is emitted from the Josephson junction driven in the AC regime. Our physical picture is substantiated with finite-element-method simulations on the electrodynamic properties of our 3D tip-sample geometry. We will discuss these findings in the framework of Josephson junctions coupled to an electro-magnetic environment [2] and also give an outlook in view of possible applications as GHz-source on the atomic scale.

[1] M. Assig et al., Rev. Sci. Instrum. 84, 033903 (2013)
[2] G.-L. Ingold et al., Phys. Rev. B 50, 1 (1994)

O 73.5 Thu 11:30 WIL A317

The Zeeman Effect in dimensionally confined, superconducting STM tips — •C. R. Ast[1], M. Eltschka[1], B. Jäck[1], M. Assig[1], M. Etzkorn[1], O. V. Kondrashov[2], M. A. Skvortsov[2,3], and K. Kern[1] — [1]MPI for Solid State Research, Stuttgart — [2]Moscow Institute of Physics and Technology, Moscow, Russia — [3]Landau Institute for Theoretical Physics, Chernogolovka, Russia

It has been shown in the 1970s that in thin films superconductivity persists in much higher magnetic fields than in the bulk. The resulting Zeeman splitting of the spin-polarized electrons has been used to measure the absolute spin-polarization of electrons in planar tunnel junctions. Transferring this concept to the superconducting tip in a scanning tunneling microscope, it is not *a priori* clear that the dimensional confinement at the tip apex is suitable to produce a similar effect. We show both experimentally and theoretically that this effect can be observed in scanning tunneling spectroscopy. The parameters for successful tip preparation as well as possible applications will be discussed.

O 73.6 Thu 11:45 WIL A317

Multi-Tip STM / Nanoprober for electrical characterization at the nanoscale — •Bert Voigtländer, Vasily Cherepanov, Peter Coenen, Stefan Korte, Marcus Blab, and Hubertus Junker — Peter Grünberg Institut (PGI-3), Forschungszentrum Jülich, 52425 Jülich, Germany, and JARA-Fundamentals of Future Information Technology

We present design and performance of an ultra compact four tip STM which integrates four independent STM units within a diameter of 50 mm resulting in a mechanical stability which enables atomic resolution imaging with each tip. The heart of this STM is a new type of piezoelectric coarse approach called KoalaDrive. The coarse positioning of the tips is done under the control of an SEM. This multi-tip instrument offers the capability to perform current and voltage measurements at the nanoscale. Due to its small size this instrument is ideally suited for integration into a cryostat. The control electronics allows each tip to be used as current probe or voltage probe. The software allows virtually any possible "concerted" spectroscopic measurements involving the four tips and the sample. We demonstrate the potential of the instrument to perform charge transport measurements at the nanoscale by various examples: Resistance/dopant profiling at freestanding GaAs nanowires, distance dependent four point measurements at Si surfaces, and gate dependent charge transport measurements on graphene.

O 73.7 Thu 12:00 WIL A317

Atomically resolved STM imaging with a single-crystal diamond tip — Vladimir I. Grushko[1], •Olaf Lübben[2], Alexander N. Chaika[2,3], Nikolay V. Novikov[1], Evgeniy I. Mitskevich[1], A. P. Chepugov[1], Oleg G. Lysenko[1], Barry E. Murphy[2], Sergey A. Krasnikov[2], and Igor V. Shvets[2] — [1]V. Bakul Institute for Superhard Materials, Kiev, 04074, Ukraine — [2]Centre for Research on Adaptive Nanostructures and Nanodevices, School of Physics, Trinity College, Dublin 2, Ireland — [3]Institute of Solid State Physics RAS, Chernogolovka, Moscow district 142432, Russia

The spatial resolution of a scanning tunneling microscope (STM) can be enhanced using light element-terminated probes with spatially localized electron orbitals at the apex atom. Conductive diamond probes can provide carbon atomic orbitals suitable for STM imaging with sub-Ångström lateral resolution and high apex stability crucial for the small tunneling gaps necessary for high-resolution experiments. Here we demonstrate that high spatial resolution can be achieved in STM experiments with single crystal diamond tips. The results of STM experiments with a heavily boron-doped, diamond probe on a graphite surface; density functional theory calculations of the tip and surface electronic structure; and first principles tunneling current calculations demonstrate that the highest spatial resolution can be achieved with diamond tips at tip-sample distances of 3-5 Å when the p orbitals of the tip provide their maximum contribution to the tunneling current. At the same time, atomic resolution is feasible even at extremely small gaps with very high noise in the tunneling current.

O 73.8 Thu 12:15 WIL A317

STM imaging of HOPG: Tip geometry effects — •Gábor Mándi[1], Gilberto Teobaldi[2], and Krisztián Palotás[1] — [1]Budapest University of Technology and Economics, Department of Theoretical Physics, Budafoki út 8., H-1111 Budapest, Hungary — [2]Stephenson Institute for Renewable Energy, and Surface Science Research Centre, Department of Chemistry, University of Liverpool, L69 3BX Liverpool, UK

Highly oriented pyrolytic graphite (HOPG) is an important substrate in technological applications, particularly in scanning tunneling microscopy (STM) calibration. Therefore, the proper interpretation of the experimentally observed STM image contrasts is very important [1]. Using a three-dimensional (3D) Wentzel-Kramers-Brillouin (WKB) tunneling model [2,3] combined with first principles electronic structure calculations, we demonstrate that the tip orientation has a considerable effect on the simulated STM images. We show that the local rotation of the apex of the STM tip can cause a triangular-hexagonal contrast change. By comparing STM topographic data between experiment [1] and large scale simulations, we can determine particular tip orientations that are most likely present in the STM experiment.

[1] G. Teobaldi et al., Phys. Rev. B 85, 085433 (2012).
[2] K. Palotás et al., Phys. Rev. B 86, 235415 (2012).
[3] G. Mándi et al., J. Phys.: Condens. Matter 25, 445009 (2013).

O 73.9 Thu 12:30 WIL A317

A new low temperature near-field optical scanning microscope — •Julia Janik[1], Claudio Dal Savio[2], and Achim Hartschuh[1] — [1]Department Chemie and CeNS, LMU München, 81377 München, Germany — [2]attocube systems AG, 80539 München, Germany

The characterisation of nanostructures with high spatial resolution and detection sensitivity can be achieved by tip-enhanced near-field optical microscopy (TENOM) [1]. Up to now nearly all TENOM measurements were performed at room temperature. Low temperature measurements on the other hand would reveal even more detailed information about material properties, for example due to reduced spectral broadening. We describe a new scheme for implementing TENOM at low temperatures. For initial experiments and testing well known quasi 1D semiconducting model systems such as single-walled carbon nanotubes (SWCNT) and cadmium selenide (CdSe) nanowires were used [2]. Here we describe our efforts and first results on our way towards low temperature near-field optical microscopy.

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[1] N. Mauser and A. Hartschuh, Chem. Soc. Rev., DOI: 10.1039/C3CS60258C (2014)
[2] M. Böhmler et al., Angew. Chem. Int. Ed. 50, 11536 (2011)

O 73.10 Thu 12:45 WIL A317

Secondary Electron Analysis with Topografiner Techonlogy — •Lorenzo G. De Pietro, Danilo A. Zanin, Hugo Cabrera, Mehmet Erbudak, Andreas Fognini, Thomas U. Michlmayr, Yves M. Acremann, Danilo Pescia, and Urs Ramsperger — ETH Zurich, Switzerland

In Near Field-Emission Scanning Electron Microscopy (NFESEM), based on the topografiner techonlogy, cold field emitted electrons from a sharp polycrystalline W-tip are the source of a primary electron beam. The applied voltage for field emission (between the tip and the sample) accelerates these electrons up to some tens of eV. After having interacted with the sample, secondary and backscattered electrons are detected, while an STM controller is used to scan the tip at a constant distance (10 to 20 nm) from the sample surface. This technique has been used to take topography images of various metals and semiconductors achieving subnanometer lateral resolution. In case of a W(110) surface partially covered by Fe a chemical contrast was observed. After having implemented energy analysis to this technique, we present a series of images generated by collecting only electrons with selected energies, i.e. true secondary electrons. This represents an important step in view of adding a spin polarization analysis and use the NFESEM as an instrument to investigate magnetic surfaces at a nanometer scale.

O 73.11 Thu 13:00 WIL A317

High-Resolution Imaging and nano-FTIR Spectroscopy using Synchrotron Radiation at the Metrology Light Source — •Peter Hermann[1], Arne Hoehl[1], Piotr Patoka[2], Bernd Kästner[1], Georg Ulrich[2], Eckart Rühl[2], Burkhard Beckhoff[1], and Gerhard Ulm[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Abbestr. 2-12, 10587 Berlin, Germany — [2]Physikalische und Theoretische Chemie, Institut für Chemie und Biochemie, Freie Universität Berlin, Takustr. 3, 14195 Berlin, Germany

Infrared radiation provided by an electron storage ring can be regarded as an ideal source for spectroscopic applications since it is up to 1000 times brighter and covers a much broader spectral range than the radiation emitted from a conventional thermal light source. The achievable spatial resolution is, however, limited by diffraction, thus preventing a resolution below the diffraction limit. This limitation can be circumvented by using near-field approaches which are based on the use of a sharp metallic probe tip acting as a nano-scale light source when irradiated by a focused synchrotron radiation (SR) beam. In the following, we report on the use of broadband SR provided by the Metrology Light Source (MLS) for near-field imaging and acquisition of nano-FTIR spectra in a wide spectral range. By using SR for imaging of Si-based samples a spatial resolution below 50 nm can be achieved. The near-field signal detection in nano-FTIR measurements is confirmed by the acquisition of spectra from a SiC sample showing the characteristic strong phonon resonance near 927 cm-1. Additionally, further results obtained from various solid matter samples are presented.