O 64: Scanning Probe Techniques: Method development

Time: Tuesday 18:30–20:30 Location: P2-OG3

O 64.1 Tue 18:30 P2-OG3

A convenient method for large scale STM mapping of freestanding atomically thin membranes — •Bernd Uder and Uwe Hartmann — Institute of Experimental Physics, Saarland University, Germany

Two-dimensional sheets atomically flat and with high flexibility are very attractive to be used as ultrathin membranes but inherently challenging for microscopic investigations. We report a method using Scanning Tunnelling Microscopy (STM) under ultrahigh vacuum conditions for large scale mapping of graphene membranes. This is achieved by operating the STM with unusual parameters. We found that large scale scanning on atomically thin graphene membranes delivers viable results using very high tip scan speeds combined with high feedback loop and low tunnelling current settings. This is successful due to a different behaviour of the freestanding membrane in STM compared to a solid substrate. The contrast on a thin membrane is ruled by tip membrane force interactions and the interplay with the integral distance regulator working at high gain. For low tunnelling currents the force interaction is tunable by changing the bias between tip and sample. We applied our method to map differences of membrane quality of commercial available single layer graphene covering 2 micrometer sized holes and multi-layered graphene covering a TEM 2000 mesh.

O 64.2 Tue 18:30 P2-OG3

Electromechanical contact resonance in band excitation piezoresponse force microscopy — •Sebastian Badur, Thomas Göddenhenrich, and André Schirmeisen — Institut für Angewandte Physik, Justus-Liebig-Universität Gießen, D-35392

Contact resonance atomic force microscopy is a key analyzation method for local piezoresponse or electrochemical strain effects. A drawback of this technique are the various parasitic contributions affecting the signal contrast formation, e.g. a topographical crosstalk, an overall distributed electrostatic force or the stiffness of the mechanical tip-to-sample coupling. In order to investigate and minimize these influences we present an approach using the band excitation method around different cantilever eigenmodes combined with a switching between the electrical cantilever and mechanical sample excitation. Measurements are performed on $BaTiO_3$ under UHV conditions.

O 64.3 Tue 18:30 P2-OG3

A dilution refrigerator based UHV spin-polarized STM operating at 30 mK in a vector magnetic field — Henning von Allwörden[1], Andreas Eich[1], Jan Hermenau[2], Andreas Sonntag[2], Jan Gerritsen[1], Daniel Wegner[1], and •Alexander Ako Khajetoorians[1] — [1]Institute for Molecules and Materials, Radboud University, Nijmegen, The Netherlands — [2]Department of Physics, Hamburg University, Hamburg, Germany

Spin-resolved scanning tunnelling microscopy (STM) has advanced as a leading technique to probe the behaviour of single spins down to the level of individual atoms. Nevertheless, a severe limitation in probing spin-dependent phenomena in materials of interest, such as quantum magnets and topological superconductors, is the extremely high energy resolution needed to resolve fine features and minute variations in spectroscopy resulting from interactions. To this end, we advance spin-resolved STM toward the lowest temperatures today, by constructing a microscope that operates in a UHV-based dilution refrigerator capable of a vector magnetic field. Moreover, this new microscope is situated in the new SPIN laboratory, located at the IMM in Nijmegen, which is optimized for ultra-low noise measurements. We present the design of this laboratory, and we illustrate our first benchmark tests at base temperature, as well as the noise characteristics.

O 64.4 Tue 18:30 P2-OG3

Scanning Tunneling Microscopy with a JFET-sensor — •Stephanie Hoepken, Sebastian Bauer, Hermann Nienhaus, Christian A. Bobisch, and Rolf Möller — Faculty of Physics, Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

We examined a new working mode for scanning tunneling microscopy (STM). It is an STM in which a junction-field-effect-transistor (JFET) serves as a sensor for the tunnelling current. The tunnelling tip is directly connected to the gate of the JFET, which is operated in an open-gate mode with no other electric connection to the gate. The drain current provides a corresponding signal at low impedance which is used for the electronic control of the tip sample distance. The technique allows us to work at very low currents in the range of about 100 to 200 fA. First of all the JFET was characterised to evaluate its operating point. At stable operation the tunnelling current is matched by the gate leakage current. By choosing the bias voltage applied to the sample, the tunnelling conductance can be set. In the recorded STM-pictures this voltage is about -1 to -2 V. Furthermore, an essential point in operating a JFET-STM is the control of the tip sample distance. The drain current's reaction to a changing tunnelling current is low pass filtered by the gate capacity, but it was found that a sufficient scanning speed can be accomplished by optimised control parameters mainly by using the proportional part of the feedback loop. With these parameters detailed pictures of an Au(111)-sample could be recorded.

O 64.5 Tue 18:30 P2-OG3

Combined pump probe experiments with scanning tunneling microscopy — •Kira Kolpatzeck, Philip Kapitza, Ebru Ekici, Rolf Möller, and Christian A. Bobisch — Faculty of Physics, Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

We will employ two experimental strategies to analyze charge carrier dynamics and luminescence with atomic scale lateral resolution by pump-probe spectroscopy. For timescales down to 1 ns, all electronic pump-probe measurements with a scanning tunneling microscope (STM) [1] are performed. Here, our first results show, that the luminescence that stems from inelastic tunneling processes can be used to quantitative map fast voltage pulses in the tunnel junctions [2]. This is achieved by performing time correlated counting of the emitted photons during the voltage pulse. In parallel, we develop and build an experiment in which THz radiation is coupled into the tunneling junction of a new build STM to allow for pump-probe experiments in the ps range [3]. The concept of the experimental setup will be presented.

[1] S. Loth et al., Science 329, 1628 (2010).
[2] C. Grosse et al., Appl. Phys. Lett. 103, 183108 (2013).
[3] T. L. Cocker et al., Nature Photonics 7, 620 (2013).

O 64.6 Tue 18:30 P2-OG3

Comparison of the signal-to-noise ratio of the first two flexural modes for qPlus AFM sensors — •Dominik Kirpal and Franz Giessibl — Universität Regensburg

Higher flexural modes are used due to their higher eigenfrequencies and spring constants. In this work we calculated theoretically and determined experimentally the sensitivity for the first two flexural modes of qPlus sensor [1,2]. We found that the sensitivity of the second mode is about 3 times higher than of the first mode. This affects the detector, oscillator and thermal noise [3]. At low temperatures the detector noise is dominant, in ambient conditions and liquid environments thermal and oscillator noise are substantial [4]. The influences of these noise contributions are discussed depending on the experimental setup.

[1] Giessibl, Applied Physics Letters, 76, 1470 (2000).
[2] Ooe et al., arXiv preprint:1605.06584 (2016).
[3] Giessibl et al., Physical Review B, 84, 125409 (2011).
[4] Wutscher, and Franz J. Giessibl, Review of Scientific Instruments 82.9 (2011): 093703.

O 64.7 Tue 18:30 P2-OG3

Fast and Reliable Pre-Approach for Scanning Probe Microscopes based on Tip-Sample Capacitance — Marc de Voogd[1], Matthijs van Spronsen[1], Floris Kalff[2], Ben Bryant[2], Oliver Ostojic[1], Arthur den Haan[1], Irene Groot[1,3], Tjerk Oosterkamp[1], Sander Otte[2], and •Marcel Rost[1] — [1]Leiden Institute of Physics, Leiden University, P.O. Box 9504, 2300 RA Leiden, the Netherlands — [2]Department of Quantum Nanoscience, Kavli Institute of Nanoscience,Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands — [3]Leiden Institute of Chemistry, Leiden University,P.O. Box 9502, 2300 RA Leiden, the Netherlands

Within the last three decades Scanning Probe Microscopy has been developed to a powerful tool for measuring surfaces and their properties. However, despite continuous improvements, the time required for a safe approach can still be very time consuming, especially if the microscope is not equipped or suited for the observation of the tip-sample distance with an additional optical microscope. Here we show that the measurement of the tip-sample capacitance provides an ideal solution for a fast and reliable pre-approach. The tip-sample capacitance shows a generic behavior as a function of the distance, even though we measured it on several completely different setups. Insight into this behavior is gained via an analytical and computational analysis, from which two additional advantages arise: the capacitance measurement can be applied for observing, analyzing, and re-tuning of the approach motor, as well as for the determination of the (effective) tip radius.

O 64.8 Tue 18:30 P2-OG3

Tuning the functionality of a junction field effect transistor at cryogenic temperatures: new prospects and possible applications — •Meike Flebbe, Paul Graf, Christian A. Bobisch, Hermann Nienhaus, and Rolf Möller — Faculty of Physics, Center for Nanointegration Duisburg-Essen, University of Duisburg-Essen, 47048 Duisburg, Germany

By cooling a conventional junction field-effect transistor (JFET) to 80 K an electrometer with extremely high impedance can be realized. It may be used as a detector for ultimately low currents or charges, e.g. for low temperature scanning probe microscopy (SPM). The characteristics of the JFET at room temperature and in the cooled state were recorded and compared. While the gate leakage current at about 300 K is in order of magnitude of a few pA, it becomes very low when the JFET is cooled to 80 K. A careful measurement provides an estimate of the leakage current of 4×10^{-20} A [1]. The electrometer can be used from DC up to a frequency of 10 kHz. Without reduction of the bandwidth signal of a few μV can be detected. Working at low frequencies currents as low as a few attoampere can be detected. Despite the high sensitivity the sensor is fairly robust. If the input voltage is out of the operational range the forward current or the Zener current of the gate junction protects the transistor against destructive charging. Finally, different schemes have been developed to apply the sensor for scanning tunneling microscopy and potentiometry.

[1] R. Möller and H. Nienhaus, patent pending, Open FET Sensor, Provendis Ref.-Nr: 4817

O 64.9 Tue 18:30 P2-OG3

Advances in scanning field-emission microscopy — •Danilo A. Zanin, Hugo Cabrera, Gabriele Bertolini, Lorenzo G. De Pietro, Alessandro Vindigni, Thomas Bähler, Oguzhan Gürlü, Mehmet Erbudak, Urs Ramsperger, and Danilo Pescia — ETH Zurich, Zurich, Switzerland

The impact of Scanning Tunneling Microscopy (STM) to nanotechnology continues to be undisputed, but this does not prevent the search for new methods with the aim of revealing aspects complementary to those highlighted by STM. Inspired by the Russel Young topografiner we designed the Scanning Field-emission Microscopy (SFM) to analyze secondary electron escaping a tip-target nano-sized junction. On one side, SFM detects "non-geometrical" aspects of the surface, which are not straightforwardly revealed by STM. On the other side, those very same electrons used to build a one-nanometer-resolved image of a surface are ultimately made available to a macroscopic environment for further processing. We report on the latest result of this technique.

O 64.10 Tue 18:30 P2-OG3

Lateral manipulation of single iron-adatoms with CO terminated tips by combined STM/AFM — •Julian Berwanger, Ferdinand Huber, and Franz Josef Giessibl — Institute for Experimental an Applied Physics, University of Regensburg, 93040 Regensburg

By positioning single iron adatoms with a scanning probe microscope on a Cu(111) surface, spin-based logical operators and quantum bits can be built on the atomic scale [1,2]. Building these devices requires a precise, controlled and reproducible mechanism for positioning single adatoms. CO terminated tips allows to image metal clusters with atomic resolution [3]. We performed lateral manipulation of single iron adatoms with a combination of scanning tunneling and atomic force microscopy using monoatomic Cu- and CO-terminated tips. For both types of tips we find that the force responsible for the manipulation is purely attractive and the predicted diffusion barrier of 28.5meV [4] is lowered due to the presence of the tips [5] by about 70%. Moreover, this work demonstrates the feasibility of using the high resolution capability of a CO tip [6] and simultaneously manipulating adatoms laterally without the need of changing the tip before.

[1] A. A. Khajetoorians et al. Science 332, 1062 (2011)
[2] S. Loth et al. Science 335, 196 (2012)
[3] M. Emmrich et al. Science 348, 6232 (2015)
[4] N. N. Negulyaev et al. PRB 79, 195411 (2009)
[5] M. Emmrich et al. PRL 114, 146101 (2015)
[6] L. Gross et al. Science 325, 110 (2009)

O 64.11 Tue 18:30 P2-OG3

Cantilever dynamics induced by light — •Sven Kraft, Heinrich Behle, Kai Wardelmann, Mohammedreza Bahrami, Dieter Schick, Semjon Köhnke, Boris Hage, Ingo Barke, and Sylvia Speller — University of Rostock, Institute of Physics, 18051 Rostock, Germany

Atomic Force Microscopy methods have been advanced to image a variety of properties on the nanoscale. In this work we discuss the interaction of light fields with the cantilever [1]. On the one hand a temporally controlled illumination of the cantilever leads to bending and oscillation due to radiation pressure and photothermal effects. The light-driven cantilever actuation can replace the dither piezo actuation. In liquids this leads to reduced dynamics in the medium and thereby to better defined resonances. On the other hand light itself, e.g. in form of spatially modulated light landscapes can give rise to additional forces which may serve as an observable to map nearfield interactions [2].

[1] D. Ramos, J. Tamayo, J. Mertens, and M. Calleja, J Appl Phys 99, 124904 (2006)
[2] D.C. Kohlgraf-Owens, S. Sukhov, and A. Dogariu, Phys Rev A 84, 011807(R) (2011)

O 64.12 Tue 18:30 P2-OG3

A Scanning Tunneling Microscope with femtosecond optical near-field excitation — •Benjamin Schröder, Katharina Kaiser, Steffen Bornemann, Claus Ropers, and Martin Wenderoth — IV. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Photochemical reactions on metal oxide surfaces are governed by the site-specific surface structure, including defect concentration and distribution. To investigate these highly-localized optical excitation mechanisms, we implemented a low-temperature Scanning Tunneling Microscope operating under ultra high vacuum conditions. Our setup features stable imaging conditions with atomic resolution under pulsed optical excitation of the tip-sample gap at peak intensities up to $1\,\mathrm{GW/cm^2}$.

Using this setup, we are able to desorb hydrogen adatoms and move oxygen vacancies from TiO_2 surfaces by applying current or voltage pulses [1,2]. Currently, we are investigating the possibility of stimulated desorption and diffusion processes by optical near-field excitation.

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[1] Acharya et al., J. Phys. Chem. C 114, 21510 (2010)
[2] Minato et al., ACS Nano 9, 6837 (2015)

O 64.13 Tue 18:30 P2-OG3

Low Vibration Laboratory with a Single-Stage Vibration Isolation for Microscopy Applications — Bert Voigtländer[1,2], Peter Coenen[1,2], Vasily Cherepanov[1,2], •Peter Borgens[1,2], Thomas Duden[3], and F. Stefan Tautz[1,2] — [1]Peter Grünberg Institut (PGI-3), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Jülich Aachen Research Alliance (JARA) Fundamentals of Future Information Technology, 52425 Jülich, Germany — [3]Konstruktionsbüro Duden, Borgsenallee 35, 33649 Bielefeld, Germany

Vibrational isolation and electromagnetic shielding are crucial for every high-precision scanning probe microscope. In many cases, multistage vibration isolation stages are used, which add considerably to the complexity (and cost) of a SPM system. For this reason, recent approaches tend towards single-stage vibrational systems which can provide similar results while requiring much lower expenditure.

In this contribution, we report on the construction and the vibrational performance of a low vibration laboratory for microscopy applications comprising a 100 ton floating foundation supported by passive pneumatic isolators (air springs), which rest on a 200 ton solid base plate. Careful optimization of the air spring system results in a vibration level of the laboratory floor well below the one induced by acceleration of 10ng for most frequencies. Additional accoustic and electromagnetic isolation is accomplished by a room-in-room concept.