O 37: Scanning Probe Techniques

Time: Tuesday 18:15–21:00 Location: Poster A

O 37.1 Tue 18:15 Poster A

Construction of a dilution fridge based UHV spin-polarized STM operational in a vector magnetic field — •Jan Hermenau[1], Andreas Sonntag[1], and Alexander Khajetoorians[2] — [1]Institute of Nanostructure and Solid State Physics, Hamburg University, Hamburg, Germany — [2]Institute for Molecules and Materials, Radboud University, Nijmegen, The Netherlands

Unraveling many of the current dilemmas in nanoscience hinges on the advancement of techniques which can probe the spin degrees of freedom with high spatial, energy, and ultimately high temporal resolution. With the development of sub-Kelvin high-magnetic field STM, two complementary methods, namely spin-polarized scanning tunneling spectroscopy (SP-STS) and inelastic STS (ISTS), can address single spins at the atomic scale with unprecedented precession. Nevertheless, common cryostat designs for spin-polarized STM sub-Kelvin application are based on 3He liquification, which are limited in base temperature, hold time, and cooling power. To address these limitations for spin-polarized detection, we demonstrate the design and construction of a dilution fridge based UHV spin-polarized microscope operational in a vector magnetic field, capable of atomic spin detection and atomic manipulation. Our design consists of tip/sample exchange at cold temperatures and features extremely low 4He consumption with a long hold time. The easy-to-use compact design is capable of cold material deposition, and it is housed in an ultra-quiet laboratory featuring a 150 isolated foundation and proper acoustical and RF shielding.

O 37.2 Tue 18:15 Poster A

Development of a Dedicated Lithographic System for Focused Electron Beam Induced Processing (FEBIP) — •Florian Vollnhals, Fan Tu, Martin Drost, Hans-Peter Steinrück, and Hubertus Marbach — Physikalische Chemie II, Friedrich-Alexander Universität Erlangen-Nürnberg, Egerlandstr. 3, D-91058, Erlangen.

Focused Electron Beam Induced Processing (FEBIP) subsumes a number of electron beam based lithographic techniques for the fabrication of nanostructures on surfaces, e.g. Electron Beam Induced Deposition (EBID) or Surface Activation (EBISA). In EBID, for example, a metal-organic precursor is dosed onto a surface and locally decomposed by a highly focused electron beam. Non-volatile fragments form a nanosize deposit while volatile ones are pumped off.[1,2]

These techniques rely on precise spatio-temporal control of the electron beam, to which end a lithographic attachment for an UHV-SEM was developed. The system is based on commercially available DAC hardware and LabVIEW as a programming environment. We will discuss some of the beam control-related challenges that were encountered during FEBIP research using standard EBL systems and present the capabilities of the new setup using examples from EBID and EBISA studies under UHV conditions.

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[1] W. van Dorp et al., J. Appl. Phys. 104 (2008), 0801301.
[2] H. Marbach, Appl. Phys. A 117 (2014), 987.

O 37.3 Tue 18:15 Poster A

Development of a compact pulsed laser system for Scanning Tunneling Microscopy — •Terence Thias, Philipp Kloth, Ole Bunjes, and Martin Wenderoth — IV. physikalisches Instut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Pulsed laser excitation in STM allows resolving processes on surfaces beyond the bandwidth of the current amplifier. A major challenge of optical excitation in STM is controlling the influence of thermal effects. We implemented a sub-micrometer precise stage that allows the scanning of the focus point of the laser beam along the tip-surface junction - even during tunnel conditions. Thereby we assure to find the spot of maximum excitation in a standardized manner guaranteeing reproducible conditions. To keep the thermal power at the tip constant, standard pump-probe pulses must be transformed into complex laser pulse patterns [1]. We have developed a compact and convenient laser setup that can be added to any STM with optical access to the sample surface. Using an optical modulator with a bandwidth in the gigahertz range and a high frequency function generator, we process a continuous wave laser beam into nanosecond pulses. By generating pulse series exclusively in an electronic way we can easily adapt parameters like pulse width or repetition rate to the demands of the experiment.

[1] Terada et al., Nature Photonics, 4(12), 2010.

O 37.4 Tue 18:15 Poster A

GXSM - a smart & customizeable SPM control — Percy Zahl[1], •Thorsten Wagner[2], and et al.[3] — [1]Brookhaven National Laboratory Upton, USA — [2]Johannes Kepler University Linz, Austria — [3]http://gxsm.sf.net

The open source and community driven scanning probe microscopy software project GXSM takes the next level to provide a highly and in-operando adaptable scanning probe microscopy (SPM) control system. A highly efficient digital signal processor (DSP) interfaces any SPM to a Linux based PC. Via a gnome based graphical user interface (GUI) standard tasks like scanning can be easily performed. The GUI allows the user also to control highly advanced tasks like mapping and probing/manipulations. Standalone, i.e., without DSP hardware, GXSM can perform image analysis and multidimensional visualization.

GXSM is based on an object oriented (C++) and modular design. Since 15 years this structure was flexible enough to adapt any further development. Plug-ins are available for background correction, data analysis, math feature detection (via the OpenCV library), statistics, scan data im-/export, and Python scripting remote control. In particular, the hardware interface is also based on this plug-in structure allowing to adapt for various DSP hardware.

In this contribution we will report on the recent developments to adapt more flexible to different SPM configurations via a kind of hot-plug signal routing on the DSP level. We will also give a status report on the efforts to migrate GXSM to the latest GTK/Gnome environment.

O 37.5 Tue 18:15 Poster A

Role of orbital structure in High-resolution STM of molecules — •Ondřej Krejčí, Prokop Hapala, Martin Ondráček, and Pavel Jelínek — Institute of Physics , Academy of Sciences of the Czech Republic, Cukrovarnická 10, Prague, 16253, Czech Republic

Recently, we demonstrated that most features visible in high-resolution AFM images of molecules can be explained by simple mechanical model considering relaxation of an atomistic particle attached to the tip. On top of this, we introduced a simple model for calculating STM current considering only inter-atomic hoppings between relaxed atomistic particle and molecule [1]. The simple model is able to reproduce the main characteristics of high-resolution STM maps in close distance regime where the relaxation effects prevail. But since it completely neglects an electronic structure of the scanned sample, it fails at far distances where the electronic structure is dominating in the STM current. In this work, we implemented an efficient method for simulation of the high resolution STM images considering the molecular electronic structure and the atomistic particle relaxation as well. The method is able to reproduce observed contrast in both the close distance and the far distance regimes, including the gradual transition between them. It gives solid theoretical background for better understanding of high-resolution STM experiments.

[1]Hapala, P. et al., Phys. Rev. B 90, 085421 (2014).

O 37.6 Tue 18:15 Poster A

Performance of the mK-STM in the new Precision Laboratory — •Jacob Senkpiel[1], Bertholt Jäck[1], Matthias Eltschka[1], Wolfgang Stiepany[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

External vibrational and electromagnetic noise can yield a strong influence on the data quality of high precision experiments, like e.g., spectroscopic measurements of a superconducting gap with a scanning tunneling microscope (STM). Especially when pushing the frontier of resolution, these factors become a crucial point to consider. Here, an STM operating at a temperature of 10 mK for which Assig et al. [1] demonstrated an energy resolution of $\Delta E = 11.4 \pm 0.3\,\mu$eV is used for probing the smallest energy scales. The influence of external noise on this system was minimized by moving it from a standard lab environ-

ment to a specially designed Precision Laboratory. The performance of the mK-STM due to the optimized vibrational damping and high level electromagnetic shielding are presented.

[1] M. Assig et al., Rev. Sci. Instrum. **84**, 033903 (2013)

O 37.7 Tue 18:15 Poster A

Scanning Tunneling Microscopy-study of the interplay between light induced effects and tunnel current on the GaAs (110) surface — Philipp Kloth, •Katharina Kaiser, and Martin Wenderoth — IV. Physikalisches Institut, Georg-August Universität Göttingen, Germany

Using a low temperature Scanning Tunneling Microscope in combination with optical excitation we have studied the effect of the tunnel current on the surface photovoltage at the GaAs (110) surface. Spectroscopic measurements show that light-generated holes at the surface can be addressed by tunneling electrons, opening an additional tunnel channel into valence band states. Current dependent analysis reveals that this additional channel can be saturated. We have performed a detailed analysis of the saturation current as a function of the optical induced carrier density and the applied bias voltage. By changing the tunnel current we can actively switch between the dominant channel being either the optically induced channel or the common channel present under dark conditions. Moreover we show that the annihilation of holes in the valence band via the tunnel current affects the tip induced band bending at the surface.

O 37.8 Tue 18:15 Poster A

Bidirectional quantitative force gradient microscopy sensors — •Christopher F. Reiche[1], Julia Körner[1], Silvia Vock[1], Volker Neu[1], Bernd Büchner[1,2], and Thomas Mühl[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung IFW Dresden — [2]Institut für Festkörperphysik, Technische Universität Dresden

Dynamic scanning force microscopy (dSFM) is a versatile high spatial resolution method to study force-related surface properties of many different samples. We present our new approach of bidirectional force gradient microscopy, that includes lateral force microscopy and is compatible with usual dSFM equipment. We also provide methods for the quantitative evaluation of the force gradient data gathered with such a sensor. Furthermore, we discuss a novel approach to greatly enhance the dSFM sensor's sensitivity while still using conventional cantilever deflection detection. This signal amplification concept may also be adapted to many other oscillation based micro- and nanosystems and methods. Finally, we apply this concept to our magnetic force microscopy probes equipped with wear-resistant iron filled carbon nanotube tips, whose monopole-like stray field characteristics make them ideal for easy and reproducible quantitative field gradient measurements [1,2].

[1] F. Wolny, T. Mühl, U. Weissker, K. Lipert, J. Schumann, A. Leonhardt, and B. Büchner, Nanotechnology 21, 435501 (2010)

[2] T. Mühl, J. Körner, S. Philippi, C. F. Reiche, A. Leonhardt, and B. Büchner, Appl. Phys. Lett. 101, 112401 (2012)

O 37.9 Tue 18:15 Poster A

Study of Nano Particle Friction Forces on Silicon using Atomic Force Microscopy — •Hannah Lauer, Daniel Geiger, Susanne Rappl, and Othmar Marti — Institute of Experimental Physics, Ulm University

For a variety of applications and industrial processes friction forces of nano particles on substrates are of prime importance. These forces are influenced by humidity, temperature and ageing phenomena of the contact zone. To investigate these parameters, a model system consisting of a planar surface and spherical particles with well known material properties like silicon was introduced. The interaction force between particle and surface was measured by means of atomic force microscopy (AFM).

A measurement procedure was developed that enables the controlled displacement and tracking of particles. Particles were moved in contact mode AFM. The force exerted by the tip is given by the torsion of the cantilever. However, this procedure is restricted to the measurement of one out of two in-plane force components. Therefore, the mean particle-surface interaction force has to be determined by statistical data analysis. The trajectory of the particles was monitored by imaging the sample in tapping mode before and after particle movement.

Experiments in progress with silica particles demonstrate the importance of adhesion. They also indicate that the rest time is an important parameter.

O 37.10 Tue 18:15 Poster A

Four Tip Scanning Tunneling Potentiometry Facilitating Low Injection Currents — •Felix Lüpke, Stefan Korte, Vasily Cherepanov, and Bert Voigtländer — Peter Grünberg Institut (PGI-3), Forschungszentrum Jülich, 52425 Jülich, Germany, and JARA-Fundamentals of Future Information Technology

We present a multi-tip scanning tunneling potentiometry implementation. While two of the four tips are used to inject a current into a sample, the third tip is scanned across the surface, recording topography and local electrochemical potential quasi-simultaneously by an interrupted feedback loop [1]. The fourth tip is used as a voltage reference probe. Choosing a distance in the μm range for the injection tips results in the current to be almost exclusively injected into the nanostructure to be studied. As a result, a small amount of current $\sim\mu$A results in a substantial amount of voltage drop $\sim$mV. The small currents needed and the straightforward measurement procedure make this application easy to implement in similar four tip setups with a minimum of hardware adjustments. The capability of the presented setup is demonstrated by experimental results on Si and Bi surfaces.

[1] T. Druga, et al., Rev. Sci. Instrum. 81, 083704 (2010)

O 37.11 Tue 18:15 Poster A

Scanning Tunneling Microscope for 37T Magnetic Field — •Jan W. Gerritsen[1], Suruchi Singh[1,2], Wei Tao[2], Bas L. M. Hendriksen[1], Peter C. M. Christianen[2], Ulrich Zeitler[2], and Jan C. Maan[2] — [1]Institute for Molecules and Materials, Radboud University Nijmegen, Netherlands — [2]High Field Magnet Laboratory, Institute for Molecules and Materials, Radboud University Nijmegen, Netherlands

We are adapting [1] and developing a scanning tunneling microscope (STM) that will work in magnetic fields up to 37T [2]. This unique instrument should enable us to image surfaces and nanostructures with very high resolution and to perform local electronic spectroscopy (STS) in hitherto unexploited magnetic field ranges. State-of-the-art STMs in superconducting magnets typically operate up to 15T. Our STM works inside the 32mm bore of a Bitter magnet with fields up to 37T and at liquid helium temperatures (1.4K). The challenge here is to develop an STM for these extreme environments. The 140l/sec cooling water for the magnet and 40kA current in the coil lead to a very bad acoustic and vibration environment for scanning probe microscopes. In our design, materials and vibration isolation for the STM head have been chosen to be compatible with these extreme conditions inside the magnet. I will show the design as well as the performance of the STM at high fields and low temperatures in topographic images and dI/dV spectroscopy experiments.

[1] J.G.A. Dubois et al., Rev. Sci. Instrum. 66, 4146 (1995)

[2] www.ru.nl/hfml/

O 37.12 Tue 18:15 Poster A

A low-vibration SPM system for the mK-regime — •P. Borgens, A. Raccanelli, V. Cherepanov, F.P. Coenen, F.S. Tautz, and R. Temirov — Forschungszentrum Jülich GmbH, Deutschland

We report the progress in development of a mk-STM system cooled by adiabatic demagnetisation refrigeration (ADR). Our system features a 4He cryostat with 1K pot able of reaching 1.2K. The magnetic cooling unit uses a 2-stage ADR pill with the first stage precooling the wiring of the STM to 500mK and the second stage providing cooling to the base temperature of down to 35mK. The 1K pot can be operated by either a mechanical pumping stage or by a high capacity noise-free sorption pump that is able of providing the pumping for up to 100h. The specially developed KoalaDrive STM provides high stability against mechanical vibrations. For further reduction of the noise the entire system is located in a electromagnetically shielded and vibrationally isolated room.

O 37.13 Tue 18:15 Poster A

3D structure determination of individual molecules by means of Atomic Force Microscopy — •Florian Albrecht[1], Coral Herranz-Lancho[2], Niko Pavliček[1,3], Mario Ruben[2], and Jascha Repp[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Institute of Nanotechnology (INT), Karlsruhe Institute of Technology (KIT), 76344 Eggenstein-Leopoldshafen, Germany — [3]IBM Research - Zurich, Säumerstrasse 4, 8803 Rüschlikon, Switzerland

Functionalizing the tip of an Atomic Force Microscopy (AFM) with a single CO molecule has been shown to be a powerful tool to deter-

mine the geometric structure of individual molecules [1-3]. So far this technique was applied to molecules with only little deviations from a planar shape. We performed AFM measurements in a low temperature combined scanning tunneling and atomic force microscope with functionalized tips. We extract the geometric structure of a non-planar molecule from a 3D data set [4, 5]. Thermal annealing of the sample leads to an on-surface reaction with different products, the identification of which is exploited to support the structure assignment of the 3D molecular structure of the reactant [2].

[1] L. Gross, et al., Science 325, 1110 (2009)
[2] D. G. de Oteyza, et al., Science 340, 1434 (2013)
[3] N. Pavliček, et al., Phys. Rev. Lett. 108, 086101 (2012).
[4] F. Mohn, et al., Appl. Phys. Lett. 99, 53106 (2011)
[5] B. Schuler, et al., Phys. Rev. Lett. 111, 106103 (2013)

O 37.14 Tue 18:15 Poster A

Influence of higher flexural modes in piezoresponse force microscopy — •Valon Lushta[1], Thomas Göddenhenrich[1], Bernhard Roling[2], and André Schirmeisen[1] — [1]Institut für Angewandte Physik, Justus-Liebig-Universität Gießen, D-35392 Gießen — [2]Physikalische Chemie,Philipps-MarburgUniversität Marburg, D-35032 Marburg

Piezoresponse force microscopy, based on contact resonance of the cantilever, is a useful tool for probing the local piezoelectric properties on ferroelectric materials. Dual AC resonance tracking and band excitation techniques have been used to investigate the local deformation and polarization of ferroelectric domains. Measurements are performed at different flexural eigenmodes of the cantilever. The results of local amplitude and phase hysteresis loops reveal, that an excitation of higher flexural modes is less sensitive to a parasitic non localized capacitive force contribution between cantilever and sample surface.

O 37.15 Tue 18:15 Poster A

Role of the tip in photon emission from Au surfaces in Scanning Tunneling Microscopy — •Berk Zengin, Hakki Tunç Çiftçi, and Oğuzhan Gürlü — Istanbul Technical University, Istanbul, Turkey

Photon emission induced by tunnelling current has been studied by means of photon scanning tunnelling microscopy (pSTM) since the advent of STM. Several reports had been published on the proper conditions of photon emission from the tip-Au surface tunnel junction. It has been shown that the tip material and its geometry play a serious role on the emitted photons. Yet, the variations on the Au surface as well as the photon emission maps were mainly related to the surface conditions. Our results show that tip cleanliness is one of the key reasons in the observed topography as well as on the photon maps. Moreover, the tunnelling current induced electromigration is also one of the events that happen at relatively high tunnelling current values. By use of different tips and tip preparation procedures we have shown that on similar thermally evaporated gold films, different results can be obtained by pSTM. Our results show that the results attained with pSTM cannot be interpreted without proper tip calibration.