O 71: Scanning Probe Techniques and New Experimental Methods

Time: Wednesday 18:15–20:30 Location: Poster A

O 71.1 Wed 18:15 Poster A

A 30mK dilution fridge UHV SP-STM (9/4T) housed in the new SPIN Laboratory — •Andreas Eich[1], Henning von Allwörden[1], Jan Hermenau[2], Andreas Sonntag[2], Jan Gerritsen[1], Daniel Wegner[1], and Alexander Khajetoorians[1] — [1]Institute for Molecules and Materials, Radboud University, Nijmegen, The Netherlands — [2]Institute of Nanostructure and Solid State Physics, Hamburg University, Hamburg, Germany

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, spin-polarized scanning tunneling spectroscopy (SP-STS) and inelastic STS (ISTS), can address single spins at the atomic scale with unprecedented precession.

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, we demonstrate a newly designed 30mK dilution fridge based UHV spin-polarized microscope in a vector magnetic field, capable of atomic spin detection and atomic manipulation. Our design consists of tip/sample exchange at cold temperatures as well as cold material deposition and features extremely low 4He consumption with a long hold time. To prevent any external perturbation of the measurements, the system is housed in the new ultra-quiet SPIN laboratory (IMM-RU) featuring a 150 ton damped foundation and proper acoustical and RF shielding.

O 71.2 Wed 18:15 Poster A

Design of a low-temperature scanning tunneling microscope with photon collection system — •Moritz Winkler[1], Lukas Gerhard[1], Kevin Edelmann[2], and Wulf Wulfhekel[2] — [1]Institute of Nanotechnology, Karlsruhe Institute of Technology (KIT) — [2]Physikalisches Institut, Karlsruhe Institute of Technology (KIT)

We provide a new design for a low-temperature ultra-high vacuum scanning tunneling microscope (STM) with a photon collection unit that guides the collected light into a spectrometer. The design has the potential of achieving a high photon yield by using a 3D-printed miniature parabolic mirror that collects photons from a large solid angle close to the tunnel junction. The photon yield is further increased by limiting the optical path to a single optical fiber. The STM will be equipped with an absolute position determination system of the tip in order to approach and examine structures manufactured by lithographic processes. By Joule-Thomson expansion of helium, the STM will operate at a temperature of around 1 K [1].

[1] A compact sub-Kelvin ultrahigh vacuum scanning tunneling microscope with high energy resolution and high stability L. Zhang, T. Miyamachi, T. Tomanić, R. Dehm and W. Wulfhekel

O 71.3 Wed 18:15 Poster A

Validation and automatization of controlled molecular manipulation techniques on an STM — •Aizhan Sabitova[1,2,3], Philipp Leinen[1,2], Matthew F.B. Green[1,2], Taner Esat[1,2], F. Stefan Tautz[1,2], Christian Wagner[1,2], and Ruslan Temirov[1,2] — [1]Peter Grünberg Institut (PGI-3), Forschungszentrum Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology — [3]National Laboratory Astana, Kazakhstan

The success of scanning probe microscopy (SPM) based hand-controlled single molecule manipulation technique [1,2] relies upon three main components. These are high-precision positioning of the SPM tip, a hand motion tracking system [1], and virtual reality goggles displaying the motion trajectory and feedback signals in real time [2]. With this, reproducible extraction of molecules from a closed monolayer on a metal surface and statistical determination of successful trajectories was achieved. Until now these experiments were performed on a low-temperature non-contact atomic force/scanning tunneling microscope (LT NC-AFM/STM), that has tunneling current as well as the frequency shift of the tuning fork sensor as feedback signals. Here, we study how successful trajectories can be transferred to an instrument without AFM capability (LT STM) and automatized to enable fast and efficient manipulation within monolayers.

[1] M.F.B. Green *et al.*, Beilstein J. Nanotechnol. 2014, **5**, 1926-1932
[2] P. Leinen *et al.*, Beilstein J. Nanotechnol. 2015, **6**, 2148-2153

O 71.4 Wed 18:15 Poster A

Fast electronic pump-probe spectroscopy using shaped sub-nanosecond pulses — •Gregory McMurtrie[1,2], Jacob Burgess[1,2], Steffen Rolf-Pissarczyk[1,2], and Sebastian Loth[1,2] — [1]Max-Planck Institut für Struktur und Dynamik der Materie — [2]Max-Planck Institut für Festkörperforschung

Pump-probe schemes make it possible to measure fast dynamical processes with the scanning tunneling microscope (STM). Electronic pump-probe spectroscopy excites and detects dynamics using voltage pulses [1] with the time scale being set by the speed at which the voltage can be changed at the tunnel junction [2], [3].

We use time domain reflectometry to measure the transmission characteristics of a low-temperature STM. Damping in the cabling and standing waves at various points of the transmission line smear the edges of the pump and probe pulses and limit the achievable time resolution. By extracting amplitude and phase information from the reflectometry measurements it is possible to compensate these imperfections and create a shaped input pulse which will have sharp edges at the STM tunnel junction. This process can shape pulses with a bandwidth of up to 3 GHz, enabling sub-nanosecond time resolution.

Pushing electronic pump-probe spectroscopy beyond the nanosecond range will enable a wide range of experiments that harness the strong interaction of electrons with spin, charge and vibration excitations.

[1] S. Loth, et al., Science 329 1628 (2010).
[2] C. Saunus, et al., Appl. Phys. Lett. 102 051601 (2013).
[3] C. Grosse, et al. Appl. Phys. Lett. 103 183108 (2013).

O 71.5 Wed 18:15 Poster A

Combining Scanning Tunneling Microscopy and pulsed optical excitation — •Judith von der Haar, Philipp Kloth, Terence Thias, Ole Bunjes, and Martin Wenderoth — IV. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

The combination of Scanning Tunneling Microscopy (STM) and optical excitation merges two of the most successful experimental techniques in solid-state physics. Especially pump-probe excitation gives the prospect to resolve surface dynamics on the atomic scale. A serious challenge of optical excitation in STM is controlling the thermal load at the tunnel junction. We present a very compact and versatile laser setup that addresses various requirements of this experimental technique. First of all, the laser source must provide a very low-noise and stable output power. Next, in order to find the spot of maximum excitation in a standardized manner, it is important to implement 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. At last, standard pump-probe pulses must be transformed into complex laser pulse patterns [1]. Using an optical modulator with a bandwidth in the gigahertz range and a high frequency function generator, we process the continuous wave laser beam into nanosecond pulses. [1] Terada et al., Nature Photonics, 4(12), 2010.

O 71.6 Wed 18:15 Poster A

New Directions in Tip-Enhanced Near-Field Optical Microscopy — •Julia Janik, Nina Mauser, and Achim Hartschuh — Department Chemie and CeNS, LMU München, Germany

The characterization of nanostructures with high spatial resolution and detection sensitivity can be achieved by tip-enhanced near-field optical microscopy (TENOM) [1].

We report on our efforts to extend this method into further directions. One direction is the application of tip-enhancement to photovoltaic and light-emitting devices as suggested in [2]. We obtained the first high-resolution photocurrent images of carbon nanotube devices using a metal tip to locally enhance optical-to-electrical transduction [3]. We show that the efficiency of the reversed process leading to electroluminescence can be increased as well.

Furthermore we are focusing on the implementation of tip-enhanced near-field optical microscopy at low temperatures (5 K). Therefore we present a new microscope design based on a solid immersion lens configuration providing very high collection angles and efficiencies. We acknowledge financial support by DFG, NIM and the ERC (NewNanoSpec).

[1] N. Mauser, A. Hartschuh, Tip-enhanced near-field optical mi-

croscopy, Chem. Soc. Rev. 43, 1248 (2014).

[2] P. Bharadwaj, B. Deutsch, L. Novotny, Optical Antennas, Adv. Opt. Photon. 1, 438 (2009).

[3] N. Mauser et al., Antenna-Enhanced Optoelectronic Probing of Carbon Nanotubes, Nano. Lett. 14, 3773 (2014).

O 71.7 Wed 18:15 Poster A

AFM for TERS: Development of probe heads for Tip-Enhanced-Raman-Spectroscopy — •Jalmar Tschakert[1], Thomas Göddenhenrich[1], André Schirmeisen[1], Marcel Weinhold[2], Thomas Sander[2], and Peter J. Klar[2] — [1]Institut für Angewandte Physik, Justus-Liebig-Universtiät Gießen — [2]I. Physikalisches Institut, Justus-Liebig-Universität Gießen

Tip-Enhanced-Raman-Spectroscopy (TERS) has become a powerful tool in material science to combine topographic and chemical imaging. Our experimental TERS setup is based on an inverted optical microscope with an x,y scan stage for scanning transparent samples. Two different type of AFM heads are developed: one with a cantilever and a fiber-optical interferometer and the other based on a quartz-tuning-fork. Both designs are compact and give a good long time thermal and mechanical stability without the need of an additional damping mechanism. Contact and non-contact measurements are controlled via GXSM software with a Soft-dB-Mk3-DSP board leading to a flexible scan control with different AFM probes as well as the option to add own user specific tasks.

O 71.8 Wed 18:15 Poster A

Hexaboride preparation techniques for Scanning Tunneling Microscopy studies — •Philipp Buchsteiner[1], Geetha Balakrishnan[2], David P. Young[3], and Martin Wenderoth[1] — [1]IV. Physikalisches Institut, Georg-August-Universität Göttingen, Germany — [2]Department of Physics, University of Warwick, United Kingdom — [3]Department of Physics and Astronomy, Louisiana State University, USA

Hexaborides (LaB6, etc.) are widely for technical applications, e.g. Electron Microscopy. Although the surface properties for these applications are important, few Scanning Tunneling Microscopy (STM) studies had been carried out [1,2]. Investigating surfaces with atomic resolution requires sample preparation ensuring atomically flat areas. Therefore different techniques have been developed for two types of single crystals. Samples of about 3mm length were glued onto GaAs. Here the hexaboride (100)-plane is orientated parallel to the GaAs(110) planes. After cleavage, Atomic Force Microscopy (AFM) studies showed large flat terraces with step heights ranging from a single bulk lattice constant of 0.4nm up to some monolayers. Low-energy Electron Diffraction (LEED) confirmed a non-reconstructed 1x1 surface periodicity. Larger samples with a few cm length and some mm in diameter were cut along the (100)-planes using a diamond wire saw to rectangular pieces. Here no GaAs carrier was obligatory and also large flat surface areas were verified with AFM.

[1] J.S. Ozcomert, M. Trenary, Surf. Sci., 265 (1992), [2] Yee, M. M. et al. arXiv.org, 1308.1085v1 (2013)

O 71.9 Wed 18:15 Poster A

Solution AFM Studies of Molecule Crystals: Exploiting Photon Pressure — •Sven Kraft, Heinrich Behle, Kai Wardelmann, Mohammadreza Bahrami, Björn Vogler, Mirjam Samelin, Semjon Köhnke, Boris Hage, Ingo Barke, and Sylvia Speller — University of Rostock, Institute of Physics, 18059 Rostock, Germany

Atomic Force Microscopy in liquids is an important tool for imaging processes in molecular layers and films. Dynamic AFM usually suffers from distorted resonance curves of the cantilever oscillation in the medium. Driving the cantilever via photon pressure is an option to improve the cantilever oscillation and acquire topographies in solutions in dynamic mode. We aim to test this approach with the aggregation and dissolution of molecule crystals in a number of solvents, in order to gain insight into the internal structure of such crystals.

[1] G.C. Ratcliff, D.A. Erie, R. Superfine, Appl. Phys. Lett. **72**, 1911 (1998)

[2] D. Ramos, J. Tamayo, J. Mertens, and M. Calleja, J. Appl. Phys. **99**, 124904 (2006)

O 71.10 Wed 18:15 Poster A

A Superconducting Tunneling Junction (STJ) Detector for Soft X-Ray Absorption Spectroscopy at 50mK — •Ivan Baev[1], Jan-Hendrik Rüscher[1], Jens Viefhaus[2], Michael Martins[1], and Wilfried Wurth[1,2] — [1]Physics Department, University of Hamburg — [2]DESY Photon Science, Hamburg

Soft X-Ray absorption spectroscopy (XAS) is an important technique at synchrotrons nowadays that allows to investigate electronic and magnetic properties in an element specific way. The investigation of non-conductive, soft organic or buried materials can't be carried out in total electron yield. In these cases an efficient fluorescence detector is needed to perform XAS measurements in partial fluorescence yield (PFY). The STJ detector is capable of count rates as high as 10 kcps per 100 μm^2 pixel size with an energy resolution of approximately 50eV for 1.5 keV photons. The STJ is furthermore integrated into a 50mK cryostat for XAS measurements at the P04 beamline at Petra III, DESY. We will present first measurements on a model system.

O 71.11 Wed 18:15 Poster A

Construction of a movable UHV chamber for in situ sample preparation of molecules on TiO2 — •Steffen Bornemann, Bernhard Spicher, and Martin Wenderoth — IV. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

TiO2 is an important material for chemical catalysis which e.g. can be applied in photocatalytic water splitting [1]. In order to investigate this system with different surface sensitive techniques, we have constructed a movable UHV chamber for in situ sample preparation of molecules on the TiO2(110) rutile surface. Samples can be transferred to different low temperature scanning tunneling microscopes as well as to an analysis chamber equipped with a low energy electron diffraction (LEED) and an Auger electron spectroscopy (AES) setup. TiO2 substrates can be prepared by direct current heating, by electron beam heating and by ion beam sputtering. The chamber is equipped with an external evaporator for molecule deposition from a liquid phase like methanol and with an electrospray deposition system for more complex, non-volatile molecules. Moreover, sub-monolayer of metals can be deposited from different electron-beam evaporators. After several cycles of sputtering and heating up to 600°C we could verify the 1x1 reconstruction of the clean TiO2(110) surface after in situ transferring the samples to the LEED setup [2]. Ex situ characterization by atomic force microscopy shows terraces connected by single and multiple atomic steps.

[1] M. Ni, M.K.H. Leung, D. Y.C. Leung, K. Sumathy, Renewable and Sustainable Energy Reviews 11, 401 (2007) [2] Hiroshi Onishi, Yasuhiro Iwasawa, Surface Science Letters 313, 783 (1994)

O 71.12 Wed 18:15 Poster A

Following ultra thin film growth by in-situ High Energy X-ray Diffraction — •Florian Bertram, Olof Gutowski, and Uta Ruett — DESY Photon Science, Notkestrasse 85, 22607 Hamburg, Germany

High energy x-ray diffraction ($\approx$ 80 keV) is a versatile tool to record diffraction patterns from surfaces, interfaces, and ultra-thin films at remarkable high speed compared to conventional diffraction measurements ($\approx$ 15 keV). Due to the high photon energy diffraction angles become smaller, which results in a much flatter Ewald's sphere in a given q-range. Therefore, crystal truncation rods (CTR's) can be recorded in grazing incident geometry by a simple rotation of a few degree with a 2D detector at a fixed position.

We demonstrate how this method can be used to record real time diffraction data during MBE growth of ultra-thin films. Here, the growth of magnetite (Fe_3O_4) on MgO(001) was studied. We could follow the evolution of the CTR's during growth with a time-resolution of 5 sec.

O 71.13 Wed 18:15 Poster A

Reprocessing with radial shock waves — Philipp Weil, •Robert Ossig, Hans-Günter Hloch, and Jürgen Bohnen — wfk - Cleaning Technology Institute, D-47807 Krefeld, Deutschland

We present a novel application to utilise radial shock waves as an effective, sustainable, hygienic and gentle method to clean sensitive surfaces (e.g. textiles). Usually, shock waves are used for medical applications, e.g. to break up kidney stones or to promote bone healing after complicated fractures. Radial shock waves are generated using the ballistic principle, where a small projectile is fired at high speed upon a metal applicator, from which radial shock waves expand into an homogenous medium (usually water). Directly behind the wave front peak pressures of up to 100 MPa and, thus, high energy input per area is achieved. While impinging on a surface, a part of the shock wave is reflected back into the water and interacts with the next impinging wave. This leads to high mechanical interactions directly at the surface, which explain

the efficient destruction of kidney stones in soft tissue. In this contribution we discuss relevant interactions between shock waves, textiles and soils and present shock wave parameters (e.g. frequency, distance to surface) for optimum soil removal and minimum surface damage. Furthermore, a comparison of the new method with typical methods, which are in use today, are presented.

O 71.14 Wed 18:15 Poster A

Laser desorption of chiral molecules — •Farinaz Mortaheb, Joern Lepelmeier, Kerstin Wachinger, Aras Kartouzian, Ulrich Boesl, and Ulrich Heiz — Chair of Physical Chemistry, Lichtenbergstraße 4, 85748 Garching

Laser desorption enables the vaporization of non-volatile and thermally unstable molecules without fragmentation and thus allows to analyze large bio- and organic molecules in the gas phase. Desorbed molecules can be analyzed mass spectroscopically by REMPI-ToF, which can be combined readily with circular dichroism to investigate the chiroptical properties of non-volatile chiral molecules in the gas phase without any interference from solvent molecules (as in solutions) or diastereomeric partner molecules. Using the example of Binol, and a prototype experimental apparatus, an optimized sample preparation recipe was found to optimize the laser desorption yield of neutral molecules. The high signal intensity and stability attained in our lab pave the way for further experiments using a purpose designed setup.

O 71.15 Wed 18:15 Poster A

Identification of nanoscale phases using Low Energy Electron Microscopy. — •Martin Hoppe, Jan Höcker, Jens Falta, and Jan Ingo Flege — Universität Bremen, Germany

Low Energy Electron Microscopy (LEEM) is an established method to investigate surface structures and morphologies with a lateral resolution in the few nanometer range. The main benefits are the *in situ* capabilities of the instrument enabling surface monitoring during manipulation such as growth and chemical reactions. In LEEM, crystal phases differing in structure or chemical composition may exhibit different intensities at a given energy. But, this does not allow for a definite identification especially on very heterogeneous surfaces. The latter can be achieved using intensity-voltage (I(V)) curves as a reliable fingerprint for each phase.[1] We show that the correlation coefficient or R_2-factor[2] can be used to compare unknown LEEM-I(V) curves to reference spectra and thus to distinguish phases on the 10 nm scale. Performing a pixel-wise automated comparison, 2D maps of the surface phases can be generated and, in a dynamic I(V)-LEEM experiment, their development during sample manipulation can be monitored. This new method will be demonstrated using examples from ruthenium oxidation[3] and chemical reactions at cerium oxide surfaces[4].

[1] *J. I. Flege et al.*, Phys. Status Solidi RRL **6**, 463 (2014)
[2] *M.A. Van Hove, W. H. Weinberg, and C.-M. Chan*, Low-Energy Electron Diffraction, Springer (1986)
[3] *J. I. Flege et al.*, ACS Nano **9**, 8468-8473 (2015)
[4] *J. Höcker et al.*, Adv. Mater. Interfaces, in press (2015)

O 71.16 Wed 18:15 Poster A

Reliability of LEED analyses for complex systems — •Lutz Hammer, Pascal Ferstl, and M.Alexander Schneider — Lehrstuhl für Festkörperphysik, Universität Erlangen-Nürnberg

The correspondence of experimental and calculated best-fit intensity spectra of a LEED structure analysis is quantitatively expressed by means of reliability factors. Most frequently the Pendry R-factor R_P is applied nowadays. Best-fit values in the range R_P = 0.2 - 0.3 or even somewhat larger are generally accepted as a proof for the correctness of the underlying structural model. In the present contribution it is shown that this only holds for structurally quite simple systems. For more complex structures, in contrast, the distinction between similar models which only vary by the presence (or absence) of very few atoms within the (large) unit cell requires a significantly better level of spectral correspondence ($R_P \ll 0.2$).

In the case study presented here different structural variations of the surface reconstruction of $Fe_3O_4(100)$ are investigated, whereby the key features of the reconstruction model (subsurface iron vacancies and interstitials) are systematically either neglected or varied in position. It is shown that those crystallographically wrong structures still produce R-factors in the range R_P = 0.2 - 0.3, occasionally even lower. The reason for this structural insensitivity lies qualitatively in the relatively small scattering contribution of a particular atom to the total wave field produced by a large surface unit cell. Approaches to improve the quality of a LEED intensity analysis as well as consistency checks to detect incomplete structural models are presented and discussed.

O 71.17 Wed 18:15 Poster A

Source Development for Ultrafast Transmission Electron Microscopy — •Nora Bach, Armin Feist, Reiner Bormann, Sascha Schäfer, and Claus Ropers — IV. Physical Institute, University of Göttingen, Göttingen

Ultrafast transmission electron microscopy (UTEM) is a novel experimental technique that combines a nanoscale spatial with femtosecond temporal resolution [1]. The imaging and diffraction resolution in this technique is governed by the brightness of the laser-driven electron source used [2].

Here, we present the design and implementation of an advanced UTEM instrument based on the modification of a commercial Schottky Field emission TEM [3]. Single-photon photoemission from a tip-shaped ZrO/W(100) emitter is employed, yielding a spectral bandwidth of 0.6 eV, a low intrinsic emittance of about 5 nm·mrad, and an electron probe size down to 1.5 nm.

We characterize the temporal structure of the electron pulses by electron-photon cross-correlation and obtain a pulse width of 300 fs (full-width-at-half-maximum). The demonstrated high beam quality of the source will enable new applications in the study of nanoscale ultrafast dynamics, including ultrafast electron holography and phase-contrast imaging.

[1] A. H. Zewail, Science 328, 187 (2010).
[2] M. Gulde et al., Science 345, 200 (2014).
[3] A. Feist et al., Nature 521, 200 (2015).

O 71.18 Wed 18:15 Poster A

VUV photon detection with acetone counters for inverse photoemission — •Christian Thiede, Iris Niehues, Anke B. Schmidt, and Markus Donath — Physikalisches Institut, Universität Münster

Inverse photoemission experiments in the isochromat mode require the use of band-pass photon detectors. The bandpass behavior is usually realized by combining the photoionization threshold of a suitable counting gas (high pass) with the transmission characteristics of an alkaline earth fluoride window (low pass). Since inverse photoemission intrinsically suffers from a low photon yield, an optimized detector efficiency is crucial for this technique. In particular, the bandpass width and the efficiency depend on the transmission characteristics of the entrance window [1], the detection gas type and pressure, the readout electronics and the counter geometry. We studied these parameters for the well-known combination of CaF_2/acetone. We provide a recipe how to operate the detector in proportional as well as in Geiger-Müller mode. [1] Thiede *et al.*, Rev. Sci. Instrum. **86**, 085101 (2015)

O 71.19 Wed 18:15 Poster A

MOKE UHV-Setup — •Vivienne Bippus, Christian Klump, Sani Noor, Christian Urban, and Ulrich Köhler — Experimentalphysik IV, Arbeitsgruppe Oberflächenphysik, Ruhr-Universität Bochum, Germany

We present a UHV-setup for measuring the magneto-optic Kerr-effect (MOKE) at variable temperatures. The setup is integrated with a number of metal and semiconductor MBE-sources pointing at the sample in the MOKE position. Therefore, in situ MOKE measurements can be carried out simultaneously during the growth process of the sample. The data acquisition software is able to record the temporal evolution of magnetic hysteresis curves. A cryostat fitted with the sample holder offers substrate temperatures down to 4.2 K. Hence, temperature, layer thickness and crystal orientation dependent measurements with a resolution of a mono-layer are possible. The poster will present details on the structure and the control of the different components used, together with examples of the coverage dependent magnetic behaviour of ferromagnetic layers on semiconductors.