O 79: Scanning Probe Techniques: STM

Time: Thursday 10:30–13:00 Location: HE 101

O 79.1 Thu 10:30 HE 101

Landau quantization in graphite studied by STM in a 30 Tesla magnet — •Bas Hendriksen[1], Suruchi Singh[1,2], Wei Tao[2], Jan Gerritsen[1], Uli Zeitler[2], Peter Christianen[2], and Jan Kees Maan[2] — [1]Institute for Molecules and Materials, Radboud University, Nijmegen, The Netherlands — [2]High Field Magnet Laboratory and Institute for Molecules and Materials, Radboud University, Nijmegen, The Netherlands

Experiments in high field magnet laboratories play an important role in the discovery of new electronic phenomena in solid state materials. Superconducting laboratory magnets are typically limited to fields up to 20 Tesla and it requires resistive Bitter magnets at dedicated large-scale facilities to go to fields as high as 37 Tesla. In this talk I will present our pioneering experiments with a scanning tunneling microscope, which operates in the 30 Tesla Bitter magnets of the High Field Magnet Laboratory (HFML) user facility in Nijmegen. This STM provides access to atomic- and nanoscale physics in the high magnetic field regime, where the magnetic length is of the order of a few nanometers and energy level splitting is significant.

I will demonstrate the STM's performance in the noisy environment of the magnets (140l/s cooling water, 40kA magnet current). I will show our first results of Landau level spectroscopy in a graphite sample at 4.2K, which exhibits the characteristics of Landau levels in graphene. I will discuss how this is a first step towards solving the mystery of the quantum Hall effect in graphene at room temperature (K.S. Novoselov et al. Science 315 (2007) 1379).

O 79.2 Thu 10:45 HE 101

Determining absolute values of the critical Josephson current from Josephson STM experiments — •Berthold Jäck[1], Matthias Eltschka[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

In Josephson junctions the critical Josephson current i_0 directly relates to the superconducting order parameter. Hence, Josephson Scanning Tunneling Microscopy (JSTM) has high potential as a local probe of superconductor physics, addressing questions such as the pairing symmetry of non-conventional superconductors [1]. However, extracting absolute values for i_0 from experiments renders difficult since both the surrounding environment and temperature strongly change the junction characteristics. Here, we present results on the Josephson effect in vanadium tunnel junctions using an STM that operates at a temperature of 15 mK [2]. Employing $P(E)$-theory as given in Reference [3], which considers the coupling to the environment and temperature effects, we can fit our experimental data. From this fit we find values of i_0 being in good agreement to values calculated from theory [4], which represents a fundamental step towards the realization of JSTM.

[1] J.Smakov *et al.*, Phys. Rev. B **64**, 212506 (2001)
[2] M.Assig *et al.*, Rev. Sci. Instrum. **84**, 033903 (2013)
[3] G.-L.Ingold and H.Grabert, Europhys. Lett. **14**, 371 (1991)
[4] V.Ambegaokar and A.Baratoff, Phys. Rev. Lett. **10**, 11 (1963)

O 79.3 Thu 11:00 HE 101

Laser induced charge dynamics at the GaAs(110) surface investigated with Scanning Tunneling Microscopy — •Philipp Kloth, Katharina Kaiser, Ole Bunjes, Terence Thias, and Martin Wenderoth — IV. physikalisches Instut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Using optical pump probe excitation and Scanning Tunneling Microscopy we have studied the carrier dynamics at the GaAs(110) surface. We have developed a compact and convenient laser setup that provides any Tunnel Microscope with time resolution in a range from nanoseconds to microseconds. Detailed spectroscopic analysis shows that photo-excited charge carriers, trapped in a very local region beneath the STM tip, contribute to the tunneling current. By changing the bias voltage or the set point current we are able to actively select whether this optically induced tunnel channel or the common tunneling channel, present under dark conditions, dominates the overall tunneling process. This allows us to distinguish between the dynamics of inter-band recombination of the electron and hole pairs and the dynamics of the charge annihilation of the photo-excited carriers via the tunnel current.

O 79.4 Thu 11:15 HE 101

A Self-Tracking Spectroscopic Method for Surface Photovoltage Measurements on Semiconducting Surfaces — •Kevin Oldenburg, Stefan Polei, Sylvia Speller, and Ingo Barke — University of Rostock, Institute of Physics, 18051 Rostock, Germany

Spatially resolved surface photovoltage (SPV) measurements by means of scanning tunneling microscopy enable access to the local band topology at semiconductor surfaces. In the presence of metallic surface states the SPV can be easily obtained from I(V) curves under continuous wave (cw) illumination [1]. For semiconducting surfaces, however, the weak Fermi level pinning leads to tip induced band bending [2] that is difficult distinguish from the effect of the SPV under cw conditions. We present a new experimental approach that automatically keeps the electric field between tip and sample constant with respect to the light intensity by tracking the SPV simultaneously with its measurement. The method is benchmarked for the case of Si(100)-c(4x2) at different bulk doping levels. The role of tip-induced band bending is discussed in comparison to alternative techniques.

[1] K. Sell et al., Phys. Stat. Sol. B 247, 1087 (2010).
[2] M. McEllistrem, G. Haase, D. Chen, and R. J. Hamers, Phys. Rev. Lett. 70, 2471 (1993).

Invited Talk O 79.5 Thu 11:30 HE 101

Spin Excitations and Correlations in Individual Molecules on Surfaces — •Markus Ternes — Max-Planck-Institute for Solid State Research, Heisenbergstr. 1, 70569 Stuttgart, Germany

Scanning probe microscopes and, in particular, the scanning tunneling microscope have been shown to be very powerful tools for the investigation of magnetism at the atomic and molecular scale.

In my talk I will discuss recent results on an all organic radical molecule with $S = 1/2$ and on cobalt-hydrogen complexes adsorbed on a strongly anisotropic surface. In these systems we detect the quantum magnetism by inelastic spin-flip excitations and the emergence of correlation effects which are due to the interactions between the localized spin and the substrate electrons. I will show that the results can be well understood by employing third-order scattering theory using a Kondo Hamiltonian which also enables a deeper insight into spectroscopic features measured on single atoms. Expanding this model by coupling the spin to a dissipative quantum bath, enables to understand the experimentally observed interplay between magnetic anisotropy and the exchange interactions with the substrate. Furthermore, I will show that by changing the coupling between individual spins the emerging spectroscopic features enables to determine the spin-spin correlation quantitatively.

O 79.6 Thu 12:00 HE 101

Scanning Tunneling Potentiometry: Magnetotransport on the Atomic Scale — Philip Willke, •Thomas Kotzott, Anna Sinterhauf, and Martin Wenderoth — IV. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

The method of scanning tunneling potentiometry (STP) has been introduced by Muralt and Pohl [1] as a technique for mapping the electrochemical potential locally and has been developed continuously [2]. Here we present a new STP setup with a home-built low-temperature STM operating at 6K and applicable magnetic field of up to 6T. We study high-resolution STP of scattering centers on a sub-nanometer scale, especially the spatial evolution of the electrochemical potential for the graphene monolayer/bilayer junction. We perform magnetotransport STP measurements mapping the local electrochemical potential as a function of the applied magnetic field. This allows us to identify localized and delocalized contributions to the magnetoresistance in epitaxial-grown graphene. This work was supported by DFG priority program 1459 "Graphene".

[1] P. Muralt, D. W. Pohl, Appl. Phys. Lett. 48, 514 (1986)
[2] T. Druga, M. Wenderoth, J. Homoth, M. A. Schneider and R. G. Ulbrich, Rev. Sci. Instrum. 81, 083704 (2010)

O 79.7 Thu 12:15 HE 101

Inelastic tunneling through a hydrogen molecule — •Matthias

Stocker, Simon Röger, and Berndt Koslowski — Universität Ulm, Ulm, Deutschland

Recent studies showed strong characteristic features in Inelastic Electron Tunneling Spectroscopy if molecular hydrogen was physisorbed on a metallic substrate surface [1,2]. In the low energy regime not only huge inelastic signals were measured but also a step-like change of the tunneling current corresponding to a strong negative differential conductivity appeared. This characteristic behavior was explained by a two-level system exhibiting two distinct conductivities, and the occupation of the two levels being controlled by the applied bias. However, details of the two-level system are a matter of speculation, yet. On the basis of detailed spectroscopic measurements, we will propose a new formalism to analyze the behavior of such I-V characteristics. We will try to explain the observed features by dynamic properties of a hydrogen molecule in the tunneling junction.

[1] F. Natterer, F. Patthey, H. Brune, PRL 111, 175303 (2013). [2] S. Li, A. Yu, F. Toledo, Z. Han, H. Wang, H.Y. He,R. Wu, W. Ho, PRL 111, 146102 (2013).

O 79.8 Thu 12:30 HE 101

Role of the microscopic tip apex in STM-IETS measurements — Norio Okabayashi[1,2], Alexander Gustafsson[3], •Angelo Peronio[1], Magnus Paulsson[3], Toyoko Arai[2], and Franz J. Giessibl[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, D-93053 Regensburg, Germany — [2]Graduate School of Natural Science and Technology, Kanazawa University, Ishikawa, Japan — [3]School of Computer Science, Physics and Mathematics, Linnaeus University, 391 82 Kalmar, Sweden

The tunnelling process at the heart of Scanning Tunnelling Microscopy (STM) involves both the electronic states of the sample under study and of the tip of the microscope. Hence, STM imaging and spectroscopy are heavily affected by the microscopic structure of the tip apex, which is difficult to characterize. This uncertainty can be in addressed by combined STM/AFM experiments, using an adsorbed CO molecule to image the tip apex itself, the so-called COFI technique [1].

With this technique, we addressed the role of tip apex termination in IETS vibrational spectroscopy, by investigating single CO molecules adsorbed on a copper surface.

References:

[1] Hofmann T, Pielmeier F, and Giessibl FJ. Chemical and Crystallographic Characterization of the Tip Apex in Scanning Probe Microscopy. Physical Review Letters 112 066101 (2014). http://dx.doi.org/10.1103/PhysRevLett.112.066101

O 79.9 Thu 12:45 HE 101

Tip radius quantification using feature size mapping of field ion microscopy images — •Sören Zint[1], Daniel Ebeling[1], Dirk Dietzel[1], Jens Falter[1,2], and André Schirmeisen[1] — [1]Institute of Applied Physics (IAP), Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]TransMIT-Center of Adaptive Cryotechnology and Sensors, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

We are presenting a novel and rapid approach to determine the tip radius of sharp tungsten tips characterized by field ion microscopy. Utilizing certain features with well known dimensions on the surface of these tips around the crystallographic [111] direction allows us to increase the accuracy of the radius measurement by almost one order of magnitude in comparison to standard methods. Employing a few reasonable approximations it is possible to derive an analytical expression for the tip radius as a function of the observed feature size on the microchannel plate and some geometric parameters of the setup. Finally, we show that field ion microscopy images can be reconstructed on the atomic level by using a perfect hemisphere with the determined radius as a starting value and a low number of modifications in the topmost surface layers. In particular, this is useful for quantifying tip-sample interactions and characterizing material properties in atomic force microscopy.