O 53: Scanning Probe Methods II

Time: Wednesday 16:00–19:15 Location: H31

O 53.1 Wed 16:00 H31

Driving a Macroscopic Oscillator with the Stochastic Motion of a Hydrogen Molecule — •Christian Lotze[1], M. Corso[2], K.J. Franke[1], F. v. Oppen[1,3], and J.I. Pascual[2,4] — [1]Freie Universität Berlin — [2]CIC nanoGUNE, Donostia-San Sebastián, Spain — [3]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin — [4]IKERBASQUE, Bilbao, Spain

Tuning Fork based STM/AFM is a well-established method combining the advantages of scanning tunneling and dynamic force microscopy, allowing stable imaging with tip oscillation amplitudes below 1 Å. In this way, conductance and Δf measurements of molecular junctions can be obtained simultaneously [1] with intramolecular resolution [2].

One of the most intriguing aspects of molecular junctions relates to the effect of structural bi-stabilities in the properties of the junction. These lead, for example, to conductance fluctuations, telegraph noise and the possibility of switching the electrical transport through the junction. In this presentation, we characterize H_2 molecules on Cu(111), a model bi-stable molecular system, using dynamic force spectroscopy. The effect of current-induced stochastic fluctuations of conductance is correlated with fluctuations in force. In our experiment, we identified the latter from frequency shift and energy dissipation measurements, picturing a regime in which electrical transport and mechanical motion are coupled in a concerted dynamics that drives the system into self-oscillation [3].

[1] Fournier, *et al*, PRB 84, 035435 (2011) [2] Gross *et al*, Science 324, 1428 (2009) [3] C. Lotze *et al*, Science 338, 779 (2012)

O 53.2 Wed 16:15 H31

Improvement of STM Resolution with H-sensitized Tips — Jose Ignacio Martínez[1], •Enrique Abad[1,2], César González[1], Fernando Flores[1], and José Ortega[1] — [1]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Madrid, Spain — [2]Computational Biochemistry Group, Institut für Theoretische Chemie, Universität Stuttgart, Stuttgart, Germany

The improvement of spatial resolution in STM is attaining a lot of attention in diverse fields such as Surface Science [1]. In particular, recent Scanning Tunneling Hydrogen Microscopy (STHM) experiments on PTCDA/Au(111) have shown unprecedented intramolecular and intermolecular spatial resolution [1]. In our work, we analyze the effect on the STM images of hydrogen interacting with tip or sample, using an accurate STHM theoretical simulation technique [2]. Notice that the standard Tersoff-Hamman approach cannot take into account the influence of the hydrogen in the STM image.

We find that the STHM resolution enhancement is due to atomic H adsorbed on the tip [3]. The adsorbed H-atoms induce important changes in the Density of States (DOS) at the Fermi level (E_F) of the tip, increasing its total value, and making it more directional. Also, due to the interaction with the tip, E_F is shifted to the middle of the PTCDA LUMO peak, increasing the DOS of the sample at E_F [3].

[1] L. Gross, Nat. Chem. 3, 273 (2011).
[2] J. I. Martínez, E. Abad, et al. Org. Electron. 13, 399 (2012).
[3] J. I. Martínez, E. Abad, et al., Phys. Rev. Lett. 108, 246102 (2012).

O 53.3 Wed 16:30 H31

Mapping the surface adsorption potential with the scanning tunneling microscope — •Georgy Kichin[1,2], Christian Wagner[1,2], Stefan Tautz[1,2], and Ruslan Temirov[1,2] — [1]Peter Grünberg Institute (PGI-3), Forschungszentrum Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology, Germany

We propose a new method that allows us to study the adsorption behavior of molecular hydrogen or deuterium on the surface with atomic scale resolution. First, the molecular gas is condensed in the junction of the low-temperature scanning tunneling microscope (LT STM). Passing the tunneling current through the junction the vibrational excitations of the molecules are induced by inelastically scattered electrons. By mapping the inelastic excitation energy along the surface we obtain the information that is related to the local adsorption potential of the gas molecules on this surface. We will discuss how this information can be used to reconstruct the quantitative information about the surface adsorption potential.

O 53.4 Wed 16:45 H31

Voltage pulse shapes in time-resolved STM measured with photons — •Markus Etzkorn[1], Christoph Grosse[1], Klaus Kuhnke[1], Sebastian Loth[1,2], and Klaus Kern[1,3] — [1]Max-Planck-Institute for Solid State Research, 70569 Stuttgart, Germany — [2]Center for Free-Electron Laser Science, 22761 Hamburg, Germany — [3]École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

Time-resolved STM measurements using electronic pulses enable the study of local dynamics in the ns-regime and below [1]. One necessary prerequisite for such measurements is the knowledge of the time-dependance of the transient bias voltage V(t) at the tunnel junction. Due to the high frequency limitations of the wiring and the impedance mismatches in the experiments, perfect pulses fed into the STM will deviate from perfectness when they reach the tunnel junction. Here we introduce a new concept that enables the direct measurement of the true transient bias voltage in the junction using the characteristic photon signal created by plasmon decay between tip and sample. It relies on the fact that both plasmon decay and photon detection are fast on the time scale of the variation of V(t). We proof that this method gives correct results by redundant measurements of the autocorrelation using an all-electronic pump-probe scheme. Over and above we show how this method can be used to characterize the transfer function of a given set-up, and how one can optimize the transient bias shape by chirp modulation of the applied pulses. [1] S. Loth, M. Etzkorn, C.P. Lutz, D.M. Eigler, A.J. Heinrich, Science **329**, 1628 (2010).

O 53.5 Wed 17:00 H31

Investigation of the stiffness of the BN-nanomesh by combined STM and AFM measurements at low temperatures — •Tobias Herden[1], Markus Ternes[1], and Klaus Kern[1,2] — [1]Max Planck Institute for Solid State Research, Heisenbergstrasse 1, 70569 Stuttgart, Germany — [2]Institut de Physique des Nanostructures, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzwerland

The single layer boron-nitride nanomesh on Rh(111) [1] was intensively investigated by an homebuilt combined STM-AFM operating in the qPlus setup [2] at low temperatures with sub-nm oscillation amplitudes. From 3D-frequency shift data we calculated the energy landscape and lateral and vertical forces acting between the tip and the BN-layer. Slight variations in the forces between the (top, hcp)- and the (fcc, hcp)-sites (i.e. the different alignments of the rim sites of the hexagonal corrugation in respect to the Rh surface) enable us to derive stiffness properties of the highly corrugated layer. Our local results are further supported by statistical evaluation of atomic-scale AFM measurements of the lateral displacement of the BN-hexagons. To get a more profound understanding of the mechanical properties of the insulating single layer system, our experimental findings are compared with theoretical calculations by Laskowski et al. [3,4].

[1] M. Corso, Science 202, 217 (2004)
[2] F. J. Giessibl, Appl. Phys. Lett. 73, 3956 (1998)
[3] R. Laskowski et al., Phys. Rev. Lett. 98, 106802 (2007)
[4] R. Laskowski et al., Phys. Rev. B 81, 075418 (2010)

O 53.6 Wed 17:15 H31

Nanoscale imaging of photoelectrons using an atomic force microscope — •Ping Yu[1] and Jürgen Kirschner[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, Von-Danckelmann-Platz 3, D-06120 Halle, Germany

Photoemission current imaging at the nanoscale is demonstrated by combining an atomic force microscope (AFM) with laser excitation of the tip-sample gap. Photoelectrons emitted from the sample are collected by the AFM tip while the tip-sample distance is precisely controlled by the van der Waals force between them. We observe pronounced photoemission current contrast with spatial resolution of 5 nm on a cesium covered Au(111) surface, which is better than its corresponding AFM topography resolution. This high spatial resolution of the photoemission current image can be attributed to the strong dependence of the local potential barrier on the tip-sample distance. Our experiments provide a method for photoelectron imaging with high spatial resolution and extend the functionality of state-of-the-art

scanning probe techniques.

O 53.7 Wed 17:30 H31

The effect of sample resistivity on Kelvin probe force microscopy — •Alfred J. Weymouth and Franz J. Giessibl — University of Regensburg, 93040 Regensburg, Germany

Kelvin probe force microscopy (KPFM) is a powerful technique to probe the local electronic structure of materials with atomic force microscopy. One assumption often made is that the applied bias drops fully in the tip-sample junction. We have recently identified an effect, the Phantom force, which can be explained by an ohmic voltage drop near the tip-sample junction causing a reduction of the electrostatic attraction when a tunneling current is present. Here, we demonstrate the strong effect of the Phantom force upon KPFM that can even produce Kelvin parabolae of opposite curvature.

Appl. Phys. Lett., 101, 213105 (2012)

O 53.8 Wed 17:45 H31

Three dimensional scanning lifetime microscopy using diamond — •Philip Engel, Andreas W. Schell, and Oliver Benson — Humboldt-Universität zu Berlin, AG Nanooptik

Knowledge of the local density of optical states (LDOS) is important for the design of nanoscale enviroments for controlled light matter interaction. Here, we use the nitrogen vacancy (NV) defect center in nanodiamond as nanoscale probe for the LDOS. The NV defect center has a long-term stability even at room-temperature, which makes it an ideal candidate as a pointlike probe glued on an atomic force microscopy tip. Due to Fermi's golden rule the LDOS can be directly measured via lifetime changes of an emitter. Recently this was shown with fluorescent dye beads in two dimensions [1]. Our technique allows for the measurement of the LDOS in all three dimensions and the single emitter character of our probe avoids inhomogeneous broadening from ensemble averaging.

[1] M. Frimmer et al., Phys.Rev.Lett. 107, 123602 (2011).

O 53.9 Wed 18:00 H31

Utilizing dynamic work function measurements to distinguish adsorbates on Si(100) — •Ferdinand Huber, Alfred J. Weymouth, and Franz. J. Giessibl — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

It has been proposed that STM with an oscillating tip can be used to measure the work function locally [1, 2]. By combining this technique with STM and AFM measurements, taken in UHV at room temperature, we should be able to distinguish between deposited adatoms and surface defects [3]. Here, we deposit Mo on Si(100) and attempt to determine its atomic structure and true adsorption sites at low coverage as there are open questions [4].

[1] J. B. Pethica, J. Knall and J. H. Wilson, Inst. Phys. Conf. Ser. **134**, 597 (1993)
[2] M. Herz, Ch. Schiller, F. Giessibl and J. Mannhart, Appl. Phys. Lett. **86**, 153101 (2005)
[3] R. J. Hamers and U. K. Köhler, J. Vac. Sci. Technol. A **7**, 2854 (1989)
[4] P. Bedrossian, Surface Science **320**, 247 (1994)

O 53.10 Wed 18:15 H31

Probing the probe: tip front atom characterization — •Florian Pielmeier and Franz J. Giessibl — Institut für experimentelle und angewandte Physik, Universität Regensburg

The angular dependence of the chemical bonding forces between a tungsten (W) tip and a carbon monoxide molecule adsorbed on Cu(111) has been demonstrated recently by means of atomic force microscopy [1]. Single , dual or tiple minima in the force profile for W tips have been observed. They originate from the different charge density distributions at the apex of the tungsten tip, resembling the high symmetry directions of the bcc crystal lattice [2]. Furthermore absolute values for the interaction forces can be given by 3D force spectroscopy [3]. Here we present data for different tip materials (iron, copper and tungsten), analyzing the different symmetries and forces allows then the identification of the foremost tip atom. This enables a detailed interpretation of experimental data. As the characterization experiment itself is rather straightforward, this method, called carbon monoxide front atom identification (COFI), can be used in general to characterize the probe prior and/or after any experiment.

[1] J. Welker, F.J. Giessibl, Science, 336, 444 (2012) [2] C. A. Wright, S. D. Solares, Nanoletters, 11, 5026 (2011) [3] H. Hölscher, S.M. Langkat, A. Schwarz, R. Wiesendanger, Applied Physics Letters, 81, 4428 (2002)

O 53.11 Wed 18:30 H31

Theoretical Scanning Probe Images of the (001) Surfaces of MnO and NiO — •Mihail Granovskij[1,2], Andreas Schrön[1,2], and Friedhelm Bechstedt[1,2] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]ETSF

In the paramagnetic state the ground-state crystal structure of the 3*d* transition metal oxides (TMOs) MnO and NiO is given by an ideal rock-salt (*rs*) structure. Below their respective Néel temperature, however, it is characterized by the formation of an antiferromagentic ordering AFM2 which is acompanied by a rhombohedral distortion along the [111] direction. The intersection of the thermally swichable magnetic ordering AFM2 with the crystal surfaces makes TMO surfaces ideal benchmark materials for the investigation of recent magnetic scanning probe techinques such as spin-polarized scanning tunneling microscopy (SP-STM) and magnetic exchange force microscopy (MExFM).

We present a density functional theory (DFT) study of the (001) surfaces of MnO and NiO inculding an on-site interaction U. Different theoretical approaches for the description of magnetic scanning probe techniques are employed. the magnetic tip is modelled by a single Fe or 5-Fe-atom pyramid. For NiO, the calculated scanning probe images explain the spin contrast and the corrugation found experimentally. For MnO, the calculated images represent interesting predictions which differ from that of NiO.

O 53.12 Wed 18:45 H31

Scanning Microwave Microscopy combined with Amplitude Modulation Atomic Force Microscopy — •Matthias A. Fenner — Agilent Technologies, Lyoner Str. 20, 60528 Frankfurt

We report the implementation of a Scanning Microwave Microscopy (SMM) in Amplitude Modulation Atomic Force Microscopy (AFM) [1]. SMM combines AFM and a Vector Network Analyzer using microwave tip sample interactions to characterize dielectric and electronic material properties on the nanometer scale. The method employs contact mode AFM to yield calibrated capacitance and dopant density values and is described in detail by Huber et al. [2].

The extension of the method to Amplitude Modulation AFM offers several benefits:

1. It can be applied to very soft matter or nanosize objects which are poorly bound to a substrate surface.

2. It can be combined with advanced AC mode techniques like Kelvin Force Microscopy for surface potential measurements or Magnetic Force Microscopy.

We report a feasibility study for this novel technique.

[1] Amplitude Modulation Atomic Force Microscopy, R. Garcia, Wiley-VCH (2010)
[2] H. P. Huber et. al, Rev. Sci. Instrum. 81, 113701 (2010)

O 53.13 Wed 19:00 H31

Infrared nanoscopy of biomaterials — Adrian Cernescu[1,2], Sergiu Amarie[2], Tobias Geith[3], Stefan Milz[4], and •Fritz Keilmann[1] — [1]Ludwig-Maximilians-University and Center for NanoScience, Garching, Germany — [2]Neaspec GmbH, Martinsried, Germany — [3]Ludwig-Maximilians-University, Institute for Clinical Radiology, Munich, Germany — [4]Ludwig-Maximilians-University, Department of Anatomy, Munich, Germany

Spectroscopic near-field imaging is enabled by combining 20nm-resolving tip-scattering near-field microscopy (s-SNOM) with an infrared continuum source. Specific contrasting of biomineral components is enabled by simply choosing the appropriate "fingerprint" infrared region that as in traditional FTIR (Fourier-transform infrared spectroscopy) identifies virtually any chemical compound. Hence nano-FTIR stands for the successful realization of combining s-SNOM and FTIR [1].

The investigated samples are nanocomposite biomaterials, namely human bone sections, human tooth specimens and mollusk shell which contain mineral nanocrystals in organic matrices [2]. The mineral parts are highlighted by their resonantly enhanced contrast due to phonons.

Our method is surface-sensitive, probing to a depth of about 30 nm. It should be straightforwardly applicable in many fields of general mineralogy, solid state research, and materials science.

[1] S. Amarie, T. Ganz, and F. Keilmann, Opt. Express 17, 21794 (2009); [2] S. Amarie, P. Zaslansky, Y. Kajihira, E. Griesshaber, W.W. Schmahl and F. Keilmann, Beilstein J. Nanotechnol. 3, 312 (2012).