O 15: Methods: Scanning Probe Techniques II

Time: Monday 14:15–17:45 Location: H41

O 15.1 Mon 14:15 H41

Advances in High Resolution 3-Dimensional Force Field Spectroscopy — •Alexander Schwarz, Uwe Kaiser, and Roland Wiesendanger — Institut für Angewandte Physik, Department Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

Atomic force microscopy using the frequency modulation technique (FM-AFM) can be employed to image surfaces with atomic resolution. Force spectroscopy allows determining the distance dependence of the tip-sample interaction force. Recently, both methods have been combined by recording spectroscopy curves at every x, y image point. This 3-dimensional force field spectroscopy technique (3D-FFS) [1,2] can be used to evaluate details of the tip-sample interaction with high resolution.

In our presentation, we will discuss the requirements to acquire high-resolution 3D-force-fields together with the dissipation signal due to non-conservative tip-sample interactions. As sample we will show data obtained on NiO(001). At close tip-sample separations, the force field $F(x, y, z)$ and the dissipation $E_{\mathrm{Diss}}(x, y, z)$ is analysed with respect to reconfigurations of atoms at the tip apex. Such reconfigurations influence the atomic scale contrast and are therefore very important to understand the relevant effects and mechanisms during atomic resolution imaging.

[1] H. Hölscher et al. Appl. Phys. Lett. **81**, 4428 (2002).
[2] S. M. Langkat et al. Surf. Sci. **521**, 12 (2003).

O 15.2 Mon 14:30 H41

Measuring energy dissipation in torsional resonance mode AFM using frequency modulation — •Ayhan Yurtsever, Alexander M. Gigler, and Robert W. Stark — Ludwig-Maximilians-Universität München, Germany

The atomic force microscope (AFM) may be used as a tool to probe hardness, elastic and viscous properties of the surface at the nanoscale. In-plane properties such as friction or shear stiffness of the sample can be measured with a lateral force modulation microscopy or by analyzing torsional vibrations. The torsional resonance mode (TR mode) allows shear force microscopy with standard cantilevers [1]. The torsion about the cantilevers long axis actuates a pendulum-like oscillation of the tip apex parallel to the sample surface with typical amplitudes of 0.2 nm to 2.0 nm. In this study, the dynamics of the torsionally vibrated cantilever are analysed by the transfer function method and finite element analysis (FEA). The results explain the fundamental mechanism for the topography feedback in TR-mode. Experimentally, we measure the energy dissipation and the frequency shift in torsional resonance mode AFM using frequency-modulation on a PMMA surface. To regulate the FM detection scheme, we utilized a Nanosurf (Liestal, Switzerland) Phase-Loop-Lock controller/detector (PLL). By monitoring the changes in the resonance frequency and excitation amplitude required to keep the oscillation amplitude constant, we were able to measure both frequency shift and dissipation caused by the tip-sample interaction.

[1] L. Huang, C. Su, Ultramicroscopy 100 (2004) 277-285

O 15.3 Mon 14:45 H41

Frequency Modulation Dynamic Force Microscopy applying amplitudes in the low nm range: Questions, findings — •Georg Hermann Simon, Markus Heyde, Hans-Peter Rust, and Hans-Joachim Freund — Fritz-Haber-Institute of the Max-Planck-Society, Faradayweg 4-6, D-14195 Berlin, Germany

Atomically resolved images of various surfaces of semiconductors [1], insulators [2] and metals [3] are given in the literature. Most of them being the result of large amplitude measurements with soft cantilevers while some have been obtained with stiff quartz tuning forks [4, 5] and small amplitudes (few nm or less). Such high resolution with small amplitudes, despite the success, raises questions concerning sensitivity, measured forces and signal to noise ratio.

Here, we have started a detailed analysis of frequency shift-distance curves obtained by our low temperature dynamic force microscope operated with a quartz tuning fork sensor in the small amplitude regime. The experimental data is compared to a simple theoretical model and results from literature. From the findings further conclusions for sensor improvement can be drawn.

[1] F. J. Giessibl, Science 267, 68 (1995)
[2] M. Reichling, C. Barth, Phys. Rev. Lett. 83, 768 (1999)
[3] K. Yokoyama, T. Ochi, Y. Sugawara, S. Morita, Phys. Rev. Lett. 83, 5023(1999)
[4] F. J. Giessibl, Appl. Phys. Lett. 76, 1470 (2000)
[5] M. Heyde, M. Sterrer, H.-P. Rust, H.-J. Freund, Appl. Phys. Lett. 87, 083104 (2005)

O 15.4 Mon 15:00 H41

Optimum excitation and detection of cantilever oscillations in vacuum — •Jannis Lübbe[1], Stefan Torbrügge[1], Sebastian Gritschneder[1], Lutz Tröger[1], Holger Schnieder[1], Toyoaki Eguchi[2], Yukio Hasegawa[2], and Michael Reichling[1] — [1]Fachbereich Physik, Universität Osnabrück, 49076 Osnabrück, Barbarastraße 7, Germany — [2]Institute for Solid State Physics, Tokyo University, 5-1-5, Kashiwa, Chiba 277-8581, Japan

The atomic resolution imaging performance of a dynamic scanning force microscope in the ultra-high vacuum critically depends on several technical parameters related to the excitation and detection of the cantilever oscillation. We designed a testing stage allowing the easy insertion and removal of a set of twelve commercial standard cantilevers for quality control prior to measurements. Resonance curves are taken by excitation of a piezo stage with a variable frequency oscillator and detection with a Lock-In amplifier. The Detection of the cantilever motion is based on a deflected laser beam coupled into the vacuum by an optical fibre and focused by an in-vacuo lens. As a laser source we use a current and temperature stabilised low noise laser diode. For low noise detection of the cantilever deflection signal, an in-vacuum quadrant detector connected to a home-built pre-amplifier was used. The detection sensitivity of this set-up and commercially available SFM set-ups used in our group are measured by analysing the thermally excited vibration of the cantilever and noise in the vicinity of the cantilever with a Fourier analyser.

O 15.5 Mon 15:15 H41

Increasing the Q-factor in the constant-excitation mode of frequency-modulation atomic force microscopy in liquid — •Daniel Ebeling[1,2], Hendrik Hölscher[1,2], Jan-Erik Schmutz[1,2], and Boris Anczykowski[3] — [1]Center for Nanotechnology (CeNTech), Heisenbergstr. 11, 48149 Münster — [2]Physikalisches Institut, Wilhelm-Klemm-Str. 10, 48149 Münster — [3]nanoAnalytics GmbH, Heisenbergstr. 11, 48149 Münster

The application of dynamic force spectroscopy in vacuum allows the mapping of tip-sample forces down to the atomic-scale. It has been shown that dynamic force spectroscopy works also in ambient conditions [1] and liquids [2] enabling the precise measurement of tip-sample forces.

By adding a Q-Control electronics to the set-up of the constant-excitation mode of the frequency-modulation atomic force microscope we are able to increase the effective Q-factor of a self-oscillated cantilever in liquid to values comparable to ambient conditions. During imaging of soft biological samples adsorbed on a mica substrate we observed an increased corrugation of the topography with increased Q-factors. This effect is caused by the reduction of tip-sample indentation forces as demonstrated by numerical simulations and an analytical approach [3].

[1] H. Hölscher and B. Anczykowski. Surf. Sci. **579**, 21 (2005).
[2] T. Uchihashi et al., Appl. Phys. Lett. **85**, 3575 (2004).
[3] D. Ebeling, H. Hölscher, B. Anczykowski, Appl. Phys. Lett. **89**, 203511 (2006).

O 15.6 Mon 15:30 H41

Influence of the Local Adsorption Environment on the Intra-Molecular Contrast of Organic Molecules in Non-Contact Atomic Force Microscopy — •Andre Schirmeisen[1], Bartosz Such[2], Domenique Weiner[1], and Harald Fuchs[1] — [1]Center for Nanotechnology (CeNTech), University of Münster, Heisenbergstr.11, 48149 Münster, Germany — [2]Marian Smoluchowski Institute of Physics, Jagiellonian University, Reymonta 4, 30-059 Krakow, Poland

Organic molecules have fascinating electrical and optical properties making them promising candidates as fundamental building blocks for miniaturized and high-capacity electronic devices. In the effort to exploit the opportunities offered by organic molecules, however, one

has to take into account that the local chemical environment of the molecule may strongly influence its properties. Thin epitaxial layers of the organic molecule 3,4,9,10-perylenetetracarboxylic dianhydrite (PTCDA) on a Cu(111) surface were imaged using non-contact atomic force microscopy in ultrahigh vacuum [1]. The second layer molecules show a distinct intra-molecular structure, which is compared to the internal charge distribution of the molecule. The molecules in the first layer, though, exhibit no detectable intra-molecular features. This effect is discussed with respect to the presence of the metallic substrate for the first layer molecules, which demonstrates the strong influence of the local adsorption environment on the internal electronic properties of organic molecules. [1] Such et al., Appl. Phys. Lett. 89, 093104 (2006)

O 15.7 Mon 15:45 H41

Kelvin Probe Force Microscopy on Electrically Inhomogeneous Fe/W(001) Films — •Ung Hwan Pi, Rene Schmidt, Alexander Schwarz, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg

Noncontact scanning force microscopy can give information about the real topography of the sample. However, this is valid only when the dominant tip-sample interaction is due to the van der Waals force. If the sample is electrically inhomogeneous, e.g., the sample has an inhomogeneous electric charge distribution, it causes additional electrostatic forces between tip and sample, which prevent real topography measurement. To nullify the electrostatic effect, the tip bias can be regulated with a special feedback scheme called Kelvin probe force microscopy. Here we applied Kelvin probe force microscopy to the pseudomorphic Fe thin film grown on W(001). In this highly strained film, the electric properties depend on the number of layers, yielding different contact potentials in each layer. The samples were prepared and measured in-situ under ultra high vacuum condition without exposing them to the atmospheric environment. When the tip bias was not regulated, the apparent step height of the film changed depending on the tip-sample bias, and a reliable measurement of topography was impossible. With Kelvin probe force microscopy, the contact potentials different in each layer could be compensated, and the real topography image could be obtained.

O 15.8 Mon 16:00 H41

Contact area dependence of friction on the nanoscale — •Dirk Dietzel[1,2], Tristan Mönninghoff[2], Andre Schirmeisen[2], Harald Fuchs[1,2], and Udo Schwarz[3] — [1]Forschungszentrum Karlsruhe (FZK), Karlsruhe, Germany — [2]Institute of Physics, University of Münster, Münster, Germany — [3]Department of Mechanical Engineering, Yale University, New Haven, CT, USA

A promising approach to analyze the fundamentals of friction on the nanometer scale is the lateral manipulation of small adsorbed islands by atomic force microscopy. In our case, the samples under investigation were metallic islands with diameters between 50-500 nm grown by thermal evaporation of antimony on highly oriented pyrolytic graphite (HOPG). With a newly developed manipulation procedure, which relies on contact-mode AFM operation, we have a simple and straightforward technique to manipulate the islands. Thereby, the lateral force signal of the AFM cantilever gives direct and quantitative information about the additional friction forces induced by the island pushing process. Using this technique, we focused on the contact area dependence of friction forces on the nanometer scale. By pushing a large variety of islands of different sizes, we found that the system shows a very clear behaviour with a linear dependence between the friction force and the contact area, thus reinforcing Amonton's law on the nanometer scale.

O 15.9 Mon 16:15 H41

Design of a High-Frequency Electric-Force Scanning Force Microscope for Vibration Spectroscopy at Single Macromolecules — Patrick Steffen, Ivo Knittel, and •Uwe Hartmann — Fachbereich Experimentalphysik, Im Stadtwald, Geb. C6.3, 66041 Saarbrücken

Mechanical properties of single macromolecules on timescales down to sub-nanoseconds are relvant to the understanding of the biological function of cell components. For an effective mechanical spectrocsopy at single macromolecules, a local excitation, with high amplitude and narrow bandwidth is necessary. In addition, detection should as well be local, and with narrow bandwidth. A complete microscope design is discussed in this contribution. A mechanical resonance of a sample macromolecule is excited by a charged AFM-tip. The oscillating sample molecule leads to an additional static force because of nonlineal tip-sample interaction. The size of this force is estimated by analytic and numerical methods. For the force modulation, signal-to-noise ratios and stabiltiy are investigated for several variants. The optimized design is suggested, incuding a suitable waveguide, and a suitable modulation of the exciting microwave.

O 15.10 Mon 16:30 H41

Optimum Excitation Conditions for SNOM-based Particle-enhanced Fluorescence Microscopy — •Thomas Härtling, Phillip Reichenbach, Marc-Tobias Wenzel, Phillip Olk, and Lukas Eng — Institut für Angewandte Photophysik, TU Dresden

Tip-enhanced microscopy, carried out for example by using a scattering near-field optical microscope (s-SNOM), is a powerful tool for nano-optical investigations. In this context, the manipulation of the fluorescent behavior of molecules with the help of single metal nanoparticles attached to the apex of a dielectric SNOM tip has been followed in the last years. This technique not only offers the advantages of high signal intensities confined to small spatial volumes. It equally provides deeper insight into processes involved in fluorescence emission stemming from molecular dipole transitions in the vicinity of metallic structures. It is known that the distance between the emitting molecular dipole and the metallic nanoparticle in such a configuration plays a key role in the competition between radiative and non-radiative decay processes of the excited dipolar state. Consequently, the fluorescence signal is strongly distance-dependent. We will discuss this dependence quantitatively both in theory and experiment taking into account parameters such as the excitation and emission wavelength of the dipole, the resonance wavelength of the particle, and the effect of the dielectric constant of the surrounding medium. Consequences concerning the optimum excitation conditions for particle-enhanced fluorescence microscopy are lined out.

O 15.11 Mon 16:45 H41

Second-harmonic near-field optical microscope in illumination mode — •Georgios Ctistis[1] and Paul Fumagalli[2] — [1]Center of Advanced European Studies and Research (caesar), Ludwig-Erhard-Allee 2, 53175 Bonn, Germany — [2]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Until now, studying non-linear properties of nanostructures or thin films in the near field was limited to apertureless near-field microscopy. However, the separation of the signal resulting from the sample from that resulting from the tip has proven to be difficult. Here, we present our studies for a scanning near-field optical microscope working in illumination mode with a metal-coated fiber tip as aperture. For such a set-up, some difficulties have to be overcome before the method can be used: propagation of short pulses through the fiber, choice of metal-coating material, and maximum intensity usable. As a result, we were able to clearly assign the generated second-harmonic signal to the surface of the silver and cobalt films measured.

O 15.12 Mon 17:00 H41

Infrared Mapping of Material and Doping Contrasts in Microelectronic Devices at Nanoscale Spatial Resolution — •A. Huber[1], J. Wittborn[2], F. Keilmann[1], and R. Hillenbrand[1] — [1]MPI für Biochemie, Nano-Photonics Group, 82152 Martinsried, Germany — [2]Infineon Technologies AG, 81726 München, Germany

We demonstrate that infrared scattering-type scanning near-field optical microscopy (s-SNOM) allows mapping of different materials and electron concentrations in cross-sectional samples of industrial integrated circuit device structures at nanoscale spatial resolution.

Our s-SNOM is based on an atomic force microscope (AFM) where the metallized probing tip is illuminated by infrared light from a tuneable CO2-laser (λ=9-12μm). The tip functions as an optical antenna, concentrating light at its apex to nanoscale dimensions independent of the wavelength. The scattering originating from the optical tip-sample near-field interaction is measured interferometrically yielding nanoscale resolved infrared amplitude and phase images along with the topography.

The optical near-field interaction depends on the sample's local optical properties determined by the dielectric function $\epsilon(\omega)$. As $\epsilon(\omega)$ is highly material specific the near-field interaction enables the non-destructive characterization of nanostructures. Here we present how s-SNOM can be applied for material specific mapping of cross-sectional samples of state-of-the-art microelectronic devices. The doped areas in Si exhibit distict infrared contrasts arising from the near-field interaction between the probe tip and free carriers (plasmons) in Si.

O 15.13 Mon 17:15 H41

A 30-nm-wide slit as a waveguide for light to the aperture of a near-field optical probe — •Daniela Diessel[1], Nicole Neuberth[1], Fabián Pérez-Willard[2], and Andreas Naber[1] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH) — [2]CFN Service Laboratory, Universität Karlsruhe (TH)

Recently we have introduced a triangular aperture probe (TA probe) for scanning near-field optical microscopy (SNOM) that combines a high optical resolution capability with a high transmission of light [1]. The near-field pattern is highly confined to only one side of the triangular aperture so that the resolving power is almost doubled as compared to a circular aperture of equal size. We could demonstrate that the TA probe is particularly suited for imaging of single molecules at a resolution down to 30 nm [2]. So far, we created the aperture by controlled squeezing of the entirely aluminum-coated tip against a smooth surface. Now we applied focused ion beam (FIB) milling for aperture formation which allowed us to routinely fabricate triangular apertures with a side length even below 20 nm. To further increase the transmission of the TA probes we used a FIB to produce a 30-nm-wide slit into the metal surface as a waveguide for light to the aperture. As a result of the slit-waveguide we observed a considerable enhancement of the near-field optical intensity at the aperture.

[1] G. Colas des Francs et al., Phys Rev B 72, 165111 (2005).
[2] D. Molenda et al., Optics Expr. 13, 10688 (2005).

O 15.14 Mon 17:30 H41

Electrical Characterization of individual nanowires with the LEEPS microscope — •Dirk Henning Weber[1], André Beyer[1], Berthold Völkel[1], Armin Gölzhäuser[1], Bianca Postels[2], Andreas Waag[2], Martin Gräser[3], Andreas Greiner[3], and Joachim Wendorff[3] — [1]Physik supramolekularer Systeme, Universität Bielefeld — [2]Institute of Semiconductor Technology, Technische Universität Braunschweig — [3]Makromolekulare Chemie, Philipps-Universität Marburg

We introduce the Low Energy Electron Point Source (LEEPS) microscope as a tool for the electrical characterization of individual freestanding nanowires. We contacted single nanowires in the LEEPS electrically and measured the specific conductivity. In addition we analysed the LEEPS image itself to extract electrical properties.

The LEEPS microscope is a projection electron microscope with electron energies from 20eV to 200eV. These electrons are emitted by a field emission tip with a radius in the atomic range. Due to the very low energy of the electrons the LEEPS image includes information about weak electrostatic fields near the object. The interference pattern of conductive nanowires appears much brighter than the interference pattern of nonconductive nanowires. With a sharp manipulation tip as a movable electrode individual nanowires were contacted electrically and the I/U curves were measured. Contacting and measurement can be observed with the LEEPS microscope subsequently. We will present I/U curves of single nanowires (i.e. ZnO, CdS, Co) as well as a comparison of LEEPS images of conductive and nonconductive wires.