O 27 Scanning probe techniques II

Time: Tuesday 15:45–18:45 Room: WIL B321

O 27.1 Tue 15:45 WIL B321

Towards the analysis of force interactions of atomically defined tip-sample contacts — •Daniel Braun[1], Thomas König[1], Jens Falter[2], André Schirmeisen[1,3], Hendrik Hölscher[3], Marcus Liebmann[4], Udo D. Schwarz[2], and Harald Fuchs[1,3] — [1]Institute of Physics, University of Münster, Münster, Germany — [2]Department of Mechanical Engineering, Yale University, New Haven, CT, USA — [3]Center for Nanotechnology (CeNTech), University of Münster, Münster, Germany — [4]II. Institute of Physics B, RWTH Aachen, Aachen, Germany

In recent years, the atomic force microscope (AFM) has been established as a tool for the imaging of surfaces with atomic resolution. However, a reliable interpretation of the observed atomic-scale contrast is often difficult since the exact structural configuration of the tip apex is generally unknown. A determination of the position of the last atoms of the tip is possible using field ion microscopy (FIM). We have built an AFM for operation at low temperatures and under ultra high vacuum (UHV) conditions based on a design that has previously been published [1]. However, significant changes in the design were necessary as the original design uses silicon cantilevers as force sensors, which are not suited for FIM. Therefore, we implemented a tuning fork as force sensor [2], allowing us to choose an appropriate tip material such as tungsten while maintaining atomic-scale resolution capabilities in AFM mode. First experimental results with both microscopy methods will be presented.

[1] W. Allers et al., Rev. Sci. Instrum. 69, 221 (1998)
[2] F. J. Giessibl, Appl. Phys. Lett. 76 1470 (2000)

O 27.2 Tue 16:00 WIL B321

Quantitative analysis of ferroelectric domain imaging with piezoresponse force microscopy* — •Tobias Jungk, Ákos Hoffmann, and Elisabeth Soergel — Institute of Physics, University of Bonn, Wegelerstraße 8, 53115 Bonn, Germany

The contrast mechanism for ferroelectric domain imaging via piezoresponse force microscopy (PFM) is investigated. A novel analysis of PFM measurements is presented which takes into account the background frequency spectrum caused by the experimental setup. Thereby all generally required features of PFM imaging with respect to phasing, amplitude, and frequency dependence are satisfied. This allows, for the first time, a quantitative analysis of the domain contrast which is in good agreement with the expected values for the piezoelectric deformation of the sample. Consequences of the inherent experimental background on the amplitude of the domain contrast (enhancement, nulling, inversion) as well as on the shape and the location of the domain boundaries are discussed.

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O 27.3 Tue 16:15 WIL B321

Measurement and simulation of grain boundaries in thin film solar cell absorbers — •Caspar Leendertz, Ferdinand Streicher, Tobias Eisenbarth, Susanne Siebentritt, Sascha Sadewasser, and Martha Ch. Lux-Steiner — Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin

Kelvin probe force microscopy (KPFM) uses electrostatic forces for the spatially resolved measurement of surface potentials. Using KPFM we studied the potential barrier at grain boundaries of $CuGaSe_2$ semiconductor thin films for solar cell applications. The long range electrostatic interaction complicates quantitative data interpretation. Therefore, we developed 3D simulations using finite element methods to estimate the spatial variation of the measured surface potentials as a function of the barrier height and doping concentration. We find that the deviation between measured and true barrier height strongly depends on the sample doping, i.e. the measured barrier height increases from 55% to 70% of the true barrier height when the doping drops from $5 \times 10^{16} cm^{-3}$ to $3 \times 10^{15} cm^{-3}$.

O 27.4 Tue 16:30 WIL B321

High resolution nc-AFM investigation of the adsorption of PTCDA on ultrathin KBr films — •Christian Loppacher[1], U. Zerweck[1], L.M. Eng[1], S. Gemming[2,3], G. Seifert[2], C. Olbrich[3], K. Morawetz[3], and M. Schreiber[3] — [1]Institute of Applied Photophysics, University of Technology Dresden, D 01062 Dresden — [2]Institute of Physical Chemistry and Electrochemistry, TU Dresden, D-01062 Dresden, Germany — [3]Institute of Physics, TU Chemnitz, D-09107 Chemnitz, Germany

Ordered growth of 3,4,9,10-perylene-tetracarboxylic-dianhydride (PTCDA) on Ag(111) partially covered by one or two monolayers KBr was investigated by noncontact AFM with molecular resolution. Different adsorption patterns are found on the pure substrate, the one covered by a single monolayer, and the one covered by two monolayers KBr. Simulations with an extended Ising-type model reproduce these experimental patterns very well [1]. The adsorbate-adsorbate and the adsorbate-substrate interaction parameters obtained from the simulation are discussed in respect to the interactions at the Ag(111)—KBr interface.

[1] K. Morawetz, C. Olbrich, S. Gemming et al., Phys. Rev. Lett., (submitted)

O 27.5 Tue 16:45 WIL B321

Investigation of dissipative interaction between probe and ligand-stabilized clusters by NC-AFM — •Georgeta Radu and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P.O. Box 151150, D-66041 Saarbrücken, Germany

In recent years, noncontact atomic force microscopy (NC-AFM) became a powerful tool for imaging at high resolution as well as for probing specific surface properties. A major advantage of NC-AFM is the ability to distinguish between conservative and dissipative interactions. In order to investigate the dissipative interaction between the AFM probe and individual clusters, thin films of ligand-stabilized Au_{55} clusters on an Au(111) substrate have been prepared. The NC-AFM images show locally ordered Au_{55} monolayer islands with single cluster resolution. Dissipative interactions can be investigated by NC-AFM by measuring the damping of the cantilever oscillation as a function of the probe-sample distance. Damping-versus-distance measurements were performed on individual clusters as well as on the bare substrate. A distance dependence corresponding to the electric-field mediated Joule-dissipation [1] was found for the energy dissipated above individual clusters as well as on the bare substrate. No additional energy dissipation due to the mechanical deformation of the ligand shell under the action of the oscillating tip was observed. This is in agreement with the theoretical calculations by Couturier et al. [2].

[1] W. Denk and D. Pohl, Appl. Phys. Lett. 59, 2171 (1991)
[2] G. Couturier et al., J. Phys. D: Appl. Phys. 34, 1266 (2001)

O 27.6 Tue 17:00 WIL B321

Site-Specific Dynamic Force Spectroscopy on NaCl — •Andre Schirmeisen, Domenique Weiner, and Harald Fuchs — Institute of Physics and CeNTech, University of Münster, Wilhelm-Klemm-Str.10, 48149 Münster, Germany

Dynamic force microscopy under ultrahigh vacuum conditions is an established tool to obtain atomically resolved images of flat surfaces. Recent advances in the technique as well as the interpretation of the underlying physical mechanisms has led to the method of dynamic force spectroscopy, which enabled researchers to determine the forces acting between tip and sample. We have measured the frequency shift and the damping curves using non-contact atomic force spectroscopy of an atomically resolved NaCl surface in ultrahigh vacuum at room temperature. Unfortunately, room temperature measurements usually suffer from considerable temperature drift effects, thus making reliable site-specific force spectroscopy a difficult task. Combining fast data acquisition with a site-averaging technique we obtained reproducible spectroscopy curves. From these spectroscopy curves we calculate the force and the energy dissipation and find that both channels depend strongly on the specific lattice sites. Furthermore, we have investigated the influence of atomic surface defects on the spectroscopy curves.

O 27.7 Tue 17:15 WIL B321

Theoretical Analysis of *Q*-controlled Dynamic Force Microscopy in Ambient Conditions — •Daniel Ebeling[1,2], Hendrik Hölscher[1,2], Harald Fuchs[1,2], and Udo D. Schwarz[3] — [1]Center for Nanotechnology (CeNTech), Münster — [2]Physics Institute, University of Münster — [3]Department of Mechanical Engineering, Yale University, New Haven, USA

The so-called Q-control method allows the active modification of the effective cantilever damping in dynamic force microscopy (DFM) by increasing or decreasing the Q-value of the cantilever [1]. This feature can be used in different ways to improve the imaging capabilities of DFM in air. Even though the Q-control method has been frequently applied in numerous experimental studies in recent years [2, 3] and the necessary driving electronics is commercially available, it is striking that an in-depth analytic description that would allow a rigorous theoretical explanation of the various features of Q-controlled dynamic force microscopy (QC-DFM) is still missing. Here, we present an analysis of QC-DFM based on the analytical solution of the equation of motion and on numerical simulations considering a model tip-sample interaction force in both cases. Explicit formulas allowing for the calculation of all relevant parameters like gain, phase, and amplitude are given. The detailed analysis of these formulas explains the observed imaging characteristics of QC-DFM.

[1] B. Anczykowski et al., Appl. Phys. A 66, S885 (1998)
[2] J. Tamayo et al., APL. 77, 582 (2000)
[3] A. Grant et al., Ultramicroscopy 97, 2919 (2003)

O 27.8 Tue 17:30 WIL B321

Hydrogen-altered Gd(0001) surfaces investigated by dynamic force microscopy — •Rene Schmidt, Alexander Schwarz, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Jungiusstr. 11, D-20355 Hamburg

Adsorbates from residual gases alter the electronic and magnetic properties of rare earth metals. Here, the chemisorption process of hydrogen on Gd(0001) islands epitaxially grown on W(110) is investigated by means of dynamic force microscopy in UHV. Frequency shift vs. bias curves show a potential difference of 0.6 V between clean and H-covered regions on Gd(0001) islands. This originates from a charge transfer between hydrogen and gadolinium, leading to a bias voltage dependent contrast in DFM images, i.e., H-covered gadolinium surface areas appear depressed for negative or elevated for positive bias voltages, respectively. These results are discussed with respect to photoemission and STM studies, which indicate, that adsorbed hydrogen locally destroys the surface state with d_{z^2}-like orbital symmetry and induces a decreasing differential conductivity near the Fermi level at low bias voltages.

O 27.9 Tue 17:45 WIL B321

Detection of electrical forces with a capacitive cantilever device — •A.-D. Müller[1], F. Müller[1], A. Käppel[2], and M. Hietschold[2] — [1]Anfatec Instruments AG, Melanchthonstr.28, 08606 Oelsnitz, Europe. — [2]TU Chemnitz, Solid Surfaces Analysis Group, 09107 Chemnitz, Europe.

The detection of electrical forces in dynamic mode AFM allows to observe contact potential differences between tip and sample as well as carrier concentration variations. For this, additional voltages are applied to the tip, while the additional electrical signals are evaluated with lock-in amplifiers. In order to observe locally generated potentials in its surrounding surface region, multiple tip cantilevers can be utilized.

This work investigates the applicability of multiple tip cantilever devices for electrical force microscopy. In contrast to conventional AFM, the tips in this devices are independently movable in vertical direction and the tip sample forces are sensed by displacement current detection [1]. Imaging of electrical properties with this devices is shown at the example of dopant patterns on n-silicon. In order to improve the understanding of the image contrast, the results are compared with numerical simulations of the electrical force interaction in dependence on applied voltage magnitudes.

[1] A.-D . Müller, F. Müller, M. Hietschold, Th. Gessner, Curr. Appl. Phys. 5, 629 (2005).

O 27.10 Tue 18:00 WIL B321

Temperature dependence of point-contact friction on silicon — •Lars Jansen[1,2], André Schirmeisen[1,2], Hendrik Hölscher[1,2], and Harald Fuchs[1,2] — [1]Institute of Physics, University of Muenster, Wilhelm-Klemm-Str. 10, 48149 Muenster — [2]CeNTech, Center for Nanotechnology, Gievenbecker Weg 11, 48149 Muenster

Due to the rising importance of the tribological properties of silicon in industrial applications like micro-electro mechanical systems (MEMS), the friction between two silicon bodies is of high interest. In order to investigate the tribological properties, we have measured the frictional forces between a Si-tip and a Si(111)-surface at different sample temperatures in the range of 30 K to 300 K by cooling the sample with a flow cryostat, using liquid nitrogen and liquid helium. The measurements are performed with a commercial Atomic Force Microscope under ultra high vacuum conditions. The temperature dependence of the friction coefficient, given by the ratio of friction to load, shows a large variation by a factor of 3-9 within the investigated temperature range with a maximum around 100 K. Furthermore, we found a drastic change in the velocity dependence of the friction. Above 150 K the friction is virtually independent of the velocity in the range from 200 nm/s to 20.000 nm/s, while below 150 K the friction is proportional to logarithm of the velocity. These findings are of great interest for the design and functionality of MEMS devices.

O 27.11 Tue 18:15 WIL B321

Relating structure and friction: Energy dissipation during the lateral manipulation of antimony nanoparticles — •Markus Heyde[1], Claudia Ritter[2], Klaus Rademann[2], and Udo D. Schwarz[3] — [1]Fritz-Haber-Institute of the Max-Planck-Society, Faradayweg 4-6, D-14195 Berlin, Germany — [2]Institute of Chemistry, Humboldt University Berlin, Brook-Taylor-Str. 2, 12489 Berlin, Germany — [3]Department of Mechanical Engineering, Yale University, P.O. Box 208284, New Haven, CT 06520-8284, USA

Despite its daily-life importance, the fundamentals of friction are still insufficiently understood. In particular, the interplay between friction, "true"contact area, and crystalline structure at the interface is an issue of current debate. Recently, a new technique had been introduced that allows determining the threshold energy dissipated during the lateral displacement of small nanoparticles on suitable substrates as a function of the particle-substrate contact area [1]. Here, we present results of an extensive study of antimony nanoparticles 1000 nm^2 to 100000 nm^2 in size moved in air on graphite substrates. Complementary studies by electron microscopy reveal the internal structure of the islands, showing a transition from amorphous to crystalline of the island's cores at about 10000-15000 nm^2 size, while the surface layers are composed of amorphous antimony oxide in all cases. However, despite the similarities of the amorphous surface layer, islands with crystalline core show significantly higher energy dissipation during motion than the ones with amorphous core. Possible reasons for this effect are discussed.

[1] Ritter et al., Phys. Rev. B 71, 085405 (2005).

O 27.12 Tue 18:30 WIL B321

Influence of wettability on microtribological properties of microsystems — •Wolfram Hild[1], Yonghe Liu[1], Michael Schuch[1], Matthias Scherge[2], and Juergen A. Schaefer[1] — [1]Institut für Physik und Zentrum für Mikro- und Nanotechnologien, TU Ilmenau, P.O. Box 100565, 98684 Ilmenau, Germany — [2]IAVF Antriebstechnik AG, Im Schlehert 32, 76187 Karlsruhe

The capillary force formed by water at smooth hydrophilic surfaces plays a crucial role in the performance and reliability of microelectromechanical systems. Capillary forces may lead to malfunctions. The negative influence of water can be excluded by various techniques, e.g. by using hydrophobic Self Assembled Monolayers (SAMs). We report the influence of wettability on the microtribological properties of Si. A microtribometer with a force resolution of 100 nN was employed to study the tribological properties of hydrophilic and hydrophobic microcontacts in air and immersed in water. The wettability of silicon surfaces was changed by etching with piranha solution (contact angle [CA] immeasurable small) and by SAMs (CA 110°). Micro friction was measured as a function of external load and sliding velocity in both environments. The influence of wettability on friction and adhesion is discussed.