O 16: Scanning probe methods II

Time: Monday 16:00–18:30 Location: MA 043

O 16.1 Mon 16:00 MA 043

ncAFM Force Spectroscopy of Long Range Tip Sample Interaction using FIM Characterized Tip — •Jens Falter[1], Daniel-Alexander Braun[1], Gernot Langewisch[1], Hendrik Hölscher[3], Harald Fuchs[1], and André Schirmeisen[2] — [1]Center for Nanotechnology (CeNTech) and Institute of Physics, University of Muenster (WWU) — [2]Institute of Applied Physics (IAP), Justus-Liebig-University Giessen — [3]Karlsruher Institute for Technology (KIT), Karlsruhe

Beyond imaging, non contact Atomic Force Microscopy (ncAFM) measures interaction forces between the sample surface atoms and the probing tip with atomic precision. Nevertheless, the full interaction geometry is often unknown because of the unknown tip structure. A comparison with theory to understand the underlying contrast mechanism therefore is often not possible. The implementation of the qplus sensor [1] allows combining ncAFM with the Field Ion Microscope (FIM)[2] which provides the tip structure with atomic precision. Here we present ncAFM force spectroscopy experiments with a FIM-characterized tip. Combining these microscopy techniques, the tip structure can be determined and compared with analytical models based on the given tip geometry. A comparison of our distance and voltage dependent force curves with theoretical models is in excellent agreement for the electrostatic force interactions while the van der Waals contribution is underestimated by the models. Furthermore, our approach provides a quantitative value for the absolute distance. [1] F.J. Giessibl, Appl. Phys. Lett. 76, 1470 (2000) [2] E.W. Müller, Z. Physik 131, 136 (1951)

O 16.2 Mon 16:15 MA 043

Development of a Diamond-based Scanning Probe Spin Sensor with sub-nm Spatial Resolution — •Eike Oliver Schäfer-Nolte[1,2], Friedemann Reinhard[2], Markus Ternes[1], Jörg Wrachtrup[2], and Klaus Kern[1] — [1]Max-Planck Institut für Festkörperforschung, Stuttgart, Germany — [2]3. Physikalisches Institut, Universität Stuttgart, Germany

The detection of single spins with high spatial resolution is a long-standing challenge in physics. The nitrogen-vacancy (NV) center in diamond is one of the few solid-state systems where the spin state can be optically measured [1]. By attaching a nanodiamond containing this "probe spin" to the tip of an atomic force microscope a controlled coupling between the NV and nearby spins on the sample can be achieved, allowing an indirect observation of these spins via the fluorescence signal from the NV [2]. This approach provides an unprecedented sensitivity by exploiting the quantum nature of the NV spin, enabling coherent manipulation by pulsed detection schemes well known from EPR- and NMR-spectroscopy. In this case the sensitivity is limited by the coherence time of the NV, which exceeds 1ms in pure diamond [3]. This corresponds to an energy resolution on the order of kHz.

We report on our efforts developing such a Scanning Probe Spin Sensor and present details of the experimental setup along with first experimental data.

References: [1] F. Jelezko, Phys. Stat. Sol. (a) 203, 3207 (2006) [2] J.M. Taylor, Nature Physics 4, 810 (2008) [3] G. Balasubramanian, Nature Materials 8, 383 (2009)

O 16.3 Mon 16:30 MA 043

Magnetoresistive Tunnelling Structures with Magnetostrictive Electrodes as Sensors for Atomic Force Microscopy — •Tobias Meier[1], Ali Tavassolizadeh[2], Dirk Meyners[2], and Hendrik Hölscher[1] — [1]Institute of Microstructure Technology, Karlsruhe Institute of Technology, D-76021 Karlsruhe, Germany — [2]Inorganic Functional Materials, Christian-Albrechts-Universität zu Kiel, D-24118 Kiel, Germany

We introduce a new approach on self-sensing cantilevers for the atomic force microscopy using magnetoresistive tunnelling structures (TMR-Sensors). As the resistance of a tunnelling barrier between two ferromagnetic electrodes strongly depends on the magnetisation of the electrodes material, one can measure the orientation of the magnetisation of the electrodes by measuring the resistance of the tunnelling barrier. Combining such a layer system with magnetostrictive materials, one can change the magnetisation of one electrode by applying mechanical strain and stress to the electrode and therefore change the resistance of the tunnelling barrier. Such TMR-Sensors show huge gauge-factors and can be integrated on an atomic force cantilever to measure its deflection.

O 16.4 Mon 16:45 MA 043

Revealing the angular symmetry of chemical bonds by atomic force microscopy — •Joachim Welker and Franz J. Giessibl — Faculty of Experimental and Applied Physics, University of Regensburg, Universitätsstraße 31, 93053 Regensburg

The angular symmetry of chemical bonds determines the structure of condensed matter from the atomic to the macroscopic scale. Angular dependence is characteristic of covalent bonding, which occurs in organic molecules aswell as bulk solids. Here, we have measured the angular dependence of chemical bonding forces between two atomic bonding partners: a carbon monoxide molecule that is adsorbed to a copper surface and the front atom of the metallic tip of a combined scanning tunneling microscope (STM) and atomic force microscope (AFM). We present tomographic maps of force and current as a function of distance that reveal the emergence of strongly directional chemical bonds and a conductive channel as tip and sample approach. The force maps show pronounced single, dual or triple minima depending on the directional preferences of the bonds that develop, while tunneling currents maps show a single dip for all three tip conditions.

O 16.5 Mon 17:00 MA 043

Molecular ordering and local work function of pentacene on ioniccrystalline surfaces — •Julia Neff[1], Jan Götzen[1,2], Peter Milde[3], and Regina Hoffmann-Vogel[1] — [1]Karlsruher Institut für Technologie, Physikalisches Institut, 76131 Karlsruhe, Germany — [2]Mechanical Engineering and Materials Science, Yale University, CT 06511, USA — [3]Institut für Angewandte Photophysik, Technische Universität Dresden, 01069 Dresden, Germany

The electronic properties of molecular thin films are closely related to their structural order. Therefore a precise control of the molecular packing and the crystalline orientation of semiconducting organic molecules like pentacene is of vital interest for the optimization of organic electronic devices. The growth of pentacene on KCl(001) and KBr(001) at submonolayer coverage was studied by dynamic scanning force microscopy. Pentacene was found to arrange in islands with an upright configuration on these bulk insulators. Molecularly resolved images of the islands show two different types of patterns that appear to switch repeatedly. In both patterns defects, such as a molecular vacancy and domain boundaries, were observed. Insight into the electronic structure is gained by Kelvin probe force microscopy. The measured charge densities show differences of about 1V between bare substrate regions and pentacene islands.

O 16.6 Mon 17:15 MA 043

Probing defects with the Phantom Force — •Alfred Weymouth, Thorsten Wutscher, and Franz Giessibl — Universität Regensburg, Regensburg, Germany.

Simultaneous force and tunneling microscopy (AFM and STM, respectively) offer complementary information that can be used to probe local phenomena. Typically, this is done by assuming the two channels represent independently the electronic and atomic structure (e.g. [1]). We have recently demonstrated that it is possible to dominate AFM data by locally altering the attractive electrostatic force between tip and sample via the tunneling current and sample resistivity [2]. While the AFM data can no longer be assumed to be decoupled from the STM data, this opens the possibility of using simultaneous AFM and STM data to probe local surface conductivity. Here we demonstrate that we can probe conductance changes over a defect on the H-terminated Si(100) surface.

[1] G.H. Enevoldsen et al., Phys. Rev. Lett., **102**, 136103 (2009).
[2] A.J. Weymouth et al., Phys. Rev. Lett., **106**, 226801 (2011).

O 16.7 Mon 17:30 MA 043

Superlubric sliding of metallic nanoparticles: The influence of contact area and crystallinity — •Dirk Dietzel[1,2], Tristan Mönninghoff[1], Michael Feldmann[1,2], Udo D. Schwarz[3], and Andre Schirmeisen[1,2] — [1]Institute of Applied Physics, University of Giessen — [2]Institute of Physics & Center for Nanotechnology, University of Muenster — [3]Dep. of Mech. Eng., Yale University, USA

The precise analysis of contact area dependence of nanoscale friction is a long standing problem in nanotribology. Currently, interest is especially spurred by the assumption that the scaling of friction with contact area might be a unique fingerprint to identify superlubric sliding. Superlubricity, or also termed structural lubricity, originates from the lattice mismatch at the interface of two atomically flat surfaces, and predicts a decrease of shear stress with contact area, and thus a sublinear contact area dependence of friction. To measure the interfacial friction we have manipulated metallic nanoparticles of different size on atomically flat surfaces by contact mode AFM techniques[1]. Our results confirm the sublinear scaling of friction with contact area. Moreover, we could identify different scaling factors for amorphous and crystalline particles. The experiments have been accompanied by numerical simulations of friction of Au and Sb particles on HOPG, which have indicated that not only contact area and crystallinity are important, but also the precise shape of the nanoparticle is crucial for friction. The good agreement between experiment and simulation enables us to quantitatively predict nanoscale friction from fundamental atomic quantities. [1]Dietzel et al., Phys. Rev. Lett. 101, 125505 (2008)

O 16.8 Mon 17:45 MA 043

Hidden Atomic Resolution - Investigation of a Complex Oxide Material with 2D Force Spectroscopy — •Christin Büchner, Leonid Lichtenstein, Stefanie Stuckenholz, Markus Heyde, and Hans-Joachim Freund — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany

For the first time, a model system of an amorphous oxide network has been prepared. A double layer film of silicon dioxide was grown on a Ru(0001) support, exhibiting a complex network of differently sized ring units [1]. This atomically flat system was investigated using frequency-modulated dynamic force microscopy (FM-DFM). Under very stable imaging conditions (UHV, low temperature), we performed two-dimensional (2D) force spectroscopy mapping. Measuring Δf(z)-curves up to very short distances to the surface, a significant variation in the contrast generating shift can be observed. The repulsive regime exhibits a significantly higher corrugations than the attractive branch. This method gives insight into the contrast formation of DFM and may be employed for different systems, where achieving atomic resolution is challenging. High resolution scanning probe microscopy images of a thin vitreous silica film will be presented together with 2D force spectroscopy data. The force mapping results will be discussed together with a general consideration of characteristic Δf(z)-curves.

[1] Lichtenstein et al., Angew. Chem. IE. doi: 10.1002

O 16.9 Mon 18:00 MA 043

A pick-and-place technique for the assembly of integrated quantum optical hybrid devices — •Andreas W. Schell, Günter Kewes, Janik Wolters, Tim Schröder, Thomas Aichele, and Oliver Benson — Nanooptik, Humboldt-Universität zu Berlin, Deutschland

Combining pre-selected nanoparticles with nano-or microstructures produced in a top down process is an important but challenging step in the production of hybrid devices for nano-optics. Here, a pick-and-place technique for the controlled bottom up assembly of integrated quantum optical devices based on atomic force microscopy combined with optical confocal microscopy is introduced [1]. This technique allows for the placement of nanoparticles on nearly arbitrarily shaped samples. By coupling nitrogen vacancy defect centers in diamond nanocrystals, which are capable of emitting single photons, to photonic and plasmonic structures like photonic crystals, photonic crystal fibers or nanoantennas using this pick-and-place technique, hybrid quantum optical elemements are produced.

[1] A.W. Schell et al., Rev. Sci. Instrum. 82, 073709 (2011).

O 16.10 Mon 18:15 MA 043

Scanning Microwave Microscopy Mapping of Semiconducting and Dielectric Components in CMOS Logic devices — •Matthias A. Fenner[1], Thomas Schweinböck[2], and Jesper Witteborn[2] — [1]Agilent Technologies, Lyoner Str. 20, 60528 Frankfurt, Germany — [2]Infineon Technologies AG, Am Campeon 12, 85579 Neubiberg, Germany

We report Scanning Microwave Microscopy (SMM) investigations of CMOS logic devices. SMM combines Atomic Force Microscopy (AFM) and a microwave Vector Network Analyzer to map the microwave signal reflected from the tip sample junction. The reflected signal depends on the impedance of the junction [1]. Varying dielectric and semiconducting material properties lead to modified impedances and can thus be detected. Applying a low frequency AC bias between tip and sample leads to modulation of the semiconductor space charge region and the reflected signal [2]. Both signals can be acquired simultaneously.

Cross sections of 90-nm technology node CMOS logic devices have been prepared and investigated using SMM to map dielectric properties and dopant density.

[1] Huber, H.P., et al., Review of Scientific Instruments, 2010. 81(11), p. 113701-9. [2] Smoliner, J., et al., Journal of Applied Physics, 2010. 108(6), p. 064315-7.