O 3: Methods: Scanning probe techniques I

Time: Monday 11:15–13:00 Location: H32

O 3.1 Mon 11:15 H32

Contrast mechanisms for the detection of ferroelectric domains with scanning force microscopy — •Tobias Jungk, Florian Johann, Akos Hoffmann, and Elisabeth Soergel — Physikalisches Institut, Universität Bonn, Wegelerstrasse 8, 53115 Bonn

We present an analysis of the contrast mechanisms for the detection of ferroelectric domains on all faces of bulk single crystals using scanning force microscopy. The experiments were carried out with hexagonally poled lithium niobate to access well-defined domain structures on every crystal face [1]. Using a rotation stage including subsequent image processing allows for the discrimination of deflection and buckling from the vertical signal, which – together with the lateral signal – yield all accessible information [2]. Thus, the domain contrast can be attributed to three different mechanisms: (i) the thickness change of the sample due to an out-of plane piezoelectric response, (ii) the lateral displacement of the sample surface due to an in-plane piezoresponse and (iii) an expansion/contraction movement in the vicinity of the domain wall on the crystallographic y- and z-faces. A careful analysis of the movement of the cantilever with respect to its orientation relative to the crystallographic axes of the sample allows a clear attribution of the observed domain contrast to the corresponding driving forces.

[1] T. Jungk, A. Hoffmann, and E. Soergel, New J. Phys. 11, 033029 (2009).

[2] F. Johann, T. Jungk, S. Lisinski, A. Hoffmann, L. Ratke, and E. Soergel, Appl. Phys. Lett. 95, 202901 (2009).

O 3.2 Mon 11:30 H32

SubSurface AFM: towards nondestructive 3D microscopy — •Gerard J. Verbiest, Johannes Simon, and Marcel J. Rost — Leiden University, Leiden, Netherlands

True nondestructive, subsurface microscopy is desired in many fields ranging from material science over biology to industry. The variety of possible applications include, e.g., microelectronics failure analysis or biological processes within cells. The key to 3D information is the use of nondestructive, ultrasonic acoustic waves, which lead to an interference pattern at the sample surface, that is measured locally with an AFM. This has been demonstrated experimentally [1].

In order to receive insights in the physical contrast mechanism and to design the most suited AFM, we are both developing an analytical model and performing finite element analysis calculations to understand the experimentally determined acoustic wave propagation in artificially created samples. We address questions like: what causes the (surface) contrast; what is the ultimate achievable resolution; and how to extract depth information?

[1] G.S. Shekhawat and V.P. Dravid; Science 310, 89 (2005) 5745

O 3.3 Mon 11:45 H32

Atomic-resolution force map measurements on single molecules — •Fabian Mohn, Leo Gross, Nikolaj Moll, Peter Liljeroth, and Gerhard Meyer — IBM Research - Zurich, 8803 Rüschlikon, Switzerland

It was recently shown that atomic resolution can be achieved in AFM imaging of individual molecules by a controlled functionalization of the microscope's tip apex [L. Gross et al., *Science* **325**, 1110 (2009)]. We present measurements that yield further insight into the nature of the contrast mechanism in this atomic-resolution imaging of molecules.

In particular, the distance-dependence of the frequency shift above admolecules was investigated with atomic resolution. The standard technique of 3D force mapping was extended to permit measuring at close tip–sample distances, in the regime of maximal attractive forces. A precise control of the interaction strength during data acquisition is essential to avoid instabilities of the imaged molecules. Our technique enables atomic resolution on both the substrate and the admolecules, simultaneously.

O 3.4 Mon 12:00 H32

Interaction of the STM/AFM tip with graphite and graphene surfaces - theoretical models — •Martin Ondráček, Vít Rozsíval, and Pavel Jelínek — Institute of Physics, Academy of Sciences of the Czech Republic, Praha

Although atomic resolution is routinely achieved on the graphite (0001) surface and graphene with scanning probe techniques (STM and AFM), there are still open questions with respect to the identification of the atomic-scale features in the images with the actual atomic and hollow sites on the surface. While it is generally agreed that the low-bias STM sees one of the two non-equivalent surface atoms of the graphite surface (the β-site atom), the interpretation of contrast in the AFM is not so simple. Depending on the experimental setup, the apparent height maxima may be located at the hollow sites or at the atomic sites. We show that any realistic modeling of the AFM must include the relaxation of the tip and surface atomic structure as well as the chemical composition of the tip. Furthermore, conductance calculations aiming to explain near-to-contact STM measurements cannot neglect multiple electron scattering. In order to meet these requirements, we combine accurate total energy DFT calculations in the PAW method with calculations of electron transport in the Green's function approach. Such an approach allows us to analyze the relation between the chemical short-range force and the electric conductance in the range from the tunneling to the contact regime.

O 3.5 Mon 12:15 H32

Searching for spin contrast on NiO with Ni tips — •Florian Pielmeier and Franz J. Giessibl — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

Nickel atoms in the NiO(001) surface show antiferromagnetic ordering at room temperature resulting from indirect exchange interactions between neighbouring Ni 3d-electrons [1]. Frequency modulation atomic force microscopy, using extra stiff qPlus sensors, was used to probe the NiO(001) surface at room temperature. At tip-sample distances in the range of a few angstroms, the different spin orientations should provide detectable contributions to the short-range interaction forces between tip and sample. Nickel was used as the tip material as it is rather inert to oxygen and is widely used in spin polarized STM. Atomic resolution images with very good signal-to-noise ratio are presented, but similar to previous measurements with Co and NiO tips [2] evidence for spin contrast has not been found yet.

[1] D. Ködderitzsch, W. Hergert, W. M. Temmerman, Z. Szotek, A. Ernst, H. Winter: Phys. Rev. B 66, 064434 (2002)

[2] M. Schmid, J. Mannhart, F.J. Giessibl: Phys. Rev. B 77, 045402 (2008)

O 3.6 Mon 12:30 H32

Challenges in constructing spin-polarized scanning probe tips — •Thorsten Wutscher and Franz J. Giessibl — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg

A central feature of scanning force microscopy (SFM) is the force dependence upon the atomic configuration and chemical identity of the tip [1, 2]. Spin-polarized tips, created with an external magnetic field, have been shown to yield spin contrast at the atomic scale [3]. In order to detect spin contrast, the apex atom has to be a magnetic atom, the spins between tip and sample should be (anti-)parallel to each other and the magnetic moment of the apex atom has to be stable. Given an appropriate tip selection, this should be possible at room temperature without the presence of an external magnetic field. *In situ* cleaved tips can avoid contamination near the tip-sample junction. Nickel oxide was chosen as a candidate tip material because it has a high N*é*el temperature and a common magnetic bulk and surface alignment. It has a rock salt structure and thus cleaves well. The tips were oriented on a quartz cantilever (qPlus sensor) for SFM experiments.

[1] Y. Sugimoto, P. Pou, M. Abe, P. Jelinek, R. Pérez, S. Morita and *Ó*. Custance, Nature, 446, 64-67 (2007)

[2] S. Hembacher, F. J. Giessibl, J. Mannhart, Science, 305, 380-383 (2004)

[3] U. Kaiser, A. Schwarz, R. Wiesendanger, Nature, 446, 522-525 (2007)

O 3.7 Mon 12:45 H32

Characterization of tips for spin-polarized scanning tunneling microscopy — Guillemin Rodary, •Sebastian Wedekind, Hirofumi Oka, Dirk Sander, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle

A common procedure to prepare tips for spin-polarized scanning tunneling microscopy is to deposit magnetic materials onto a W-tip, which was electrochemically etched and subsequently flashed to 2200 K under UHV conditions [1]. However, this macroscopic tip preparation does not necessarily yield a certain magnetic sensitivity. We show that depositing Cr or Co/Cr bilayers on a W-tip can lead to vastly different magnetic tip responses in external fields [2]. We find that the microscopic tip preparation by voltage pulses under imaging conditions is decisive for the resulting magnetic configuration at the tip apex. We propose a conclusive characterization of the magnetic configuration of the tip apex. We show that both careful tip preparation and characterization by tunneling spectroscopy need to be augmented by measurements in magnetic field to ensure a reliable analysis of a magnetic contrast in spin-polarized scanning tunneling microscopy studies.

[1] R. Wiesendanger, Rev. Mod. Phys. **81** (2009)1495. [2] G. Rodary, S. Wedekind, H. Oka, D. Sander, J. Kirschner, Appl. Phys. Lett. **95** (2009) 152513.