O 77: Poster Session VI: Scanning probe techniques: Method development I

Time: Wednesday 13:30–15:30 Location: P

O 77.1 Wed 13:30 P

Identifying the atomic configuration of the tip apex using STM and frequency-modulation AFM with CO on Pt(111) — •Oliver Gretz, Alfred J. Weymouth, and Franz J. Giessibl — Institute of Experimental and Applied Physics, Department of Physics, University of Regensburg, 93053 Regensburg

We investigated the atomic structure of metal tips by scanning individual CO molecules adsorbed on Pt(111) using scanning tunneling microscopy (STM) and frequency-modulation atomic force microscopy (FM-AFM). When scanning very close over a CO molecule, the frontmost atoms of the tip can be individually resolved in both the FM-AFM image and in the STM image. This is in contrast to previous work where CO was adsorbed on a different substrate: Cu(111). In this previous study, individual atoms could not be observed in the raw STM image but only in FM-AFM. We discuss the mechanisms behind the higher spatial resolution in STM. On Cu(111), the occupied surface state plays a large role in STM images near the Fermi level, and as adsorbed CO repels the surface state, it appears as a wide trough in STM images. In contrast, Pt(111) lacks an occupied surface state and an adsorbed CO molecule appears as a peak. We investigate if CO bending strongly influences the STM images, concluding that the atomic resolution of the tip over Pt(111) is due to highly localized through-molecule tunneling and CO bending is insignificant for contrast formation. Modelling the current between the CO and front atoms of the tip supports our findings.

Gretz et al., Phys. Rev. Research 2, 33094 (2020).

O 77.2 Wed 13:30 P

Strumming a Single Chemical Bond — •Alfred J. Weymouth, Elisabeth Riegel, Oliver Gretz, and Franz J. Giessibl — Universität Regensburg

Atomic force microscopy and scanning tunneling microscopy can image the internal structure of molecules adsorbed on surfaces. One reliable method is to terminate the tip with a nonreactive adsorbate, often a single CO molecule, and to collect data at a close distance where Pauli repulsion plays a strong role. Lateral force microscopy, in which the tip oscillates laterally, probes similar interactions but has the unique ability to pull the CO over a chemical bond, load it as a torsional spring, and release it as it snaps over with each oscillation cycle. This produces measurable energy dissipation. The dissipation has a characteristic decay length in the vertical direction of 4 pm, which is 13 times smaller than the decay length in typical STM or AFM experiments.

Physical Review Letters, 124, 196101 (2020)

O 77.3 Wed 13:30 P

Bond-Level Imaging of Organic Molecules Using Q-Controlled Amplitude Modulation Atomic Force Microscopy — •Daniel Martin-Jimenez[1,3], Alexander Ihle[1,3], Sebastian Ahles[2,3], Hermann A. Wegner[2,3], André Schirmeisen[1,3], and Daniel Ebeling[1,3] — [1]Institute of Applied Physics (IAP), Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany — [2]Institute of Organic Chemistry, Justus Liebig University Giessen, Heinrich-Buff-Ring 17, 35392 Giessen, Germany — [3]Center for Materials Research (LaMa), Justus Liebig University Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

The bond imaging atomic force microscopy (AFM) technique has become an invaluable tool for studying organic molecules on surfaces. The functionalization of the AFM-tip with a single CO molecule improves the lateral resolution and allows to visualize the chemical structure of adsorbed organic molecules. Such experiments are usually performed at low temperatures in UHV environment in the frequency modulation (FM) mode. Here, we use the Q-controlled amplitude modulation (AM) mode for imaging organic molecules with CO-functionalized tips in constant-height mode. By reducing the effective quality factor (Qeff) of the sensor from about 20000-30000 to 1500-4000, we are able to image molecules with atomic resolution. By using appropriate imaging parameters, an increased effective signal-to-noise ratio is achieved in the Q-controlled AM mode (on the order of 30-60 %). This advantage over the conventional FM mode might, e.g., be used for increasing the experimental throughput.

O 77.4 Wed 13:30 P

High-precision atomic force microscopy with atomically-characterized tips — •Alexander Liebig, Angelo Peronio, Daniel Meuer, Alfred J. Weymouth, and Franz J. Giessibl — Institute of Experimental and Applied Physics, University of Regensburg, Germany

Traditionally, atomic force microscopy (AFM) experiments are conducted at tip-sample distances where the tip strongly interacts with the surface. This increases the signal-to-noise ratio, but poses the problem of relaxations in both tip and sample that hamper the theoretical description of experimental data. Here, we employ AFM at relatively large tip-sample distances where forces are only on the piconewton and subpiconewton scale to prevent tip and sample distortions. Acquiring data relatively far from the surface requires low noise measurements. We probed the $CaF_2(111)$ surface with an atomically-characterized metal tip and show that the experimental data can be reproduced with an electrostatic model. By experimentally characterizing the second layer of tip atoms, we were able to reproduce the data with 99.5 % accuracy. Our work links the capabilities of non-invasive imaging at large tip-sample distances and controlling the tip apex at the atomic scale [1].

[1] A. Liebig, A. Peronio, D. Meuer, A. J. Weymouth and F. J. Giessibl, New J. Phys. 22, 063040 (2020).

O 77.5 Wed 13:30 P

Charging single metal nanoparticles grown on thin alumina films by the AFM tip — Baptiste Chatelain, •Ali El Barraj, Clemence Badie, Lionel Santinacci, and Clemens Barth — Aix-Marseille University, CNRS, CINaM, 13288 Marseille, France

The characterization of charges inside a single metal island or nanoparticle (NP), which are supported on an insulating thin film, is of high interest in research fields like heterogeneous catalysis and microelectronics. The reason is that charges in a NP can have a large impact onto the NP*s catalytic activity and that they can interfere with the underlying insulating film, partially via defects of the film. Whereas the first aspect is certainly of importance in catalysis, the second phenomenon is of particular interest in micro-electronics because a detailed analysis of the charge-insulator interaction can explain phenomena that are related to leakage currents and device performance.

It has been already shown hat electrostatic force microscopy (EFM) and Kelvin probe force microscopyt (KPFM) are suitable techniques for charge manipulation experiments at nano-objects like NPs and that they can be used to monitor, in particular, the charge-insulator interaction. Here, we use KPFM to study injected charges inside PdNPs and AuNPs, which are grown on 15 to 80nm thin ALD grown aluminum oxide (alumina) films. We show that the alumina films have a high insulating character, which allows injecting charge into the surface or NP without loosing the charge into the film. Apart from the material specific results, we discuss the experimental procedures and related difficulties that may appear during charge manipulation experiments.

O 77.6 Wed 13:30 P

Ultra-Shallow Dopant Profiles in H:Si(001) as In-Situ Electrodes in Scanning Probe Microscopy — •Alexander Kölker, Takashi Kumagai, Martin Wolf, and Matthias Koch — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

To fully enable the potential of nano-devices a detailed understanding of the underlying physics is of importance linking the atomic structure to the electronic properties of the device. Although scanning probe microscopy (SPM), with its outstanding spatial resolution, is sensitive to both, the experimental capabilities are limited by the vertical arrangement of the tip-sample junction. Therefore it is often impossible to characterize an electrical nano-circuit in-operation with a conventional SPM. These restrictions can be addressed using multi-tip scanning tunneling microscopy (STM) [1]. However, upgrading an existing STM with additional electrodes requires severe and cost-intensive modifications of the experimental setup. Here, we demonstrate the applicability of ion-implanted electrodes as a feasible way to enhance a commercial Createc GmbH low-temperature SPM with additional electrodes. These electrodes are in close proximity to the surface and act as drain or gate and show ohmic behaviour [2], even after high temperature surface preparation needed to achieve an atomically flat surface. We used STM spectroscopy to probe the transition from metallic to

insulating at the electrode interface. First gating experiments of dangling bonds on the H:Si(001) surface are presented. [1] B. Voigtländer et. Al, Rev. Sci. Instrum. 89, 101101 (2018) [2] A.N. Ramanayaka et. al Scientific Reports 8, 1 (2018)