# O 6: Scanning probe methods I

Time: Monday 10:30–13:00 Location: MA 043

O 6.1 Mon 10:30 MA 043

**Combined ion and electron sputtering for STM tip cleaning** — •David Hellmann, Ludwig Worbes, Hanna Fedderwitz, Nils Könne, Konstantin Kloppstech, and Achim Kittel — EHF, Physik, Fak. 5, Carl von Ossietzky Universität Oldenburg, Carl-von-Ossietzky-Straße 9-11, 26129 Oldenburg

In STM applications, atomic resolution of a surface reconstruction close to the ground state is considered as an indicator for a clean STM tip and sample surface. Diverse cleaning procedures are suggested in literature for both, tip and samples [1]. In practice not all of them seem to work reliably. Especially removing carbon residues from tips without reducing their sharpness can be challenging. In our experience using a combination of oxygen and electron sputtering yields good and, of equal importance, reproducible results. For this we employ a commercial ion gun and a home made minituarised electron source, respectivily [2]. Here we report about the results of a systematic investigation focused on this combined treatment. Literature: [1] C. J. Chen, Introduction to Scanning Tunneling Microscopy, 2nd ed. (Oxford University Press, Oxford, 2008). [2] D. Hellmann, L. Worbes and A. Kittel, Rev. Sci. Instrum., 82 (2011)

O 6.2 Mon 10:45 MA 043

**Ultra compact 4-tip STM/AFM for electrical measurements at the nanoscale** — •Vasily Cherepanov, Stefan Korte, Marcus Blab, Evgeny Zubkov, Hubertus Junker, Peter Coenen, and Bert Voigtländer — Peter Grünberg Institut (PGI-3), Forschungszentrum Jülich, 52425 Jülich, Germany, and JARA-Fundamentals of Future Information Technology

A new type of ultra miniature nano drive was specially developed to serve as an SPM coarse positioning unit. This Koala Drive makes the scanning probe microscopy design ultra compact and leads accordingly to a high mechanical stability. We use the Koala-drive to build a compact 4-tip STM/AFM where four independent scanning units are integrated on a diameter of 50 mm. Here we present the design of the microscope and show several measurement examples to demonstrate the device performance, such as four point measurements on silicide nanowires and graphene samples.

O 6.3 Mon 11:00 MA 043

**Development of a Scanning Tunneling Microscope for Measurements down to 15 mK** — •Maximilian Assig, Fabian Zinser, Markus Etzkorn, Christian R. Ast, and Klaus Kern — Max-Planck-Institut für Festkörperforschung,

The investigation of novel physical phenomena implies the design and the construction of new instruments and measurement techniques, which can overcome experimental limitations and open new areas in measurement accuracy. Scanning Tunneling Microscopy (STM) is a technique for probing the electronic structure of single adsorbed atoms, molecules and nanostructures at surfaces with atomic resolution. In this contribution we present the realization of a scanning tunneling microscope (STM) operating at temperatures of 15 mK which is accomplished by attaching the STM to a dilution refrigerator. We can apply high magnetic fields up to 14 T perpendicular and 0.5 T parallel to the sample surface. An ultra high vacuum (UHV) preparation chamber is attached to the cryostat allowing *in situ* preparation of the samples to be investigated. The electronic resolution of our STM was verified by taking tunneling spectra between a superconducting Aluminum tip and a Cu(111) surface at the base temperature of the cryostat. From fits to the BCS theory of superconductivity we were able to extract an upper limit for the effective temperature of the electrons which is $T_{\mathrm{eff}} = 87 \pm 3\,\mathrm{mK}$ for our best measurement. This corresponds to an energy resolution of $\Delta E = 3.5 \mathrm{k_b T} = 26 \pm 1\,\mu\mathrm{eV}$.

O 6.4 Mon 11:15 MA 043

**Spatial variations of heat transfer at nanoscales investigated by Near-field Scanning Thermal Microscopy (NSThM)** — •Ludwig Worbes, David Hellmann, Hanna Fedderwitz, Nils Könne, Konstantin Kloppstech und Achim Kittel — EHF/EPKOS, Institut für Physik, Universität Oldenburg

Due to the advance in nanoscience heat transport at small length scales is receiving more attention as a field of fundamental research as well as one influencing future technologies.

The Near-field Scanning Thermal Microscope (NSThM) is a tool to investigate heat transport on a nanoscale[1]. It is based on a UHV-STM, featuring a tunneling probe with an integrated miniaturized thermocouple temperature sensor. Therefore, we can measure the temperature change of the tip due to heat flux between a heated or cooled sample and the probe in the range of distances between (tunnel-) contact and a few nanometers with spatial resolution.

This heat flux can be mediated by different mechanisms: A possible transport mechanism is thermal near field radiation especially relevant for small distances. A strong enhancement of near field heat flux by thin and electrical high resistive layers or adsorbed molecules is predicted by theory [2]. Another possibility is phononic or electronic heat transport through adsorbed molecules forming a molecular junction between sample and probe. We present measurements performed on Au(111) surfaces to discuss the influence of adsorbates.

[1] Uli F. Wischnath et al., Rev. Sci. Instrum. 79, 073708 (2008) [2]A.I. Volotkitin, B. N. J. Persson, Rev. Mod. Phys. 79, 1291 (2007)

O 6.5 Mon 11:30 MA 043

**Next generation SPM control system extends the range of applications in surface science** — •Alessandro Pioda — SPECS Surface Nano Analysis GmbH

Novel scanning probe microscopy techniques, modes of operation, and advances in microscope hardware are pushing the boundary for signal resolution and flexibility in SPM measurements. Here we present a new state of the art SPM control system, which improves signal precision, resolution, bandwidth and noise performance by about one order of magnitude compared to current generation controllers. The controller incorporates the performance of expensive dedicated instruments in a compact modular multichannel package. In combination with the well proven and flexible Nanonis SPM control software, this next generation controller is the ideal platform for the most demanding microscopy, spectroscopy and transport measurements tasks, opening the door to a larger range of applications compared to current systems. Furthermore, the flexible and easily configurable user interface of the controller and the large number of measurement channels allows its operation as a high performance DC and AC source and measurement interface with ppm precision and multiple lock-in amplifiers, opening new perspectives for materials research.

O 6.6 Mon 11:45 MA 043

**Determination of the electron-phonon coupling in ultra-thin Pb films with STM** — •Tobias Märkl[1], Michael Schackert[1], Martin Hölzer[2], Sergey Ostanin[2], Arthur Ernst[2], and Wulf Wulfhekel[1] — [1]KIT, Karlsruhe — [2]MPI, Halle

The typical quantity to characterize the electron-phonon coupling of a material is the energy-dependent Éliashberg function $\alpha^2F(\omega)$ determining the superconducting properties of the material. It can be determined with tunneling spectroscopy in the superconducting state and inversion of the Éliashberg equations or directly using inelastic tunneling spectroscopy (ITS) in the normal state.

We used scanning tunneling microscopy (STM) at 1K in UHV to locally measure inelastic tunneling spectra of thin Pb films on Cu(100) and CuN/Cu(100) to determine $\alpha^2F(\omega)$ as function of the local Pb thickness. The films were prepared in situ with varying thickness up to 25 atomic layers and were in the normal state due to the proximity effect. We find a good agreement of the obtained Éliashberg function with ab initio calculations for bulk lead.

O 6.7 Mon 12:00 MA 043

**Scanning tunneling microscopy of Ni layers on W(110)** — •Johannes Schöneberg, Alexander Weismann, and Richard Berndt — Institut für Experimentelle und Angewandte Physik der Universität Kiel Leibnizstr. 19 D-24118 Kiel

The growth and electronic properties of one to seven monolayers of Ni grown on W(110) were investigated with a low-temperature scanning tunneling microscope. The features in dI/dV spectra from these layers are distinctly different. We analyze the data experimental in terms of bulk band structure calculations. Financial support through SFB 668 is acknowledged.

O 6.8 Mon 12:15 MA 043

**Single Molecule and Single Atom Sensors for Atomic Resolution Imaging of Chemically Complex Surfaces** — •Georgy Kichin[1,2], Christian Weiss[1,2], Christian Wagner[1,2], Stefan Tautz[1,2], and Ruslan Temirov[1,2] — [1]Peter Grünberg Institute (PGI-3),Forschungszentrum Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology, Germany

To image the inner structure of molecules have always been the challenge for the surface science. Recently we have demonstrated that this task can be solved with a low-temperature scanning tunneling microscope (STM) if molecular hydrogen or deuterium is condensed in the junction [1,2,3]. In this contribution we will demonstrate that individual Xe atom, single CO and $CH_4$ molecules adsorbed at the tip apex of the STM produce similar resolution as achieved with hydrogen [4]. This result supports our earlier claim that a single molecule adsorbed at the STM tip can act as a nanoscale force sensor / signal transducer.

[1] R. Temirov et al. *New J. Phys.*,**10**, 053012, (2008)
[2] C. Weiss et al. *Phys. Rev. Lett.*, **105**, 086103, (2010)
[3] C. Weiss et al. *J. Am. Chem. Soc.*, **132**, 11864, (2010)
[4] G. Kichin et al. *J. Am. Chem. Soc.*, **133**, 16847, (2011)

O 6.9 Mon 12:30 MA 043

**Electron transport studies through a single octanethiol molecule** — •René Heimbuch, Avijit Kumar, Hairong Wu, Bene Poelsema, and Harold Zandvliet — Physics of Interfaces and Nanomaterials, MESA+ Institute for Nanotechnology, University of Twente, the Netherlands

Single molecules, used as functional electronic components define the field of molecular electronics. These molecules need to be contacted via electrodes to the macroscopic world. Previously, a single octanenthiol molecule was trapped between an STM tip and a substrate and the conductance was measured. In our work, we study the full transport through a single octanethiol molecule bridging the gap between the STM tip and the substrate. Control over the switching behavior of the molecule has been achieved through careful tuning of the electrodes' interspace and voltage. For an electric field exceeding $4 - 6 \cdot 10^9$ V/m, the switch can be turned "ON". Once trapped, we also measure an increase in the conductance of the molecule upon compression. This method is used to investigate the transport properties of the molecule as function of temperature.

O 6.10 Mon 12:45 MA 043

**Atomic Forces and Energy Dissipation of a Bi-Stable Molecular Junction** — •Christian Lotze[1], Martina Corso[1], Katharina Franke[1], Felix von Oppen[2], and Nacho Pascual[1] — [1]Inst. f. Experimentalphysik FU Berlin — [2]Inst. f. theoretische Physik FU Berlin

Tuning Fork based dynamic STM/AFM is a well established method combining the advantages of scanning tunneling and dynamic force microscopy. Using tuning forks with high stiffness, stable measurements with small amplitudes, below 1 Å can be performed. In this way, conductance and frequency shift measurements of molecular junction can be obtained simultaneously [1] with intramolecular resolution [2].

One of the most intriguing aspects of molecular junctions relates to the effect of structural bi-stabilities to the properties of the junction. These lead, for example, to conductance fluctuations, telegraph noise and the possibility to switch the electrical transport through the junction.

In this presentation, we characterize a model bi-stable molecular system using dynamic force spectroscopy. The effect of current-induced stochastic fluctuations of conductance are correlated with fluctuations in force. In our experiment we identified the last from both, frequency shifts and energy dissipation measurements, picturing a regime in which electrical transport and mechanical motion are coupled.

[1] N. Fournier *et. al*, PhysRevB 84, 035435 (2011),
[2] L. Gross *et. al*, Science 324, 1428 (2009)