O 101: Scanning Probe Techniques: AFM

Time: Friday 10:30–12:45 Location: MA 144

O 101.1 Fri 10:30 MA 144

Probing higher force gradients with Atomic Force Microscopy on the graphene surface — •Daniel Meuer, Thomas Hofmann, Alfred John Weymouth, Andrea Donarini, and Franz Josef Giessibl — Universität Regensburg, D-93053 Regensburg

Graphene is a very important material for applications in the future, because of its outstanding material properties. The atomic structure of graphite, graphene and carbo-nanostructures were investigated by Scanning Tunneling Microscopy [1] and with Atomic Force Microscopy [2] in several studies.

In this contribution we analyze the higher harmonics of the cantilever oscillation. The signal of the nth harmonic of the cantilever deflection connects to the nth force gradient [3]. Our hypothesis is that the strong signal is a signature of the two top carbon layers that abruptly rehybridize from sp2 to sp3 by forming and breaking a covalent bond between the graphene layer and the buffer layer beneath.

[1] G. Binnig, et al., Europhysics Lett. (EPL) 1, S. 31-36 (1986); S.-I. Park et al., App. Phys. Lett. 48, S. 112 (1986); D. Tománek et al., Phys. Rev. B 35, S. 7790-7793 (1987);

[2] H. Hölscher, et al., Phys. Rev. B 62, S. 6967-6970 (2000); S. Hembacher et al., Proc. of the Nat. Academy of Sciences 100, S. 12539-42 (2003);

[3] U. Dürig, N. J. Phys. 2, 5.1-5.12 (2000); S. Hembacher, et al., Science 305, 380 (2004)

O 101.2 Fri 10:45 MA 144

Information in multifrequency AFM data — •Daniel Platz[1,2], Daniel Forchheimer[2], Erik A. Tholén[3], John E. Sader[4], and David B. Haviland[2] — [1]Max-Planck-Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, D-01187 Dresden, Germany — [2]KTH Royal Institute of Technology, Albanova University Center, SE-114 19 Stockholm, Sweden — [3]Intermodulation Products AB, Vasavägen 29, SE - 169 58 Solna, Sweden — [4]The University of Melbourne, Victoria 3010, Australia

In contrast to conventional amplitude or frequency-modulated AFM, multifrequency AFM is characterized by tip motion that contains more than one single oscillation frequency. The additional frequency components might be generated by a nonlinear tip-surface force, a multifrequency drive scheme, or both. Each frequency component is usually considered as an individual channel carrying information about the tip-surface interaction. However, it is generally not understood exactly which information about the tip-surface force is encoded in each of the individual frequency components. We present a clear definition of "information" in the context of multifrequency AFM, and we introduce a general method, called numerical kernel estimate (NKE), for the analysis of multifrequency AFM spectra. We demonstrate the capabilities of NKE by applying it to the analysis of Intermodulation AFM. This analysis reveals the fundamental limitations of force measurement from spectral data. Moreover, we use NKE also for the design of new multifrequency drive schemes that are optimal for the extraction of a maximum amount of information about the tip-surface force.

O 101.3 Fri 11:00 MA 144

High Resolution at High Viscosity - Dynamic Force Microscopy at Low Q-Factors — •Stefan Weber[1,2], Jason Kilpatrick[2], Timothy Brosnan[2], Victor Bergmann[1], Suzanne Jarvis[2], and Brian Rodriguez[2] — [1]Physics of Interfaces, Max Planck Institute for Polymer Research, Mainz, Germany — [2]Conway Institute of Biomedical and Biomolecular Research, University College Dublin, Dublin, Ireland

Atomic force microscopy (AFM) is often used in non-aqueous liquid environments for in situ investigations of processes including chemical reactions, lubrication and molecular ordering. These environments often exhibit a much higher damping, lowering the quality factor (Q) of the cantilever resonance. It is generally expected that AFM operation in such environments will not yield atomic scale resolution due to increased noise resulting in a reduced signal-to-noise ratio (SNR).

Recently, we have demonstrated that true atomic resolution can be obtained in a highly viscous environment. In particular, we imaged the atomic structure of highly ordered pyrolytic graphite (HOPG) and mica surfaces with SNR values comparable to ultra-high vacuum systems (Weber, S.A.L., et al., Nanotech., 2014. 25(17): p. 175701). We also investigated the influence of the Q-factor of a cantilever on the thermal noise of the relevant AFM signals, namely amplitude, phase and frequency shift. This new understanding of the noise contributions to the imaging process opens up a new route to high resolution AFM studies in a wide range of viscous fluids.

O 101.4 Fri 11:15 MA 144

A sophisticated Feedback Control algorithm for High-Speed AFM — •Anne-D. Mueller and Falk Mueller — Anfatec Instruments AG, Melanchthonstr. 28, 08606 Oelsnitz.

The need to track surface features in Scanning Probe Applications (SPM) while increasing the scan speed leads to the complication, that the feedback parameters (e.g. Ki and Kp) entered by the user become more difficult to determine. As a result, the surface is not tracked with optimum performance.

This contribution utilizes a control theory approach to determine the microscope's closed loop transfer function in Z. An algorithm to automatically determine the optimum parameter set is presented that considers a scan speed driven bandwidth. As a result, Ki and Kp become system specific, while the strength of the tracking representing the sample roughness is left as the only free user entry. This completely new approach not only simplifies the control of an AFM; it automatically leads to an optimum noise level. Surprisingly, the feature tracking bandwidth can be tuned higher than the system's bandwidth.

With the help of a simulation circuit for contact and dynamic mode AFM operation, the frequency dependence of the feature tracking on the entry parameters is simulated and studied. Finally, the method is applied to real feedback systems demonstrating unexpected performance.

O 101.5 Fri 11:30 MA 144

Capillary force acting on a particle correlated with the shape of the meniscus — •Frank Schellenberger, Periklis Papadopoulos, Stefan Weber, Michael Kappl, Doris Vollmer, and Hans-Jürgen Butt — Max Planck Institute for Polymer Research, Mainz, Germany

Capillary bridges play a important role for the stability of colloidal systems. The forces of these bridges strongly correlates with their shape. It is possible to measure capillary forces with an Atomic Force Microscope (AFM), but it is impossible with such a device to image the shape of the capillary bridge at the same time.

Analytical and numerical calculations exist that correlates the force of the capillary bridges with the shape of the liquid . However experimentally capillary bridges could not directly be imaged with the corresponding force in the micrometer range so far. A Laser Scanning Confocal Microscope (LSCM) can visualize the shape of a liquid bridge on solid surface in a three-dimensional form. We built a combined LSCM and AFM device and measured the forces with colloidal probes on liquid surfaces. The combination of force spectroscopy and confocal microscopy allows us to image capillary bridges and simultaneously measure the corresponding force.

With our setup we can now verify the theoretical forces, calculated from the shape of the meniscus, and the corresponding force curves. We present our results of the simultaneous AFM and LSCM measurements of capillary bridges.

O 101.6 Fri 11:45 MA 144

The contact charging of insulators by atomic force microscopy — •Monika Mirkowska[1,2], Markus Kratzer[1], Stefan Klima[1,2], Helmut Flachberger[2], and Christian Teichert[1] — [1]Institute of Physics, Montanuniversität Leoben, Austria — [2]Chair of Mineral Processing, Montanuniversität Leoben, Austria

Better understanding of tribocharging and contact electrification of dielectric materials is of great interest for technological applications like tribocharging separation of mineral particles and secondary raw materials. The underlying mechanisms are still not well understood. The charging of calcite single crystal surfaces upon contact with an Atomic Force Microscope (AFM) tip and micrometer sized single calcite particles attached to the end of commercial AFM cantilevers has been investigated using Kelvin Probe Force Microscopy (KPFM). The resulting surface charge depends on the type of charging (static charging, matrix of static charging, rubbing), the load force, and the value of the initial surface potential. A charge decay, within several tens of hours, has been observed. Increasing the sample temperature accelerated this charge decay process. Sequential charging of the same area with opposite sign could be performed, showing that the preceding charging does not alter the charging behavior.Experiments were carried out under various conditions.

O 101.7 Fri 12:00 MA 144

The Meaning of Temperature in Interferometric Detection Schemes — •Alexander Schwarz[1], Gotthold Fläschner[1], Kai Ruschmeier[1], Roland Wiesendanger[1], Reza Bakhtiari[2], and Michael Thorwart[2] — [1]University of Hamburg, Institute of Applied Physics, Jungiusstr.11, 20355 Hamburg — [2]University of Hamburg, I. Institute of Theoretical Physics, Jungiusstr. 9, 20355 Hamburg

The force sensitivity of cantilevers used in atomic force microscopy (AFM) scales with $\sqrt{T}$. A convenient way to obtain the temperature T is measuring the power spectral density around the resonance frequency and subsequent application of the equipartition theorem. However, in interferometric detection schemes, where the backside of the cantilever acts as one mirror of a Fabry-Perot cavity, the dynamic of the cantilever motion can be influenced by the light, e.g., due to photothermal effects [1,2]. In this case the so-called *mode temperature* and not the *phonon temperature* is measured.

In our presentation we describe a procedure to determine the phonon temperature of the cantilever for a Fabry-Perot type interferometric detection scheme, if radiation pressure dominates over photothermal effects. Moreover, we also explain how laser noise can influence the cantilever motion. Our analysis shows that the recorded power spectral density are best described by Fano line shapes, which can exhibit a dip instead of a peak at resonance. Indeed, we were able to observe such a peculiar antiresonant behavior experimentally.

[1] C. H. Metzger and K. Karrai, Nature **432**, 1002 (2004).
[2] H. Hölscher et al., Appl. Phys. Lett. **94**, 223514 (2009).

O 101.8 Fri 12:15 MA 144

Dynamic Friction Force Microscopy at Surface Defects on HOPG — •Felix Mertens, Thomas Göddenhenrich, and André Schirmeisen — Institut für Angewandte Physik, Justus-Liebig-Universität Gießen, D-35392 Gießen

Dynamic friction force microscopy is a valuable scanning probe technique for the detection of friction properties on the nanometer scale. An off-resonance modulation of a sample surface induces non-linear cantilever bending oscillations, where the resonance response is a very sensitive measure of the interaction at the tip-sample contact. Images reveal surface steps and grain boundaries on graphite surfaces. The dynamic response furthermore contains information about elastic properties of surface steps. A signal pulse is applied to the modulation piezo and a fast Fourier transform of the cantilever real-time oscillation exhibits resonance parameters of the oscillation.

O 101.9 Fri 12:30 MA 144

A Closer Look into Operating Perovskite-Sensitized Solar Cells — •Stefan Weber[1], Victor Bergmann[1], Javier Ramos[2], Mohammad Nazeeruddin[3], Michael Graetzel[3], Shazada Ahmad[2], and Ruediger Berger[1] — [1]MPI for Polymer Research, Mainz, Germany — [2]Abengoa Research, Seville, Spain — [3]EPFL, Lausanne, Switzerland

Solar cells based on novel hybrid organic-inorganic halide perovskites have recently reached power conversion efficiencies comparable to silicon solar cells. Nevertheless, the exact charge generation mechanism in perovskites is still unclear. The aim of our study is to apply scanning probe microscopy (SPM) for measuring the electrical potential in the different layers of the device under working conditions. Therefore, a SPM setup was equipped with a sample illumination and placed in an inert atmosphere to avoid photo-oxidation of the sensitive materials. We prepared smooth cross sections of the solar cell by means of focused ion beam milling. This way, the internal interfaces between the different materials in the fully functional device were accessible for frequency modulation Kelvin Probe Force Microscopy (FM-KPFM). Our measurements revealed that the investigated perovskite devices have an internal potential distribution that represents a p-i-n type junction solar cell. Upon illumination under short-circuit conditions, we found an unbalanced charge transport inside the device with holes accumulating in the preovskite layer. These results are important for understanding the physics of perovskite solar cells [Bergmann, V.W. et al (2014); Nature Comm. 5, 5001].