IPF 2008 Frontiers in Imaging: from Cosmos to Nano
Room: 312 - Session IPF+NC-MoA

Materials Imaging with Subatomic Resolution

Moderator: R. Ludeke, IBM (Retired), J. Murday, University of Southern California

2:00pm **IPF+NC-MoA1 Spatially Resolved Vibrational Imaging with Sub-Nanometer Resolution**, ***W. Ho***, University of California, Irvine **INVITED**

Vibrational spectroscopy has proven to be a powerful technique for chemical analysis, and its capability has been improved steadily over the years. At the limit of sensitivity is the detection of the vibration of a single bond and the imaging of such a signal would provide unprecedented spatial resolution in chemical visualization. In addition to revealing the chemical constituents at the atomic level, vibrational imaging at the sub-nanometer scale also can provide dynamical information such as charge and energy transfer, electron-vibrational coupling, and light-matter interaction. With the initial demonstration of inelastic electron tunneling spectroscopy and microscopy with a scanning tunneling microscope (STM), it is now possible to investigate with atomic scale resolution a wide range of inelastic phenomena that involve vibrational excitation. The scanning capability of the STM enables vibrational imaging of the interior of single molecules, their interactions with the environment, the coupling of electrons to vibrations in electron transport, and optical phenomena with atomic scale spatial resolution.

2:40pm **IPF+NC-MoA3 Attosecond Nanoplasmonic-Field Microscope**, ***M.I. Stockman***, Georgia State University, *U. Kleineberg*, Ludwig-Maximilians University, Germany, *M. Kling*, *F. Krausz*, Max Plank Institute for Quantum Optics, Germany **INVITED**

Nanoplasmonics deals with collective electronic dynamics, which arises due to elementary excitations called surface plasmons. Because of the very broad bandwidth, the surface plasmons undergo ultrafast dynamics unfolding on time scales as short as a few hundred attoseconds. So far, the ultrafast spatiotemporal dynamics on the nanoscale has been hidden from direct access in the real space and time. We propose an approach that will, for the first time, provide direct, non-invasive access to the nanoplasmonic dynamics with nanometer-scale spatial resolution and on the order of a few hundred attoseconds temporal resolution. This method combines photoelectron emission microscopy and attosecond streaking metrology. It offers a valuable new way of probing ultrafast nanolocalized fields in nanoplasmonic systems. This approach will be interesting both from a fundamental point of view and in the light of the existing and potential applications of nanoplasmonics.

4:00pm **IPF+NC-MoA7 Atomic Motion Observed with sub-Angstrom Resolution in the Electron Microscope**, ***P.E. Batson***, IBM T.J. Watson Research Center **INVITED**

The recent successful introduction of aberration correction optics into the electron microscope has produced an instrument that can routinely image the positions of single atoms and structure of small groups of atoms. In fact, the signal from a single atom is strong enough to obtain good quality images in a few tens of milli-seconds, allowing the taking of sequences of images to follow atomic processes. In the microscope, atomic level objects are vigorously excited by the electron beam, and this energy deposition is observed to speed up normal processes – island coalescence, structural changes, and nucleation of growth -- so that they are observable in relatively short times. In many cases, imaging in bulk specimens shows similar atomic level behavior. Thus stress relaxation and atomic redistribution within bulk structures may be observable in the presence of the electron beam, and so may be quantified if the electron beam interaction can be well understood. The combination of Electron Energy Loss Spectroscopy with atomic resolution imaging promises to obtain local electronic structure within the bulk, but changes in the bulk structure caused by energy deposition will complicate interpretation. This presentation will discuss these observations and suggest what types of mechanisms may contribute to the observed behavior.

4:40pm **IPF+NC-MoA9 Force Microscopy with Subatomic Resolution**, ***F.J. Giessibl***, University of Regensburg, Germany **INVITED**

A theoretical analysis of the factors that determine the spatial resolution of the force microscope led to the conclusion that optimal results are expected to occur when the oscillation amplitude of the cantilever in dynamic atomic force microscopy (AFM) has a magnitude similar to the range of the forces at play. When the cantilever is to oscillate with small amplitudes in a stable fashion under the influence of the field of the chemical bonding forces present between tip and sample, cantilevers with a stiffness of roughly 1kN/m instead of the commonly used 40 N/m are required.[1] Soon after these findings, experimental force microscopy data was published that shows "subatomic" resolution, that is the imaging of features within single atoms.[2] While these findings were debated, a direct comparison of scanning tunneling microscopy and AFM data showed that when probing a tungsten tip with a graphite surface (a "light-atom probe"), subatomic orbital structures with a spatial resolution of less than one Angstrom can be obtained in the force map, while a map of the tunneling current only shows the known atomic resolution.[3] Optimized subatomic contrast is obtained when recording the higher harmonics of the cantilever motion.[3] The idea of the light atom probe was carried further in a collaboration with the IBM Low Temperature STM group in Almaden, San Jose where an adsorbed CO molecule was used to probe the tip atom. It requires quite a large force to move a CO molecule laterally[4] and this molecule is an excellent probe for the orbital structure of the front atom of the metal tip. Ideally, one wishes to create a probe with a perfectly perpendicularly oriented CO molecule at the very end of the tip. First steps towards that goal will be discussed. We also address the question why "traditional" dynamic AFM has apparently not yet demonstrated subatomic resolution.

[1]F.J. Giessibl, H. Bielefeldt, S. Hembacher and J. Mannhart, Appl. Surf. Sci. 140, 352 (1999); F.J. Giessibl, Rev. Mod. Phys. 75, 949 (2003).
[2]F.J. Giessibl, H. Bielefeldt, S. Hembacher, J. Mannhart, Science 289, 422 (2000).
[3]S. Hembacher, F. J. Giessibl, J. Mannhart, Science 305, 380 (2004).
[4]M. Ternes, C. P. Lutz, C.F. Hirjibehedin, F.J. Giessibl, A. J. Heinrich, Science 319, 1066 (2008).

5:20pm **IPF+NC-MoA11 Cryolectron Microscopy of Biological Macromolecules on Its Way Toward Near Atomic Resolution and Multiple Conformations**, ***U. Luecken***, FEI Company, The Netherlands, *H. Zhou*, University of California, Los Angeles, *H. Stark*, Max Planck Institute of Biophysical Chemistry, Germany **INVITED**

I will report on the latest results just shown at the Gordon conference on Three dimensional Electron Microscopy and found teo of the world leading scientists in macromollecular complex imaging and Virus research.

Authors Index

Bold page numbers indicate the presenter