Wednesday Morning, November 15, 2006

Ultra-Bright Light Sources Topical Conference
Room 2001 - Session UB-WeM

Ultra-Bright Light Sources Topical Conference
Moderator: C. Wöll, Ruhr-Universitat Bochum, Germany

8:00am **UB-WeM1 Spectro-Microscopy with Undulator Radiation: Towards the Resolution Limits***, **E. Umbach**, T. Schmidt,* University of Wuerzburg, Germany*; H. Marchetto,* Fritz-Haber-Institute MPG, Germany*; U. Groh,* University of Wuerzburg, Germany*; R. Fink,* University of Erlangen, Germany **INVITED**

It is a dream of surface science to combine methods such as LEED, XPS, ARUPS, PhD, NEXAFS, and XAES with high spatial resolution and with microscopic techniques. Numerous successful microscopes called LEEM or X-PEEM are commercially available today. The heart of these instruments is a simple low-energy electron microscope consisting of objective and projective lenses and a 2-dim detector. However, due to aberrations these instruments are limited in their spatial and energy resolution. A collaboration of several groups has designed and built a new type of spectro-microscope that combines a "normal" LEEM/PEEM instrument with aberration corrections (chromatic AND spherical) and energy resolution using an imaging energy filter. The instrument is installed at BESSY II and uses photons and elec-trons as sources. A spatial resolution of 0.5 nm at an energy resolution of <100 meV is theoretically achievable at a hundred times higher transmission compared to conventional instruments. This instrument called SMART is now in the final phase of testing and commissioning. Concept, technical realization, and present achievements will be reported. The SMART allows to combine nearly simultaneously various electron micros-copy techniques (LEEM, PEEM, X-PEEM, MEM) with various high-resolution electron spectroscopy and electron diffraction techniques from small sample spots (nano-XPS, -ARUPS, -XAS, -LEED). First experiments on the growth mecha-nisms and dynamics of organic thin films, their dependence on substrate and sub-strate morphology, their molecular orientation, and on the internal structure of mi-crocrystallites show the potential of the instrument and will be presented in the talk.

8:40am **UB-WeM3 Soft X-Ray Spectromicroscopy at the NSLS***, **C. Jacobsen**,* Stony Brook University **INVITED**

Soft X ray spectroscopy can be used to provide information on the concentration of various organic functional groups. By taking a series of images over a closely-spaced range of photon energies around an x-ray absorption edge, one obtains spectrum-per-pixel data much as is done in spectrum imaging in electron energy loss spectroscopy. At Stony Brook, we have developed a series of scanning transmission x-ray microscope systems which operate in the 280-800 eV energy range at the National Synchrotron Light Source. These microscopes use Fresnel zone plates as focusing optics; recent optics have 30 nm finest zone width and 160 micron diameter for good working distance when used for studies at the carbon edge (290 eV). When using this system for studies in biological and environmental science specimens, one obtains very rich but complex data which are not possible to analyze by traditional approaches (exhaustive electronic state modeling and spectrum fitting) used for studies of single molecular types. Instead, we have developed pattern recognition approaches which allow one to analyze the data in terms of the predominant spectroscopic themes. Recent applications in biological and environmental science will be described.

9:20am **UB-WeM5 X-ray Tomography: Imaging Biological Cells at Better than 50 nm Resolution***, **C. Larabell**,* University of California at San Francisco and Lawrence Berkeley National Laboratory*; M.A. Le Gros,* Lawrence Berkeley National Laboratory **INVITED**

X-ray tomography is an emerging new imaging technique that can examine whole, hydrated specimens with a spatial resolution approaching 15 nm. X-ray imaging at photon energies below the K- absorption edge of oxygen, referred to as the water window, exploits the strong natural contrast for organic material embedded in a mostly water matrix. With a transmission X-ray microscope using Fresnel zone plate optics, specimens up to 10 microns thick can be examined. Because of the low NA of X-ray lenses (NA=0.05), combined with the effect of polychromatic illumination and a wavelength dependant focal length, the effective depth of field is large (6-10 microns). The experiments presented here were performed at the Advanced Light Source using a full field transmission X-ray microscope, which employs a bend magnet X-ray source and zone plate condenser and objective lenses. The condenser zone plate acts as a monochromator and the X-ray images are recorded directly on a cooled, back-thinned 1024x1024 pixel CCD camera. Live cells were rapidly frozen by a blast of liquid nitrogen-cooled helium gas, and maintained at –140 degrees C by a steady flow of cold helium. We have used this imaging approach to obtain 3D reconstructions of cells in their native state at better than 50 nm isotropic resolution. These images reveal remarkable details of the nuclear and cytoplasmic architecture of fully hydrated whole cells. With X-ray imaging, the internal structures are not masked by ice and the resulting images are inherently of high contrast. In addition the proteins, lipids and nucleic acids are detected by the amount of carbon and nitrogen they contain, generating quantifiable data based on their absorption coefficient. Data collection is extremely fast, with a complete data set for tomographic reconstruction requiring less than 3 minutes. Consequently, X-ray tomography is an exciting new high-throughput approach for obtaining 3-D, quantifiable information from whole, hydrated cells

10:40am **UB-WeM9 Diffraction Microscopy***, **J. Kirz**,* Stony Brook University and Lawrence Berkeley Lab **INVITED**

A coherently illuminated isolated specimen creates a speckle pattern in the far field. If the intensity of this diffraction pattern is recorded with sufficient detail, the image of the specimen can be reconstructed using an iterative algorithm. The principles of this "lensless" imaging technique will be presented, along with a description of the instrumentation used, and the technical challenges involved. The ultimate limitating factor in resolution is radiation damage to the specimen. While this technique is now being used by several groups, we will emphasize the work done by the Stony Brook/Cornell group working at the Advanced Light Source.

11:20am **UB-WeM11 Science at the Free-Electron Lasers at DESY in Hamburg: Status and Perspectives***, **W. Wurth**,* University of Hamburg, Germany **INVITED**

Free-Electron Lasers in the extreme ultraviolet and in the X-ray regime offer ultrashort photon pulses with extremely high peak brilliance. These properties open exiting new possibilities for research in laser-matter interactions, ultrafast science, spectroscopy, and structural analysis with applications in physics, chemistry, materials science, and life sciences. The novel sources will allow to probe matter on atomic length and time scales with unprecedented detail. Fascinating science is envisioned in the fields of femtosecond dynamics of non-equilibrium states and ultrafast processes in molecules, clusters and condensed matter systems as well as in life sciences. This will be complemented by novel imaging techniques based on the unique coherence properties of the new sources. In my talk I will report on first scientific results obtained in the XUV-regime with the Free-Electron Laser in Hamburg (FLASH) in operation since 2005. In addition, I will review the status and the perspectives of the European X-ray Free-Electron Laser facility (XFEL) to be built at DESY in Hamburg.

12:00pm **UB-WeM13 In-Situ Electronic Structure Study of Chemical Reactions with Photon-In/Photon-Out Soft-X-Ray Spectroscopy***, **J.-H. Guo**,* Lawrence Berkeley National Laboratory

The electronic structure ultimately determines the properties of matter. Photon-in/photon-out soft-x-ray spectroscopy has been the subject to a revived interest owing to the new generation synchrotron facilities and high performance beamline and instruments. Soft-x-ray absorption spectroscopy (XAS) probes the local unoccupied electronic structure, soft-x-ray emission spectroscopy (XES) probes the local occupied electronic structure, and resonant inelastic soft-x-ray scattering (RIXS) probes the intrinsic low-energy excitations, such as charge transfer, proton energy transfer etc. Photon-in/photon-out soft X-ray spectroscopy is essentially bulk sensitive, since the attenuation length of photons in this energy range is typically hundreds of nanometers in solid matter. The penetration depth offers a few experimental opportunities not present in electron based spectroscopies. Here we take advantage of the large photon attenuation length to perform the first X-ray emission study of liquid water and solutions. The liquid cell has a window to attain compatibility with UHV conditions of the spectrometer and beamline, The synchrotron radiation enters the liquid cell through a 100 nm thick silicon nitride window and the emitted X-rays exit through the same window. This allows in particular liquid/solid interfaces to be studied. A number of examples, including some recent experimental findings, then illustrate the potential of XAS and XES applications in materials sciences.

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