Novel Trends in Synchrotron and FEL-Based Analysis Focus Topic
Room: 112 - Session SA-MoM

Imaging and Nanodiffraction (8:20-10:00 am) & Novel Insights in Correlated Materials, Organic Materials and 2D Solids (10:40 am -12:00 pm)
Moderator: Herrmann Dürr, Stanford University, Petra Rudolf, University of Groningen

8:20am **SA-MoM1 Nanoscale Chemical Imaging by Soft X-ray Spectro-microscopy and Spectro-ptychography**, ***Adam Hitchcock***, *X.H. Zhu*, McMaster University, Canada, *J. Wu*, McMaster University, *D. Shapiro, T. Tyliszczak*, Lawrence Berkeley Lab, University of California, Berkeley **INVITED**

Recent improvements in instrumentation and data analysis for soft X-ray spectromicroscopy and spectro-ptychography have made significant advances in spatial resolution and sensitivity. These improvements are providing researchers with new tools to contribute to solving real world technological issues as well as making fundamental discoveries. This presentation will give an overview of the performance of current instrumentation, report on exciting advances taking place in soft X-ray spectro-ptychography, and outline opportunities for *in situ* and *operando* studies. Spectro-ptychography studies of the magnetism of individual magnetosomes in magnetotactic bacteria by X-ray magnetic circular dichroism (XMCD). Results for 2D and 3D chemical analysis of polymer-electrolyte fuel cells will be presented.

Research performed at the Advanced Light Source, funded by DoE, BES, and at the Canadian Light Source, funded by CFI, NSERC, U. Saskatchewan, Saskatchewan, WEDC, NRC and the CIHR. The SHARP code used for ptychographic data analysis was developed by the Center for Applied Mathematics for Energy Research Applications (CAMERA) at LBNL, led by Jamie Sethian, in collaboration with Uppsala University .

9:00am **SA-MoM3 Imaging Single Cells in a Beam of Live Cyanobacteria with an X-ray Laser**, ***Gijs van der Schot***, Uppsala University, Sweden **INVITED**

Imaging live cells at a resolution higher than achieved using optical microscopy is a challenge. Ultra-fast coherent diffractive imaging[1] with X-ray free-electron lasers (XFELs) has the potential to achieve sub-nanometer resolution on micron-sized living cells[2]. Our container-free injection method can introduce a beam of live cyanobacteria into the micron-sized focus of the Linac Coherent Light Source (LCLS) to record diffraction patterns from individual cells, with low noise at high hit rates[3]. We used iterative phase retrieval[4-6] to derive two-dimensional projection images directly from the diffraction patterns. Synthetic X-ray Nomarski images[7], calculated from the complex-valued reconstructions, show cells in a similar manner to what one would expect to see using a Nomarski microscope, only at higher resolution than currently available. In a first experiment, we collected diffraction patterns to 33-46 nm full-period resolution, and reconstructed the exit wave front to 76 nm resolution[3]. In a second experiment, we demonstrate that it is indeed possible to record diffraction data to nanometer resolution on live cells with an intense, ultra-short X-ray pulse as predicted earlier[2,3]. These results are encouraging, and future developments to the XFELs and improvements to the X-ray area-detectors will bring sub-nanometer resolution reconstructions of living cells within reach.

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References

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3. van der Schot, G. *et al.* Imaging single cells in a beam of live cyanobacteria with an X-ray laser. *Nat. Commun.* **6**, 5704 (2015).

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10:00am **SA-MoM6 Nanoscale Tomography and Spectroscopy with the HZB X-ray Microscope**, ***Gert Schneider***, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Germany

The Helmholtz-Zentrum Berlin (HZB) operates a full-field transmission X-ray microscope (TXM) at the BESSY II electron storage ring. The advanced optical setup of the HZB-TXM permits NEXAFS spectroscopic applications as well as correlative fluorescence and nanoscale tomographic imaging of cryogenic fixed cells in a fully hydrated state. An overview of recent results in material and life sciences will be presented [1-8]. Investigations on TiO2 nanostructures using NEXAFS spectromicroscopy at the Ti-L- and O-K-absorption edges will be shown [1,2]. Additionally, first results on the nanoscale morphology of organic solar cells will be discussed. Reconstructions taken from 3D X-ray datasets allow to visualize sub-cellular ultrastructures in mammalian and plant cells e.g. algae. Quantitative studies as e.g. the number of cell organelles in the cell volume are possible [4]. Scientific findings on the nucleation of hemozoin in Plasmodium falciparum by nanoscale tomography with the HZB-TXM will be demonstrated [5]. Studies of the interaction of viruses like the Herpes virus [6] or vaccinia virus [7] with mamillian cells will be presented. In addition, nanoscale X-ray tomography paves the way to a better understanding of the interaction of nanoparticles with cells [8].

[1] P. Guttmann et al., Nature Photonics 6 (2012), 25-29

[2] K. Henzler et al., Nano Letters 13 (2013), 824-828

[3] G. Schneider et al., Nature Methods 7 (2010), 985-987

[4] E. Hummel et al., PLoS ONE 7 (12) (2012), e53293

[5] S. Kapishnikov et al., PNAS (2012) DOI: 10.1073/pnas.1118120109

[6] C. Hagen et al., J. Struct. Biol. 177 (2012), 193-201

[7] FCO J. Chichon et al., J. Struct. Biol. 177 (2012), 202-211

[8] D. Drescher et al., Nanoscale 5 (2013), 9193-9198

10:40am **SA-MoM8 Exploring All-optical Magnetic Switching with Resonant X-rays**, ***Alexander Reid***, SLAC National Accelerator Laboratory **INVITED**

The ability to write a magnetic `bit', a stable magnetic domain, with a single sub-picosecond optical pulse is now known and demonstrated in magnetic materials from amorphous ferrimagnets, such as GdFeCo, to crystalline ferromagnets, such as FePt. However, understanding the underlying physics of this process remains a fundamental challenge in magnetism dynamics. The process of all-optical switching of magnetization begins with the absorption of the optical pulse by the magnetic material, this creates a highly non-equilibrium state. The evolution of this state is controlled by many factors, from fundamental coupling interactions to material heterogeneity. Resonant x-rays allow a powerful tool for exploring the evolution of this non-equilibrium state and beginning to answer questions about how and why reversed magnetic order can emerge deterministically. Powerful new x-ray sources, such and the Linac Coherent Light Source, produce femtosecond x-ray pulses with a high spatial coherence and brightness. Using such sources, and techniques such as x-ray circular magnetic dichroism, the transient elemental magnetism can be monitored during the switching process. Further, the intrinsically shorter wavelength of x-rays enables monitoring of the spatial aspects of the switching process down to length scales of a few nanometers. We detail recent measurement of the spatio-temporal dynamics of the switching process in the prototype materials GdFeCo and TbFeCo, which have led to new insights about the evolution of the optical magnetic switching process.

11:20am **SA-MoM10 Ultrafast Dynamics in Magnetic Systems**, ***Gerhard Gruebel***, Magnetic Dynamics, Germany **INVITED**

Ultrafast Dynamics in Magnetic Systems

Gerhard Grübel

DESY and The Hamburg Centre for Ultrafast Imaging (CUI)

Hamburg, Germany

Understanding ultrafast magnetization Dynamics on the nano-scale is a forefront problem in modern magnetism research with direct impact on the quest for faster and smaller storage devices. Probing the magnetization

element-specifically and on the nanometer lenght-scale is a pre-requisite when probing technologically relevant material systems with complex composition.

X-ray free electron laser (FEL) sources with their unique properties delivering ultrashort and super intense soft X-ray pulses allow for the first time to address magnetization dynamics on the relevant time-and lenght scales.

We present recent results obtained on multi-domain Co/Pt magnetic multilayer samples with perpendicular magnetic anisotropy, pumped with short IR and THZ pulses. As a probe we use small angle X-ray scattering from the magnetic domains which, via X-ray magnetic circular dichroism at the Co M-edge, allows us to simultaneously obtain information on the magnitude of the local magnetization amd the characteristic lenght scale of the domains. The FEL sources FLASH at DESY (Hamburg) and FERMI at ELECTRA (Trieste) were used at a wavelenght of 20.8 nm corresponding to the CO M-edge.

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