New Trends in Structural Electronic Characterization of Materials, Interfaces, and Surfaces Using Synchrotron and FEL Based Light Sources Focus Topic
Room On Demand - Session LS-Invited On Demand

New Trends in Structural Electronic Characterization of Materials, Interfaces, and Surfaces Using Synchrotron and FEL Based Radiation Sources Invited On Demand Session

LS-Invited On Demand-1 Soft X-ray Resonant Inelastic Scattering (RIXS) to Study the Magnetic and Electronic Properties of Materials*, Nicholas Brookes,* ESRF, France **INVITED**

Soft x-ray resonant inelastic x-ray scattering (RIXS) spectroscopy has made many advances in the past few years mainly due to improved experimental facilities at third generation synchrotron sources [1].

In this talk the technique will be introduced and the current possibilities offered by soft x-ray RIXS will be demonstrated using results from the ESRF. In particular, some of the work on transition metal oxides like the nickelates [2,3], the cuprates [4] and iron [5] will be highlighted.

[1] Brookes et al. NIMA 903, 175 (2018).

[2] Betto et al. PRB **96**, 020409(R) (2017).

[3] Lu et al. PRX 8, 031014 (2018).

[4] Peng et al. Nat. Phys. 13, 1201 (2017)

[5] Brookes et al. Under review

LS-Invited On Demand-7 Bulk and Interface Hard-X-ray Bandmapping with Spin Resolution Combining Full-field Momentum Imaging with ToF-recording*, Gerd Schönhense,* Johannes Gutenberg University of Mainz, Germany **INVITED**

Photoelectron momentum microscopy (MM) is an alternative approach for ARPES, combining full-field k-space imaging with hemispherical or time-of-flight (ToF) energy analyzers. The heart of ToF-MM is a fast delay-line detector (DLD), recording position and time t of each counting event (at rates up to ~$5x10^6$ cps). 3D (k_x,k_y,t)-recording is advantageous in low-intensity experiments with soft or hard X-rays, spin mapping, or time-resolved ARPES at FEL sources. This contribution gives an overview with examples and an outlook on ongoing developments.

MM with X-ray excitation gives access to 4D bulk spectral functions ρ(E_B,**k**), yielding bands, Fermi surfaces and -velocity distributions [1]. The band structure is captured in a tomographic-like mode via direct transitions to a final-state sphere, whose k-radius is tuned via the photon energy. PETRA III (Hamburg) provides 50ps photon pulses with 192ns period (40-bunch mode) at beamlines P04 (hν=300-1700eV; resolving power >10^4) and P22 (2300-7500eV; r. p. up to 10^5 with Si(333) monochromator). Information depths of 10-20nm allow studying buried structures like a 2D e-gas at an inner interface or bulk bands of a Heusler compound capped with 2nm MgO or 1nm Au.

Imaging spin filters are powerful tools complementing MM [2]; the effective figure-of-merit increases when exploiting ToF as third "coordinate" [3]. Using circ.-pol. soft X-rays, we uncovered a relation between the *Fano* spin component (along the photon helicity), the perpendicular spin component (oriented like spin in *Mott* scattering) and the circular dichroism [4]. Hard X-ray spin-MM allowed quantifying the spin gap in the half-metallic Heusler ferromagnet Co_2MnSi and the degree of (bulk) spin polarization close to E_F in magnetite, being controversially discussed for decades.

First experiments at FLASH (DESY, Hamburg) suggest a large potential of ToF-MM for fs pump-probe photoemission [5]. Event coordinates (E_B,**k**), arrival time and intensity of the corresponding FEL pulse, delay and parameters of the pump pulse are streamed in real-time and sorted into a multidimensional histogram memory. Current technical improvements concern a new objective lens without extractor field, correction and suppression of space-charge shifts, and a novel *dispersive-plus-ToF* hybrid MM. A drift section and fast DLD (<80ps time res.) behind a large single hemisphere will facilitate ToF at synchrotrons with 500MHz multibunch filling.

[1] K. Medjanik et al., *Nat. Mat.*16, 615 (2017) and *J. Synchr. Rad.***26**, 1996 (2019); [2] C. Tusche et al., *Ultramicrosc*. **159**, 520 (2015); [3] G. Schönhense et al., *Ultramicrosc*. **183**, 19 (2017); [4] D. Vasilyev et al., *J. Phys.* C **32**,135501 (2020); [5] D. Kutnyakhov et al., *Rev. Sci. Instrum*. **91**, 0130109 (2020)

LS-Invited On Demand-13 My Adventures with Synchrotrons: From Discovering New Types of Magnetism to Helping NASA*, Mikel Holcomb,* West Virginia University, USA **INVITED**

In many areas of science and the world, competition is seen as an opportunity to obtain improved performance or results. Utilizing many techniques (bulk magnetometry, neutron reflectometry and resonant x-ray magnetic scattering), we have discovered and explored the existence of competing magnetic phases in many single layer thin films that results in giant negative magnetization. We have focused on the system of complex oxide $La_{0.7}Sr_{0.3}MnO_3$. While transmission electron microscopy images show pristine epitaxial growth, the data supports that there are regions of different magnetic order. This results in interesting magnetic measurements, that share similarities with ferrimagnets with competing magnetic lattices. This competition results in spontaneous negative magnetization that aligns counter to a small applied magnetic field and inverted hysteresis loops near room temperature. This behavior has much in common with superparamagnetic nanoparticles. In this talk, the time, field and temperature dependence of these samples will be discussed to help understand this phenomenon. The switch from negative to positive magnetization effectively doubles the change in magnetization, important for some types of devices. We acknowledge funding support from NSF (DMR-1608656) for growth and optimization and DOE (DE-SC0016176) for the magnetic characterization of our films.

LS-Invited On Demand-19 Extending Time-Resolved X-Ray Diffraction using Coherence*, Mark Sutton,* McGill University, Canada **INVITED**

The use of x-ray diffraction for in-situ or in-operando measurements is now relatively common. It generally combines the power of x-ray structural measurements with x-ray's penetrating abilities to be able to perform other experimental techniques in combination. This allows one to observe how the atomic structure is or is not coupled to other material properties or underlies the processing of the material. Small angle x-ray scattering is often used, but when there is predominately crystalline order, wide angle x-ray scattering provides more detailed information. Often a trade off between better time-resolution and lower structural resolution is made to study the fastest processes. Over the last several years coherence has begun to play an important role in x-ray diffraction. Techniques like x-ray correlation spectroscopy (XPCS) and coherent diffraction imaging (CDI) being primary examples and the trade-off between the two techniques is similar to the trade-off between higher time resolution and higher structural resolution. In this talk I will explore information that is available from speckle patterns that is beyond conventional XPCS but is not as complete as CDI.

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