MA 24: Joint Session "Soft X-ray Resonant Scattering for Complex Structural and Magnetic Investigations" (jointly with KR), Organization: Eberhard Goering (MPI-IS Stuttgart)

Time: Wednesday 9:30–12:30 Location: BH 243

Invited Talk MA 24.1 Wed 9:30 BH 243

Soft X-ray Resonant Magnetic Reflectometry of Ferromagnet/Antiferromagnet Interfaces - Probing the Origin of Exchange Bias — •Sebastian Brück[1], Gisela Schütz[2], Kannan M. Krishnan[3], and Eberhard Goering[2] — [1]University of New South Wales and Australian Nuclear Science and Technology Organization, Sydney, Australia — [2]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany — [3]University of Washington, Seattle, USA

Magnetic interface coupling effects such as exchange bias, the coupling of a ferromagnet to an adjacent antiferromagnet, are very difficult to probe directly by volume integrating techniques due to the small interface to volume ratio. During the last decade, soft x-ray resonant magnetic reflectometry has proven to be a powerful new tool to tackle this problem. Its combination of element selective magnetic sensitivity and high resolution depth profiling capability allows probing even very small magnetic effects at an interface. Investigations by different groups on a broad variety of exchange bias systems based on FeF2, MnPd, CoO, and IrMn have revealed a complex magnetic configuration at the interface. The antiferromagnet shows uncompensated rotatable magnetic moments which are confined to the direct neighborhood of the ferromagnet but also exotic pinned uncompensated magnetic moments. Especially the latter are interesting for our understanding of exchange bias since they should be responsible for the hysteresis loop shift in these systems. We review recent findings in the field and use them to illustrate the capabilities of SXRMR for the investigation of magnetic interface effects.

Topical Talk MA 24.2 Wed 10:00 BH 243

Orbital reflectometry of nickelate heterostructures — •Eva Benckiser — Max Planck Institute for Solid State Research, Heisenbergstraße 1, 70569 Stuttgart, Germany

The occupation of d-orbitals has a key influence on the physical properties of transition metal oxides. Heterostructures of these oxides offer the possibility to control the orbital occupations because the electronic structure is very sensitive to changes in the transition-metal-oxygen bond distances induced by strain, dimensional constrains, and the chemical bonding to ions with different electronic configuration. However, atomic-scale modulations of the orbital occupation could thus far not be probed in a quantitative manner. We present results from a polarized soft x-ray resonant reflectivity study on superlattices composed of metallic $LaNiO_3$ and insulating $LaAlO_3$, $LaGaO_3$, or $DyScO_3$. We will demonstrate that it is possible to derive quantitative, spatially resolved orbital polarization profiles with differences of $\sim 3\%$ in the occupation of Ni e_g orbitals in adjacent atomic layers and discuss these results in context with recent theoretical predictions.[1–3] The possibility to quantitatively correlate theory and experiment on the atomic scale opens up new perspectives for orbital physics in oxide heterostructures. [1] Chaloupka, J. and Khaliullin, G., Phys. Rev. Lett. 100, 016404 (2008). [2] Hansmann, P. et al., Phys. Rev. Lett. 103, 016401 (2009) and arXiv:1111.1111 [3] Han, M. J., Marianetti, C. A. & Millis, A. J. Phys. Rev. B **82**, 134408 (2010)

Invited Talk MA 24.3 Wed 10:30 BH 243

Manipulating magnetic and electronic ordering phenomena by electric fields and electromagnetic radiation — •Urs Staub — Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI. Switzlerand

Complex oxides may exhibit very interesting magnetic properties such as the appearance of the colossal magneto-resistance effect, complex charge and orbital ordering phenomena as well as cross-talk of magnetic and electric polarizations in multiferroics. These effects open up the possibility of manipulating magnetism by electric fields or electromagnetic radiation. Here I will give examples, which show how resonant soft x-ray magnetic diffraction can be used to monitor changes to the underlying magnetic structure. I will discuss how the insitu application of an electric field can change the magnetic order or domain population in a multiferroic, how spins can be canted by x-rays or how fast an antiferromagnetic phase transition can be induced by an ultrafast optical excitation, being monitored by ultrafast magnetic x-ray diffraction.

15 min. break

Topical Talk MA 24.4 Wed 11:15 BH 243

Theory of resonant x-ray spectroscopy — •M. W. Haverkort — Max-Planck Institute for Solid State Research, Stuttgart, Germany

Within the first half of this talk I will review the theoretical interpretation of x-ray absorption spectroscopy (XAS), elastic resonant x-ray diffraction (RXD) and resonant inelastic x-ray scattering (RIXS). I will briefly review how XAS can be used to measure the element specific magnetic susceptibility separated to its spin and orbital momentum contributions. Either with the use of sum-rules or by comparison to theory. Next, I will show how with the use of the optical theorem this understanding of XAS can be extended to RXD. This gives access to measure in a quantitative way the element resolved ordered spin and orbital moments. I will then continue to discuss RIXS, an inelastic scattering technique, which due to recent experimental improvements, allows one to measure dispersing magnetic excitations in small samples and thin films. Using the relations between inelastic scattering, elastic scattering and absorption spectroscopy a quantitative theory for RIXS is derived, which allows for an interpretation of the RIXS spectra very similar to Neutron spectroscopy.

In the last half of the talk several experimental results will be presented which show how these techniques can be used to gain understanding in the magnetic interactions in transition metal compounds.

Topical Talk MA 24.5 Wed 11:45 BH 243

Cycloidal Magnetic Order and Ferroelectricity: Manipulation and Imaging with Soft X-Rays — •Eugen Weschke[1], Enrico Schierle[1], Victor Soltwisch[1], Detlef Schmitz[1], Andrej Maljuk[1,2], and Dimitri Argyriou[1,3] — [1]Institut für komplexe magnetische Materialien, Helmholtz-Zentrum Berlin für Materialien und Energie, Germany — [2]Institut für Festkörperforschung, IFW Dresden, Germany — [3]European Spallation Source, Lund, Sweden

Materials with coupled order parameters, such as the magnetoelectric rare-earth manganites, offer interesting means of manipulation, like switching of magnetic order by electric fields. Ordering phenomena in these complex materials can be nicely studied by resonant scattering due to the element-selectivity of the method. In the soft x-ray region, in particular, spatial correlations involving the 3d and 4f electrons and their magnetic moments are directly addressed via dipole transitions. The method is applied to study cycloidal magnetic structures that occur in connection with ferroelectric order in $DyMnO_3$ and $GdMnO_3$, using circularly polarized synchrotron radiation to address the handedness of the structure [1]. The possibility to manipulate ferroelectric domains with the synchrotron beam is also demonstrated, which eventually provides a means to evidence ferroelectric polarization in cases where other methods are not conclusive or difficult to apply.

[1] E. Schierle et al., Phys. Rev. Lett. 105, 167207 (2010).

MA 24.6 Wed 12:15 BH 243

Local Magnetic Structure at the Fe_3O_4/ZnO Interface — •Sebastian Brück[1], Markus Paul[2], He Tian[3], Ozan Kirilmaz[2], Andreas Müller[2], Kai Fauth[1], Eberhard Goering[4], Jo Verbeeck[3], Gustaaf van Tendeloo[3], Michael Sing[2], and Ralph Claessen[2] — [1]University of New South Wales and ANSTO, Sydney, Australia — [2]Physikalisches Institut, Universität Würzburg, Würzburg, Germany — [3]Electron Microscopy for Materials Science, University of Antwerp, Antwerp, Belgium — [4]Max Planck Institute for Intelligent Systems (former Metals Research), Stuttgart, Germany

Magnetite, Fe_3O_4, is a half-metal with 100% spin polarization of the minority band at the Fermi level. This together with its good conductivity match to standard semiconductors makes it a promising candidate for polarized spin injection into semiconductor materials such as Si, GaAs, or ZnO. An important aspect for such applications is the magnetism directly at the interface between Fe_3O_4 and the semiconductor. Soft x-ray resonant magnetic reflectometry (XRMR) is a technique which is capable of providing structural and magnetic depth profiles with 0.1nm resolution. We present a detailed XRMR and electron energy loss spectroscopy (STEM/EELS) study of an epitaxial Fe_3O_4 thin film grown directly on a semiconducting ZnO substrate. Consistent chemical profiles at the interface between ZnO and Fe_3O_4 are

found from XRMR and EELS. The magnetic depth profile of tetragonal Fe^{3+} and octahedral Fe^{2+} ions in Fe_3O_4 is derived with monolayer resolution and reveals a change in the Fe stoichiometry directly at the interface.