X-ray Magnetic Circular Dichroism: From the basics to high spatial and temporal resolved experiments.

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The X-ray Magnetic Circular Dichroism (XMCD) effect is a change of the absorption of circular polarized X-rays based on the sample magnetization. Due to its element specific nature, first investigated in 1987 [1], a new tool for atom based magnetization measurements have been found. Quite close to the first experimental findings P. Carra, T. Thole and co-workers developed the so called sum-rules [2], which a quantitative way of spin- and orbital-magnetic moment determination, given in units of the Bohr- Magneton. XMCD is based on a resonant excitation from a localized core shell to the magnetism related partially filled shell, for example in order to investigate Fe based magnetism in any complex Fe compound an excitation from the 2p shell into the unoccupied 3d shell has to be conducted, therefore probing the 3d magnetism. As XMCD is based on circular polarized X-rays, synchrotron radiation sources are usually necessary to perform such experiments. In this lecture a short introduction to different experimental methods how to measure the XMCD effect will be given, providing depth sensitivity, from a few nm to bulk. In addition typical experimental artefacts are discussed, including ways to prevent or even better how to use them. One of the most intriguing points is the quantitative investigation of the orbital magnetic moment, which is mostly quenched in 3d transition metals. This small orbital magnetic moment is still very important for many of the magnetism related material properties, as perpendicular anisotropy, easy axis behaviour, coercive field, resonant frequencies and much more. Many examples will be provided, showing how XMCD allows a deep microscopic understanding of magnetic properties.

Due to the XMCD effect X-ray optical properties are strongly influenced by magnetism. Therefore, any x-ray related method could be transferred into a magnetic counterpart [3]. One method based on this transformation is X-ray Resonant Magnetic Reflectivity (XRMR)[4]. As conventional non resonant reflectivity provides details about interface roughness and layer thickness in bi- or multilayer structures, XRMR allows the determination of magnetic profiles of buried layers, as induced or reduced interface magnetism, observed in magnetic dead layers or proximity magnetism respectively. Due to the high sensitivity even single ferromagnetic atomic layers could be studied quantitatively.

As synchrotron radiation is inherently pulsed, based on electron bunches traveling in the storage ring, time resolved pump probe experiments could be conducted. Scanning x-ray microscopy (STXM) results will be presented, which allow quantitative imaging with a time resolution down to the electron bunch length (about 40ps). Utilizing a new coherent imaging method, called Ptychography, also a spatial resolution down to the diffraction limit of the x-rays is possible, typically a view nm.

References

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