Utilizing the Huge Anisotropic X-Ray Magnetic Linear Dichroism in Transition Metal Systems

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To be able to engineer magnetic nanostructures comprised of multiple layers with different magnetic characteristics for device applications in information storage technology, requires the precise determination of the spin structure in heteromagnetic nanostructures. Soft x ray magnetic dichroism spectroscopies play an ever increasing role in improving our understanding of complex magnetic nanostructures since these techniques provide elemental and chemical site-specific magnetic information with high sensitivity and tunable probing depth. Using spectroscopic information for magnetometry and magnetic microscopy, i.e., to determine the alignment of magnetic moments relative to the crystal axes and to image domains, requires the detailed knowledge and theoretical understanding of spectral shape and magnitude of dichroism signals as well as their dependence on the relative orientation of polarization, external field, and crystallographic axes.

In this presentation we will discuss the first observations as well as accurate theoretical description of anisotropic x ray magnetic linear dichroism (XMLD) at the transition metal $L_{2,3}$ edges in Fe_3O_4 [1], $CoFe_2O_4$ [2], $NiFe_2O_4$, and NiO [3], and the rare earth $M_{4,5}$ edges in EuO [4]. We show unambiguously that − contrary to common belief − spectral shape and magnitude of the XMLD is not only determined by the relative orientation of magnetic moments and x ray polarization but that their orientation relative to the crystallographic axes has to be taken into account. The XMLD angular dependence reflects the symmetry of the crystal field and can be well reproduced using atomic multiplet theory.

The observed anisotropy of the XMLD is a general phenomenon and is expected in any magnetic system. Consequently, conclusions based on the interpretation of XMLD spectra without accounting for its anisotropy have to be reconsidered. Using XMLD-PEEM we investigated the magnetic coupling at the Co/NiO interface taking explicitly into account the angular dependence of the XMLD with respect to the crystallographic axes [5]. We find that the Co moments are aligned perpendicular to the NiO moments. We discuss the impact of the anisotropic XMLD on the intensity ratio of the two peaks at the Ni L_2 edge, which is commonly employed to determine the spin orientation in antiferromagnets using XMLD.

We also show that the anisotropy in XMLD can be used to explore the degree of localization and the existence of local moments in dilute magnetic semiconductors [6] and half-metallic Heusler alloys [7].

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