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### **Title**

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## New aspects of angle-dependent x-ray dichroism

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X ray magnetic dichroism (XMD) spectroscopies utilizing synchrotron radiation are important tools for the study of magnetic solids. XMD is unique in its intrinsic element specificity and chemical-site sensitivity that allows the separation of the contributions of multiple magnetic species in alloys or layered systems. Most importantly, theoretically derived sum rules link, for example, x-ray magnetic circular dichroism intensities to spin and orbital magnetic moments enabling the use of polarized x rays for quantitative magnetometry. Although magnetic spectroscopy techniques have found widespread use for the study of magnetic systems, very fundamental aspects like the dependence of the XMD signal on the relative orientation of external magnetic field, x-ray polarization, and crystalline axes have not been studied in detail to date. In this contribution, we present a systematic study of the Fe  $L_{2,3}$  x-ray magnetic linear dichroism (XMLD) in ferrimagnetic  $Fe_3O_4$  (001) and (011) thin films and of Mn  $L_{3,2}$  x-ray magnetic circular dichroism (XMCD) from the ferromagnetic semiconductor (Ga,Mn)As [1]. The Fe  $L_{2,3}$  XMLD in  $Fe_3O_4$  (001) and (011) thin films is found to exhibit a strong dependence on the relative orientation of external magnetic field, x-ray polarization, and crystal lattice. All XMLD spectra can be described as a linear combination of three fundamental spectra and the angular dependence can be derived from atomic calculations based on the crystal field symmetry. These spectra can be used as a sensitive probe for the electronic and magnetic structure. Remarkably anisotropic Mn  $L_{2,3}$  XMCD spectra from the ferromagnetic semiconductor (Ga,Mn)As were observed and states with cubic and uniaxial symmetry can be distinguished by careful analysis of the angle dependence of the spectra. The multiplet structures with cubic symmetry are qualitatively reproduced by calculations for an atomiclike  $d^5$  configuration in tetrahedral environment, and show zero anisotropy in the orbital and spin moments within the experimental uncertainty. However, hybridization with the host valence bands is reflected by the presence of a preedge feature with a uniaxial anisotropy and a marked dependence on the hole density.

- [1] K.W. Edmonds, G. van der Laan, A. Freeman, N.R.S. Farley, T.K. Johal, R.P. Campion, C.T. Foxon, B.L. Gallagher, and E. Arenholz, *Phys. Rev. Lett.* 96, 117207 (2006)