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Experiment title:
Magnetic Circular Dichroism in Photoemission and X-Ray Absorption from Tb-Fe Alloys and Multilayer

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Report:

Magnetic circular dichroism (MCD) in x-ray absorption (XA) and photoemission (PE) provide powerful tools for an element specific magnetic analysis of heteromagnetic systems and multilayers [1]. In core-level PE, strong MCD has been observed in the 4f multiples of rare earths (RE) [2], which is well understood within atomic theory [3]. In the present experiment we have investigated the MCD in *resonant* PE from ferromagnetic RE metals (Gal, Tb) and alloy films ($TbFe_x$). Exploiting the high degree of circular polarization and the excellent energy resolution of the Dragon BL 26, high resolution $M_{IV,V}$ MCD-XA spectra were recorded which opened the door for a detailed study of MCD in *resonant* PE in the range of $3d \rightarrow 4f$ excitations,

As samples we used ≈ 100 Å thick epitaxial Gd and Tb films grown in situ on W(l 10) by metal-vapor deposition at pressures below 10-10 mbar [2]. Well-ordered films were obtained by annealing, as confirmed by LEED. The films were remanently magnetized in plane by an in-vacuo electromagnet; a grazing incidence geometry was chosen for the incoming light to achieve large MCD effects. XA spectra were recorded in the total-electron yield mode.

High-resolution $M_{,}$XA spectra of a ferromagnetic Gd metal film are shown in the top panel of Fig. 1. (a). The associated MCD spectrum below provides a wealth of new

spectral features which stimulate a reanalysis of the Gd $M_{IV,V}$ edge by atomic multiplet theory. In addition, high-resolution Tb $M_{IV,V}$ XA spectra (not shown here) were obtained from ferromagnetic Tb metal and $TbFe_x$ films.

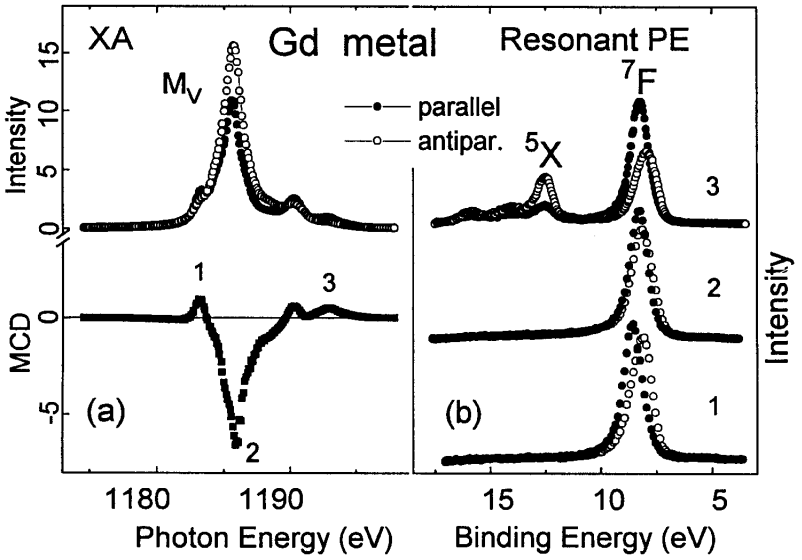

Fig. 1: (a) High resolution M_V x-ray absorption spectra from a ferromagnetic Gd metal film. Solid (open) symbols denote nearly parallel (antiparallel) orientation of photon spin and sample magnetization, with the associated MCD spectrum below. (b): Resonant Gd 4f-PE spectra in the region of 3d→4f excitations at energies 1,2, and 3 (cf. Fig. l(a)).

For the first time, MCD in *resonant* PE has been studied in the energy range of 3d→4f excitations where the 4f PE cross section is substantially enhanced, due to interference between the direct 4f PE channel and the core excitation with subsequent decay [4]. Fig. l(b) presents resonant Gd 4f-PE spectra at selected photon energies of the M_v edge. At point 1, the spectra show the ^7F PE multiplet with the shape closely resembling the off-resonance case. At the peak of the M_v edge, at point 2, the 4f PE signal is enhanced 50 times over the direct PE channel, but with nearly overlapping spectra for parallel and antiparallel orientation. The largest MCD effect is observed at point 3, where a new multiplet-structure at higher binding energies appears. It has previously been identified in resonant 4d→4f excitation as a group of ^5X states, which can only be reached via a spin-flip excitation [4]. In the same way we have studied the 3d→4f PE resonance of Tb where - in analogy to the Gd 4f ^5X states - a two-spin flip state has been discovered. Concluding, MCD in resonant 3d→4f PE can provide a new tool for studying thin-film compound magnets and magnetic interfaces where a selective enhancement of the PE cross section of an individual element is desirable. It offers higher bulk sensitivity than MCD in resonant 4d→4f PE [4].

[1] See e.g. Samant et al., Phys. Rev. Lett. 72, 1112 (1994).

[2] K. Starke et al., Phys. Rev. B 48, 1329 (1993).

[3] G. van der Laan and B.T. Thole, Phys, Rev. 48,210 (1993); and refs. therein.

[4] K. Starke et al., submitted to PRB - rap. comm. (August 1996); and refs. therein.