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Effects of symmetry on circular and linear magnetic dichroism in angle-resolved photoemission spectra of Gd/Y(0001) and Fe-Ni/Cu(001)

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We have observed circular and linear magnetic dichroisms in angle-resolved photoemission spectra of 50-monolayer Gd films grown on Y(0001) and 6-monolayer Fe-Ni alloy films grown on Cu(001). The 4*f* level of Gd and the Fe 3*p* level of the Fe-Ni alloy were measured. A different geometry was used for the magnetic circular dichroism than was used to measure the magnetic linear dichroism. The geometries were chosen so that the shape of the magnetic circular dichroism is predicted to be equal to the shape of the magnetic linear dichroism for four-fold symmetric Fe-Ni/Cu(001) but not for three-fold symmetric Gd/Y(0001). Experimental results are presented.

In this paper we examine the effect of symmetry (experimental geometry and sample symmetry) on magnetic linear and circular dichroism measured in angle-resolved photoemission. In particular we chose separate geometries for measuring magnetic circular and magnetic linear dichroisms. The geometries were chosen such that samples with four-fold symmetry about the sample normal may have magnetic circular and magnetic linear dichroisms of the same shape. But samples with three-fold symmetry should not exhibit circular and magnetic linear dichroisms of the same shape. The samples studied are three-fold symmetric Gd films grown on Y(0001) and four-fold symmetric Fe-Ni alloy films grown on Cu(001). After presenting the methods of the experiment, we briefly review parts of a model of magnetic dichroism developed by Venus and coworkers (Refs. 1 and 2) and our specialization and extension of it, particularly for FeNi/Cu(001). (Ref. 3 and 4). We then show the results of our measurements.

All of the photoemission spectra were recorded at the Spectromicroscopy Facility (beamline 7) of the Advanced Light Source at Lawrence Berkeley Laboratory using undulator radiation and a spherical-grating monochromator (Ref. 5). Both circularly- and linearly-polarized light were used. Circularly polarized light was generated with a multilayer acting as a phase-retarder, approximating a quarter-wave plate (Ref. 6 and 7).

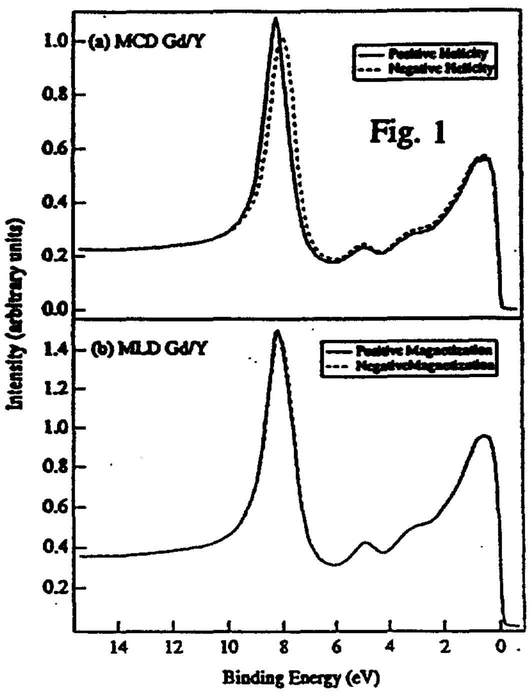
Venus and co-workers (Ref. 1 and 2) have developed a model of magnetic dichroism particularly useful for comparing dichroism spectra that are measured with different experimental geometries or with different light polarization, or both. We have refined and extended this model for in-plane magnetization $\left(\vec{M} \| \pm \hat{x}\right)$ and normal emission, $\left(\vec{k} \| - \hat{z}\right)$ as discussed in Refs. 3 and 4. For C_{4v} symmetry (i.e., NiFe/Cu(001)) a particularly simple pair of equations can be derived. For the C_{3v} symmetry of Gd/Y(0001). the relationship between circular and linear dichroism will not be so simple or elegant.

Circular $D_C^M = 2[P_c] \cos\theta \, \mathrm{Imag} \, \{<M|z|k><k|y|M>\}$ (Eq. 1)

Linear $D_L^M = [1+P_L] \cos\theta \, \mathrm{Real} \, \{<M|z|k><k|y|M>\}$ (Eq. 2)

We performed magnetic dichroism measurements on two systems; three-fold symmetric (C_{3v} about the surface normal) Gd films grown on Y(0001) (Ref. 10) and four-fold symmetric (C_{4v}) Fe-Ni films grown on Cu(001) (Refs. 3 and 4).

The MCD and MLD spectra of Gd/Y(0001) are shown in Figure 1. The difference spectra are illustrated in Figure 2. The MCD and MLD signal do not have the same line shape as can be seen in Fig. 2, where the MLD signal has been multiplied by 4.1 so that the height of the positive peaks in the MCD and MLD signals are equal. Because Gd/(0001) does not have C_{4v} symmetry we expect the MCD and MLD signals to be different, as is observed.



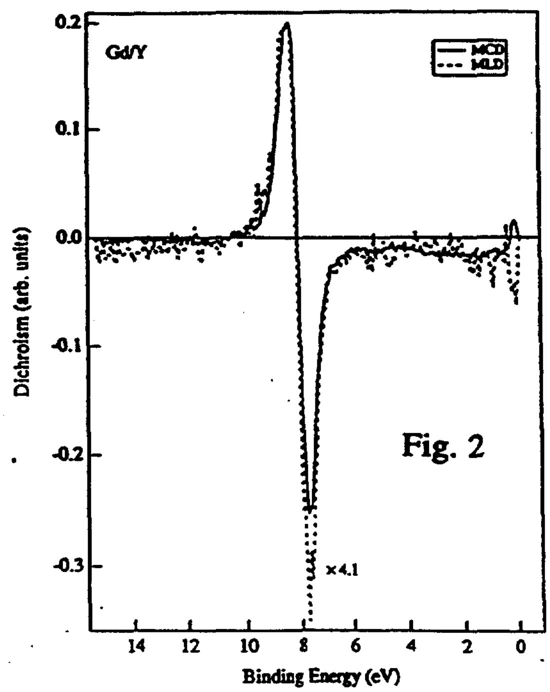
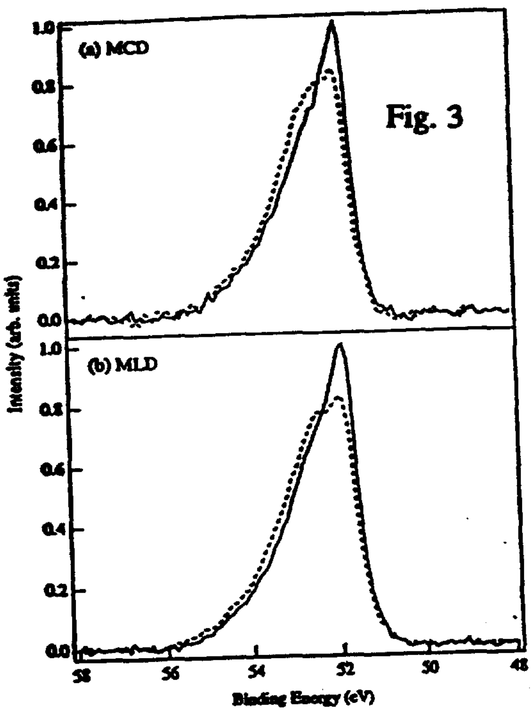


Fig. 1 Magnetic dichroism spectra of the Gd $4f$ level in Gd grown on Y(0001): (a) magnetic circular dichroism; (b) magnetic linear dichroism. All spectra taken at $h\nu = 95$ eV.

Fig. 2 Difference spectra of Gd on Y(0001) derived from the magnetic dichroism spectra in Fig. 2

The MCD and MLD results for the Fe $3p$ level of Fe-Ni/Cu(001) are shown in Figure 3. Because Fe-Ni/Cu(001) has C_{4v} symmetry, the MCD and MLD signals may have the same shape. The inelastic backgrounds were subtracted, using seventh-order polynomials fitted to the first and last 2-eV of each spectrum. The corresponding MCD and MLD difference spectra are shown in Fig. 4. Clearly, these are very strongly similar, if not quite identical.



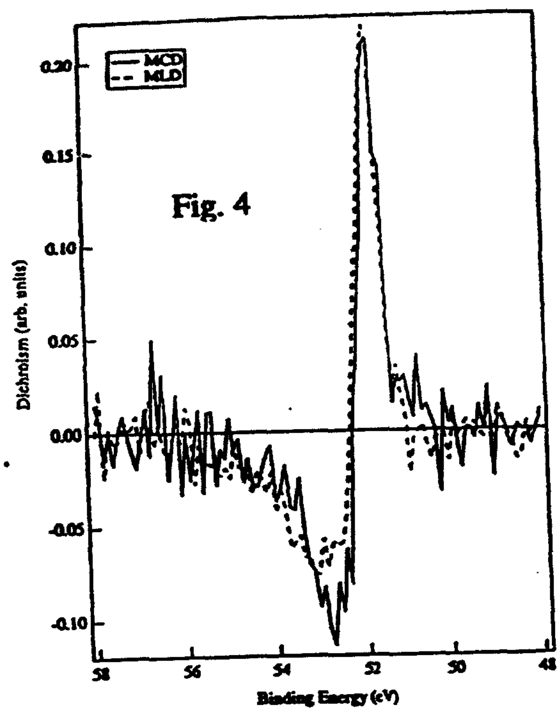


Fig. 3 Magnetic dichroism spectra of the Fe $3p$ level in Fe-Ni grown on Cu(001). Inelastic backgrounds were subtracted from each spectrum. Then the areas under the Fe $3p$ levels were normalized to a common value.

Fig. 4 Magnetic circular dichroism (solid line) and magnetic linear dichroism (dashed line) of Fe-Ni on Cu(001) shown on a common scale.

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