28A/2004G006

Temperature and incident angle dependence of MCD of XES for Gd thin films

Yasuhiro TAKAYAMA*[1], Tetsuo YOSHIDA[1], Satoshi NAKAMURA[1]
Naoya SASAKI[1], Hiroyoshi ISHII[1], Tsuneaki MIYAHARA[1]
[1]Tokyo Metropolitan Univ., Hachioji-shi, Tokyo 192-0397, Japan

Introduction

The magnetic circular dichroism (MCD) of the x-ray emission spectra (XES) has been expected to be a powerful technique in studying the bulk magnetism. Up to now, however, it has not been established the method to obtain the quantitative value of the magnetization from the MCD of XES. It has been reported that the magnetization of rare-earth compounds estimated from the MCD of XES was too small as compared with that estimated from the SQUID magnetometer [1]. In order to investigate the reason of the discrepancy, we have measured the temperature and incident angle dependence of the MCD of XES for Gd film samples.

Results and Discussion

We have prepared 500 Å Gd thin films by evaporating on a Si substrate in the ultra-high vacuum condition. The measurement of the MCD of XES was performed at an undulator beamline BL-28A. The temperature of the sample was controlled between 40 K and 250 K with a He cryostat and an electric heater. We have changed the incident angle ϕ between 10 degree and 80 degree, where ϕ is the grazing angle of the incident SR to the sample surface. The magnetic field generated by the permanent magnet was applied parallel to the incident vector of the SR. We have set the excitation energy to be 138.5 eV, which corresponds to the resonant excitation to the pre-threshold peak ($^8D_{9/2}$ state) of the Gd $4d$-$4f$ absorption [1].

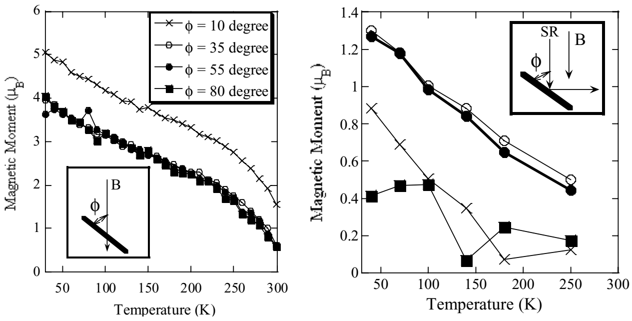

Figure 1: Temperature dependence of the magnetic moment per one Gd atom of the thin film estimated by SQUID (left) and MCD of XES without correction (right).

Fig. 1 shows the magnetic moment per one Gd atom for Gd thin films. The temperature dependence of the magnetic moment estimated by the SQUID magnetometer (μ_{SQUID}) has small dependence on the angle between the direction of the applied field and sample surface ϕ. The magnetization for ϕ = 10 degree is larger than those for other angles, because the magnetic easy axis is parallel to the sample surface and the magnetization is easily saturated in the condition of ϕ = 10 degree. The magnetic moment estimated from the MCD spectra (μ_{MCD}) by using the Kramers-Heisenberg formula are much smaller than μ_{SQUID}, and the angle and temperature dependence of μ_{MCD} is also quite different from that of μ_{SQUID}.

The discrepancy of the temperature and incident angle dependence of magnetization implies that some corrections are necessary to obtain the correct value of the magnetization from the MCD spectra. At first, the saturation and self-absorption effects give large influence, if the sample thickness can not be neglected as compared with the inverse of the absorption coefficient. These effects strongly depend on the incident angle ϕ. Another effect is the surface magnetization of the thin film. It is expected that the direction of the magnetization is different on the surface and in the bulk. The measurement of the MCD is expected to be surface sensitive near ϕ = 0 and 90 degrees due to the saturation and self-absorption effects. By considering these corrections, the agreements of μ_{SQUID} and μ_{SQUI} were improved as shown in Fig. 2.

The result of this study shows that the corrections of saturation and self-absorption effects and the magnetic anisotropy are extremely important for the quantitative estimation of the magnetization form the MCD of XES. For this reason, the measurement of the absorption of the coefficient and the magnetic anisotropy are required.

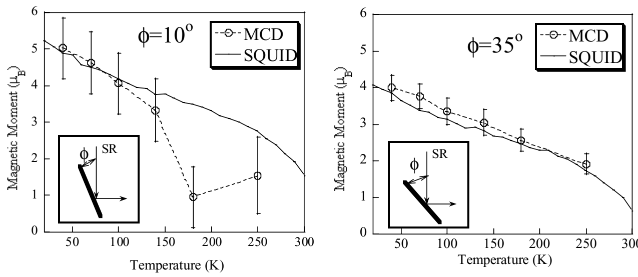

Figure 2: Comparison of μ_{SQUID} and μ_{MCD} for ϕ = 10 and 35 degrees. Agreements of the behaviors of μ_{SQUID} and μ_{MCD} were improved by considering the saturation, self-absorption effects and the magnetic anisotropy. The agreements for other ϕ were also remarkably improved.

References

[1] Y. Takayama et al., J. Electron Spctrosc. Relat. Phenom. 144-147, 731 (2005).

* takayama@phys.metro-u.ac.jp