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Magnetic circular dichroism of x-ray emission and absorption for Gd/Co multilayers

Yasuhiro TAKAYAMA*[1], Tetsuo YOSHIDA[1], Takeshi OKAMURA[1], Hideo OHTSUBO, Hidetsugu SHIOZAWA[1], Hiroyoshi ISHII[1], Tsuneaki MIYAHARA[1]
[1]Tokyo Metropolitan Univ., Hachioji, Tokyo 192-0397, Japan

Introduction

Recently, measurements of the magnetic circular dichroism (MCD) of x-ray emission spectra (XES) have been actively performed in the VUV, soft x-ray and hard x-ray regions, since the measurements give much information on the electronic states and are very bulk-sensitive as compared with those of the x-ray absorption. We have shown that a large MCD appears in the 5*p*-4*d* emission after the 4*d*-4*f* excitation for Gd [1]. To make use of the merit of the bulk-sensitive measurement of the XES, we have estimated the magnetic moment of the Gd/Co multilayers by the XES and compared the result estimated from the MCD of the x-ray absorption.

Result and Discussions

We have prepared six kinds of multilayers with different Gd concentration. These samples were made by the MBE method. The measurements of the x-ray absorption and emission were performed at the beamline BL-28A. We have measured the 4*d*-4*f* x-ray absorption for Gd and the 3*p*-3*d* x-ray absorption for Co by the total photoelectron yield (TEY) method. For the XES, we have observed the 5*p*-4*d* emission after the 4*d*-4*f* (^{8}D) excitation for Gd and the 3*p*-3*d* emission after the 3*d*-3*p* excitation for Co. Fig. 1 shows the typical spectra of the Gd 5*p*-4*d* emission after the 4*d*-4*f* (^{8}D) excitation.

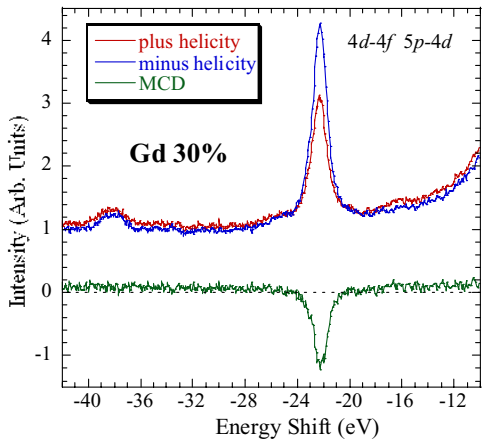

Fig. 1 Typical spectra for the Gd 5*p*-4*d* emission. Blue and red lines show the x-ray emissions when the helicity of the incident photon is parallel and anti-parallel to the direction of the applied magnetic field, respectively.

By fitting the observed spectrum with a calculated one based on the atomic model, we have estimated the magnetic moment of Gd. Fig. 2 shows the magnetic moments of Gd in the mulitilayers estimated from the 5*p*-4*d* x-ray emission, 4*d*-4*f* TEY and 3*d*-4*f* TEY. The 3*d*-4*f* TEY was measured at the BL25SU, Spring8. As for the 4*d*-4*f* XES (red line) and 3*d*-4*f* TEY (green line), the sign (=direction) of the magnetic moments for Gd changed between the Gd concentration of about 20~30 %. At the same concentration, the sign of the magnetic moment for Co also changed, and the signs of the magnetic moments for Gd and Co were always opposite each other for all samples. This shows that the magnetic moments for Gd and Co antiferromagmetically couple each other, and the dominant one turns to the direction of the applied magnetic field. However, the evaluated magnetic moment for Gd are different in the three measurements, and the magnetic moment comes to have a more positive component as the measurement is more surface-sensitive. The surface of the multilalyer is Gd layer for all samples and this layer always has the positive magnetic moment, since this layer couples with only one side of the Co layers. We found that the magnetic states on the surface and in the bulk are quite different for Gd/Co multilayers.

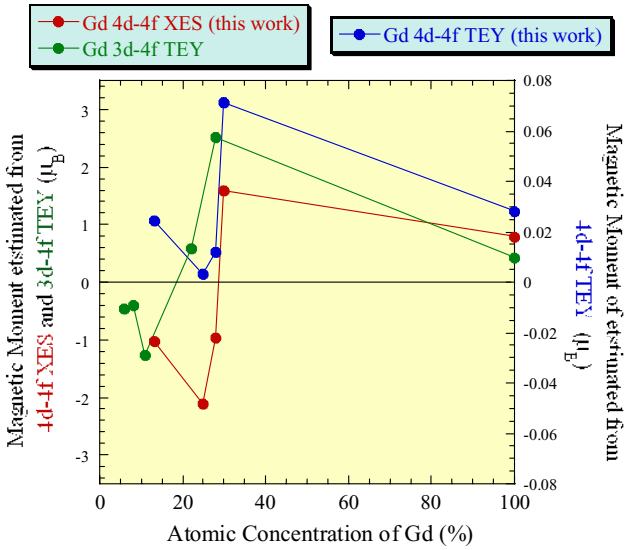

Fig. 2 Magnetic moment of Gd in the multilayers estimated by the three measurements as a function of the atomic concentration of Gd in the multilayers.

References

[1] Y. Takayama et al., J. Phys. Soc. Jpn. 71, 340 (2002).

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