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Magnetic Circular Dichroism of 2*p* → 1*s* Resonant X-ray Emission Spectroscopy in Ferrimagnetic Ferrites MFe$_2$O$_4$ (M=Mn, Fe, Co, and Ni) and Y$_3$Fe$_5$O$_{12}$

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Introduction

X-ray emission spectroscopy (XES) is a powerful tool to investigate electronic states in details. In particular, magnetic circular dichroism (MCD) of XES provides information about magnetic states. The pre-peak feature peculiarly observed in X-ray absorption spectrum (XAS) at the *K*-edge is still discussed as a possibility of 1*s* → 3*d* electric quadrupole (E2) transition. MCD-XES can give us the answer about E2 transition more clearly. In this report we present the results of MCD-XES of 2*p* → 1*s* emission, and discuss the electronic states of Mn, Fe, and Co in the ferrites.

Experimental

The experiment was performed at the beamline BL-28B. Polycrystalline ferrites (MFe$_2$O$_4$; M=Mn, Fe, Co, and Ni, Y$_3$Fe$_5$O$_{12}$) were used in this work. Magnetic field of 1.1 T was applied parallel to the direction of the incident X-rays. Angles of the incident and scattered X-rays were fixed to 30 and 60º, respectively, away from the normal direction of the sample surface. X-rays emitted from the sample were analyzed using cylindrically bent crystals InSb 440 for Mn $K\alpha_{1,2}$, Ge 333 for Fe $K\alpha_{1,2}$, and Ge 440 for Co $K\alpha_{1,2}$. XES spectrum was recorded by the position-sensitive proportional counter (PSPC). MCD-XES spectrum was obtained by the difference of the XES spectrum between parallel and antiparallel fields. Energy resolution was estimated to be about 2.0 eV in the measurement energy range.

Results and Discussion

Figure 1 shows Fe 2*p* → 1*s* MCD-XES spectrum together with XES spectrum. MCD-XES signal is clearly observed at $K\alpha_1$ and $K\alpha_2$ peaks of XES. The MCD-XES spectrum is mainly shown two dispersion-type profiles; a negative-to-positive profile for $K\alpha_1$ and a positive-to-negative one for $K\alpha_2$ with increasing emitted photon energy. The MCD-XES intensity in the pre-edge region reaches 4% of XES peak intensity although the intensity in the main-edge region is less than 0.5%. The enhancement of the intensity in the pre-edge region strongly reflects 3*d* electronic states through the hybridization with 4*p* states.

As shown in Fig. 1, the MCD-XES between Fe$_3$O$_4$ and Y$_3$Fe$_5$O$_{12}$ becomes opposite in sign to each other although the spectral profile is almost same. The result is corresponding to the reversal of the sign observed in *K*-edge MCD-XAS spectrum between these ferrites [1].

Mn and Co 2*p* → 1*s* MCD-XES in MnFe$_2$O$_4$ and CoFe$_2$O$_4$ have been also observed. Figure 2 shows the result of MCD-XES for Mn $K\alpha_{1,2}$. The spectral profile is similar to the result of Fe$_3$O$_4$. The resemblance of these MCD-XES spectral profiles indicates that the origin of the dichroism in ferrites and its electronic states are quite similar, while the MCD-XAS spectrum at Mn, Fe and Co *K*-edges is obviously different from each other.

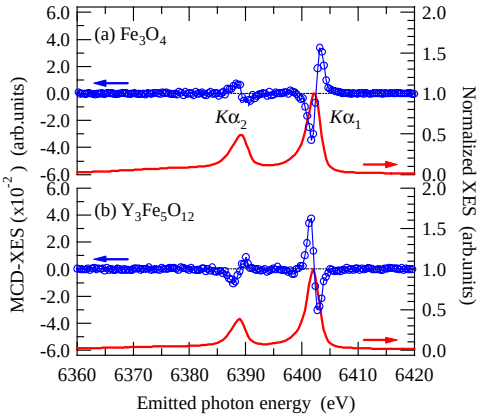

Figure 1: Fe 2*p* → 1*s* MCD-XES and XES spectra in (a) Fe$_3$O$_4$ and (b) Y$_3$Fe$_5$O$_{12}$. Incident photon energy is 7111.5 eV, whose energy is corresponding to the pre-peak energy of *K*-edge XAS spectrum.

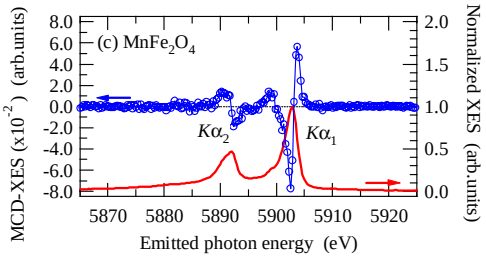

Figure 2: Mn 2*p* → 1*s* MCD-XES and XES spectra in (c) MnFe$_3$O$_4$. Incident photon energy is 6541.0 eV, whose energy is corresponding to the pre-peak energy of *K*-edge XAS spectrum.

References

[1] N. Kawamura *et al.*, J. PHYS. **IV** FRANCE **7**, C1-269 (1997).

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