16A/2010G187 & 2010S2-001

X-ray magnetic circular dichroism study of $FeCr_2S_4$

Virendra Kumar VERMA[*1], Vijay Raj SINGH[1], Keisuke ISHIGAMI[1], Goro SHIBATA[1], Takayuki HARANO[1], Toshiharu KADONO[1], Atsushi FUJIMORI[1], Tsuneharu KOIDE[2], Kenya OHGUSHI[3], Yoshinori TOKURA[3]

[1]Department of Physics, University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan
[2]Photon Factory, IMSS, High Energy Accelerator Research Organization, Tsukuba, Ibaraki 305-0801, Japan
[3]Dept. of Applied Physics, University of Tokyo, Tokyo 113-8656, Japan

Introduction

Transition metal-based spinel compounds (AB_2X_4), have been a hot topic of experimental and theoretical studies for researchers [1]. $FeCr_2S_4$ is a ferromagnetic semiconductor with T_C ~ 170 K. This material shows large negative magnetoresistance near the Curie temperature [2]. Park *et al*. [3] reported a band-structure calculation for $FeCr_2S_4$ in which each sublattice of the Fe and Cr transition metals orders ferromagnetically, while the two sublattices are coupled antiferromagnetically to each other. Recently, the electronic structure of $FeCr_2S_4$ has been studied by density functional calculation. [4]. Here, we report on Fe and Cr $L_{2,3}$ x-ray absorption and x-ray magnetic circular dichroism (XMCD) measurements of $FeCr_2S_4$ single crystal in order to study the electronic structure and magnetic properties of Fe and Cr ions in single crystal and we find that the Fe ions show large orbital magnetic moment at 80K.

Experiment

The sample studied here is a single crystal of $FeCr_2S_4$. The $FeCr_2S_4$ single crystal was grown by a chemical vapor transport method with $CrCl_3$ as a transport agent. The sample is cleaved *in-situ* to obtain a clean surface. The XAS and XMCD measurements were done at BL-16 of KEK-Photon Factory (PF), Japan. The XAS spectra were taken in the total electron yield (TEY) mode.

Results and Discussion

The XAS spectra were taken in a magnetic field of 1T at temperature of 80K and are denoted by μ_- and μ_+ for left and right circularly polarized light, respectively. The XMCD spectrum was obtained by taking a difference between the XAS spectra with negative and positive helicity of the circular polarized light. Figures 1 (a) and (b) show the Fe and Cr 2*p*-3*d* XAS and the XMCD spectra, respectively. The main two groups of the peaks shown in the XAS spectra are due to the $2p_{3/2}$ (L_3 edge) and $2p_{1/2}$ (L_2 edge) spin-orbit components. The Fe and Cr ions were in the 2+ and 3+ states, respectively, and both sublattices were found to be antiferromagnetically coupled to each other, finding from the opposite signs of the XMCD signals. From the sum rule analysis, the orbital magnetic moments of Fe and Cr ions are found to be 0.14 and 0.006 μ_B/ion, respectively. In the Fe ions, the spin and orbital moments have the same sign, whereas opposite sign is found in the Cr ions. This is because the *d* states of Fe^{2+} are more than half filled while those Cr^{3+} is less than half filled of *d* states. The orbital moment of the Cr ions is found to be small due to the d^3 configuration of Cr. However, the large orbital moment of the Fe ions is remarkable since the spin-orbit interaction within *e* levels of Fe should be small. A possible reason of large orbital magnetic moment of Fe ions is that the crystal-field splitting is small in $FeCr_2S_4$.

References

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* vkverma@wyvern.phys.s.u-tokyo.ac.jp

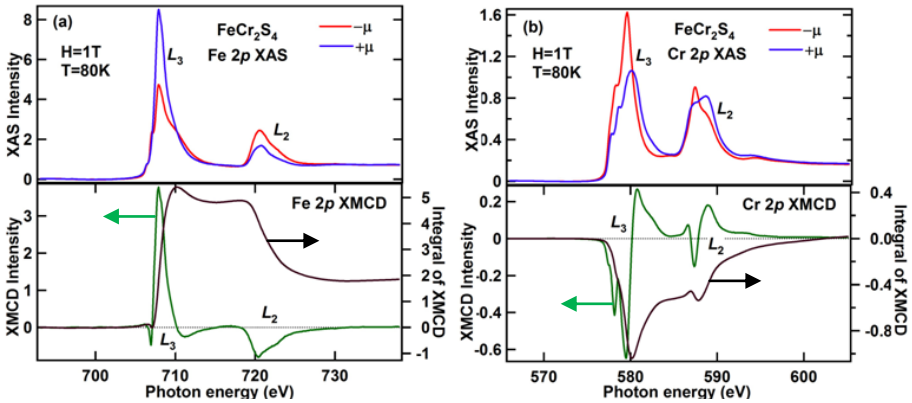

Figure 1: Fe and Cr $L_{2,3}$-edge XAS and XMCD of $FeCr_2S_4$ single crystal.