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Study on the ion-irradiation induced ferromagnetism in CeO_2 by means of SQUID magnetometer and synchrotron radiation X-ray spectroscopy

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1 Introduction

Recently, we have found that CeO_2, which is intrinsically non-magnetic at room temperature, becomes ferromagnetic by the irradiation with high energy heavy ions[1]. In this report, we show the results of the x ray photo emission spectroscopy (XPS) and the extended x-ray absorption fine structure (EXAFS) measurements, and discuss the origin of the ion irradiation induced ferromagnetism in CeO_2.

2 Experiment

Ceo_2 bulk pellets were synthesized by using a conventional ceramic process. The dimension of the samples was 5 mm in diameter and 0.5 mm thick. They were irradiated with 200 MeV Xe ions at the tandem accelerator of JAEA Tokai Research Center. The maximum fluence was $4x10^{13}/cm^3$. After the irradiation, the magnetization of the samples were measured as a function of external magnetic field at room temperature. The chemical state of Ce atoms and the atomic arrangement around Ce atoms were estimated by using XPS and EXAFS measurements at BL27A and BL27B of KEK-PF, respectively.

3 Results and Discussion

Fig. 1 shows the saturation magnetization of CeO_2 samples as a function of Xe ion fluence. The saturation magnetization increases with increasing the ion fluence, reaches the maximum value and then decreases for the higher fluences. The result of the XPS measurement shows that the valence state of some Ce atoms changes from 4+ to 3+ by the ion irradiation.

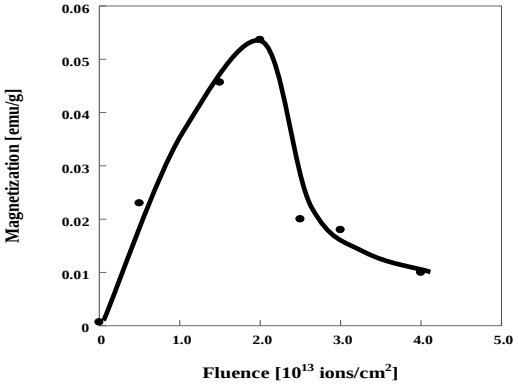

Fig. 1: Saturation magnetization of CeO_2 as a function of Xe ion fluence.

To keep the charge balance in the sample, the decrease in Ce valence have to be accompanied by the existence of O vacancies. Therefore, the experimental result of XPS measurement means that O vacancies are produced by the irradiation. As Ce3+ atom has only one 4f electron. we have tentatively concluded that the irradiation induced ferromagnetism of CeO_2 is attributed to the unpaired 4f electrons around Ce3+ atoms. The quantitative analysis has never been done yet.

As can be seen in Fig. 1, the irradiation-induced magnetization decreases for higher ion fluences. Fig.2 shows the EXAFS-FT spectra near Ce-L_3 absorption edge for unirradiated sample and the sample irradiated to the fluence of $3x10^{13}/cm^2$. In the figure, two peaks are observed. The left peak corresponds to O atom and the right one corresponds to Ce atom. The decrease in peak height for the both peaks means that the atomic arrangement around Ce atoms are disordered by the ion irradiation. This result suggests that the decrease in magnetization for higher fluences is due to the disordering of atomic arrangements and therefore the decrease in magnetic ordering.

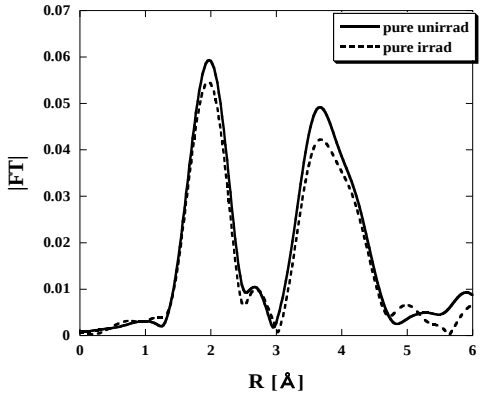

Fig. 2: EXAFS-FT spectra for unirradiated CeO_2 (solid line) and that for CeO_2 irradiated to the fluence of $3x10^{13}/cm^2$(dashed line)..

Reference

[1] K. Shimizu *et al*., *Nucl. Instrm. Meth. B*286, 291 (2012).

Fig. 1: This is the logo of the Photon Factory.

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