Soft X-ray MCD of nano-sized transition metal oxides in zinc oxides

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Transition metal doped semiconductor has been a potential candidate for spintronic devices. Recently ferromagnetic behaviors at room temperature were reported on Mn-doped ZnO[1]. However, the origin of the ferromagnetism is still controversial.

In the present study, we made a combined study of soft x-ray MCD measurements and first principles calculations on Mn doped ZnO thin films with special interests on the local environment of the dopant.

The Mn-$L_{2,3}$edge x-ray absorption spectrum (XAS) and magnetic circular dichroism (MCD) were measured at BL25SU of SPring-8. Circularly polarized light from the twin helical undulator was monochromatized and irradiated normally on the sample surface. The measurement of MCD was performed at 42K under a magnetic field of about 1.4T. The magnetic field was applied perpendicularly to the sample surface with permanent magnet made of Nd-Fe-B alloy.

$Zn_{1-x}Mn_xO$ thin films were fabricated on a Al_2O_3 substrate by the pulsed laser deposition (PLD) method using an excimer KrF laser source. The thin films were covered with a thin gold layer in order to prevent charge-up and degradation of the sample.

Figure 1 shows Mn-$L_{2,3}$edge XAS spectrum of $Zn_{1-x}Mn_xO$ thin film with x=0.05. The spectrum is in good agreement with that reported in literature.[2] In order to interpret the XAS, we have developed a novel first principles technique that can handle correlation effects among 3*d* electrons and a core-hole in a rigorous manner using fully relativistic wave functions.

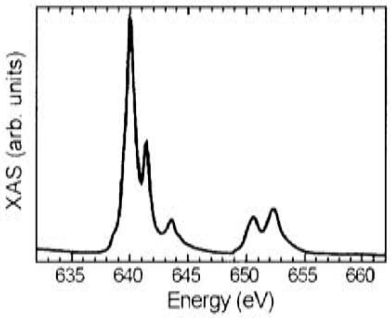

Fig.1 Mn $L_{2,3}$ edge XAS spectrum of $Zn_{1-x}Mn_xO$ thin film with x=0.05.

References

(1) P. Sharma *et al.*, Nat. Mater., **2** 673 (2003).
(2) S-J. Han *et al.*, Appl. Phys. Lett., **83** 920 (2003).

Temperature Dependence of Local 4f moments in $Ce_xLa_{1-x}Ni$

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Based on measurements of bulk magnetic susceptibility, $Ce_xLa_{1-x}Ni$ has been known to change its magnetic property from the coherent Kondo state to the paramagnetic state when x is decreased. The transition point is supposed to be around x=0.6.

However because many coherent Kondo systems show the temperature dependence of 4f local moments that is different from those of bulk measurements, we have implemented measurements of 4f local moments in $Ce_xLa_{1-x}N$, for x=1.0, 0.9, 0.7, and 0.4.

The starting samples were made with an Ar furnace. The bulk magnetic property was measured with SQUID, which shows behaviors very similar to the already reported data. The clean sample surface was obtained with breaking it in an ultrahigh vacuum chamber attached to the BL25SU. The magnetic field was applied with an electromagnet that can produce maximum field of 2.2 tesla.

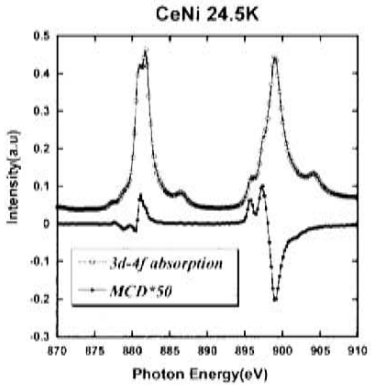

Figure 1

We first checked 5d moments of Ce together with 3d moments of Ni. We did not detect any meaningful moments of these states within the experimental accuracy.

Next we measured the MCD signals associated with Ce 3d-4f excitation, with the polarization switching mode where the circular polarization was switched with the frequency of 1 Hz using kicker magnets that modifies the orbit of the stored electrons passing through the two tandem undulators. In order to eliminate possible false MCD signals we also switched the magnetic field and repeated the measurements.

Figure 1 shows the typical results of the absorption spectra and the MCD spectra for x=1.0. The hybridization satellite is clearly observed, suggesting rather high Kondo temperature.

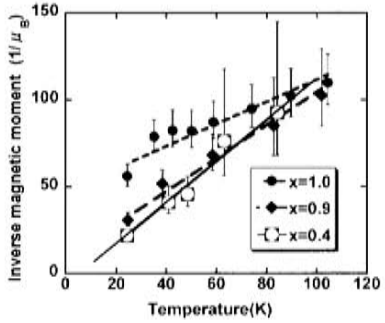

Figure 2

On the other hand as shown in Fig. 2, the Curie-Weiss plots of the 4f moments indicates different tendency, where the Weiss temperature for x=0.9 is much lower than the bulk data. The sample with x=0.4 gives even a ferromagnetic behavior like a skutterudite $PrFe_4P_{12}$, though they do not become ferromagnetic at lower temperatures. The difference between the MCD data and the SQUID data together with the Curie-Weiss like behavior suggests that the Kondo-like property comes from a single site effect.