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Fe_3O_4 Nanoparticles and their Magnetic Properties using X-Ray Magnetic Circular Dichroism

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1 Introduction

Nano-sized materials show superior physical and chemical properties due to their mesoscopic effect, small object effect, quantum size effect and surface effect compared to atomic or bulk [1-4]. Literature suggest that Fe_3O_4 magnetic nanoparticles (MNPs) are non-toxic and biocompatible and also show superparamagnetic behaviour, high coercivity and low Curie temperature, so due to this nature it have intensively studied. Recently, Fe_3O_4 MNPs have brought out some new kinds of biomedical applications such as dynamic sealing [5], biosensors [6], and extraction of DNA/RNA from blood samples [7].

2 Experiment

The MNPs studied here are Fe_3O_4 with an approximate diameter 5 to 20 nm. The Fe_3O_4 MNPs were prepared by co-precipitation method due to its efficient and robust performance and the fact that it does not require any specialised equipment. For this a solution of FeCl2 and FeCl3 in a 1:2 molar ratio is prepared and slowly dripped in to a pre heated NaOH solution. This forms a black precipice consisting of Fe_3O_4 particles. The sample is annealed in controlled oxygen 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.

3 Results and Discussion

The XAS spectra obtained with applied magnetic fields of +3.0 and -3.0 T are denoted by m+ and m- which represent left and right circularly polarized light, respectively as shown in Fig 1. The XMCD spectrum was recorded by taking a difference between the XAS spectra with negative and positive helicity of the circular polarized light. Figures 1 show the Fe 2p-3d XAS and the XMCD spectra, respectively. The main two groups of the peaks shown in the XAS spectra are due to the 2p3/2 (L3 edge) and 2p1/2 (L2 edge) spin-orbit components. Sharp negative, positive and negative peaks (denoted by Oh (Fe2+), Td (Fe3+), and Oh (Fe3+)) occur in the 2p3/2 edge of the XMCD spectra, respectively, around hn= 708.5, 709.7, and 710.4 eV. The Fe ions were in the mixed state 3+ and 2+ states, and both sublattices at Oh sites (Fe3+ and Fe2+) were found to be antiferromagnetically coupled to Fe3+ (Td sites), finding from the opposite signs of the XMCD signals. From the sum rule analysis, the orbital and spin magnetic moments of Fe ions are found to be 0.22 and 2.1 μB/Fe, respectively. The observed morb and mspin of Fe ions are found to be 0.74 and 1.2 μB/Fe, respectively at 0.5T. XMCD peak intensity remains high down to an applied field of 0.5 T indicating that ferromagnetism exists in this sample. The XMCD line shape (not shown here) is independent of the magnetic field. The slope of the XMCD intensity vs H curve indicates the paramagnetic part of the Fe magnetic moment.

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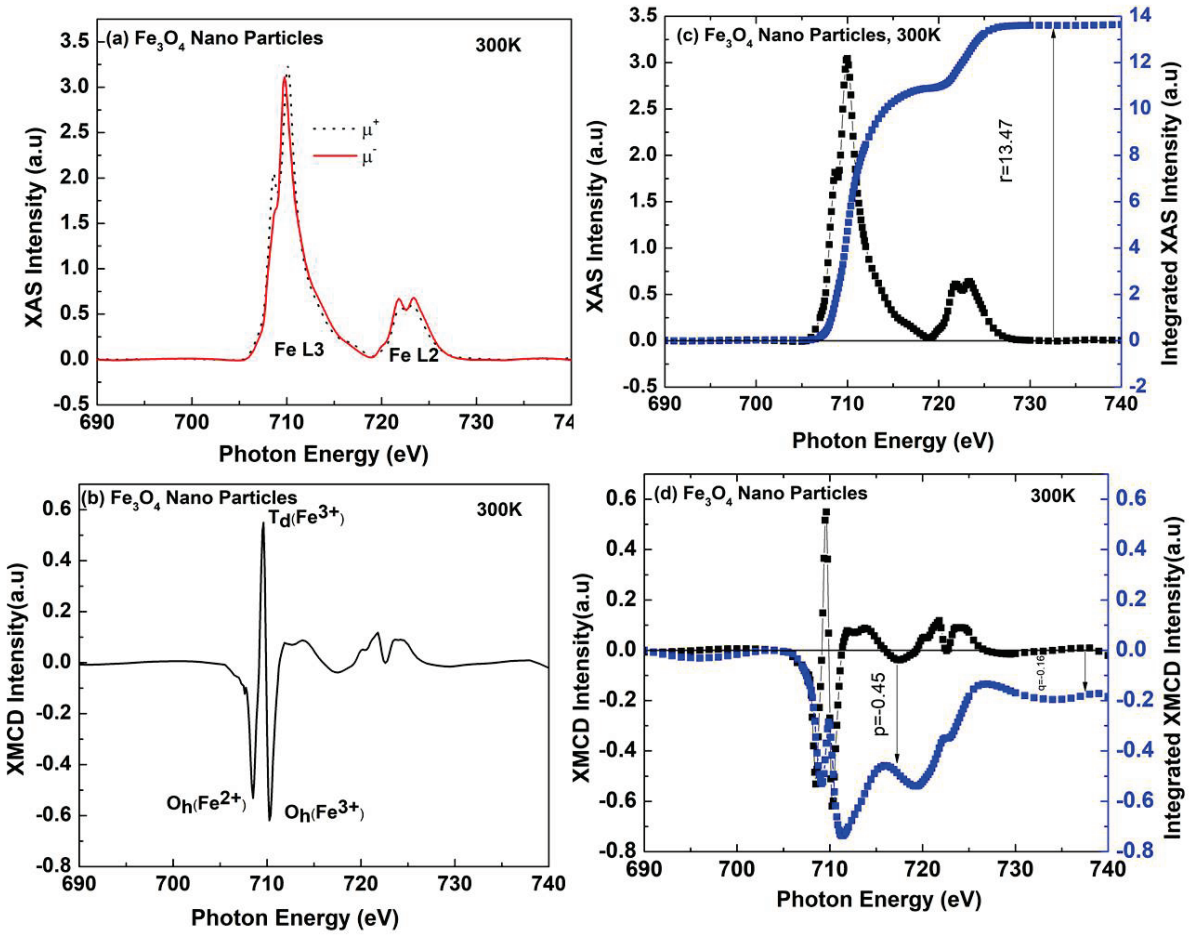

Fig. 1. Fe L2,3-edge of anatase Fe_3O_4 magnetic nanoparticles (MNPs) taken in the TEY mode at T = 300 K and H =± 3 T. (a) XAS. (b) XMCD spectra (c) integrated XAS and (d) integrated XMCD of Fe_3O_4 MNPs