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Magnetic properties of silica coated Fe_3O_4 nanoparticles using X-ray magnetic circular Dichroism

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1 Introduction

Magnetite (Fe_3O_4) exhibits high chemical activity, high reactivity with atmospheric oxygen and rapid agglomeration leading to the reduced magnetism and trouble in grafting with other material [1]. In order to overcome such problem and to enhance the efficiency of Fe_3O_4 as a magnetic beads, we are coating it with inert oxide silica, as it provides a kind of stability and prevents degradation of magnetic nanoparticles (MNPs) [1]. Silica is an ideal material for chemical coating of Fe_3O_4, due to its stability and versatility of surface modification. Fe_3O_4 MNPs have received considerable attention due to its diverse method of synthesis, biocompatibility, non-toxicity, high field irreversibility and environment friendly in nature [2]. The ease of use of magnetic beads with surface coating makes them automation friendly and well suited for the range of applications including the sample separation for next generation sequencing, PCR, Protein purification, molecular and immmuno diagnostics, magnetic activated cell sorting and also ease the challenges associated with the extraction of nucleic acid from different kind of sample[1-2]. These magnetic beads are nano-sized particles of Fe_3O_4 which shows superparamagnetic behaviour with strong magnetic susceptibility, lack of remanent field, coercitivity and the absence of hysteresis due to this nature they are intensively studied [1-2].

2 Experiment

The nanoparticles coated with silica were prepared by hydrolysis and the polycondensation of the tetraethylorthosilicate (TEOS) with the ethanol solution of TEOS being added to the stable suspension of citric acid coated nanoparticles.The effect of various parameters on the quality of coating were evaluated systematically. The quality of silica layer was depicted using electron microscopy and by performing leaching of the nanoparticles in HCl. While the surface reactivity was examined by grafting (3-aminopropyl) triethoxysilane (APS) onto the nanoparticles. The experimental condition for the coating procedure favours the heterogeneous nucleation of silica on the surface of the nanoparticles, enabled the preparation of very thin silica layers, less than 2nm thick. The decrease of silica layer's thickness to an almost homogeneous layer of Si-OH at the nanoparticles surfaces. The detailed samples preparation is described somewhere else [2]. The X-ray absorption spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD) measurements were done at BL-16 of KEK-Photon Factory (PF), Japan. The XAS spectra were taken in the total electron yield (TEY) mo;

3 Results and Discussion

We have performed XAS measurements of Silica coated Fe_3O_4 NPs in the magnetic field ± 3T. Here, m^+ and m^- represent left and right circularly polarized light, respectively which is shown in Fig 1 (a). Fig 1 (b) showed the XMCD spectrum which is the difference of XAS spectra with positive and negative helicity of circular polarized light. The XAS and XMCD spectrum show two main peaks which arises due to spin- orbit interaction. These two peaks are named as $2p_{3/2}$ (L_3 edge) and $2p_{1/2}$ (L_2 edge). In the $2p_{3/2}$ edge of the XMCD spectrum shows three peaks which are at 708.5, 709.6 and 710.3 eV and represent O_h (Fe^{2+}), T_d (Fe^{3+}), and O_h (Fe^{3+}), respectively. The Fe ions are in the mixed state (3+ and 2+ states). In Fe_3O_4 NPs both sublattices at O_h sites (Fe^{3+} and Fe^{2+}) were found to be antiferromagnetically coupled to Fe^{3+} (T_d sites), observing from the opposite signs of the XMCD signals. To calculate magnetic moment, we have used sum rule which suggest that spin magnetic moment (m_{spin}) was in the range of 2.2-2μ_B/Fe and orbital magnetic moment (m_{orb}) 0.4-0.3μ_B/Fe in the magnetic field 3T-0.5T. From the data it is clear that ferrromagnetism exists in the sample.

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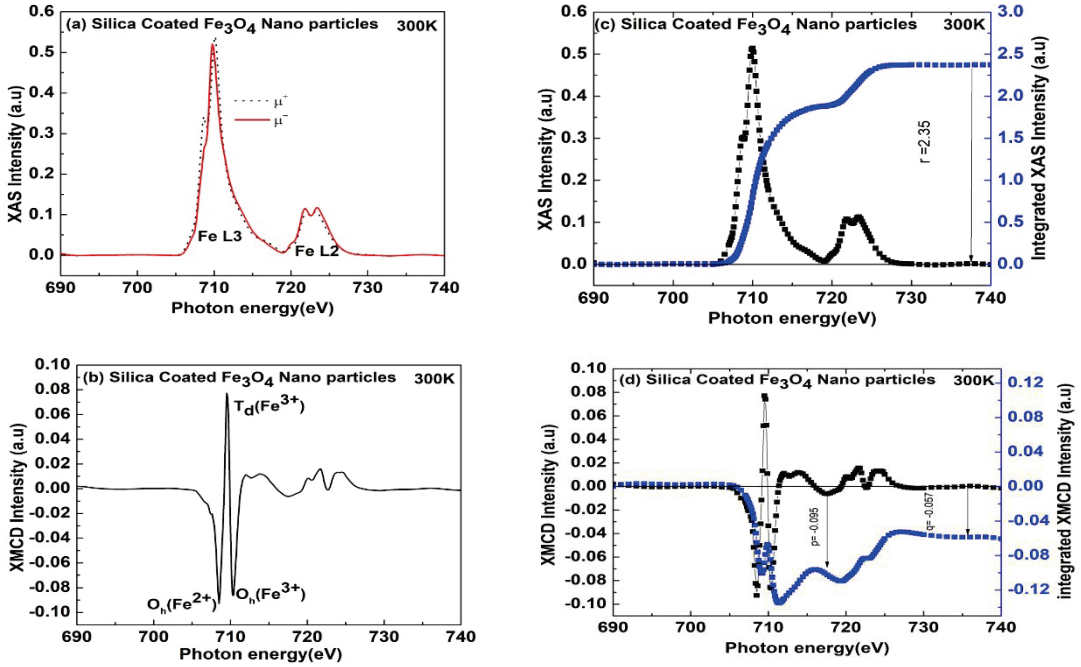

FIG. 1. Fe $L_{2,3}$-edge of Silica coated Fe_3O_4 magnetic nanoparticles (MNPs) taken in the TEY mode at T = 300 K and H =± 3 T. (a) XAS. (b) XMCD spectra (c) integrated XAS and (d) integrated XMCD of silica coated Fe_3O_4 MNPs

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