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Response of iron oxide on hetero-nanostructures of soft and hard ferrites

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ABSTRACT

Core-shell nanostructures of Zinc and Cobalt ferrites synthesized by solution evaporation route are observed to perform novel magnetic response. The structural and morphological analyses of $ZnFe_2O_{4-core}/Fe_3O_{4-shell}$ and $CoFe_2O_{4-core}/Fe_3O_{4-shell}$ nanoparticles (NPs) are confirmed with X-ray diffractometer (XRD) and high resolution transmission electron microscopy (HRTEM). Physical properties measurement system (PPMS) investigations at room temperature reveal that the synthesized core-shell NPs (~8 nm in diameter) are in super-paramagnetic state. The coercivity of $ZnFe_2O_4/Fe_3O_4$ is much lower than that of $CoFe_2O_4/Fe_3O_4$ NPs (e.g., at 5 K: $H_c = 0.6kOe$ for $ZnFe_2O_4/Fe_3O_4$ and H_c = 18kOe for $CoFe_2O_4/Fe_3O_4$. Fe_3O_4 is preferable to reduce magnetic hardness for Zinc ferrite and enhance for Cobalt Ferrite.

1. Introduction

Magnetic core-shell nanoparticles (NPs) have been given offensive considerations over the last five decades and continue to sustain attention because of their potential in biomedical [1] and data storage applications [2].

Recently, bimagnetic core-shell (CS) nanostructures have gone potential interest because of particular interest in several magnetic properties such as interparticle interactions, magnetization reversal process, magnetic anisotropy, exchange bias and thermal stability [3]. In fact, CS nanomaterials with ferromagnetic (FM) and antiferromagnetic (AFM) structures have yield diverse characteristics in magnetic resonance imaging, optimizing hyperthermia, magnetic resonance amplifiers, magnetic recording media, and permanent magnets [4-7]. However, simple nanoparticles have equally importance along with CS geometry [8]. Soft and hard magnetic materials are equally important for such applications. CS nanostructures comprise of Fe/Fe_3O_4 [9] Sm(CoFe)/Fe_3O_4 [10] $CoFe_2O_4$/MFe_2O_4 (M = Zn, Fe, Mn), $FeTiO_3$/M (Ni, NiFe) [11], etc. have been studied and these reports depicts their remarkable magnetic properties over simple NPs.

In current work, we have synthesized soft and hard ferrites as core material and iron oxide as a shell to investigate the overall magnetic properties. The synthesis of core-shell NPs has been performed with Cobalt Nitrate ($Co(NO_3)_2 \cdot 6H_2O$), Zinc Nitrate ($Zn(NO_3)_2 \cdot 6H_2O$), Iron Nitrate ($Fe(NO_3)_3 \cdot 9H_2O$), Oxalic acid ($H_2C_2O_4$) and Nitric acid (HNO_3). All the mentioned materials were used without any further purification.

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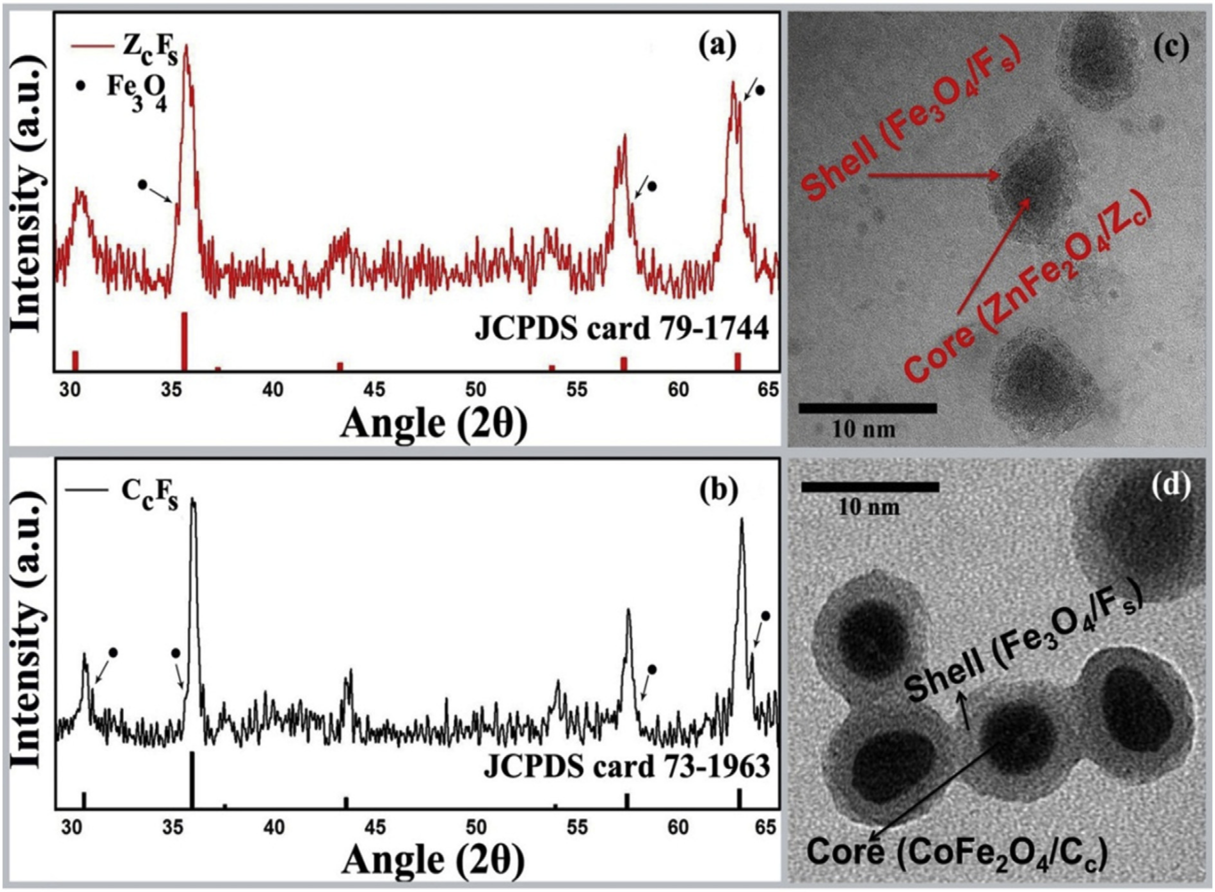

Figure 1. XRD of (a) Z_CF_S and (b) C_CF_S. Morphology of Z_CF_S and C_CF_S by TEM is represented in (c) and (d), respectively.

2. Experimental section

2.1. Synthesis of core-shell nanoparticles

Zinc Ferrite, Iron oxide coated Zinc Ferrite, Cobalt Ferrite and Iron oxide coated Cobalt Ferrite NPs have been prepared by solution evaporation method. Initially 0.1 *M* Zinc Nitrate and Iron Nitrate were stirred at room temperature with 0.2 *M* Oxalic acid in a glass beaker. To avoid any impurity phases 2 *M* Nitric acid was dropped into the solution followed by constant stirring of 30 minutes. The solution was heated at 120 °C after homogenously mixture of solutions and heating process was maintained until all solution evaporates. In order to improve crystallinity, the obtained product was annealed at 600 °C inside a furnace for 6 hrs. Afterwards, 0.2 *M* Iron Nitrate and Oxalic acid was mixed homogenously and heated at 70 °C for 30 minutes under constant stirring. Core-shell nanoparticle of Zn Ferrite (core) and Iron oxide (shell) was then obtained once the annealed product was mixed under continuous sonication for 15 minutes at room temperature. Similar method was adopted for the synthesis of Cobalt Ferrite (core) and Iron oxide (shell) NPs.

Later on, the prepared core-shell NPs were named Zinc Ferrite (Z), Iron oxide coated Zinc Ferrite (Z_CF_S), Cobalt Ferrite(C) and Iron oxide coated Cobalt Ferrite (C_CF_S).

2.2. Characterizations

Structural investigation of synthesized core-shell nanoparticles was performed with industrial X-ray diffractometer (XRD:D/Max 2400 – Rigaku, $\lambda = 0.154056$ nm), after homogenously dispersion of nanoparticles in small quantity on amorphous glass slide. The analysis was carried out in 2θ range of 30–65° with 0.5 scan rate. Morphological estimations were examined by Transmission electron microscope (TEM: Jeol 2011), followed by uniform dispersion of nanoparticles in hexane and then fall drop wise onto the surface of carbon coated grid. Low and high temperature magnetic measurements of nanoparticles were inspected by vibrating sample magnetometer integrated in physical property measurement system under applied field of ±5T (PPMS: Quantum Design, 9T).