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Synthesis of Fe_2O_3 Nanoparticles and Study of its Structural, Optical Properties

S. Saha and A. K. Bhunia

Department of Physics and Technophysics, Vidyasagar University
Midnapore-721102, India
Email sahaphys.vu@gmail.com

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ABSTRACT

A simple slow chemical reduction method has been successfully deployed to fabricate iron oxide nanoparticles. The structural characteristics were investigated through X-ray diffraction. The crystal unit cell of the nanoparticles was found to be hexagonal. The morphology of the nanostructures was studied using field emission scanning electron microscopy. The nanopartiles are spherical in shape. The estimated band gap from the UV-VIS absorption spectra shows formation of nanoparticles. The photoluminescence spectrum shows presence of surface states.

***Keywords*:** Iron oxide, Nanoparticles, UV-VIS Spectra, Band gap, Photoluminescence

1. Introduction

The synthesis of magnetic nanoparticles has become a particularly important area of research and is attracting a growing interest because of the potential applications such advanced magnetic materials, catalysts, high-density magnetic recording media and medical diagnostics [1,2,9]. Magnetic iron oxide nanoparticles and their dispersions in various media have long been of scientific and technological interest. Iron oxides exist in many forms in nature, with magnetite (Fe_3O_4), maghemite (γ -Fe_2O_3) and hematite (α-Fe_2O_3) which are probably most common. Magnetite (Fe_3O_4) has recently been considered an ideal candidate for biological applications, both as a tag for sensing and imaging, and as an activity agent for antitumor therapy [3,4,8]. Magnetite and maghemite have attracted attention in biomedical applications because of their biocompatibility and low toxicity in the human body [5]. Hematite (α-Fe_2O_3) has also great scientific and technological importance since this material can be used in information storage, color imaging, magnetic refrigeration, gas sensing, ferrofluids, catalysts and so on[6,10]. While a number of suitable methods have been developed for the synthesis of magnetic nanoparticles (MNPs) of various different compositions, successful application of such magnetic nanoparticles in the areas listed above is highly dependent on the stability of the particles under a range of different conditions. We report here a simplistic, surfactant free and simple chemical route of Fe_2O_3 nanostructures and the structural, optical properties coming out from those product materials. In this study we have established the synthesis of well crystalline, well dispersed, faceted metal oxide (Fe_2O_3) by a simple slow chemical reduction method. The crystalline phases of the prepared samples were

identified by X-ray diffraction (XRD). The morphological properties were investigated by field effect scanning electron microscope (FESEM). The absorbance spectra were obtained from UV-VIS spectrophotometer. The fluorescence spectrum of the as prepared samples was obtained by using Hitachi-F7000-FL spectrophotometer.

2. Synthesis and characterization

Iron oxide (Fe_2O_3) nanoparticle was synthesized by the slow chemical reduction method. 5 mM aqueous solutions of $FeCl_3$ (Merck) were prepared using de-ionized water. After the mixture was stirred for 20 min, pH was adjusted to 7.0 with a 5M NaOH solution; subsequently 10 ml of a 10 mM aqueous solution of $NaBH_4$ was poured instantaneously. A fine precipitate was obtained and filtered, then washed three times with de-ionised water, after that water was removed with acetone. Acetone was used as a dehydrating agent since it has a high solubility for water but not for the metal salts involved.

3. Structural determination (XRD) and morphology study

The powder X-ray diffraction (XRD) pattern on the samples were recorded by a X-ray diffractometer (miniflex II, desktop-X-ray diffractometer) using Cu-kα radiation of wave length $\lambda = 1.54\ A^0$ for 2Θ ranging from 20^0 to 80^0. Figure-1 shows the XRD patterns of these samples. The peaks are identified comparing with ICDD data. The nanoparticles formed are of Fe_2O_3. The crystal unit cell of the nanoparticles was found to be hexagonal

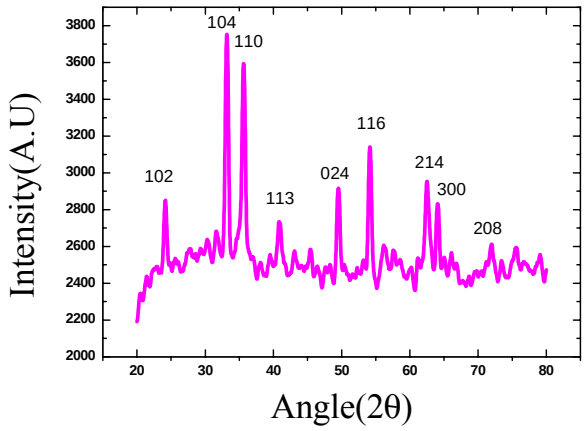

Figure 1: The XRD pattern of the sample Fe_2O_3-nanomaterials

The morphology of the samples were observed using ZEISS SUPRA-40 field emission scanning electron microscope (FESEM) operating at 5 kV accelerating voltage and the working distance between the samples and the detector was 1.5 cm. Typical FESEM image of the as prepared Fe_2O_3 nanorods is shown in Fig. 2. Particle-like nanostructures were clearly observed. The nanoparticles are randomly distributed in the powdered sample. The average diameter of the nanoparticles 12 nm.

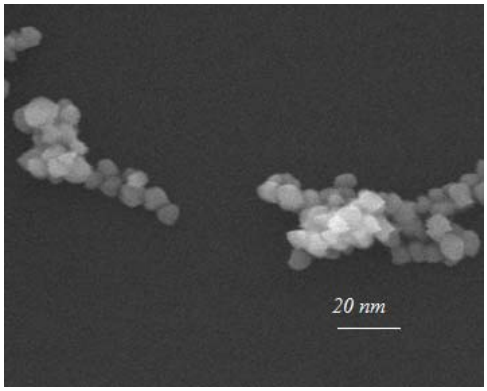

Figure 2: FESEM images of the a as synthesized Fe_2O_3 nanoparticles

4. Optical properties of synthesized Fe_2O_3 nanoparticles

Optical properties of Fe_2O_3 samples were determined through UV-VIS. The optical absorption spectra of the samples were recorded by using Shimadzu-Pharmaspec-1700 UV-VIS after ultrasonication of the samples in water. Figure 3 shows the optical absorbance spectra of Fe_2O_3 samples.

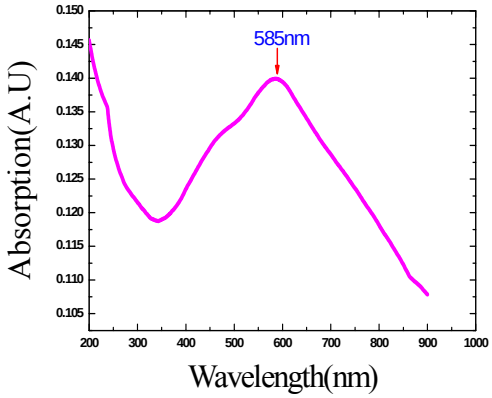

Figure 3: Absorption spectra of the Fe_2O_3 nanoparticles

Optical absorption coefficient has been calculated in the Wavelength region200–900 nm. The bandgap of the as-prepared nanoparticles are are determined from the relation

$$(\alpha h\nu)^2 = c(h\nu - E_g)$$

where C is a constant. E_g is the band gap of the material and α is the absorption coefficient. Figure 4 shows the plot of $(\alpha h\nu)^2$ vs. energy (hν) and it is used to determine band gap. The bandgap of the sample is found to be 2.86 ev, which is greater than the bulk Fe_2O_3 (2.2 ev) [7]. Thus there is a blue shift relative to the peak absorption of bulk Fe_2O_3 . Fig.5 displays the photoluminescence spectra of as-prepared Fe_2O_3 samples.. The fluorescence spectrum of the as prepared samples was obtained by using Hitachi-F7000-FL spectrophotometer. Photoluminescence spectra display peak around 604 nm and

emission which appear as fine structure on the higher energy side. The PL peaks around 624 nm may be attributed due to the surface states which may arises from the deep trap formed due to iron vacancy.

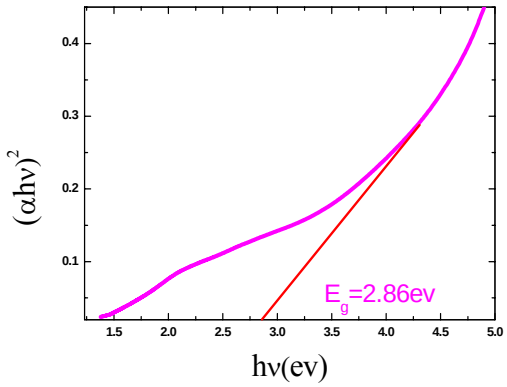

Figure 4: The plot of $(\alpha h\nu)^2$ vs. energy ($h\nu$) to determine band gap

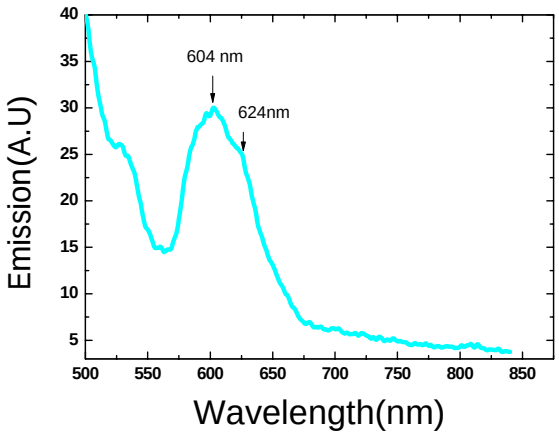

Figure 5: Photoluminescence spectra of as-prepared Fe_2O_3 samples

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