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Research Paper

Investigation of Optical and Structural Properties of Iron Oxide Nanostructures Synthesized by Co-Precipitation Method

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Abstract: In this research, iron oxide nanostructures have been successfully synthesized using the co-precipitation method. The results of structural studies using X-ray diffraction (XRD) analysis showed that the synthesized samples have a simple cubic structure. The lattice parameter of these synthesized nanostructures was calculated with the aid of the Rietveld refinement method. It was found that the lattice parameter is about 8.388 Å. Electron microscopy images (SEM) showed that the samples have sheet likes shapes. From SEM images, it was found that the synthesized nanosheets' thickness was about 33 nm. The optical properties of the samples were also studied using ultraviolet-visible spectroscopy. These studies showed that the samples have a broad absorption peak of about 350 nm. The samples were irradiated with a beam with a wavelength of 205 nm to measure the emission spectra. There were several emission peaks observed in the emission spectra of samples. The highest emission peaks were observed at 482nm and 527 nm, respectively.

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1. INTRODUCTION

Today nanoparticles in different morphology have been used in a wide variety of applications. The special properties offer new and interesting optical, mechanical, and magnetical applications [1-7].

In particular, magnetic nanoparticles (MNPs) have attracted a great deal of attention because of their successful use in a wide range of industries with properties such as magnetic fluids, magnetic energy storage, catalysts, environmental modifiers, magnetic inks, magnetic resonance imaging (MRI) [8-10].

The most common materials for synthesizing magnetic nanoparticles are compounds of iron, cobalt, or nickel combined with other metals such as copper, zinc, strontium, and barium [14]. It is necessary to fully control particles' physical and chemical properties in the fabrication of magnetic nanoparticles to accommodate many different applications [11]. In particular, depending on the desired characteristics and the field of end-use, three main routes for preparation have been developed over the past decades: chemical, physical and biological, the first type comprising 90% of all synthesis methods [16-17].

According to the main methods mentioned, magnetic nanoparticle preparation is made in different ways. These methods include; Sedimentation, thermal decomposition, microemulsion, hydrothermal, polyol, sol-gel, biomass, and sediment dispersion.

The co-precipitation method is probably the most popular method for synthesizing nanoparticles. In particular, due to the non-toxic properties of the commonly used materials, they are widely used in medical applications [18]. With the aid of this method, MNPs can be synthesized at room temperature [15]. Through this synthesis method, MNPs can be widely produced in 5 to 40 nm diameter range. In general, the resulting size, shape, and magnetic properties depend on the reaction conditions such as the type of salts used [20], pH, and ionic strength [21-22].

Due to the widespread applications of iron nanoparticles in this study, the co-precipitation method, as a simple and inexpensive method, was used to synthesize iron oxide nanosheets. The optical and structural properties of fabricated samples were studied.

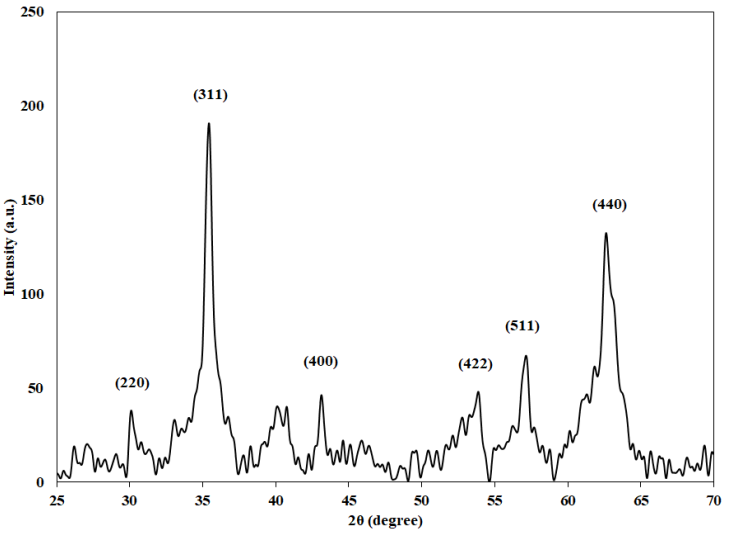

Fig. 1. X-ray diffraction pattern (XRD) of the fabricated sample. The X-ray diffraction pattern has good accordance with standard diffraction patterns (ICSD-01-075-0033) which shows the formation of iron oxide (Fe_3O_4) crystal structure.

2. SYNTHESIS OF IRON OXIDE NANOSTRUCTURES

According to different methods of preparing iron nanoparticles, a simple method with high efficiency for synthesis was considered. For this purpose, 1 gr of polyvinyl alcohol is dissolved in 600 ml of distilled water and heated using a heater-stirrer at 80-70 ^{o}C. Then 1.6 g of iron chloride powder was added to the prepared solution and was stirred with a magnetic stirrer. After that, aqueous sodium hydroxide solution was added drop by drop to the solution to precipitate the nanoparticles at the bottom of the container. At this step, the solution was stirred for one hour with a magnetic stirrer at 1500 rpm. After passing the desired time, the obtained sediment was separated from the rest of the solution using the Whatman filter paper. The resulting material was washed several times alternately with ethanol and water to prepare a pure sample. The obtained nanostructures were transferred from filter paper to a glass plate, dried using an oven, and then collected. The structural and optical properties of the synthesized nanomaterials were studied using various analysis devices.

3. CHARACTERIZATION AND RESULTS

A. X-ray diffraction spectrum (XRD)

To prove the synthesis of iron oxide composition, X-ray diffraction (XRD) patterns of samples were prepared using an X-ray diffractometer device

(Bruker-D8 Advance). A comparison of the results of X-ray diffraction patterns with standard diffraction patterns (ICSD-01-075-0033) proved the successful synthesis of iron oxide (Fe_3O_4) (Figure 1). As can be seen in the figure, most of the crystal planes are related to (311), (440), and (511) planes. Rietveld refinement analysis determined that the structure of synthesized iron oxide samples has a simple cubic structure with a lattice parameter of a = 8.388A. The average crystallite sizes were estimated to be 21 nm using the Debbie-Scherer relationship.

B. Sample morphology

From scanning electron microscopy (SEM) (MIRA-TESCAN) images, it was concluded that the synthesized samples have sheet-like shapes. As shown in Figure 2, the thickness of iron oxide nanosheets is about 33 nm.

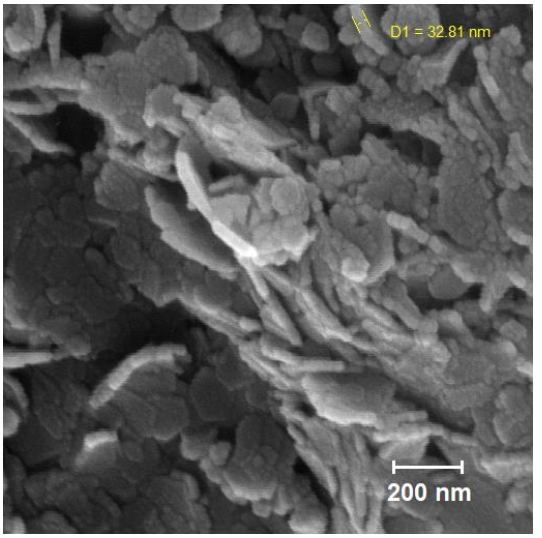

Fig. 2. Scanning electron microscope (SEM) image of fabricated iron oxide nanosheets. The thickness of nanosheets are about 33 nm.

C. Absorption spectrum

The absorption spectra of the sample were measured using an ultraviolet-visible spectrophotometer (PG-Instruments T92+) in the range of 200 to 900 nm. The results of this measurement are shown in Figure 3. As shown in the figure, only one broad absorption peak about 350 nm

was observed for samples. The obtained spectrum is similar to the absorption spectra obtained by other researchers for iron oxide [23].

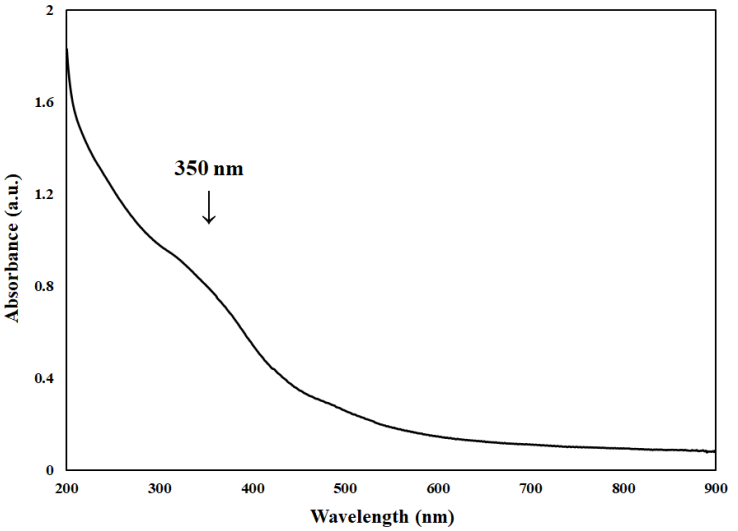

Fig. 3. Sample absorption spectra. The sample has only one broad peak about 350 nm.

D. 3.4. Fluorescence spectrum

The fluorescence spectra of the sample were measured using a photoluminescence device (Perkin LS-45). In this measurement, the sample was irradiated with a wavelength of 205 nm, and then its emission spectrum was measured in the range of 200 to 800 nm (Figure 4).

As seen in this figure, the sample has an emission spectrum at wavelengths of 348 nm, 365 nm, 452 nm, 482 nm, 527 nm, 662 nm, and 884nm. As shown in figure 4, the highest emissions peak intensities are related to 482 nm and 527 nm wavelengths, respectively.

4. CONCLUSION

In this study, iron oxide nanosheets were fabricated successfully via a simple and straightforward method. SEM images of samples showed the formation of nanostructures with sheetlike morphology. X-ray diffraction patterns revealed that the fabricated nanosheets have a simple cubic structure. One broad peak was observed in UV-visible spectra of fabricated nanosheets. Several emission peaks were observed in the photo

fluorescence spectra of the sample under an excitation beam of 205 nm wavelength.

Due to iron oxide's well magnetic properties, the nanoparticles were widely used in biology and medicine for magnetic separation of biological products and cells and magnetic conduction for intelligent drug delivery to the desired tissue in the body [24-25]. Surface chemistry, size, and charge of magnetic particles affect the biological distribution of nanoparticles [26].

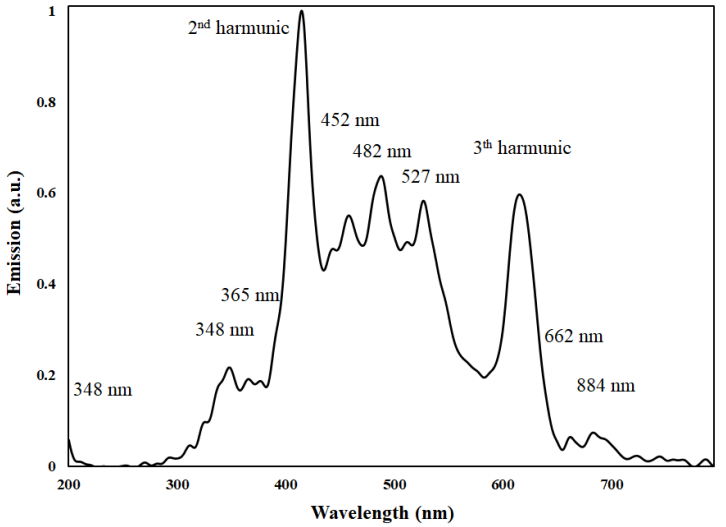

Fig. 4. Sample Fluorescence spectra. The sample was excited at the wavelength of 205 nm. There are several emission peaks were observed in the emission spectra of the sample.

Accordingly, in this research, the synthesis of this valuable nanostructure has been attempted to provide a way for further studies, especially in medicine. This study showed that the synthesis of these materials using the co-precipitation method is a successful method in synthesizing iron oxide nanosheets.

X-ray diffraction spectra showed the successful synthesis of iron oxide. Comparison of the X-ray diffraction pattern with the standard pattern, it was proved that most of the synthesized nanosheets are in the form of magnetic iron oxide, i.e., Fe_3O_4. In other words, synthesized nanosheets can interact with a magnetic field. The structure of Fe_3O_4 has

paramagnetic properties. This means that when these synthesized nanostructures are exposed to an external magnetic field, all of the electrons' spins will be oriented in the direction of the external field.

The important thing about paramagnetic materials is that by cutting off the external magnetic field, the orientation of the electrons' spins will be oriented randomly. The energy difference between these two states is transferred to the surrounding medium in the form of thermal energy. This property can be used to transfer heat energy by applying an alternating magnetic field to this material. This property has many applications, especially in medicine and the treatment of diseases.

It should be noted that, in fact, the combination of magnetic properties, non-toxicity, and having several emission spectra along with the specific morphology of synthesized nanomaterials make these materials suitable candidates for various applications such as medical imaging, intelligent drug delivery, or even direct treatment for example in destroying cancerous tissues.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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