Iranian Journal of Pharmaceutical Sciences
Spring 2008: 4(2): 115-118
www.ijps.ir

Original Article

# Preparation and Characterization of Manganese Ferrite Nanoparticles via Co-precipitation Method for Hyperthermia

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**Abstract**

In this work, Mn ferrite nanopowders were prepared by co-precipitation method and were characterized. Phase identification of the nanopowders was performed by X-ray diffraction method and the mean particle size of the nanopowders was calculated by Scherrer's formula, using necessary corrections. Magnetic parameters of the prepared nanopowders were measured by a vibrating sample magnetometer. A sensitive thermometer was used to measure the increase in temperature due to application of an alternating magnetic field on suspended magnetic nanopowders in water. Transmission electron microscope investigations showed that the particle size distribution was homogeneous and their size was in a good agreement with those obtained by Scherrer's formula. The results show that a single phase Mn ferrite can be obtained by co-precipitation method at 70 °C with a mean particle size of 5 nm and a 5 °C temperature increase is achievable in an AC magnetic field.

*Keywords:* Co-precipitation method; Hyperthermia; Magnetic loss; Nanoparticles.
*Received:* December 4, 2007; *Accepted:* February 20, 2008

## 1. Introduction

Soft magnetic oxides, $MnFe_2O_4$, where Mn is a divalent cation, have a spinel structure, and then named spinel ferrites too, and in the bulk form have many applications in telecommunication and electronics [1]. Nanoparticles of these magnetic oxides have different characteristics in comparison with the bulk ones [2]. The use of magnetic particles to induce hyperthermia in biological tissues is an important factor for tumor therapy [3, 4]. Hyperthermia is a therapeutic procedure, which is used to raise the temperature of a region of the body affected by cancer to 42-46 °C. This method involves the introduction of ferromagnetic nanoparticles into tissues, and their subsequent irradiation with an alternating electromagnetic field. Hyperthermia is a promising approach in cancer therapy. The challenge in this method is to restrict local heating of the tumor surrounding [5]. This goal can be partially accomplished by the physical phenomenon of losses when magnetic nanopowders are injected within the cancer tissue and then heated in an alternating electromagnetic field [6]. There are different loss mechanisms in bulk magnetic materials and magnetic nanoparticles. Relaxation loss is the main portion of losses in particles with

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dimensions below 100 nm [6]. This means that by controlling the particle size of a magnetic nanoparticle, we can adjust the heat generation under an oscillating magnetic field [4]. In this work, Mn ferrite nanopowders were prepared via coprecipitation method for hyperthermia application.

## 2. Material and methods

A 500 ml solution, containing 0.51 molar $FeSO_4.7H_2O$ and a 500 ml solution, containing 0.24 molar $MnSO_4.H_2O$ were prepared. These solutions were mixed and added to a 6 molar NaOH solution at the temperature ~14 °C (pH of the medium was about 14). After stirring at the same temperature for 10 min., the obtained precipitate was washed off several times by distilled water while a pH=7 was obtained. After each washing, an ultrasonic bath was used to extract the ions through the precipitates. To dry the washed precipitate, a magnetic stirrer with hot plate was used. This procedure was done at 70 °C for 1.5 h and a continuous stream of oxygen gas was run into the precipitate all the time. At this time a black dry powder was obtained.

The crystal structure of the powders was characterized by an X-ray diffractometer (Bruker, Advanced D8), using CuKα radiation (λ=1.54 A). The particle size was calculated by Scherrer's formula. Particle morphology of the sample was investigated by a transmission electron microscope (TEM), Philips CM12. Magnetization curve of the powder was obtained by a vibrating sample magnetometer (VSM).

To measure the temperature increase, a mixture of one gram of Mn ferrite nanoparticles and 100 ml of distilled water was prepared. Ten ml of the mixture was then placed at the center of a 20 turns RF coil and an AC current (f=400 kHz) was applied. A sensitive thermometer was used to measure the temperature increase.

## 3. Results and discussion

Figure 1 shows XRD pattern of the co-precipitated nanopowders. As can be seen, all main peaks are related to a single-phase spinel structure (10-0319 Jacobsite, Syn.). Mean particle size of the nanopowders is about 5 nm that was obtained by Scherrer's formula and necessary corrections. Figure 2 shows TEM photograph of the single-phase nanopowders and as can be seen there is a uniform distribution of particle size with mean particle sizes between 3 and 10 nm, which is in agreement with the Scherrer's result.

Figure 3 shows the room temperature

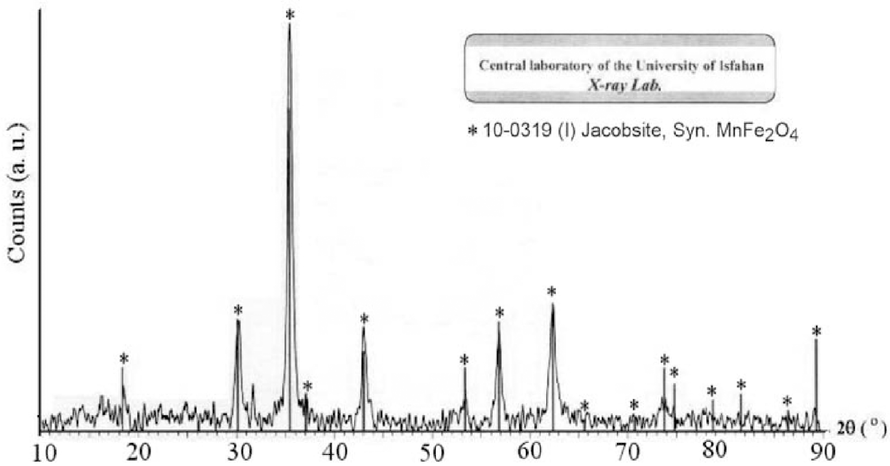


**Figure 1.** XRD pattern of the coprecipitated Mn ferrite.

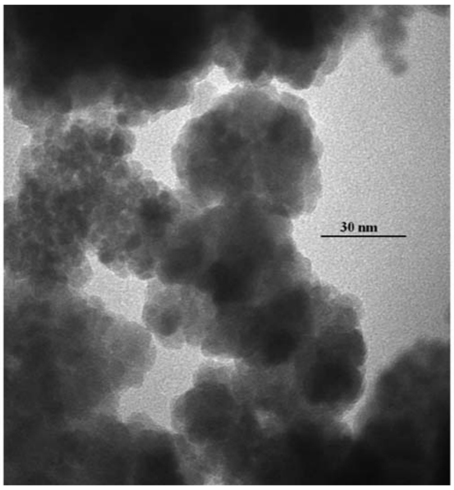


**Figure 2.** TEM photograph of the single phase Mn ferrite.

hysteresis loop of the coprecipitated Mn ferrite and as can be seen the saturation magnetization of the nanopowders is 54.2 emu/g, which is less than the saturation magnetization of bulk Mn ferrite (60 emu/g) [7]. This difference can be explained by core-shell coupling model elsewhere [8]. In this model, it is supposed that each particle consists of a core with ferrimagnetic order and a constant thickness nonmagnetic shell with spin glass order. It is obvious that by decreasing the particle size, the surface-to-volume ratio of a particle will increase, which leads to a reduction of magnetization of the particles [8]. Temperature increase measurement due to a mixture of the nanoparticles and distilled water (10 g/l) in presence of an AC magnetic field (f=400 kHz) show that a 5 °C temperature increase is achievable after 20 min. as the particle size of the nanoparticles is less than 10 nm, this can be due to relaxation loss [6].

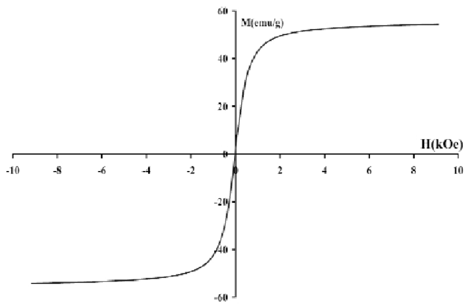


**Figure 3.** Room temperature hysteresis loop of the coprecipitated Mn ferrite.

## Acknowledgements

This study was completed at Isfahan University (research project No. 850304). The authors would like to thank research chancellor of the University for the financial supports. The authors also thank Mr. M. Doosti for his helps in designing and making RF generator.

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