Organic driving agent assisted synthesis of MnFe2O4 nanoparticles by microwave irradiation

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Abstract

In this research, manganese ferrite, $MnFe_2O_4$, nanoparticles with a pure cubic crystalline phase were synthesized by a fast solvent free auto-combustion method using microwave irradiation. Iron (III) nitrate nonahydrate and manganese nitrate hexahydrate as initial materials were mixed together with some organic agent as a fuel and oxidant. Then, the prepared mixture was transferred into a domestic microwave oven with the power of 900 W for 20 minutes. The experimental strong point of this strategy is the use of a simple, low-cost, fast method for synthesis of nanomaterials and also placing in the category of green chemistry reactions. Microstructural studies were done using Fourier transform infrared spectrum (FT-IR), X-ray diffraction (XRD), field emission scanning electron microscope (FE-SEM).

Keywords: nanoparticles, microwave, manganese ferrite, combustion, solvent free

1. Introduction

Nanoparticles have attracted great attention over past decade due to novel properties compared with bulk materials. Among the inorganic nanoparticles, ferrite nanoparticles have received great attention because of their interesting magnetic properties as well as extensive potential applications in color imaging, magnetic recording media, soft magnetic materials and ferrofluids. $MnFe_2O_4$ is one of ferrite nanoparticles that can be an important candidate in the practical applications such as high density magnetic recording media, photocatalysts and adsorbents in water purification.

Up to now, many methods have been reported to synthesize magnetic ferrite nanomaterials such as coprecipitation [1, 2], hydrothermal/solvothermal [3, 4], mechanochemical [5, 6], and sol-gel [7, 8] methods. The usual synthesis methods need to the long time reaction and difficult

reaction conditions. The preparation of magnetic ferrite via auto-combustion microwave method is introduced as a facile, low cost and promising technique towards the new environmental friendly technologies for the synthesis of the nanomaterials. The theory of this technique is based on the concept of driving chemistry, where the volatile molecules i.e. CO_2, H_2O and N_2 are released due to combustion reaction and a stable product remains.

In this research, magnetic manganese ferrite nanoparticles were synthesized by the solid state procedure without any additional treatment, and organic solvents. So it can be introduced as an environmentally friendly powder technology. As noted, the use of such one-pot system for the synthesis of pure single phased structure of manganese ferrite nanoparticles has not been yet reported.

2. Experimental

2.1. Preparation of manganese ferrite

$Fe(NO_3)_3.9H_2O$ and $Mn(NO_3)_2.6H_2O$ with the molar ratio of 2 : 1 were mixed with each other in the presence of glycine (Gly) as fuel and ammonium nitrate as driving agents. The mixture was transferred into the alumina crucible and put into a domestic microwave oven with the power of 900 W for 20 min. After the treatments, the voluminous sponge-like products were collected, washed with distilled water and ethanol several times to remove the residual initial materials, centrifuged, dried at 80°C overnight and then analyzed.

2.2. Characterization

Fourier transform infrared (FT-IR) spectrum was recorded on a Shimadzu-8400S spectrometer in the range of 400–4000 cm^{-1} using KBr pellets. The X-ray diffraction (XRD) patterns were recorded by a STOE powder diffraction system using Cu Kα radiation (wavelength, λ=1.54060A°). Scanning electron microscopy (SEM) images were taken on VEGA\TESCAN S360 with gold coating.

3. Results and discussion

Fig 1. Shows the FT-IR spectrum of product. The observed sharp peak around 570 cm^{-1} is related to Fe-O bond and the peak near 430 cm^{-1} belongs to Mn-O bond [4].

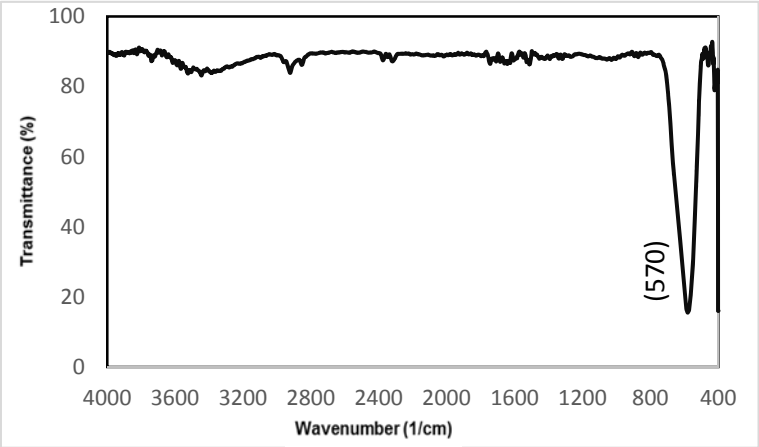

Fig. 1. FT-IR spectrum of the synthesized $MnFe_2O_4$ nanoparticles.

Fig. 2 presents the X-ray diffraction pattern of the resultant product. This pattern confirms the formation of a pure phase of $MnFe_2O_4$ matching with the crystalline system of cubic phase (ASTM card No. 01-073-1964).

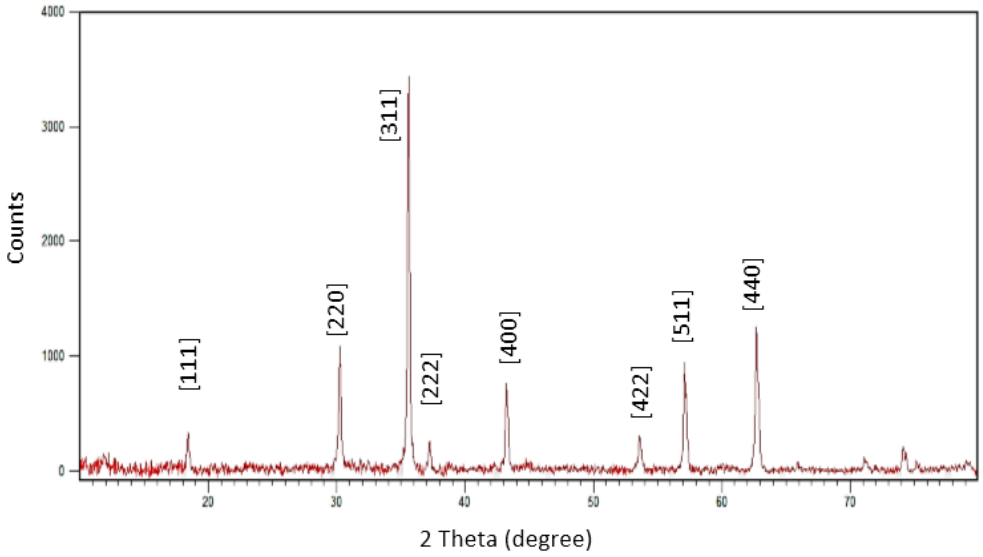

Fig. 2. XRD pattern of the prepared $MnFe_2O_4$ nanoparticles.

Fig. 3 indicates the FE-SEM images of the product, $MnFe_2O_4$ nanoparticles, after microwave treatment. They revealed a particulate morphology with average particle size of 56 nm for the synthesized manganese ferrite.

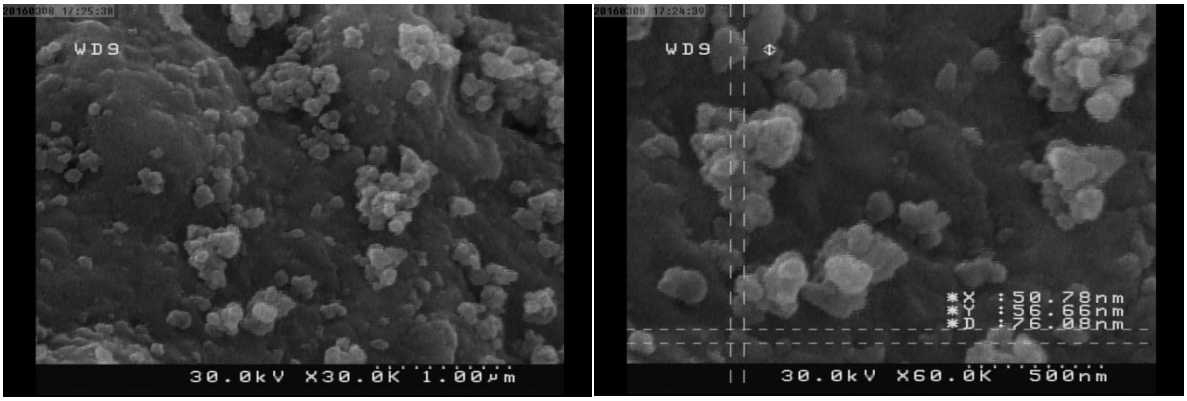

Fig. 3. FE-SEM images of $MnFe_2O_4$ nanoparticles.

4. Conclusion

In short, we successfully prepared magnetic $MnFe_2O_4$ nanoparticles with considerable magnetic properties using a new and facile technique. The pure cubic crystalline phase of $MnFe_2O_4$ was obtained by using a fast solvent free auto-combustion method and characterized by XRD. The particle size was confirmed using SEM. This technique can be a promising perspective to prepare the pure phase of nano-sized ferrites with a great potential in industrial applications.

Acknowledgments

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References

1. J. Azadmanjiri, H. K. Salehani “A study on the formation of $MnFe_2O_4$ nano-powder by coprecipitation method” *Physica Status Solidi* 2 (2007) 253-255.

2. R. Shahraki, M. Ebrahimi, S. A.Seyyed ebrahimi, S. M. Masoudpanah “Structural characterization and magnetic properties of superparamagnetic zinc ferrite nanoparticles synthesized by the coprecipitation method” *Magnetism and Magnetic Materials* 324 (2012) 3762-3765.

3. L. Dung, F. Gao, L. Wang, S. Jin, H. Wu “Hydrothermal synthesis and characterization of $MnCo_2O_4$ in the low-temperature hydrothermal process: Their magnetism and electrochemical properties” *Journal of Advanced Ceramics* 2(3) (2013) 266-273.

4. Z. Zhang, Y. Wang, Q. Tan, Z. Zhong, F. Su “Facile solvothermal synthesis of mesoporous manganese ferrite ($MnFe_2O_4$) microspheres as anode materials for lithium-ion batteries” *Journal of Colloid and Interface Science* 398 (2013) 185-192.

5. Z.Z. Lazarevic, C. Jovalekic, A. Recnik, V.N.Ivanovski, “Study of manganese ferrite powders prepared by a soft mechanochemical route” *Journal of Alloys and Compounds* 509 (2011) 9977– 9985.

6. A.A. Magaeva, E. P. Naiden, O.G. Terakhova, V. I. Itin, K. A. verchekov, “Mechanochemical Synthesis, Phase Composition, Structural Parameters, and Magnetic Properties of Manganese Ferrospinels” *Nanotechnologies in Russia* 8, (2013) 495–501.

7. L. Zhang, Y. Wu, “Sol-Gel Synthesized Magnetic $MnFe_2O_4$ Spinel Ferrite Nanoparticles as Novel Catalyst for Oxidative Degradation of Methyl Orange” *Journal of Nanomaterials* 6 (2013) 940-946.

8. J. Li, H. Yuan, G. Li, Y. Liu, J. Leng, “Cation distribution dependence of magnetic properties of sol–gel prepared $MnFe_2O_4$ spinel ferrite nanoparticles” *Magnetism and Magnetic Materials* 322 (2010) 3396-3400.