

Synthesis, Characterization and Magnetic Study of Zinc Ferrite Nanoparticles

J. Mayekar¹, V. Dhar², S. Radha³

Department of Physics, Jai Hind College, Mumbai, India^{1,2}

Department of Physics, University of Mumbai, Mumbai, India³

ABSTRACT: Spinel Zinc Ferrite ($ZnFe_2O_4$) nanoparticles are synthesized by wet chemical precipitation method followed by thermal decomposition. Zinc nitrate and ferric nitrate are used as precursors. It is the simple chemical route for the formation of zinc ferrite nanoparticles. Structural, elemental and morphological studies of the synthesized zinc ferrite nanoparticles are done by X Ray Diffraction (XRD), Energy Dispersive X Ray Spectroscopy (EDAX) and Scanning Electron Microscopy (SEM). The particle size of the synthesized zinc ferrite nanoparticles is found to be of the order of 20 nm by Debye Scherrer equation and Scanning electron micrograph. The magnetic behavior of the synthesized nanoparticles is done using Squid Magnetometer. The synthesized nanoparticles have saturation magnetization of 28.33 emu/gm.

KEYWORDS: Magnetic Study, Nanoparticles, EDAX, Xray Diffraction, Zinc Ferrite.

I. INTRODUCTION

Nanotechnology is Interdisciplinary science of understanding and control of matter at dimensions of roughly 1–100 nm. At this scale unique phenomena enable novel applications. The physical and chemical properties of the nanomaterials depend on particle size and shape or morphology. So nowadays the focus is on synthesizing nanoparticles by controlling their size and morphology for specific applications. Magnetic nanoparticles are found to have novel applications. Quantum size effects and large surface area of magnetic nanoparticles dramatically change some of the magnetic properties. Magnetic nanoparticles of spinel ferrites are of great interest especially because of the fundamental relationships between magnetic properties and their crystal chemistry and structure. The rich crystal chemistry in spinel ferrite systems offers excellent opportunities for understanding and fine-tuning the superparamagnetic properties of nanoparticles by chemical manipulations [Mathew et al, 2007].

Spinel ferrites have the structure AB_2O_4 . In this structure A and B display tetrahedral and octahedral cation sites, respectively, and O indicates the oxygen anion site. Metal spinel ferrite nanoparticles have the general molecular formula MFe_2O_4 (e.g., M = Zn, Ni, Co, Mn, or Mg), and they have a face-centered cubic (fcc) close packing structure. Among the spinel ferrites, Zinc ferrite $ZnFe_2O_4$ has been studied extensively. It has applications as soft magnets and low-loss material at high frequency because of its low coercivity and moderate saturation magnetization. It also has high magnetic performance and excellent chemical stability [Nasseri et al., 2011a].

Zinc ferrite is very important material and is used extensively in electronics industry [Yang et al 2008], magnetic resonance imaging [Liub et al 2008], catalysis [Velinov et al, 2012], biomedical fields [Gupta et al, 2005], photo catalytic applications [Lakshmi et al, online] etc. Zinc ferrites nanoparticles are being studied extensively because of its applications. Zinc Ferrite nanoparticles are synthesized using different processes such as wet chemical [Ladole 2012], thermal treatment method [Naseri et al 2011b], sol gel [Gong et al 2005], aerogel [Hamdeh et al 1997], hydrolysis [Ammar et al 2012], combustion method [swamy et al 2006] etc. In this paper zinc ferrite nanoparticles are synthesized using double co-precipitation method followed by thermal decomposition at high temperature.

The bulk $ZnFe_2O_4$ is a normal spinel with Zn^{2+} ions only on the tetrahedral (A) sites and Fe^{3+} ions only on the octahedral (B) sites. It shows antiferromagnetic properties below the Neel temperature of about 10 K and behaves paramagnetic at room temperature [Chinnasami et al 2000]. Further research on nano-crystalline $ZnFe_2O_4$ have suggested that the cation distribution in this material is partly inverted and exhibits anomaly in its magnetization. Neel

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

suggested that small antiferromagnetic particles can exhibit super-paramagnetism and weak ferromagnetism due to uncompensated spins in the two sublattices [Deraz et al 2012].

In this paper the zinc ferrite nanoparticles exhibit superparamagnetic behavior.

II. EXPERIMENTAL

Zinc nitrate and ferric nitrate salts were used as precursors. Starch was used as stabilizing agent to control the agglomeration of particles. All the chemicals were purchased from Merck with greater than 97% purity. 0.1 gm starch and 14.7 gm of zinc nitrate were dissolved in 100ml distilled water. This solution was heated using magnetic stirrer with continuous stirring till it attained 60°C. Once the desired temperature was reached, 1 M sodium hydroxide solution was added to above solution drop by drop.

Another solution of 0.1 gm starch and 4.040 gm of ferric nitrate in 100 ml of distilled water was prepared. This solution was added to above solution. The temperature of the solution decreased. The solution was further heated till 60°C. Once the temperature was reached, 1M sodium hydroxide solution was added drop by drop. Brown colored precipitate was formed. The precipitate was centrifuged at 10000 RPM and later it was dried at 50°C for 1 hour in oven. The obtained powder was kept in muffle furnace at 400°C for 4 hours. Zinc ferrite nanoparticles were hence obtained.

III. RESULTS AND DISCUSSIONS

A. X Ray Diffraction Spectroscopy

Phase identification was performed by Analytical X ray diffractometer using Cu K α radiation (40 KV, 20 mA). Peak intensities were collected by step scanning over a 2 θ range from 15° to 75° with a step size of 0.02° remaining for 10s at each step. The average grain size is calculated by the Scherrer equation and is found to be of the order of 21.03 nm. The ZnFe₂O₄ nanoparticles have a degree of crystallinity. The XRD pattern shows the peaks at (220), (311), (400), (422), (511), (440), (620), (533) and (622) which confirm the presence of single-phase zinc ferrite with face centered cubic structure. Except some impure phases of ZnO all the phases correspond to the standard pattern of Zinc ferrite(cubic, a = 0.8441 nm, space group: Fd3m, Z = 8; ICDD PDF: 22-1012)

The lattice parameters were calculated using the formula

$$\frac{1}{d^2} = \frac{4}{3} \left\{ \frac{h^2 + k^2 + l^2}{a^2} \right\} + \frac{l^2}{a^2}$$

Using this formula, the value of a is found to be 0.8478 nm which is slightly higher than reported in standard pattern JCPDS data.

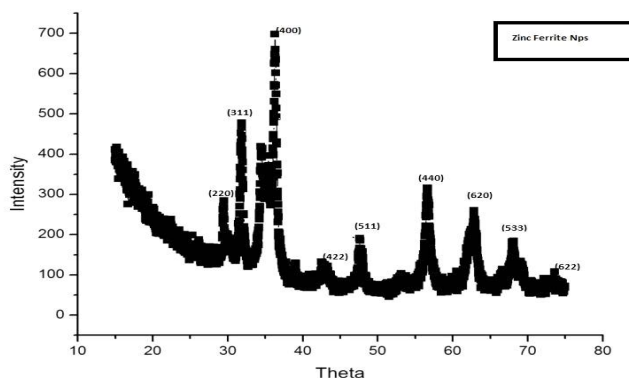


Fig. 1 XRD graph of Zinc ferrite nanoparticles

The crystallite size of zinc ferrite nanoparticles is based on x ray diffraction line broadening and is calculated by using

Debye Scherrer formula as

$$D = \frac{0.9\lambda}{\beta \cos \theta}$$

Where D is the average crystallite size
 β is full width half maxima of the peak in XRD pattern
 θ is Bragg's angle.
 λ is X- ray wavelength.

B. Energy Dispersive Spectroscopy

Elemental composition of the synthesized samples is determined by Energy dispersive xray spectroscopy (EDX). From the following graph, it is clear that the zinc ferrite nanoparticles are pure and contains no impurities of any other elements.

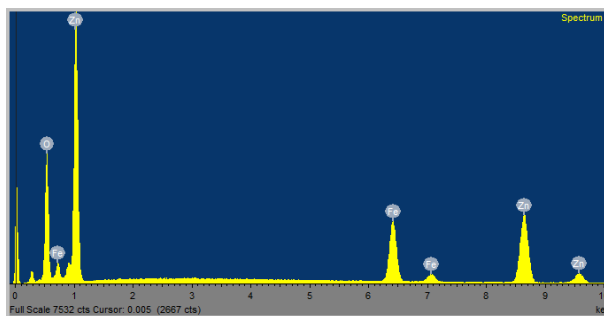
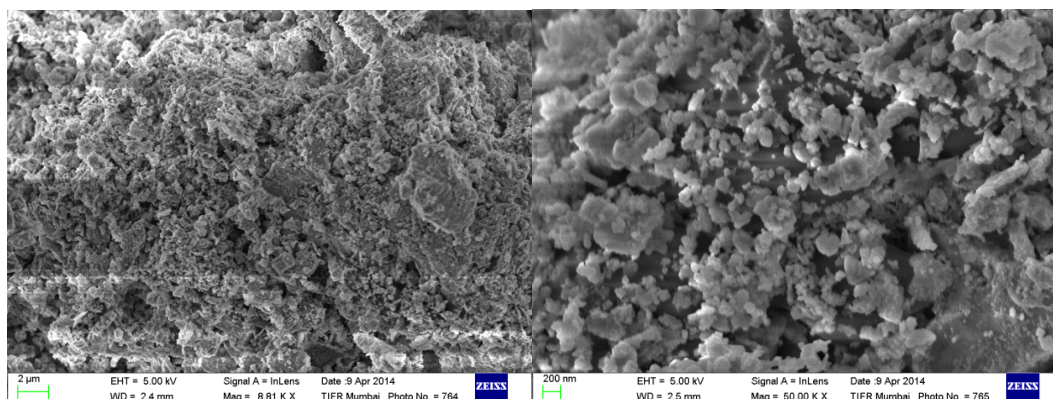


Fig 2: Edax spectra of Zinc Ferrite nanoparticles

C. Scanning Electron Microscopy



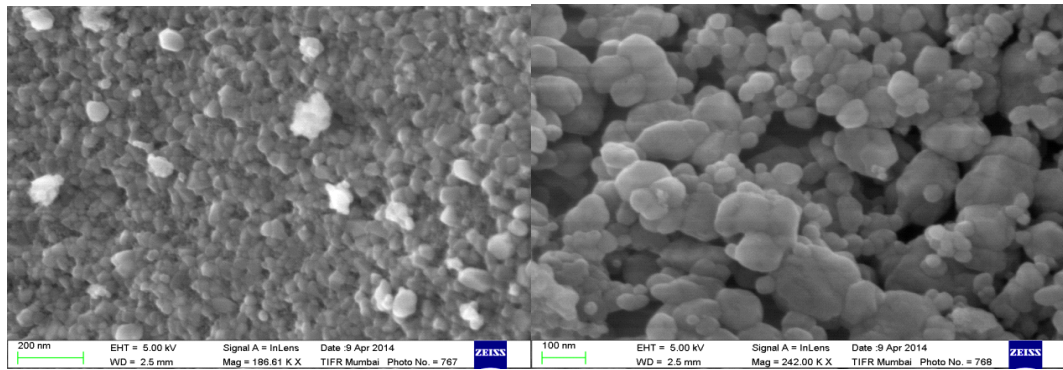


Fig 3: Scanning electron microscopic image of zinc ferrite nanoparticles at different magnifications

Above images show the zinc ferrite nanoparticles at different magnification. From the SEM micrograph it is clear that mostly the particles are mostly spherical in nature. The particle size is nonuniform. Average particle size is of the order of 20 nm which agrees with the XRD data.

D. Magnetic characterization

Magnetic study is done using Squid magnetometer. A field of 3 KOe is applied and change in moment is noted with change in temperature at zero field cooling (ZFC) and field cooling FC.

For the zinc ferrite nanoparticles the peak is obtained around 20 K which is characteristic of blocking transition followed by a gradual decrease in magnetization at low temperature. The blocking temperature is a function of the experimental time scale, external magnetic field, particle volume, anisotropy constant and interparticle interactions [Poddar et al 2006]

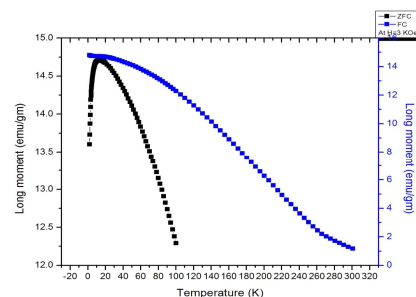


Fig 4: ZFC and FC curves of Zinc ferrite nanoparticles at 3000 Oe field

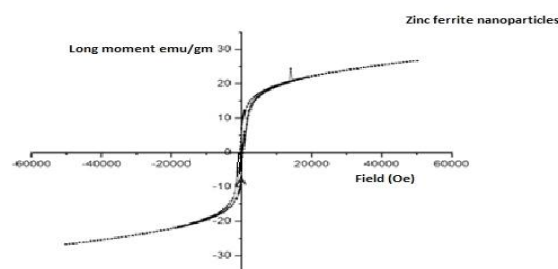


Fig 5: BH loop of Zinc Ferrite nanoparticles

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

The BH curve is used to calculate saturation magnetization (M_s), remanent magnetization (M_r), and the coercivity of the synthesized samples at room temperature. The M_s and M_r value was found to be 28.33 emu/gm and 10.23 emu/gm respectively for zinc ferrite nanoparticles. The graph shows that the zinc ferrite nanoparticles exhibit good ferromagnetic behaviour.

IV. CONCLUSION

Zinc ferrite nanoparticles are synthesized having particle size of the order of 20 nm. The synthesized nanoparticles show good crystallinity, and they are nonuniform in nature. The nanoparticles show deviation in magnetic property from that of the bulk. The saturation magnetization of the synthesized zinc ferrite nanoparticles is found to be of the order of 28.33 emu/gm. It indicates good saturation magnetization value.

These nanoparticles showing magnetic behavior can be used for biomedical applications. This method is cost effective and can be used for synthesis of other ferrite nanoparticles also.

The further aim of this study is to study antibacterial property of these nanoparticles for Biomedical Applications.

V. ACKNOWLEDGEMENT

Authors acknowledge Tata Institute of Fundamental Research, Mumbai for XRD and SEM characterization of samples.

REFERENCES

- [1] Daliya S. Mathew, Ruey- Shin Juang, 2007: An overview of the structure and magnetism of spinel ferrite nanoparticles and their synthesis in microemulsions, Chemical engineering Journal, 129, 51-65
- [2] Mahmoud Goodarz Naseri, Elias B. Saion, Mansor Hashima, Abdul Halim Shaari, Hossein Abasstabar Ahangard, 2011: Synthesis and characterization of zinc ferrite nanoparticles by a thermal treatment method, Solid state communications
- [3] J. M. Yang, F. S. Yen, 2008: Evolution of intermediate phases in the synthesis of zinc ferrite nanoparticles prepared by the tartrate precursor method, Journal of alloys and compounds, 450, 387-394.
- [4] J. Ping Liub, Jinming Gao, 2008, Zinc ferrite nanoparticles as MRI contrast agents, Chem. Commun., 2224-2226
- [5] Nikolay Velinov, Eina Manova, Tanya Tsoncheva, Claude Estournes, Daniela Paneva et al, 2012, Spark Plasma sintering synthesis of $Ni_{1-x}Zn_xFe_2O_4$ ferrites: Mossbauer and catalytic study, solid state sciences, Elsevier, vol. 14, pp. 1092-1099
- [6] Gupta AK, Gupta M., 2005: Cytotoxicity suppression and cellular uptake enhancement of surface modified magnetic nanoparticles, Biomaterials, 1565-73
- [7] K. Nivethitha Lakshmi, Dr. Sathanalakshmi, online: Synthesis, size characterization and photocatalytic activities of zinc ferrites and cobalt ferrites nanoparticles using oxidative degradations of methylene blue, crystal violet and Alizarin Red dyes in Aqueous medium at 25°C, (IJIRSE), International Journal of Innovative research in Science and Engineering, ISSN, 2347-3207
- [8] Chandrashekhar Ladole, 2012, Preparation and characterization of spinel zinc ferrite $ZnFe_2O_4$, International journal of chemical Sciences, 10(3), 2012, 1230-1234
- [9] M. G. Naseri, E.B.Saion, M. Hasheem, A.H. Shari, H. A. Ahngar, 2011: Synthesis and characterization of zinc ferrite nanoparticles by thermal treatment method, vol. 151, issue 14-15, pages 1031-1035
- [10] C. Gong, D. Chen, X. Jiao, 2005: Sol gel synthesis of hollow zinc ferrite nanoparticles, Journal of sol gel science and technology, vo. 35 issue 1, pp 77-82
- [11] H. H. Hamdeh, J. C. Ho, S.A. Oliver, R.J. Willey, G. Oliver, And G. Busca, 1997: Magnetic properties of partially- inverted Zinc ferrite aerogel powders, Journal of Applied Physics, 81, 1851
- [12] S.Ammar, N. Jouini, Fievet, Z. Beji, L.Smiri, P.Moline, M.Danot, J.Greneche, 2006: Magnetic properties of zinc ferrite nanoparticles synthesized by hydrolysis in a polyol medium, 2006, Journal of Physics: Condensed matter, vol.18 no. 39
- [13] P.M.P.Swamy, S. Basavaraja, A. Lagashetty, N.V.Srinivas Rao, R. Nijaagunappa, A. Venkatraman, 2011: Synthesis and characterization of zinc ferrite nanoparticles obtained by self propagating low temperature combustion method, Bulletin of material Science, vol. 34, no. 7, pp 1325-1330.
- [14] C.N.Chinnasamy, A. Narayanasamy, N. Ponpandian, K. Chattopadhyay, H. Guerault, J.M.Greneche, 2000: Magnetic properties of nanostructured ferrimagnetic zinc ferrite, Journal of Physics: Condensed Matter, 12, 7795
- [15] N.M.Deraz, A.Alarifi, 2012: Microstructure and magnetic studies of zinc ferrite nanoparticles, International journal of chemical science, , 6501-6511
- [16] P. Poddar, J. Gass, D.J. Rebar, S. Srinath, H. Srikanth, S. A. Morrison, E. E. carpenter, 2006; Magnetocaloric effect in ferrite nanoparticles, Journal of Magnetism and Magnetic Materials 307,227-231