Synthesis, structural & optical properties of magnesium ferrite

Rahul Upalaikar,
Assistant professor,
Department of Physics,
H.P.T Art's and R.Y.K. Science College, Nashik, India, 422005

Abstract- Powdered sample of spinel magnesium ferrite was synthesized by using sol-gel method. Structure of spinel magnesium ferrite was confirmed by using X-ray diffraction. Average crystalline size and lattice parameter of powdered sample is calculated using X- ray diffraction. FTIR analysis confirms the different vibrational modes of formation of spinel structure of magnesium ferrites.

Keywords – Magnesium ferrite, X-ray diffraction, FTIR

I. Introduction

Ferrite nanoparticles are a large group of magnetic particles that have piqued the interest of many researchers due to their interesting magnetic, electric, chemical& optical properties. Their applications ranges from medical to modern information technologies like satellite communication, memory devices, antenna cores, computer components, sensors & biosensors, refrigeration, quality filter circuit, high frequency transformers, wide band transformers, high frequency electronic circuitry, microwave applications, multilayer chip conductor, electromagnetic wave absorber.[1]–[8]

Spinel ferrites have face centered cubic structure and characterized by MFe_2O_4 formula where M denotes the divalent metal ions like Mg, Zn, Cu, Al. Spinel ferrites can have normal spinel structure, inverse spinel structure or mixed spinel structure. In spinel structure, all metal ions occupy tetrahedral sites, whereas all Fe^{+3} occupy octahedral sites. In inverse structure, all metal ions occupy octahedral site while Fe^{+3} ions are distributed over both tetrahedral & octahedral sites [9]. Among family of ferrites, magnesium ferrite ($MgFe_2O_4$) having mixed spinel structure is imperative due its wide range of applications in sensors, photo catalyst, hypothermia, biomedical applications [10]–[14] as it shows low saturation magnetization, high resistivity properties. For synthesis of magnesium ferrite, many methods like co precipitation[15], hydrothermal[16], electrochemical[17], sol gel [18] are used. Out of these methods, simple and versatile sol-gel autocombustion process has emerged as an important technique for synthesis and processing of advanced ceramics (structural and functional), catalysts, composites and crystalline spinel oxide materials. In sol-gel autocombustion process, the exothermicity of the redox (reduction-oxidation or electron transfer) chemical reaction is used to produce useful materials with homogeneous mixing and good stoichiometric control. Sol-gel autocombustion is an attractive method for the manufacturing of technologically useful materials at low cost compared to conventional ceramic process[19]

In this paper, our work leads to synthesis of magnesium ferrite using sol gel method & structural properties of it studied using X-ray diffraction.

II. Materials & methods

Materials

For synthesis of magnesium ferrite, analytical grade magnesium nitrate ($Mg(NO_3)_3.6H_2O$), & ferric nitrates ($Fe(NO_3)_3.9H_2O$), reagents are used without further purification. Double distilled water is used throughout the synthesis & citric acid is used as reducing agent.

Method

Separate solutions of magnesium nitrate and ferric nitrate are prepared in stoichiometric amounts in double distilled water to make copper ferrite. These solutions were combined in a beaker, which was kept constantly stirring and heated to 150°C. As a reducing agent, citric acid is added to the beaker. Evaporation converts the solution into a viscous gel after 3 hours. The gel was then heated to 250°C to achieve self-sustaining combustion, yielding burned brownish magnesium ferrite fluffy powder. This burned fluffy brownish powder is annealed in a furnace at 900°C for 4 hours before being used for further characterization.

III. Results and Discussion

Structural properties

X-ray diffraction (XRD) pattern of magnesium ferrite powder is shown in figure 1. From X-ray diffraction pattern, phase, crystalline size and lattice parameter of the powdered sample is obtained. The XRD pattern shows spinel structure having Fd3m space group having peaks (2θ) at 18.6°, 30.05°, 35.68°, 57.93°, and 62.38°. Most intense peak (2θ) is at 35.68° having hkl parameters (311) . Average crystalline size is calculated using Debye-Scherer formula $D = \frac{0.9\lambda}{\beta cos\theta}$ where λ is the wavelength of X-ray radiation, β is full width half maxima for most intense peak, θ -Bragg's angle for the most intense peak. Lattice parameter is calculated by using formula $a = d_{hkl}\sqrt{h^2 + k^2 + l^2}$, where d_{hkl} is inter-planner spacing & hkl are Miller indices. Using given formula calculated value of lattice constant & average crystalline size are 8.32 °A and 71.91 nm

FTIR Spectroscopy

Fig.2 shows far FTIR spectra magnesium ferrite. The far FTIR gives information about the crystal's vibration mode. Far FTIR spectra is recorded in the region 300 to 700 cm-1. FTIR spectra shows, position of two strong bands at 400 cm-1 & 580 cm-1 confirms spinel structure of ferrite[11]. First band appearing in the wavelength at 400 cm-1 can be attributed to vibration of bond between octahedral metal ion & oxygen ion. The second band at 580 cm-1 shows vibration of tetrahedral metal ions & oxygen ions.

IV. Conclusion

Magnesium ferrite is synthesized using the sol-gel method in this paper, and the spinel structure of magnesium ferrite is confirmed using X-ray diffraction. The calculated values of lattice constant and average crystalline size from X-ray diffraction were 8.32 °A and 71.91 nm, respectively. FTIR analysis confirms the formation of spinel structure of ferrites. FTIR spectroscopy reveals the cations and anions distribution on octahedral and tetrahedral lattice sites

References

[1] F. C. Mascarenhas, N. Sykam, M. Selvakumar, and M. G. Mahesha, "Green reduction of graphene oxide using Indian gooseberry (amla) extract for gas sensing applications," *J. Environ. Chem. Eng.*, vol. 8, no. 2, p. 103712, Apr. 2020, doi: 10.1016/j.jece.2020.103712.

[2] S. Chandra, M. D. Patel, H. Lang, and D. Bahadur, "Dendrimer-functionalized magnetic nanoparticles: A new electrode material for electrochemical energy storage devices," *J. Power Sources*, vol. 280, pp. 217–226, Apr. 2015, doi: 10.1016/j.jpowsour.2015.01.075.

[3] A. Fallah Shojaei, K. Tabatabaeian, S. Shakeri, and F. Karimi, "A novel 5-fluorouracile anticancer drug sensor based on ZnFe2O4 magnetic nanoparticles ionic liquids carbon paste electrode," *Sensors Actuators B Chem.*, vol. 230, pp. 607–614, Jul. 2016, doi: 10.1016/j.snb.2016.02.082.

[4] M. Hasanzadeh, N. Shadjou, and M. de la Guardia, "Iron and iron-oxide magnetic nanoparticles as signal-amplification elements in electrochemical biosensing," *TrAC Trends Anal. Chem.*, vol. 72, pp. 1–9, Oct. 2015, doi: 10.1016/j.trac.2015.03.016.

[5] N. A. Frey, S. Peng, K. Cheng, and S. Sun, "Magnetic nanoparticles: synthesis, functionalization, and applications in bioimaging and magnetic energy storage," *Chem. Soc. Rev.*, vol. 38, no. 9, p. 2532, 2009, doi: 10.1039/b815548h.

[6] R. Ahmad, I. Hussain Gul, M. Zarrar, H. Anwar, M. B. khan Niazi, and A. Khan, "Improved electrical properties of cadmium substituted cobalt ferrites nano-particles for microwave application," *J. Magn. Magn. Mater.*, vol. 405, pp. 28–35, May 2016, doi: 10.1016/j.jmmm.2015.12.019.

[7] R. S. Yadav *et al.*, "Impact of Nd3+ in CoFe2O4 spinel ferrite nanoparticles on cation distribution, structural and magnetic properties," *J. Magn. Magn. Mater.*, vol. 399, pp. 109–117, Feb. 2016, doi: 10.1016/j.jmmm.2015.09.055.

[8] K. K. Kefeni, T. A. M. Msagati, and B. B. Mamba, "Ferrite nanoparticles: Synthesis, characterisation and applications in electronic device," *Mater. Sci. Eng. B*, vol. 215, pp. 37–55, Jan. 2017, doi: 10.1016/j.mseb.2016.11.002.

[9] J. B. Goodenough and P. E. Tannenwald, "Oxide magnetic materials," *Solid-State Electronics*, vol. 7, no. 7. pp. 556–557, 1964. doi: 10.1016/0038-1101(64)90095-4.

[10] Y.-L. Liu, Z.-M. Liu, Y. Yang, H.-F. Yang, G.-L. Shen, and R.-Q. Yu, "Simple synthesis of MgFe2O4 nanoparticles as gas sensing materials," *Sensors Actuators B Chem.*, vol. 107, no. 2, pp. 600–604, Jun. 2005, doi: 10.1016/j.snb.2004.11.026.

[11] S. K. Durrani, S. Naz, M. Mehmood, M. Nadeem, and M. Siddique, "Structural, impedance and Mössbauer studies of magnesium ferrite synthesized via sol–gel auto-combustion process," *J. Saudi Chem. Soc.*, vol. 21, no. 8, pp. 899–910, Dec. 2017, doi: 10.1016/j.jscs.2015.12.006.

[12] S. Maensiri, M. Sangmanee, and A. Wiengmoon, "Magnesium Ferrite (MgFe2O4) Nanostructures Fabricated by Electrospinning," *Nanoscale Res. Lett.*, vol. 4, no. 3, p. 221, Mar. 2009, doi: 10.1007/s11671-008-9229-y.

[13] H. Roy Dakua, N. Venkataramani, and S. Prasad, "Effect of quenching on the magnetic properties of Mg-ferrite thin films," *AIP Adv.*, vol. 6, no. 5, p. 055919, May 2016, doi: 10.1063/1.4943924.

[14] S. I. Hussein, A. S. Elkady, M. M. Rashad, A. G. Mostafa, and R. M. Megahid, "Structural and magnetic properties of magnesium ferrite nanoparticles prepared via EDTA-based sol–gel reaction," *J. Magn. Magn. Mater.*, vol. 379, pp. 9–15, Apr. 2015, doi: 10.1016/j.jmmm.2014.11.079.

[15] E. Agouriane *et al.*, "Structural and magnetic properties of CuFe2O4 ferrite nanoparticles synthesized by co-precipitation," *J. Mater. Environ. Sci.*, vol. 7, no. 11, pp. 4116–4120, 2016.

[16] T. A. Atia, P. Altimari, E. Moscardini, I. Pettiti, L. Toro, and F. Pagnanelli, "Synthesis and characterization of copper ferrite magnetic nanoparticles by hydrothermal route," *Chem. Eng. Trans.*, vol. 47, pp. 151–156, 2016, doi: 10.3303/CET1647026.

[17] S. D. Sartale, C. D. Lokhande, and M. Muller, "Electrochemical synthesis of nanocrystalline CuFe2O4 thin films from non-aqueous (ethylene glycol) medium," *Mater. Chem. Phys.*, vol. 80, no. 1, pp. 120–128, 2003, doi: 10.1016/S0254-0584(02)00462-5.

[18] A. Subha, M. G. Shalini, B. Sahu, and S. C. Sahoo, "Structural transformation and magnetic properties of copper ferrite nanoparticles prepared by sol–gel method," *J. Mater. Sci. Mater. Electron.*, vol. 29, no. 24, pp. 20790–20799, 2018, doi: 10.1007/s10854-018-0221-8.

[19] A. Sutka, G. Mezinskis, G. Strikis, and A. Siskin, "Gas sensitivity of stoichiometric and excess-iron Ni-Zn ferrite prepared by sol-gel auto-combustion," *Energetika*, vol. 58, no. 3, Nov. 2012, doi: 10.6001/energetika.v58i3.2467.

Figure 1

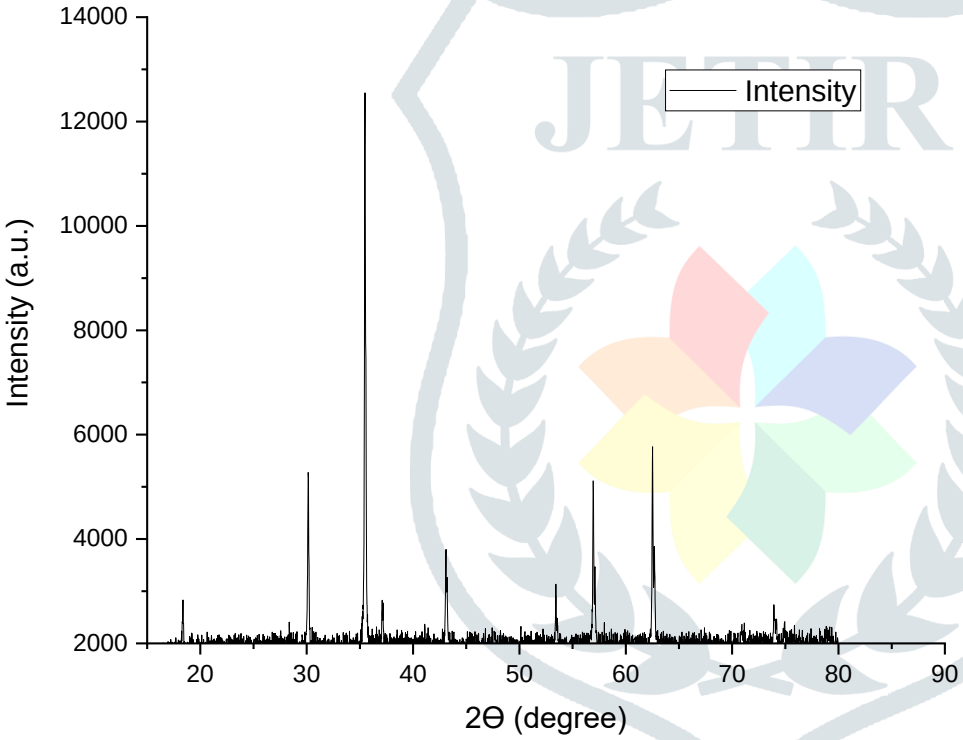
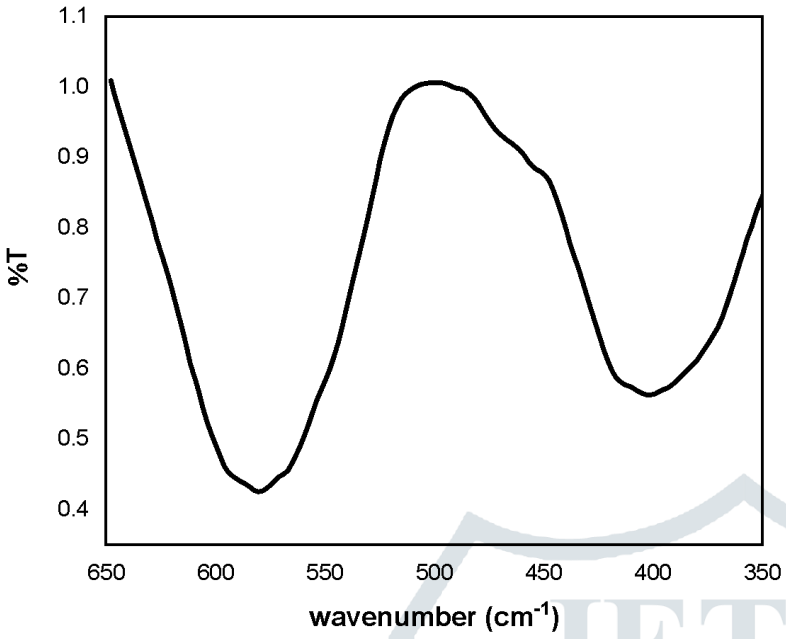


Figure 2


1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
%T
650
600
550
500
450
400
350
wavenumber (cm-1)