International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Special Issue: 09 | Sep -2017 www.irjet.net p-ISSN: 2395-0072
One Day International Seminar on Materials Science & Technology (ISMST 2017)
4th August 2017
Organized by
Department of Physics, Mother Teresa Women's University, Kodaikanal, Tamilnadu, India

SYNTHESIS & MAGNETIC PROPERTIES OF MAGNESIUM FERRITE ($MgFe_2O_4$) NANOPARTICLES VIA SOL GEL METHOD

[1]M. Easwari, [2]Dr. Sr. S .Jesurani.

[1]Assistant professor, Dept. of Physics, Thiravium College of Arts & Science for Women, Tamilnadu, India.
**Associate professor, Dept. of Physics, J.A. College for women (Autonomous), Tamilnadu, India.*

Abstract - *Magnesium Ferrite ($MgFe_2O_4$) nanoparticles were prepared by citrate sol-gel method. The structure, composition and magnetic properties of the gel precursor characterized by powder SEM, FT-IR and VSM. The functional groups were analyzed by FT-IR spectrum. XRD confirmed the spinel cubic structure of $MgFe_2O_4$. The average particle size was calculated approximately in the range of 20-30 nm. The surface morphology studied by SEM. The magnetic properties of the samples were investigated using VSM.*

Keywords: **Magnesium ferrite nanoparticles, FT-IR, XRD, SEM, EDAX, VSM.**

1. INTRODUCTION

Recent research interests on spinel ferrites are due to their unique optical, electrical, and magnetic properties. These characteristics are strongly dependent on their size, shape, and dispersion [1]. Study of spinel ferrite MFe_2O_4 (where M = Fe, Mn, Zn, Co, Mg, Cu, Ni) nanoparticles has great significance in modern technologies such as contrast enhancement of magnetic resonance imaging, high density data storage, and magnetic carriers for site-specific drugs delivery [2]. Amongst the spinel ferrite families, magnesium ferrite ($MgFe_2O_4$) is a soft magnetic n-type semiconducting material [3, 4]. The spinel ferrite particles synthesized by solid-state methods show an assembly of irregular shapes and agglomerations [5, 6]. Magnesium ferrite ($MgFe_2O_4$) is one of the most important ferrites. It has a cubic structure of normal spinel-type and is a soft magnetic n-type semiconducting material, which finds a number of applications in heterogeneous catalysis, adsorption, sensors, and in magnetic technologies [7]. Recently, nanostructures of magnetic materials have received more and more attention due to their novel material properties that are significantly different from those of their bulk counter parts [8-12].

A wide variety of methods are being used to synthesize spinel ferrite nanoparticles including citric acid combustion method, sol-gel auto combustion method, hydrothermal method, co-precipitation method, thermolysis, wet chemical co precipitation technique, self-propagating and microemulsion [13–17]. Among these methods sol-gel method [18] is widely used for the synthesis of nanoparticles of ferrite. This method has the advantages of simple preparation, cost-effective and gentle chemistry route resulting in fine and homogeneous powder.

In the present investigation, $MgFe_2O_4$ nanoparticles are synthesized by sol-gel method. The structure, composition, thermal and magnetic properties of the gel precursor is characterized by powder XRD (X-ray diffraction), FT-IR (Fourier transform Infrared Spectroscope), SEM (Scanning Electron Microscope). The magnetic properties of the samples were investigated using VSM (Vibrating Sample Magnetometer).

2. MATERIALS & METHODS

2.1. Materials

Magnesium nitrate [Mg $(NO_3)_2.6H_2O$], Ferric nitrate [Fe $(NO_3)_3.9H_2O$], ethylene glycol [$C_2H_6O_2$] and Citric acid [$C_6H_8O_7$].

2.2. Methods

Magnesium ferrite nanoparticles are prepared by sol-gel method. A small amount of metal nitrates are first dissolved in a minimum amount of ethylene glycol. Chelating agent added to it. The final solution is magnetically stirred for 4h at room temperature & then surplus water is removed in a vacuum rotary evaporator at 60-80°C until a gel is obtained. For about 10h, the obtained gel is dried in a hot air oven at 100, 150, 250°C which are labeled as sample A, B & C.

3. RESULTS & DISCUSSION

3.1. FTIR

As shown in fig.1, 2, 3, the formation of $MgFe_2O_4$ structure in the synthesized samples are further supported by FTIR spectrum. The band 3421 cm^{-1} could be attributed the O-H stretching vibration of H_2O absorbed be by the sample. The peak at 2337 cm^{-1} is described to H-O-H bending of the absorbed water. The C=O stretching characteristic peak located at 1667 cm^{-1} in the PVA red shifts in the composite. At 14553cm^{-1} there is a significant change in the CH bending band. The bands with the peak at 572, 462 cm^{-1} are assigned to the deformation vibration of Fe-OH groups. The two main metal-oxygen bands at 559, 466 cm^{-1} are observed in the FT-IR spectrum of the synthesized Magnesium ferrite samples. These two bands are usually assigned to vibration of ions in the crystal lattices. This indicates the presence of uniformly distributed ferrite particles.

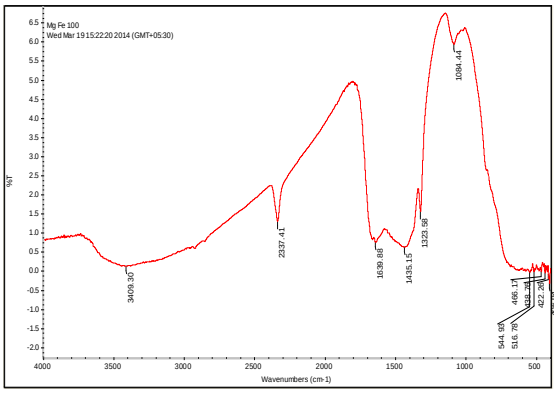

Fig.1. FTIR for Sample-A.

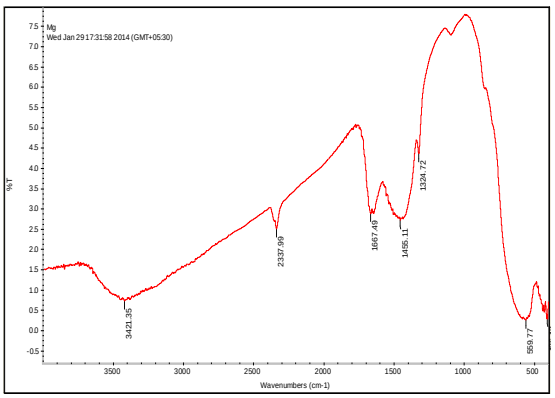

Fig.2. FTIR for Sample-B.

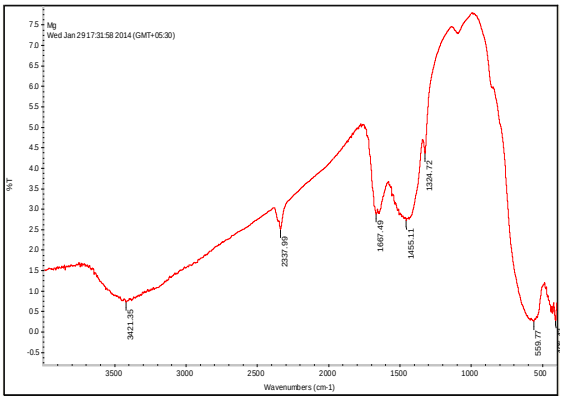

Fig.3. FTIR for Sample-C.

3.2. XRD

The XRD pattern was compared with the standard powder diffraction pattern (JCPDS card No.17-464). The major planes correspond to (200), (311), (222), (400), (422), (511) were found to be matched which confirmed the presence of Magnesium ferrite. The average particle size was calculated from line broadening using the Debye - Scherrer equation,

$$D = K_\alpha \lambda / \beta \cos \theta$$

Where, λ = wavelength of the x-ray radiation.

k_α = constant (0.91).

β = full width at half maximum.

θ = diffracting angle.

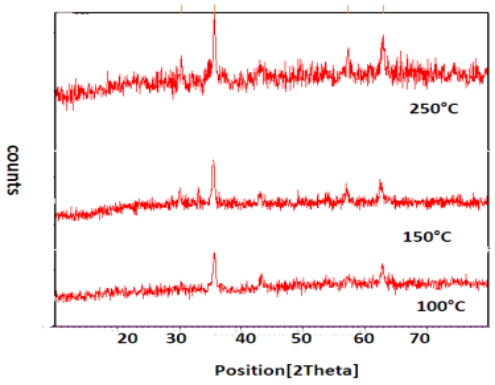

Fig.4. XRD patterns for Sample-A, B & C

3.3. SEM

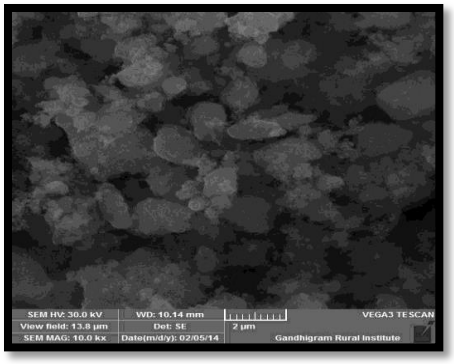

Fig.5.SEM for Sample-B

The SEM micrograph of the magnesium ferrite nanoparticles is shown in Fig.5. It shows that the ferrite particles are spherical with average crystallite size of ~ 20-30 nm.

3.4. VSM

The magnetic hysteresis loop and magnetic property of the synthesized $MgFe_2O_4$ samples are studied at room temperature using a vibrating sample magnetometer (VSM) and is shown in Fig.6.

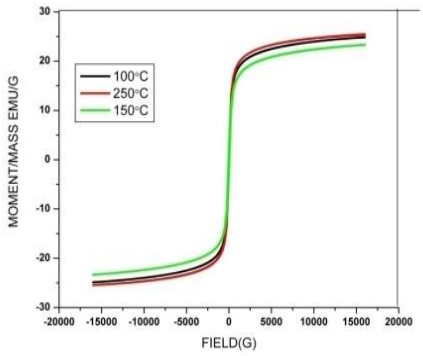

Fig.6. VSM curves for Sample-A, B & C.

The sample exhibits ferromagnetic behavior at room temperature. The magnetic property of the material has been known to be dependent on the sample shape, crystallinity, magnetization direction etc [19]. The saturation magnetization (M_s), remanent magnetization (M_r), coercivity (H_c) is 25.4 $emug^{-1}$, 1.48 $emug^{-1}$ and 27.7 G for magnesium ferrite nanoparticles at 250°C, respectively. The saturation magnetization (Ms) of the sample is close to the reported bulk value, which is due to the spin canting at the surface of ferrite nanoparticles [20] and also due to the substitution of a part of Mg^{2+} in the octahedral sites by fe^{2+} with higher magnetic moment from the reported results it can be seen that magnetic property are also influenced by the synthesis process. The influence of this preparation method on magnetic property is under study.

4. CONCLUSION

The sol-gel method is well suited for the synthesis of nano-sized $MgFe_2O_4$. The powder XRD reveals the purity of the sample. Average crystallite size calculated from Scherrer's equation. FT-IR spectroscopy is a valuable method to identify the impurity free nanocrystalline spinel $MgFe_2O_4$. SEM image confirmed that particles have spherical shape. From these results we conclude that the sol-gel process provides an interesting synthesis technique with the advantages like low cost and simple preparation.

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