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RESEARCH ARTICLE

STRUCTURAL, MAGNETIC AND DIELECTRIC PROPERTIES OF MG-CO FERRITE NANOPARTICLES SYNTHESIZED BY CO-PRECIPITATION METHOD

*,[1]Loganathan, A. and [2]Kumar, K.

[1]Engineering Physics Section, Annamalai University, Annamalai Nagar, Tamil Nadu, India -608 002
[2]Department of Physics, Annamalai University, Annamalai Nagar, Tamil Nadu, India - 608 002

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ABSTRACT

The magnetic materials occupied great place in the development of modern data storage system. The present study stated the synthesis of soft magnetic Mg-Co ferrite particles in co-precipitation method. The synthesized ferrite was characterized with X-ray diffraction (XRD), Fourier Transform Infrared (FT-IR) spectroscopy, SEM, and Vibrating Sample Magnetometry (VSM) analysis. The XRD and FTIR analysis revealed the formation of single phase spinel ferrites. The grain size of synthesized particle was in nano meter range with saturation magnetization of 21.129 emu/g at 12kOe. The dielectric analysis was carried out in different temperatures and found that the dielectric constant was increased with temperature.

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INTRODUCTION

The spinel type ferrite materials are considered as excellent electronic and magnetic materials, used in extensive range of technological applications because they are economical, more stable and their specific electrical (Rane *et al*., 2001), and magnetic (Kotnala *et al*., 2009) properties. Among the spinel structure ferrite materials, Magnesium ferrite is a soft magnetic material with low coercivity and moderate magnetization which is useful in inductor, sensor, high-density recording media, catalyst (Shah *et al*., 2012; Franco *et al*., 2011). At room temperature, Mg ferrite exhibits partially inverse spinel structure and its degree of inversion is sensitive in the method of preparation and thermal histroy. Due to its high resistivity, Mg-ferrite is suitable candidate for high frequency applications. Similarly, Cobalt ferrite is a hard magnetic material with large coercivity and moderate magnetization, it is used as in permanent magnet and data storage applications (Maaz *et al*., 2009).

The magnetic moment of materials is a quantum phenomenon which arises from atomic scale of the material. In this universe, every atom contains the composition of fundamental particles such as proton, neutron and electron.

**Corresponding author: Loganathan, A.*
Engineering Physics Section, Annamalai University, Annamalai Nagar, Tamil Nadu, India -608 002

The nucleus of an atom which contains protons and neutrons fixed in their lattice position and their contribution in magnetization is negligible. The negative charge electron posses two kinds of motion in the atom, such as spinning about their own axis and revolve around the nucleus. Basically, the moving electron around the nucleus is considered as small current loop and creates a magnetic field around it. And spinning electron also produces another magnetic field. The contribution of orbital motion of electrons is very weak in magnetization and their values are mostly omitted. On the other hand, the contribution of the electron spin is a strong preference in magnetization possesses. Whether spin or orbital magnetic moment of an atom dominates one another, produce net magnetic moment in a particular direction. Naturally, some of ions like, Fe, Co, Cu, Ga etc, exhibit magnetic moment. However, some ions behave like non magnetic in nature, which is due to the spin and orbital magnetic moment of an atom orientated in the opposite direction and cancel one another. Thus produce no net magnetic moment, which is called as a non-magnetic atom. In a solid material, number of atoms are arranged in their lattice position, their individual magnetic moments of the atoms interact with neighboring atoms, and aligned with one another and point in the same direction. Thus produce a net magnetic moment of material. The word magnetic and its properties are mainly related to the three ferromagnetic elements: iron, cobalt and nickel.

For preparation of spinel structure ferrite nanoparticles, different techniques were adoapted in literature, such as co-precipitation (Loganathan *et al*., 2015), sol–gel (Druc *et al*., 2014)], solid-state reaction, solution combustion synthesis (SCS) (Da Dalt *et al*., 2011) etc. Among the mentioned types, co-precipitation method possess many advantages like, simple procedure, inexpensive and less instrumentation compare to many physical methods, large quantities of materials can be obtained, higher purity level of obtaining products, more possibilities to the doping of foreign cations, respectively. In the present work, we prepare $Mg_{0.8}\,Co_{0.2}\,Fe_2\,O_4$ (Mg-Co ferrite) nanoparticle in co-precipitation method and are characterized by XRD, FT-IR, FE-SEM and VSM techniques.

MATERIALS AND METHODS

In this attempt, co-precipitation method was adopted for the preparation of Mg-Co ferrite particles. The analytical grade chemicals were used for preparation of ferrite particles. The initial aqueous solution was produced in distilled water by dissolving desired stoichiometric proportion of metal nitrates (iron nitrate, magnesium nitrate and strontium nitrate). The prepared solution was continuously stirred and headed on a magnetic stir for one hour. Then the NaOH solution was mixed with metal nitrate solution as a precipitant at 90°C. The obtained precipitate was dried in electric oven at 100°C and calcinated for 3 hours in air atmosphere at 900°C. At the end, dried powder was mixed homogeneously in mortar and agate for 30 min to get the fine powder.

The FT-IR measurement was performed by Perkin Elmer Spectrum RXI (FT-IR) spectrometer in transmission mode. The phase analysis, crystallite size synthesized powders were determined by X-ray diffraction (XRD) technique with Cu*Kα* radiation in X' PERT PRO-PANalytical, PHILIPS. The surface morphology of the synthesized nanoparticles was observed by the FE-SEM analysis at different magnifications. The magnetic behavior of synthesized ferrite particle was performed by VSM analysis (Lake Shore-7404) in room temperature.

RESULTS AND DISCUSSION

Structural Analysis

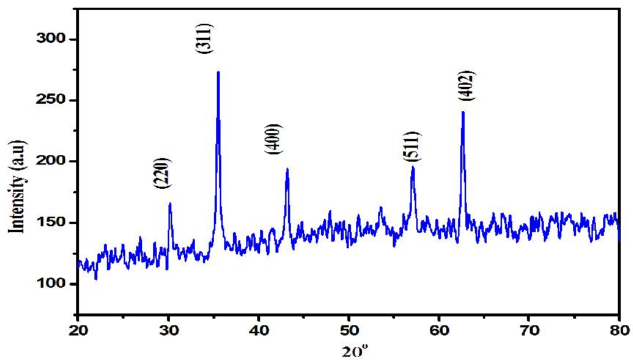

Fig.1. X-ray diffracion spectra of Mg-Co ferrite obtained at 900°C

The structural characterization of present ferrite is carried out by powder XRD measurements and shown in figure.1. The peaks are presented at 35.5°, 43°, 57° and 62.5° corresponding to spinel structure Mg ferrite. The lattice parameter of present Mg-Co ferrite is calculated from XRD data using the following formula, $a= d_{hkl}\ (h^2+k^2+l^2)^{1/2}$, where, d_{hkl} is the interplaner distance and hkl are the miller indices (Shah *et al*., 2012). Further, the crystalline size (D) of synthesized ferrite particles is also derived from the high intensity reflection plane using Scherrer equation (Satalkar *et al*., 2014), $D= K\lambda/\ \beta \cos \theta$, where, K is the shape factor, λ is the wavelength of X-ray (0.15418 nm), θ is the diffraction angle in 311 plane, respectively. β is the full width at half maximum (FWHM) of diffraction peak. The calculated value is 8.3838 A° and 56 nm, respectively.

Functional analysis

The FT-IR technique is a non-destructive technique, which is used to identify the functional groups present in the synthesized samples. Fig. 2 depicts the FT-IR spectrum of Co^{2+} substituted $Mg_{0.8}\,Sr_{0.2-x}\,Fe_2O_4$ nanoparticles , that are obtained at 900°C. The presences of two frequency assignment at below 800 cm^{-1} are belong to spinel structure of ferrite materials (Waldron, 1955). The appearance of high frequency assignment at 594 cm^{-1} is due to the Fe-O bond vibration of tetrahedral coordination, and low frequency assignment at 424 cm^{-1} is due to the Fe-O bond vibration of octahedral coordination, respectively (Zaki *et al*., 2014). The difference in the frequency assignment is due to the difference in the bond length between octahedral and tetrahedral coordinates.

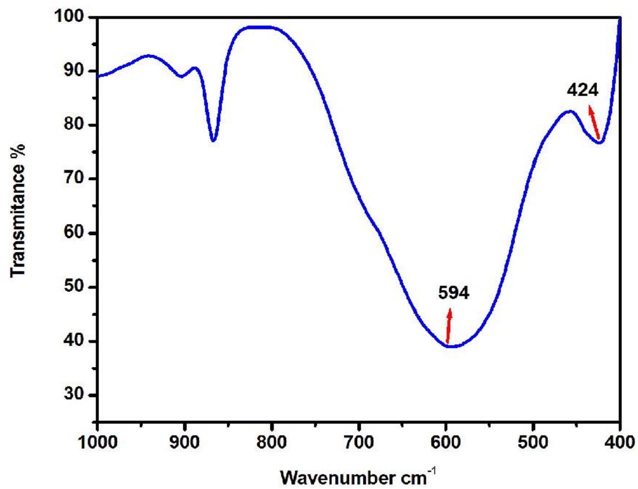

Fig.2. FT-IR spectra of Mg-Co ferrite particle in the wave number range between 1000-400 cm-1

Micro structural study

The electric and magnetic properties of ferrites strongly dependent on the morphology of the particle. The morphological distribution of ferrite particles is investigated by FE-SEM measurements and shown in Fig.3. From the image, irregular shaped particles are observed with random distribution. At low magnification, particles appear with rough surface and are in micro meter range. Hence, nanosized particles appear at higher magnifications. The agglomerations of magnetic particles are unavoidable due to presence of magnetic interactions between ferrite particles (Sagar *et al*., 2014).

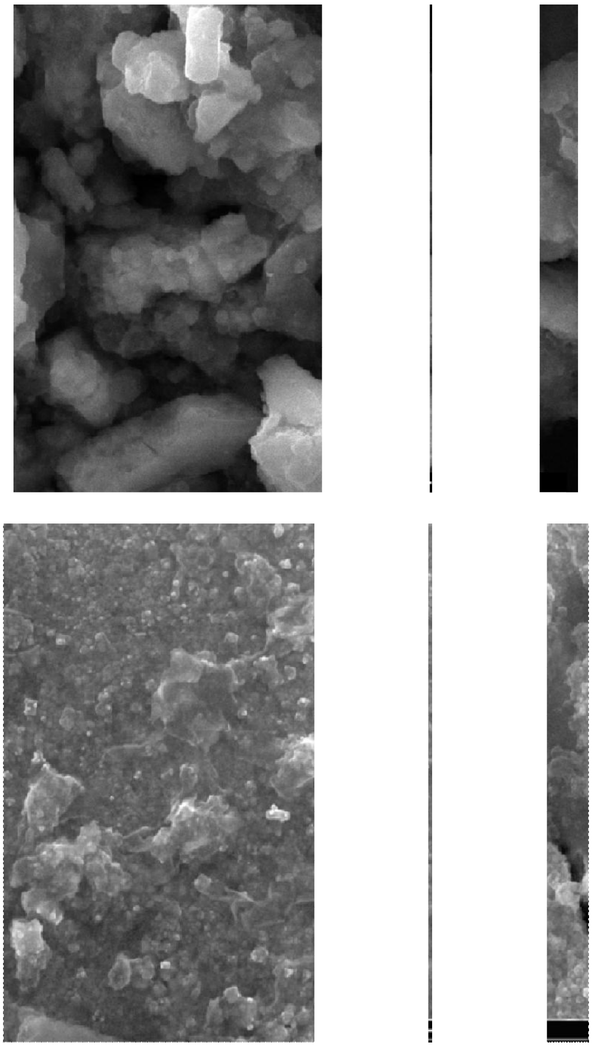

Fig.3. SEM image of Mg-Co ferrite particles at different magnifications

Magnetic studies

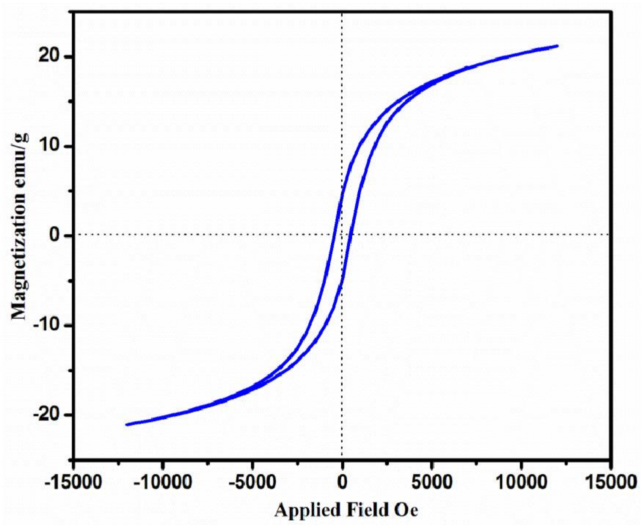

Fig.4. Room temperature magnetic hysteresis loop of Mg-Co ferrite particles

The magnetization measurement of present composition is measured in VSM analysis at room temperature and its corresponding hysterias loop is shown in Fig.4. The magnetization of ferrite particles linearly increase with strength of applied field. This linear increase in magnetization implies that the domains of magnetic materials is rotate and align in the direction of applied field. A further increase in the applied field, the magnetization of material attains maximum of 21.129 emu/g in the applied field strength of 12 kOe. The obtained magnetization value of present ferrite particle is comparatively less than bulk magnesium ferrite (~ 30.3 emu/g) (Franco *et al*., 2011).

The low value of saturation magnetization is due to two factors, ferrimagnetic nature and reduced size of particles. In ferrimagnetic materials, metal ions are distributed in two crystallographic sites, named tetrahedral and octahedral sites, respectively. From the literature, magnesium ferrite and cobalt ferrite exhibit inverse spinel structure in room temperature. The magnetic Co^{2+} and Fe^{3+} ions are distributed in both A and B-site. According to the Neel sublattices model, the cations in the spinel structured ferrite material is distributed in octahedral and tetrahedral sites, respectively (Mastia *et al*., 2006). The total magnetic moment of unit cell is equal to vector sum of magnetic moments between A and B sites. At nanoregime, the number of surface atoms are increased, which form the magnetic dead layer around the magnetic interior. The remnant magnetization (Mr) value of 4.8078 emu/g is observed for the present ferrite particles.

Dielectric study

The dielectric property of ferrite is an important property of material, which is used to find its storing and dissipating of electrical energy when subjected to electromagnetic fields. Spinel structured ferrite materials are good dielectric materials which favor in electronic application. The dielectric properties of materials arise from different kind of polarization like electronic, ionic, dipolar and space charge polarization, respectively. In this present attempt, dielectric measurement is carried out with different testing temperatures and shown in Figure 5.

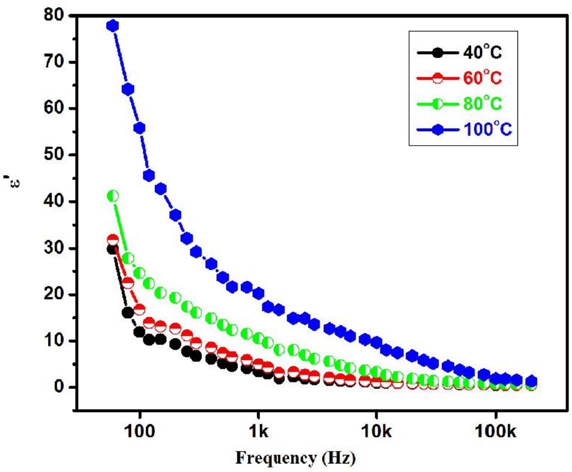

Figure 5. Dielectric results of Mg-Co ferrite at different testing temperature

The dielectric constant of present Mg-Co ferrite linearly decreases with frequency in all the testing temperature. This is due to the presence of different dielectric polarizations mechanism in the ferrite. At lower frequency, space charge is available in ferrites and they contribute in polarization mechanism, further their contribution is reduced in higher frequency (George *et al*., 2007). And also the dielectric constant increases with increase in temperature. The charge carrier concentration is increased with temperature, thus indicates the semiconducting behavior of ferrite particles (Kumar *et al*., 2013).

Conclusion

Nanosized Mg-Co ferrite particles were synthesized by chemical co-precipitation method and synthesized particles were characterized by XRD, FT-IR, FE-SEM and VSM measurements. XRD measurement revealed that the synthesized particle was in nano sized spinel structured ferrite. The formation of spinel structure was confirmed by FT-IR measurement by two strong frequency assignments in below $800cm^{-1}$. Magnetic measurement revealed the ferromagnetic behavior of ferrite particles at room temperature. The dielectric polarization of ferrite particle was decreased with increase in frequency, whereas it was increased with increase in temperature.

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