THE STRUCTURAL, ELECTRIC AND MAGNETIC PROPERTIES OF $MgGd_{0.1}Fe_{1.9}O_4$ FERRITE PROCESSED BY SOLID STATE REACTION TECHNIQUE

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Abstract: The excellent combination of magnetic, electric and dielectric properties of Gd-Mg ferrites can be used to fulfill the future demand for high-frequency applications. $MgGd_xFe_{2-x}O_4$ (x=0.0 and x=0.1) ferrites, with improved initial permeability and extremely low relative loss factor (RLF), are prepared by solid state reaction technique. The structural studies were made by using XRD which confirm the single-phase spinel structure. The magnetic properties such as initial permeability and relative loss factor with frequency, in the range 0.075-30 MHz, at room temperature have been investigated. The values of RLF in the presently studied ferrites at room temperature are of the order of 10^{-4}-10^{-5}. Low values of RLF exhibited by these ferrites suggest its utility in inductor and transformer applications. The mechanisms responsible to these results have been discussed in detail in this paper.

Keywords: Initial permeability, Relative loss factor, X-ray diffraction.

Introduction: Mg ferrite may be used in lower requirement television yokes and fly back transformers because of the lower cost over Mn and because its higher resistivity eliminates the need for taped insulation between yoke and winding [1]. Mg-Gd ferrites have emerged as one of the most important materials finding applications in various electrical and magnetic devices because of their high dc resistivity, improved dielectric properties and low losses [2-3]. The initial permeability of Gd-Mg ferrite has been increased by 8-10 times and the value of RLF has been reduced by 10-100 times as compared to mixed Mg-Mn ferrites prepared by conventional ceramic method [4]. The values of RLF in the presently studied ferrites at room temperature are of the order of 10^{-4}-10^{-5}. Low values of RLF exhibited by these ferrites suggest its utility in inductor and transformer applications. The important magnetic properties of ferromagnetic spinel ferrites mainly depend on the magnetic interactions between cations with magnetic moments that are situated in the tetrahedral (A) and the octahedral [B] sites.

Experimental details: Ferrite powders in the $MgGd_xFe_{2-x}O_4$ system where x=0.05 and 01 were prepared by using the standard ceramic technique. Analytical grade reagents MgO, Gd_2O_3 and Fe_2O_3 were weighted in appropriate proportions and mixed thoroughly by wet blending with de-ionized water in an agate mortar and pestle. The mixed powders were dried and calcinated at 800°C for 3 hours to improve the homogeneity of the constituents. After cooling to room temperature the samples were mixed with a small quantity of polyvinyl alcohol as a binder and milled. The powders were compressed into pallets uniaxially under a pressure of 3 to 5 ton/ inch² in a stainless steel dies. The pellets were finally sintered at 1000° C for three hours and were cool down to room temperature. The single- phase nature of the prepared samples was checked by X-ray diffraction studies, which were made by Cu-K_α radiation of wavelength 1.54 Å using Riga Ku-Denki X-ray diffractometer. The dielectric constant and dielectric loss were determined by precision LCR meter 4285 A frequency range 0.1 MHz to 30 MHz. The dc resistivity of the samples at room temperature was measured by using a Keithley 2611 system.

Results and discussion: The X-ray diffraction patterns for the ferrites powder obtained on sintered at 1000°C corresponded to that of the single-phase spinel structure and are shown in figure 1.

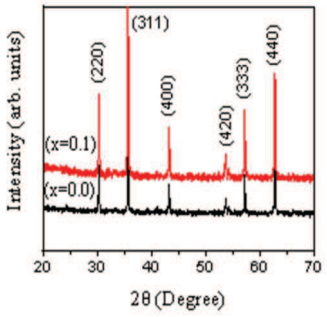

Figure 1. XRD patterns of $MgGd_xFe_{2-x}O_4$ (x=0.0 & 0.1)

The diffraction peaks are quite sharp because of the micrometer size of the crystallite. The morphology and the size of particles of $MgGd_{0.1}Fe_{1.9}O_4$ power sintered at 1273K were checked by SEM, is shown in figure 2. The average particle is about 0.1– 2 μm at 1000°C. The lattice parameter a, was calculated by using the following relation

$$a=d_{hkl}(h^2+k^2+l^2)^{1/2}, \quad (1)$$

Where the values of lattice parameter a, for each composition are calculated.

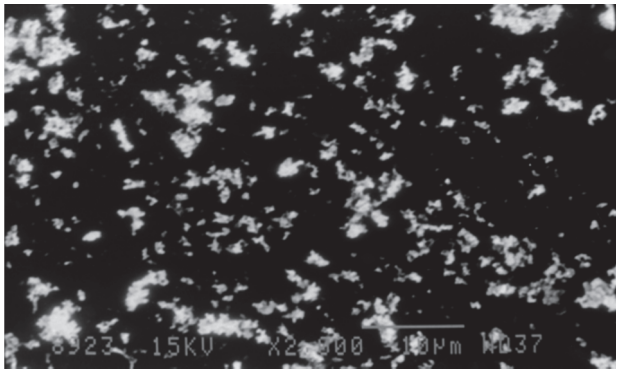

Figure 2. SEM of $MgGd_{0.1}Fe_{1.9}O_4$ powder sintered at 1000°C

Figure3. shows the variation of electrical conductivity with temperature. It is observed that the conductivity increases with an increase in temperature of the sample and showing the semiconducting behavior of ferrite.

The value of conductivity raises slowly with an increase in temperature upto 400K, later drastic increase in conductivity has been observed. The observed two-stage temperature dependence of conductivity (σ) may be represented by following relation [5]

$\sigma=\sigma_L e^{-E_L/kT}+\sigma_H e^{-E_H/kT}$ (2) Where σ_L and σ_H are pre-exponential factors, E_L and E_H are the activation energy for low and high temperature conductance stages, respectively. With an increase in temperature of the ferrite will help the bound charges to be freed and participate in the conduction process, with the result of increase in conductivity. The dc electrical resistivity of $MgGd_{0.1}Fe_{1.80}O_4$ ferrite has been increased by more than one order of magnitude as compared to $MgFe_2o_4$ ferrite. This is ascribed to two causes. One main cause is the increase in the porosity resulted from the doping of Gd^{3+} ions content in Mg ferrite. The other is the addition of Gd^{3+} ions in place of Fe^{3+} ions limits the degree of conduction by blocking Verwey's hopping mechanism, resulting in an increase of resistivity.

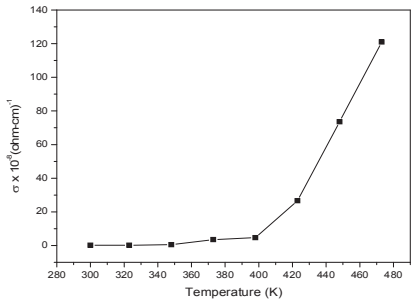

Figure 3. Variation of electrical conductivity of $MgGd_{0.1}Fe_{1.9}O_4$ ferrite with temperature

Table 1:			
Ferrite	M_s(emu/gm)	μ_i	RLF
$MgFe_2O_4$	30	277.1	$6.8x10^{-5}$
$MgGd_{0.1}Fe_{1.9}O_4$	52.24	288.79	$5.5x10^{-5}$

The ferrite in the present system is mostly inverse. This increase in saturation magnetization is attributed to the magnetic interactions in ferrites. The magnetic order in the cubic ferromagnetic spinels is due to super exchange interaction mechanism occurring between the metals ions in the tetrahedral (A) and octahedral [B] sub-lattices.

The net saturation magnetization in ferrimagnetic is given by equation [6]:

$M_s=M_B-M_A$ (3)

In case of $MgGd_{0.1}Fe_{1.9}O_4$ sample the Fe^{3+} ions are replaced by the Gd^{3+} ions at the [B] site. The octahedral site preference energy is large for Gd^{3+} ($4f^7$) ions as compared to tetrahedral site preference energy. So due to the large octahedral site preference energy Gd^{3+} ions occupy [B] sites only. Since the magnetic moment of Gd^{3+} ions ($8\mu_B$) is more than Fe^{3+} ions ($5\mu_B$), a replacement of Fe^{3+} ions by Gd^{3+} ions results an increase in the magnetic moment of the magnetic ions [7]. This results an increase in the magnetic moment at the [B] sub-lattice, so that the overall total magnetic moment increases as shown in table 1. The increase in initial permeability can be explained from the following relationship

$\mu_i=M_s^2D_m/K_1$ (4)

Where D_m is the average grain diameter, K_1 is the magneto-crystalline anisotropy constant and M_s is the saturation magnetization. As μ_i is proportional to

M_s^2, the variation of μ_i with Gd^{3+}ions should be affected in a manner similar to that of variation of M_s^2 with Gd^{3+}ions.

As the RLF is inversely proportional to initial permeability and from table 1, the initial permeability is increasing with an increase in Gd^{3+} ions content, so the RLF is found to be decreasing with increasing Gd^{3+} ions concentration.

Conclusions: $MgGd_xFe_{2-x}O_4$(x= 0.0 & 0.1) ferrites were successfully synthesized by solid state reaction technique. The values of dc resistivity have been increased due to the doping of Gd^{3+} ions in Mg ferrite. Incorporation of Gd^{3+} ions results in an increase in initial permeability and saturation magnetization. Relative loss factor has been decreased due to the doping of Gd^{3+} ions in Mg ferrite. The values of RLF in the presently studied ferrites at room temperature are of the order of 10^{-4}–10^{-5}. Low values of RLF and high resistivity exhibited by these ferrites suggest its utility in high frequency applications.

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