Magnetic and Electric Properties of $MgGd_{0.15}Fe_{1.85}O_4$ Spinel Ferrite

ARTICLE · JULY 2011

DOI: 10.1063/1.3606280

5 AUTHORS, INCLUDING:

Dr. Gagan Kumar Bhargava
Himachal Pradesh University

Sangeeta Thakur
Tata Institute of Fundamental Research

Magnetic and Electric Properties of $MgGd_{0.15}Fe_{1.85}0_4$ Spinel Ferrite

Jagdish Chand[a,b], Gagan Kumar[a,c], Sangeeta Thakur[a], S.K.Sharma[d] and M. Singh[a]

[a]Department of Physics, Himachal Pradesh University, Shimla, 171005, India
[b]Department of Physics, Govt. P. G. College, Solan, India
[c]Department of Applied Sciences, Green Hills Polytechnic College, Solan, India
[d]Instituto de Fisica Gleb Wataghin, Universidade Estadual de Campinas (UNICAMP) Campinas, SP, Brazil
Email: jagdishlect@gmail.com

Abstract. $MgGd_{0.15}Fe_{1.85}O_4$ ferrite with improved magnetic and electrical properties has been synthesized by solid state reaction technique and has been investigated for microstructures, magnetic and electric properties. The electric and magnetic properties of $MgGd_{0.15}Fe_{1.85}O_4$ ferrite have been studied as a function of frequency and temperature. The dc electrical resistivity of $MgGd_{0.15}Fe_{1.85}O_4$ ferrite was found to increase up to 90 times more as compared to $MgFe_20_4$ ferrite. The value of saturation magnetization (M_{sat}) has been increased from 30.70 emu/gm to 41.5 emu/gm and remnant magnetization (M_r) of $MgGd_{0.15}Fe_{1.85}O_4$ ferrite was found to be increase up three times as compared to Mg ferrite. The values of saturation magnetization, remnant magnetization and initial permeability have been increased due to the replacement of Fe^{3+} ions by Gd^{3+} ions in Mg ferrite. High resistivity and improved magnetic properties ($M_{sat,}$ M_r) can be correlated with better compositional stoichiometry and the replacement of Fe^{3+} ions by Gd^{3+} ions. The mechanisms responsible to these results have been discussed in this paper.

Keywords: Saturation magnetization; Remnant magnetization; Resistivity; Initial permeability
PACS: 75.85.+t; 75.60.Ej

INTRODUCTION

Ferrites have been the emerging focus of recent scientic research and technological point of view [1-3]. 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 magnetic properties and low losses. The magnetic properties of spinel ferrites are influenced by numerous factors such as cationic composition, nature of pure ferrite, microstructure, homogeneity, stochiometry and nature of the additive. In the present study, we have investigated the effect of substitution of Gd^{3+} ions on the magnetic and electric properties of $MgFe_20_4$ ferrite. The dc resistivity of a ferrite is an important property, since it determines its performance at high frequencies, where eddy current losses may be high, resulting in a significant loss of energy.

EXPERIMENTAL

Ferrite powder of composition $MgGd_{0.15}Fe_{1.85}O_4$ was prepared by using the standard ceramic technique. The powders were dried and calcinated at 800^0C for 3 hours. The pellets were finally sintered at 1000^0 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 magnetic properties have been investigated by (VSM) and initial permeability was determined by Agilent Technologies 4285A Precision LCR meter in the frequency range from 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 DISCUSSIONS

The X-ray diffraction patterns for the ferrite powder corresponding to that of the single-phase spinel structure shown in Figure1 for the compositions $MgGd_{0.15}Fe_{1.85}O_4$.

Solid State Physics, Proceedings of the 55th DAE Solid State Physics Symposium 2010
AIP Conf. Proc. 1349, 1169-1170 (2011); doi: 10.1063/1.3606280

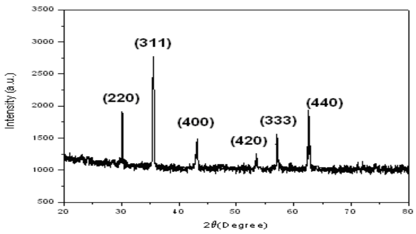

FIGURE 1. XRD pattern for $MgGd_{0.15}Fe_{1.85}O_4$ ferrite.

The average particle size is about 0.1 to 1μm at 1000^0C.The magnetization of $MgGd_{0.15}Fe_{1.85}O_4$ sample does not saturate even at the maximum field attainable (H=20 k0e),while pure Mg ferrite sample attain saturation magnetization in the applied field [Fig. 2]. For $MgGd_{0.15}Fe_{1.85}O_4$ sample the saturation magnetization, M_{sat} is determined by extrapolating the M versus I/H curve to I/H=0 [4].

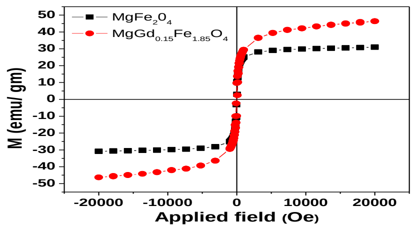

FIGURE 2. Variation of magnetization with applied field for $MgFe_2O_4$ & $MgGd_{0.15}Fe_{1.85}O_4$ at 300 K.

The saturation magnetization (Ms) obtained at room temperature was found to be 41.5 emu/g and remnant magnetization (Mr) was 10 emu/g while the value of M_s & M_r for $MgFe_20_4$ sample are 30.70 emu/g & 3.9 emu/g respectively. Since the magnetic moment of Gd^{3+} ions is more than Fe^{3+} ions, a replacement of Fe^{3+} ions by Gd^{3+} ions at B site results an magnetic moment increases. The variations of initial permeability (μ_i) with frequency at room temperature is shown in Fig.3.

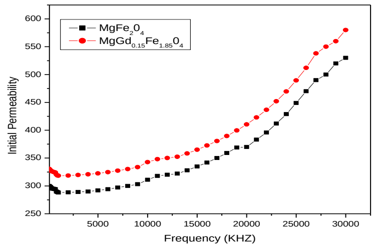

FIGURE 3. Variation of initial permeability with frequency for $MgFe_20_4$ & $MgGd_{0.15}Fe_{1.85}0_4$ at 300 K.

The increase in μ_i above 5 MHz may indicate the beginning of a possible presence of resonance with peaks occurring at higher frequencies. The resonance occurs due to the matching of Larmor frequency of the electrons spin with the applied frequency. $MgGd_{0.15}Fe_{1.85}O_4$ ferrite has higher value of μ_i as compared to $MgFe_20_4$ ferrite. These variations can be explained from the following dependence of μ_i [5]

$$\mu_i = M_s^2 D_m / K_1$$

Where Dm is the average grain diameter, K_1 is the magneto-crystalline anisotropy constant and Ms is the saturation magnetization. It has been observed that the average grain diameter D_m changes insignificantly due to the substitution of Gd^{3+} ions in Mg ferrite. As μ_i is proportional to M_s^2, the variation of μ_i with Gd^{3+} ions substitution should be affected in a manner similar to that of variation of $M_s^2$with Gd^{3+} ions substitution which can be obtained from the Table 1.

TABLE 1. Magnetic and electrical parameters for $MgFe_20_4$ and $MgGd_{0.15}Fe_{1.85}0_4$ ferrites.

Lattice constant(A^0)	**M_s (emu/gm)**	**M_r (emu/gm)**	**Resistivity (Ω-cm)**
$MgFe_20_4$	30.70	3.9	$1.12x10^7$
$MgGd_{0.15}Fe_{1.85}0_4$	41. 5	10	$1.05x10^9$

CONCLUSIONS

$MgGd_{0.15}Fe_{1.85}0_4$ ferrite has been synthesized by solid state reaction technique. Replacement of Fe^{3+} ions by Gd^{3+} ions results an improvement in saturation magnetization, remnant magnetization, initial permeability and dc resistivity. High value of dc resistivity, of the order of 10^9 Ω-cm, makes this ferrite suitable for the high frequency applications where eddy current losses become appreciable.

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