The Electric and Dielectric Properties of Gd^{3+} Doped Mg 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. Gd doped Mg ferrite with improved electric and dielectric properties have been synthesized by solid state reaction technique. Gd-Mg ferrite has been investigated for micro structural, electric and dielectric properties. The microstructral, electric and dielectric properties have been studied as a function of Gd^{3+} ions concentration at room temperature. The dc electrical resistivity has been increased by two orders of magnitude as compared to $MgFe_2O_4$ ferrite. The value of dielectric loss factor has been reduced due to the replacement of Fe^{3+} ions by Gd^{3+} ions in Mg ferrite. Higher value of dc resistivity (10^9Ω-cm) and low values of the dielectric loss factor of the order of 10^{-3} are also the cardinal achievements of the present investigation. The mechanisms responsible to these results have been discussed in detail in this paper.

1. Introduction

Ferrites have been the emerging focus of recent scientific 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 dielectric properties and low losses [4]. The dc resistivity of Gd-Mg ferrite has been increased by two orders of magnitude as compared to Mg ferrite. High value of dc resistivity (10^9Ω-cm) makes this ferrite more effective in high frequency applications. The values of dielectric loss factor in the presently studied ferrites at room temperature are of the order of 10^{-3}[5].

2. Experimental Details

Ferrites powder of compositions $MgGd_xFe_{2-x}O_4$(x=0.0, 0.05, 0.1 & 0.15) were prepared by solid state reaction 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 1073K for 3 h to improve the homogeneity of the constituents. The powders and pellets were finally sintered at 1273K for 3h at a heating rate of 5.83˚C/min and slowly cool down to room temperature. The dielectric constant and dielectric loss were determined by Agilent Precision LCR meter. The dc resistivity of the samples at room temperature was determined by using a Keithley instruments.

3. Results and Discussion

Fig. 1 shows the diffraction patterns of Mg-Gd ferrites samples sintered at 1273K. All the samples can be indexed as the single-phase cubic spinel structure. The morphology and the size of particles of $MgGd_{0.1}Fe_{1.9}O_4$ power sintered at 1273K were checked by SEM, shown in Fig. 2. The average particle size is about 0.1–2μm at 1273K.

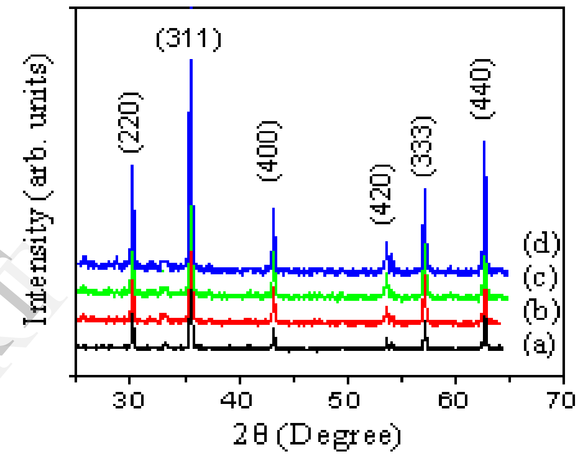

FIGURE 1. XRD patterns of $MgGd_xFe_{2-x}O_4$ samples (x= 0.0, 0.05, 0.1 & 0.15 sintered at 1273K.

The dc electrical resistivity of $MgGd_{0.15}Fe_{1.85}O_4$ ferrite has been increased by two orders 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

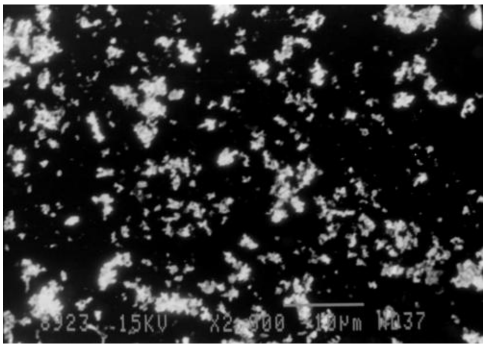

FIGURE 2. SEM of $MgGd_{0.1}Fe_{1.9}O_4$ power sintered at 1273K.

Verwey's hopping mechanism, resulting in an increase of resistivity.

The porosity of the samples is calculated and its value increases with an increase in Gd^{3+} ions content. Fig.3 shows the variation of dielectric constant of $MgGd_{0.15}Fe_{1.85}O_4$ ferrite with frequency at different temperature. Initial decrease in dielectric constant with frequency can be explained by the phenomenon of dipole relaxation. The resonance may arise due to the matching of the frequency of charge transfer between $Fe^{2+} \leftrightarrow Fe^{3+}$ and that of the applied electric field. The dielectric constant decreases with increase in Gd^{3+} ions concentration.

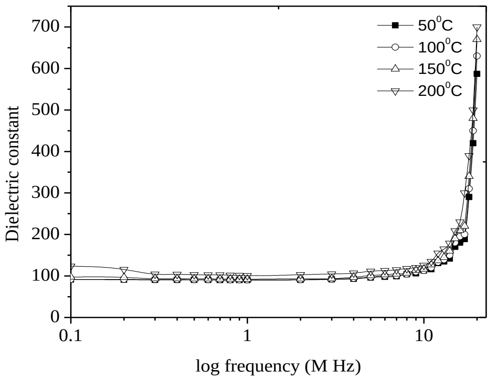

FIGURE 3. Variation of dielectric constant of $MgGd_{0.15}Fe_{1.85}O_4$ ferrite with frequency at different temperature.

This can be correlated with the enhancement of porosity with an increase in Gd^{3+} ions content. Higher porosity results in lower dielectric constant. Fig.4. shows the variation of dielectric constant of $MgGd_{0.15}Fe_{1.85}O_4$ with temperature at different frequencies. The dielectric constant increases with temperature at all frequencies. The hopping of charge carriers is thermally activated with the rise in temperature; hence, the dielectric polarization increases, causing an increase in dielectric constant. Dielectric loss is an ingredient part of the total core loss in ferrites. Hence for low core losses, low values of dielectric losses are required. The dielectric loss of the presently studied ferrites is of the order of 10^{-3}.

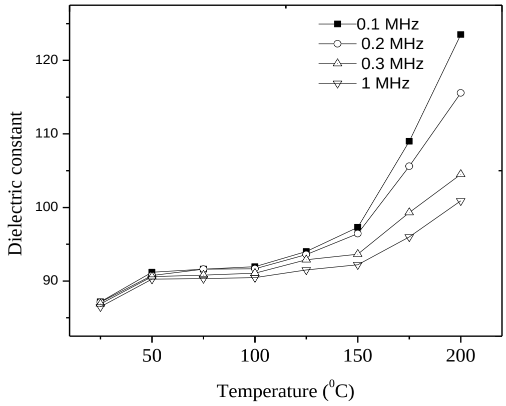

FIGURE 4. Variation of dielectric constant with temperature at different frequencies.

Conclusions

Mg-Gd ferrites were successfully synthesized by solid state reaction technique. High value of dc resistivity, of the order of 10^9 Ω cm, makes this ferrite suitable for the high frequency applications. Low values of dielectric constants obtained for the ferrites warrant their application at high frequencies as microwave absorbers. Very low values of dielectric losses exhibited by these ferrites suggest its utility in microwave communications.

References

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