Study of Behavior of Dielectric Properties in Substituted Mg-Cd ferrites

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Abstract- Spinel ferrites with general formula $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ (x=0,0.2,0.4, 0.6, 0.8, and 1.00; y=0, 0.05 and 0.10) were prepared by standard ceramic method. The observations of variation of dielectric constant and loss tangent is reported in Cr^{3+} substituted ferrites synthesized by normal solid state reaction method. The formation was confirmed by X-ray diffraction technique. Variation of dielectric constant and loss tangent with substitution was explained on the basis of conduction mechanism.

Index Terms- dielectrics, ferrites, magnesium and cadmium ferrites.

I. Introduction

Ferrites have many applications at radio frequencies. They find applications at microwave frequencies due to their high dielectric constant. Early study shows that, the dielectric constant of ferrites depends upon methods of preparation, chemical compositions and substitutions. The study of composition and frequency dependence of dielectric behavior gives valuable information regarding localized charge carriers and dielectric polarization. Rezlescu and Rezlescu [4] studied dielectric parameter as a function of composition, temperature and frequency for Cu-Zn, Cu-Ni and Cu-Mn ferrites. The dielectric properties of Ni-Zn ferrites were studied by Murthy et al [5]. They that found decrease in the dielectric constant with increase in frequency and they explained the behavior on the basis of electron happing from Fe^{2+} to Fe^{3+} ions. Microstructure, frequency and temperature dependent dielectric properties of Co-Li ferrites were studied by Watave et al [6] and explained the behavior on the basis of Koops theory. Composition and frequency dependent dielectric properties of Li-Mg-Ti ferrites were studied by Bellad et al [7]. Dielectric behavior of Ti^{4+} substituted Mg ferrites was studied by Ahmed et al [8] and found that dielectric constant decreases with increasing Ti^{4+} concentration. EI Hiti [9] studied the dielectric behavior and ac conductivity of zinc substituted Ni-Mg ferrites.. Effect of Gd^{3+} substitution on dielectric behavior of Cd-Cu ferrite is also studied by Kolekar et al [10] and showed decrease in dielectric constant with Gd^{3+} substitution. Dielectric properties 0f mixed Mg-Zn ferrites were studied by Ravinder et al [11]. They found that dielectric constant decreases with trivalent substitution and explained the results on basis of space charge polarization.

In this communication a detailed study of the effect of composition and frequency on the dielectric properties in the Cd^{2+} and Cr^{3+} substituted magnesium ferrites is done. The study also offers valuable information on the behavior of localized electric charge carriers which can lead to better conduction and dielectric polarization in such systems which in turn help to explain the results on magneto-electric effect.

II. EXPERIMENTAL

Polycrystalline spinel ferrites $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$(x=0,0.2,0.4, 0.6, 0.8, and 1.00; y=0, 0.05 and 0.10) was prepared from the basic oxides viz Fe_2O_3, MgO, CdO and Cr_2O_3. by usual standard ceramic method. These oxides were thoroughly mixed in their molar proportion and wet milled using acetone. The powders of each sample were presintered at 700 ^{0}C for 12 h and sintered at 1050 ^{0}C for 12 h. The ferrites were mixed with 2%PVA as a binder and pressed into pellets using the hydraulic press applying a pressure of about 5 tones per square inch.

The sintered ferrites powder compositions were characterized by X-ray diffraction using Philips powder diffractometer (PW 3710) using CuKα radiation of wavelength 1.54A^0 and are also characterized by IR absorption spectroscopy at room temperature in the range of 350 cm $^{-1}$ to 800 cm $^{-1}$ using FTIR spectrophotometer.

The dielectric constant and dielectric loss tangent measurement for each sample was carried out at room temperature in the frequency range from 20 Hz to 1 MHz. The parallel capacitance (Cp) and loss tangent (tanδ) were measured by using Hewlett-Packard precession LCR-Q meter (model HP 428A) with accuracy 0.05 % for Cp and 0.005 for dielectric loss tangent (tanδ) at all test frequencies.

III. RESULTS AND DISCUSSION

A. Characterization

X-ray diffraction study reveals that all the compositions under investigation are face centered cubic spinel. Typical X-ray diffractogram is presented in fig.1. The lattice constant was calculated from X-ray diffractograms and it was found to increase with Cd^{2+} concentration. Such increase in the lattice constant due to addition of cadmium content is reported in the literature [12]. This increase in lattice constant is attributed to the difference in ionic radii of Cd^{2+} ion (1.03A^0) and Fe^{3+}ion (0.67A^0). On substitution of Cr^{3+} ion, the lattice constant is found to decrease [12]. This also attributed to the difference in ionic radii of Cr^{3+} ion (0.63A^0) and Fe^{3+}(0.67A^0).

Typical IR absorption spectrum is presented in Fig.2. From this IR absorption spectrum, two dominant absorption bands around 600 cm^{-1} (ν_1) and 400 cm^{-1} (ν_2) are observed which are due to the tetrahedral and octahedral sites respectively [13] which are characteristics of ferrites family. From this characterization study it was confirmed the formation of required ferrites.

B. Dielectric properties

The typical plot of dielectric constant (έ) verses Log F is presented in Fig 3. The plot shows dispersion of dielectric constant at lower frequencies while at higher frequencies it levels off. The dispersion in dielectric constant at lower frequency suggests that process of polarization is of Maxwell –Wagner interfacial polarization [14, 15]. The Maxwell-Wagner polarization in these ferrites is directly related to Verway type conduction [16] with jumping of electrons from $Fe^{2+}$to Fe^{3+}. This clearly shows that electronic and ionic conduction significantly contributes in the polarization process. At lower frequency the grain boundaries of lower conductivity are effective while at higher frequency the ferrite grains of moderate conductivity are prominent. It also observed that the dielectric constant of cadmium ferrites in the low frequency range is much higher than that of magnesium ferrites. This is beacause dielectric constant depends on grain size and we observe that grain size increases with increase in cadmium content in Mg-Cd ferrites. Similar behavior is also reported earlier [17].

The typical plot of dielectric loss tangent (tanδ) versus log of frequencies is presented in the Fig.4. From the plot it can be seen that the dielectric loss tangent decreases with increase in frequency for all the compositions. From these plots it is seen that cadmium ferrites has higher dielectric loss in the low frequency range, which may be due to smaller resistivity of the ferrites. The smaller value of dielectric constant at lower frequency range for $MgFe_2O_4$ is due to larger value of resistivity. Also from figure, it can be seen that dielectric constant in Cr^{3+} substituted (y=0.05 and 0.1) Mg-Cd ferrite has similar type of dispersion as that of unsubstituted ferrite (y=0). However it can be seen that the dielectric constant decreases with increase in Cr^{3+} content.

The dielectric constant is higher in chromium substituted cadmium ferrites than that of chromium substituted mixed Mg-Cd ferrites. The decrement in dielectric constant in Mg-Cd ferrites with Cr^{3+}content can be attributed to the increase in resistivity with Cr^{3+} in these ferrites. In Cr^{3+} substituted (y=0.05 and 0.10) Mg-Cd ferrites, Cr^{3+} occupies B-sites which replaces Fe^{3+} ions causing increase in resistivity [17, 18]. Substituted Cr^{3+} participates in the process of polarization. Due to stable valency of Cr^{3+}, it does not contribute to the conduction but provides the hindrance and hence reduction in dielectric constant. Mechanism of dielectric polarization in ferrite is similar to that of conduction mechanism and the increase in the local displacement in direction of applied field determines polarization [19]. It supports increase in dielectric constant with Cd^{2+} content and decrease in dielectric constant with Cr^{3+} content.

IV. CONCLUSIONS

The study of dielectric behavior reveals that dielectric constant and dielectric loss tangent shows dispersion with frequency for Mg-Cd ferrites and Cr^{3+} substituted Mg-Cd ferrites, which is attributed to interfacial polarization. The dielectric polarization depends on composition and found increasing with Cd^{2+}content whereas decrease with Cr^{3+} substitution. Substituted Cr^{3+} ion reduces the conduction resulting decrease of dielectric constant and dielectric loss tangent.

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Figure captions

Fig.1 Typical X-ray diffractogram of $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ ferrites system x=0.4 y=00

Fig. 2 Typical IR absorption spectrum of $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ with x=0.4, y=00.

Fig.3 Typical plot of dielectric constant (ε’) versus Log F for $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ ferrites system (y=0.00).

Fig.4 Typical plot of dielectric loss tangent (tanδ) versus Log F for $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ ferrites system (y=0.05).

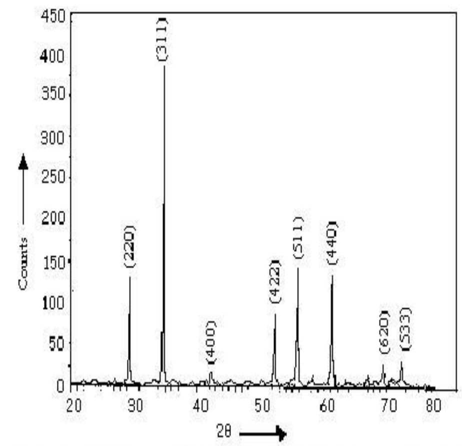
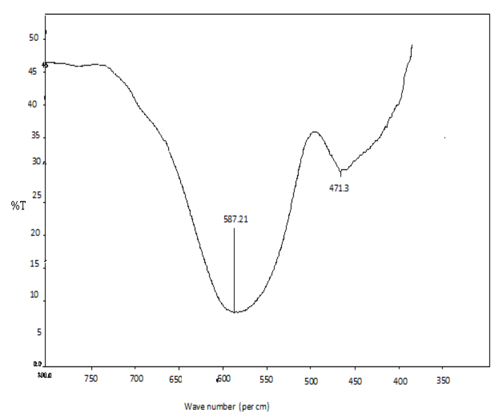


Fig. 1 Typical XRD Pattern of $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ Ferrite System with x=0.6, y=0



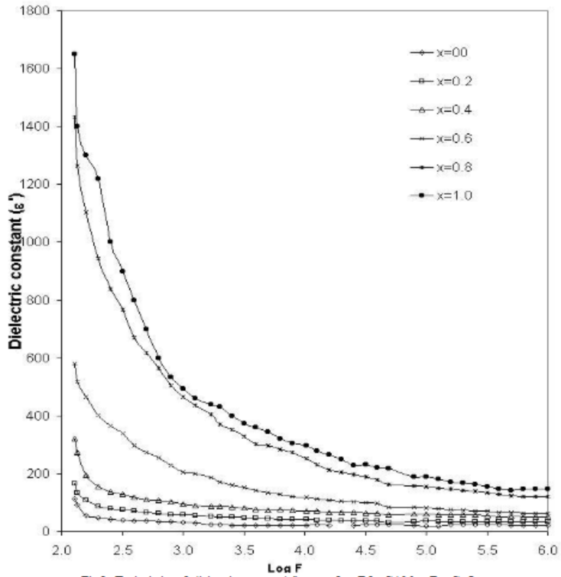


Fig.3 Typical plot of dielectric constant (ε') versus Log F for $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ ferrites system (y=0.00).

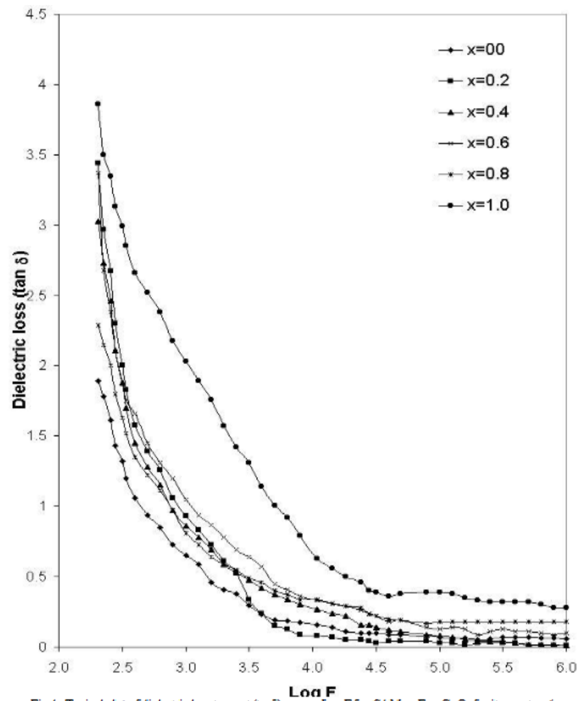


Fig.4 Typical plot of dielectric loss tangent (tanδ) versus Log F for $Cd_xMg_{1-x}Fe_{2-y}Cr_yO_4$ ferrites system (y=0.05).