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ORIGINAL ARTICLE

Dielectric Investigations of Zn Doped $MnFe_2O_4$ Spinel Ferrite Nanoparticles

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Abstract:

The zinc doped manganese spinel ferrite nanoparticles of chemical formula $Mn_{1-x}Zn_xFe_2O_4$ with x=0.00 and 0.20 were investigated for their dielectric behavior. The powdered samples were compressed into circular disc and used for dielectric measurements as a function of frequency at room temperature. The dielectric parameters as dielectric constant, dielectric loss and dielectric loss tangent were studied as a function of frequency for both bare and zinc doped manganese spinel ferrite nanoparticles.

Keywords: Dielectric constant, Dielectric loss tangent, Frequency

Introduction:

The studies of dielectric behavior are equally important from fundamental as well as applied point of view in spinel ferrites apart from their magnetic properties. They are very good dielectric materials in the applications ranging from microwave to radio frequencies. The low electrical conductivity, high permeability etc made them very useful materials for the applications as for inductor, transformer cores and in switch mode power supplies [1-3]. The order of magnitude of conductivity influences the dielectric and magnetic behavior of ferrites [4]. It is mostly dependent on the preparation method and sintering condition. Hence, the spinel ferrites sintered in air atmosphere are highly characterized by conducting grains separated by highly resistive grain boundaries [5]. Also the substitutions of non-magnetic ions like zinc strongly influence the dielectric properties of these spinel ferrites [6, 7]. It is well known that the nanocrystalline spinel ferrites exhibit interesting dielectric properties as compared to their bulk counterpart.

In the light of above facts it was decided to synthesize the zinc doped manganese spinel ferrite nanoparticles using sol-gel auto combustion method. Further, to study its dielectric behaviour as a function of frequency at room temperature.

Results and Discussion:

Dielectric Properties:

The sintered powder of both the samples in the form of circular disc was used for dielectric measurement. The LCR-Q meter was used for measurements in the range frequency 50Hz-1MHz. The surfaces of the pellet were silver pasted for good Ohmic contact. The dielectric response of spinel ferrite as a function of frequency can be either linear or non-linear.

Dielectric constant

The variation of dielectric constant of Mn-Zn spinel ferrite samples as a function of frequency in the range 50Hz-1MHz for samples x=0.00 and 0.20 is presented in figure 1. It is observed from figure 1 that the dielectric constant decreases as frequency increases indicating the usual behavior of the dielectric constant with frequency for spinel ferrites. From figure 1 it is observed that the dielectric constant at lower frequencies decreases sharply and remains constant at higher frequency. At lower frequencies the rapid decrease in dielectric constant can be attributed to the polarization of cations due to change in it its valence state. On the other hand at high frequency it remains constant due to the inability to follow the electric field applied externally. The observed dielectric behavior of Mn-Zn spinel ferrite can be explained on the basis of Maxwell-Wagner interfacial model which depends on the heterogeneous structure consisting grains and poor conductivity grain boundaries.

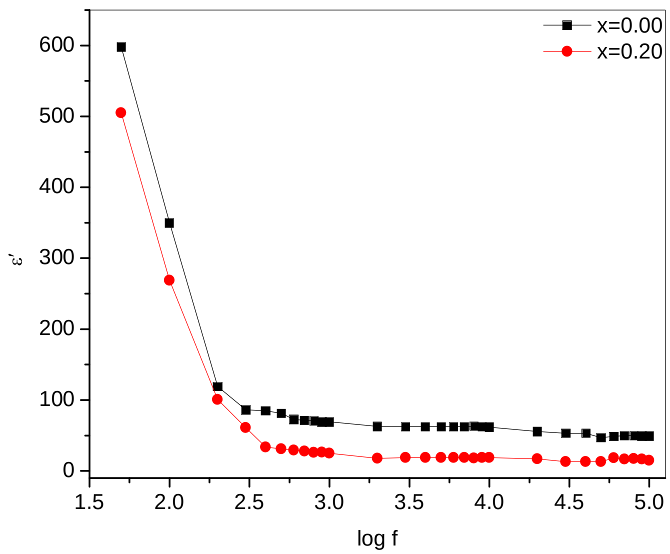

Figure 1: Dielectric constant of $Mg_{1-x}Zn_xFe_2O_4$ (x = 0.00 and 0.30) at room temperature

According to hoping mechanism the electrons reach to insulating grain boundaries and accumulate there which results in the increased interfacial polarization under applied electric field. Hence, the dielectric constant at lower frequencies is high. While at high frequencies the interfacial polarization decreases with the increases in the frequency and attains a constant value since the polarization of induced moments could not follow the applied electric field. Also the electronic exchange between Fe^{3+} to Fe^{2+} lags behind the applied frequency. Thus, the dielectric constant at high frequency is almost constant. The lower values of dielectric constant at high frequency are in close agreement with the reports [8]. The dielectric constant of bare magnesium spinel ferrite nanoparticles is more as compared to that of zinc substituted manganese spinel ferrite nanoparticles.

Dielectric loss:

The variation of dielectric loss of nanocrystalline Mn-Zn spinel ferrite as a function of frequency at room temperature is depicted in figure 2. It is observed that the dielectric loss decreases as the frequency increases. The dielectric loss rapidly decreases at low frequencies and becomes slow and constant at higher frequencies.

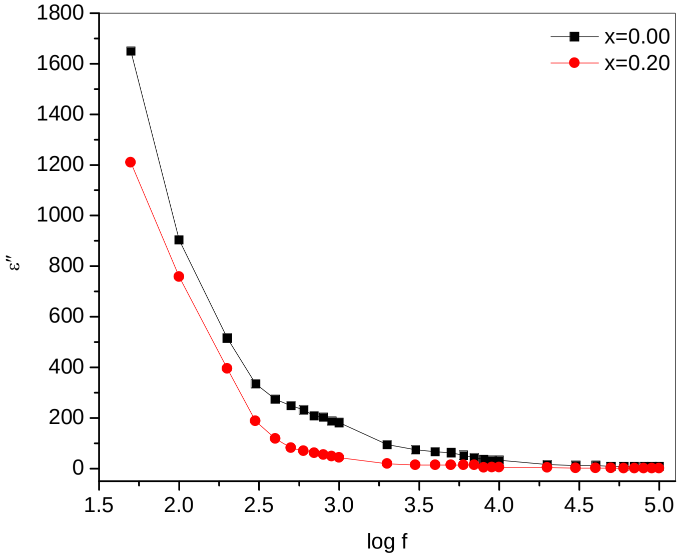

Figure 2: Dielectric loss of $Mg_{1-x}Zn_xFe_2O_4$ (x = 0.00 and 0.30) at room temperature

Dielectric loss tangent (tanδ):

The dependence of dielectric loss tangent (tanδ) with frequency is shown in figure 3. It is evident from figure 3 that the dielectric loss tangent varies exponentially with increase in frequency. At low frequency the dielectric loss tangent decreases rapidly whereas at high frequency the dielectric loss tangent remains almost constant.

It can be further seen from figure 3 that tanδ does not show any peak with frequency in the frequency range under study, for any of the samples. The absence of the peak is perhaps due to small contribution of dielectric permittivity to show any observable variation of loss factor with frequency. Further, the decrease of tan δ with increasing frequency is attributed to the fact that the hopping frequency of charge carriers cannot follow the changes of the externally applied electric field beyond a certain frequency limit. Our results on dielectric studies are in good agreement with that reported in the literature [9].

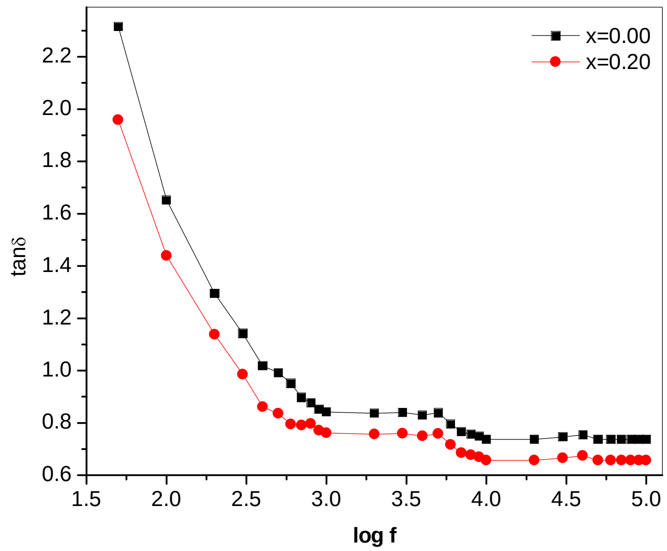

Figure 3: Dielectric loss tangent of $Mg_{1-x}Zn_xFe_2O_4$ (x = 0.00 and 0.30) at room temperature

Conclusion:

The dielectric parameters as dielectric constant, dielectric loss and dielectric loss tangent are in the reported range. The dielectric constant as a function of frequency followed the Maxwell-Wagner interfacial polarization model which has decreased on magnesium substitution. The dielectric loss and dielectric loss tangent also exhibit usual dielectric behavior.

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