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RESEARCH ARTICLE

SYNTHESIS AND DIELECTRIC PROPERTIES OF ZN DOPED MAGNESIUM FERRITE NANOPARTICLES AT ROOM TEMPERATURE

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ABSTRACT

The zinc doped magnesium spinel ferrite nanoparticles were prepared by using sol-gel auto combustion synthesis method of the general chemical formula $Mg_{1-x}Zn_xFe_2O_4$ where x=0.00 and 0.30. The raw materials used were the metal nitrates as oxidants and citric acid as a fuel in ratio of 1:3. The sintered samples were compressed into circular discs and used for dielectric measurements as a function of frequency in the range of 50Hz-1MHz 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 magnesium spinel ferrite nanoparticles.

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INTRODUCTION

In spinel ferrites apart from the magnetic properties, studies of dielectric behavior are equally important from fundamental as well as applied point of view. The polycrystalline spinel ferrites are very good dielectric materials in the applications ranging from microwave to radio frequencies. The properties as low electrical conductivity and high permeability made them very useful for inductor, transformer cores and in switch mode power supplies (Smit, 1959; Bhagwat, 2015 and Alange, 2016). The order of magnitude of conductivity which is preparation method and sintering condition dependent influences the dielectric and magnetic behavior of ferrites (Verma, 1999). The ferrites sintered in air atmosphere are highly characterized by conducting grains separated by poorly conducting grain boundaries (Dais, 1998). Also the substitutions of magnetic and non-magnetic ion influence the dielectric properties of doped ferrites (Ghodake, 2016 and Kakade, 2016). It is well known that the nanocrystalline spinel ferrites exhibit interesting electrical and dielectric properties as compared to their bulk counterpart. In view of above fact the aim of the present work was to synthesize the zinc doped magnesium spinel ferrite nanoparticles using sol-gel auto combustion method. Further, to study its dielectric behaviour as a function of frequency at room temperature.

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Synthesis

The raw materials used for the synthesis are magnesium nitrate, zinc nitrate and ferric nitrate as oxidants and citric acid as a fuel. The ratio of metal nitrates to fuel was chosen as 1:3. The metal nitrates of respective metal ions are weighed and dissolved in minimum amount of distilled water separately. The same process is followed for each nitrate and citric acid. The solutions of all metal nitrates were mixed together and stirred for some time.

Then the solution of citric acid was added to the solution of metal nitrates, thereafter the pH of the mixed solution was adjusted to 7 by adding ammonia drop by drop. Initially the temperature was kept at 90^0C, on formation of gel it was further raised to 120^0C. The gel burnt within very short time resulting fluffy ash. The ash was ground using pestle and mortar and sintered at 700^0C for 6h. 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 of 50Hz-1MHz.

RESULTS AND DISCUSSION

Dielectric Properties

The dielectric response can be linear or non-linear which can be expressed as real and imaginary parts of dielectric constant. The real part of dielectric constant represents the amount of energy stored in a dielectric material while how much is the energy loss represented by imaginary part of dielectric constant.

Dielectric constant

The variation of dielectric constant as a function of frequency for samples x=0.00 and 0.30 is presented in figure 1. It is observed from figure 1 that the dielectric constant decreases as frequency increases suggesting the usual dispersion of dielectric constant with frequency. The dielectric constant at lower frequencies decreases rapidly and remains constant at higher frequency. The sharp decrease in dielectric constant at lower frequencies can be attributed to the polarization of cations due to change in it its valence state and at high frequency it remains constant due to the inability to follow the electric field applied externally. Thus the occurred dispersion can be attributed to the interfacial polarization. The observed dielectric behavior can be explained on the basis of Maxwell-Wagner interfacial model which depends on the heterogeneous structure consisting grains and grain boundaries. 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 synchronize with 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 (Dinesh Varshney, 2013). On the other hand the large values of dielectric constant often exhibited at low frequency are due to heterogeneous effects such as pores, grain surfaces and layers. The dielectric constant of bare magnesium spinel ferrite nanoparticles is low as compared to that of zinc substituted magnesium spinel ferrite nanoparticles.

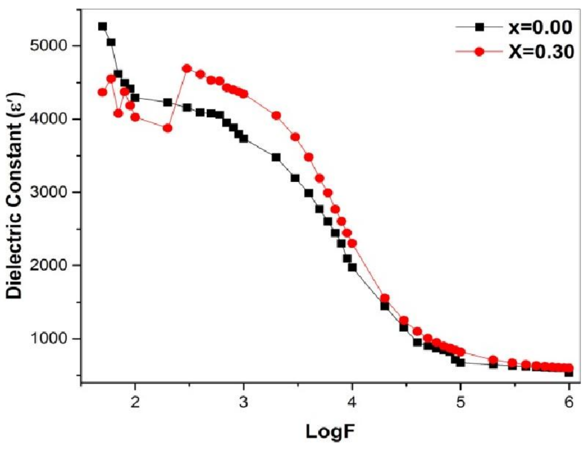

Figure 1. Dielectric constant of $Mg_{1-x}Zn_xFe_2O_4$ (x = 0.00 and 0.30) at room temperature

Dielectric loss

The variation of dielectric loss 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 decrease in dielectric loss is rapid at low frequencies and becomes slow at higher frequencies. Further, it is observed that the peak at a certain frequency appeared which can be attributed to the resonance effect.

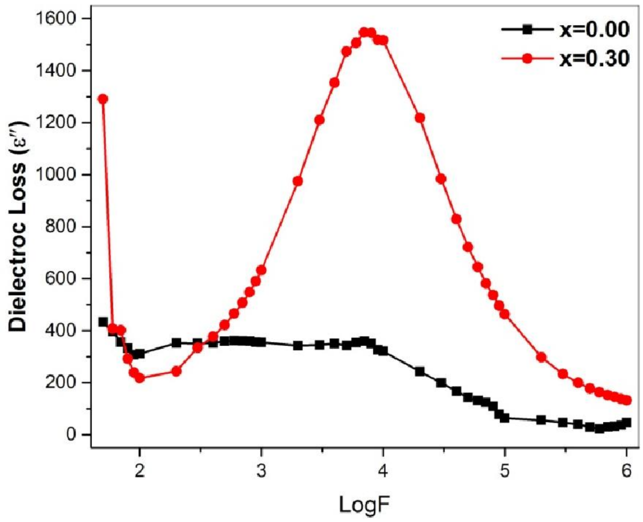

Figure 2. Dielectric loss of $Mg_{1-x}Zn_xFe_2O_4$ (x = 0.00 and 0.30) at room temperature

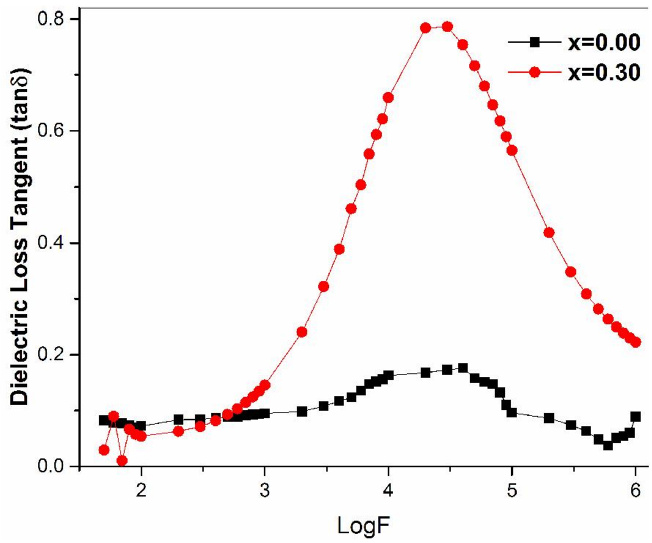

Figure 3. Dielectric loss tangent of $Mg_{1-x}Zn_xFe_2O_4$ (x = 0.00 and 0.30) at room temperature

Table 1. The dielectric constant, dielectric loss and dielectric loss tangent for $Mg_{1-x}Zn_xFe_2O_4$ (x = 0.00 and 0.30) at different frequencies

Frequency (Hz)	Dielectric constant		Dielectric loss		Dielectric loss tangent	
	x=0.00	x=0.30	x=0.00	x=0.30	x=0.00	x=0.30
100	4295.57	4028.47	311.42	217.42	0.07	0.05
1000	3733.52	4344.99	355.06	632.41	0.10	0.15
10000	1971.07	2301.98	321.28	1517.35	0.16	0.66
100000	669.73	820.08	64.29	463.22	0.10	0.56
1000000	532.33	595.64	47.38	132.46	0.09	0.22

Dielectric loss tangent

The dielectric loss tangent is commonly termed as the essential part of core loss factor in ferrites. The dielectric loss tangent of bare and zinc doped magnesium spinel ferrite is shown in figure 3. The observed behavior of dielectric loss as a function of frequency is abnormal which can be attributed to resonance effect. There is presence of the peaks in the dielectric loss curve at a certain frequency. The resonance occurs when the jumping frequency of electron between Fe^{3+} to Fe^{2+} well match with that of frequency of applied signal. When the hopping frequency of charge carriers equal with the frequency of applied field the maximum energy is transferred to the oscillating ions and the peaks observed which results in to the power loss. The similar behavior of the dielectric loss was observed for aluminium substituted Ni-Zn spinel ferrite (Hashim Mohd, Alimuddin, 2012). The values of dielectric constant, loss and loss tangent for both the samples are tabulated in table 1 at different frequencies. It is revealed that the values of all parameters decrease as frequency increases. It indicates that all the parameters at lower frequencies decreases rapidly while at higher frequencies they decrease slowly. Also all the parameters have enhanced upon substitution of zinc in magnesium spinel ferrite.

Conclusion

The behavior of dielectric constant as a function of frequency is usual following Maxwell-Wagner interfacial polarization model. The dielectric constant of magnesium spinel ferrite nanoparticles enhanced on zinc substitution. The dielectric loss and dielectric loss tangent exhibit the peaks at the certain frequencies which revealed the resonance effect. The zinc doping has enhanced all the parameters of magnesium spinel ferrite.

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