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Electrical Properties of Zn Substituted $MgFe_2O_4$ Spinel Ferrite Nanoparticles

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ABSTRACT
The DC electrical properties of nanocrystalline magnesium and zinc substituted magnesium spinel ferrites are presented here. The DC electrical resistivity of Mg-Zn spinel ferrite was studied as a function of temperature for both the samples. The semiconducting behavior of the studied samples was observed as a function of temperature. The enhancement in the electrical resistivity was also observed with zinc substitution. The activation energies obtained are in the range of 0.571-0.628 eV.
Keywords: *Mg-Zn spinel ferrite, DC resistivity, Activation energy*

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INTRODUCTION

Spinel ferrites are the most important and widely studied magnetic materials due to their interesting technological applications by number of researchers. Spinel ferrite with cubic spinel structure possesses two interstitial sites as tetrahedral A-site and octahedral B-site. Depending upon the ionic radii and site preference energy the metal cations reside at tetrahedral and octahedral sites [1, 2]. Among spinel ferrites, magnesium ferrite ($MgFe_2O_4$) is an important spinel ferrite having inverse spinel structure, whose degree of inversion depends on method of preparation and heat treatment. Magnesium ferrite is one of the important magnetic oxides having magnetic applications in the area of memory and switching circuits of digital computer and microwave devices. It has the applications in the field of heterogeneous catalysis, adsorption, sensors, and in magnetic technologies [3-8] which depend on the substitution of cations. Zinc is a non magnetic ion and prefers to occupy tetrahedral (A) site. The substitution of zinc in magnesium ferrite can lead to modification in the structural, electrical, magnetic etc properties.
The aim of the present work was to investigate the DC electrical properties of zinc substituted nanocrystalline magnesium spinel ferrite using standard measurement technique.

RESULTS AND DISCUSSION

The nanocrystalline spinel ferrite of chemical formula $Mg_{1-x}Zn_xFe_2O_4$ with x=0.00 and 0.30 was prepared by sol-gel auto combustion synthesis method. The crystal structure of the prepared samples was investigated using X-ray diffraction (XRD) technique. The results of XRD patterns showed the single phase cubic spinel structure (not shown here) of investigated samples. The pellets of circular shape of dimensions 10mm diameter and 3mm thickness were used for electrical measurements. The silver paste was pasted on both surfaces of pellet for the good Ohmic contact. The electrical measurements were carried out by two-probe method in the temperature range of RT-850K. The log of resistivity versus the 1000/T plots for both the samples is shown in figure 1.

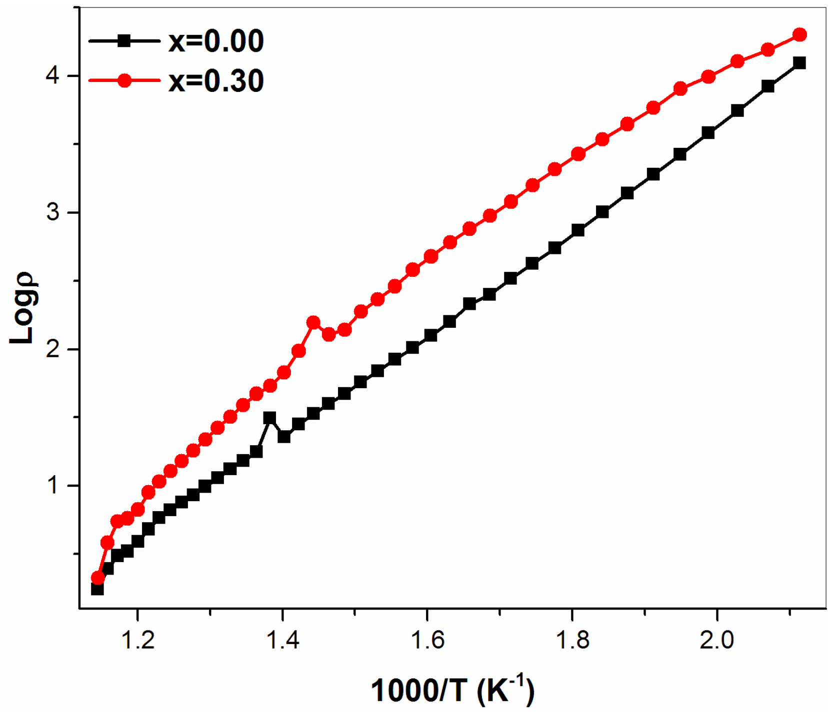

Figure 1: DC electrical resistivity of $Mg_{1-x}Zn_xFe_2O_4$ (x = 0.00 and 0.30) as a function of temperature

It is revealed that the electrical resistivity of the sample decrease with increase in temperature. The decrease in DC electrical resistivity with the temperature is due to the increase in drift mobility of the charge carriers. It is worth to mention here that the exponential dependence of electrical resistivity on the temperature is the one of prime characteristic features of the ferrite material. It indicates the semiconducting behavior of samples by obeying the Arrhenius relation [9]. The conduction in spinel ferrite can be explained on the basis of hopping mechanism. In hopping mechanism the charge carrier jumps from ion to ion not through the crystal lattice. In ferrite the conduction occurs due to the electronic exchange between Fe^{3+} to Fe^{2+}. Moreover, the electrical resistivity of magnesium spinel ferrite was found to increase with zinc substitution. The increase in DC resistivity can be attributed to the reduction in hopping between iron ions. The Arrhenius relation was used to calculate the activation energy for each sample and presented in table 1. It is found that the activation energy on zinc substitution has increased which corresponds to the low conductivity value of the sample.
It is well known fact that, for spinel ferrites two distinct regions observed in logρ vs 1000/T plots. The either sides of the change in slope indicate paramagnetic region and ferrimagnetic regions. The temperature at which the change in slope occurs indicates the Curie temperature for that sample. The similar reports for spinel ferrite are reported [10-13]. The Curie temperature for both the samples was estimated and tabulated in table 1. It is noticed that the Curie temperature decreased on zinc substitution.

Table 1: Activation energies in paramagnetic region (E_p), ferromagnetic region (E_f), change in activation energy (ΔE) and Curie temperature (T_c)

Comp x	Ep (eV)	Ef (eV)	ΔE (eV)	Tc (^{0}C)
0.00	0.323	0.894	0.571	723
0.30	0.322	0.950	0.628	693

CONCLUSION
The DC electrical resistivity of the zinc substituted magnesium spinel ferrite nanoparticles indicates the semiconducting behavior. The DC electrical resistivity and activation energy increased on zinc substitution while the Curie temperature decreased.

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