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Synthesis and DC Electrical Properties of Nanocrystalline Mn-Zn Spinel Ferrite

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Abstract:

The DC electrical properties as a function of temperature of zinc substituted manganese spinel ferrite nanoparticles prepared by sol-gel auto combustion synthesis method have enumerated in this article. The raw materials as metal nitrates and citric acid as a fuel in ratio of 1:3 were used during synthesis. The sintered samples were compressed into circular discs and used for electric measurements. The electrical parameters like DC electrical resistivity, Activation energy, Curie temperature were focused during the investigations.

Keywords: Mn-Zn spinel ferrite, Sol-gel auto-combustion, DC resistivity, Activation energy

Introduction:

In the recent years, intense research has been carried out on nanosize spinel ferrites due to the high surface to volume ratio, which makes them useful in the applications of field of imaging and therapy [1, 2], drug delivery [3], catalyst [4] etc. The important applications of spinel ferrites are due to accommodation of variety of cations at their interstitial sites, tetrahedral (A) and octahedral [B] sites. The divalent, trivalent and tetravalent cation can also be incorporated in spinel lattice to bring out variation in electrical and magnetic properties.

The properties of ferrite materials are sensitive to many parameters such as method of preparation, preparation conditions, preparation parameters, nature and type of substituent, cation distribution [5]. All these parameters can play a crucial role in the modification of the electrical and magnetic properties which can be useful for the desired applications. The most commonly used wet chemical method for the synthesis of nanosize spinel ferrite is the sol-gel auto combustion method. This method has several advantages over the other methods due to their high chemical homogeneity, low processing temperature and the possibility of controlling the size, morphology of particles etc, and therefore it is widely used.

In the present investigation the zinc substituted manganese spinel ferrite was prepared by using sol-gel auto combustion method and studied its DC electrical resistivity as a function of temperature.

Synthesis:

The raw materials used for the synthesis were manganese nitrate, zinc nitrate and ferric nitrate and citric acid as a fuel. The metal nitrates to fuel ratio was chosen as 1:3. The metal nitrates of respective metal ions were weighed and dissolved in minimum amount of distilled water. The solutions of all metal nitrates were mixed together and stirred for some time. Then the solution of fuel was added, thereafter the pH of the mixed solution was adjusted to 7 by adding ammonia drop by drop. The reaction was carried out at temperature 90^0C. After around 5h the gel burnt to form the fluffy ash. The as-prepared powder was ground using pestle-mortar and sintered at 700^0C for 6h. The sintered powder of both the samples was compressed into circular disc of dimensions 10mmX3mm. The two-probe setup was used for measurements as a function of temperature.

Results and Discussion:

DC electrical resistivity of spinel ferrite is one of the useful characterization techniques to understand conductivity mechanism in ferrites. The DC electrical resistivity of Mn-Zn spinel ferrite samples was estimated by two-probe method in the temperature range of 450-800K. The samples in the form of pallet were used for the measurement. The silver paste was applied on both the surfaces of the pallet for good ohmic contact. A thermal cycle was given to each sample and measurements of current and voltage were carried out during cooling of temperature. The temperature of the sample was measured using chromel-alumel thermo couple. By knowing the values of current and voltage across the sample, the resistance R and thereby resistivity of the sample was calculated by using the relation,

$\rho = RA / t \quad \Omega\text{-cm}$

where, R is resistance of the sample, A is surface area of the sample and given by πr^2, r is radius of the pellet and t is the thickness.

DC electrical resistivity:

The DC electrical resistivity studies of $Mn_{1-x}Zn_xFe_2O_4$ ferrite samples with x = 0.0, and 0.20 were carried out. The plots showing the variation of logarithm of electrical resistivity (log ρ) as a function of temperature (1000/T) are presented in figure 1. It is evident from figure 1 that, both the plots obeys Arrhenius relation. The resistivity of each sample decreases with increasing temperature indicating semiconducting behaviour of the sample. Similar behaviour of resistivity was observed in other spinel ferrite reported in the literature [6, 7]. DC electrical resistivity calculated using the measured resistance R and dimensions of the pallet at room temperature of the samples was found to be increased from 121×10^5 Ω-cm to 266×10^5 Ω-cm with Zn^{2+} substitution.

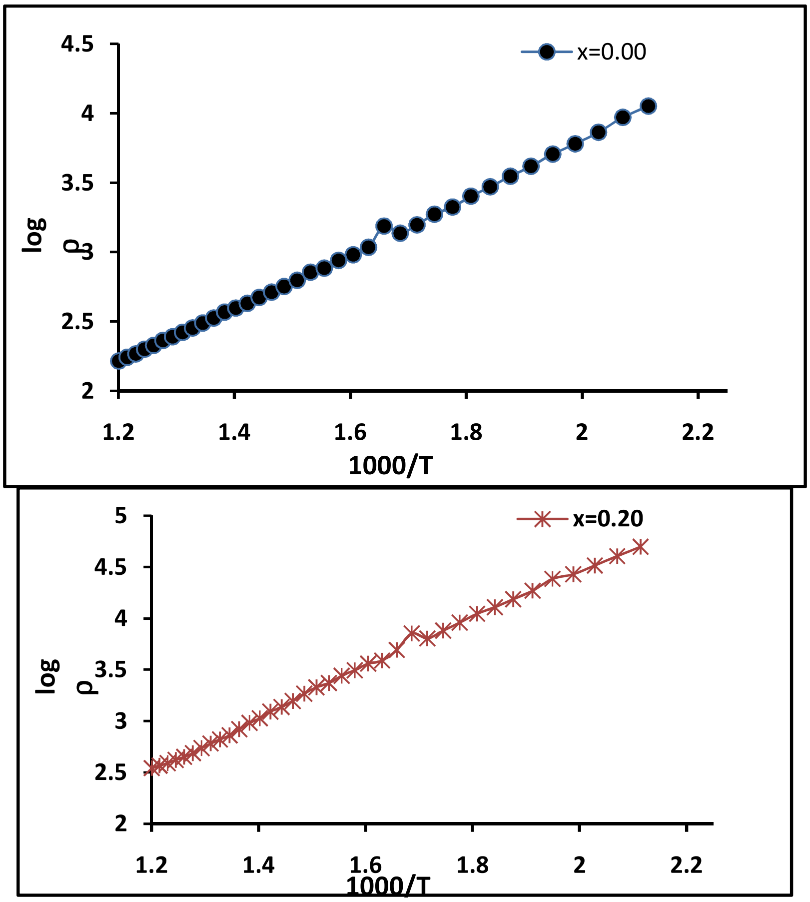

Figure 1: DC resistivity plots of $Mn_{1-x}Zn_xFe_2O_4$ with x=0.00 and 0.20

Curie temperature (Tc):

The graphs drawn in the figure 1 shows the slope at a particular temperature for each sample indicating that sample undergoes transition from ferrimagnetic phase to paramagnetic phase, this temperature is known as Curie temperature. The temperature corresponding to kink in the resistivity plots may corresponds to Curie temperature of the sample. Curie temperature of bare and zinc substituted manganese spinel ferrite is 573K and 547K respectively which suggests that it has been decreased on zinc substitution.

Activation Energy:

Activation energy of both the samples was calculated using the linear plots drawn between log (σ) and 1000/T and using the relation.

$\rho = \rho_0 \exp (Eg / kT)$

The values of activation energy are 0.18eV and 0.34eV for nanocrystalline manganese and zinc substituted manganese spinel ferrite respectively.

Conclusion:

The electrical behavior of both the samples as a function of temperature was usual. The observed semiconducting behavior of the zinc substituted manganese spinel ferrite follows the Arrhenius relation. The resistivity of nanocrystalline manganese spinel ferrite upon zinc substitution has enhanced. The Curie temperature has decreased with zinc substitution. The activation energy of manganese spinel ferrite enhanced from 0.18eV to 0.34eV upon zinc substitution.

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