International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
© 2021 | IJSRST | Volume 8 - Issue 1
doi : https://doi.org/10.32628/IJSRST21810027

Structural and Electrical Properties of Nano [$Ni_{0.6}Zn_{0.4}Fe_2O_4$] Spinel Ferrite

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ABSTRACT

Nano Ni-Zn ferrite with composition $Ni_{0.6}Zn_{0.4}Fe_2O_4$ is prepared by using sol-gel auto-combustion method with citric acid as a fuel. The structural properties of synthesized nano-ferrite is characterized by powder X-ray diffraction (XRD) technique while the electrical properties have been studied using two probe method. The X-ray diffraction study confirms that, there is a formation of single-phase cubic spinel with most intense peak at [311] having lattice constant of 8.3585 A^0 and the average particle size is found to be 45.63 nm. In addition to this, the electrical resistivity of Ni-Zn Ferrite decreases with increase in temperature which exhibits semiconductor nature.

Keywords : Nano Ni-Zn ferrite, sol-gel technique, XRD, Electrical Resistivity.

I. INTRODUCTION

Ferrites have generated diverse technical interest due to their most interesting applications in electronic circuits as inductors, in high frequency systems, in power delivering devices, in magnetic recording media, transformer core, microwave absorber (1) (2). Among the various ferrites, nickel (Ni) substituted zinc (Zn) ferrites plays important role in technological application due to their high saturation magnetisation, low coercivity, high resistivity and low electric loss (3). The choice of cations and their distribution in tetrahedral 'A' and octahedral 'B' sites in a ferrite is interesting and useful for the characterisation (4). $ZnFe_2O_4$ has normal spinel structure, where Zn^{2+} ions in 'A' site and all Fe^{3+} ions are distributed in 'B' sites, whereas $NiFe_2O_4$ has inverse spinel structure in which Ni^{2+} ions mainly in 'B' sites and Fe^{3+} ions equally distributed in 'A' sites and 'B' sites. Thus, Ni-Zn ferrites forms a mixed spinel in which tetrahedral sites occupied by Zn^{2+} and Fe^{3+} and octahedral sites occupied by Ni^{2+} ions and Fe^{3+} in the lattice (5).

A wide verity work has been done on the structural, electrical and magnetic properties of Ni-Zn ferrite. Verma and Goel found that, the DC electrical resistivity of Ni-Zn ferrite greater than 108 Ω cm can be prepared by precursor method (6). The different experimental technique used for the preparation of Ni-Zn ferrite such as, sol-gel auto combustion (7), co-precipitation (8), ball milling (9), micro-emulsion (10), hydrothermal (11). Sol-gel auto combustion synthesis process is low cost, easy to control the particle size and efficient for homogeneous mixing of all components for the formation of nanocrystallites. In combustion synthesis process, organic compounds such as urea, glycine, citric acid and alanine have been used as a fuel to enhance the efficiency of combustion and metal nitrate acts as oxidant as well as cation sources. The fuel monohydrated citric acid presented the greatest time and temperature of combustion reaction (12) (13).

The present work deals with the synthesis of $Ni_{0.6}Zn_{0.4}Fe_2O_4$ by sol-gel auto combustion method using citric acid as fuel. The purpose of the study is to investigate structural and electrical properties of Ni-Zn Spinel ferrites for various application.

II. EXPERIMENTAL

Initially the AR grade precursor in the form of nitrates i.e. $Ni(NO_3)_2.6H_2O$, $Zn(NO_3)_2.6H_2O$ and $Fe(NO_3)_3.9H_2O$ are mixed in molar proportion in an aqueous solution of deionised water with constant stirring to transform into the gel. The gel was burnt in a self-propagating combustion way to form a loose powder. Then the powder is grounded in an agate mortar and annealed at 900 ^{0}C for 8 hrs in the furnace with a cooling at a rate of 75 ^{0}C/hr. In this way, the crystalline powder of $Ni_{0.6}Zn_{0.4}Fe_2O_4$ was prepared. The crystallinity of such sample was investigated by X-ray diffraction method using Phillips diffractometer (Model - PW 1051).

To carry out electrical studies, the crystalline powder is again grounded with polyvinyl alcohol which acts as a binder. Afterward, the fine powder is pressed by using a hydraulic press with a pressure of 5 tons to form a pellet. These pellets were again sintered at 1000 ^{0}C for 8 hours to reduce the porosity and increase the density. The silver paste was applied on both sides of pallet to obtain good ohmic contacts. The electrical characterization have been done by using a two-probe method in the temperature range 100 ^{0}C - 550 ^{0}C.

III. RESULTS AND DISCUSSION

The characterisations which have been carried out in the present work are discussed as follows:

X-ray Diffraction:

Fig.1 illustrate the X-ray diffraction (XRD) pattern of prepared $Ni_{0.6}Zn_{0.4}Fe_2O_4$ sample annealed at 1000 ^{0}C. The broadening of peaks is an indication for the formation of nano -crystalline nature of the present spinel ferrite. From the XRD data, it is reveal that, the most intense peak corresponds to the crystal plane [311] while, the crystallite size of 49 nm having d value 2.5202 A^0 is calculated by Debye-Scherrer equation (14).

$$D = 0.9 \lambda / \beta \cos\theta$$

where, D is a crystalline size, β is a full width half maxima, λ is a wavelength of X-ray beam of Cu - K_α (1.5406 A^0) and θ is the angle of diffraction. The prominent peaks in XRD data are corresponding to planes [111], [220], [311], [400], [422], [511], [440], [620], [533] which indicates the formation of cubic spinel structure. The average crystalline size found to be 45.63 nm. The lattice parameter 'a' is found to be 8.3585 A^0.

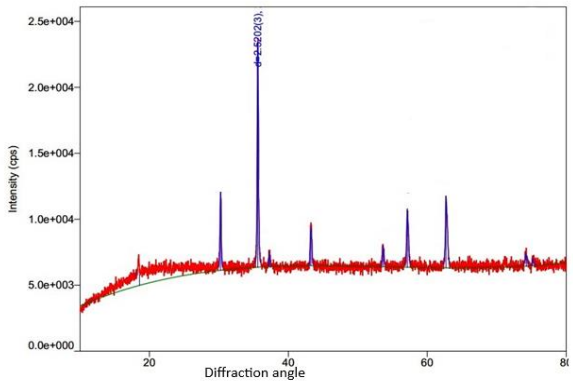

Fig. 1 : XRD Patterns of $Ni_{0.6}Zn_{0.4}Fe_2O_4$

DC Electrical Resistivity:

The DC electrical resistivity of the Ni-Zn spinel ferrite sample have been carried out in the range 100 ^{0}C - 550 ^{0}C using two probe method. The DC resistivity were calculated using the equation

$$\rho = \frac{A\,R}{t}$$

where, A is the area of the pellet, R is the resistance of the sample and t is the thickness of the pellet.

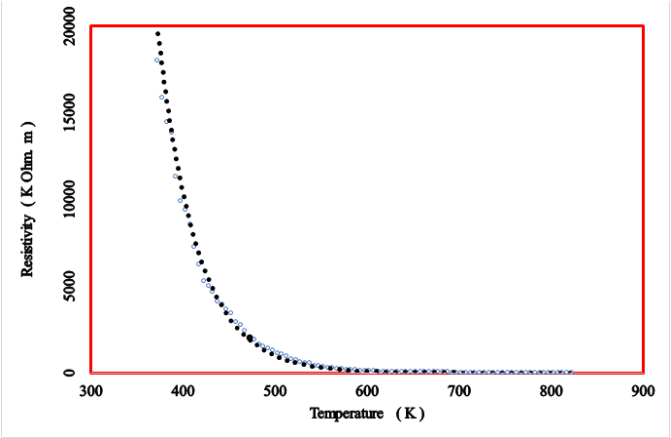

Fig. 2. Variation of Resistivity (K Ω m) with Temperature (K)

The variation DC electrical resistivity (KΩ m) with the temperature (K) is as shown in Fig.2. From this figure it can be seen that, the resistivity of the sample goes on decreasing with rapid rate of loss at initial level i.e. broadly in the range 400 K - 450 K. This rate of decrease becomes lower down after 450 K and remains almost constant after 550 K temperature. Such decrease in electrical resistivity with temperature can be very well explained with the help of Verwey and de-Boer mechanism (15). According to them, the high sintering temperature leads to the formation Fe^{2+} ions and at the same time Ni^{2+} ion which oxidises to Ni^{3+} ion at octahedral site. The spinel ferrite consists of cations at tetrahedral sites and octahedral sites and the Fe^{2+} and Ni^{3+} ions have strong preference for octahedral sites hence, there is exchange of valence electron between Fe^{2+} and Fe^{3+} and holes between Ni^{3+} and Ni^{2+} which results into the conduction in ferrite and the magnitude of exchange depends on number of ion pair of Fe^{2+} and Fe^{3+} on octahedral sites. Such decrease of resistivity with increasing temperature also indicates the semiconductor nature of the ferrites (16).

IV. CONCLUSION

The Nanosize Ni-Zn ferrite with composition [$Ni_{0.6}Zn_{0.4}Fe_2O_4$] have been prepared by sol-gel auto-combustion method. The X-ray diffraction study confirms the formation of single-phase cubic spinel structure with most intense peak at [311] and the average particle size is found to be 45.63 nm calculated by using the Debye-Scherrer equation. Whereas, the DC resistivity is found to decrease with the increase in temperature which exhibits the semiconductor nature of the sample.

V. ACKNOWLEDGEMENT

The author (DTY) acknowledges generous support from Dr. D. S. Choudhary, Professor, D. B. Science College, Gondia, Maharashtra.

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Cite This Article :

Dr. Ramesh N. Taikar, Sadanand R. Sarve, Disha T. Yele, Dr. Deepak R. Taikar, Kalpana R. Nagde , " Structural and Electrical Properties of Nano [Ni 0.6 Zn 0.4 Fe2 O4] Spinel Ferrite", International Journal of Scientific Research in Science and Technology(IJSRST), Print ISSN : 2395-6011, Online ISSN : 2395-602X,Volume 8, Issue 1, pp.115-118, January-February-2021. Available at doi : https://doi.org/10.32628/IJSRST21810027

Journal URL : http://ijsrst.com/IJSRST21810027