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Study of Electrical and Optical Property of Nickel Ferrite Synthesised by Solution Combustion Method

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ABSTRACT

Nickel Nano Ferrite particles are synthesized by solution combustion method using urea as fuel and then obtained sample is characterized with XRD and FTIR. XRD spectra confirms the cubic spinel structure of ferrites and the crystallite size is in range of 20-40 nm. Chemical structure is analyzed with FTIR spectra. UV-Visible spectrophotometer is carried out to study the optical properties and the direct optical energy band gap is evaluated. Dielectric properties and AC conductivity is studied. The conductivity increases with increase of frequency and is consistent with Koop's phenomenological theory.

Keyword : NanoFerrite, dielectric constant, AC conductivity, optical properties.

I. INTRODUCTION

At the nanoscale the properties of materials change drastically due to quantum effects. As surface to volume ratio increases the surface reactivity of particles also increases. Nano-ferrites are magnetic particles and have many emerging applications ranging from bio-medical devices to industrial based applications such as in Tissue and tumor treatment, MRI, as adsorbents, as effective waveguides, microwave absorber, in catalysis of reactions, agent of wastewater treatment etc [1-6] Ferrites are widely studied materials owing to their important applications. Among Ferrites transition metal ferrites are prominently studied. Among Ferrites are a class of ferrites called as spinel ferrites. Spinel Ferrites have formula MFe_2O_4 where M is divalent metal. Generally spinel ferrites have the properties of soft magnetic materials coupled with tunable electrical properties [7] Nickel Ferrite ($NiFe_2O_4$) is a soft ferrite and has Inverse spinel structure in which ferric ions (Fe^{+3}) are at tetrahedral sites whereas octahedral sites are occupied by 1:1 ratio of both nickel ions (Ni^{+2}) and ferric ions (Fe^{+3}) and thus Nickel Ferrite can be expressed by the formula $(Fe^{+3})_A[Ni^{+2}Fe^{+3}]_BO_4^{-2}$ [8]. Nickel ferrites find extensive applications due to their desired properties. Some applications include biomedical cyto-genotoxicity applications [9,10] environmental applications like pollution control[11]photocatalytic and electrochemical application[12]for gas sensor applications[13]for dye removal etc.. The properties of prepared Ferrites depend on preparative techniques, compositions and

structural parameters [14,15]. There are many methods used in the preparation of ferrite nanoparticles such as sol-gel method, hydrothermal method, co-precipitation method, solution combustion method and also by method of Green synthesis [16,17]. In the present work, solution combustion Synthesis (SCS) is employed which has advantages like high crystalline sample is obtained due to high reaction temperature and also short reaction time of process with simple equipment.

II. Experimental

The required chemicals for sample preparation are obtained from Otto chemicals and are in Analytical (AR) grade. Solution combustion method is employed in the synthesis of Nickel nano-ferrite.Stoichiometric ratio of Nitrates i.e., Nickle Nitrate Hexahydrate ($Ni(N0_3)_2.6H_20$)(14.54 gm) and Ferric Nitrate Nonahydrate ($Fe(N03)_2.9H20$)(40.39 gm) and the fuel urea (6.66 moles) is taken in 50 ml deionized water and stirred on a magnetic stirrer to get clear solution. The solution is prepared with fuel to oxidizer ratio of 1 i.e. the solution is neither fuel rich nor fuel lean. The solution is then taken in the silica crucible and heated in Muffle furnace at 500^0C. Obtained product is calcined at 300^0C.

III. Results and Discussion

3.1 XRD Analysis

XRD Analysis is carried out with Philips X – Ray Diffractometer in the 2θ range of 10 to 80^0 as shown in Fig 1. Sharp crystalline peaks are observed for 2θ values of 30.7, 36.7, 44.8, 54.9, 59.1 and 66.9^0 and these could be indexed to (hkl) planes (220), (311), (400), (422), (511)and (440) respectively and hence confirming the cubic spinel structure of ferrites and also agrees with the JCPDS data (JCPDS card No.22- 1086). The crystallite size is calculated using Debye-Scherre formula and it is in range of 20-40 nm.

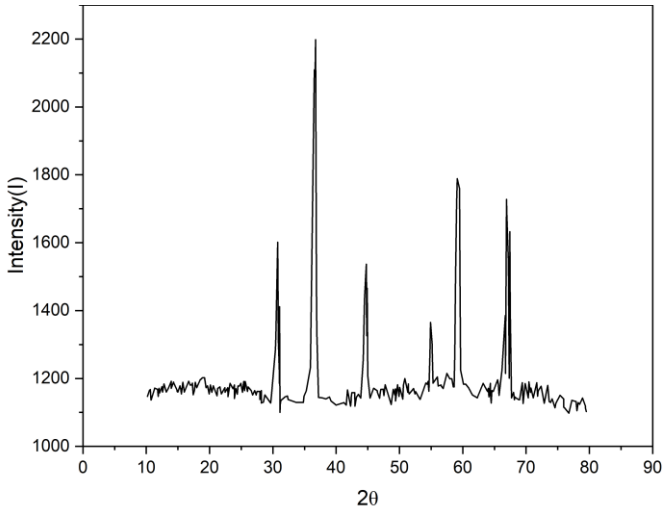

Fig.1 XRD spectra of Nickel Ferrite

3.2 FTIR Analysis

FTIR analysis is done to study the chemical structure of the sample. FTIR is carried in the wave number range of 400 cm^{-1} to 4000 cm^{-1} (Perkin-Elmer spectrometer) and is shown by Fig.2. IR absorption shows two absorption bands at wavenumber of 464.84 cm^{-1} and 624.89 cm^{-1} and these correspond to stretching motions in tetrahedral A site and octahedral B site of e Fe^{+3}- O^{-2} bond. The wide peak around 3500 cm^{-1} is due to OH group vibration.[18]

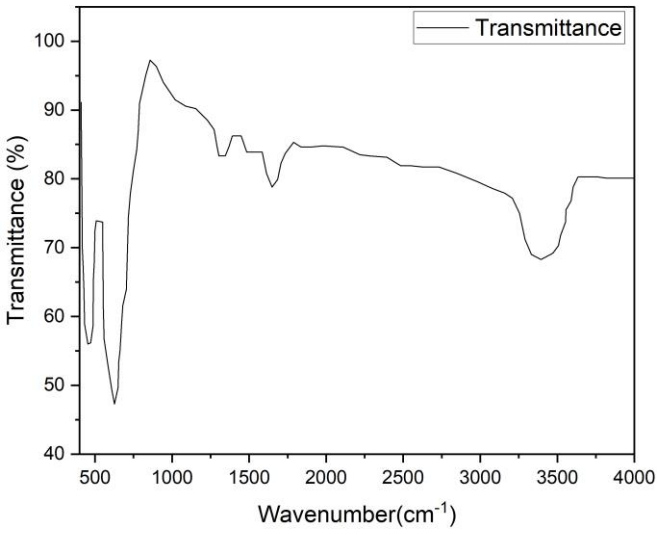

Fig.2 FTIR spectra of Nickel Ferrite

3.3 UV – Visible absorption

UV-Visible spectroscopy gives information of the chemical structure of the sample. UV-Visible

absorption is done in the wavelength range of 200-600 nm with double beam monochromatic spectrophotometer. The UV-Visible absorption spectra seen in figure 3 shows two peak absorbance at wavelength of 211.4 nm and 258.19 nm both lying in the UV region. Optical band gap of NanoNickel ferrite is calculated with Tauc equation by plotting $(\alpha h\nu)^2$ vs $h\upsilon$ and extrapolating linear region of graph to get direct optical band gap value which is 3.89eV. This can find applications in ultraviolet region of photovoltaics.

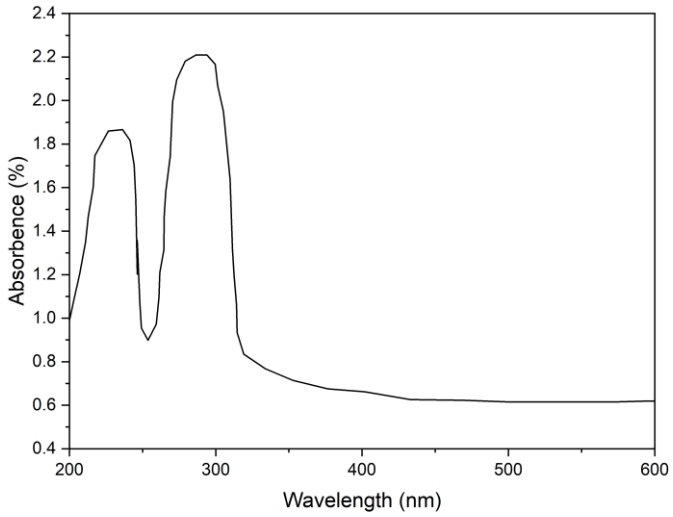

Fig. 3 UV-Visible spectra of Nickel Ferrite

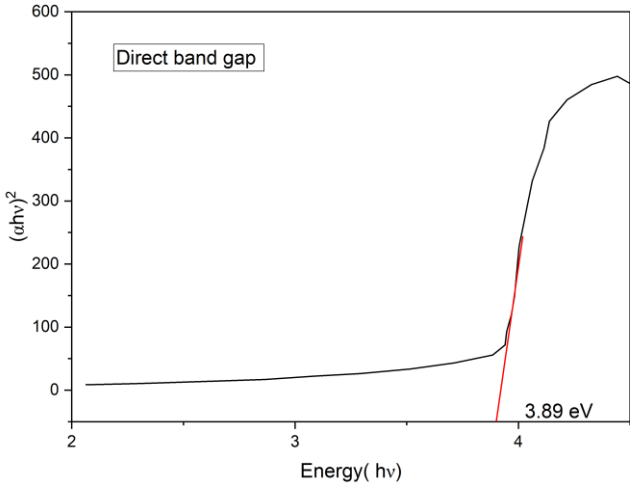

Fig.4 Tauc plot for Nickel Ferrite

3.4 Dielectric properties

Dielectric constant was measured for Nickel nanoferrite in the frequency range of 1 to 9 MHz at room temperature. The dielectric behaviour in ferrites is due to various types of polarization i.e. electronic, ionic, orientational and the space charge polarization and also the dielectric constant is dependent on the method of synthesis, grain size and porosity of ferrites. The dielectric constant is evaluated using the relation,

$$\varepsilon' = Cd/\varepsilon_{\circ}A$$

The dielectric constant as shown in Fig.5 decreases with increase in frequency. There is steep decrease of dielectric constant at lower frequencies and an almost frequency-independent linear behaviour at high frequencies, and agrees well with the Maxwell–Wagner model [19]. Ferrites have inhomogeneous structure and at the grain boundaries, space charge polarization occurs and this effect is pronounced at lower frequency as consistent with Koop's model. The alignment of space charge carriers takes time and at high frequency the dielectric constant decreases.

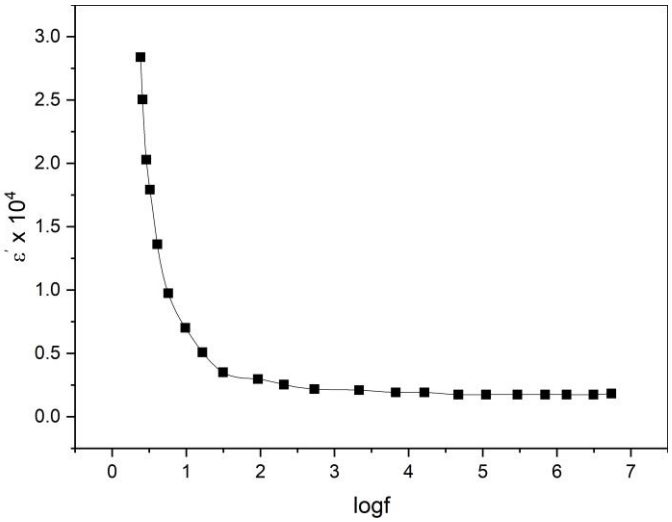

Fig.5 Variation of Dielectric Constant (ε') as function of Logf (frequency)

3.5 AC conductivity

AC conductivity is measured as a function of frequency. The conductivity increases with increase in frequency. The conductivity of ferrites is based on the hopping of the electrons between Fe^{+2} and Fe^{+3} which increases with applied frequency.[20]and is consistent with Koop's phenomenological theory according to which Ferrites have inhomogeneous structure and at low frequencies, the conductivity is due to the grain

boundaries while the dispersion at higher frequencies is due to the conducting grains

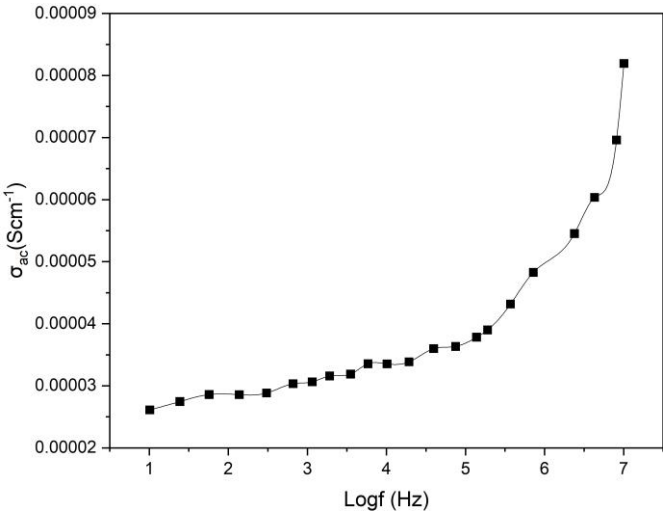

Fig.6 Variation of AC conductivity with logarithmic frequency

IV. CONCLUSION

Nickel Nanoferrite, the inverse ferrite has been synthesized by Solution combustion method and then analyzed for structural and chemical nature withXRD and FTIR. XRD spectra reveals cubic spinel structure and FTIR shows characteristic metal oxygen vibration at tetrahedral and octahedral sites both lying below 1000 cm^{-1}. UV- visible absorption has two peaks in the UV region indicating large band gap energy and by Tauc method the direct optical band gap is evaluated to be 3.89 eV. Dielectric constant decreases with frequency steeply and then becomes independent of frequency at 10^2 Hz and is seen to be linear thereafter and AC conductivity increases with frequency.

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