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Synthesis Structural and Infrared Properties of Nickel Ferrite ($NiFe_2O_4$) Nanoparticles

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ABSTRACT- Nickel ferrite ($NiFe_2O_4$) citric acid assisted neutron diffraction in nanocrystalline form with maximum yield and phase purity was obtained through auto-combustion synthesis. The nanoparticles prepared to form pure phase were sintered at 600 ^oC for 5 hours. In addition, sinuous nanoparticles were characterized by X-ray diffraction (XRD) and spectrophotometers for the structural and infrared spectra, respectively. The room temperature XRD pattern confirmed the formation of single phase with cubic spinel structure of sintered nickel ferrite Nanoparticles. The estimated particle size was found to be 27 nm, through Scherer's formula, which confirms the nanocrystalline nature of the prepared nickel ferrite nanoparticles. IR spectra recorded in range the formation of the spinel structure with two characteristic bands near 400 cm^{-1} and 600 cm^{-1} at 400 cm^{-1} to 1000 cm^{-1} has been confirmed.

Keywords: $NiFe_2O_4$, Neutron diffraction auto combustion, XRD, IR.

INTRODUCTION-

In recent years, nanosized spinel ferrites have gained great importance from the point of view of basic and applied research. Applications of nanocrystalline spinel ferrite have opened up new possibilities in various fields. Like Electronics, information technology, storage media, biomedical, transportation, ferrofluids, etc [1-2]. Spinel ferrites at the nanoscale exhibit novel properties such as superparamagnetism, quantum confinement, single domain structure, high permeability, and chemical stability. The magnetic and electrical properties of spinel ferrite mainly depend on several parameters such as synthesis methods, synthesis parameters, cation distribution, nature and types of dopants and exposure to various radiations.

Recently, the technically important nickel spinel ferrite has attracted considerable research interest due to the need for miniaturization of the electronic devices in which it is employed. It has high power Resistivity, low dielectric loss, good chemical stability etc. which find application in microwave devices, recording heads, antenna rods etc. Nanostructured nickel ferrite exhibits small hysteresis and, therefore, is considered a good core material for power transformers and telecommunications applications. Nanoparticles nickel ferrite is also used in gas and humidity sensing and catalytic applications.

In the last decade, spinel ferrite nanoparticles have been synthesized in several ways, such as, co-precipitation, hydrothermal, solvothermal, sonochemical, reverse micelles, neutron diffraction auto-combustion, etc. Among synthesis methods, combustion synthesis has confounded an important interest in the manufacture of homogeneous, non-agricultural, multi-component metal oxides, as its inexpensive precursors. Short preparation time, slight heating and relatively simple manipulations. The combustion method is based on a mixture of metal nitrates which is an oxidizing agent and acts as a fuel reducing agent.

In the combustion method fuel plays an important role in determining the morphology, grain size and crystal structure and consequently its physical properties. Nowadays, the green synthesis route has emerged as a simple and viable alternative to chemical synthesis methods and physical methods. In this we report, Neutron diffraction auto-combustion synthesis of $NiFe_2O_4$ nanoparticles and their structural and infrared properties.

EXPERIMENTAL

Nickel ferrite ($NiFe_2O_4$) nanoparticles were prepared by neutron diffraction auto combustion method using citric acid as fuel. AR grade chemicals such as nickel nitrate ($Ni(NO_3)_2 \bullet 6H_2O$), ferric nitrate ($Fe(NO_3)_3 \bullet 9H_2O$) and citric acid ($C_6H_8O_7$) was used for neutron diffraction synthesis. The prepared nanoparticles were sieved at a temperature of 600° C for 5 h. Powder X-ray

diffraction pattern of sinuous nanoparticles using Brooker D8 Advance X-ray defractometer with Cu-Kα radiation (λ = 0.15406 nm) to confirm the phase and structure of the prepared nanoparticles. IR spectra were recorded with the help of spectrophotometer in the range of 400 cm^{-1} to 1000 cm^{-1}.

RESULTS AND DISCUSSIONS-

1 X-ray diffraction studies-

The X-ray diffraction pattern of nickel ferrite nanoparticles is shown in fig. 1. X-ray diffraction pattern revealed all permitted cubic spinel structured planes. All peaks of the XRD pattern match well with JCPDS (JCPDS Card no 10-325). Analysis of the XRD pattern also revealed the formation of a single phase compound nanocrystalline nature. Various structural parameters were investigated using XRD data.

The average crystalline size (t) was obtained from Scherer's equation,

$$t = \frac{0.9\lambda}{\beta cos\theta} \quad \text{..... 1}$$

The values of the lattice constant for all, using the values of Bragg's angle 2θ and interplanar spacing d

The composition is calculated using the following relation.

$$a = d\sqrt{h^2 + k^2 + l^2}\ A \quad \text{..... 2}$$

The X-ray density of nickel ferrite nanoparticles was calculated using the standard relation given by the equation,

$$d_x = \frac{Z \times M}{V \times N_A}\ gm / cm^3 \quad \text{..... 3}$$

The bulk density of the current sample was determined using the Archimedes principle. Toluene was used as a liquid medium to measure bulk density. The value of bulk density is given in table 1.

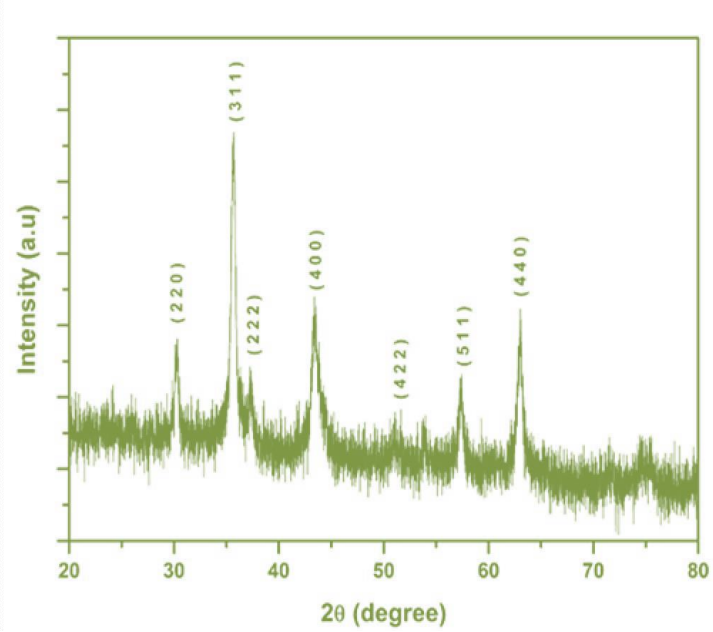

Fig. – 1: X-ray diffraction pattern of $NiFe_2O_4$ nanoparticles

The percentage porosity of the current sample was calculated from the following relation;

$$P = 1 - \frac{d_B}{d_X} \ \% \qquad \text{..... 4}$$

The obtained values of crystallite size (t), lattice constant (a), X-ray density (d_x), bulk density (d_B) and porosity ($P_{\%}$) are listed in table 1.

Table 1 Value of Crystallite size (t), Lattice parameter (a), X-ray density (d_x), bulk density (d_B) and porosity ($P_{\%}$) $NiFe_2O_4$ nanoparticles

Composition	$t_{(nm)}$	$a_{(Å)}$	$d_{x\,(gm/cm)}$	$d_{B\,(gm/cm)}$	$P_{\%}$
$NiFe_2O_4$	27	8.32	5.42	3.76	30.15

2 Infrared studies-

The IR spectrum of the sample was recorded in the range from 1000 cm^{-1} to 400 cm^{-1} which is shown in fig 2. Generally, it is assigned to the vibration of ions in the crystal lattice of the solid. In particular, there are two main broad metal – oxygen bonds that all confirm the formation of spinel oxides. The presence of the peak which is seen at 608 cm^{-1} (Corresponding to the vibrations of the metal stretch at the tetrahedral site (M_{tetra}-O)) and the peak that is seen at 415 cm^{-1} (Relating to the stretching vibrations of the metal at the octahedral site (M_{octa}-O)) proves that the product formed is spinel ferrite.

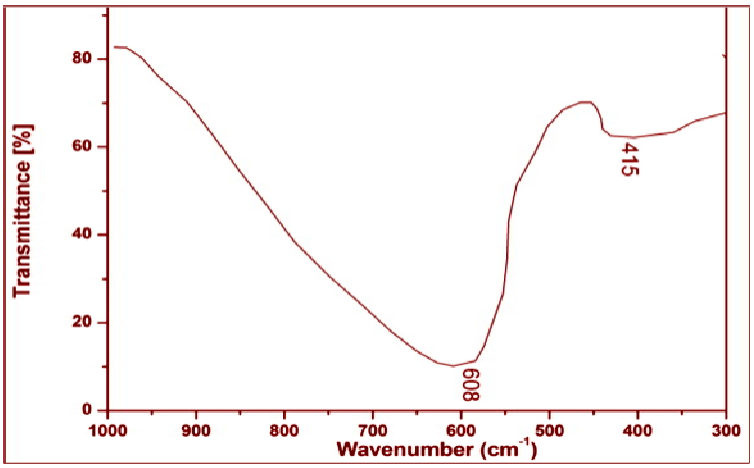

Fig. – 2: IR spectrum of $NiFe_2O_4$nanoparticles

CONCLUSION-

Nickel ferrite nanoparticles were successfully obtained using the neutron diffraction auto-combustion synthesis method. Analysis of the XRD pattern confirmed the pure phase cubic formation and nanocrystalline nature of the prepared nanoparticles. The estimated particle size was found to be 27 nm through Scherer's formula, which confirms the nanocrystalline nature of the prepared nickel ferrite nanoparticles. The IR spectra recorded in the range from 400 cm^{-1} to 1000 cm^{-1} have confirmed the formation of spinel structure with two characteristic bands near 400 cm^{-1} and 600 cm^{-1}

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