Indian Journal of STEAM Vol.01 Issue-01 Sept. 2020

MAGNETIC AND ELECTRICAL PROPERTIES OF NICKEL FERRITES NANOPARTICLES

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Abstract: New research is showing magnetic and electrical conductivity of nickel ferrite ($NiFe_2O_4$). $NiFe_2O_4$ ferrite nanoparticles can be synthesized using the process of molten salt synthesis. X-ray diffraction (XRD), Fourier Transform Infra Red (FTIR), Scanning Electron Microscopy (SEM), and SQUID characterized the as-synthesized $NiFe_2O_4$ ferrite. $NiFe_2O_4$ ferrite phase identification was done using both XRD and FTIR spectra. For ferrite the mixed morphology has been observed. Ferrite has been observed for the soft magnetic behavior. By testing I-V characteristics, the electrochemical efficiency of the $NiFe_2O_4$ ferrite is analyzed. The findings of the electrochemical investigations indicate that the electrical conductivity increases with ferrite.

Key Words: Ferrite, Catalyst, XRD, Electrical, Magnetic.

1. INTRODUCTION

Spinel ferrite nanomaterials (SFNMs), as electric and magnetic nanoparticles, have generated considerable interest in recent years. These are metal oxides with general formula AB_2O_4 spinel composition, where A and B represent various metal cations in the tetrahedral (A) and octahedral (B) positions, at least in the ferric chemical model. A special class of ceramic materials is ferrites. They show ferromagnetic behavior. Ferromagnetic materials experience significant changes in their physical, electrical, and magnetic behavior regarding their macroscopic behavior, especially at nanoscale. The ratio of surface to volume is greater for particles of nano size than for macro particles. Due to ferromagnetic and electrical properties the ferrites have a broad range of applications, particularly when the particle size approaches the nanometer scale.

Due to its soft ferrite character with an inverse spinel structure with low magnetic coercion, high permeability, moderate permittivity in a high frequency region, and high electrical resistivity. $NiFe_2O_4$ has recently attracted considerable attention. Hierarchal $NiFe_2O_4$ has established possible applications in catalysis [1], high frequency electronics [2], gas sensing [3], microwave system components such as phase shifters, tunable signal philtres, more recently in spintronics, and biomedical applications [4]. Because of its induction heating effect, $NiFe_2O_4$ has been used in drug delivery system and hyperthermia therapy. Obviously, the basic specifications of these applications are the tuning of electrical resistivity, soft ferromagnetic properties at room temperature, reduction of power loss due to the eddy current and the material's chemical stability in various environments.

2. EXPERIMENTAL

The $NiFe_2O_4$ catalyst was synthesized with a synthesis of molten salt. In the relevant ratio, AR grade Ni $(NO_3)_2.6H_2O$, Fe $(NO_3)_2.9H_2O$, NaOH, NaCl were dry mix. The powder was then ground for 90 minutes in agate and mortar. Exothermic reaction begins instantaneously. After a few minutes the reaction becomes soggy and the color gradually switches to light red in one minute and the color eventually becomes brown in 10 minutes. The mixture was then rinsed for an hour to 500°C. Subsequently, the mixture was cooled to room temperature and washed with distilled water to extract NO^{3-} and Cl^- ions and unreacted salts. Corresponding qualitative test confirmed the elimination of the above ions. After 4 hours of washing the catalyst was dried in an oven at 80°C.

3. CHARACTERIZATION

Fourier Transform Infra-Red nickel ferrite spectra were reported with vertex 80 FTIR on 3000 Hyperion Microscope. Phase purity and impurity detection of nickel ferrite nanoparticles at room temperature was investigated using Powder X-ray diffraction (XRD) on the Philips (Xpert) X-ray diffractometer using Cu kα wavelength 1.540 Å. Particulate microstructure and morphology were defined by JEOL JSM-7600F FEG-SEM. Catalyst magnetization was tested at room temperature by Quantum Design USA make SQUID device (Model MPMS XL).

4. RESULTS AND DISCUSSION

4.1 Results OF XRD

The nickel ferrite X-ray diffraction pattern is depicted in Figure 1. The pattern confirms structure of single phase cubic spinel. The pattern of XRD shows clearly extended peaks at $2\theta = 29.10$, 34.12, 44.02, 54.34, 55.84 and 61.40. The data was related respectively to the lattice planes (220), (311), (222), (422), (511), and (440). The all diffraction peaks of nickel ferrite were as per JCPDS card number 10-0325. The peak extension may be due to the formation of small crystallites. The constant a given lattice is 9.23 Å and the interplanar spacing d is 2.23 Å. Using Debye Scherer equation (1), the crystallite size was determined using the most extreme 311 value.

$$D = \frac{0.9\lambda}{\beta cos\theta} \quad \text{---------} \ (1)$$

Where D is the size of the crystal, where λ is the wavelength of the X-ray, where θ is the angle of the Braggs in the radians, and β is the full width in the radians at half the limit.
Nickel ferrite 's crystalline size was found to be 41 nm which was useful for nanoparticles' magnetic and dielectric properties.

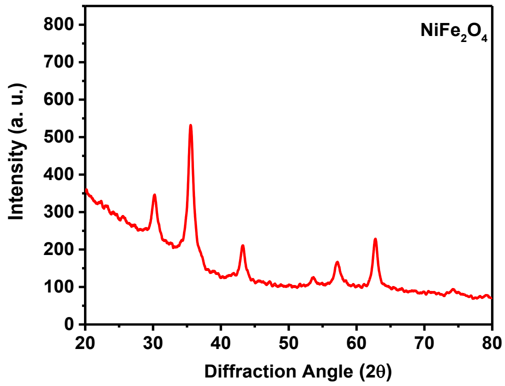

Fig.1: XRD spectra of $NiFe_2O_4$.

4.2 FTIR

Nickel ferrite catalyst spectra from Fourier Transform Infra Red (FTIR) were recorded at room temperature in the range of 400 cm^{-1} to 4000 cm^{-1}. The spectra for the FTIR is shown in Figure 2. The characteristic nickel ferrite peaks were well in line with literature reporting. Two most popular bands at υ_1-583 cm^{-1} and υ_2-432 cm^{-1} were due to tetrahedral and octahedral stretching vibrations respectively [22]. Absorption bands within the range above are indication of the catalyst's single phase spinel structure. The tetrahedral band υ_1 is stronger than the octahedral band υ_2. That observation is a consequence of the first rule of selection. Catalyst peaks and reused catalyst tetrahedral and octahedral position remain unchanged.

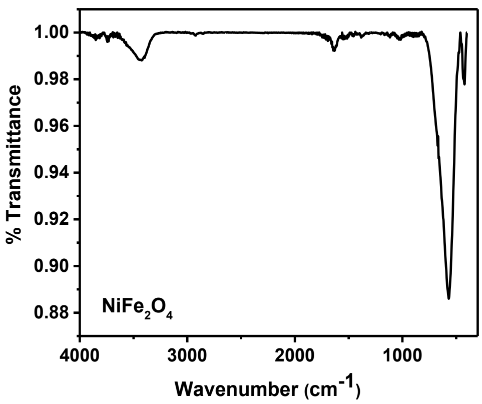

Fig.2: FTIR spectra of $NiFe_2O_4$.

4.3 SEM

Using scanning electron microscopy, the structural and surface morphological analysis of nickel ferrite was carried out. Figure 3 revealed the SEM image of the as-synthesized nickel ferrite nanoparticle. The aggregated and irregular size of the nanoparticles was observed from figure. The more numbers of nickel ferrite nanoparticles are spherical in shape, some small size nanocrystal with a size of 15-20 nm has been deposited on spheres. Some particle growth occurs as expected and has size 60-70 nm. Due to mixed size and form of nanostructures, the large surface area of the sample of nickel ferrites was observed. These areas can improve as-synthesized sample magnetic and dialectical properties.

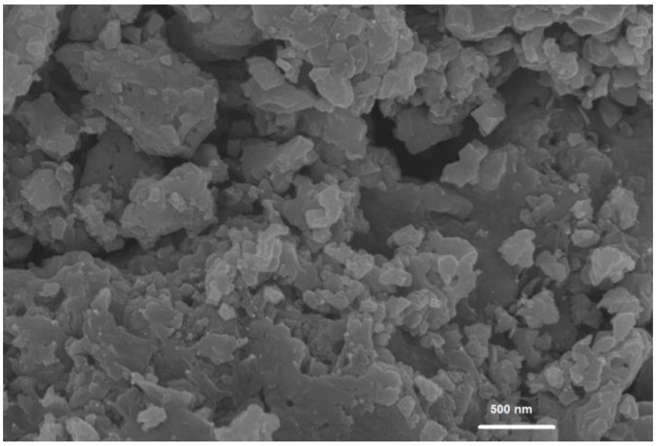

Fig.3: SEM image of $NiFe_2O_4$ nanoparticles.

4.4 MAGNETIC PROPERTIES

Many researchers clarified the importance of magnetic properties of nanoparticles in different fields. In this case, a vibrating sample magnetometer (VSM) was used to analyze the magnetic properties of the Nickel ferrite catalyst at 298K. Figure 4 shows a graph of $NiFe_2O_4$'s magnetic properties. The graph reveals a loop of nickel ferrites with 'S 'shaped hysteresis. From figure, for as-synthesized catalyst, saturation magnetization (Ms), coercivity (Hc) and remanent magnetization(Mr) were determined [5]. Coercivity (Hc), saturation magnetization (Ms), and residual magnetization(Mr) were observed as 64.2082 Oe, 31.0413 Emu / g, and 1.2617. In the inset a slight extension of the hysteresis loop shows the catalyst is soft ferrite. The as-synthesized nickel ferrite catalyst was magnetic and easy for handling.

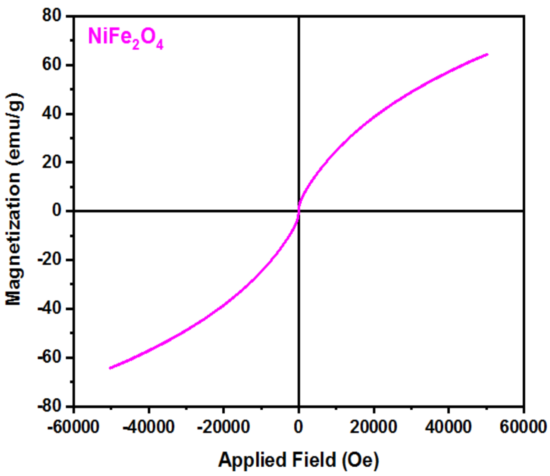

Fig.4: I-V Characteristic Plot of $NiFe_2O_4$.

4.5 ELECTRIC PROPERTIES

The as-synthesized nickel ferrite nanoparticles which were tested for conductivity experiment. For this reason, thin layer of the nickel ferrite was deposited with a spacing of 3 mm in between two parallel plates. The current-voltage (I-V) characteristics obtained at room temperature (RT) in the case of $NiFe_2O_4$ are found to be linear, suggesting ohmic behavior (Figure 5). As the voltage increases the current for $NiFe_2O_4$ nanoferrites catalyst also increases. This increase in the electric properties of nickel ferrites were attributed to the hierarchal morphology, good crystalline size and large surface area.

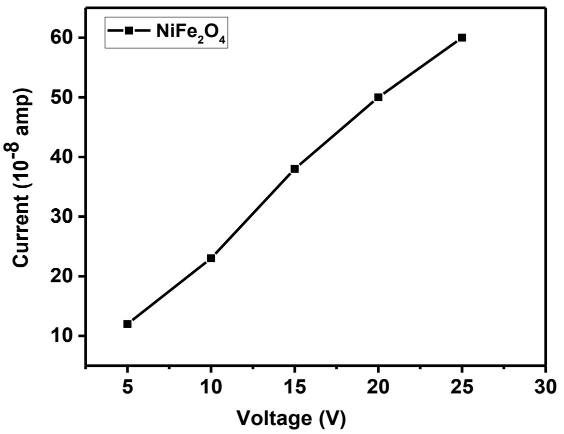

Figure 5: I-V Characteristic Plot of $NiFe_2O_4$.

5. CONCLUSION

The $NiFe_2O_4$ was prepared using the synthesis method of molten salt. Different physicochemical techniques characterized the synthesized $NiFe_2O_4$ ferrite, and tested for electrical and magnetic properties. The ferrite $NiFe_2O_4$ has a cubic spinel structure. Verified phase formation using XRD and FTIR spectra. $NiFe_2O_4$ ferrite's magnetic properties exhibit a gentle nature. The electrical properties of nickel ferrite were further checked and the current- voltage properties of the samples suggest ohmic behavior of the material's electron transport properties.

6. ACKNOWLEDGMENT

All the authors are grateful to Vice Chancellor Dr. Sayali Gankar and to all heads of institutes of D. Y. Patil university, ambi, pune for motivation and support. The special thanks to founder padmashree Dr. D. Y. Patil (Dada), and president honorable Dr. Vijay Patil for providing research facilities at DY Patil University Pune Ambi.

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