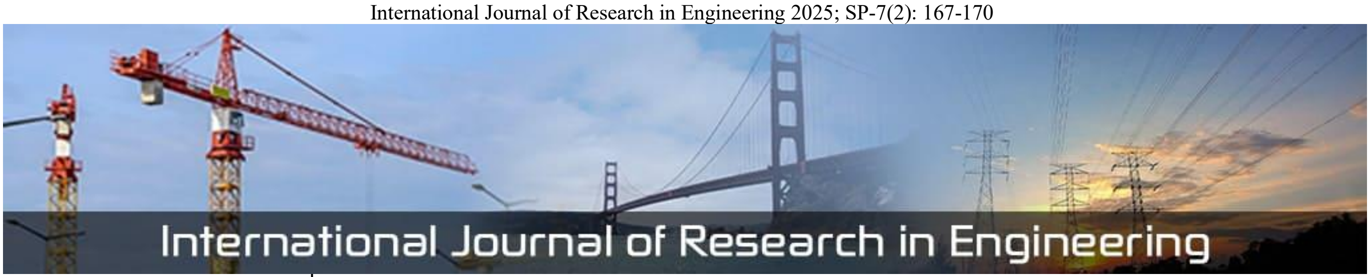

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Synthesis and characterization of nickel ferrite nanoparticles

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Abstract
This paper presents the synthesis and characterization of Nickel Ferrite Nanoparticles. Nickel Ferrite Nanoparticles were synthesized through chemical co-precipitation method. These synthesized Nickel Ferrite nanoparticles have been characterized for structural magnetic properties. Further, these synthesized Nickel Ferrite nanoparticles have been heat treated at high temperature but below melting point to remove volatile impurities and then characterized again for structural properties. The structural change has been observed after heat treatment from amorphous phase to crystalline phase of Nickel Ferrite. The results have been compared and discussed with earlier obtained similar results.

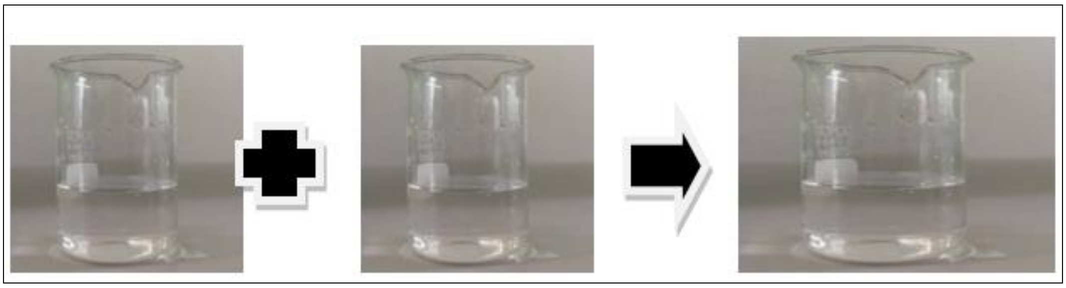
Keywords: Nickel ferrite, nanoparticles, X-ray diffraction, amorphous, crystalline

1. Introduction
In recent years, the ferrites' nanoparticles (NPs) have been studied due to their different technical applications [1-3]. Particularly, a distinct merit of ferrite over other magnetic material such as iron and metallic alloys is their high electric resistivity, sufficiently low dielectric loss over a wide range of frequency, high corrosion resistance, and thermodynamic stability due to which ferrite performs much better at high frequency. Further, spinal ferrite materials have also gained renewed attention because of their important properties and applications like for example the application of highly stable and magnetically recoverable MFe2O4(M = Zn, Co, Mn) spinel ferrite nanoparticles reported as heterogeneous catalysts for the reduction of nitroarenes.[4]. Similarly, the application of zinc and copper ferrites' nanoparticles (NPs) has been investigated as H_2S gas sensors fast response time [5]. Jae Kyeong Han *et al*. reported the MR characteristics of the zinc-doped spinel ferrite ($Zn_{0.417}$ $Fe_{2.583}$ O_4) nanoparticles dispersed in silicone oil [6]. K.Srinivasa Rao *et al*. reported the structural and magnetic properties of cobalt ferrite nanoparticles [7]. Similarly, A.B. Shinde *et al*. reported structural and electrical properties of Cobalt ferrite nanoparticles which were obtained by sol-gel method [8]. The semiconducting nature of the nano-crystalline $Co_{1-x}Ni_xFe_2O_4$ was studied by variation of resistivity and thermal emf with temperature by P.P. Hankare *et al*. [9]. Further, Seema Joshi *et al*. measured the dielectric permittivity, loss tangent, ac conductivity and optical properties of Nickel ferrite nanoparticles which were synthesized by wet chemical co-precipitation method [10]. Similarly, these ferrites' nanoparticles (NPs) have been reported different applications like in sensors, magnetic cards, recording devices, magnetic drug delivery & other biomedical applications, solar cells etc. Out of which Nickel Ferrite Nanoparticles have been of immense scientific interest because of its technologically important electromagnetic properties [1-11]. In this paper, synthesis along with characterization of structural properties of Nickel Ferrite Nanoparticles have been presented.

2. Results and discussions
2.1 Synthesis
There are different synthesis methods to prepare ferrite materials (including nickel ferrite nanomaterials) such as sol-gel process, mechanical alloying, hydrothermal technique and co-precipitation method etc. [4-11]. Out of which, Co-precipitation method is an economical way

for the production of ultra-fine powders. And so, in the present work, Nickel Ferrite is prepared by chemical co-precipitation route using $FeCl_3$, Ni $(NO_3)_2$ and NaOH in appropriate quantity as per chemical reaction. As the process steps shown in Figure (1), firstly the aqueous solutions of Ni $(NO_3)_2$ and $FeCl_3$ made and then in next step, Sodium hydroxide solution was added drop-wise to aqueous solution of Ni $(NO_3)_2$ and $FeCl_3$ with constant stirring.

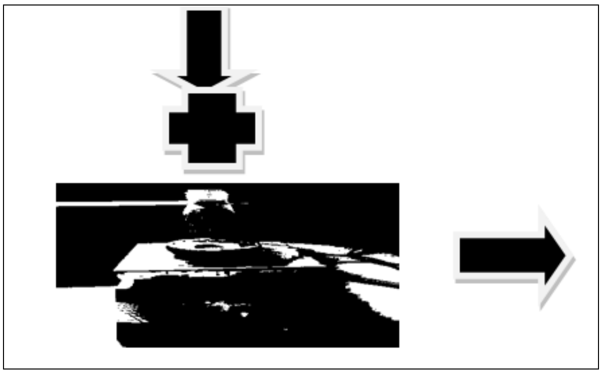
Step 1.



$FeCl_3$, deionized water Ni $(NO_3)_2$, deionized water Aqueous sol. of (Ni $(NO_3)_2$ &$FeCl_3$

Step 2.

NaOH Solution drops



Aqueous sol. of (Ni $(NO_3)_2$ and $FeCl_3$ (with constant stirring)

Precipitate after filtered & washed

Fig 1: Synthesis Process

The resulting precipitate is filtered and washed several times. The precipitation was dried in oven at 80^0C for several hours. Further, it was heat treated at around 850^0C for 11 hours in order to remove volatile impurities.

2.2 Structural Characterization: Structural characterization has been carried out by powder x-ray diffraction (XRD) with the wavelength of CuK_α radiation is 1.544Å. Figure 2 shows the XRD pattern $NiFe_2O_4$ (as synthesized nanoparticle without heat treatment) at room temperature. From this XRD pattern, Figure clearly shows that the synthesized sample at room temperature is almost amorphous in nature.

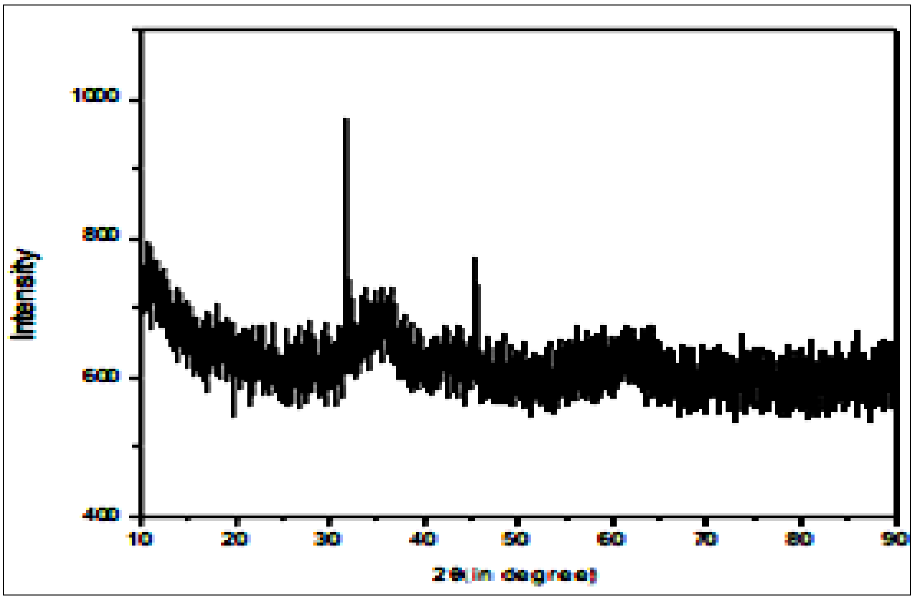


Fig 2: XRD of $NiFe_2O_4$ (as synthesized nanoparticle without heat treatment)

Next, Figure 3 shows the XRD pattern of heat treated synthesized $NiFe_2O_4$ (i.e. synthesized nanoparticle sample with heat treated at around 850^0C). From this XRD pattern, figure clearly shows that the heat treated synthesized sample is converted into a crystalline form after heat treatment which may be demonstrated by sharp peaks with straight line. The peak locations of this XRD pattern is indexed as heat treated synthesized $NiFe_2O_4$ with cubic structure according to the standard JCPDS (Card No. 10-0325

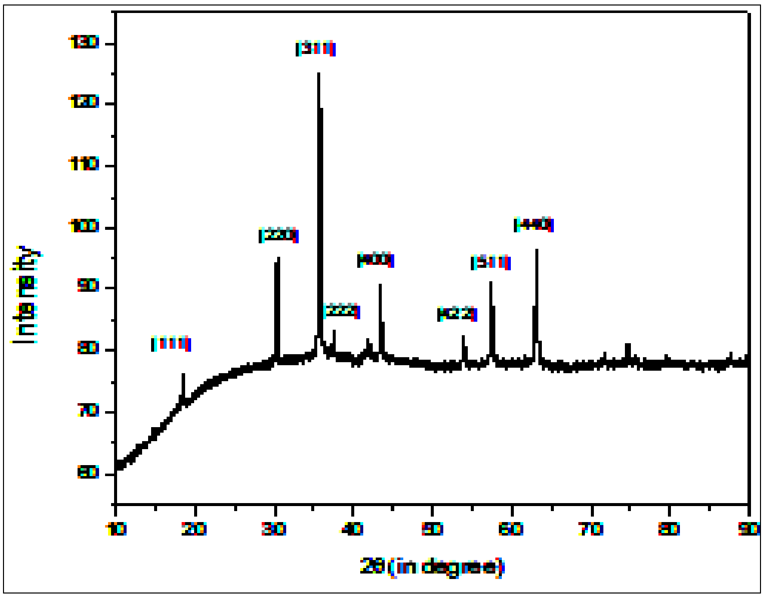


Fig 3: XRD of heat treated synthesized $NiFe_2O_4$ nanoparticle

Further, the average crystallite sizes (D) of heat treated nickel ferrite nanoparticles have been estimated using the Debye-Scherrer's Formula using the highest reflection peak (311) in the XRD pattern, which is comes out to be around ~58 nm. The overall XRD data are found in good agreement and well match at almost same temperature with earlier similar published work in which nickel ferrite nano-particles had been synthesized at low temperature by the sol-gel auto-combustion method [11].

3. Conclusion

Nickel ferrite ($NiFe_2O_4$) nanoparticles were synthesized through chemical co-precipitation method. Additionally, the synthesized Nickel ferrite nanoparticles were heat treated at around 850^0C for 12 hours in order to change its amorphous phase to crystalline phase. Structural characterization had been carried out with the help of X-ray diffraction patterns of the samples before and after the heat treatment. The x-ray diffraction patterns of the samples before heat treatment exhibit no sharp crystalline peak, which is confirming the almost amorphous nature of the sample. The XRD pattern of the sample after heat treatment shows that the synthesized Nickel ferrite nanoparticles has converted from amorphous to crystalline nature. The major crystalline peaks indicate that $NiFe_2O_4$ particles after heat treatment converted in cubic structure. Crystallite size was also calculated using Sherrer formulae from the broadening of the XRD peaks. The results have been compared and discussed with earlier obtained similar results.

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