Structural Morphological Properties of $BaFe_2O_4$ Nano-Particles

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Abstract

Barium ferrite nanoparticle synthesized through low-temperature hydrothermal technique. Synthesized nanoparticle was characterized by X-ray diffraction (XRD) and Field emission scanning electron microscope (FESEM). An average diameter of 10.9 nm is found from X-ray diffraction and the cubic spinel structure. Morphological properties analyzed Field emission scanning electron microscope. The specific surface area of 49.6 m^2/g is obtained for barium ferrite nanoparticle. Elemental percentages and atomic wait estimated with Energy dispersive X-Ray analysis results shown that no secondary rudiments presented.

Keywords: Nano Materials; X ray diffraction; FESEM.

1. Introduction

Barium ferrite nanoparticles are used in the field of magnetic materials, storage devices, transformer sores, and various biomedical applications owing their specialized characteristics of structural and dielectric and optical, surface properties. And, the absorption of electromagnetic wave considered as major application in these days due to electromagnetic interference creates problems to environment and electromagnetic application [1]. Generally, the ferrite named as AB_2O_4 where A tetrahedral occupied site and B octahedral occupied site. The ferrite has 32 octahedral and 64 tetrahedral sites. Each lattice of unit cell contains 16 octahedral sites occupied by trivalent iron atoms and 8 tetrahedral sites occupied by metal divalent atoms [2].

Many researchers have successfully synthesized $BaFe_2O_4$ nano-particles by various synthesis techniques such as co-precipitation [3], sol-gel [4], reactive milling [5], sonochemical [6], solvothermal [7], ultrasonic [8], Thermal decomposition [9], hydrothermal technique [10] to investigate the structural, morphological, properties. But hydrothermal method offers many advantages over the rest of methods such as the low cost for sample preparation, high crystallinity, simplicity and usage of low temperatures [11]. In this investigation additionally dielectric properties, impedance spectroscopic analysis and magnetic permeability properties are explored for as-synthesized nano-particles which have not been reported earlier by a hydrothermal technique.

2. Experimental Procedure

To synthesize $BaFe_2O_4$ nano-particles Ba $(NO_3)_2$ $6H_2O$, Fe $(NO_3)_3$ $9H_2O$ (each of 99.8 % purity, Sigma Aldrich) and NaOH are taken as precursors. Barium and iron nitrates are dissolved in distilled water by a ratio of nitrates (gm): water (ml) as 1:3. The resultant solution is stirred until it gets converted into particle shape. NaOH (gm) is added little to the solution (ml) in 1:4 (NaOH: nitrates) ratio. The p^H of 11 is maintained to the mixture to achieve pure spinel phases. Furthermore, the mixture is vigorously stirred for 2hr and transferred into a 200ml steel autoclave. The sealed autoclave is heat treated at 150^0C for 8hr. After the autoclave is slowly cooled to room temperature. The precursor in the autoclave is filtered, washed with acetone and distilled water for several times till p^H is decreased to 7. Later barium ferrite nano-particles are separated from the autoclave and dried at 60^0C for 6hr. The as-prepared powder is characterized using X-ray diffractometer (Bruker X-Ray Powder Diffraction Meter, $Cu_{K\alpha}$, λ=0.15418nm), Field-emission Scanning Electron Microscope (Ultra 55 FE-SEM Carl Zeiss), to study structural and morphological characteristics.

3. Results and Discussions

3.1. Structural analysis

Fig.1 shows the variation of intensity as a function of angle (2θ) from 10^0 and 80^0 for $NiFe_2O_4$ nanoparticles. The diffractogram pattern of as-prepared sample exhibited single phase formation of a face-centered cubic structure with high crystallinity. The location of Bragg lines with reflections from the planes of (111), (220), (311), (222), (400), (422), (511), (440), (620), (533), (622) and (444). The locations of main peaks are used to find inter-planar spacing (d) of Bragg's lines. Thus, the obtained Ba ferrite nanoparticles are highly pure in phase. The average crystallite size 'D' (8.9nm) is determined from average full-width half maxima (FWHM) of reflection peaks using Debye-Scherrer formula [12].

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

where β is FWHM, λ is wave length of $Cu_{K\alpha}$ source (0.1542nm) and θ is diffraction angle.

The lattice constants (a, b & c) are computed from inter-planar spacing and Miller indices (h k l). Lattice constant found to be as 'a' 0.9nm. X-ray density (4.993g/cm^3) of nanoparticles is calculated from the relation $D_x = ZM/Na^3$, where 'Z' is the no. of molecules per unit cell (Z=8), 'M' is the molecular weight of the composition, 'N' is Avogadro's number (6.023 x 10^{23}) and 'a' is the lattice parameter.

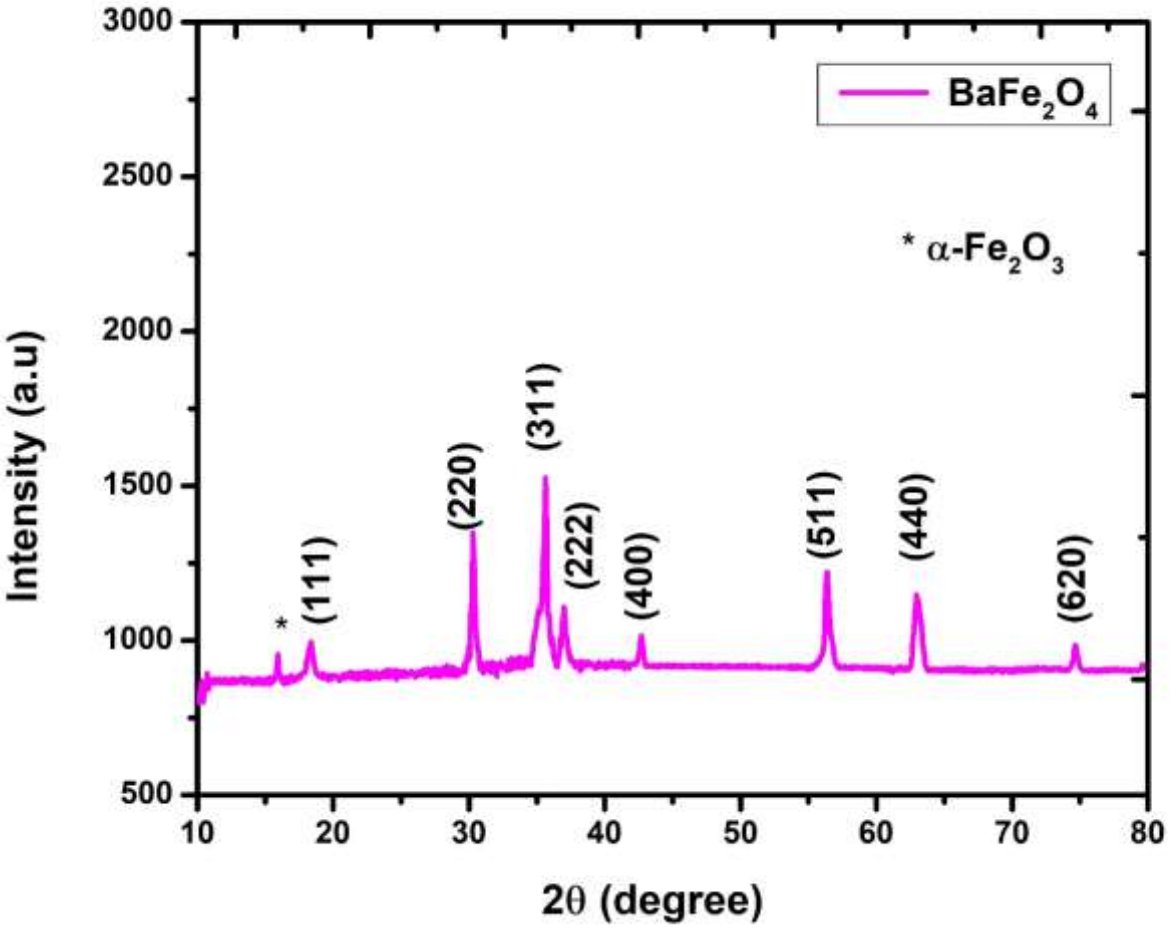

Fig.3.1 XRD diffraction pattern

3.2 Surface Morphology

The FE-SEM photographs reviled surface and morphological data of as-synthesized $BaFe_2O_4$ powder samples are shown in Fig.4. The spherical shape of grains is identified. Average grain size (G_a) is found to be of order 52.5nm using linear intercept method and is given by formule

$$G = \frac{1.5\ L}{MN} \quad \text{_____ (6)}$$

Where L=the total test line length, M=the magnification, N=the total number of intercepts which the grain boundary makes with the line. The photographs seems as the influence of chemical reaction in hydrothermal technique explicates the shape of the grains and rise to the small agglomeration which shows in photographs. The distribution of size 40nm – 60 nm found.

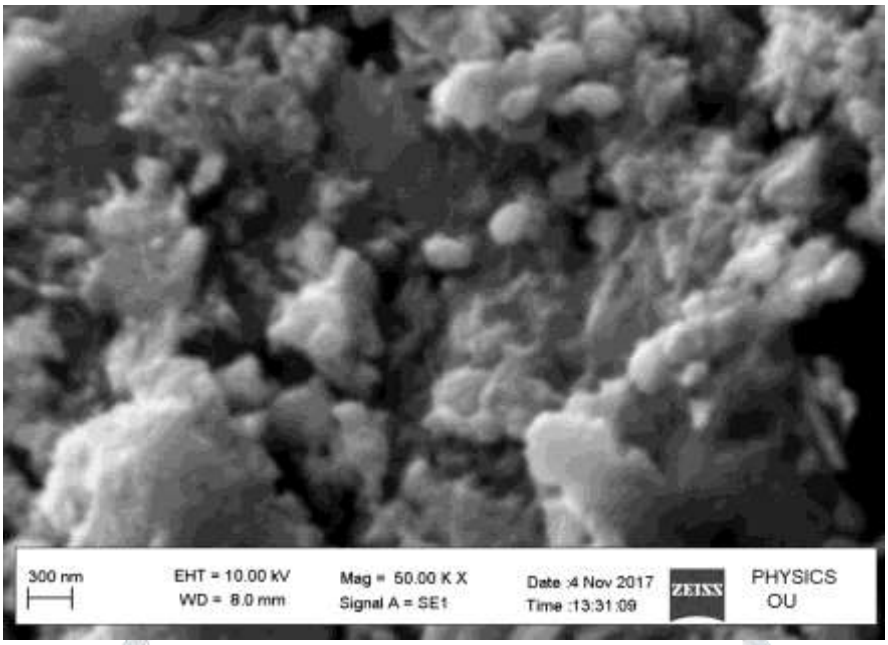

Fig.3.2 FE-SEM image of BF nano particle

3.3. Energy dispersive X-ray (EDX) analysis:

The synthesized composition was introduced to the EDX analysis for taking data of impurities elements presents in the composition. EDX results clear that there are no impurities found in the composition as shown fig 3.3. Individual elemental percentage and atomic wait was presented in the table 3.1. The stoichiometric ratio of as prepared bariuem ferrite is very close to the results given by the EDX. It shows the stoichiometry in the synthesis matches experimental quantity. EDX attributes the inhibited elements and impurities in the samples with their At% and Wt%.

No impurities are noticed in the EDX spectrum once again confirming that the synthesized barium ferrite nanoparticles are pure in nature.

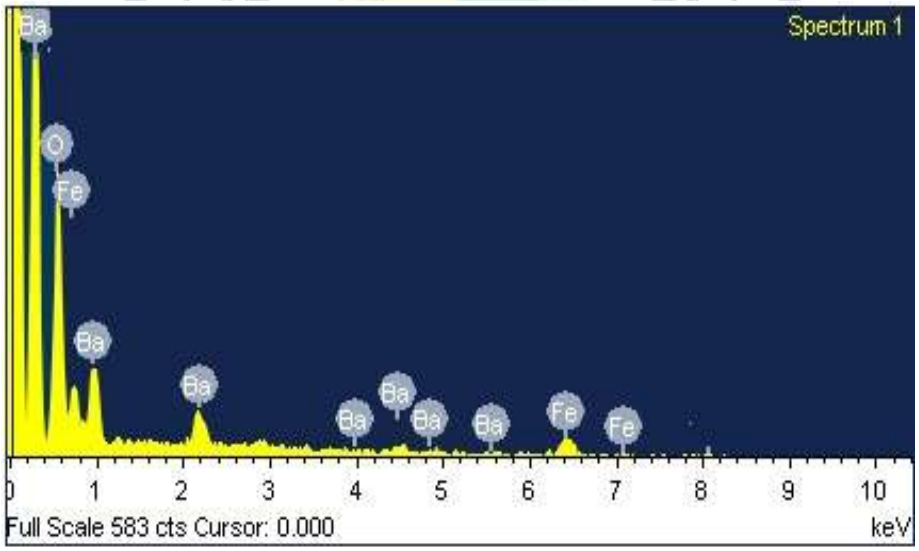

Fig.3.3 EDX analysis of Barium ferrite nanoparticle

Elements	At%	Wt.%
Ba	57.6	24.52
Fe	22.6	31.34

O	19.8	44.14
Total	100	

Table.3.1. Elemental percentages of Barium ferrite nanoparticle

4. Conclusions

The cubic phase barium ferrite (CF) nanoparticles were synthesized via a low temperature hydrothermal approach. The XRD and FESEM raveled as cubic spectra and morphological properties of BF nano particle. The average crystallite size (D) and the related parameters of mixed and single-phase BF nanoparticles were found. The FESEM exhibited the formation of almost homogeneous spherical shaped grains of particles respectively with small agglomeration. EDX characteristics shows their is no any other elements and impurities presented in the samples with their At% and Wt% except bariuem ferrite compositional elements.

5. **Acknowledgements**

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