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EFFECT OF SHOCK WAVES ON HIGHLY STABLE BARIUM FERRITE ($BaFe_{12}O_{19}$) NANOPARTICLES

*J. Bosco Franklin[1], R. Kirubakaran[1], C. Flora[1], Theophil Anand G[1], S. A. Martin Britto Dhas[1] and S. John Sundaram[1]**

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Abstract

Low cost and simple co-precipitation method was involved in preparing Barium Ferrite $BaFe_{12}O_{19}$ (BaFe) Nano particles. The prepared BaFe NPs were calcinated at 800°C through which the phase purity was achieved. The calcinated samples were divided into 3 part and exposed to different number of shock waves, and the effect of shock waves were studied using various analysis like X-Ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), optical absorption studies and Scanning electron microscopic studies. From XRD it is observed that the BaFe NPs have Phase Purity even after shock treatment. FTIR spectrums helped in studying of inter molecular bonds of BaFe NPs. Optical absorption studies found the bandgaps of BaFe NPs 4.9eV, 5.0eV and 5.3eV before and after shock treatments. SEM images determined the structure of BaFe NPs.

Keywords: Barrium, Ferrites, Magnetic behaviors, Shock treatment.

1 Introduction

The applications of Barium Ferrate ($BaFe_{12}O_{19}$) are mainly due to low cost, high Curie temperature and high Coercivity. It can used as oxidising reagent in chemical synthesis and it can remove colour, cyanide bacterial agent and waste water treatment. Ferrites were used in super ion batteries; many form of barium ferrite can be prepared in variety of method. Where Barium belongs to 2A group of S block element and Ferrite is halogen family of p block element which readily react with most of metal and has high electro negativity. Because of ferrites being the transitional metal it show oxidation state and exhibit colour property of d-d transition Fe ($3d^6\,4s^2$) where 4 unpaired electron present in ground state. To production of $BaFe_{12}O_{19}$ the Ba and Fe should be defined molar ratio first and solubility and washing process and finally $BaFe_{12}O_{19}$ compound is obtained [1]. Ferrites have magnetic and electric properties, Whereas Barium ferrate can be produced in different methods like co-precipitation, sol-gel method thermal evaporation. Out of this method co- precipitation method is one of the best methods for production of large amount of nanoparticles in low cost using simple equipment [2]. The synthesized sample ($BaFe_{12}O_{19}$) was made into nanosize which is 10^{-9}m size range in powder form after calcination.

In recent days shocks have been used in many places and some as in orthopaedics. To treat insertion Tendinopathies and used in disintegrate kidney stone and cure soft tissue disorder. It can change the mechanical, electrical and thermal properties of solids [3]. The shock can be low energy (or) high energy shock depending on places it can be used. The prepared sample is given two different number of shock pulses. The shock waves are used for identifying either the phase has been changed or not in the sample and peak shift. Ferrate is polymorphic under high pressure and high temperature. Materials undergo phase change. Some metal like Aluminium, Nickel, Iron and Oxides have polymeric so that the material has specific application. Under high pressure and temperature, it change the phase transform. By applying shock wave to nanoparticles it tends to rearrange themselves such as dislocation, size of the particle may vary. Iron has various forms in nature as that magnetite (Fe_3O_4), maghemite (gamma-Fe_2O_3), Hematite, (alpha- Fe_2O_3) magnate. Under the influence of shockwave structural and molecular stability of Barium Ferrite ($BaFe_{12}O_{19}$) nanoparticles were observed. We have found lot of scope in Fe_2O_3 due to technology impact. Barium ferrite where obtained by co-precipitation method which were used for preparing permanent magnets [4]. When a sample is loaded with shock wave, it undergoes high dynamic pressure, high temperature and stress. This causes changes in physical and chemical properties. After the shock wave the sample shows decreasing the value of Coercivity and grain size [5]. After preparing Barium Ferrate by co-precipitation method it is exposed to shocks of 100 and 150 shock pulses. Shock wave loaded sample can be analysed by various technique like XRD, UV, FTIR and SEM technique.

2 Experimental Sections

*Corresponding author: e-mail johnsundaram@shctpt.edu
[1] Department of Physics, Sacred Heart College (Autonomous), Tirupattur - 635 601, Tamilnadu, India,

2.1. Synthesis of Barium Ferrite (BaFe) Nanoparticles;

Barium Nitrate ($Ba(No_3)_2$) and Ferric Nitrate Nonahydrate $Fe(NO_3)_3 \cdot 9H_2O$ in the ratio of 1:12 were mixed to get Barium Ferrite $BaFe_{12}O_{19}$ (BaFe). In a beaker the precursor of Barium and Ferrite [$(Ba(No_3)_2)$ and $Fe(NO_3)_3 \cdot 9H_2O$] were added in ratio 1:12 to form 50 ml of homogeneous solution . Under constant stirring Ammonium solution was added so that brown colour precipitation is formed. The precipitation was washed 3 times with water and 4 times with ethanol in order to remove impurities. The washed sample was dried in hot air oven at 100°C for 24 hours. The dried sample was made into fine powder using mortar and pestle, and then the powdered sample was calcinated at 800°C for 2 hours. The calcinated powder is labelled as BaFe control nanoparticles and used for further studies.

2.2.Shock wave loading

We use an automatic shock tube to generate the shock waves. It consists of three sections such as Driver section, Diaphragm section and Driven section. The synthesized BaFe nanoparticles were exposed to different shock waves at 2 MPa pressure and temperature 864 K with a 2.2 Mach number. The sample that has to expose to shock pulses was hold by sample holder which placed 1cm apart from open end of driven section [6]. The control BaFe was made into 3 parts where 2 of them were exposed to different numbers of shock pluses such as 100 shock pulses and 150 shock pluses. Finally the samples labelled as BaFe 100 and BaFe 150 respectively.

3 Results and Discussion

3.1. POWDER X-Ray Diffraction;

Powder X-Ray Diffraction (XRD) technique was used to analysis the structural change in sample after the impact of shock wave [7]. XRD pattern of Barium Ferrite ($BaFe_{12}O_{19}$) nanoparticle was shown in Figure 1. The sharp peak depicts that the formation of good crystalline quality of the prepared sample. The plane (1 0 6), (0 0 8), (1 0 7), (1 1 4),(2 0 2) (2 0 3), (2 0 5), (1 0 10), (2 1 4) and (1 0 13) of BaFe corresponding to hexagonal structure (a=b≠c). All the planes matches with JCPDS card no # 84-0757 [8]. The grain size of nanoparticle was estimated using Debye Scherer formula.

$$D = \frac{k\lambda}{\beta cos\theta} \quad (nm)$$

Where,
D= Grain size or crystallite size (nm),
K = Scherrer constant,
λ= wave length of X-ray used,
β- Full width Half maximum (FWHM) (in radian)
θ- Bragg's angle (deg).

The diffraction pattern shows that the sample subjected to shock has crystalline nature. Comparing to BaFe control NPs, the emphasis explicitly that the test material is stable even after 100 shocks. It demonstrates the periodic arrangements of atomic lattice plane are not affected even after number of shock

The crystallite size is found to be 47 nm for BaFe control and for the 100 and 200 shocks crystallite size slightly increases to 48 nm and 48 nm respectively. Hence, from the XRD peaks it is found that when the shock pulse increases the crystalline size also increases [9].

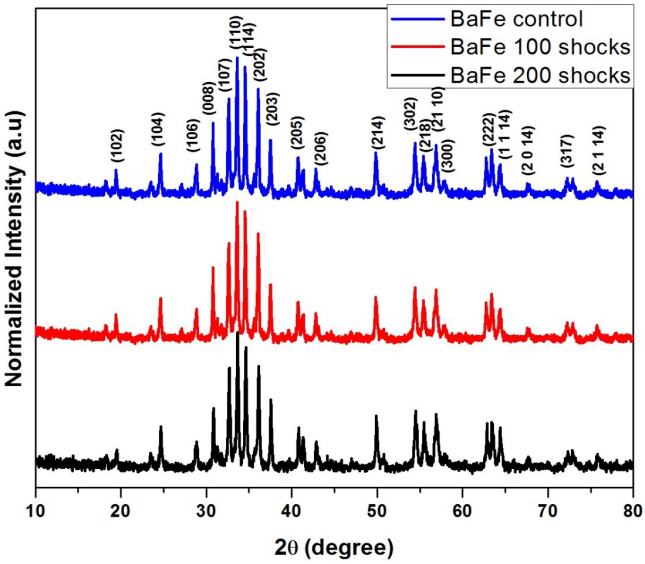
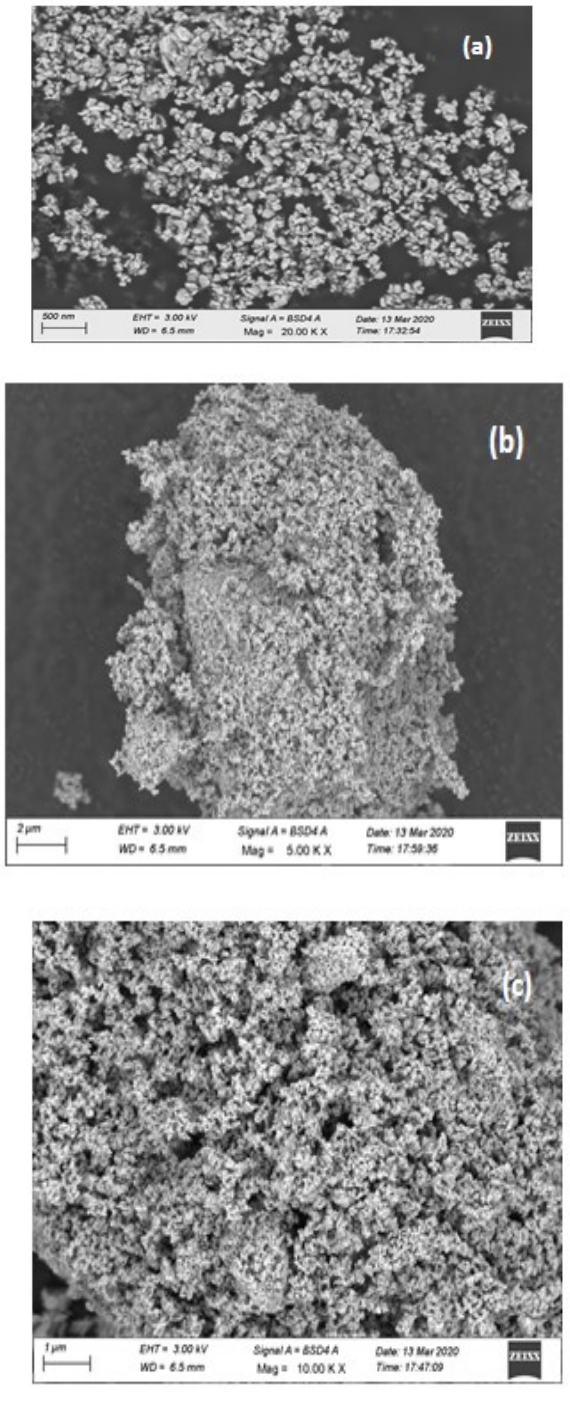


Fig 1: powder XRD patter of BaFe control and shock loaded BaFe

3.2. Morphology Analysis;

SEM is used to study morphological changes occurred after shock pulse loaded condition [10]. The SEM image of BaFe control is shown in the Fig 2; (a) and it is observed that the particles arranged unevenly separated particles. Fig 2; (b) and (c) show the images of shock loaded BaFe 100 and BaFe 200 samples respectively. After the shock treatment it is observed that the formation of agglomeration in BaFe 100 the particles reduced and they got compressed. Due to repeating shock pluses the particle again becomes separate, this may due to rearrangement of atoms and they don't have a defined structure.



Figure; 2 shows Scanning Electron Microscopic images of BaFe Control (a) and, shock loaded samples BaFe 100 shocks (b) and BaFe 200 Shocks (c).

3.3.FTIR(Fourier Transform Infrared Spectroscopy)

FTIR analysis used to identify the presence of molecular bonds in the material. In this present work to determine the effect of shock waves in those bonds was analysed. The FTIR were recorded between 400 cm^{-1} to 4000 cm^{-1} for Barium Ferrite (BaFe) [11]. Fig 3 shows the FTIR spectrum of BaFe Control and Shock loaded BaFe NPs. FTIR spectrum reveals bands for metal oxide stretching which ranges from 573.23 cm^{-1} to 747.145 cm^{-1}[12]. The band at 1450 cm^{-1} is due to carbonate groups. From the FTIR spectra it is noted that there was not much shift even after 200 shocks. This shows that shock waves do not affect any of the molecular bonds in Barium Ferrite nanoparticles.

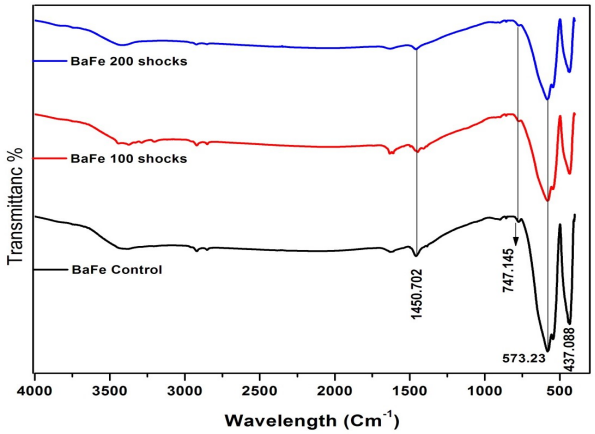


Figure 3 shows the FTIR spectra of BaFe Control and, shock loaded samples BaFe 100 shocks and BaFe 200 Shocks.

3.4. Optical absorption studies;

Optical absorption properties of the BaFe NPs have recorded using UV Visible spectroscopy. The prepared material was dispersed in water, and that solution was taken to record the absorption of BaFe NPs.

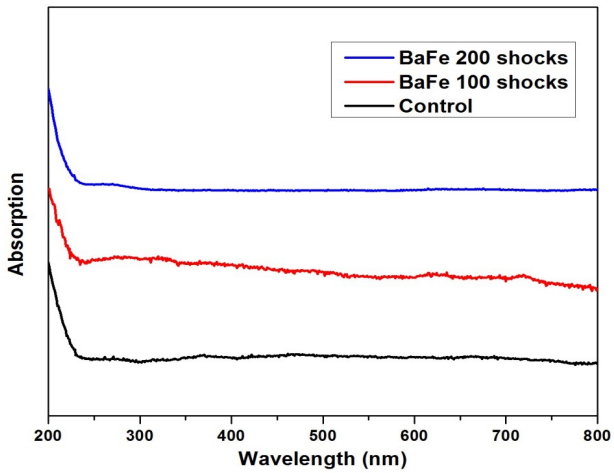
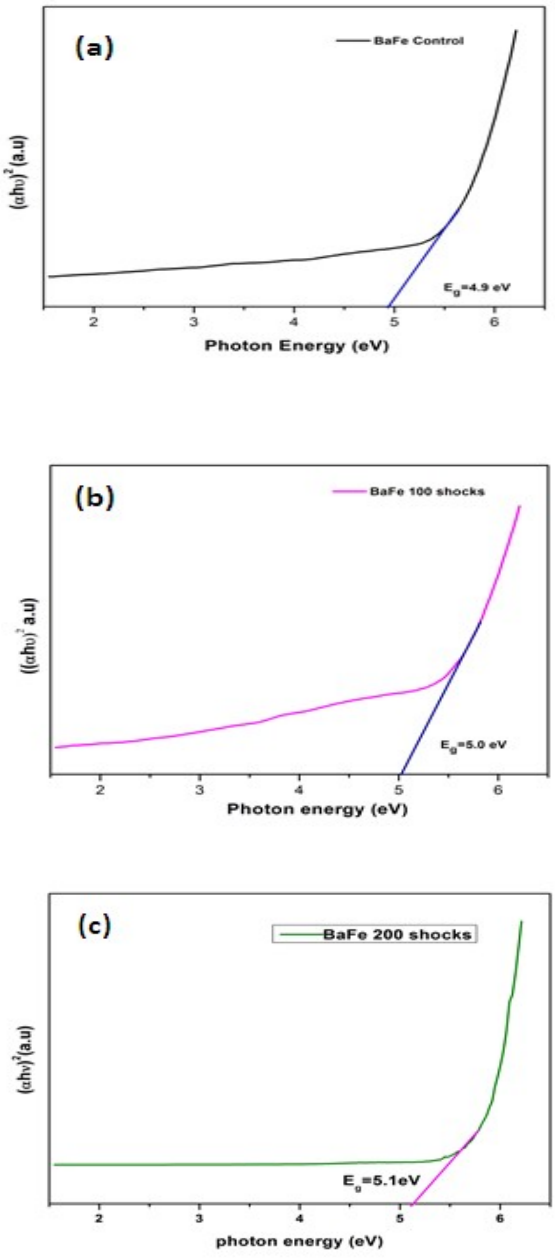


Figure 4; Shows the optical absorption spectrum of BaFe Control and, shock loaded samples BaFe 100 shocks and BaFe 200 Shocks.

From Fig 4 it is found that BaFe NPs have low absorption in UV visible spectroscopy. Bandgap of these samples were calculated using Tauc's formula [13],

$$\alpha h\nu = C(h\nu - E_g)^{n/2}$$

Where E_g is the Photon energy, α is the absorption coefficient, $h\nu$ is the photon energy and C is constant relative material. The Tauc plots of BaFe control and shock loaded BaFe 100 and BaFe 200 was given in the Fig 5;



Figure; 5 shows the Tauc plots of BaFe control, BaFe 100 shocks and BaFe 200 Shocks.

From these plots the band gaps of BaFe control, BaFe-100 and BaFe-200 were determined as 4.9eV, 5.0eV and 5.3eV respectively. This shows that the energy gap of the BaFe NPs increases with increasing number of shock waves.

4.CONCLUSION

In summary the nanocomposite of Barium Ferrite ($BaFe_{12}O_{19}$) were synthesised by co-precipitation method. The material exposed to different shock treatments. XRD pattern confirms the formation of Barium Ferrites and BaFe NPs does not changes their phase even after shock treatment it shows that the BaFe NPs has stabled phase and the crystallite size increases with increasing number of shock wave. From FTIR spectroscopy it is observed metal oxide stretching at 573.23 $cm^{-1}$and 747.145 cm^{-1}. Shock wave doesn't affect the molecular bonds of BaFe NPs. From optical analysis it is clear that the energy gap increases with increasing number of shockwaves. SEM image shows undefined agglomerations before shock treatment and after shock treatment the gaps between the particles disappears, they compressed together. From these studies it is clear that BaFe NPs were affected by shock treatment.

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