Synthesis of bismuth ferrite nanoparticles by microwave irradiation

Azadeh Tadjarodi*, Fatemeh Shahrab

Research Laboratory of Inorganic Materials Synthesis, Department of Chemistry,
Iran University of Science and Technology
(E-mail: tajarodi@iust.ac.ir)

Abstract:

Magnetic bismuth ferrite nanoparticles were prepared by microwave method. We used Iron (III) nitrate nonahydrate, bismuth nitrate as initial reagents, glycine as an organic template and ammonium nitrate as co-oxidizer. This solid phase reaction was done under microwave radiation with the power of 900 W for 20 minutes. After the treatment, the result compound washed with distilled water and ethanol and dried at 70°C. This method has advantages such as simple, fast, reduces energy and environmental friendly. The product was characterized by Powder X-ray diffraction (PXRD), Scanning electron microscopy (SEM), Fourier transform infrared (FT-IR) and vibrating sample magnetometer (VSM). Also, the adsorption behavior of congo red as an organic pollutant was evaluated.

Keywords: Microwave, Nanoparticles, Bismuth ferrite, Glycine, Congo red

1. Introduction

Multiferroics are compounds that showing magnetic and ferroelectric properties together at room temperature. This coupling increases their applications in emerging field of spintronics, photonic devices, electronic devices, nono volatile memories , recording devices, magnetocapacitive devices, sensors, etc [1-4]. Among all multiferroic materials, Bismuth ferrite has attracted a great deal of attention because of photocatalytic properties.

Due to the wide range of applications, bismuth ferrite has been synthesized using different methods such as hydrothermal synthesis [5], polymer-assisted hydrothermal synthesis [6], microwave–hydrothermal synthesis [7], microwave induced solid-state decomposition [8], sol–gel process [9], sonochemical [10], co-precipitation [11] and etc. Solid state synthesis is one of the most useful routes for preparation of bismuth ferrite. Using microwave radiation in solid state synthesis points many advantages such as versatile, simple and rapid process, and also allows effective synthesis of a variety of nanosize materials. Herein, we report a fast, simple and clean method to the synthesis of bismuth ferrite whit microwave assisted combustion in solid state.

Nanoparticles bismuth ferrite characterized by X-ray diffraction (XRD), Scanning electron microscopy (SEM), Fourier transform infrared (FT-IR) and Vibrating sample magnetometer (VSM).

2. Experimental

2.1 Synthesis nanopowder $BiFeO_3$

All of chemicals were purchased from Merck Co. and used without further purification. To prepare nanopowder $BiFeO_3$, analytical-grade starting materials include bismuth nitrate [$Bi(NO_3)_3.5H_2O$] and Iron nitrate [$Fe(NO_3)_3.9H_2O$] with the molar ratio of 1:1 and also glycine and ammonium nitrate ($(NH_4)(NO_3)$, 99%) with the molar ratio of 1:2 as a fuel and organic driving agent were used. The mixture was transferred into crucible with jacket of CuO layer in around and placed under microwave radiation with power 900 W for 20 min. The result compound washed with distilled water and ethanol and dried in an oven at 70°C for12 h.

2.2 Adsorption experiment

25 mL the congo red as a pollutant with the different concentrations (ppm) and 0.025 g $BiFeO_3$ powder was stirred in dark for 3 h. In appropriate interspace times, about 5 mL of suspenseons were analyzed for UV-vis absorption at 200-800 nm.

2.3 Characterization techniques

Fourier Transform Infrared (FT-IR) spectrum was recorded on a Shimadzu-8400S spectrometer in the range of 400–4000 cm^{-1} using KBr pellets. In order to investigate the crystal structure, we used X-ray powder diffraction (XRD) with Cu–Ka radiation. The powder morphology was observed by a scanning electron microscope VEGA\TESCAN S360 with gold coating. Also vibrating Sample Magnetometer (VSM) and the UV-Vis absorption in the wavelength range of the 190–800 nm on a UV-Vis spectrometer (ShimadzuUV- 1700) were used.

3. Results and Discussion

FT-IR spectrum of the bismuth ferrite nanoparticles shows two strong absorptive bands about 560 and 440 cm^{-1} that attributed to O–Fe–O and Fe–O stretching vibrations of FeO_6 groups in the perovskite compounds (Fig. 1) [10].

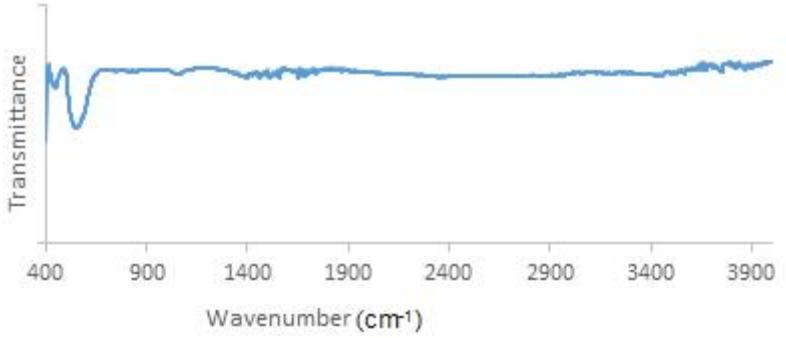

Fig.1 FT-IR spectrum bismuth ferrite nanoparticles

The XRD patterns of bismuth ferrite nanoparticles were shown in Fig. 2 and confirms the formation $BiFeO_3$ phase, matching with the crystalline system of phase rhombohedrally distorted pervoskite structure (ASTM card No.01-086-1518).

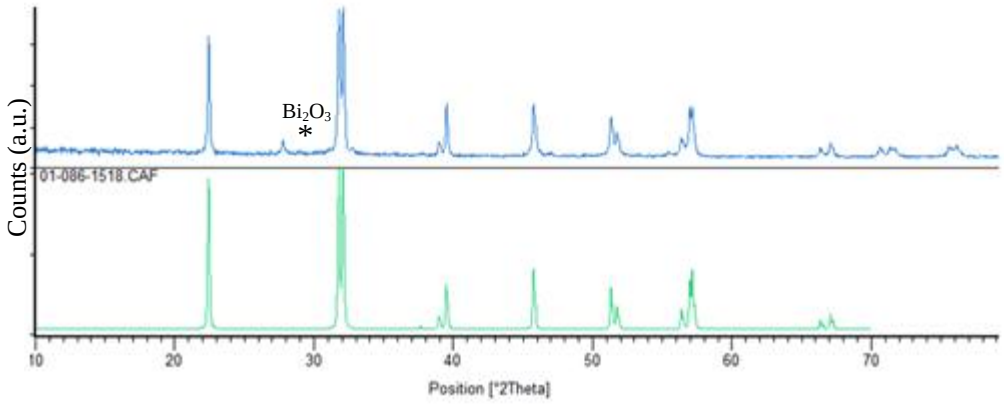

Fig.2 XRD patterns of bismuth ferrite nanoparticles

Fig.3 indicates scanning electron microscopy image of bismuth ferrite nanoparticles with average size about 65 nm and a porous structure.

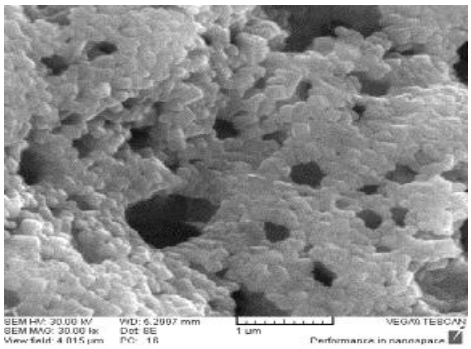

Fig.3 SEM image of bismuth ferrite nanoparticles

The magnetic property of bismuth ferrite nanoparticles was determined by vibrating sample magnetometer (VSM). Figure 4 shows an S-like shape at room temperature with specific saturation magnetization (Ms) amount of 0.66 emu/g. Therefore, bismuth ferrite nanoparticles are soft magnetic material.

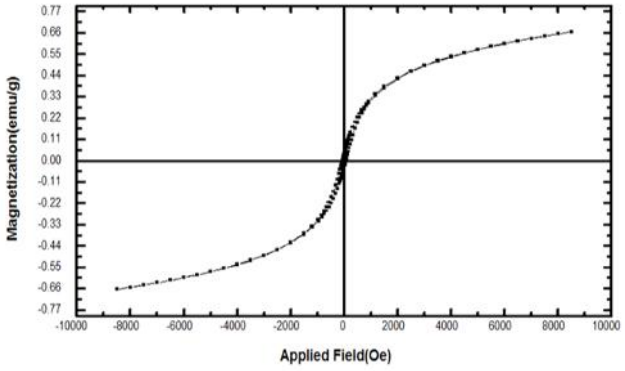

Fig.4 VSM of bismuth ferrite nanoparticles

Adsorption behavior of congo red dye as a pollutant was evaluated. We used 25 mL the congo red with the concentration 10- 500 ppm and 0.025 g $BiFeO_3$ powder in each experiment.
The adsorption isotherms of Langmuir and Freundlich were used to evaluate the adsorption process:

$$\frac{C_e}{q_e} = C_e\left(\frac{a_L}{K_L}\right) + \left(\frac{1}{K_L}\right)$$

$$\text{Log } q_e = \text{Log } K_F + \frac{1}{n} \text{ Log } C_e$$

q_e (mg/ g) is the amount of congo red adsorbed at the equilibrium, c_e (mg/L) is congo red concentration in solution and a_L (L/ mg) and K_L(L/g) are the Langmuir constants. Also K_F and n are constants isotherms of Freundlich.
The mechanism of absorption Langmuir and Freundlich for nanoparticles $BiFeO_3$ is shown in Fig. 5. The correlation coefficients (R^2) shows that mechanism of absorption has good accordance to Langmuir model.

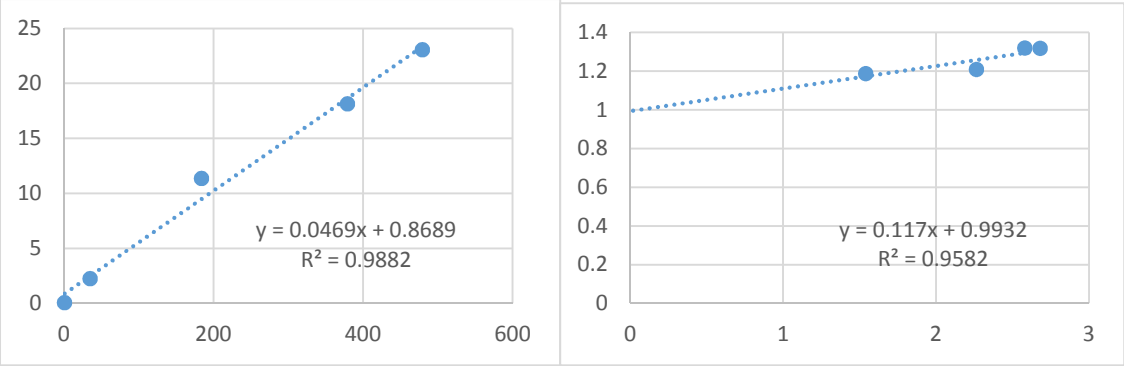

Fig. 5 Adsorption isotherms of Langmuir (a) and Freundlich (b) of the synthesized $BiFeO_3$

Conclusions

In this work, magnetic $BiFeO_3$ nanoparticles were synthesized by microwave irradiation in power 900 W for 20 min. This procedure is simple, low-cost, safe and suitable for preparation of industrial perovskite phase $BiFeO_3$ nanoparticles in electromagnetic applications. The size of obtained $BiFeO_3$ nanoparticles were about 65nm and specific saturation magnetization (Ms) amount of 0.66 emu/g. It should be noted that bismuth ferrite nanoparticles exhibited good absorption for congo red dye as a pollutant.

References

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