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Auto-combustion Preparation and Characterization of $BaFe_2O_4$ Nanostructures by Using Lemon Juice as Fuel

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ABSTRACT

In this work, barium monoferrite nanoparticles have been successfully synthesized *via* a simple sol-gel auto-combustion method. The synthesis was based on the reaction between $Ba(NO_3)_2$ and $Fe(NO_3)_3$ in aqueous medium, in present of lemon juice as surfactant and fuel agent. The products were characterized by X-ray diffraction, scanning electron microscopy, and photo luminescence techniques. Effects of lemon juice amount and the temperature have been investigated to achieve an optimal condition. It was found that the phase and morphology of products could be seriously influenced by these parameters. Vibrating sample magnetometer (VSM) was used to study the magnetism properties of $BaFe_2O_4$ samples.

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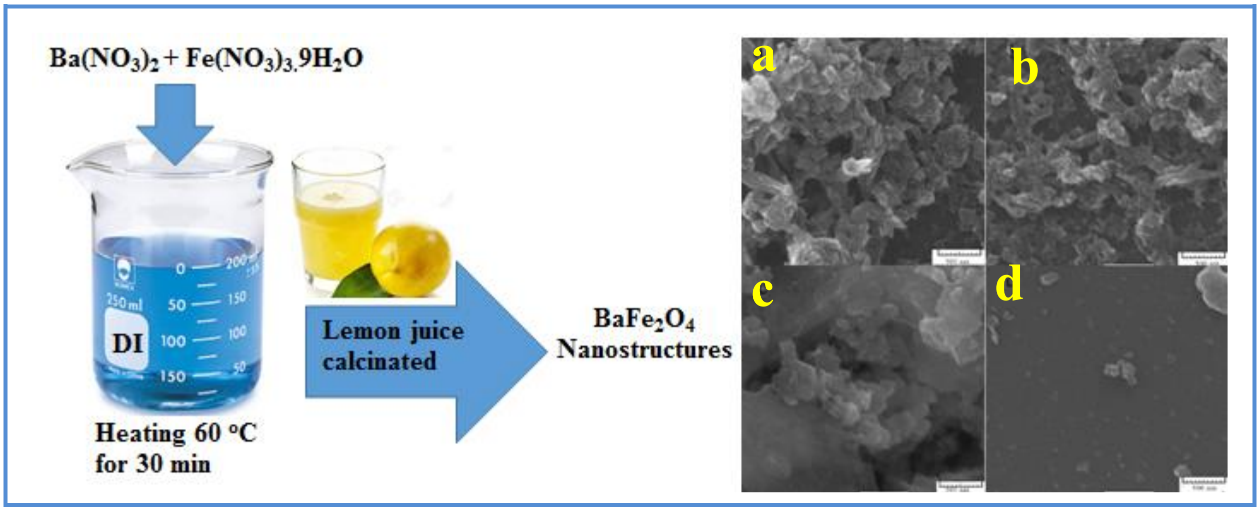
Graphical Abstract



Introduction

Nanomaterials have been broadly investigated for the fundamental scientific and technological interests in order to access new classes of functional materials possessing unique properties and applications [1-5]. During recent years, nano ferrites have been intensively pursued because of their special physical properties and potential application in various areas [6, 7]. $BaFe_2O_4$ can be used as military applications, data storage device, medical diagnostics, radar systems and silent room [8, 9]. These materials are the most commercially important magnetic materials because of not being easily substituted by other magnets. In comparison to $BaFe_2O_4$ bulk, its nanostructures have different magnetic and electrical properties that can be controlled. The relation of the magnetic properties with size of the nanomaterials has been shown in prior studies [10-15].

Various methods, e.g., citrate gel combustion method [16], hydrothermal [17], polymeric precursor method [18] and some other methods have been used for preparing nano-sized $BaFe_2O_4$ particles. Accordingly, the aim of the present work was to assess and optimize the effects of important operating parameters influencing the dimensions of $BaFe_2O_4$ nanostructures by sol-gel auto-combustion method using lemon juice as surfactant and fuel agent.

Experimental

Materials and methods

All the chemical reagents used in our experiments were of analytical grade, and purchased from Merck. $Ba(NO_3)_2$ and $Fe(NO_3)_3.9H_2O$ were used as starting materials. The molar ratio of Ba^{2+} to Fe^{3+} was fixed at 2. The mixtures of barium nitrate and ferric nitrate solutions in the presence of lemon juice (1.5:1; 3:1; 6:1 lemon juice/nitrates molar ratios) were heated up to 60 °C for 30 min under sonication to form a clear aqueous solution. The white precipitate was calcinated at different temperatures of 600 °C, 700 °C and 800 °C for 2 h (Table 1). The products were characterized by XRD, SEM and VSM.

The magnetic characteristics of nanoparticles, at room temperature, were investigated with a magnetometer instrument (Meghnatis Daghigh Kavir Co.; Kashan Kavir; Iran) by scanning the magnetic field between ±10000 Oe. The XRD patterns were acquired using a Philips, XRD instrument with a Ni-filtered CuKα radiation. The SEM images were recorded using a LEO 1455 VP instrument after coating a very thin layer of Pt (using a BAL-TEC SCD 005 sputter coater) on the samples, to induce conduction to the sample surface, prevent charge accumulation, and help obtain improved contrast.

Results and Discussion

The effect of the molar ratio of lemon juice to nitrates on the size of the products was shown in Figure 1. and the result was presented in Table 1. The sample which was prepared without lemon juice (Figure 1a) was defined as the bulk sample. The related SEM image shows particles with size of 150 nm (Figure 1a). The molar ratio of lemon juice to nitrates of 1.5 was the minimum amount of lemon juice needed to attach metal ions under the assumption that metal ions substitute the hydrogen from –COOH groups in lemon juice. When this ratio was 1.5, the citric acid molecules in lemon juice as chelating agent could orient in different directions, hence, the obtained particles had little opportunity for connection together and average particle size was obtained about 80 nm (Figure 1b). In ratio of 3 (Figure 1c), chelating agent had been arranged as solid structures, in order to collision possibility of the particles had become further and the particles size of the powders increased to approximately 120 nm. By increasing this ratio to 6 (Figure 1d), steric hindrance around particles was been more and the size of particles is being smaller (100 nm).

Table 1. The preparation conditions of the $BaFe_2O_4$ nanoparticles

Sample No.	Lemon juice/nitrates molar ratios	Calcinations temperature (°C)	Product size (nm)	Morphology
1	-	-	150	
2	1.5	-	80	
3	3	-	120	
4	6	-	100	
5	1.5	700		star-like
6	1.5	800		rod-like

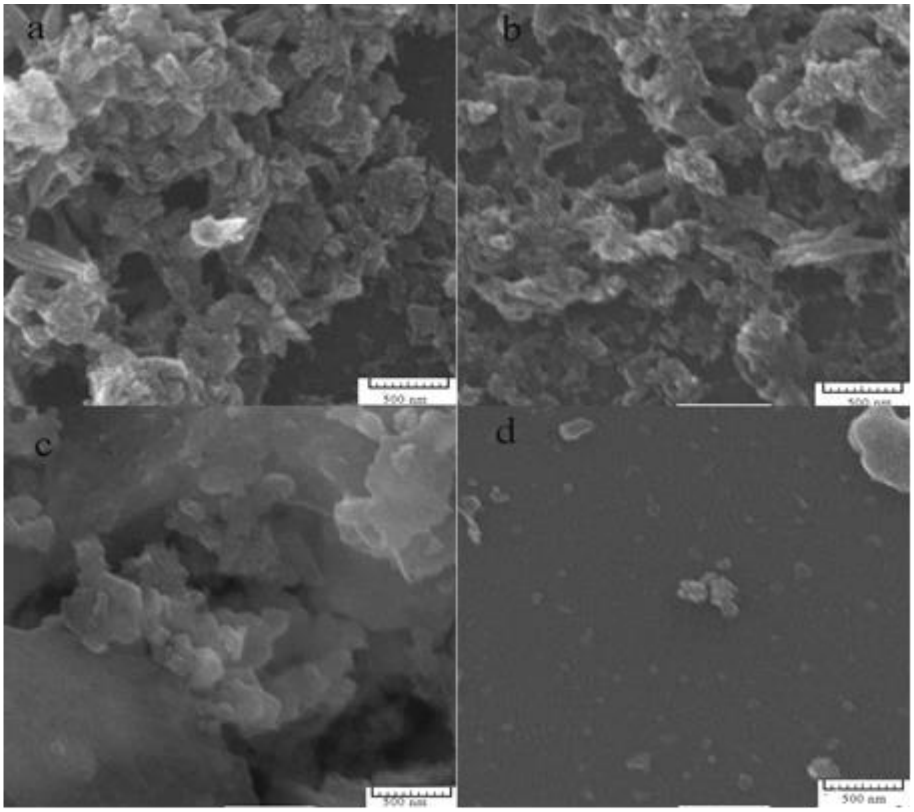


Figure 1. SEM images of $BaFe_2O_4$ prepared using different ratio of lemon juice; (a) 0.0, (b) 1.5, (c) 3 and (d) 6

Figure 2. show SEM images of samples as synthesized at calcinations temperature 700 and 800 °C *via* sol-gel method in the presence of lemon juice (molar ratio 1.5). In the calcination temperature of 700 °C star-like nanostructures were shaped (Figure 2b). The morphology of as-prepared products was changed from star-like nanostructures to rod-like nanostructures when calcinations temperature was 800 °C as exhibited in Figure 3a. it was due to the presence of lemon juice.

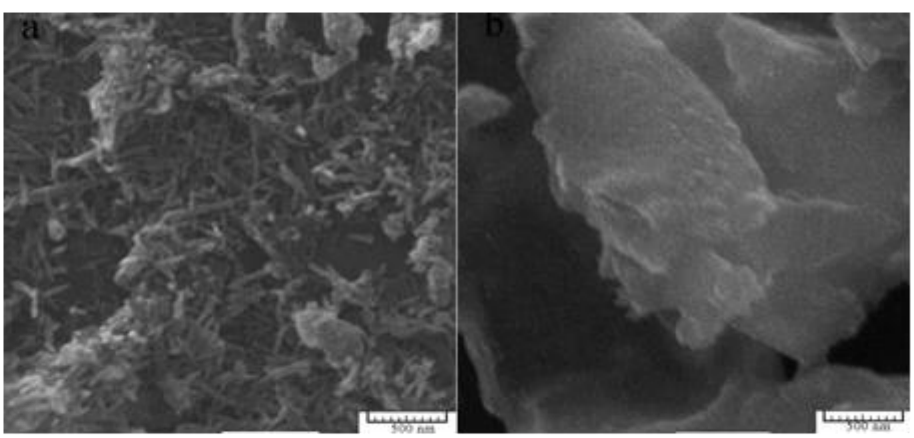


Figure 2. SEM images of $BaFe_2O_4$ synthesized at different calcinations temperature (b) 700 and (a) 800 °C *via* sol-gel method in the presence of lemon juice

The crystal structure and composition of the as-prepared products were determined by XRD. The XRD pattern of barium monoferrite nanostructures were achieved under conditions of calcinations temperature in 800 °C and in the presence of lemon juice. No remarkable diffraction of other phases can be found in the Figure revealing that a pure barium monoferrite nanostructure phase has been formed.

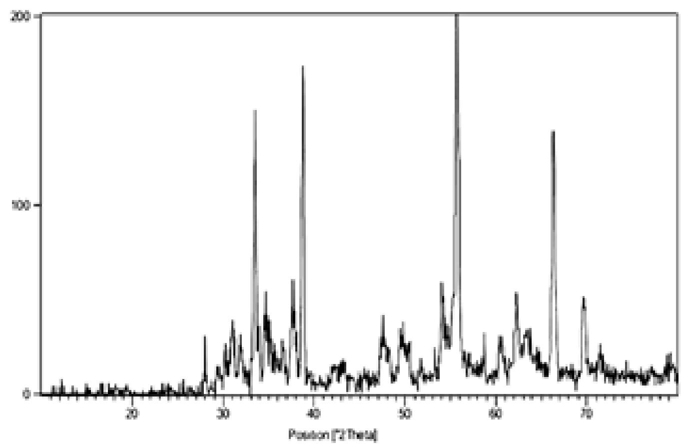


Figure 3. XRD pattern of $BaFe_2O_4$ prepared in the presence of lemon juice

Figure 4. shows a magnetic hysteresis loop of the sample annealed at 800 °C for 2 h. The loop is distorted in a manner that we refer as goose-necked. The specific saturation (*б*s) and coercivity (Hc) are also obtained from VSM measurement. The specific saturation magnetization of synthesized $BaFe_2O_4$ is about emu/g. The specific saturation magnetization of bulk barium ferrite prepared by chemical method is about 55 emu/g. The intrinsic coercivity is about 6000 Oe and it exhibits characteristics of single magnetic domains.

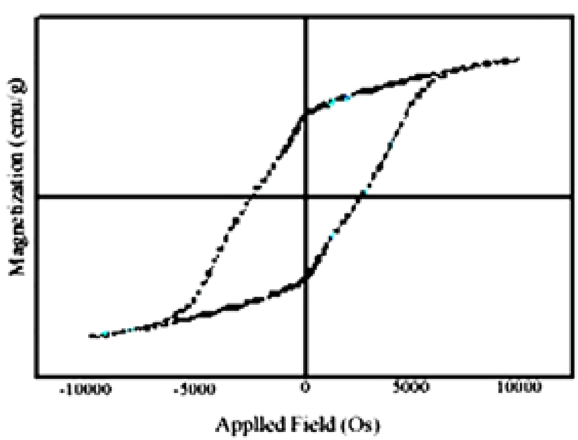


Figure 4. VSM emage of $BaFe_2O_4$ prepared in the presence of lemon juice

Conclusion

In summary, barium monoferrite nanostructures have been successfully synthesized from metal nitrates and lemon juice using a simple sol-gel method. By adjusting the lemon juice/nitrates molar ratio and calcinations temperature, we could obtain barium monoferrite nanostructure with star-like and rod-like morphologies. To the best of our knowledge, it is the first time that lemon juice is used for the synthesis of barium monoferrite nanostructures and also it is the first time that star-like and rod-like morphologies are obtained by sol-gel approach.

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