

ELECTRON SPIN RESONANCE RESPONSE OF BaFe₁₂O₁₉ NANOPARTICLE EMBEDDED POLYDIVINYLBENZENE MAGNETIC FILM

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ABSTRACT

Electron spin resonance (ESR) spectra of the produced BaFe₁₂O₁₉ nanoparticles embedded poly divinylbenzene magnetic film were recorded depending on the ESR power. The ESR experiments were performed at seven different power values from 0.01 to 10 mW. ESR signal amplitude was observed to change exponentially with the applied ESR power. The ESR values of the film were found to be at a microwave frequency of 9225 MHz and a magnetic field of 296 mT. The effective gyromagnetic ratio, g_{eff} , of the film was calculated by using the room temperature ESR data. It is concluded that the produced magnetic film has a strong transitions of $g_{eff} \sim 2.23$. The source of the ESR signals are Fe³⁺ S-state ions belonging to BaFe₁₂O₁₉ nanoparticles.

Keywords: Electron spin resonance, Barium ferrite nanoparticles, Magnetic polymer film.

1. INTRODUCTION

Barium ferrite (BaFe₁₂O₁₉) nano composite particles have a great interest due to the extraordinary magnetic properties such as large magnetic saturation, high magnetic anisotropy, high coercive field [1-5]. The BaFe₁₂O₁₉, m-type hexagonal crystal structure, is a well-known great performance permanent magnetic material and recently has been studied in electromagnetic absorption, magnetic recording media and microwave devices [6]. By compared with other nano particles, barium ferrite nano particles are very well absorbance materials [7].

Many producing methods have been used to obtain barium ferrite nano particles. These methods are known as mechanical milling [5], sol-gel [8,9], hydrothermal, micro emulsion process [10] and atmospheric plasma spraying [11].

Barium ferrite nano particle surfaces can be coated with polymer matrix or surfactant to improve their mechanical properties. With this way, their production price, improvement in corrosion resistance and high production rates can be achieved [12]. However, the improvement in the mechanical properties of the materials can be cause a change in the magnetic properties of the materials.

In the present work, we demonstrate electron spin resonance (ESR) response of the poly [DVB/BaFe₁₂O₁₉] magnetic film as a function of applied electron spin resonance.

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2. EXPERIMENTAL

Materials used in this investigation are divinylbenzene (DVB), barium ferrite (97% trace metal basis, particle size <100 nm) nano particles and toluene which are supplied from Aldrich Chemical Company (USA). The preparation procedure of the poly [DVB/ BaFe₁₂O₁₉] magnetic film has been given our previous work [13]. Here, we summarized the steps. The glass materials utilized in this study were cleaned with acetone, ethanol and pure water by ultrasonically and then dried in air. To ensure deposition of poly [DVB/ BaFe₁₂O₁₉] magnetic films surface polymerization technique was used. In this technique, BaFe₁₂O₁₉ (0.5 g) nano particles were dissolved in DVB (1.5 mL) and toluene (5 mL) and 2,2' azobisisobutyronitrile (200 mL) were added as diluting agent in this mixture. Then, the mixture was stirred magnetically (500 rpm) in polymerization medium to ensure homogeneity. This mixture was maintained for 2 hours under nitrogen atmosphere in a polymerization medium. Finally, the mixture was transferred to glass substrate and kept at 60° during the day.

ESR signals of the poly [DVB/BaFe₁₂O₁₉] composite film were recorded at room temperature by using a JEOL JESFA-300 Spectrometer (X-band, 9.65 GHz, Japan). The instrument settings were: microwave power range, 0.1 to 10 mW; modulation amplitude, 2 mT; field center, 250 mT; modulation frequency, 100 kHz; modulation width, 0.01 mT; sweep time, 30 s and microwave frequency = 9224.834 MHz.

3. RESULTS AND DISCUSSION

Figure 1 shows ESR spectra of the poly [DVB/BaFe₁₂O₁₉] magnetic film under different ESR power at room temperature. ESR, which is also known as electron paramagnetic resonance (EPR), is a unique method to work with materials consisting unpaired electrons. An ESR spectrum is obtained by sweeping the magnetic field H to achieve magnetic resonance when $h\nu = g\beta H$ at a fixed microwave frequency ν [14]. The g -value of the poly [DVB/BaFe₁₂O₁₉] magnetic film is calculated from the resonance condition according to the formula [14]:

$$g = \frac{h\nu}{\beta H_r} \quad (1)$$

where h -Planck constant, ν -microwave frequency, β -Bohr magnetron, H_r -induction of resonance magnetic field. The effective gyromagnetic ratio, g_{eff} , of the poly [DVB/BaFe₁₂O₁₉] magnetic film was found to be 2.23 (corresponding resonance field 296 mT).

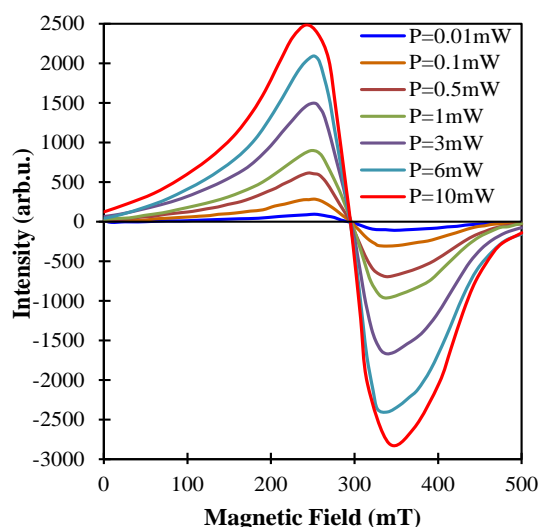


Figure 1. ESR signal shapes of the poly [DVB/BaFe₁₂O₁₉] magnetic film depending on the ESR power

It is seen that in Figure 2, ESR amplitude of the poly [DVB/BaFe₁₂O₁₉] composite film changing linearly with (ESR power)^{1/2}. The inset in Figure 2 shows that the increase in ESR amplitude depending on applied ESR power from 0.01 mW to 10 mW.

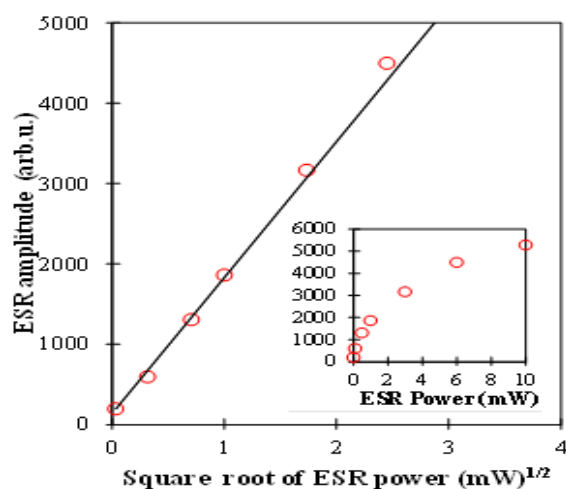


Figure 2. A plot of ESR signals amplitude as a function of the square root of the microwave power. The inset in Figure 2 shows the increase in ESR amplitude depending on applied ESR power

The magnetic component of the applied electromagnetic radiation (microwave) interacts with magnetic moments of the Fe atoms in BaFe₁₂O₁₉ molecular structure. The increase in ESR signal intensity is related to the electron spin distribution in composite film, S-states ions of Fe atoms in BaFe₁₂O₁₉, impurities in the film components and chemical environment of the electron magnetic moments. The ESR response of the film to the applied ESR power seems to be exponential due to the saturation of the ESR energy states of the unpaired electrons belonging to Fe atoms. Fe³⁺ ions are iso-electronic (3d⁵) with ⁶S ground states [15]. S-ion states have long spin-lattice relaxation times. Therefore, ESR spectra of these ions can easily be observed in ESR experiments performed at room temperature.

4. CONCLUSION

In the present work, we have studied ESR response of the poly [DVB/BaFe₁₂O₁₉] magnetic film at room temperature. The ESR study has revealed that the poly [DVB/BaFe₁₂O₁₉] magnetic polymer film shows strong transition of $g_{\text{eff}} \sim 2.23$ (296 mT) due to the Fe³⁺ S-state ions. The changes in the ESR line shape and intensity of the synthesized magnetic polymer due to the increasing ESR power reflects degree of the spin transitions of the unpaired electron between two energy states, and these variations are also affected due to the interactions between magnetic electron spins and lattice belonging to poly divinylbenzene, and other atoms, Ba and O atom in BaFe₁₂O₁₉. Electron spin relaxation time is dominated by variation in the velocity of energy transfer during these interactions due to increase in the applied ESR power. The ESR signal shape and intensity is very sensitive to the electron spin relaxations in the magnetic polymer films. Magnetic film heating during increasing of ESR power in time also plays an important role on the ESR signal shape and intensity.

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