Barium Strontium Hexa-Ferrite-LLDPE Composite Based Microwave Absorber

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Abstract

Composites of $Ba_{0.4}Sr_{0.6}Fe_{12}O_{19}$ - Linear low density polyethylene (LLDPE) with 3wt. % & 5wt.% EG content are synthesized and characterized for microwave absorption ability. The complex permittivity and permeability of the composites are measured using Nicolson Ross method in the frequency range 8.2GHz to 12.4GHz. The real part (ε_r') and imaginary (ε_r'') part of complex permittivity of both the composites shows a periodic fluctuation of same trend with enhanced values for 5wt.%, similarly, the complex permeability shows a periodic behavior with increasing frequency, however the relative enhancement is not significant for 3wt. % & 5 wt.% composites. Based on measured values of complex permittivity and permeability, single layer microwave absorber is design using transmission line model. The calculated reflection loss (RLc) value~-12.306dB at 11.98GHz and -10dB absorption bandwidth of 0.071GHz.

***Keywords*:** Magnetic Microwave absorber, Barium Strontium Hexa-Ferrite, LLDPE, Reflection loss

Introduction

Electromagnetic interference (EMI) shielding is the immediate solution to the electromagnetic pollution generated due to over exploitation of wireless technology specialally in the microwave frequency. EMI shielding can be achieved either by reflection or absorption mechanism; however, absorption mechanism has certain advantages such as camouflaging in warfare, no effect of backscattering etc. Absorbers generally consist of a filler material inside a material matrix. The filler consists of one or more constituents that do most of the absorbing. An electromagnetic wave absorption characteristic of material depends on its dielectric properties (complex permittivity, $\varepsilon_r = \varepsilon_r' - j\,\varepsilon_r''$), magnetic properties (complex permeability, $\mu_r = \mu_r' - j\,\mu_r''$), thickness and frequency range [1,2]. Dielectric composite absorption at microwave frequencies depends on the ohmic loss of energy, which is achieved by adding conductive fillers like carbon black, graphite or metal particles. On the other hand, magnetic composite absorption depends on magnetic hysteresis effect of the magnetic materials, like ferrite, incorporated into the matrix [3]. Magnetic shields are finding wide application in reducing EMI. Magnetic absorbing material depends on magnetic losses. Magnetic loss depends on the imaginary part of the permeability. Higher the value of imaginary part the more is the loss. Ferrites have higher value of imaginary part of permeability; so they are used as magnetic absorber. Hexaferrite are, due to exclusive combination of their magnetic properties, remarkable for various applications, such as hard magnets, magnetic recording media, micro and millimetre wave devices, and absorbers. The most known hexa ferrite compound is BaM–hexa ferrite (BaHF) with chemical formula BaFeO [4].

In this paper, magnetic substrate composed of $Ba_{0.4}Sr_{0.6}Fe_{12}O_{19}$ - Linear low density polyethylene (LLDPE) is investigated for microwave absorption characteristics in the frequency range of 8.2GHz to 12.4GHz.

1. Experimental

1.1. Preparation of substrate

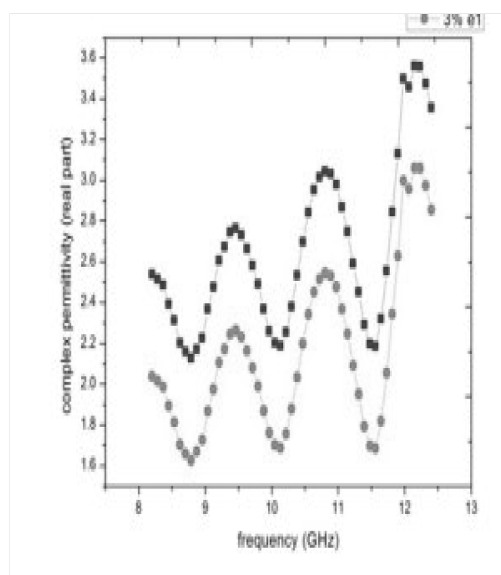
M-type barium ferrite ($BaFe_{12}O_{19}$) particles are prepared from nitrate precursors using co-precipitation technique. Barium nitrate (≥98%) and iron (III) nitratenonahydrate (≥98%) precursors are used as the base materials to which sodium hydroxide is added drop wise to control the size of the particles. Aqueous solutions of barium and iron salts are prepared separately by dissolving the salts in reverse osmosis (RO) deionized water maintaining the molar ratio of barium to ferric nitrate as 1:12 with constant magnetic stirring condition. The iron and barium salt solutions are mixed together and heated at 70°C with continuous magnetic stirring for one hour. 4M (25 ml) solution of sodium hydroxide is prepared separately and slowly added to the salt solution drop wise. The pH of the solution is maintained to a level of 11-12. A few drops (~ 0.1 ml) of oleic acid ($C_{17}H_{33}COOH$) are added to the solution as a surfactant and coating material. Thesystem is cooled to room temperature. Subsequently, the precipitate is washed with distilled water and ethanol to get the precipitate free from sodium and nitrate compounds. Finally, the precipitate is dried at 100°C. The dried powder is crumbled and annealed at three different temperatures, 700°C, 800°C and 900°C for two hours to get barium ferrite particles and then micro structurally analyzed [5 - 6].

$Ba_{1-x}Sr_xFe_{12}O_{19}$ is synthesized by adding solution of strontium (II) nitrate (≥97%) in stoicheometric ratio at the mixing stage. The substituted precursor powders are annealed at 900°Cwith a temperature stability of ±1 °C for two hours to form substituted barium ferrite. Annealing temperature of 900 °C is chosen for synthesis of substituted ferrite, as all the further studies conducted on $BaFe_{12}O_{19}$ ferrite showed that 900 °C is the optimum temperature for synthesis [5 - 6].

The synthesized ferrite and LLDPE powder are mechanically blended at~15000 rpm for 3wt% and 5wt.% of filler in the base matrix to obtain pellets of different dimensions $10.16\ \text{mm} \times 22.86\ \text{mm} \times d\ \text{mm}$ different microwave characterization[7 - 8].

1.2 Microwave characterization

Complex permittivity and permeability of $Ba_{0.4}Sr_{0.6}Fe_{12}O_{19}$ – LLDPE composites are measured using Nicolson Ross method.The measured values of complex permittivity of (3wt.%&5wt.%) $Ba_{0.4}Sr_{0.6}Fe_{12}O_{19}$ – LLDPE composites are plotted as a function of frequency over the ranges 8.2 GHz to 12.4 GHz, as shown in the figure 1.The real part (ε_r') and imaginary (ε_r'') part of complex permittivity of 3wt. % & 5 wt.% composites shows a periodic fluctuation of same trend with enhanced values for 5wt.%, Similarly, the complex permeability shows a periodic behavior with increasing frequency, however the relative enhancement is not significant for 3wt. % & 5 wt.% composites. The measured complex permittivity and permeability values showed that the developed composites as potential material for designing and fabricating microwave absorber.



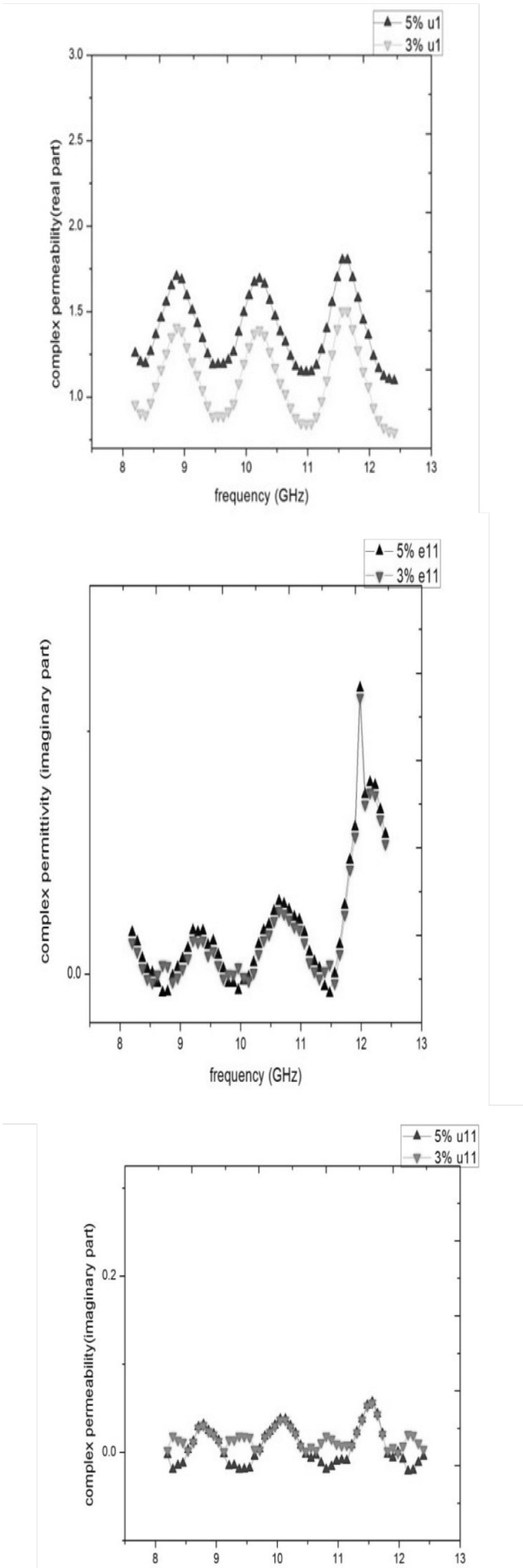


Figure 1: Complex permittivity and permeability of Bao_4Sro_6 $Fe_{12}O_{19}$ –LLDPE

1.3Design of a single Layer absorber and reflection loss calculation

A single layer absorber with a metal back is designed based on transmission line theory (TLM) and the reflection loss study is carried out using the following equations[6].

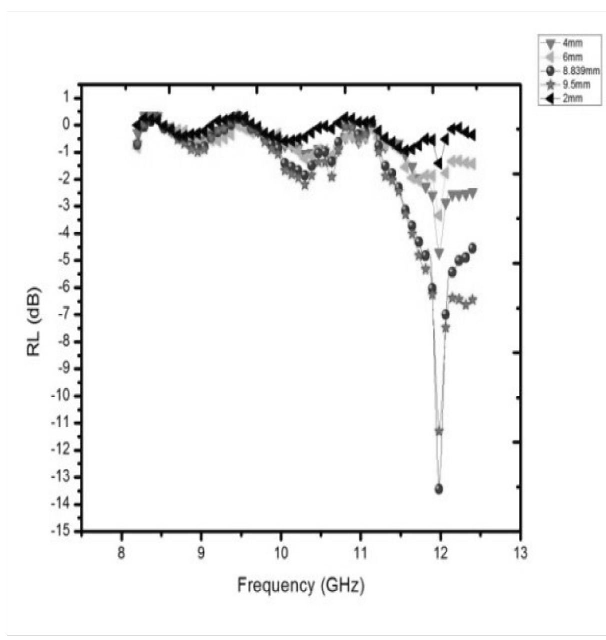
$$RL_c = 20\log\left|\frac{Z_{in}-Z_0}{Z_{in}+Z_0}\right| \quad (1)$$

$$Z_{in} = Z_0\sqrt{\mu_r / \varepsilon_r}\, tanh\,(j2\pi f/c)\sqrt{\mu_r\varepsilon_r}d \quad (2)$$

$$RL_c = 20\log\left|\frac{Z_0\sqrt{\mu_r/\varepsilon_r}\, tanh\,(j2\pi f/c)\sqrt{\mu_r\varepsilon_r}d-Z_0}{Z_0\sqrt{\mu_r/\varepsilon_r}\, tanh\,(j2\pi f/c)\sqrt{\mu_r\varepsilon_r}d+Z_0}\right| \quad (3)$$

Where $\boldsymbol{Z_{in}}$ is the input impedance at the air-absorber interphase, $\boldsymbol{Z_0}$ (=377Ω) is the impedance of free space, $\boldsymbol{f}$ is the frequency of operation and $\boldsymbol{d}$ is the thickness of the composite.

A MATLAB program is developed based on equation (3) to estimate the minimum RL_c value for different $Ba_{0.4}Sr_{0.6}Fe_{12}O_{19}$ - LLDPE composites by varying thickness, ***d***, over the X-band.



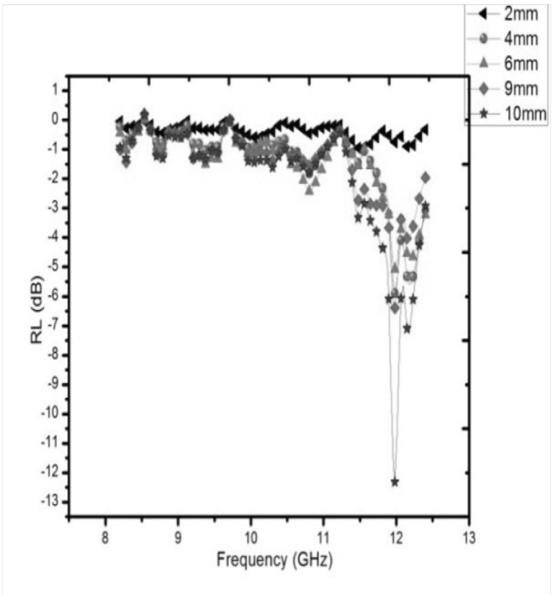


Figure 2: Reflection loss, RL_c of (3 and 5) wt. % $Ba_{0.4}Sr_{0.6}Fe_{12}O_{19}$ - LLDPE composites with different thickness

Figure2, shows reflection loss, RL_c values of conductor backed (3 and 5) wt. % $Ba_{0.4}Sr_{0.6}Fe_{12}O_{19}$ - LLDPE composites with different thickness (*d*=1 to 10 mm) are calculated as a function of frequency over the X-band. The thickness is varied within 1 to 10mm limit.

It is seen that the RL graph for 5wt. % of thickness 8.839mm gives minimum reflection loss of -13.442 dB and 3wt. % of thickness 10mm gives minimum reflection loss of -12.306 dB at frequency 11.98GHz. Also 5wt.% and 3 wt.% shows a -10dB bandwidth of 0.08GHz and 0.071GHz.

Conclusion

Barium strontium hexa ferrite - LLDPE composite is developed as a conductor backed single layer absorber, using transmission line model, where the thickness of the magnetic absorber substrate is optimized for maximum reflection loss over the X-band. Single layer absorber 5 wt.% of the composite at thickness 8.839 mm gives the maximum reflection loss(RL) of -13.442 dB with 0.071 GHz <-10dB bandwidth at frequency 11.98 GHz.

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