Design of Flexible Microwave Absorber based on Expanded Graphite-LLDPE Composites for X-Band Applications

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Abstract

In this present investigation, a flexible microwave absorber were designed using expanded graphite (EG)–Linear low density polyethylene (LLDPE) composites in (3, 5, & 7) wt.% of EG for application in the frequency range of 8.2-12.4 GHz. Initially, complex permittivity of the composites were measured by Agilent 85071E material measurement software, showing that both real(ε_r') and imaginary (ε_r'') permittivity increases with increase of EGwt. % in the composites. However, (ε_r') values of the composites decreases along the increasing frequency and imaginary parts (ε_r'') shows fluctuating behavior with frequency. Based on the measured values of complex permittivity, conductor back single layer microwave absorber is design with thickness optimization for the developed compositesand calculated reflection loss(RL) values ~-60dB at 12.2GHz for thickness of 2mm is observed with -10dB bandwidth of ~2 GHz.

Keywords: Flexible Microwave absorber, expanded graphite, LLDPE, Reflection loss

Introduction

Exploitation of wireless technology creates an environment of electronic pollution termed as Electromagnetic Interference (EMI) [1-8].EMI shielding is fabricated in the structure of sheets. 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. Dielectric compositeabsorption at microwave frequencies depends on the ohmic loss of energy, generally achieved by adding conductive fillers like carbonblack, graphite or metal particles. The absorption properties of the composites are influenced by the inclusions properties. In RAM application, Polymer nanocomposites with carbon nano tubes as reinforces have got widest consideration in RAM application, due to their good mechanical, electrical, and thermal properties [9-10]. However, cost effectiveness is the major issue for their commercial applications. Graphite flakes can be used in composites as re-ferred in [11] for less cost effectiveness, where the flake thickness was of the order of few mi-crons and good absorption is observed above 12 GHz. Another promising composite reinforcement can be expanded graphite flakes, with the characteristics of very low density, good electrical, thermal and mechanical properties [12–15].

Another characteristic to be considered while fabricating microwave absorbing material is the influence of base matrix. Depending on the properties of the base matrix the desired microwave absorber can be mould. Flexible absorber helps in manipulating the design structure and can be useful in many applications. LLDPE being very flexible, good resistance to chemicals as well as low cost can be used as base matrix while developing flexible microwave absorber.

In this present work, EG-LLDPE composite with varying composition and thickness is designed to achieve microwave absorption properties in the X-band frequency. The developed composite are characterized for complex permittivityin X band. Reflection loss of the composite is additionally addressed, using transmission line (TL) technique for conductor backed single layer structure.

1. Experimental

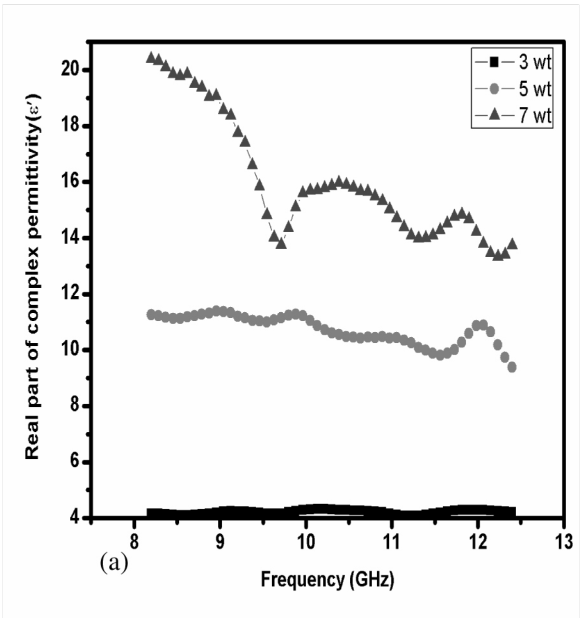
1.1. Fabrication of dielectric composite material

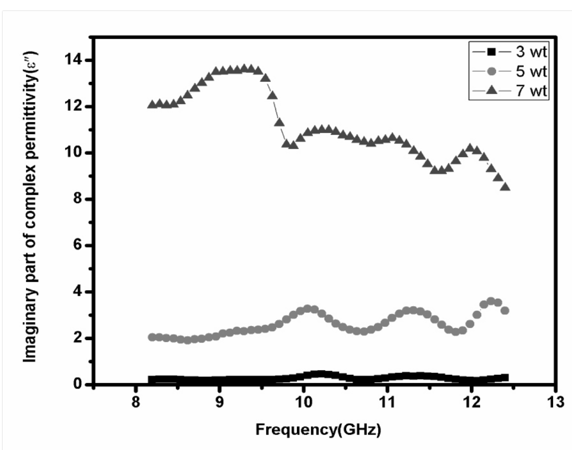
Expanded graphite was synthesized using chemical oxidation and thermal treatment method discussed elsewhere [4].The EG flakes and LLDPE powder are mechanically blended at ~ 15000 rpm for different weight percentages of EG. The mixture was placed in a specially designed three-piece die-mould consisting of a cavity, upper and lower plunger with spacer and initially heated up to 100–120°C. A pressure up to 1.5-2 tons is slowly applied and the fixture with the sample was isothermally heated at 150°C for 2 hours and then allowed to cool at room temperature. For different characterization, Pellets of different dimensions were molded. With the provision of varying the thickness, d, of the sample ,a three piece die mould with spacer is designed and fabricated for microwave characterization in the X-band with the sample dimension of 10.16 mm × 22.86 mm × d mm.

1.2Characterization techniques and Analysis

Using Agilent 85071E material measurement software compatible with Agilent 8722ES vector network analyzer was used to measure Complex permittivity employing Nicolson–Ross method[16]. The measured values of complex permittivity of (3,5 and 7) wt. % EG-LLDPE composites were plotted as a function of frequency over the ranges 8.2 GHz to 12.4 GHz. The real parts (ε_r') and imaginary parts (ε_r'') of complex permittivity of the composites are shown in figure 1(a) and figure 1(b). It is seen that with increase of EG wt. %both $\varepsilon_r'$and ε_r''increases. ε_r' values of the composites decreases along the increasing frequency and imaginary parts (ε_r'') shows fluctuating behavior with frequency. The (ε_r'') spectra for 5 wt. % shows almost a constant value of ~2.0 till 9 GHz and at 12.23 GHz a resonance peak is observed with (ε_r'') ~ 3.6. With increase in the EG wt. % the values of (ε_r'') increases and the broad resonance peak are observed around 10.19 GHz, 12.23 GHz, and 9.47 GHz for 3, 5, and 7wt. % composites, respectively.

The dielectric loss tangent $\left(tan\delta_e = \varepsilon_r'' / \varepsilon_r'\right)$ of the developed composites was calculated using the measured value of ε_r' and ε_r''over the X band. Figure 2 shows the frequency dependent $tan\delta_e$ variation for different (3,5 and 7) wt. % EG-LLDPE composites. The $tan\delta_e$spectra for 5 wt. % composites shows a constant value ~ 0.18 from 8.14 GHz to ~9 GHz and then abruptly increase to a maximum value ~0.30 at 10.09 GHz correspondence to the resonance peak of ε_r'' spectra for 5 wt. % composite. The $tan\delta_e$spectra for 3wt. % composites shows a constant value ~ 0.05 from





(b)

Figure 1: Complex permittivity spectra for 3 to 7 wt. % EG-LLDPE composites with Agilent software (a) Real parts and (b) Imaginary parts

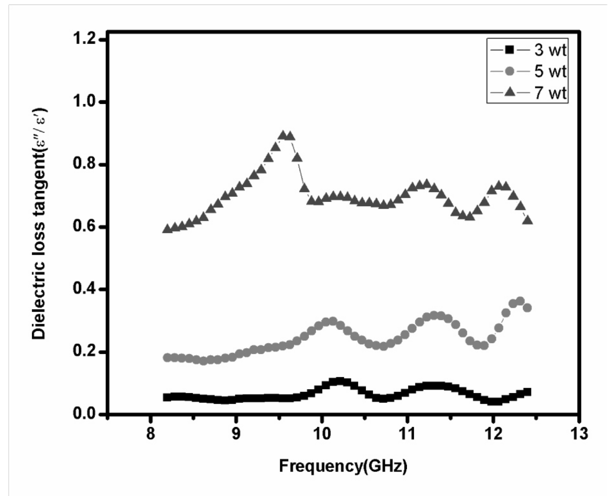


Figure 2 Dielectric loss tangent spectra of EG-LLDPE composites over the X-band

8.16 GHz to ~9.7 GHz and then increase to a maximum value ~0.10 at 10.2 GHz correspondence to the resonance peak of ε_r'' spectra for 3 wt. % composite. The $tan\delta_e$spectra for 7wt. % composites show a constant value ~ 0.679 from 9.8 GHz to ~10.86 GHz. The maximum resonance peak is observed ~0.89 at 9.5 GHz for 7 wt. % composite. From the dielectric loss spectra for the composites it is seen that the developed EG-LLDPE composites have the potential characteristics for microwave absorption.

1.3 Reflection Loss calculations

The reflection loss,RL_cvalues of conductor backed (3,5 and 7) wt. % EG-LLDPE composites with differentthickness (*d*=0.5,1,1.5,2,2.5,3,3.5,4,4.5,5, 5.5,6 mm) were calculated as a function of frequency over the X-band. Figure 3 shows the frequency dependent calculated RL_c value of the developed composites of 3wt% with varied thickness (0.5 to 6mm) in the frequency range 8.2 GHz

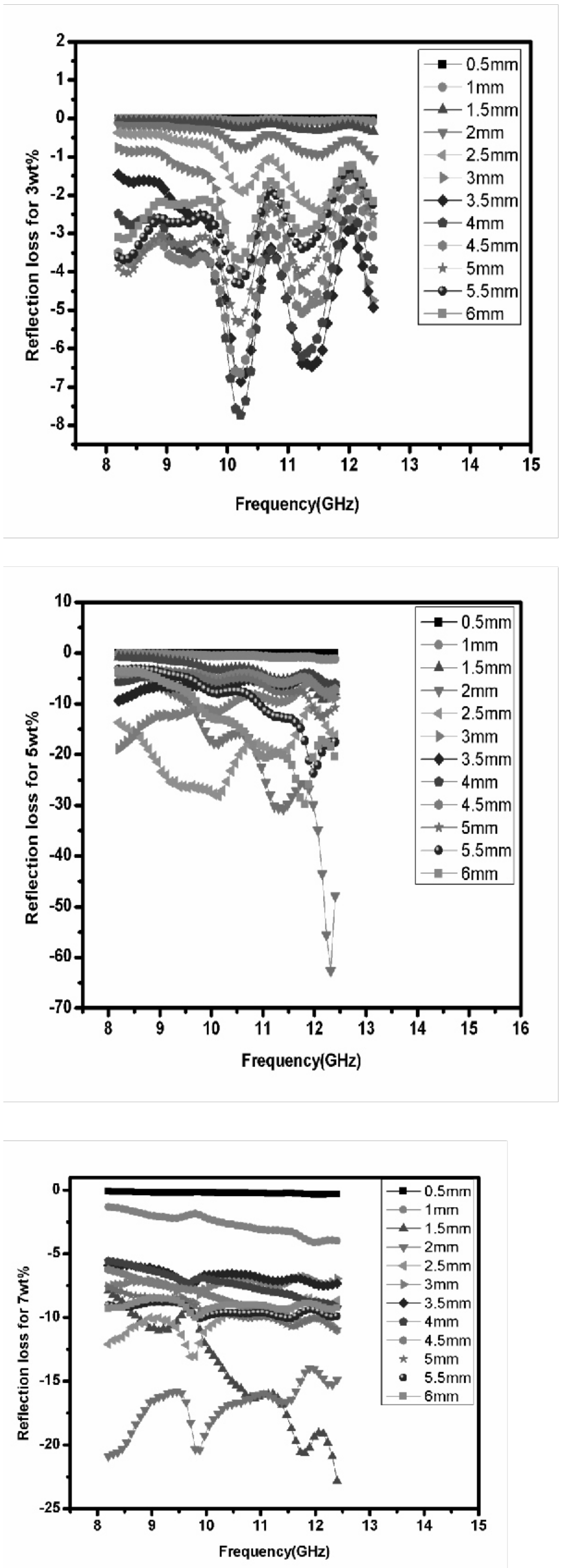


Figure 3: Calculated Reflection loss curve of EG/LLDPE composites

to 12.4 GHz. It is seen from figure 3(a) that RL_c<-10dB for all the composites wt. % EG is observed, which is due to impedance mismatch at the air-substrate interface and makes the surface more reflecting. [17]. Hence the values of RL_c for 0.5 to 6 mm thickness of 3wt% EG-LLDPE composites are very low for all the compositions. The RL_c values for 3wt% of 0.5 to 6 mm thickness absorber design is shown in the figure 3(a), whereas RL_c~-60 dB is observed for 2mm thickness of 5 wt. % composition at 12.4 GHz in fig 3(b). 3 wt. %, 5 wt. % and 7wt. % EG-LLDPE composite show a maximum RL_c~–7.6 dB (4mm thickness), -60dB (2mm thickness) and -20 dB (2mm thickness) with peaks at 10 GHz, 12 GHz and 9.9 GHz, respectively. The composites of 7wt.% with 0.5 to 6mm thickness single layer absorber gives a low value of RL_c in the frequency range of 8.2 GHz to 12.4 GHz.

Conclusions

Flexible substrate of EG-LLDPE compositeswere developed as microwave absorbing material for X-band. The dielectric loss values calculated from measured value of complex permittivity shows that developed composites have potential to use as microwave absorber. The conductor backed single layer absorber designed and optimized with thickness variation of the dielectric substrate showed *for* 3 wt. %, 5 wt. % and 7wt. % EG-LLDPE composite, a maximum RL_c~–7.6 dB (4mm thickness), -60dB (2mm thickness) and -20 dB (2mm thickness) with peaks at 10 GHz, 12 GHz and 9.9 GHz, respectively. Thus, the designed flexible substrate can be fabricated as microwave absorber for certain frequency range in X-band.

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