Preparation (Soft Polyurethane Foam/Graphite) Composites For Microwave Absorption In X-Band Frequency

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Abstract:

The aim of this study is to produce sheets of microwave absorbing materials using Graphite in different concentrations (5wt.% - 40wt.%) and dispersed in a Soft Polyurethane Foam matrix. The study also aims to measure the electromagnetic properties (transmission, return loss and relative absorbed power) of these sheets in the x-band frequency range (8.5–12.4) GHz using closed waveguide technique .It is found that the lower value of Return Loss is (-30dB) in less than (5wt.%) graphite loading, and the relative absorbed power are close to (5%) of the incident radiation in all frequencies. The higher value of the return loss is (-18dB) in (30wt.%) Graphite loading, and the relative absorbed power value is close to (25%) of the incident radiation in 10GHz. These composites are very useful in producing the EMI Shielding, absorbing sheets and microwave anechoic chambers.

Keywords: Polyurethane Composites , Return Loss , microwave anechoic chambers

1) Introduction

The electromagnetic interference (EMI) shielding is designed and developed to minimize the electromagnetic interference and to improve compatibility of microwave circuits. EMI shielding in the range of 8.5 to 12.4 GHz (x-band) is more important for military , and commercial applications ,scientific electronic devices, microwave anechoic chambers, etc [1,2].There are various types of electromagnetic shields like single and multi layered [3,4] , conductive polymers [4-6] , conductor-insulator composites [2,7] ,etc. Polymeric materials have been largely used as a matrix for EMI studies partially because of their easy fabrication into various shapes, light weight, resistance to corrosion, flexibility and processing advantages.

An electromagnetic wave absorber used in EMI shielding can be divided into tow categories according to the absorbing principle. The absorbing is done by using the magnetic lossy and the dielectric lossy materials. These materials are also identified as the magnetic absorbers and the dielectric absorbers respectively [8,9].

The magnetic absorber has been fabricated by mixing magnetic lossy materials (zinc, nickel, ferrite, etc.) with a flexible medium such as rubber, polymeric resin, etc. Since this method uses magnetic additives of high weight, it has the weakness of being heavy and showing poor EM absorption characteristics in microwave frequencies.

The dielectric absorber has been prepared by adding some conductive powders such as carbon black, graphite, conductive polymers to the polymer matrix in order to induce the dielectric lossy by enhancing the conductivity of the matrix among them. The carbon black which weighs about one fourteenth of ferrite is widely used due to its good absorption performance in high frequencies.

Recently carbon black (multi-walled carbon nanotubes , single-walled carbon nanotubes and Graphite) is commonly used as conducting fillers loaded with polymeric foams like (polyurethane ,polyethylene , etc.) because of its effective and light weight. This type of polymeric foam composites is used to produce, microwave anechoic chambers, absorbing sheets, and microwave absorbing materials [10-11].

In this paper (Soft Polyurethane Foam/Graphite) composites are prepared successfully with different concentration of Graphite powder

(5wt.% – 40wt.%) loadings .The Return Loss(*RL*) , Transmitted coefficient (*T*) , Reflection Coefficient (*R*) and relative absorbed power (A_{abs}), are measured by using closed waveguide technique in x-band frequency.

2) Composite preparation:

Soft Polyurethane Foam (SPUF) prepared from (commercial polyol, Diphenylmethylate-diisocyanate (MDI), Distilled water as the blowing agent, rutile (Tio_2) as pigment) is used as a matrix polymer and Graphite powder which is used as conductive fillers with various loadings. The pure SPUF and (SPUF/Gr) composite are both prepared by a one-step method. The process of preparing the (SPUF/Gr) composites is described as follows:

Appropriate amounts of (Polyol, Distilled water, Rutile) are mixed together by stirring for 10 mins, and dried Graphite powder is added into the solvent and sonicated for 15 min using Bransonic bath model (220) to disperse Graphite particles. Then the Graphite suspension is added to the polyol mixture and stirred for about 10 mins, after that the suspension is sonicated for 15 min using the same device by which uniform mixture is obtained. An appropriate amount of the MDI is added to the mixture and stirred for about 20 sec. After that, the mixture is immediately poured into a foil rectangular mold (3 cm × 3 cm × 4 cm) and put in an oven at 60°C to allow the foam to rise and then set at room temperature for 24 hr to produce (SPUF/Gr) composite. The samples are then cut in the desired sizes. Other composites with different loadings of the Graphite are prepared similarly. Table (1) Shows Formulations of polyurethane composites.

Table 1: Formulations of Soft polyurethane Foam with Graphite.

polymeric Reagents(g)*	Foam with 0% Gr	Foam with 5% Gr	Foam with 10% Gr	Foam with 20% Gr	Foam with 30% Gr	Foam with 40% Gr
MDI	1.80	1.80	1.80	1.80	1.80	1.80
Polyol	3.60	3.60	3.60	3.60	3.60	3.60
Water	0.027	0.027	0.027	0.027	0.027	0.027
Rutile	0.27	0.27	0.27	0.27	0.27	0.27
Graphite(Gr)	0	0.284	o.569	1.139	1.709	2.278

Total weight of polymeric reagents(SPUF) with Rutile= 5.697 g*

3) Microwave measurement:-

The electromagnetic properties of the samples are measured at x-band frequency using the waveguide technique (closed system) as shown in Fig (1) [2, 12-13].

The preparation samples which are about 1.3 cm thick are cut to fit in the cross section of the rectangular wave guide (2.29×1.02 cm^2). The sample is inserted in the waveguide (sample holder) so that it fills the entire cross-section in order to prevent any leakage of EM energy. Incident and transmitted powers are performed at (9 – 12) GHz to measure the transmission coefficient.

The return loss for the composites is also measured. Now the directional coupler is used as a reflectometer. The test system is calibrated by using a short circuit plate in port (2) to provide a (0 dB) return loss reference. Change the short circuit by DUT (sample holder terminated with matching load) and measure the power reflected from the sample.

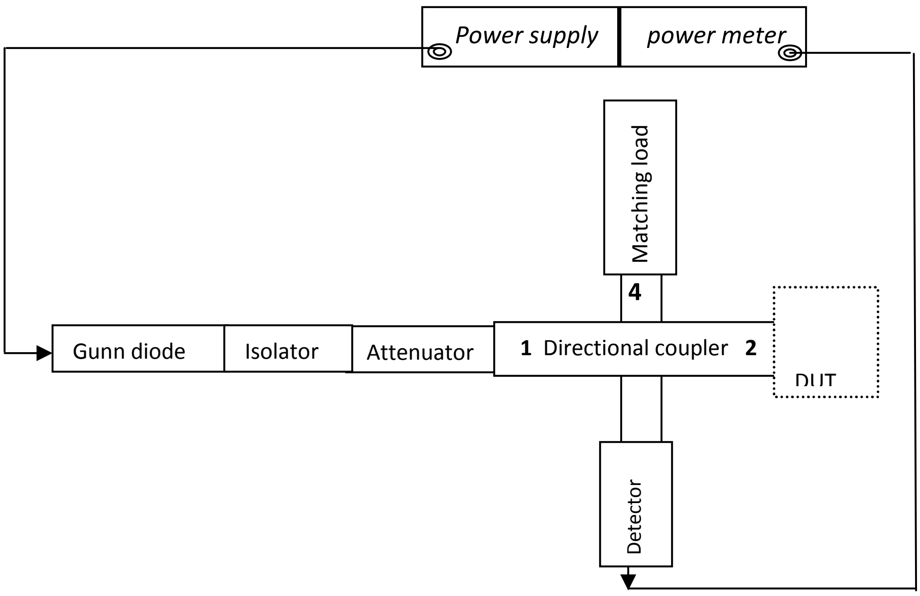

Fig. 1: Experimental setup for measurement

4)Results and Discussion

The return-loss measurements have indicated interestingly that the main mechanism of the composite material is reflection and not absorption, The return loss (*RL*) due to the reflection can be represented as[2,8]:-

$$RL(dB) = -10\log\left(\frac{P_r}{P_i}\right)$$

and the transmission coefficient(T) is represented as:-

$$T(dB) = -10\log\left(\frac{P_t}{P_i}\right)$$

where P_i is the incident power density at a measured point before the sample is in place and P_r ,P_t are the reflected and transmitted power density at the same point when the sample is in place.

The variation of the return loss as a function of frequency is shown in Fig. 2. It is clear that the composites which have a lower value of graphite loading (below 5wt.%) yield a lower value of *RL* reaching about -30dB at 10GHz , and increasing RL with increasing graphite loading. The higher value of *RL* is -18dB in graphite loading (30wt.%) at the same frequency. The marginal frequency dependence of *RL* may be due to some structural effects, such as the geometrical distribution of the filler and the interaction of electromagnetic waves with the graphite.

The variation of the reflection coefficient (*R*) as a function of the graphite loading over frequency range (9-12) GHz is shown in Fig. 3. It is clear the reflection coefficient increases with the increase of the graphite loading, reaching a higher value (0.125) in the graphite loading (30wt.%) at that frequency. Since the density of the composite decreases when the graphite loading becomes more than (30wt.%), the reflection coefficient decreases also.

Figure (4) shows the variation transmission coefficient (*T*) for (SPUF/Gr) composites with graphite loadings of (5wt.%-40 wt.%), a long the frequency range of (9–12)GHz. It can be noticed that the transmission coefficient is invariant (close to ~1) with graphite loadings at (9.5GHz, 11.5GHz). While the coefficient (*T*) reaches the lowest value (0.73) as the graphite loading becomes (30wt.%) at 10GHz, because of the aggregations of graphite particles. Forming a continuous conductive network leads to the formation of a conductive mesh structure in the insulating polymer. For higher graphite loadings (above 30wt.%) the coefficient (*T*) increases with the increasing graphite content.

Figure (5) shows the relative absorbed power for (SPUF/Gr) composites with the graphite loading (5wt.% - 40wt.%) for different frequencies. It is observed that the relative absorbed power (A_{abs}) is very low (close to 5%) for the graphite loading below

(5wt%) at all frequencies. At higher loadings (above 10wt.%) the A_{abs} increases with the increase of graphite loadings and reaching its highest value at about 30wt% loadings. Then it decreases again after this graphite loading. This is because the increase of the filler particles number in the conductive mesh of composites leads to unenhance the properties of the composite (decreases the density of composites).

The polymer composite, which properties are describe above, prepared in this study and can be used to prepare absorbed sheets for microwave which are used to coat the floors and walls of scientific lab because of its ability to reduce reflections. The prepared polymer composite can be widely used because of its low coast due to the affordability of its elementary materials.

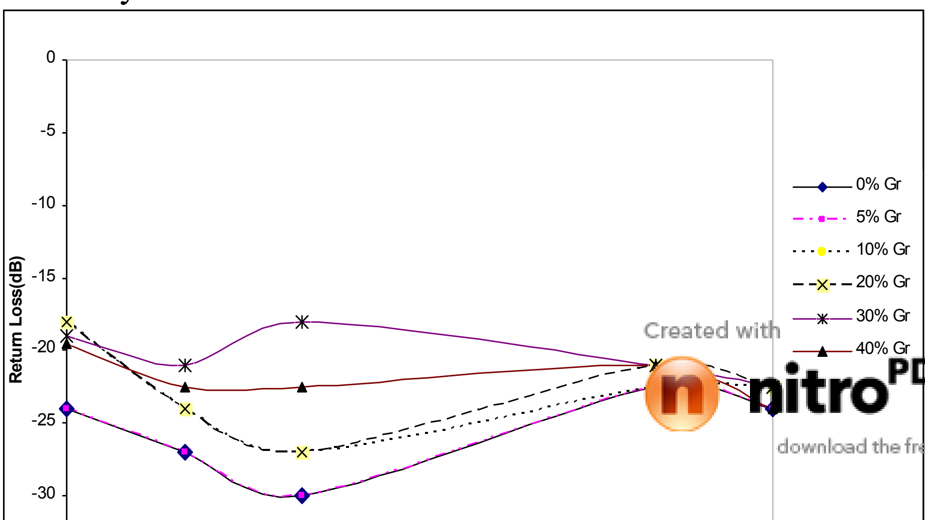

Fig (2): The variation of return loss as a function of frequency in (x-band) for (SPUF/Gr) composites.

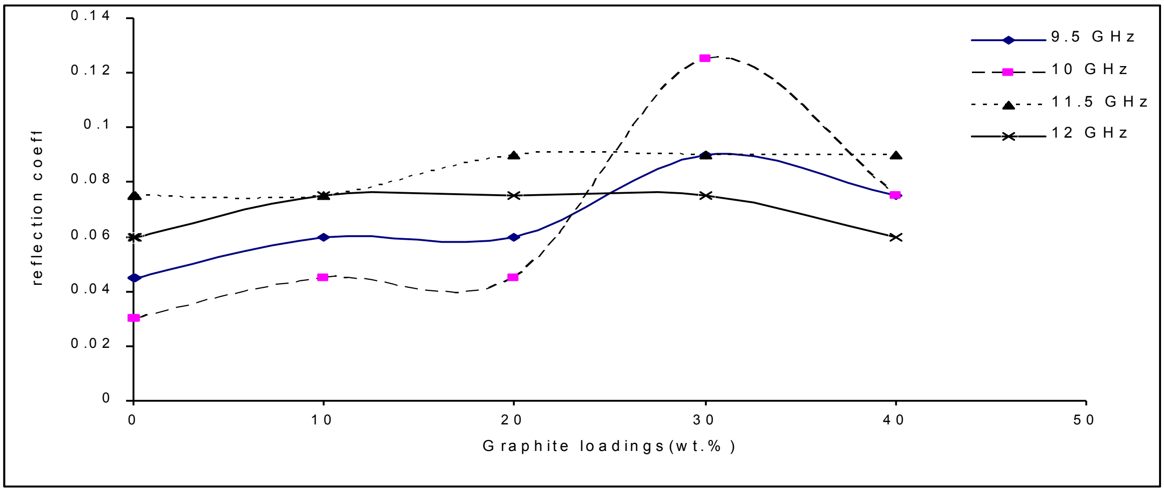

Fig (3): The variation of reflection coefficient as a function of graphite loadings in (SPUF/Gr) composites.

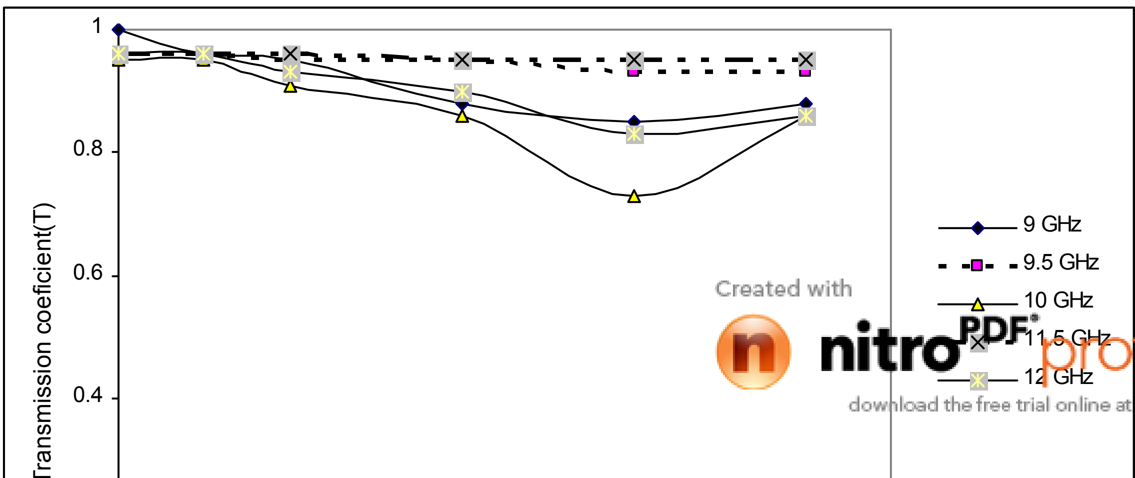

Fig (4): The variation of transmission coefficient as a function of graphite loadings in (SPUF/Gr) composites.

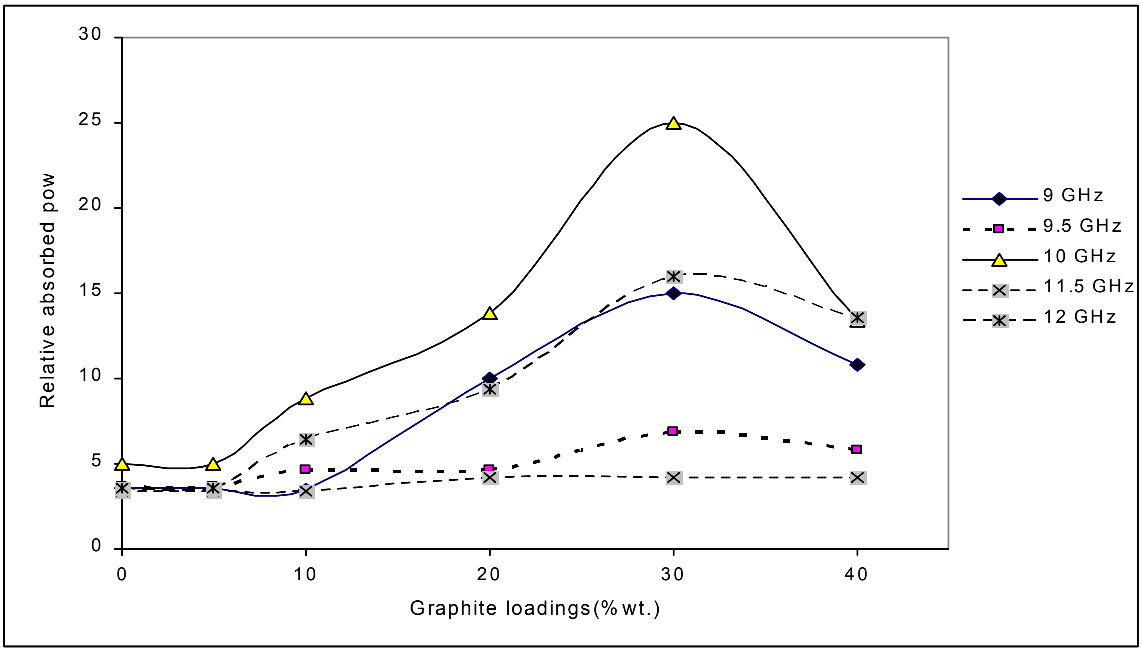

Fig (5): The variation of relative absorbed power as a function of graphite loading in (SPUF/Gr) composites.

5) Conclusion:

In this study the (SPUF/Gr) composite with different concentration of Graphite powder is done using a closed waveguide technique in the x-band frequency. The return loss (*RL*) and relative absorbed power (A_{abs}) increase as the graphite loading increases. The greatest enhancement in (*RL*) and (A_{abs}) properties happens at (30wt.%) loading for 10 GHz, and reaches -18 dB , 25% respectively, and then decreases again above this weight. The relative absorbed power is dependent on the thickness, and it increases with the increase of its value.

The composite materials prepared in this work present the proper characteristics of flexibility, lightweight, good absorbing properties. Additionally they are relatively easy and inexpensive to produce absorbed sheets and microwave anechoic chambers.

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