International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 05 May 2024
Page No: 1334 - 1340
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0184

Advanced Polymer Composite with Graphene Content for Emi Shielding

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Abstract
One of the increasingly common unexpected outcomes of the extensive usage of electronic devices and systems is electromagnetic interference (EMI). The need for efficient fillers and shielding materials to manage electromagnetic interference (EMI) and associated issues is rising. Adding more filler typically means greater production costs, poor dispersion, and unintended agglomeration, which makes polymer composites harder to work with and mechanically weak. Therefore, it is highly desired to design a strong composite with conductive filler content that nonetheless performs well as an EMI shield. Therefore, using a graphene substrate and dispersion of conducting polymers such as polyacetylene and MWCNT fillers, a hybrid polymer composite based on polyetherimide is proposed in this research. Next, the enhancement of EMI shielding efficiency is examined. The design of the graphene substrate was completed with a coating based on nano filler, and the blending methods of the polymer matrix and the reinforcing filler materials are explored. ANSYS-HFSS software is then used to assess the shield's efficacy among others, and the results demonstrated improved performance. Therefore, by putting the suggested design into practice, high-performance EMI shielding materials can be created by combining various shield fillers. As a result, the composites' mechanical, electrical, and EMI shielding qualities will all improve.
Keywords: *Crosslinked Graphene Substrate; Coupled Nano Stratum Coating Technique; Electromagnetic Interference; Graphene; Intercolated Polyacetophenimide.*

1. Introduction

Electromagnetic interference (EMI) has become a major concern owing to rapid advancements in the electronics industry and telecommunications networks. Conducting polymers are a convenient choice for EMI shielding applications (Ravindren et al., 2019). Variously important forms of conducting polymers have been produced using Nano electronics and nanotechnology (Panda and Acharya, 2019). Polymer nanocomposites, made up of polymer matrices and nanometrical reinforcement phases, are commonly used in composite materials due to their ease of processing and shaping. Graphene is [18] a two-dimensional substance with nanoscale diameter and thickness, used for improving thermal and electromagnetic interference shielding properties of nanocomposites (Ha et al., 2019). It has been used in radar absorption and EMI shielding applications for hybrid compounds with Graphene Nano platelets as fillers. From numerous literatures and other documents here we propose a novel polymer composite with Graphene content for improving EMI shielding effectiveness [19]. There are four chapters in this work. An introduction, a description of the completed assignment, simulation details, and results make up the first three chapters. The last chapter is conclusion.

2. Advanced Polymer Composite with Graphene Content for EMI Shielding

The electromagnetic interference (EMI) caused by high-frequency electrical radiation has grown to be a serious danger to information security. To

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maintain high conductivity in shielding, electrical conductivity is required, and filler particles typically meet this requirement [20]. Conversely, nastier filler particles lead to severe electrical percolation and inadequate device impedance, hence reducing composite conductivity to an extreme degree. Furthermore, a high filler quantity causes the shield to become unstable at high temperatures due to poor dispersion in the matrix and limited thermal stability [1]. Therefore, a unique Intercolated Polyacetophenimide matrix can be developed, in which multiwalled carbon nanotubes are introduced as fillers, to improve the shield's intrinsic conductivity and improved characteristics. Polyetherimide combined with di butyl sebacate, thiophene, and acetylene polymers will make up Polyacetophenimide [2]. Here we discuss about the development of novel polymer composite with Graphene content. The selection method of different polymer composites, [3] how it is mixed in various proportions, method of adding Graphene and Multi Walled Carbon Nano Tubes as fillers etc are discussed in detail [4]. Coupled magnetic stirrer technique is used to combine different polymers. Coupled Nano stratum technique is used to add Graphene substrate(Guan et al., 2018).

3. Novel Polymer Composite Design and Preparation Method

Recently, conductive filler materials have been employed with conducting polymer-based electromagnetic interference shields to increase the shielding's conductivity and thermal durability. In this case, the polymer matrix is composed of a mixture of polyetherimide with conducting polymers such as acetylene and thiophene. The name we can suggest as Polyacetophenemide. Polyetherimide is a thermoplastic with excellent performance in engineering applications. High strength and stiffness at high temperatures, dimensional stability, [5] long-term heat resistance, and good electrical qualities are some of its qualities. We have selected a blend of conductive polymers (acetylene and thiophene) with better qualities since EMI shielding material should have conductive capabilities and we want to minimise the amount of filler. [6] The properties of the Polyetherimide polymer (Ahmad et al., 2017) are shown in Table 1 below. Properties of Multi Walled Carbon Nano Tubes are given in Table 2.Properties of Thiophene are given in Table 3. (Roncali, 1992). The properties of Acetylene (West, 1980) are shown in Table 4.

Table 1 Properties of Polyetherimide

Density	1,270 (kg/m^3)
Melting point	219 (°C)
Thermal conductivity	0.22 (W/mK)
Tensile modulus	3,276 (MPa)
Tensile strength	126 (MPa)
Poisson's ratio	0.36
Coefficient of thermal expansion	5.58×10^{-6} (C^{-1})
Glass transition temperature	227 (°C)
Melt index	0.42 (g/min)
Linear thermal expansion	3.3 (°C)

Table 2 Properties of Mwcnts

Purity %	98%
-OH Content	1.76 Wt%
Outer diameter	10-20 nm
Inner diameter	5-10 nm
Length	0.5-2.0 μm
Surface area	>200 m^2/g
Density	0.22 g/cm^3
Electrical conductivity	>100 S/cm

Table 3 Properties of Thiophene

Molar mass	84.14 g/mol
Density	1.051 g/mL
Melting point	-38°C
Boiling point	84°C
Magnetic susceptibility (χ)	$-57.38\cdot10^{-6}$ cm^3/mol
Refractive index (n_D)	1.5287

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Table 4 Properties of Acetylene

Molar mass	26.038 g·mol^{-1}
Density	1.1772 kg/m^3
Melting point	-80.8°C
Conductivity	4.4×10^{-5} Siemens/cm
Magnetic susceptibility (χ)	-12.5×10^{-6} cm^3/mol

3.1 Rule of Mixtures Formulae

Inorder to find the permittivity,permeability and density we use rule of mixtures formulae

Permittivity

$$\epsilon = (1 - V_m)\ \epsilon_m + V\ \epsilon_f \quad \text{--Equation 1}$$

Where ϵ - permittivity, Vm - Volume fraction of matrix, ϵm - permittivity of matrix, ϵf - permittivity of fiber. The permittivity value and volume fraction of each component is shown in table 4.

Table 5 Permittivity Value and Volume Fraction of Components

Material	Volume fraction		Permittivity value
polyetherimide	50 = 0.5	Matrix	2.25
polyacetylene	15=0.15	Matrix	2
mwcnt	5=0.05	Fiber	60
polythiophene	15=0.15	Matrix	6
di butyl sebacate	15=0.15	Matrix	4.5
Graphene 6.9			

$$V_m=(0.5+0.15+0.15+0.15)\ /4 = 0.2375$$

$$\epsilon_m = \frac{2.25+2+6+4.5}{4} = 3.6875$$

$$V_f = 0.05$$

$$\epsilon_m = 60$$

Substituting all values in equation 3 we get permittivity as 5.8 table 5. Also, permittivity of graphene is 6.9. Therefore, permittivity is = (5.8+6.9)/2 =6.35

3.2 Permeability

$$P = P_m + 2P_m \frac{Pf - Pm}{Pf + Pm - Vf(Pf - Pm)} \text{---Equation2}$$

Where Pm - permeability of matrix composite, Pf - permeability of the fiber composite, Vf – Volume fraction of the fibre. The permeability value and volume fraction of each component is shown in table 6.

Table 6 Permeability Value and Volume Fraction of Components

Material	Volume fraction		Permeability value
polyetherimide	50 = 0.5	Matrix	0.01
polyacetylene	15=0.15	Matrix	3x10^{-8}
mwcnt	5=0.05	Fibre	3
polythiophene	15=0.15	Matrix	0.1
di butyl sebacate	15=0.15	Matrix	5.4
Graphene 82.95			

P_m = (0.01+3e-8+0.1+5.4)/4 = 1.377

P_f = 3

Substituting values of P_m, P_f, V_f in equation 2 we get,

P= 2.41

Also the Permeability of graphene is 82.95

Therefore, overall permeability = (2.41+82.95)/2 = 42.68

3.3 Density

$\rho V = \rho_m V_m + \rho_f V_f$ (Equation 3)

Where ρm, ρ_f - density of matrix and fibers, V_m, V_f - Volume matrix and fibers.

The density value and volume fraction of each component is shown in table 7

Table 7 Density Value and Volume Fraction of Components

Material	Volume fraction		Density value
polyetherimide	50 = 0.5	Matrix	1.2
polyacetylene	15=0.15	Matrix	0.4
mwcnt	5=0.05	Fiber	0.22
polythiophene	15=0.15	Matrix	1.05
di butyl sebacate	15=0.15	Matrix	0.940
Graphene = 2.65			

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V_m=(0.5+0.15+0.15+0.15) /4 = 0.2375
Vf =0.05
ρ_m = (1.2+0.4+1.05+0.940)/4 = 0.8975
ρf = 0.22
Substituting all values in equation 3 we get ρ= 0.22 Also, the density of graphene is 2.65. Therefore, total density is (0.22+2.65)/2= 1.435. From this the properties of novel polymer composites are found. The new Polymer composite can be named Polyacetophenemide. As Graphene and MWCNT are added its properties are also considered for calculation. So, the calculated values are given in ANSYS HFSS simulation software.

4. Simulation Details and Result

The simulations that were run and the performance analysis of the suggested structure are described in this section. A comparison section is also provided to demonstrate how the suggested shield material has improved. ANSYS HFSS was then used to analyse the EMI shield for the recommended work. The model's inputs are the mass density, permeability, and dielectric permittivity. Using the rule of mixtures formula for the composite shield material, the input values are determined. Equations (1), (2) and (3) are used to determine the dielectric permittivity of the composite (Ávila et al., 2015) and are provided as input. S parameters were used to calculate the shield's distinctive performance values. The parameters S21 and S12 indicate the transmission coefficient, which is ascertained by the S parameter plot, while S11 and S12 represent the reflection coefficient.

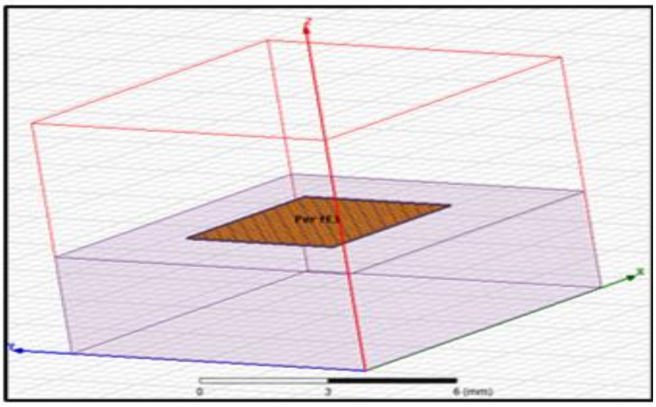

Figure 1 Model of Strip Material

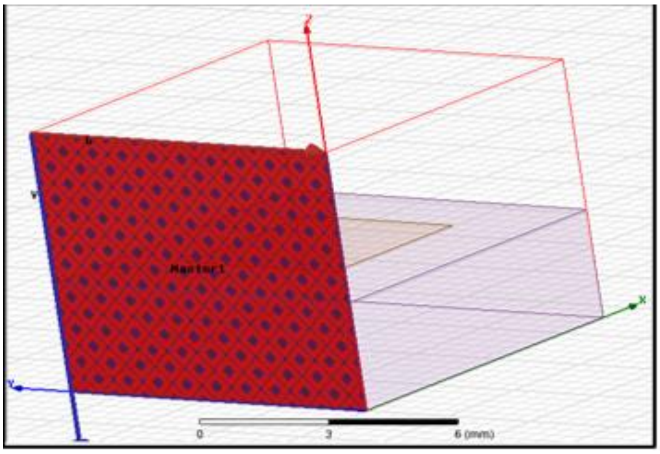

Figure 2 Model with Boundary Box

The following is a description of the software analysis's findings4. A boundary box encloses the model of the strip material in HFSS that is displayed. The shield model was created using a 4x4 cm patch with a 2 mm [11] thickness and a 9x9x3 cm boundary box. Figures 1 and 2 depict it.

4.1 The Characteristic Performance Values are Given as Input

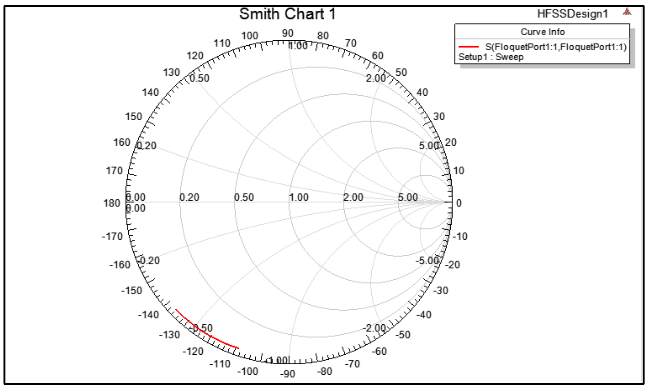

Figure 3 Smith Chart

A Smith chart is used to show the system's impedance as a function of frequency. Figure 3 depicts it [12]. According to the chart, the source impedance is located on 0.8 circles, while the shield resistance is located on 0.075 circles. As a result, the resistance and impedance are, respectively, 7.5 and 0.8 ohm. [7] Fillers and graphene substrate together hence offer good conductivity and lower resistance values. Because of this, the innovative methods[8] mentioned above enhance the shielding's

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https://doi.org/10.47392/IRJAEH.2024.0184

performance by lowering the amount of filler used, preserving [9] appropriate filler dispersion, enhancing electrical conductivity, raising thermal stability, and improving connectivity.

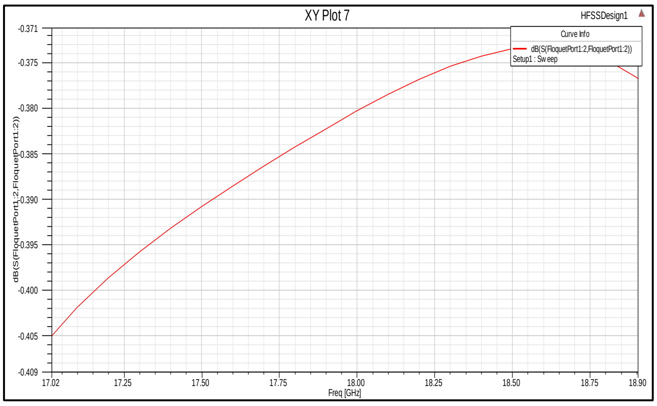

Figure 4 Transmission Coefficient Curve

The relationship between the transmitted wave's amplitude and the incident wave's amplitude is shown by the transmission coefficient curve Figure 4. It measures the net transmitted power, which is represented by the transmission coefficient and was found to be 0.373 at 18.6 GHz, since S12, for which the [10] input and output ports are different [14]. Equation (4) is used to calculate the value of absorption, which is found to be 0.254 based on the values of reflectivity and transmission (Geetha et al., 2009).

SA+SR+ST=1—Equation (4)

where SR stands for shield reflection, SA for shield absorption, and ST for shield transmission.

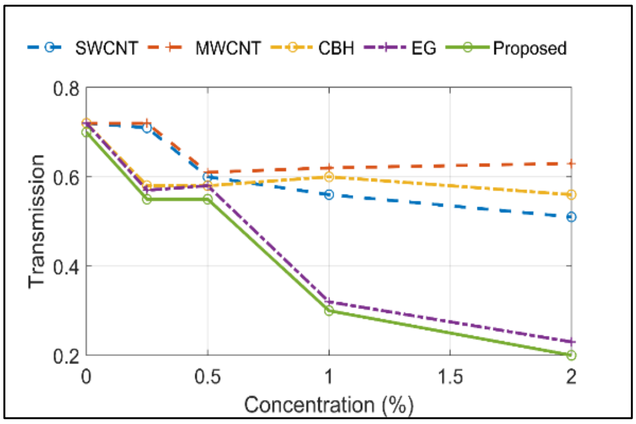

Figure 5 Transmission vs Concentration

Plotting the transmission value vs filler concentration (Banerjee et al., 2020) is shown in Figure 5. The suggested material is compared to different filler [15] concentrations of carbon black (CBH), exfoliated graphite (EG), single-walled carbon nanotubes (SWCNT), and multiwalled carbon nanotubes (MWCNT) at [16] concentrations ranging from 0.5 to 2%. Plot demonstrates that the suggested material, with 2% filler addition concentration, has the lowest transmission characteristics capability of 0.2 [17].

Conclusion

The EMI shield material in this work was developed using polymer matrix materials. The material was subsequently analysed and its various properties were identified using ANSYS-HFSS software. To improve the performance of the EMI shield, Graphene and conductive polymers were added to the selected materials. This was then simulated using HFSS software. Plots and charts produced by the analysis were used to determine the S-parameter characteristics for absorption, reflection, and transmission. Thus, it can be said that at a high frequency of 20 Hz, the shield material has good SE_T values of 0.373 dB. Lastly, a comparison of the suggested model with varying filler content and material reinforcement revealed a 30.75% increase in absorption.

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