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RESEARCH ARTICLE

Preparation and Characterization of (PMMA-PVC-MWCNTs) Nanocomposite for EMI Shielding Application

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Abstract

The (PVC-PMMA-MWCNTs) nanocomposites have prepared by Solution cast technique with different concentrations of CNTs (0, 0.5, 1, 1.5, 2, 2.5), casted in a clean glass plate. The structures of nanocomposites have been studied. The structural properties include Fourier Transform infrared spectroscopy (FTIR), scanning electron microscope (SEM). The effect of radar in the range (8-12) GHZ on (PVC-PMMA-MWCNTs) nanocomposite films, were studied as applications for shielding from Electromagnetic Interference (EMI), and has been noticed that the shielding effectiveness increases with the increase of concentration of MWCNTs.

Keywords: *Blend polymer, Cast method, MWCNTs, PMMA, PVC.*

Introduction

Polymer is multipurpose material having many individual properties like low density, reasonable strength, flexibility, easy processibilty, etc. However, the mechanical properties of these materials are inappropriate for many engineering applications [1]. Hence; there is a continuous search towards new polymeric materials with enhanced properties. Initially, blending of different type of polymer was used to fabricate new materials with unique properties [2]. However, blending lead to only secondary improvement in physical properties which were still unsuitable for engineering applications. So to improve the strength and stiffness of polymer materials different kinds of organic and inorganic fillers were used.

It was observed that strength and stiffness of long fibers strengthened thermosetting polymer is comparable to metals at a fraction of their weight. As a result of which these material were used in aircraft and in sport equipment [3]. However, processing of these materials is very difficult; therefore small fiber or particle reinforced composites were advanced. The common particle fillers used were silica, carbon black, metal particles etc. But significantly high filler loading was wanted to achieve desired mechanical property, which thus increased cost and made processibility difficult.

So to achieve high mechanical properties at minimized filler loading, nanofillers were used. The nanofiller reinforced polymer matrix is known as polymer nanocomposite. Polymer nanocomposites are a new group of composite materials, which is receiving significant attention both in academia and industry .Because it provide extra-large interfacial area for all the composites, the nano-element, and polymer. As a result, the nanofiller reinforced composites show enhanced toughness. It also possesses greater thermal and oxidative stability, better barrier, mechanical properties as well as unique properties like self-extinguishing behavior.

Compared to different range of nanofillers, carbon nanotubes (CNTs) have emerged as the most promising nanofiller for polymer composites due to their unusual mechanical and electrical properties [4].Presently, one of the most interesting applications of CNTs is the CNT/polymer nanocomposites [5].

Polymethyl methacrylate (PMMA) & Polyvinyl chloride (PVC)

Poly (methyl methacrylate) (PMMA), also known as acrylic or acrylic glass, is a transparent thermoplastic often used in sheet form or shatter-resistant alternative to glass, and contact lenses.

The same material can be used as a casting resin, in inks and coatings, and has many other uses. PMMA is an amorphous, hard, stiff but brittle. PMMA is a strong and lightweight material. PMMA is often preferred because of its moderate properties. Easy handling and processing, and having low cost, but behaves in a brittle manner when loaded. It has good abrasion and UV resistance and excellent optical clarity [6, 7].

As for Polyvinyl chloride (PVC) it is the most widely used member of the vinyl family. It is most commonly used in pipe and fittings. PVC offers excellent corrosion and weather resistance. It has a high strength-to- weight ratio and is a good electrical and thermal insulator. PVC may be used to temperatures of 140°F (60°C) and is readily available in sheets, rods, and tubing. PVC may be cemented, welded, machined, bent and shaped readily [8, 9].

Multi-walled Carbon nanotubes (MWCNTs)

MWNTs consist of multiple layers of graphene rolling along itselfs with diameters ranging from 2 to 50 nm counting on the number of graphene tubes. These tubes have an approximate inter-layer distance of 0.34 nm; it was first discovered by M. En doin 1978, as part of his Ph.D. But real interest in CNTs started when Iijima (1991) first reported it in 1991. The field thrives after that and the first polymer composites using CNT as filler was reported by Ajayan et al (1994) [10].

Theory

The influence of CNTs on the Electromagnetic interference (EMI) shielding effectiveness (SE) of the PVC/ PMMA/ MWCNTs composites was measured in the X-band (8-12 GHz) frequency range by vector network analyzer (ANRITSU MS 4642) as shown in Fig. 1. The dimensions of the test samples were 4 cm × 4 cm. The samples under the test were sandwiched between two waveguides of the network analyzer.

The network analyzer sent a signal down the waveguide incident to the sample, and the receivers detected and recorded the reflected and transmitted signals from the samples. Based on the received signals, the scattering parameters were evaluated to calculate the reflectance and transmittance of each sample [11], such that:

$$R = \left|\frac{P_R}{P_I}\right|^2 = |S11|^2 = |S22|^2 \quad \ldots \quad 1$$

$$T = \left|\frac{P_T}{P_I}\right|^2 = |S12|^2 = |S21|^2 \quad \ldots \quad 2$$

Where R is the reflectance, T is the transmittance, P_I, P_R, and P_T are the incident, reflected, and transmitted powers, respectively, S11 and S22 are the reflected voltage magnitudes divided by the incident voltage magnitude in the ports 1 and 2, respectively, S12 is the transmitted voltage magnitude from the port 2 to the port 1 divided by the incident voltage magnitude in the port 2, and S21 is the transmitted voltage magnitude from the port 1 to the port 2 divided by the incident voltage magnitude in the port 1. The shielding effectiveness (SE) of the samples is defined as the logarithm of the ratio of incident power to transmitted power with a unit in dB:

$$SE_R = 10\log_{10}\left(\frac{1}{1-R}\right) = 10\log_{10}\left(\frac{1}{(1-|S_{11}|^2)}\right) \quad \ldots \quad 3$$

$$SE_A = 10\log 10\left(\frac{1-R}{T}\right) = 10\log_{10}\left(\frac{1-|S_{11}|^2}{|S_{12}|^2}\right) \quad \ldots \quad 4$$

$$SE_{OA} = SE_R + SE_A \quad \ldots \quad 5$$

Where SE_R and SE_A are shielding by reflection and absorption, respectively, and SE_{OA} is the overall shielding effectiveness.

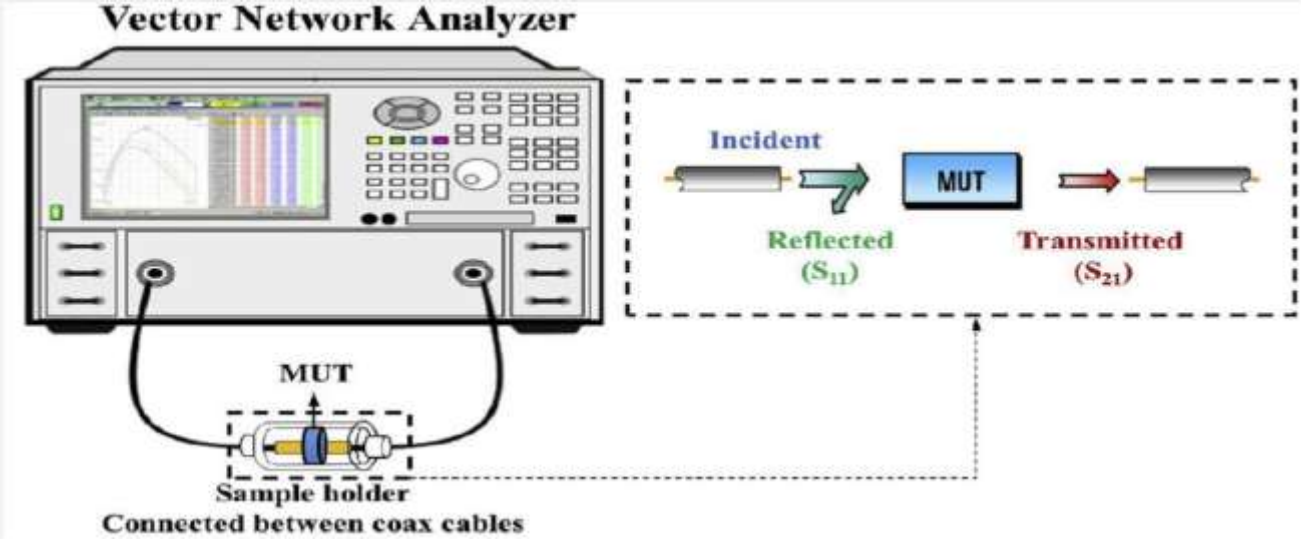

Figure 1: Schematic diagram of a vector network analyzer (VNA)

Experimental Details

Materials Used

Basic materials used are polymethyl methacrylate (PMMA) of molecular weight 120000 supplied by chemical point UG / Germany, and polyvinyl chloride (PVC) supplied by Gerhard Buchmann KG TUTTLINGEN/ GERMANY. Multi wall carbon nanotube (MWCNTs) (purity: 95%, provided by Sigma-Aldrich).

Preparation of PMMA/PVC/MWCNTs Composite Films

Composites of PMMA/PVC/MWCNTs were prepared using the casting method as: 1gm amount of PMMA and PVC Weight ratio of PMMA and PVC (70: 30 wt.%), respectively was dissolved in THF (tetrahydrofuran) (20ml) as a solvent with magnetic stirring about 20 minutes at 25 ℃ [12] until a homogenous viscous liquid solution was formed. MWCNTs added to the blend solution (drop by drop) with weight percents of 0, 0.5, 1, 1.5, 2, and 2.5, and dispersed by ultrasonication The resulting homogeneous solutions (PMMA/PVC/MWCNTs) were casted onto a clean glass plate(15 holes; 4×4 cm^2) Fig.2. and dried at 25℃ for 24 h.

Any residual solvent left was removed by drying the samples at 25 ℃ for 3h under vacuum [13]. The films were removed and their thickness (40 µm) was measured using Electronic Digital caliper micrometer. Calculated weight of PMMA/PVC blend and MWCNTs mass fractions were prepared according to:

$$w\% = \frac{wCo}{wCo + wblend} \times 100 \quad \ldots \quad 6$$

Where wCo and $wblend$ represent the weights of MWCNTs and the polymer blend, respectively.

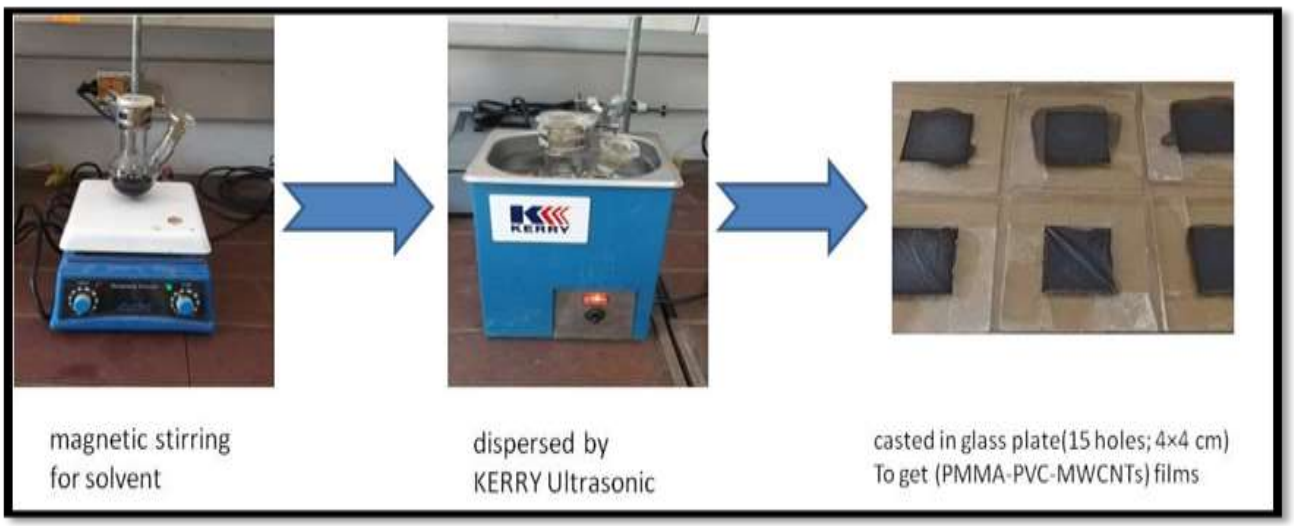

Figure 2: Preparation of PMMA/PVC/MWCNTs nanocomposite films

Results and Discussion

Scanning Electron Microscope (SEM)

SEM shows the very detailed three dimensional images at very high magnifications. The surface structure of the composite (PMMA/PVC/MWCNTs) can be imaged through SEM with high clarity. SEM images depict the surface morphology of composite before and after addition concentration of (MWCNTs) which are shown in (Fig. 3). The surface morphology of the (PMMA/PVC/MWCNTs) nanocomposite films shows many aggregates randomly distributed on the top surface of the films (Figs.3 a,b,c) When adding (0,0.5,1) wt.% of (MWCNTs), and when adding (1.5,2,2.5) wt.% of (MWCNTs) led to the formation of a dense ,entangled PVC- PMMA–MWCNT layer on the surface also fabricating honeycomb structures (Figs.3 d,e,f). The results indicate that the (MWCNTs) tended to form aggregates, and the network of MWCNTs dispersed in the polymer composites improves with the loading of MWCNTs [14, 15].

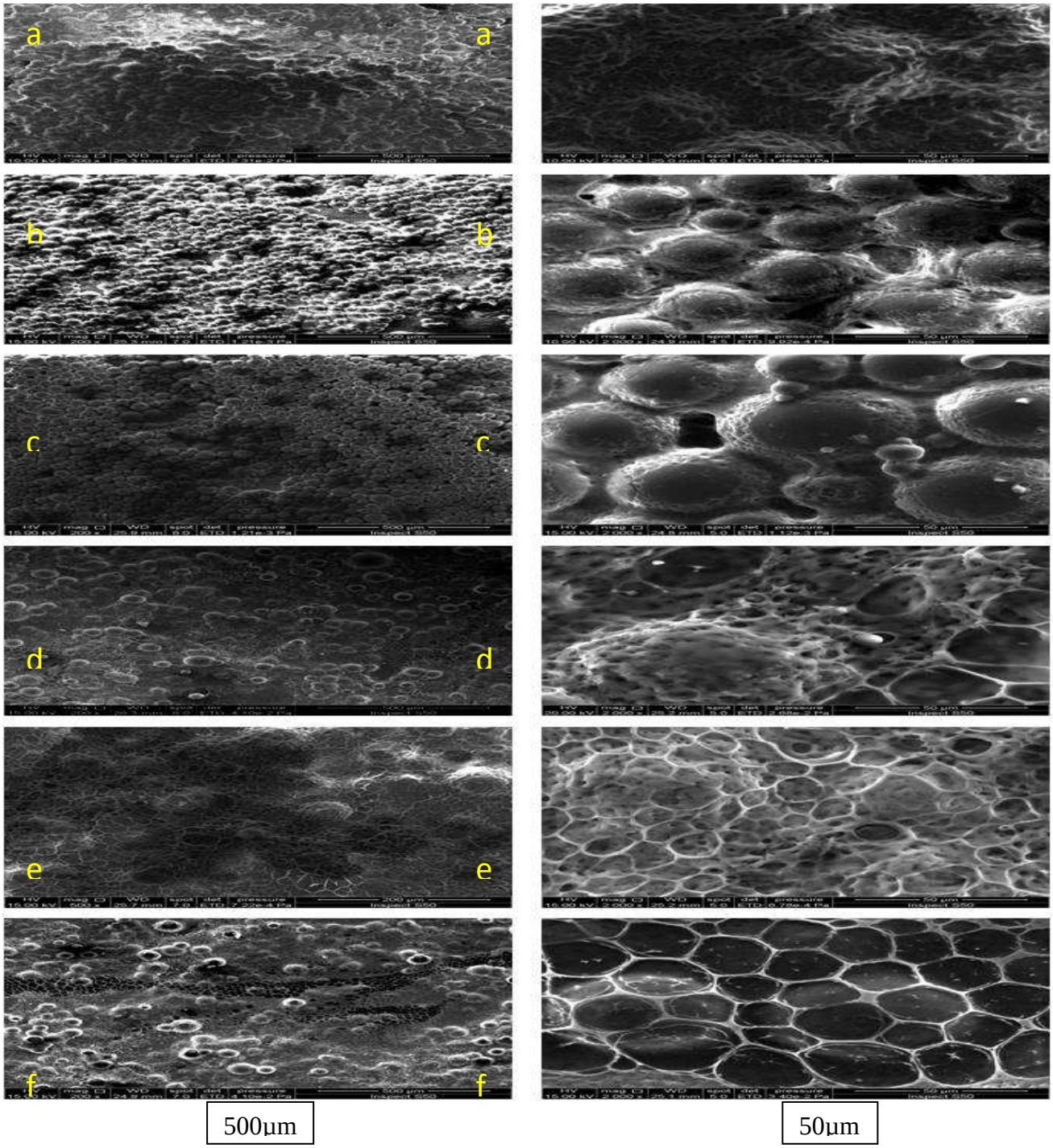

Figure 3: SEM images of (PVC-PMMA-MWCNTs) composites films for (a) 0 wt%, (b) 0.5 wt.% MWCNTs, (c) 1 wt.% MWCNTs, (d)1.5 wt.% MWCNTs, (e)2 wt.% MWCNTs and (f)2.5 wt.% MWCNTs.

FTIR Measurement

Fourier transform infrared (FT-IR) absorption spectra of (PMMA- PVC) blend are shown in Fig. 4. (PMMA-PVC) blend showed an IR absorption band at 1253 cm^{-1} was due to –OCH3 stretching. A sharp band located at 1728 cm^{-1} was ascribed to the carbonyl (C=O) group. The bands at 3437 cm^{-1} and 3600 cm^{-1} were attributed to the OH group hydroxyl aggregates. The bands at 2958 cm^{-1} proof of the presence of the CH3 bond, 2912 cm^{-1}, and 2843 cm^{-1} were assigned to(C–H) stretching. The presence of a peak at 752-840 cm^{-1} indicates the presence of (C-Cl) carbon-halogen bond [16]. Blending of PMMA and PVC showed characteristic absorption bands for both PMMA and PVC. This may imply that an interaction between PMMA and PVC occurs [17].

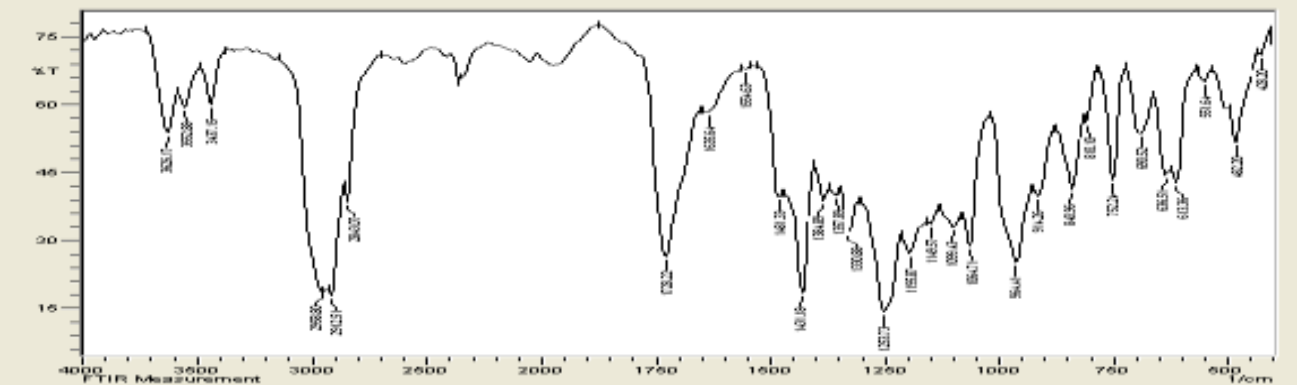

Figure 4: FTIR spectrum of (PVC-PMMA).

(Figs 5, 6, 7, 8) shows the FT-IR absorption spectra of the (PMMA-PVC-MWCNTs) nanocompsite with different concentrations of MWCNTs. The following was observed: The sharp bands at 1149 cm^{-1}, 1195 cm^{-1} increased, while the sharp band at 551 cm^{-1} decreased. This may be due to the link between the functional group inside the blend and MWCNTs ions, the results of the Fourier transform infrared spectroscopy (FTIR) spectra of (PMMA-PVC-MWCNTs) nanocompsite films are in agreement with [18]. It has been observed that when the concentration of MWCNTs become (2.5wt %) the (FT-IR) absorption spectra can't be collected for nanocomposite films because they became very dark and non transparent.

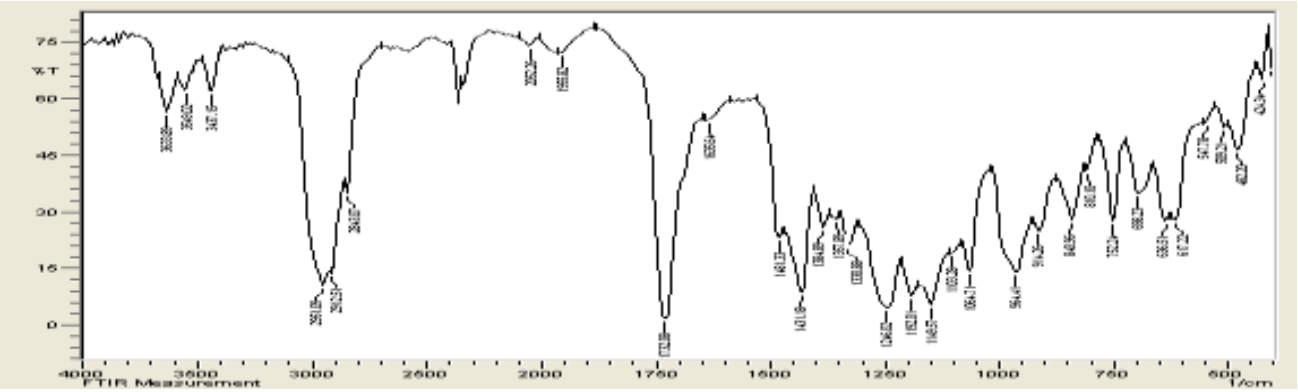

Figure 5: FTIR spectrum of (PVC-PMMA) &0. 5wt% MWCNTs

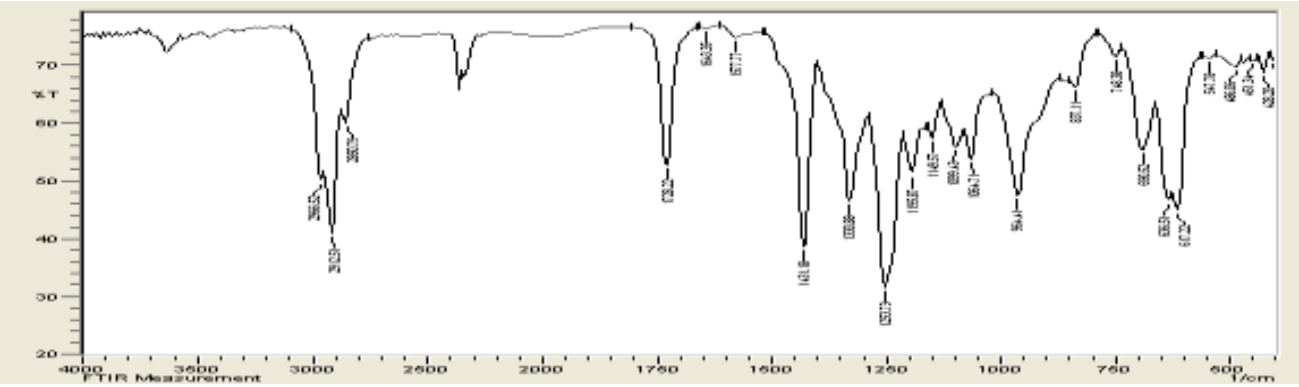

Figure 6: FTIR spectrum of (PVC-PMMA) &1wt% MWCNTs

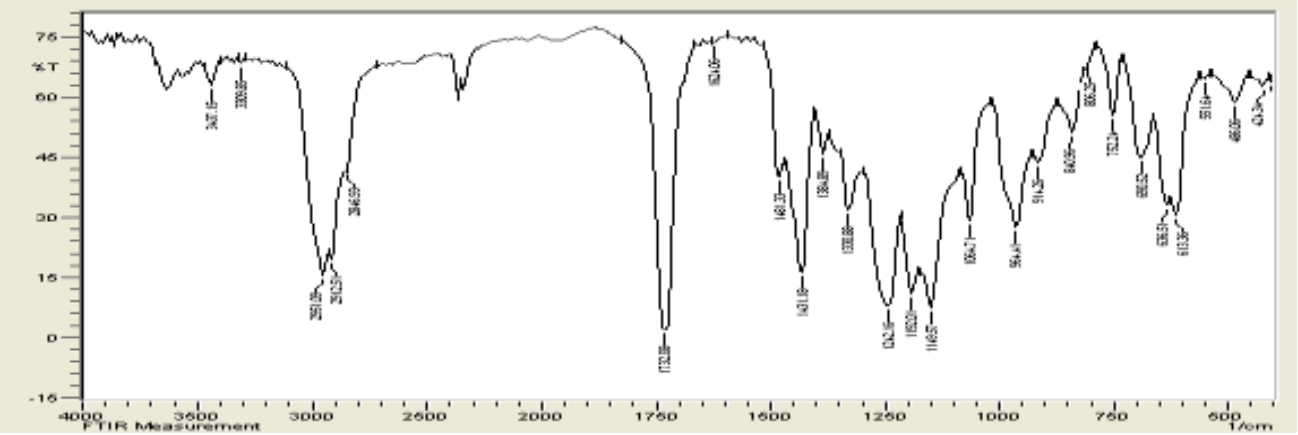

Figure 7: FTIR spectrum of (PVC-PMMA) &1.5wt% MWCNTs

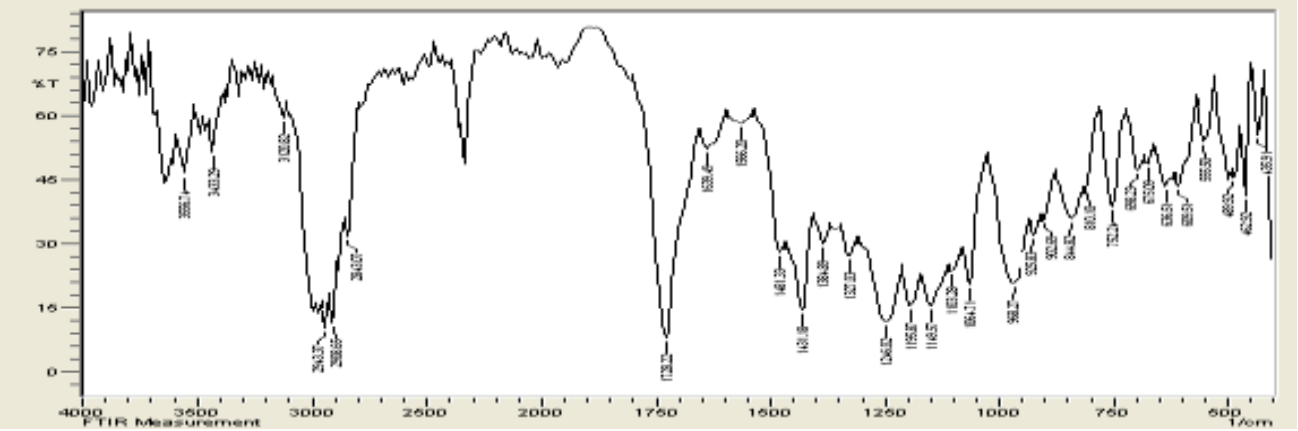

Figure 8: FTIR spectrum of (PVC-PMMA) &2wt% MWCNTs

Electromagnetic Interference Shielding Effectiveness (EMI SE) Application

Fig. 9 shows the variation in the SE_{oA} values of the (PMMA-PVC-MWCNTs) for different concentration of MWCNTs, at 8-12 GHz. The SE_{oA} increases with the MWCNTs content, suggesting that the absorption contribution to the EM SE increases with the MWCNTs loading increment .The primary mechanism of the EMI shielding is usually a reflection of the EM radiation incident on the shield, which is a consequence of the interaction of the EMI radiation with the free electrons on the surface of the shield. Absorption is usually a secondary mechanism of EMI SE, whereby electric dipoles in the shield interact with the EM waves in the radiation [19].

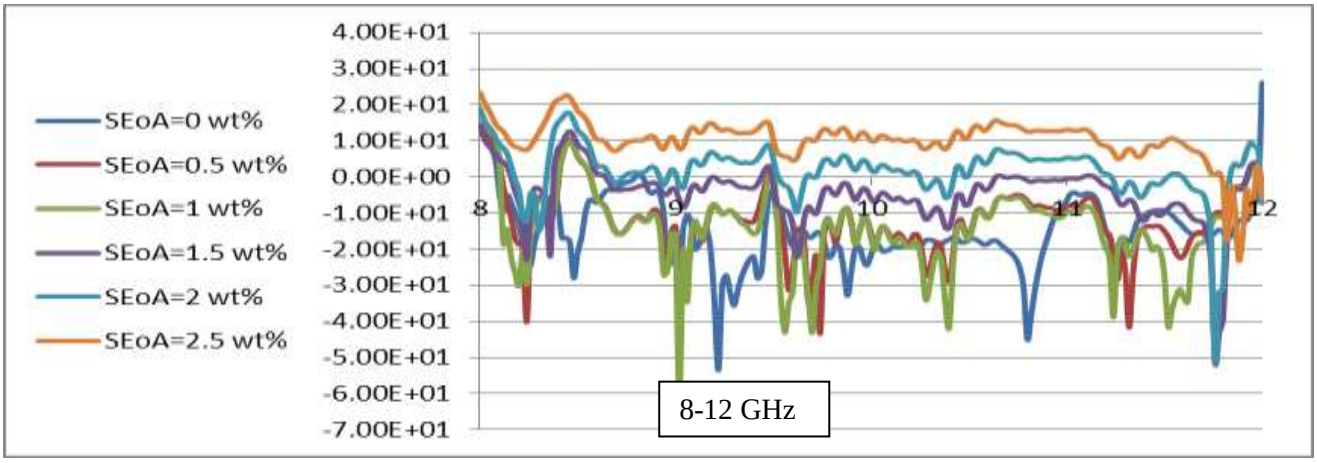

Figure 9: SET as a function of frequency measured in the 8-12 GHz range, of different (PMMA-PVC-MWCNTs) nanocomposites

From (Fig. 10) the EMI SE value increased dramatically with a slight MWCNTs wt % increment. In fact, the highest EMI SE_{oA} of approximately 10 dB was achieved from 2.5 wt% MWCNTs in the composite at a particular frequency in the X-band region, over and above; it was found that SEA increases and SER decreases as the MWCNTs content increments.

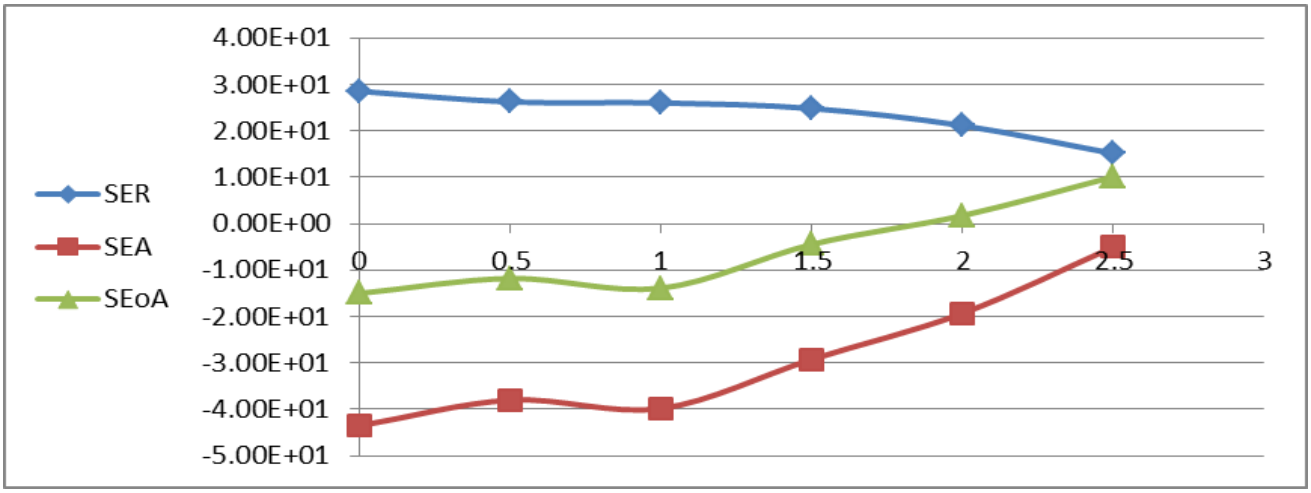

Figure 10: Comparison of SEo A, SER, and SEA in the 8–12 GHz range for (PMMA-PVC-MWCNTs) composites with different concentration

The scope of this research is to determine the minimum percentage of filler for a sample of 40µm thickness to obtain a maximum SE. The mean values of SER, SEA and SEoA for the composites which calculated by Eqs.(3, 4, 5) for different MWCNTs wt% are listed in (Table 1) below [20]:

Table 1: Mean SER, SEA and SEoA of (PMMA-PVC-MWCNTs) composites.

Concentration wt%	SER dB	SEA dB	SEoA dB
0	2.85E+01	-4.35E+01	-1.50E+01
0.5	2.62E+01	-3.80E+01	-1.18E+01
1	2.60E+01	-3.98E+01	-1.39E+01
1.5	2.48E+01	-2.92E+01	-4.45E+00
2	2.11E+01	-1.93E+01	1.74E+00
2.5	1.51E+01	-5.02E+00	1.01E+01

Conclusions

The shielding effectiveness is defined as the process of using specialized materials to reduce the EMI fields or waves that enter a specific enclosure. The shielding performance highly depends on type, size and thickness of the utilized materials along with the frequency range.

In this work, (PMMA-PVC-MWCNTs) nanocomposites structures have been successfully synthesized for potential SE and absorption applications. The EM properties of these composites in waveguides were theoretically and experimentally investigated in the (8-12) GHz range of frequency. For microwave characterization, the effects of various MWCNTs compositions on the shielding effectiveness of the (PMMA-PVC-MWCNTs) composites were calculated using the measured of vector network analyzer and were implemented in shielding effectiveness and absorption applications.

The Shielding effectiveness of the different (PMMA-PVC-MWCNTs) nanocomposites showed that the overall Shielding effectiveness increased with the filler content, which confirmed the correlation between the Shielding effectiveness value and the MWCNTs filler content.

References

1. Khot, Shrikant N, et al (2001) Development and application of triglyceride-based polymers and composites. Journal of applied polymer science, 82 (3):703-723.
2. Waghmare RV, et al (2007) Study of dc electrical conductivity of paranitroaniline doped (1: 1) polyvinylchloride and poly (methyl methacrylate) poly blends. Bulletin of Materials Science, 30 (2):167-172.
3. Michler, Goerg H (2016) Atlas of polymer structures: Morphology, deformation and fracture structures. Carl. Hanser Verlag GmbH Co KG,.
4. Ishikawa Hiromi, Fudetani Shuichi, Hirohashi Mitsuji (2001) Mechanical properties of thin films measured by nanoindenters. Applied surface science, 178 (1-4):56-62.
5. CAI Lintao Tabata, Hitoshi KAWAI Tomoji (2000) Self-assembled DNA

networks and their electrical conductivity. Applied Physics Letters, 77 (19): 3105-3106.

6. Achari V Balasubramanyam, et al (2007) Electrical, optical, and structural characterization of polymer blend (PVC/PMMA) electrolyte films. Ionics, 13 (5): 349-354.
7. Patel Gaurang, Sureshkumar MB, Patel Purvi (2011) Structural, Optical and Mechanical Properties of PVC/PMMA Polymer Blend by Spectroscopic Techniques. In: AIP Conference Proceedings. AIP, 645-648.
8. LU JY, et al (2014) Preparation and properties of antibacterial polyvinyl chloride. European review for medical and pharmacological sciences, 18 (10): 1448-1453.
9. Mansour SH, Iskander BA, Nasrat LS (2006) Effect of various temperature environments on the performance of PVC/ATH composites as insulating material. Polymer-Plastics Technology and Engineering, 45 (7): 857-863.
10. Choudhary Veena GUPTA Anju (2011) Polymer/carbon nanotube nanocomposites. In: Carbon nanotubes-polymer nanocomposites. In tech Open.
11. BASICS, Agilent Network Analyzer (2004) Agilent technologies. URL: http://cpliterature. product. agilent. com/litweb/pdf/5965-7917e. pdf,.
12. JIA Puyou, et al (2017) Self-Plasticization of PVC materials via chemical modification of mannich base of cardanol butyl ether. ACS Sustainable Chemistry & Engineering, 5 (8): 6665-6673.
13. Alotaibi, Mohammad Hayal, et al (2018) SEM analysis of the tunable honeycomb structure of irradiated poly (vinyl chloride) films doped with polyphosphate. Heliyon, 4 (12): e010-13.
14. HSU, Je-Chuan, et al (2017) Absorption behavior of poly (methyl methacrylate)-multi walled carbon nanotube composites: effects of UV irradiation. Physical Chemistry Chemical Physics, 19 (10): 7359-7369.
15. Bhatia, Ravi, et al (2018) A critical review of experimental results on low temperature charge transport in carbon nanotubes based composites. Reviews in Physics, 3: 15-25.
16. Khan, Mohammad Saleem QAZI, Raina Aman WAHID, Mian Said (2008) Miscibility studies of PVC/PMMA and PS/PMMA blends by dilute solution viscometry and FTIR. African Journal of Pure and Applied Chemistry, 2 (4): 041-045.
17. Patel, Gaurang (2015) Spectroscopic investigations on polymer blends/ composites. PhD Thesis.
18. Alghunaim NS (2015) Spectroscopic analysis of PMMA/PVC blends containing CoCl2. Results in Physics, 5: 331-336.
19. Fahad A, et al (2016) Dielectric Behavior of OPEFB Reinforced Polycaprolactone Composites at X-Band Frequency. International Polymer Processing, 31 (1): 18-25.
20. Ahmad, Ahmad F, et al (2018) Attenuation performance of polymer composites incorporating NZF Filler for electromagnetic interference shielding at microwave frequencies. J. Mater. Sci. Eng., 5.

