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ELECTROMAGNETIC INTERFERENCE SHIELDING OF MULTI-WALLED CARBON NANOTUBES/POLYANILINE NANOCOMPOSITES

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Abstract

In the present investigation multi-walled carbon nanotubes (MWCNTs) –polyaniline nanocomposites was developed by compression molding technique of desired size. Initially the MWCNTS were functionalized by acid treatment to attached carboxylic functional groups on the surface of nanotubes to facilitate the interaction with polymer. These composite were characterized by scanning electron microscope (SEM), FTIR, and for electromagnetic interference (EMI) shielding. The experimental results show favorable interaction between PANI and different wt.% of functionalized MWCNT. The electrical conductivity was measured by four probe method, which shows that the electrical conductivities of PANI-MWCNTs composite continuously increase from 0.45 Scm^{-1} to 2.9 Scm^{-1} with increasing the wt% of MWCNTs from 0 to 12 wt. % respectively. The EMI shielding nano-composite was increases from 45 dB to 90 dB with increasing the nanotube content and it was absorption dominated. The investigation studies infer that MWCNTs-polyaniline nanocomposites can be used lightweight EMI shielding materials to protect electronic devices and components from electromagnetic radiation.

Keywords: Carbon Nanotubes, Polyaniline, Electrical Conductivity, EMI shielding.

1.Introduction

Due to increase in the technological advancement, there are different types of threat realized by the human. One of such threat is electromagnetic radiation. Electromagnetic radiation in term of classical theory , the flow of energy at the universal speed of light through free space or through material medium in the form of the electric and magnetic field. It may come in the form of lightning strikes, interference from radio emitters, nuclear electromagnetic pulses or even high power microwave threats. Therefore there is need to develop the electromagnetic interference shielding (EMI) material that protect human being from radiation. Traditional radiation shielding materials include boron, tungsten, Titanium, tantalum, silver, gold, or some combination of these materials etc. But these materials have disadvantages like high density, corrosion and difficulty in processing. A, light weight material is always preferred as radiation shielding materials in aerospace transportation vehicles and space structures. EMI shielding refers to the reflection and absorption of electromagnetic radiation by material. In case of reflection of the radiation by the shielding material, the shield material must have mobile charge carrier (electron or holes) which interact with the electromagnetic field in the radiation. As a result, the shield material tends to be electrically conducting. The electrical conductivity is not scientific criteria for shielding, as conduction requires connectivity in the conduction path. Metals are therefore the most common materials for EMI shielding and they function mainly by reflection due to the free electrons in them. The metal sheets are bulky, so metal coating made by electroplating, electroless plating and vacuum deposition are commonly used for shielding [1]. But it suffers from their poor wear or scratch resistance. However, absorption of shield material depends on the electric or magnetic dipoles, which interact with electromagnetic field of the radiation. The conductive polymers have been investigated intensively in the last two decades due to their interesting physical properties and potential application in advanced technologies. Polyaniline (PANI) is one of the first intrinsic conducting polymers that used in various applications. Carbon-based polymer composites are attractive compared to conventional metal and polymer based EMI shielding materials due to their light weight, corrosion resistance, flexibility, and processing advantages. Therefore in this investigation the Multi-walled carbon nanotube–polyaniline nanocomposites are prepared which can solve the problem of conductivity and continuous conduction path which is the prime requirement of EMI shielding materials.

2.Experimental

The multi-walled carbon nanotube (MWCNTs) was used for the development of nanocomposite which was synthesized by chemical vapor deposition process. As such MWCNTs have limited surface functional groups on the surface for making the chemical interaction with polymer. Therefore, MWCNTs were functionalized by acid treatment (sulphuric acid and nitric acid in the ratio of 1:3). The polyaniline-MWCNTs nanocomposites were prepared by compression molding technique using die-mold. The different wt. % of MWCNTs (1 to 20 %) was mixed with polyaniline. The composites of 2mm thickness, 2mm width and 5cm length were prepared. The moulding temperature of composite was 137^0C and remains in the om the platen of hydraulic press till its melting temperature of 245^0C.

The MWCNTs and surface functionalized MWCNTs were characterized by FTIR. The morphology of MWCNTs and nanocomposites was studies by scanning electron microscope. The electrical conductivity of nanocomposite was measured by four probe technique. The electromagnetic interface shielding effectiveness was measured in the X band region frequency (8.2 to 12.4 GHz) by two port of Vector network analyzer (VNA E8263B Agilent Technologies).

3.0 Results and Discussion

Figure 1(a) shows the SEM micrograph PANI used for the development nanocomposite. Figure 1(b) shows the micrograph of multi-walled carbon nanotubes in which diameter of nanotubes varies from 50-100 nm and length is few microns. The surface morphology of PANI / MWCNT composite is also studied by SEM are shown in the figure 1 (c,d,e and f) with different weight fraction of MWCNTs (1,5, 10 and 12%) . The micrograph shows that the MWCNTs were well dispersed in the composite. There was a homogeneous coating of polyaniline on MWCNTs. This is indicative of good interaction between nanotubes and polyaniline. As each MWCNT supports a quite considerable mass of PANI, It can also be seen that the composite displays a new interwoven fibrous structure with the diameter in the range of several tens of nanometer and length up to several micrometer. This new network may give rise to conductive pass ways and lead to highly conductivity. The globular or spherical shaped particles of polyaniline can be seen easily. Even at higher content of nanotubes, the CNTs are will dispersed in the matrix. But at 12 wt % of CNTs, there is some agglomerated form of CNTs but are not is bundle (figure 1f). Figure 2 shows the FTIR spectra of MWCNTs and functionalized MWCNTs. The broad peak at around 3400cm^{-1} is assigned to O—H stretch vibration of hydroxyl groups, the peak at 1740cm^{-1} and 1616cm^{-1} corresponded to the carboxylic C=O stretch vibration, and the peak at 1454 cm^{-1} is attributed to C—C stretching vibration of main structure of MWNT. The peak at 1122cm^{-1} corresponds to C-O stretch. The peaks at 2927 and 2858cm^{-1} are assigned to C—H stretch vibration of methylene produced at the defect sites of acid-oxidized MWNT surface.

Figure 3 shows variation electrical conductivity of nanocomposites with increasing MWCNTs content. The composite prepared showed improvement in electrical conductivity as compared to blank polyaniline. The electrical conductivity has been measured from pure polyaniline (0%MWCNT) to 12wt% of MWCNT. It increases moderately from 0.4348 Scm^{-1} for neat PANI t to a maximum at 2.9 S cm^{-1} for 12 wt.% CNTs. It is clearly shown that with the increasing concentration of MWCNT electrical conductivity is also increase linearly, these result also shows that higher concentration of MWCNT gives good networking for electrical conduction because MWCNT have high electrical conductivity. This is a higher conductivity than that of the reported for similar composites[7]

Electromagnetic interference (EMI) shielding effectiveness (SE) is defined as the attenuation of the propagating electromagnetic (EM) waves produced by the shielding material. SE measurements were carried out in the frequency range of 8.2-12.4 GHz and keeping the input power level at -5 dBm. When electromagnetic radiation is incident on the material, the absorptivity (A), reflectivity (R) and transmissivity (T) must sum to the value "one", that is, $T + R + A = 1$. For a transverse electromagnetic wave propagating inside the shield material with negligible magnetic interaction, the total shielding efficiency (SE_T) of the shield material can be expressed as

SE_T (dB) = 10 log10 (P_I /P_T) = 20 log10 (E_I/ E_T) = 20 log10 (H_I/H_T)

Where P_I (E_I or H_I) and P_T (E_T or H_T) are the intensity (electric or magnetic field) of incident and transmitted electromagnetic waves through a shielding material respectively. SE_T is described in decibels (dB) and can be described as the sum of the contribution due to reflection (SE_R), absorption (SE_A), and multiple reflections (SE_M) i.e.

$SE_T = SE_R + SE_A + SE_M$

Multiple reflections (SE_M) are the positive and negative correction term induced by the reflecting waves inside the shielding barrier.

Figure 4 shows EMI shielding effectiveness of PANI-CNT composites with increasing MWCNTs contents. Figure 4a shows the total shielding effectives with increasing nanotube contents. The total shielding effectiveness increases with increasing CNT contents. The total shielding effectiveness is the contribution of reflection and absorption of shielding effectiveness. In this it is observed that the total shielding effectiveness is dominated by the absorption phenomena. This might be due to the nonconductive polymer phase and CNTs have Fe catalyst. As result the magnetic properties contribute in the absorption phenomena.

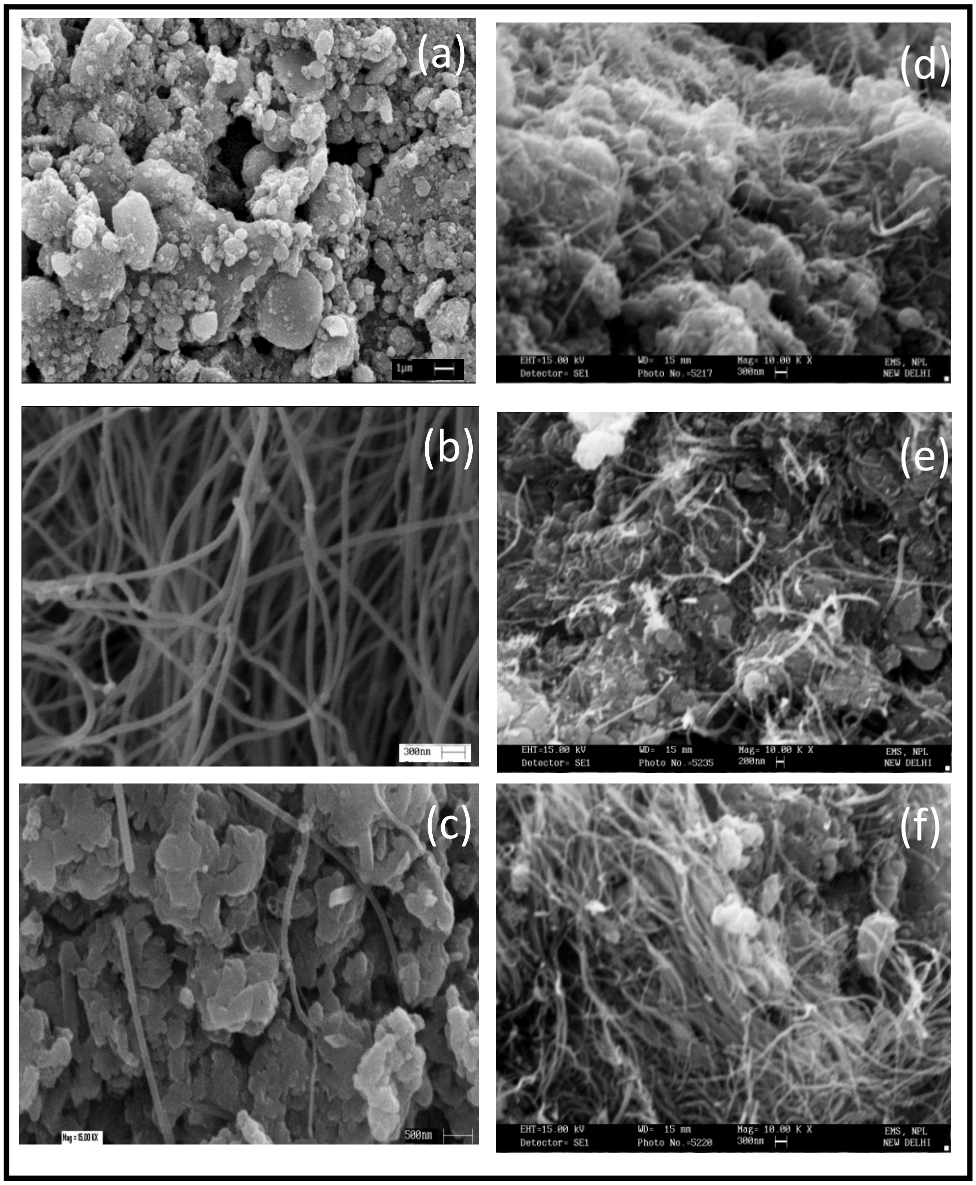

Figure 1: SEM micrographs of (a) PANI, (b) MWCNTS, PANI-MWCNTS nano-composites (c) with 1 wt.% of MWCNTs) (d) with 5 wt.% of MWCNTs (e) with 10wt.% of MWCNTs, and (f) with 12 wt.% of MWCNTs .

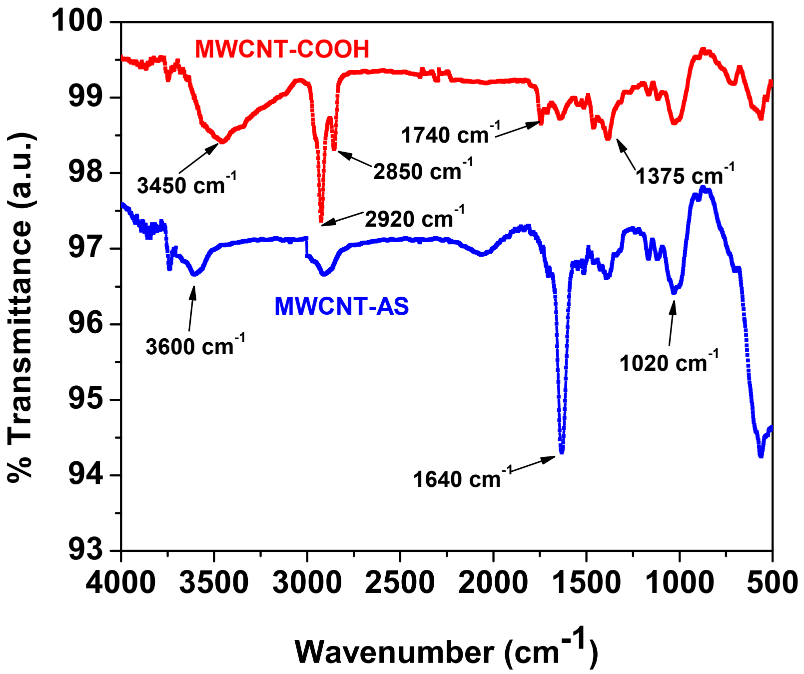

Figure 2: FTIR spectra of as such MWCNTs and Functionalized MWCNTS

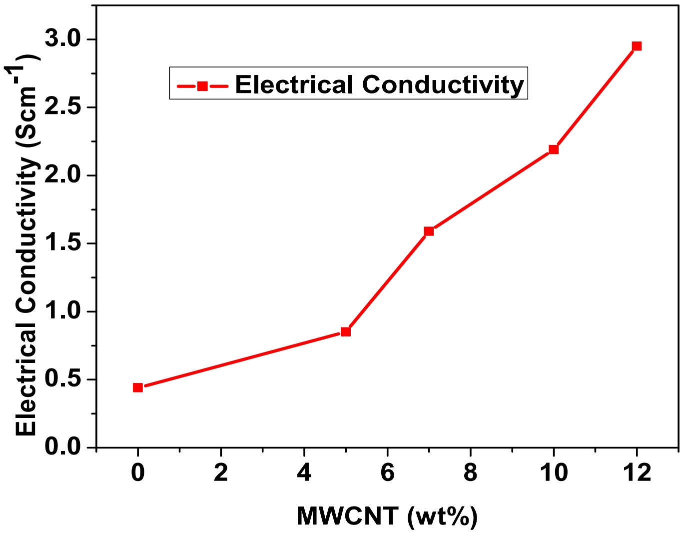

Figure 3: Electrical conductivity with increasing MWCNTs content in PANI-MWCNTs composites

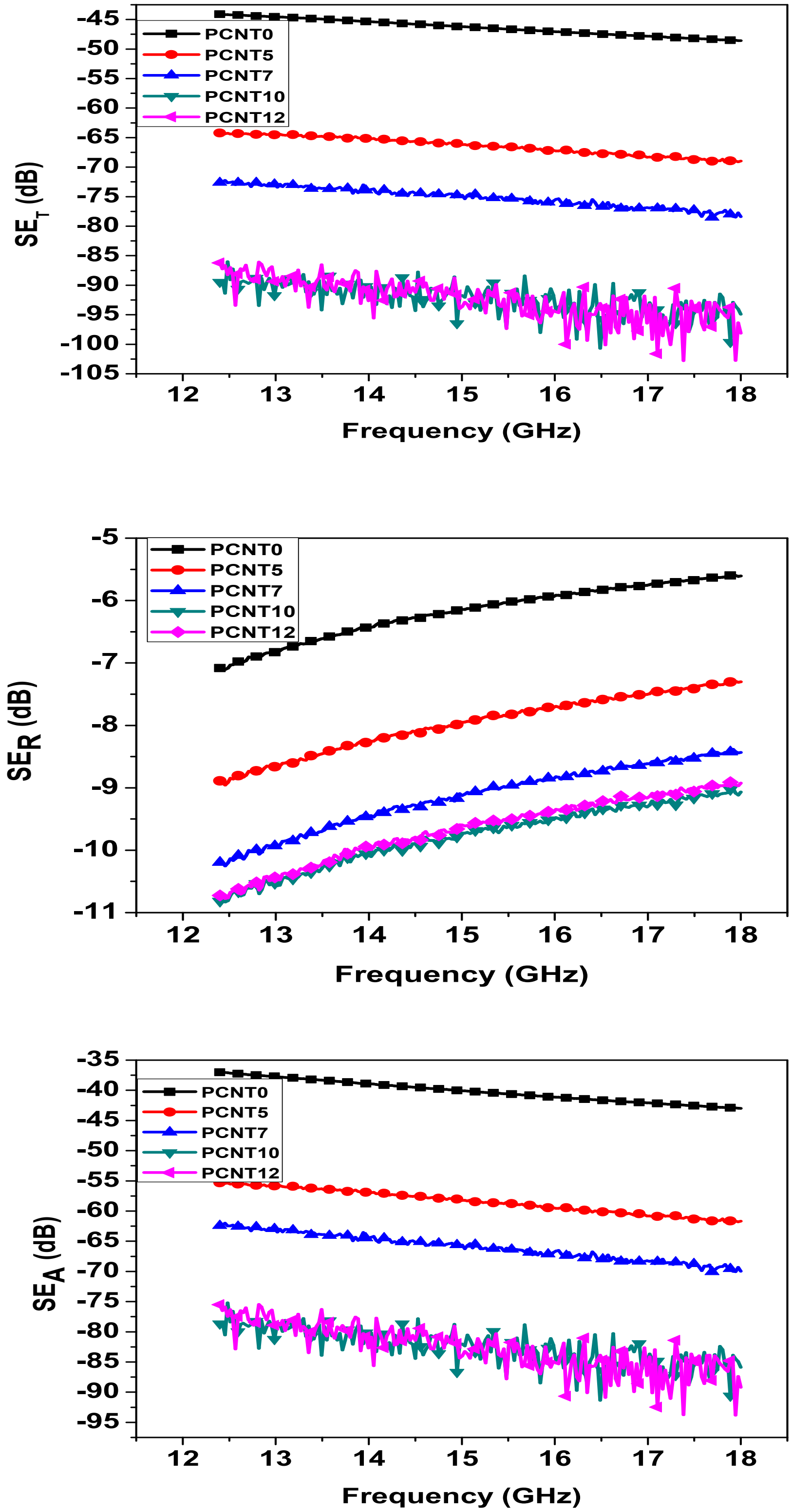

Figure 4: Shielding Effectiveness (SE) of PANI-MWCNTs nanocomposite (a) SE_T (b) SE_R and (c) SE_A

4.Conclusions

The PANI-MWCNTs nanocomposites possesses EMI shielding effectiveness 45 dB to 90 dB with increasing the nanotube content and it was absorption dominated. The investigation studies infer that MWCNTs-polyaniline nanocomposites can be used lightweight EMI shielding materials to protect electronic devices and components from electromagnetic radiation.

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