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A study on electrical properties of polymer enhancement by multiwalled carbon nanotube

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ABSTRACT

In this research study composite materials (Epoxy resins / multi walled carbon nanotubes) were prepared by mixing ratio of multi walled carbon nanotubes (MWCNTs) (1,2,3 and 4 %wt.). The techniques were implemented by mixing blend epoxy resins with MWCNTs through magnetic stirrer for 15min. Homogenize the blend was carried out using the homogenizer equipment ultrasonic liquid processor with high-intensity for 5min and followed by the addition of the hardener to the mixture. The molds prepared by casting EP/MWCNTs composite.

The electrical conductivity of EP/MWCNTs composite was obtained by A.C equipment. The results showed that there was an evolution from insulator state to semiconductor state when increasing the mixing ratios of MWCNTs. The electrical conductivity was improved by three orders than samples of pure epoxy resins matrix.

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ت دراسة حول الخصائص الكهربائية للمواد البوليمر المعززة بواسطة الأنابيب النانوية الكربونية متعددة الجدران

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الكلمات المفتاحية:

راتنجات الايبوكسي
الأنابيب النانوية الكربونية
متعددة الجدران
المواد المتراكبة

الـــخُـــلاصـــة

في هذه الدراسة البحثية تم تحضير المواد المتراكبة (راتنجات الايبوكسي / الأنابيب النانوية الكربونية متعددة الجدران) عن طريق خلط نسبة الأنابيب النانوية الكربونية متعددة الجدران *(MWCNTs) (1*، *2*، *3*و ٤٪). كانت عن طريق خلط مزيج راتنجات الايبوكسي مع *MWCNTs* من خلال محرك مغناطيسي خلال ١٥ دقيقة. قمنا بتجانس المزيج بواسطة معدات المجانسة المعالج السائل بالموجات فوق الصوتية بكثافة عالية خلال ٥ دقائق ثم إضافة المصلب إلى الخليط. القوالب المعدة بصب مركب *EP / MWCNTs* بنسب خلط مختلفة (١ ، ٢ ، ٣ و ٤٪) من *(MWCNTs)* . يتم الحصول على خصائص التوصيل الكهربائي للمتراكب *EP / MWCNTs*بواسطة معدات التيار المتناوب. أظهرت النتائج أن هناك تطورًا من حالة

المادة العازلـة إلـى حالـة أشباه الموصـلات عنـد زيـادة نسب الخلـط لــ .MWCNTs تم تحسين الموصلية الكهربائية بثلاث مرات عن عينات اساس راتنجات الايبوكسي النقية.

1. INTRODUCTION

Nowadays, the polymers performance has become an actual significant part in many fields as a result of their advantages over conventional materials for example resistance to corrosion, ease of processing, and low-fees manufacture [1]. In addition, polymers are calm to handle and take numerous degrees of choice for controlling their properties. The development of the polymer's properties may arise trough the filling process with several nano-fillers such as fibers, semiconductors, organic, metals and inorganic constituent part besides carbon constructions. Epoxy resins are thermosetting polymers and they are the largest commonly used resins [2]. They are with low molecular weight organic liquids holding epoxide groups. MWNT consists of concentric cylinders of graphite, coaxially organized with inter layer departures of ~0.34nm, nearly inter plane spacing of graphite sheets. The diameter of MWNTs varies from as low as 2nm to further more 100 nm [3]. The dielectric spectroscopy equipment is the technique utilized for the measurements of the dielectric properties of materials such as a function of frequency. The functional electric filed and temperature too may be changeable in the measurements [4].

The explanation for dielectric constant is associated with the material's permittivity. The Permittivity of materials can be defined as the capability of polarized materials to reply to an applied field. It is the ratio of the Materials permittivity to the Permittivity of space [5].

$$\varepsilon_r(\omega) = \frac{\varepsilon(\omega)}{\varepsilon_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$\boldsymbol{\varepsilon}$ - the material permittivity and it is bigger than $\boldsymbol{\varepsilon}_o$, and ε_r - relative permittivity is higher than unity. The relative permittivity can be expressed in complex equations as shown in:

$$\varepsilon_r = \varepsilon' - j\varepsilon'' \quad \ldots\ldots\ldots\ldots\ldots(2)$$

ε'- dielectric constant which is the real part and the ε'' – dielectric losswhich is the imaginary part [6]. Tan δ represents the ratio of dielectric loss to dielectric constant as shown in:

$$tan\delta = \frac{\varepsilon''}{\varepsilon'} \quad \ldots\ldots\ldots\ldots\ldots..(3)$$

The mechanism of conduction which related to the pure polymer materials are designated as insulator materials. The doped polymers are changed in the conduction properties from insulator materials to semiconductor materials. The relative carrier concentration (n) and the carrier mobility (μ) related to the conductivity σ [7].

$$\sigma = e\, n\, \mu \quad \ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

For intrinsic conductivity, n is the reductions exponentially with growing band gap, then the polymer materials have comparatively great band gap, therefore, n is small in normal temperature degree, so as to a small value of n chiefs to a small amount of undoped polymers conductivity even if the polymer materials have large carrier mobility [8]

2. EXPERIMENTAL DETAILS

The raw materials that were used to compose the tests are:

In this research, it was utilized 1 gallon epoxy resin 1:1 (Crystal Clear Resin) and Hardener (Super Gloss Coating) its electrical conductivity from 10^{-6} to 10^{-5} S/m, density equivalent to 1.02 gm /cm^3 and mixing time is 42 min at 30^o C.

MWCNTs nano powder manufacturer by Guangzhou Hongwu Material Technology Co., Ltd. Diameter:10-30nm and Length:1-2um, 5-20um.

For dielectric examinations of Epoxy / MWCNT nanocomposite the dielectric samples varied in the form of molds were utilized for molding the composite materials.

- Balance (d = 0.1mg) was utilized to weigh the mixing ratios of the epoxy resin and fillers.
- Magnetic stirrer has programmed thermometer and multi-speed 0-1000 rpm and utilized to improve the spreading for multi walled carbon nanotubes.
- By vacuum less than 10^{-4} bar from rotary vacuum equipment was utilized to vanished the bubbles from the blend of epoxy resin with nanotubes.
- To obtain batter dispersion, Homogenizer (50Watt, 23KHz, 110Volt) was utilized for fillers in epoxy resin.

MWCNTs mixing ratios were weighted and manually mixed with epoxy resin at the balance equipment located into the gloves box to obtain good homogeneity of samples. By magnetic stirrer nanotubes were mixed with epoxy resin at 500 rpm during 25 minutes to obtain good distribution and less agglomeration. Then for 5 min. procedure of ultrasonic homogenizer was performed to obtain dispersion. EP / MWCNT were mixed with hardener for 5 min. The third procedure was by utilizing vacuum equipment (10^{-3} bar) to vanished the bubble [9]. Four composites samples of EP pure and EP / MWCNTs composites with different mixing ratios were prepared for electrical properties is identical to the specification of ASTM (D150) as shown in the table (1):

Table (1). Composites samples with different mixing ratios

No.	Samples
1	Ep
2	EP/1% MWCNTs
3	EP/2% MWCNTs
4	EP/3% MWCNTs
5	EP/4% MWCNTs

3. RESULTS AND DISCUSSION

The dielectric spectroscopy equipment is the technique used to measuring the properties of dielectric composite materials when applying electric filed as a function of frequencies. The equipment range of frequencies were 40Hz – 110MHz and electrode diameter is 1 cm. The dielectric properties were measured (relative permittivity; real part of dielectric constant and tan delta) with the frequency range of 10^3 - 10^6 Hz of the pure epoxy and epoxy nanocomposites. The permittivity and tan delta were measured with applied voltage of 500 mV at a room temperature.

The variations of Relative Permittivity of Epoxy / MWCNTs composites as a function of frequency variety with mixing ratios can be shown in figure (1):

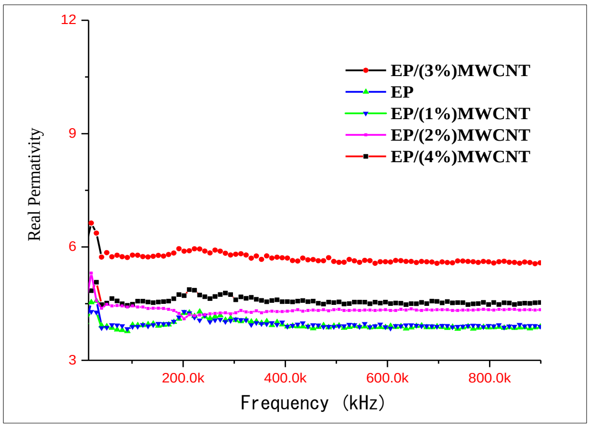


Figure (1): Real permittivity with frequency for EP and EP/MWCNTs composites with 1,2,3 and 4%wt. of MWCNTs.

By utilizing formula one can obtain the electrical conductivity. It may be determined as shown in figure (2) that the raise in the mixing ratio of MWCNTs improves electrical conductivity [10].

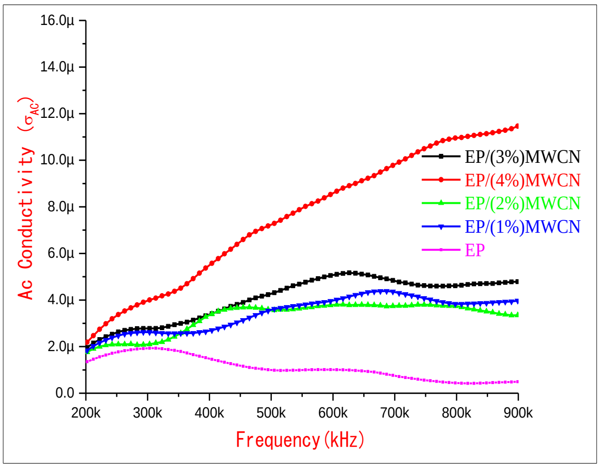
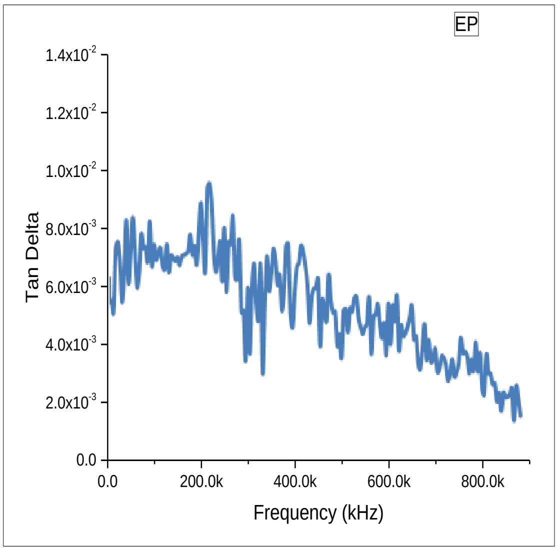
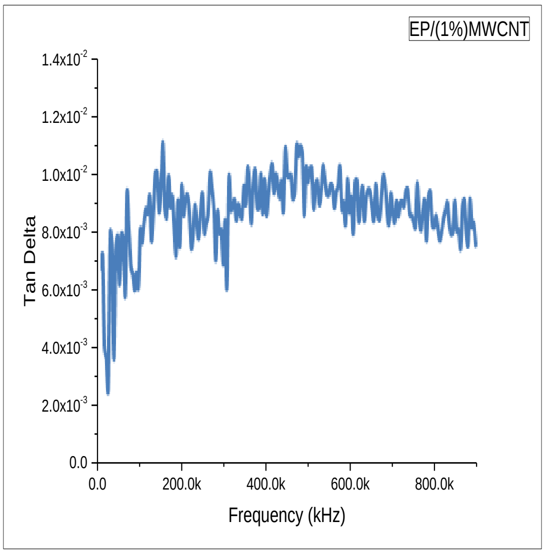
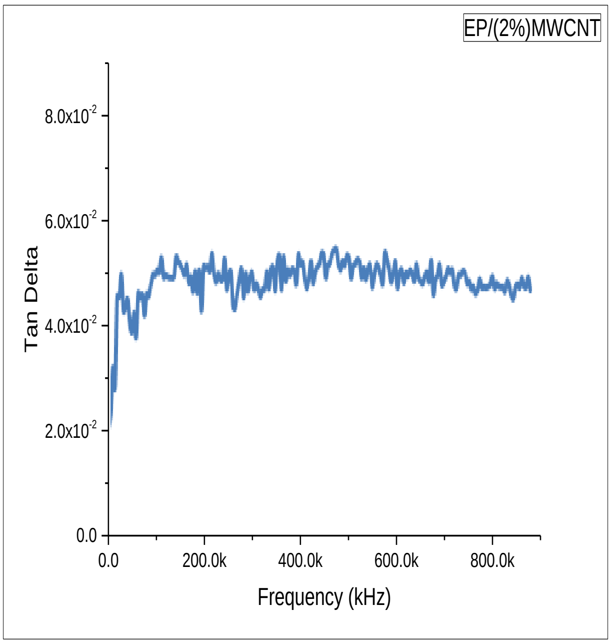


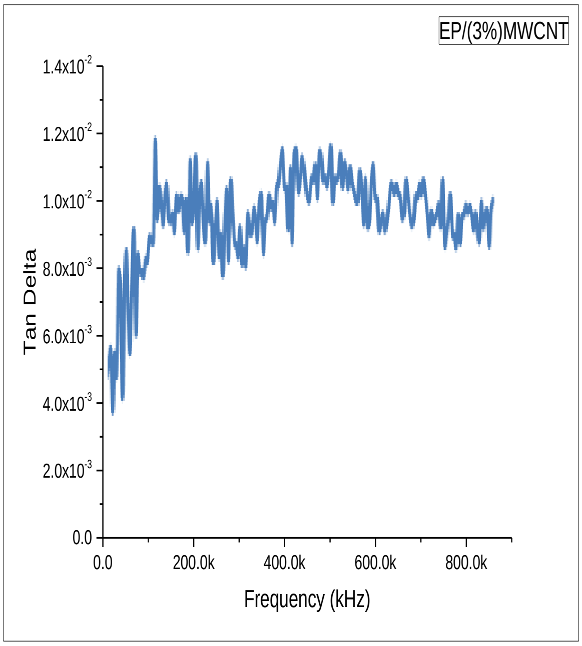
Figure (2): Electrical conductivity as function frequency for epoxy an EP/MWCNTs composites with 1,2,3and 4%wt of MWCNTs

The changes of the frequency as a function of tan delta for EP with variant mixing ratio of MWCNTs composite materials with 1, 2, 3 and 4 % wt. at room temperature are shown in the figure (3):









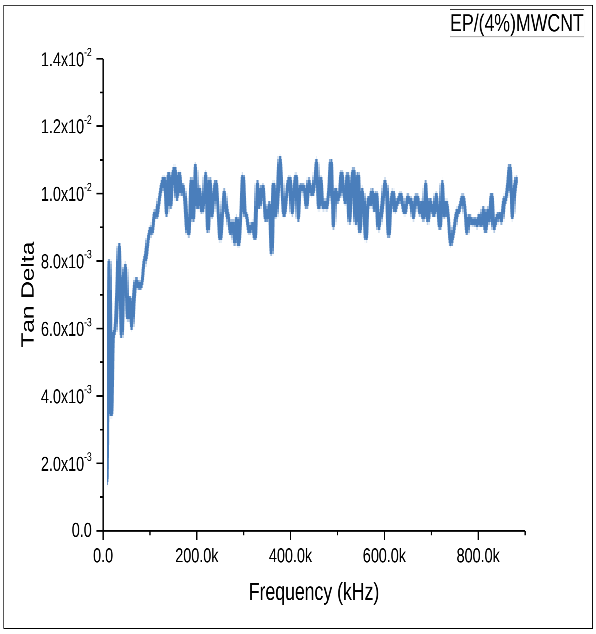


Figure (3): Tan delta as a function of frequencies for epoxy pure and with different mixing ratios from MWCNTs composites.

5. CONCLUSIONS

The epoxy symbols of permittivity were ruled by the numeral of orientable dipoles present in the system and their capability to orient below an applied electric field. At low frequencies of applied voltage, all the free dipolar functional groups in the epoxy chain can themselves oriented because a raise permittivity amount at these frequencies. The adding of carbon nanotubes as a conductive doping to dielectric host (e.g. polymer) has involved much notice due to the brilliant electrical properties of CNTs and their huge aspect ratios (>1000). The electrical conductivity of pure epoxy was improved by adding EP/MWCNTs nanomaterials with high conductivity properties and it was higher compared with pure epoxy as shown in Figures (1) and (2) that the permittivity of epoxy and epoxy/MWCNTs compounds increases with decreasing frequency. Hence, chains of epoxy near the surfaces of non-transferred epoxy nanolayers act to restrict charge transfer at chains and interface regions. The raised immovable epoxy nanocoating depends on the diameter of the nanotubes and the interface area. In addition, we also note that the amount of aliasing in the permittivity curves is small due to the high dispersion of the composite materials by the ultrasonic device used, Tan delta shows gradual heights with increasing frequency function. Tan delta is based on the electrical conductivity in epoxy composites as shown in Figures (3) Tan delta increases with increasing frequency and then slowly start to decrease.

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