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THE EFFECT OF APPLIED VOLTAGE ON STRUCTURE AND ELECTRICAL PROPERTIES OFPOT.MWCNT/PMMA NANOFIBERS

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Abstract

The POT doped with multiwalled carbon nanotubes (MWCNTs) were prepared through in situ oxidative polymerisation method. Then POT-MWCNT/PMMA nanofibers were successfully prepared by electrospinning under the influence of increasing the applied voltage. The POT-MWCNT/PMMA nanofibers were characterized by Scanning electron microscopy (SEM), Fourier transform infrared spectroscopy and X-ray diffraction in order to know the effect of the increase in voltages on the structure properties and morphology of the prepared samples. The electrical conductivity was measured and it was found that the electrical conductivity increases from 1.02×10^{-3} $S.cm^{-1}$ to 1.46×10^{-3} $S.cm^{-1}$ when the applied voltage increases during preparation.

Key words: POT.MWCNT/PMMA, nanofibers, electrospinning

1. Introduction

Polymers Since their discovery was considered to be insulators until 1977 were discovered conductive polymers where these polymers have alternating single (σ) and double (π) bonds along the main polymer chain [1]. Conductive polymers are characterized by low energy optical transition, low ionization potential and great electron affinity [2].

Polymer/CNT nanocomposite it's a combination of conductive polymers like (polyaniline, polypyrrole, polythiophene) with CNT. These nanocomposites have attracted the attention of many researchers due to their electrical properties which cannot be obtained when using each material alone, and also their use in electronic devices applications [3].

Among the many conductive polymers, poly (O-toluidine) (POT) polymer attracted great interest because its enter into many applications such as electronic devices, electrochromic, secondary batteries, and biosensors [4]. Poly (o-toluidine) (POT) is a PANI derivative which has the $-CH_3$ group in the ortho position of the aromatic ring of the aniline monomer [5].

Electrospinning is a technique used to produce nanofibers and is characterized by being an inexpensive method and can also use a variety of materials to produce large quantities of electrospun nanofibers [6]. This process is affected by many factors such as molecular weight of the polymer, solution properties like (viscosity and conductivity), flow rate, ambient parameters like (temperature and humidity), and needle gauge where these factors affect the diameters of nanofibers and have been extensively studied by Amakrishna et al 2005, Theron et al 2004 [7].

Nanofibers are structures with diameters less than 1 μm. Where it's have low density, low specific mass and high pore volume [8]. These distinctive characteristics made it enter in a wide range of applications such as filtration, wound dressings, energy conversion and storage, sensors, and electronic materials [9].

In this study, POT.MWCNT/PMMA nanofibers were prepared by electrospinning method. The structure and electrical properties of the samples were studied under the influence of applied voltages between the collector and the tip of the needle.

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2. Experimental

POT-MWCNT powders were prepared through in situ oxidative polymerisation method, at 4 wt% of MWCNT accordance with the method previously described by [10]. To preparation of POT-MWCNT solution, 0.15 g of POT-MWCNT powder was dissolved in 5 ml chloroform $CHC1_3$ and stirred for 24 hours. After that, 0.125 g of PMMA was added to help in fiber formation. This solution was used to fabricate fibers by electrospinning setup where the flow rate was 2.5 ml/min, the distance between collector and the needle was 20 cm, the needle gauge 23G, rotating speed is 1000 rpm and under of different applied voltages (10, 15, 20 KV). POT-MWCNT/PMMA nanofibers characterize by using SIDCO England series FTIR spectrometer. The optical properties of POT-MWCNT/PMMA nanofibers measured by UV spectrophotometer with range (300-900nm) and electrical properties of the samples measured at room temperature. The morphological characteristics of the samples were imaged using a scanning electron microscope. The structure properties of prepared samples were examined using Philips X-ray diffractometer.

3. Results and Discussion

Fig. 1 shows the X-ray diffraction (XRD) patterns of POT-MWCNT/PMMA nanofibers prepared by electrospinning under at different applied voltages. X-ray diffraction patterns showed that the POT-MWCNT/PMMA nanofibers have polycrystalline structure, it was found that these nanofibers at applied voltages 10 KV have the diffraction peak at $2\theta=31.36^o$ and when the voltages were increased to 15 and 20 KV the sharpness and the intensity of the peak slightly increased. This result proved the effect of the applied voltages on the structure of the POT-MWCNT/PMMA nanofibers [11]. The average crystallite size (C.S.) of the samples can be calculated from the X-ray spectrum through the full-width at half maximum (FWHM) method (Scherrer relation) [12].

$$\mathbf{C.S. = (D\ \lambda)/(\Delta\beta \cos\theta)} \qquad \mathbf{(1)}$$

Where $\Delta\beta$ is the FWHM of the XRD peak at diffraction angle θ, λ is the X-ray wavelength and D is the Scherrer's constant (D=1). Table 1 includes the values of the average crystallite size of the prepared nanofibers under the influence of increasing applied voltages.

Table1. The values of the crystallite size for POT-MWCNT/PMMA nanofibers

Applied voltages KV	Crystallite size nm	σ S/cm	Nanofibers diameters nm
10	61.87	1.02×10^{-3}	390
15	60.14	1.23×10^{-3}	292
20	81.16	1.46×10^{-3}	253

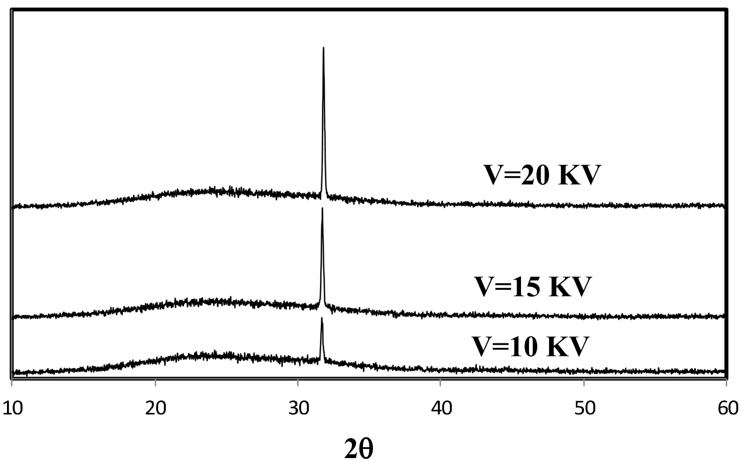

Fig.1. XRD spectra of POT-MWCNT/PMMA nanofibers samples

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The morphology of the POT-MWCNT/PMMA nanofibers has been studied by scanning electron microscopy (SEM). Fig.2 the SEM image shows the effect of the increasing the applied voltage on the morphology of POT-MWCNT/PMMA nanofibers. From the images it can be seen that porous nanofiber with good and clear alignment have been obtained, as well as these nanofibers do not contain any cracks or knots, and the surfaces of these nanofibers are smooth and full of porous at all applied voltages where these porous is attributed to the rapid evaporation of the solvents during the electrospinning process that prevents the crystallization of macromolecular chains and reduces the density of fibers [13]. On the other hand, it can be observed that nanofiber with diameters about of 390 nm have been obtained at a preparation voltage of 10 kV and the nanofiber diameter decrease to about 253 nm when the applied voltage increasing to 20 KV, the decrease in nanofiber diameter is attributed to the stretching of the polymer solution in correlation with charge repulsion inside the polymer jet [14]. Where these results indicate an improvement and enhancement the nanofibers morphology. These porous nanofibers have a wide range of applications due to its surface area as it enters into the filtration, biomedical and fuel cell [15].

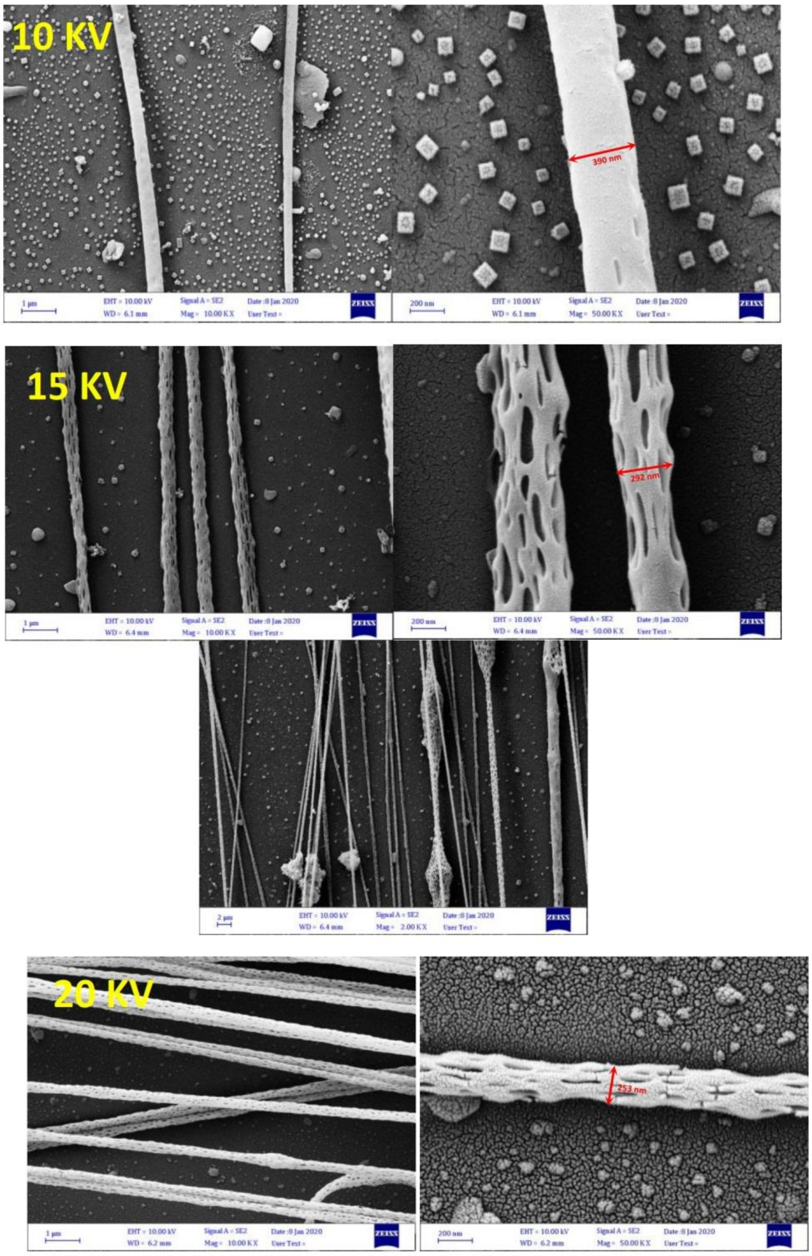

Fig.2. SEM images of POT-MWCNT/PMMA nanofibers samples

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The FTIR spectra POT-MWCNT/PMMA nanofibers are shown in Fig.3. The Fourier Transmittance Infrared Spectroscopy (FTIR) spectra were used to illustrate the bonds and functional groups of the POT-MWCNT/PMMA nanofibers. The peaks appears around 1143.83 to 1259.56 cm^{-1} corresponds to the C-N vibrational modes and the two other peaks around 1435.09 and 1456.46 cm^{-1} are ascribed to the symmetric deformation of methyl ($-CH_3$) group. The peak around 744.55 cm^{-1} which corresponds to the 1, 2, 4 – substitution in the benzenoid rings [11]. From the Fig.3canbe notice the effect of increased voltages on POT-MWCNT/PMMA nanofibers.

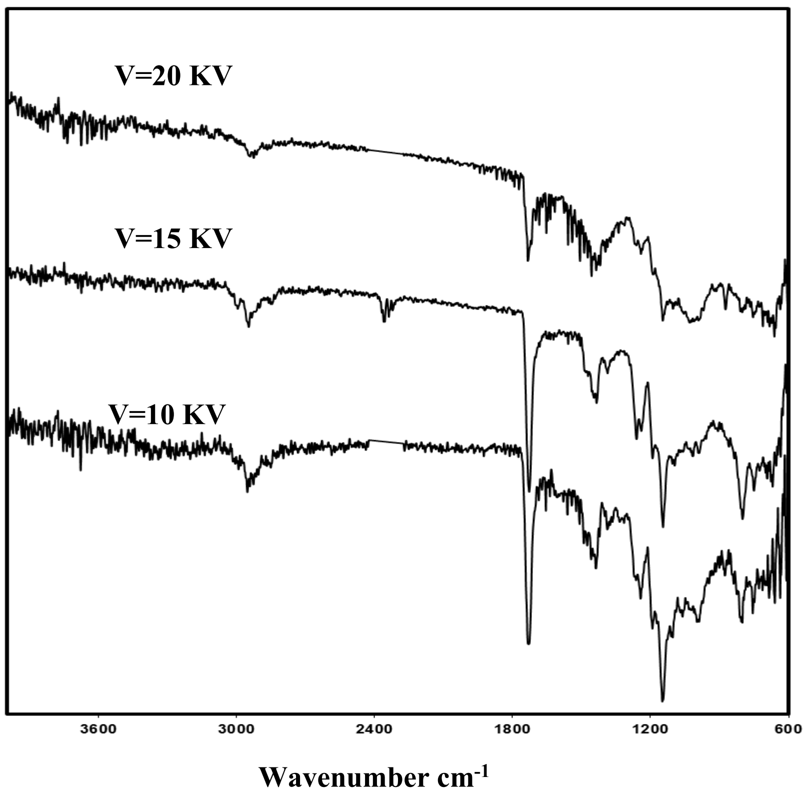

Fig.3. FTIR spectra of POT-MWCNT/PMMA nanofibers samples

UV-Visible absorption spectra of POT-MWCNT/PMMA nanofibers are shown in Figure. 4. From the figure it can be seen that the absorption of the prepared sample at 10 KV decreases with increasing wavelength while the absorption of the prepared samples at 15 and 20 KV increases with increasing wavelength to reach the highest value at wavelength 470 nm then return to decrease with increasing wavelength. Also it can be observed that the increase in applied voltages increases the absorption of the prepared samples where the reason for these changes is due to the change in morphological and structural characteristics as a result of increased applied voltages during preparation.

The optical transmittance spectra of POT-MWCNT/PMMA nanofibers under the influence of increasing applied voltages are shown in Fig. 5, which show the opposite behavior in absorption spectra for nanofibers

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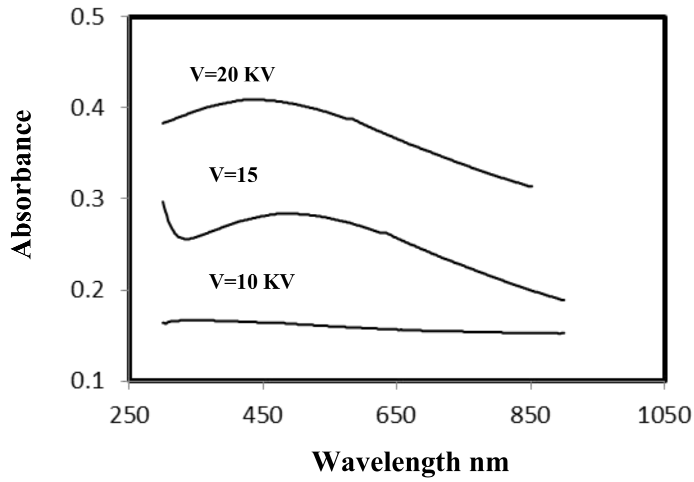

Fig.4. Absorbance spectra of POT-MWCNT/PMMA nanofibers samples

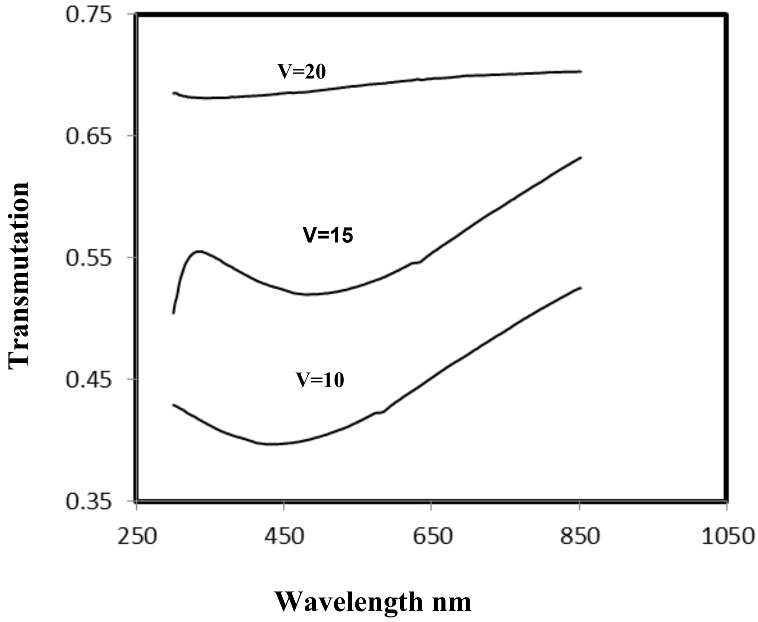

Fig.5. Transmutation spectra of POT-MWCNT/PMMA nanofibers samples

The I-V curve of the POT-MWCNT/PMMA nanofibers is shown in Fig. 6. And the conductivity value tabulated at Table 1. The results showed that the conductivity increases slightly when the applied voltages are increased, where the conductivity value was 1.02×10^{-3} $S.cm^{-1}$ at the applied voltage 10 KV and increased to 1.46×10^{-3} $S.cm^{-1}$ at applied voltage 20 KV. This increase in conductivity attributed improved structural properties and morphology, especially decreasing diameters of nanofibers with an increase in preparation applied voltages [16].

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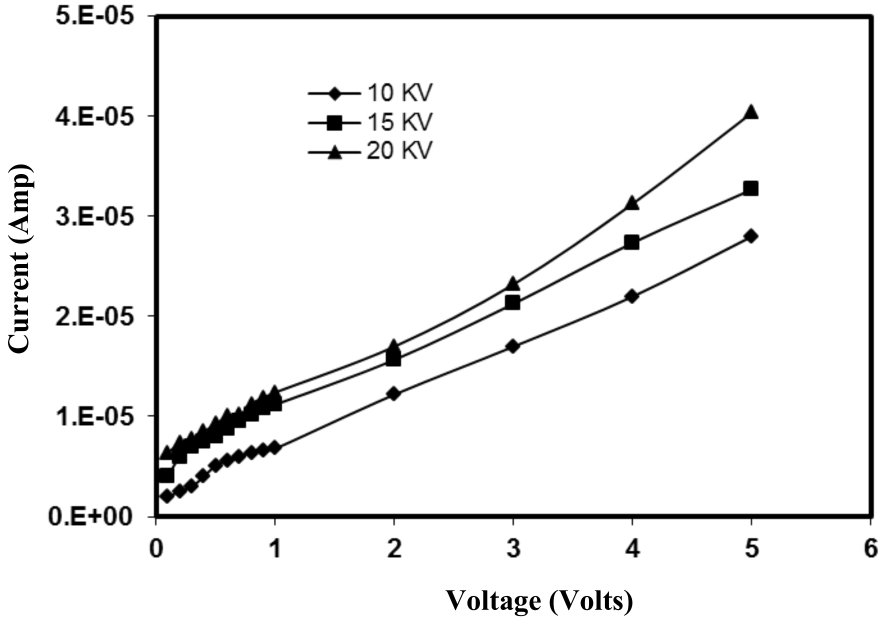

Fig.6.The I-V curves for POT-MWCNT/PMMA nanofibers samples

4. Conclusion

In this work, POT-MWCNT/PMMA nanofibers were successfully fabricated using electrospinning method. The effect of increasing the applied voltages on the electrospun POT-MWCNT/PMMA nanofibers was studied by using several techniques such as SEM, XRD, UV-Visible, FTIR and I-V measurement. The results revealed the polycrystalline structure of all samples. The results showed that the changes in structural properties and morphology as a result of increased applied voltages. The I-V measurement of prepared samples show that values of the electrical conductivity increase with increasing applied voltages where the highest value for the electrical conductivity is1.46×10^{-3}S.cm^{-1} at applied voltage 20 KV.

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