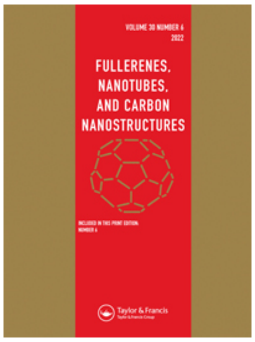


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# Enhancing the physical properties of polystyrene nanofibers by adding multiwall carbon nanotubes and natural dye

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FULLERENES, NANOTUBES AND CARBON NANOSTRUCTURES
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# Enhancing the physical properties of polystyrene nanofibers by adding multiwall carbon nanotubes and natural dye

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**ABSTRACT**

Polymeric nanocomposites of polystyrene nanofibers and multiwall carbon nanotubes and natural pigment were synthesized using electrospinning technique the polystyrene concentration was 12 wt.% and multiwall carbon nanotube was added by (0, 100, 140, 200 ppm), and natural pigment added by two drops (0.063 g) to the prepared solutions and many tests were carried out to the prepared solutions and the final samples. The solution tests included viscosity test by using cone-plate viscometer and surface tension test using du-nouy ring method. The nano textiles tests included the Fourier transform infrared spectroscope (FTIR) test, Field emission scanning electron microscopy (FESEM) test, contact angle test, and ultraviolet test to extract the energy bandgap using (tauc plot) method. The tests results showed that the viscosity increased by increasing the multiwall carbon nanotube and natural pigment and surface tension slightly increased at a high ratio of 200 ppm of multiwall carbon nanotube and natural pigment and physical type of reaction between the components were confirmed through FTIR, and the addition of multiwall carbon nanotube and natural pigment makes the fibers smoother and fewer beads formation and increase the multiwall carbon nanotube addition made the samples more hydrophobic and the charts of tauc plot show that increasing the MWCNT with natural pigment addition will increase the electrical sensitivity of the prepared samples in which the energy band gap dropped from 1.18 ev to 0.2 ev for the sample of Polystyrene/200 ppm MWCNT/natural pigment this is regarded as an indication of using it as a typical electrical sensor.

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**KEYWORDS**
PS; MWCNT; natural pigment; electrical sensitivity

## 1. Introduction

Most of the trends today concentrate on the use of natural materials because of their excellent effects when compared to synthetic materials in terms of their cheapness, availability, and desired characteristics the electrospinning method, was invented in 1934 by Formhals. In recent years, Reneker and colleagues devoted attention to this method, which has characterized electrospinning for a variety of polymer solutions.[1]

The electrospinning method utilizes a high voltage to create a highly electrically charged polymer solution or liquid jet that hardens on its route to the collecting system, which generates fibers, with diameters ranging from the sub-micrometer to the nanoscale. Because of the small diameter of the fibers, electrospun fibers have a large surface area that provides different morphologies and characteristics than bulk. Also, with a combination of extremely smaller fiber size and a high aspect ratio, the electrospinning technique may create continuous fibers.[2]

The characteristics of the Electrospun fibers, as well as non-woven webs from Electrospinning, have been emphasized, including large porosities, small diameters, significant pore interconnectivity, and a high surface to volume ratio. Due to the above, several synthetic and natural polymers, including single mixed polymers, have been electrospun into textiles that are suitable for different uses, such as filtration, thermal insulation as also for the manufacturing of protective clothes, sensors, conduction apparatus, wound clothing and fabric manufacturing facilities.[3]

The manufacturing of the collected fibers depends on a number of variables: (a) viscoelastic force related to solution concentration,[4–6] the average molecular weight of polymer and solution viscosity,[6–8] (b) the surface tension which in turn depends on the concentration of the prepared solution, the average molecular weight of polymer and solvent surface tension,[9] (c) gravitational force that is related with the density of the solution, polymer molecular weight average, and solvent surface tension,[4] (d)The electrostatic force that has been said to depend on the applied electrostatic field (i.e., the applied electrostatic potential divided by the distance of collection) and the conductivity of the solution[6,9]

Carbon nanotubes (CNT) considered as one of the most interesting materials today, owing to their characteristics like greater surface area, better aspect ratio, strong chemical resistance, superior thermal properties, higher strength from steel by 10- 1000 times, and close to diamond ∼ 1 TPa. for

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**Table 1.** Natural pigment content analysis.

| Element | Value |
|---|---|
| N | 17.5 ppm |
| P | 5.5 ppm |
| K | 12.1 ppm |
| CL | 0.3 Meq/L |
| $HCO_3$ | 0.1 Meq/L |
| $SO_4$ | 4.5 Meq/L |
| Electrical conductivity | 36 S/cm |

CNT and diamond (1-2 TPa), cheap prices and high electrical conductivity of (105- 107 S/cm).[10,11]

Polystyrene is the other that has a high mechanical performance, good chemical inertness, great processability, technological advancement.[10]

So, it seems very promising from a mechanical and electrical point of view to distribute or integrate carbon nanotubes inside the nanofibers matrix in order to produce composite materials. Combining high aspect ratio, high compact length, high strength and rigidity, low density, high conductivity, high durability and extensibility, the ability to cope with cross-section and twisting, and compressive capacity of carbon nanotubes make excellent candidates for nano-composite product production without fractures.[11]

In this study, we produced a sample having the desired characteristics that qualify it to be utilized as a sensor. As it has the greater electrical conductivity derived from multi-wall carbon nanotube improved by addition natural pigment which has a photoreceptor naturally and a higher mechanical property acquired from the polystyrene, these compounds offer us a broad variety of electronic, sensing applications.

## 2. Experimental part

### 2.1. Materials used: use this style for level three headings

General-purpose polystyrene (GPPS) with 99% purity obtained from American polymers service Inc. (APS), multi-wall carbon nanotube (MWCNT) with purity > 95%, outside diameter < 8 nm, inside diameter 2-5 nm, length 2-20 μm, electrical conductivity >100 S/cm, Natural pigment obtained from Eurypos daisy flower leaves which is a genus of flowering plants in the sunflower family. Table 1 shows the components of the pigment extracted from the flowers. Dimethylformamide (DMF) with boiling point (153 o C) and 99.7% purity was used as a solvent, it was obtained from CDH company, these materials were used to prepare nanocomposites textiles.1.

### 2.2. Solutions preparation

Firstly, we dissolved polystyrene with concentration 12 wt.% in DMF using a magnetic stirrer for 3 hrs. at room temperature, this process was repeated three times to get four solutions, MWCNT was added to the prepared solutions by ratios (0, 100, 140, 200 ppm), homogeneous dispersion of MWCNT in the prepared solutions were obtained via ultrasonication for 15 min. and 40 °C, then natural pigment was added by (0.063 g) to each solution, then the solutions were placed on the magnetic mixer for 10 min to obtain homogeneous solutions. before electrospun.

**Table 2.** Surface tension results for (a)pigment/pure PS (b) pigment/100 ppm MWCNT (c) pigment/140 ppm MWCNT (d) pigment/200 ppm MWCNT.

| 12 wt.% PS + Pigment | |
|---|---|
| Sample | Surface tension (mN/m) |
| Pigment | 29.60 |
| Pure polystyrene/ 0.063 g Pigment | 29.24 |
| PS/100 ppm. MWCNT. /0.063 g Pigment | 29.18 |
| PS/140 ppm. MWCNT. /0.063 g Pigment | 27.71 |
| PS/200 ppm. MWCNT. /0.063 g Pigment | 33.08 |

### 2.3. Solution characterization prior electrospinning

Brookfield viscometer was used to measure the viscosity of the solutions at (15 rpm), in (cp units) and surface tension of the solutions also measured using TEN202 surface interfacial tensiometer (du-nouy ring) method and units were in mN/m.

### 2.4. Electrospinning process

We take (1 ml) injection syringe with an internal diameter of 0.5 mm to pump the solutions using a syringe pump at a flow rate (1 ml/hr.) and at room temperature with (20 cm) tip-collector distance and applied voltage (20 kV) then fibers collected on rotating drum operates with speed (480 rpm). Finally, we obtained nanofibers textiles made from 12 wt.%PS/ 0.063 g natural pigment/MWCNT (0,100,140.200 ppm).

### 2.5. Characterization of the prepared nano textiles

#### 2.5.1. Fourier transform infrared spectroscopy (FTIR) test

This test was carried out using (IR Affinity-1 Shimadzu –Japan) for the prepared pure samples to know the type of interaction between them and the types of chemical bonds.

#### 2.5.2. Field emission scanning electron microscopy (FESEM) test

This test carried out using (TESCAN GAIA3) instrument to the prepared samples to know the average fibers diameter, fiber smoothness, fibers orientation, chemical composition using edx mounted on it for the prepared samples.

#### 2.5.3. Atomic force microscopy (AFM) test

This test was used to show the effect of carbon nanotubes weight ratios and the natural pigment addition on the topography of prepared Nanocomposites Nanofibers using AA3000 Scanning Probe Microscope.

#### 2.5.4. Ultraviolet (UV-visible) test

This test was carried out on the prepared nanofibers textiles samples using Shimadzu UV-1800 UV/Visible Scanning Spectrophotometer to extract the energy band gap depending on the absorption spectra and using tauc plot with origin pro software to draw the curves.

## 3. Results and discussion

### 3.1. Surface tension results

The surface tension values decreased slightly when increasing the MWCNT and natural pigment addition to the solutions. And start increase at (PS/200 ppm MWCNT/natural pigment) sample these results closely deals with the results of T. Jarusuwannapoom.[12]

For the pure polystyrene solutions and the effect of the MWCNT addition not make any significant change this is because the surface tension does not depend on the concentration of additives without completely dissolving them in the medium, the surface tension of the solvent used as mentioned M. Cloupeau and B. Prunet-Foch.[11]

The addition of natural pigment by two drops did not make any significant increase in the surface tension values because when the pigment added to the polymeric solution it caused of the presence of two solutions the first is the polymeric solution and the second the pigment solution that

**Table 3.** Viscosity results.

| 12 wt.% PS + Pigment | |
|---|---|
| Sample | Viscosity (cp) |
| Pigment | 3.4 |
| Pure polystyrene/ 0.063 g Pigment | 16.27 |
| PS/100 ppm. MWCNT. /0.063 g Pigment | 16.34 |
| PS/140 ppm. MWCNT. /0.063 g Pigment | 24.09 |
| PS/200 ppm. MWCNT. /0.063 g Pigment | 25.78 |

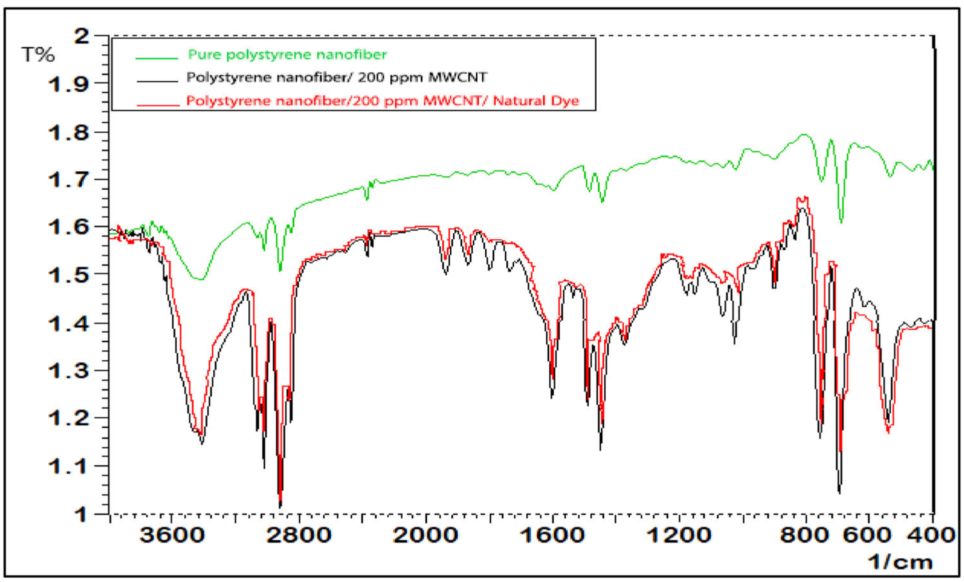


**Figure 1.** FTIR test of polystyrene nanofibers and polystyrene reinforced with 200 ppm. Multi-wall carbon nanotubes nano textile.

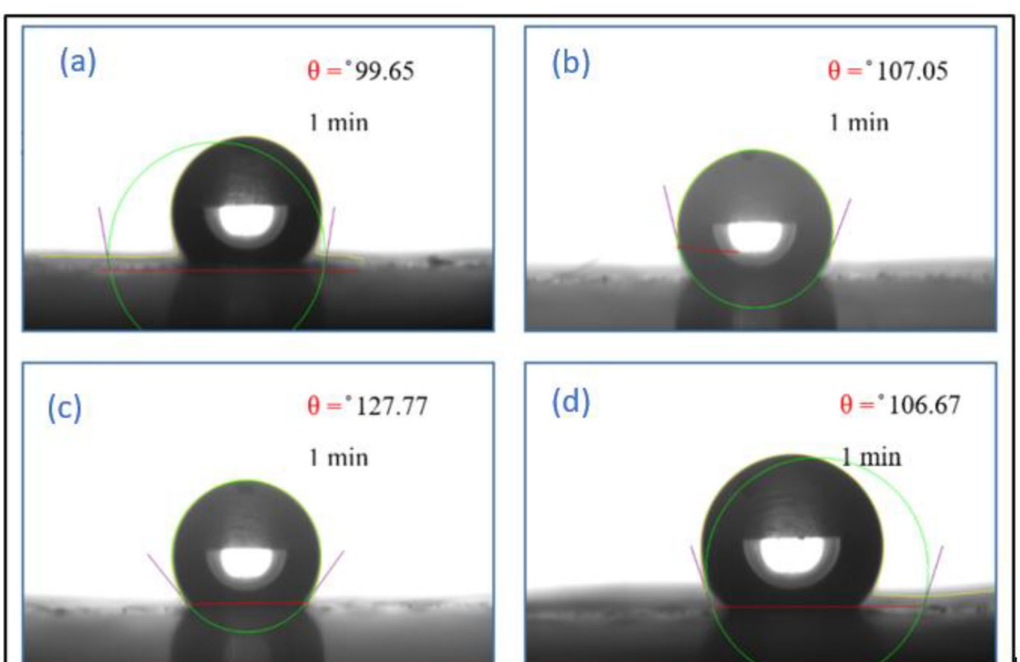


**Figure 2.** Contact angle analysis of four samples (a)pigment/pure PS (b) pigment/100 ppm MWCNT (c) pigment/140 ppm MWCNT (d) pigment/200 ppm MWCNT.

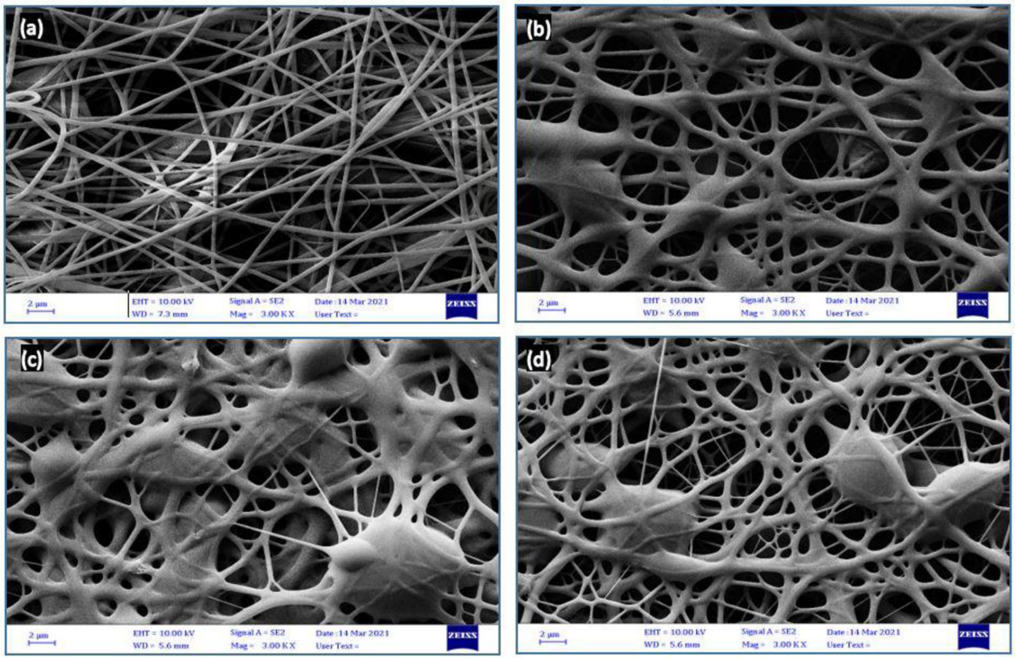


**Figure 3.** FESEM images for (a) (PSNF) pure (b) (PSNF)/100 ppm.MWCNT (c) (PSNF)/200 ppm. MWCNT (d) (PSNF)/200 ppm. MWCNT.

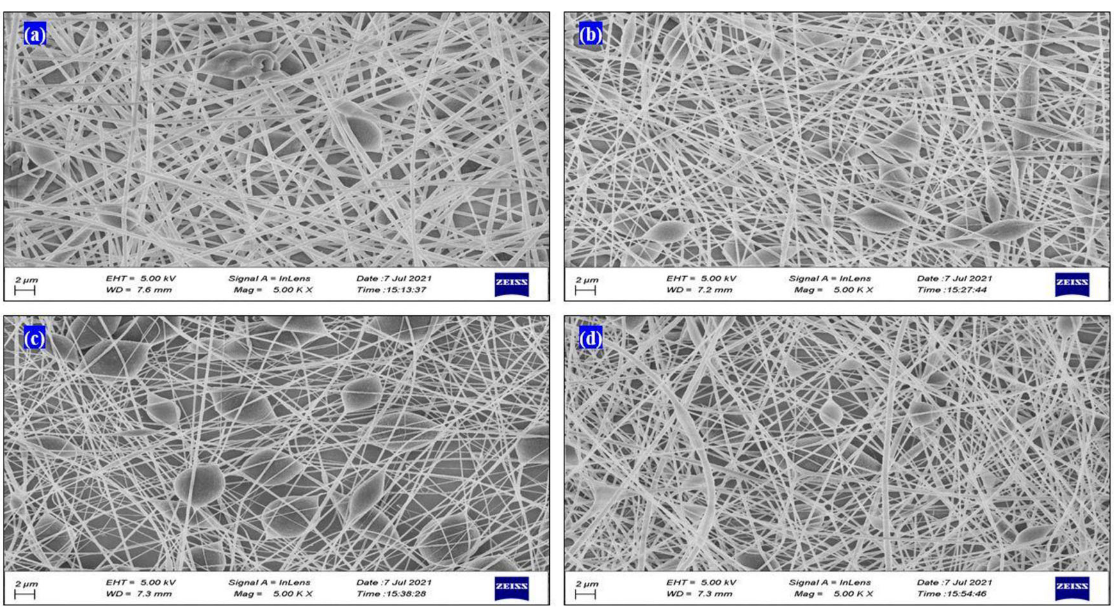


**Figure 4.** FESEM images for (PSNF/0.063 g pigment) where (a) pure PSNF (b) PSNF/100 ppm. MWCNT (c) PSNF/140 ppm. MWCNT (d) PSNF/200 ppm. MWCNT.

is not totally dissolved in the polymeric solution is the reason of the slightly increment as shown in Table 2.

### 3.2. Viscosity Results

Table 3 shows the values of solution viscosity, it can be observed that the viscosity increases with the addition of the natural pigment and increasing multiwall carbon nanotube ratios this is because when adding the natural Pigment with MWCNT to the polymeric solutions will cause more resistance to the mobility of solution molecules which leads to increase the viscosity of the solution, this is good to have nanofibers with little beads formation as shown in the FESEM results as mentioned by.[13]

### 3.3. Fourier transforms infrared spectroscopy (FTIR) results

Figure 1 shows the FTIR spectrum of (free PS nanofibers, PS/MWCNT nanocomposites nanofibers, and PS/MWCNT/yellow natural pigment), it can be observed that there is a strong peak at 1100 cm-1 compared to free PS nanofibers, this is referred to successful incorporation between PS and MWCNT. As well as, there are clear peaks at (1240) cm-1 due to the presence of O-H vibration which happened via incorporation of pigment with PS/MWCNT nanocomposites. Also, we can observe that there are strong peaks between (2800 – 3600) cm-1 represents both aliphatic and aromatic C-H stretching bands. peaks also become strongly sharp due to the successful joining of carbon nanotubes,

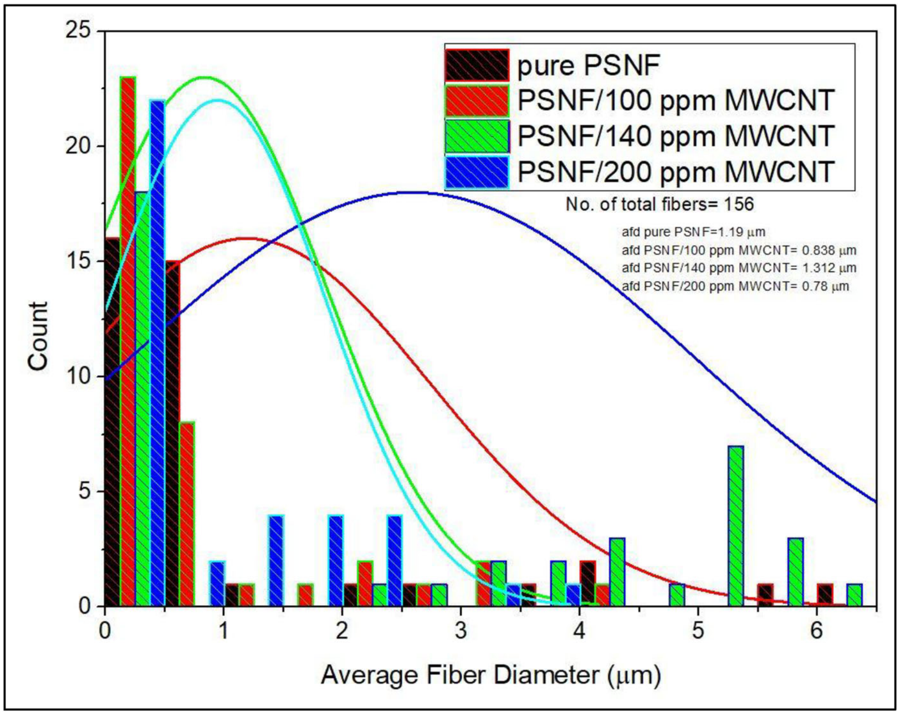


Figure 5. Average fibers diameter.

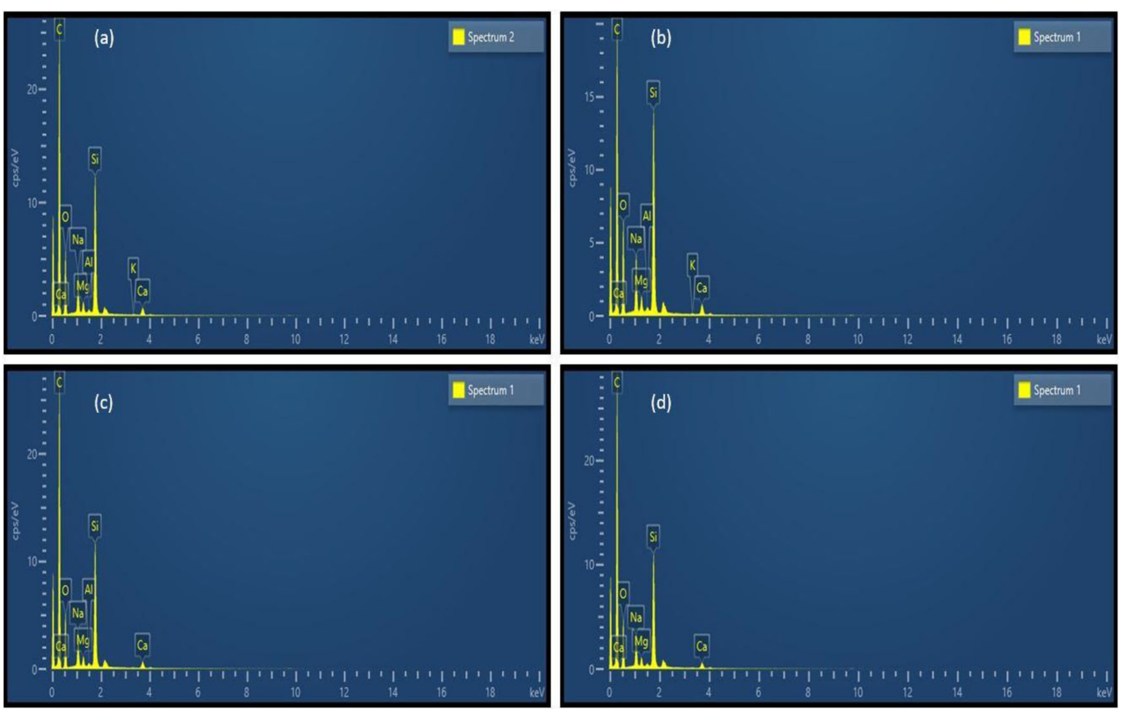


Figure 6. EDX images for (a) Pure PSNF/0.063g natural pigment(b) PSNF/100 ppm MWCNT/0.063g natural pigment(c) PNF/140 ppm MWCNT/0.063g Natural Pigment(d) PNF/200 ppm MWCNT/0.063g Natural Pigment.

yellow pigment, and polystyrene fibers. This is matches with Durigon 2020 and Miftah 2016.

### 3.4. Contact angle test

Figure 2 shows, the contact angle values increased from 99.65° for pure polystyrene nanofibers to 106 with PSNF/natural pigment and 127 for polystyrene/natural pigment/140 ppm MWCNT. This is due to the presence of a carbon group that prevents the formation of aqueous hydrogen bonds. This is deals with Kaseem 2016.

### 3.5. Field emission scanning electron microscopy results

Figure 3 show the SEM images of free PS nanofibers, PS/100 ppm MWCN, PS/140 ppm MWCNT, and PS/200 ppm

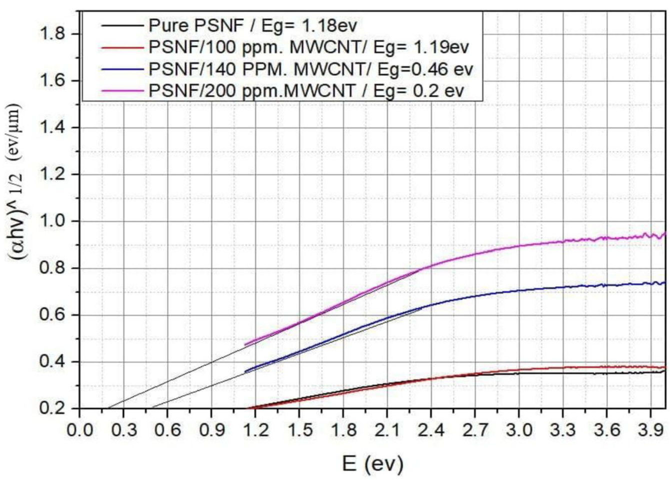


**Figure 7.** Bandgap values for the prepared samples.

MWCNT, when increasing the MWCNT ratios the average fibers diameter decreased due to the fact that MWCNT leads to increase the electrical conductivity of solutions. we also notice the addition of natural pigment leads to increase the electrical conductivity too, due to present more free ions to increase the value of electrical conductivity up to (36 S/cm) this make the fibers smoother and fewer beads from addition MWCNT alone the average fibers diameter values were (1.19 μm) for pure polystyrene nanofiber with (0.063 g) natural pigment and (0.78 μm) for PSNF/200 ppm MWCNT/0.063g natural pigment. The FESEM and average fibers diameter are shown in the Figures 4 and 5 respectively. Also, the elements present in the nano textiles samples are shown in Figure 6. These results close to

Adding of pigment to prepared solutions leads to enhancement of stability of electrospinning process via enhancement of viscosity and surface tension as well as conductivity of solutions, and this leads to free beads nanofibers in contrast to solutions free pigment as in Figure 3.

### 3.6. Bandgap results

Figure 3 show the SEM images of free PS nanofibers, PS/100 ppm MWCN, PS/140 ppm MWCNT, and PS/200 ppm MWCNT, when increasing the MWCNT ratios the average fibers diameter decreased due to the fact that MWCNT leads to increase the electrical conductivity of solutions. we also notice the addition of natural pigment leads to increase the electrical conductivity too, due to present more free ions to increase the value of electrical conductivity up to (36 S/cm) this make the fibers smoother and fewer beads from addition MWCNT alone the average fibers diameter values were (1.19 μm) for pure polystyrene nanofiber with (0.063 g) natural pigment and (0.78 μm) for PSNF/200 ppm MWCNT/0.063g natural pigment. The FESEM and average fibers diameter are shown in the Figures 4 and 5 respectively. Also, the elements present in the nano textiles samples are shown in Figure 7.[14]

This is due to the yellow pigment has little energy gap value and it works on supporting the electron to travel from valence band to the conduction band with very depressed energy and very little time, this produces high sensitivity solar cells with high activity. This matched with.[1]

## 4. Conclusions

1. We conclude that the addition of MWCNT to polystyrene nanofibers leads to enhance the electrical sensitivity of prepared textile and it can be used as a media for solar cell application.
2. Adding carbon nanotubes to the polymer solution may lead to the appearance of some unwanted beads in the nanofiber fabric.
3. Better values of the energy gap and a texture free of unwanted beads with the better softness of the fabric were obtained by adding yellow flower pigment, which leads to much higher efficiency of the prepared fabric for sensors of the solar cells.

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