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University of Babylon - College of Materials Engineering

Department of Polymers and Petrochemical Industries

Effect of carbon nanotubes on the physical and chemical properties of polystyrene

Graduation project submitted to the Department of Polymers and Petrochemical Industries -Faculty of Materials Engineering - University of Babylon as part of the requirements for obtaining a bachelor's degree

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Supervisor Acknowledgment

I acknowledge that this tagged project: (The effect of carbon nanotubes on the physical and chemical properties of polystyrene)

Prepared by the student: (Fatima Ali Saleh, Mustafa Ahmed Abbas)

It was done under my supervision in the Department of Polymers and Petrochemical Industries - College of Materials Engineering

Signature- :

Supervisor Name-:

Academic Rank-:

Date- :

Dedication

To my father, my brothers and my friends who were doing in return for my miss Hummers

To my honorable professors who had great credit and the first role in supporting me and clarifying important and valuable information for me

I dedicate my graduation project to you, and I hope that God will prolong your life for me and grant you always success and success

Fatima Ali Saleh

Mustafa Ahmed Abbas

Thanks

At the outset, we thank God Almighty for having enabled us to complete the research project. Then I would like to thank Dr. (Dr. Hana Jawad) who supervised my graduation project, whose experience was invaluable in formulating the most important topics and methodology of the project. Then I would like to express my appreciation to my colleagues for their wonderful cooperation and support for me.

I would also like to thank all the teaching staff in the Department of Physics for their valuable guidance throughout the period of my studies. Their feedback provided me with the right experience that enabled me to choose the right direction and .successfully complete my project

In addition, I would like to thank my parents for their wise advice and great support. You have always been the first support for me. Finally, I could not have completed this letter without the support of my friends who gave me motivating advice, moral support and everyone who had a contribution to making the project

Fatima Ali Saleh

Mustafa Ahmed Abbas

Abstract

Experts and researchers unanimously agree that nanotechnology is the most important development that occurred in the last half of the twentieth century. Where it took the attention of all universities, institutes and scientific institutions. Nanotechnology has become at the forefront of the most important and exciting fields in physics, chemistry, biology, engineering and many other fields. It has given great hope to scientific revolutions in the near future that will change the direction of technology in many applications. In order to give a clear insight into this technology, we presented in the first chapter in a simplified way the concept and principles of nanotechnology in the hope that we realize its interesting facts, with reference to the history of this technology and how it arose, and the difference between the scientific terms (nanoscience, nanotechnology, nanoscale). After that, we mentioned nanoparticles and the methods of preparing them, and finally we showed the reasons and reasons for the wide and great interest in this technology and its future prospects.

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Introduction

Chapter one

Introduction

1-1 introduction

There is always a fundamental need to apply new materials with improved properties in industry. Carbon nanotubes (CNTs) have attracted great research interest from various areas of engineering and science due to their outstanding chemical and physical properties such as high hardness and high strength but very low density. These hollow, cylindrical nanostructures were generated by hexagonal unit cells that were discovered by Iijima in 1991. Several studies have been conducted in order to estimate and develop the properties of carbon nanotubes. Determination of the tensile strength (up to 63 GPa), Yunck's modulus (about 1 Tb), and the vibrational stability of carbon nanotubes were among the most important objectives of these research papers. Investigations into short fiber-reinforced composites began several decades ago, before the discovery of carbon nanotubes.

1-2 What are carbon nanotubes?

They are allotropes of carbon with cylindrical nanostructures. It should be noted that carbon nanotubes have a length to diameter ratio of 132,000,000:1, which appears to be much longer than any other material. These carbon molecules have novel properties that make them useful in many applications in nanotechnology, electronics and optics, as well as in many other fields related to materials science, as well as a host of other potential uses in the fields of architecture. It may also have some uses in the manufacture of body armor. They exhibit exceptional strength, unique electrical properties and good heat conductors.

Nanotubes are a member of the fullerene family of structures, which also includes Baki's spheres. The nanotube may be covered with a hemisphere of the fullerene structure (buckyball). We also note that its name derives from its size, as the diameter of the nanotube is only a few nanometers (which is equivalent to approximately 1/50,000 the width of a human hair), while its length can increase to 18 centimeters (as it appeared in 2010). [1] The nanotubes are thus classified as single-walled nanotubes and multi-walled nanotubes.

Applied quantum chemistry—particularly orbital hybridization—is the best way to describe chemical bonds in nanotubes. The chemical bonding of nanotubes consists of bonds with sp2 orbital hybridization, similar to those of graphite. These bonds, which are stronger than the sp3 bonds found in diamond, provide the nanotubes with their unique strength and toughness. In addition, the nanotubes line themselves up as "ropes" held together by van der Waals forces.

1-3 History

Nanotechnology is a scientific precedent for the twenty-first century that will lead the world to a new industrial revolution that provides many benefits to humanity, especially in the fields of computer technology, medicine and materials science (material science) in Nano dimensions, so we will talk about carbon nanotubes, or what is known as nanotubes. Which takes a large space in the field of nanotechnology.

In 1991 the nanotube was discovered by the Japanese scientist Ijima Sumio while he was studying carbon products in the process of electric discharge between two carbon electrodes, while using the transmission electron microscope (TEM Transmission Electron Microscope). But before we start studying the nanotube, we must get acquainted with the single-walled carbon sphere called Fullerene.

In 1985, Kroto and Smalley were able to discover the monolayer ball consisting of 60 carbon atoms, and it was the most stable among the carbon balls with a number of more or less than 60 atoms, thus realizing Euler's theorem. To the architect Buckminster Fuller, after which it was named Fullerene (see Figure 1-1).[2]

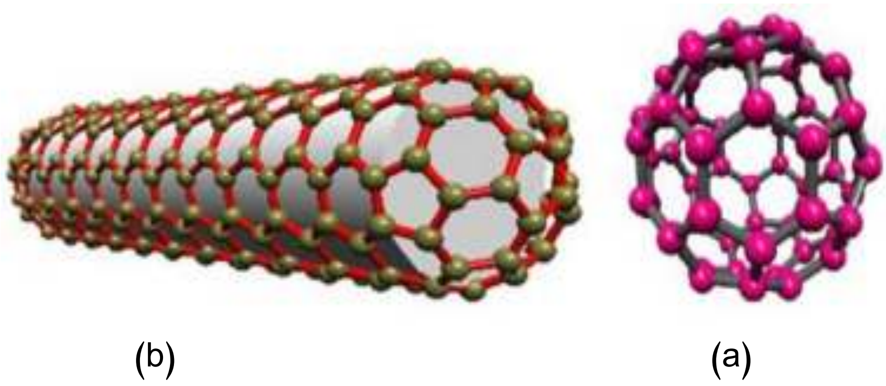


Figure (1-1): (a) The monolayer sphere, that is, fullerene, made of 60 carbon atoms.

(b) Single Walled Carbon NanoTube (SWCNT: Single Walled Carbon Nanotube)

1-4 Previous work

1− Making carbon nanotubes with polystyrene

Single-walled and multiple-walled carbon nanotubes were functionalized with a polystyrene copolymer, poly(styrene-co-p-(4-(4‘-vinylphenyl)-3-oxabutanol)). The functionalization reaction conditions were designed for the esterification of the nanotube-bound carboxylic acids. The polymer-attached carbon nanotubes are soluble in common organic solvents, making it possible to characterize the samples using not only solid-state but also solution-based techniques. The solubility has also allowed an intimate mixing of the functionalized carbon nanotubes with polystyrene. Results from the characterization of the functionalized carbon nanotubes, including the chemical and thermal defunctionalizations of the soluble samples, and the fabrication of polystyrene−carbon nanotube composite thin films using a wet-casting method are presented and discussed.[3]

2- Fabrication and Material Characteristics of Polystyrene/Carbon Nanotubes (PS/CNT)

Polystyrene/carbon nanotube (PS/CNT) composites have attracted considerable attention in research and industry fields due to high strength and electrical conductivity of CNT. Recently, several investigations showed that the PS/CNT composites exhibited the significant enhancement in thermal, mechanical, and electrical properties at room and/or high temperatures as well as possessed excellent process-ability which was quite similar to those of pure polymers. In this study, the various processing methods used to fabricate the composites are outlined with a special focus on solution processing, melt mixing, in-situ polymerization, etc. This paper discusses the non-covalent and covalent modifications of CNTs with PS, which are commonly applied to improve the dispersion and compatibility of the PS/CNT composites. The thermal, rheological, and mechanical properties of the present composites are also reviewed. The influences of different variables, such as type and content of CNT processing method and temperature, on the electrical responses are also highlighted. The discussion of the different properties in this study concluded that the addition of CNT would be beneficial for improving the materials performance of PS composites for industrial applications.[4]

Chapter Two

Physical foundations

Chapter Two

2-1 What are carbon nanotubes?

Carbon nanotubes are very small, very thin tubes or cylinders made only of carbon (C) atoms. Its tubular structure is visible only through electron microscopes. It is a black solid, consisting of very small bundles or bundles of several dozen nanotubes, strung together to form an intricate network.

The prefix "Nano" means "very small". The word "Nano" used in the measurement means that it is one billionth of a measurement. For example, a nanometer (a nanometer) is one billionth of a meter, i.e. 1 nanometer = 10^{-9} m.

Each small carbon nanotube consists of one or more sheets of graphite wrapped around itself. They are classified into single-walled nanotubes (a single coiled sheet) and multi-walled nanotubes (two or more cylinders, one inside the other).

Carbon nanotubes are very strong, have a high resistance to breakage, and are very flexible. It conducts heat and electricity very well. They also make a very light material.

These properties make it useful in various fields of application, such as the automotive, aerospace, electronics, and other industries. They have also been used in medicine, for example to transport and deliver anti-cancer drugs, vaccines, proteins, etc.

However, it must be handled with protective equipment as it can cause damage to the lungs when inhaled.[5]

2-2 Construction of carbon nanotubes

2-2-1 Physical Structure

Carbon nanotubes are extremely fine and small tubes or cylinders whose structure can only be seen with an electron microscope. It consists of a sheet of graphite (graphene) wrapped in a tube.

Figure (2-1): Nano-tube

They are hollow, cylindrical particles consisting only of carbon atoms. The carbon atoms are arranged in the form of small hexagons (six-sided polygons) similar to benzene and connected to each other (benzene condensed rings).

Tubes may or may not be clogged at their openings and can be quite long when compared to their diameters. It is equivalent to graphite sheets wrapped in seamless tubes[6] .

2-2-2 Chemical composition

CNTs are polycyclic structures. The bonds between carbon atoms are covalent (ie they are not ionic). These links are at the same level and are very strong.

The strength of the C=C bonds makes carbon nanotubes extremely tough and strong. In other words, the walls of these tubes are very strong.

The out-of-plane joints are very weak, which means that there are no strong joints between one tube and the other. However, they are attractive forces that allow the formation of bundles or bundles of nanotubes[7].

2-3 Classification by number of tubes

Carbon nanotubes are divided into two groups: single-walled nanotubes, or SWCNTs. Single-walled carbon tube, multi-walled nanotubes, or MWCNTs. (Multiwall Carbon Nanotube)

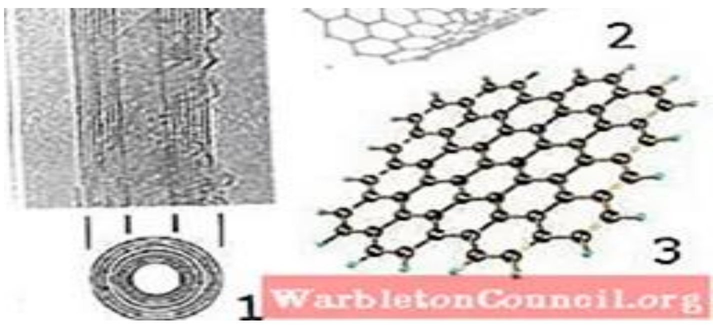


Figure (2-2): classifications of nanotubes

Single-walled carbon nanotubes (SWCNTs) consist of a single graphene sheet wrapped in a cylinder, in which the vertices of the hexagons fit together perfectly to form a seamless tube.

Multi-walled carbon nanotubes (MWCNTs) consist of concentric cylinders placed around a common hollow center, that is, two or more hollow cylinders placed within each other[8].

2-4 physical properties

Carbon nanotubes are solid. They come together to form bundles, bundles, bundles, or "chains" of several dozen nanotubes, strung together to form a very dense and complex network.

They have greater tensile strength than steel. This means that they have a high resistance to fracture when subjected to stress. In theory it could be hundreds of times stronger than steel.

It is very flexible, and it can be bent, twisted and folded without damage and then back to its initial shape. They are very light. They are good conductors of heat and electricity. They are said to have a very diverse electronic behavior or to have a high electronic conductivity. CNT tubes in which hexagons are arranged in the shape of an armchair have metallic or metal-like behaviour. Those arranged in a zigzag and spiral pattern can be metallic and semiconductor.[9]

2-5 Chemical properties

Due to the strength of the bonds between carbon atoms, carbon nanotubes can withstand very high temperatures (750 °C at atmospheric pressure and 2800 °C in vacuum).

The ends of the nanotubes are more chemically reactive than the cylindrical part. If they are subjected to oxidation, the ends are oxidized first. If the tubes are closed, the ends open. When treated with nitric acid HNO3 or sulfuric acid H2Sw4 under certain conditions, CNTs can form carboxylate-COOH or quinone-type groups O=C-C44-C=0

Carbon nanotubes with smaller diameters are more reactive. Carbon nanotubes can contain atoms or molecules of other types in their internal channels[10].

2-6 What is polystyrene?

Polymer of styrene/in particular: a rigid transparent thermoplastic with good physical and electrical insulating properties and particularly used in molded products, foams and sheet materials[11].

2.7 Experiment

The materials used in this study are polystyrene and carbon nanotubes. The weight percentages of carbon nanotubes are (0,3,6 and 9)wt.%. The samples were prepared using casting technique thickness ranged between (72-84)µm.The resistivity was measured at room temperature using Keithly electrometer type (616C).The volume electrical conductivity σ_V defined by :

$$\sigma_V = \frac{1}{P} = \frac{L}{RA} \quad (1)$$

Where:

A = guard electrode effective area.

R = volume resistance (Ohm).

L = average thickness of sample (cm).

The dielectric properties of PS-CNTs composites were measured using (Agilent impedance analyzer 6500B).

In the frequency (f) range (1-10) MHz at room temperature. The measured capacitance, C (w) was used to calculate the dielectric constant, έ (w) using the following expression:

$$\acute{\varepsilon}\,(W) = C(W)\,\frac{d}{\xi_o A} \quad (2)$$

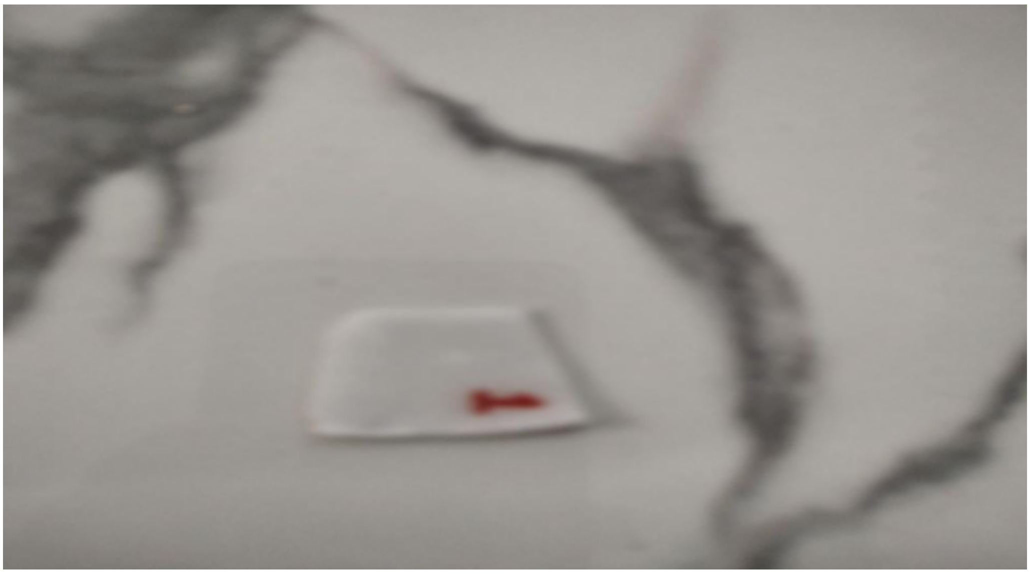
Where d is sample thickness and A is surface area of the sample. Whereas for dielectric loss ε" (W):

$$\varepsilon''(w) = \acute{\varepsilon}(w) \times tan\delta(w) \quad (3)$$

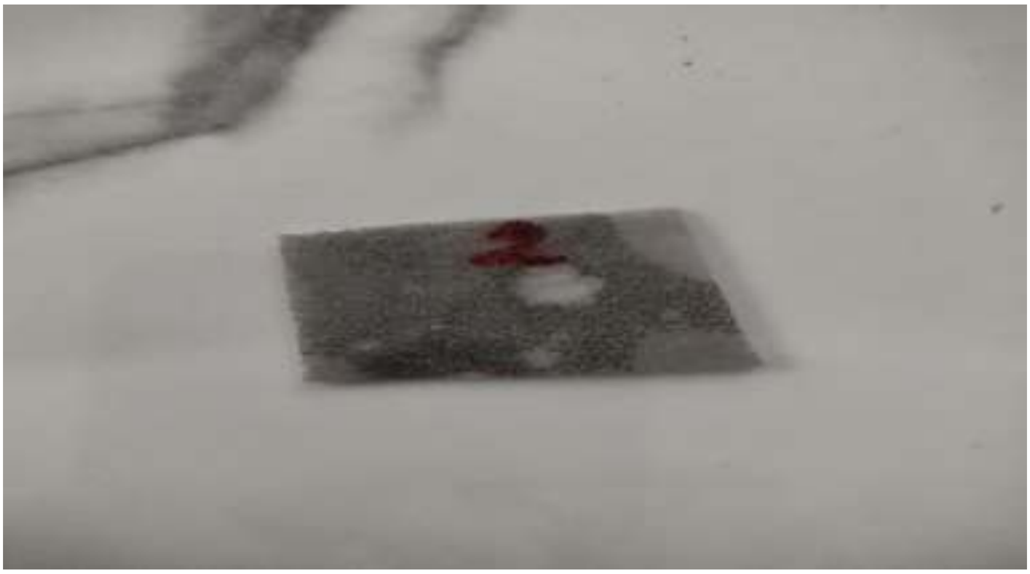
Where $tan\delta(w)$ is dissipation factor. The AC conductivity σ_{ac} can be calculated by the following equation:

$$\sigma_{ac}(w) = \xi_o w\ \varepsilon'' \quad (4)$$

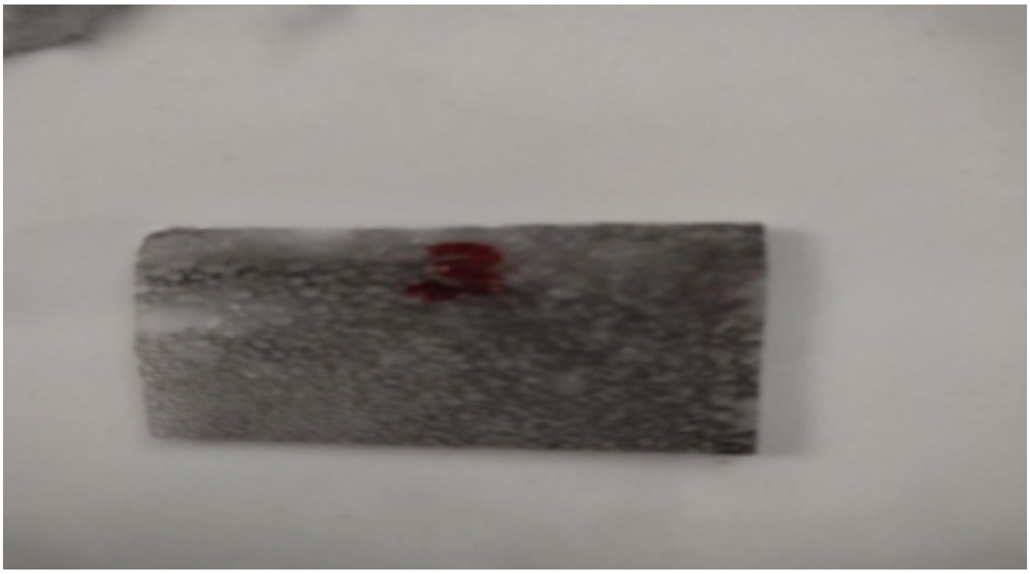
The transmission & absorption spectra of PS-CNTs composites have been recording in the length range (400-1000) nm using UV-2400 PC spectrophotometer.



Figure(2-3):- polystyrene(PS)



Figure(2-4):- polystyrene(PS)+1 CNTs13



Figure(2-5):- polystyrene(PS)+2 CNTs14

Figure(2-6):- polystyrene(PS)+ 3 CNTs

Chapter Three

Results and Discussion

3.1 Results and Discussion

Figure (3-1) shows the variation of electrical conductivity of polystyrene composites with increasing carbon nanotubes content. The general theory to explain the conduction mechanism of fibers or particle-filled polymer composites is the "theory of conductive paths [12]. To obtain electrically conductive composites the carbon nanotubes aggregates have to arrange themselves in continuous paths where the conductive elements are either in direct contact or can move electrons via hopping or tunneling mechanisms[13]

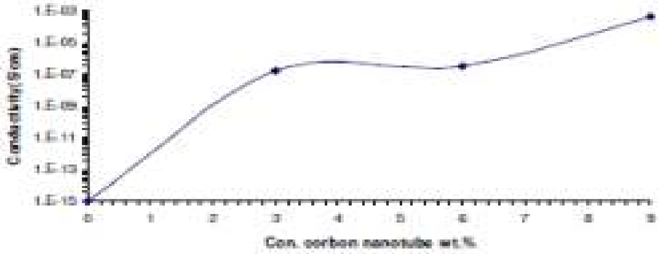


Figure 3-1: Variation of D.C electrical conductivity with Carbon nanotube wt. % concentration.

Figure (3-2) show the variation of the dielectric constant of PS-CNTs composite with frequency for different filler concentration

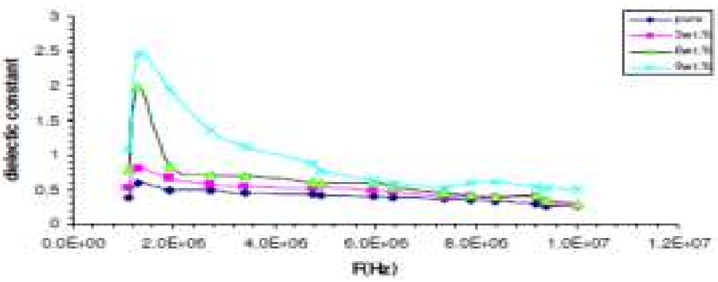


Figure 3-2: Variation dielectric constant with frequency for (PS-CNTs) composite.

The dielectric constant decreases with increasing of frequency, this may be attributed to the tendency of dipoles, the high value of dielectric constant at low frequency might be due to the interfacial effect. At low carbon nanotubes concentration, the dielectric values are low, characteristics of dielectric behavior, and increasing the carbon nanotubes concentration caused an increase in the average number of concentrations among the conductive particles. At high concentrations of carbon nanotubes the dielectric constant is due to formation of a continuous network of carbon nanotubes particles through the composite [14].

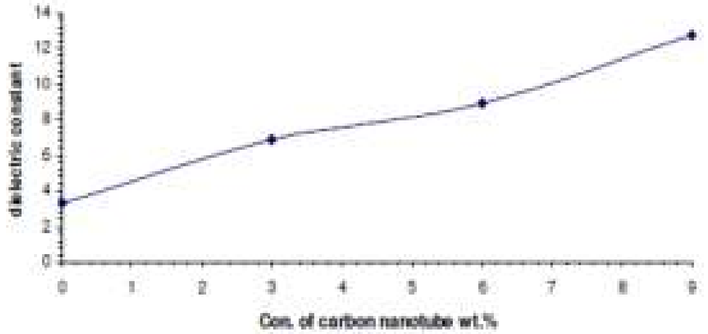


Figure 3-3: Variation dielectric constant with carbon nanotube concentration for (PS-CNTs) composite.

The variation of dielectric loss with frequency for (PS- CNTs) composites at different concentration of dopants is as depicted in figure (3-4).

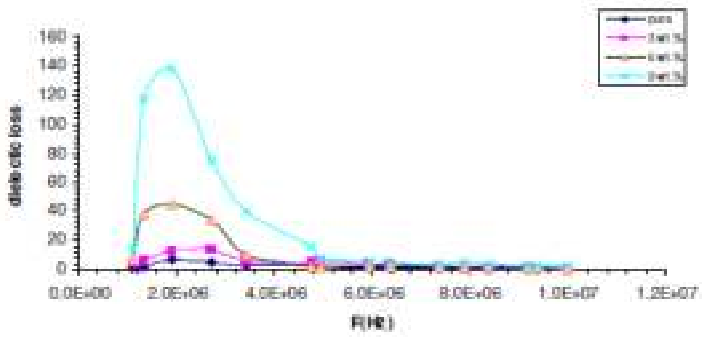


Figure 3-4: Variation dielectric loss with frequency for (PS-CNTs) composite.

It is clear from the graph that dielectric loss decreases with increasing the frequency. The larger value of dielectric loss at low frequency could be due to the mobile charges within the polymer backbone. The higher value of dielectric loss for the higher concentration of dopant can be understood in terms of electrical conductivity, which is associated with the dielectric loss as shown in figure(3-5)[15,16].

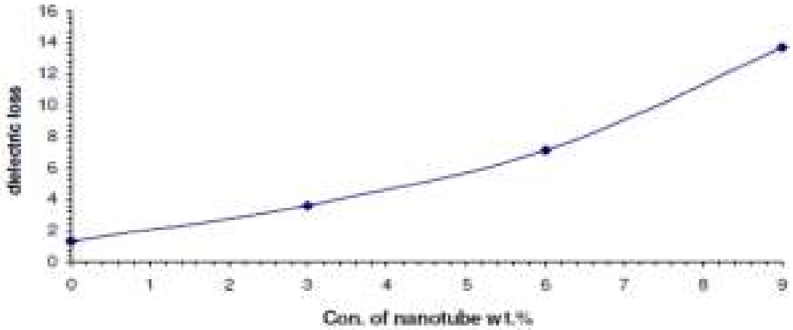


Figure 3-5: Variation dielectric loss with carbon nanotube concentration for (PS-CNTs) composite.

The behavior of A.C conductivity of PS- CNTs composite for various concentration of the filler as a function of frequency at room temperature is show in figure(3-6).

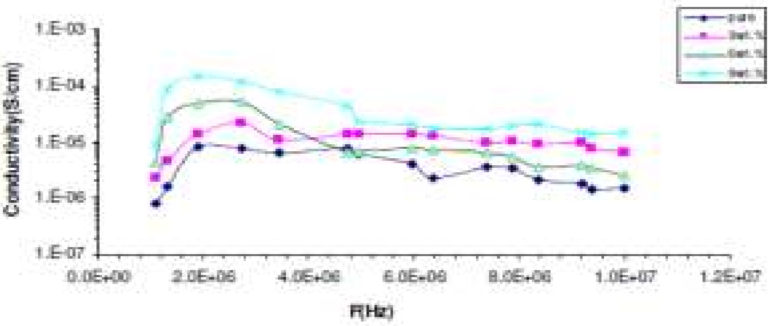


Figure 3-6: Variation A.C. electrical conductivity with frequency for (PS-CNTs) composite.

The A.C conductivity response to the applied field frequency at low and intermediate range is flat, and at high frequency range there is a transition region where the response starts to bend downward. The bending region is shifted towards the frequency value as the concentration of filler increases. For specimens of high filler content the behavior of A.C conductivity can be determined by conductive pathways of conductive network which formed as a result of infinite clusters formation.

The flat response of A.C conductivity at these frequency ranges can be attributed to the fact that electrons will not have trouble traveling over large distances within these infinite clusters before it just hop to other clusters. This can be justified by the fact that most conductors give a flat response in the same frequency ranges[17].At lower concentrations of the filler the A.C electrical conductivity of the composite increases slightly; while at higher concentrations the conductivity increases sharply where the composite becomes a conductive substance as shown in figure (3-7).

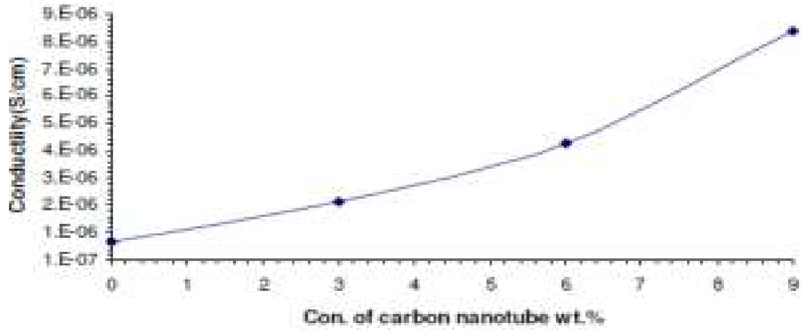


Figure 3-7: Variation A.C electrical conductivity with carbon nanotube concentration for (PS-CNTs) composite.

At high filler content, the mount of the interconnecting networks is increased and the contact resistance between the fibers is decreased, and hence a good electron conduction is achieved resulting in transformation of the polymer insulator to a conductive polymer composite [18].

The optical absorbance as a function of the wavelength of the incident light for PS-CNTs composites of various filler contents is shown in figure (3-8). The figure shows that the intensity of the peak increased as a result of filler addition but no shift in the peak position, i.e. adding different amounts of filler to pure polymer do not change the chemical structure of the material but new physical mixture is formed.

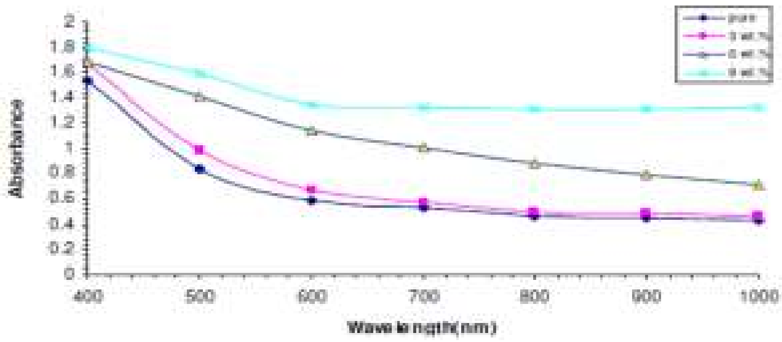


Figure 3-8: Optical Absorbance for (PS-CNTs) composite with various wavelength

The absorption coefficient (α) was calculated in the fundamental absorption region from the following equation[19]:

$$\alpha = 2.303\frac{A}{d} \qquad (5)$$

Where: A is absorbance and d is the thickness of sample.

Figure (3-9) shows the relationship between the absorption coefficient and photon energy of the PS-CNTs composites. We note the change in the absorption coefficient is small at low energies, this is indicates, that the possibility of electronic transitions is a few. While at high energy, the change of absorption coefficient is large this is indicates the large. Probability of electronic transitions are the absorption edge of the region. The results showed that the values of absorption coefficient of the PSCNTs composites less than 104cm-1 which indicates to the indirect electronic transition [20]. The variations of extinction coefficient (k=__/4_) with wave length for (PS-CNTs) composite as shown in figure (3-10). The extinction coefficient increases with increasing of CNTs concentration. This behavior of extinction coefficient ascribed according to high absorption coefficient. [21].

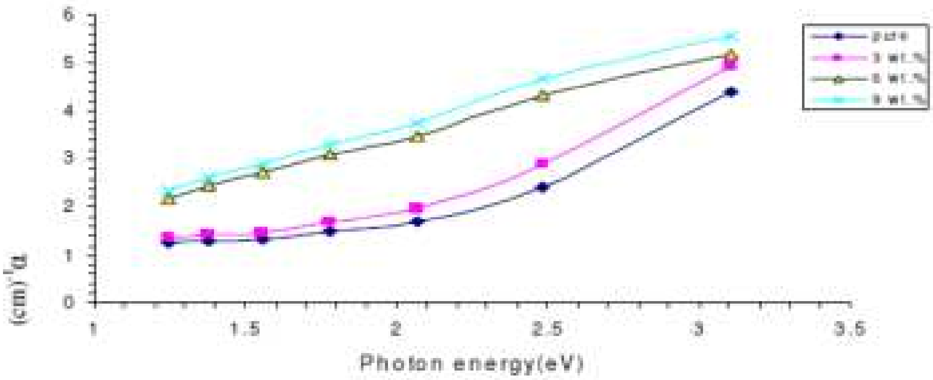


Figure 3-9: The relationship between the absorption coefficient and photon energy of the (PS-CNTs) composites

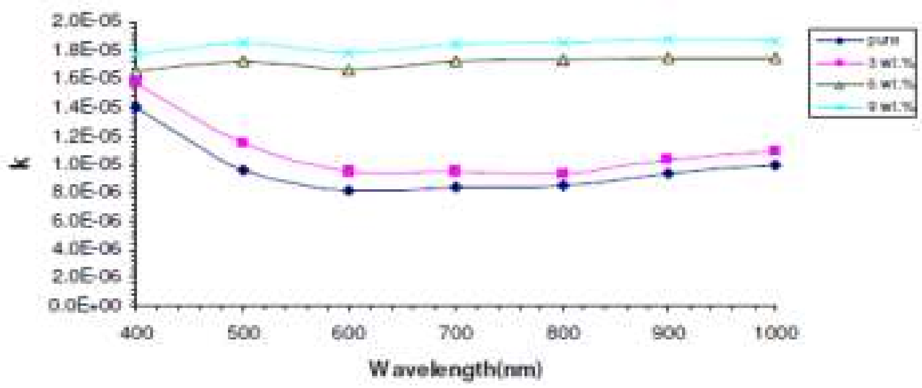


Figure 3-10: Extinction coefficient for (PS-CNTs) composite with various wavelength

Figure (3-11) shows the variation of the refractive index ($\boldsymbol{n} = \frac{1+\sqrt{R}}{1-\sqrt{R}}$) of composites a function of wavelength. The refractive index increase as a result of filler addition, this behavior can be attributed to the increasing of the packing density as a result of filler content.

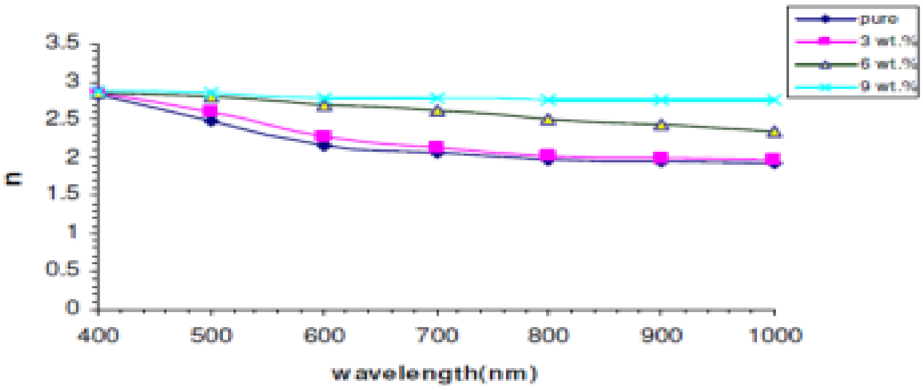


Figure 3-11: Refractive index for (PS-CNTs) composite with various wavelength

Figures(3-12,3-13) show the variation of real and imaginary parts of dielectric constants ($\varepsilon_1 = n^2 - k^2 \; and \; \varepsilon_2 = 2nk$) of (PS-CNTs) composites .It is concluded that the variation of ε_1 mainly depends on (n^2) because of small values of (k^2), while ε_2 mainly depends on the (k) values which are related to the variation of absorption coefficients[22].

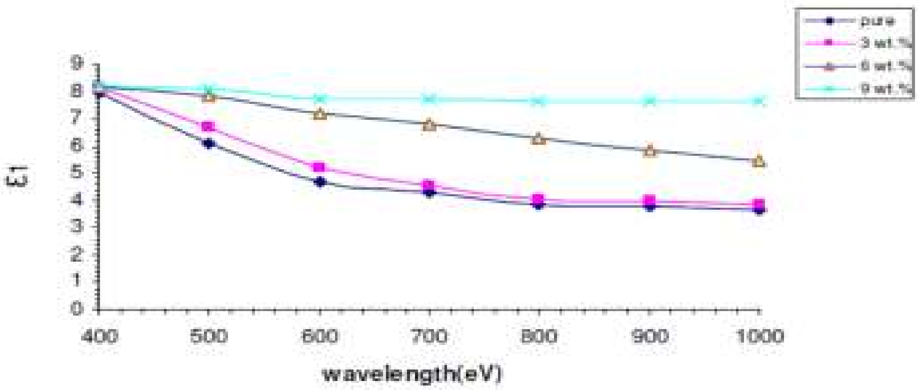


Figure 3-12: Real part of dielectric constant for (PS-CNTs) composite with various wavelength

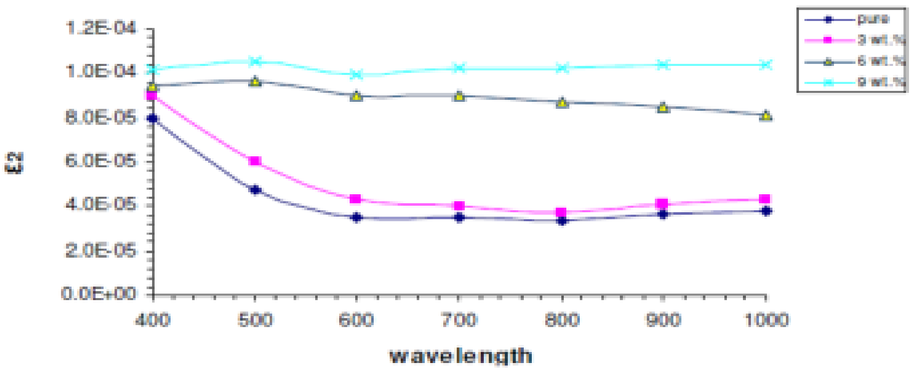
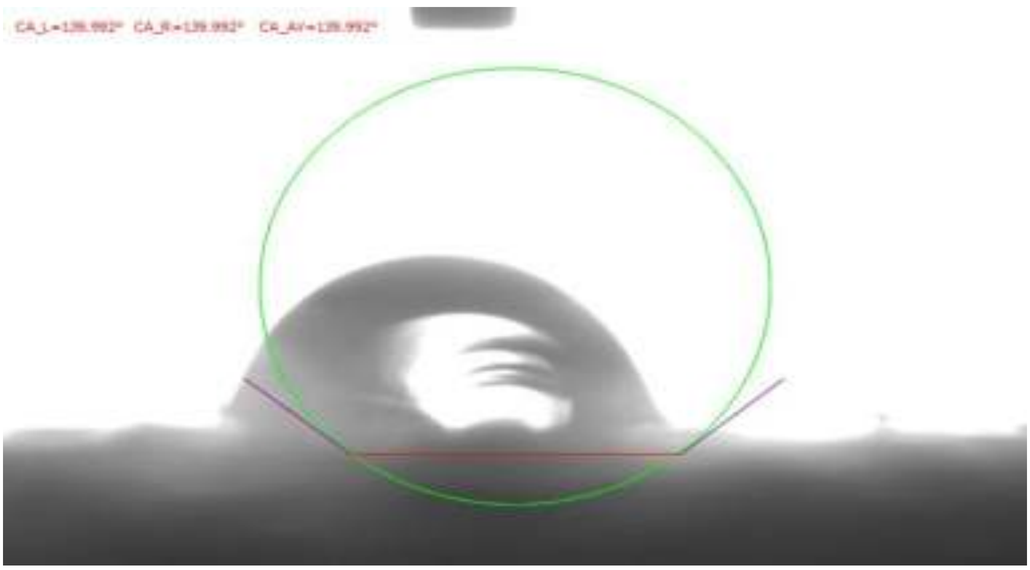


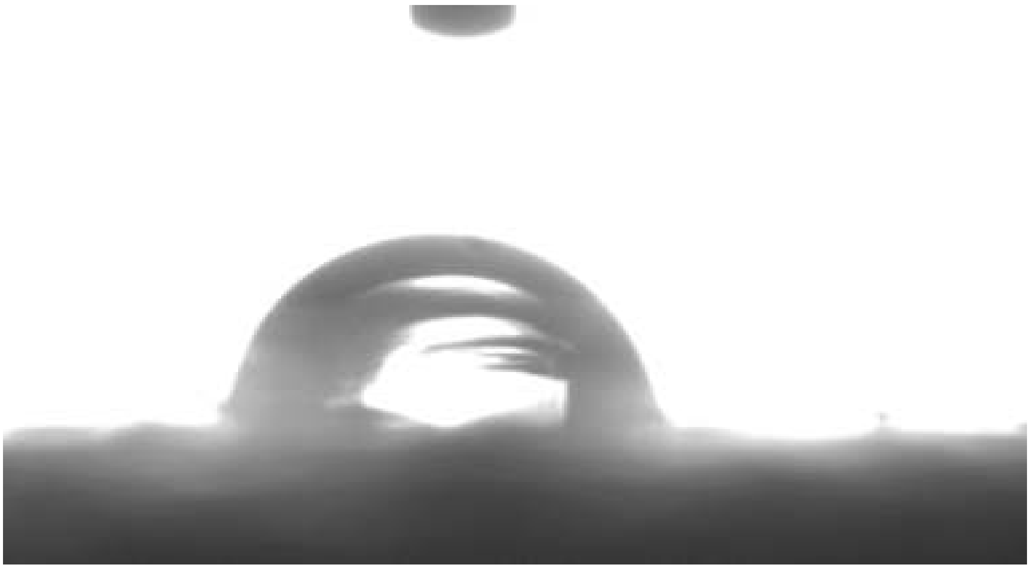
Figure 3-13: Imaginary part of dielectric constant for (PS-CNTs) composite with various wavelength

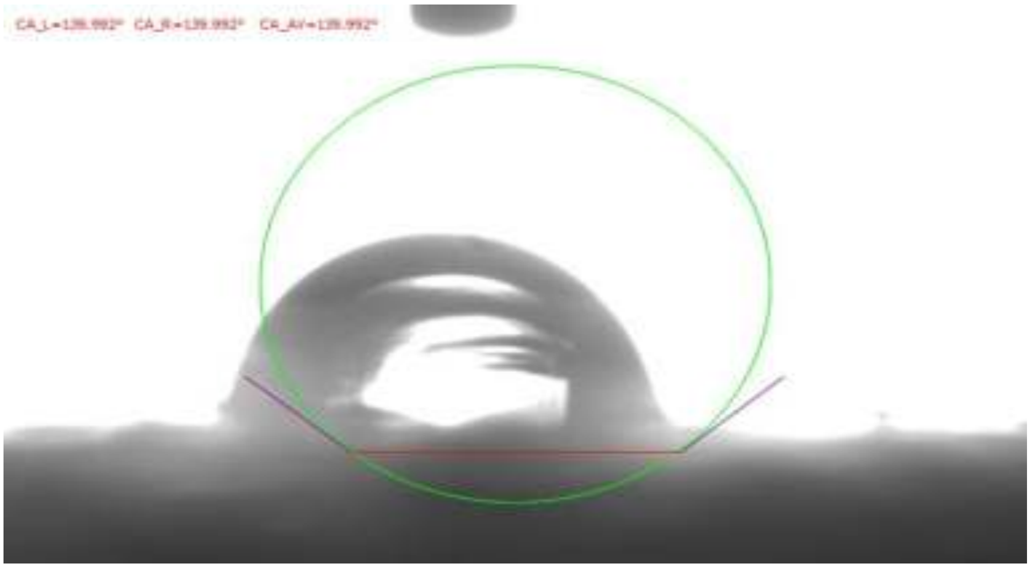
S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
AW	SFE	V_AV	V_R	V_L	S_AV	S_R	S_L	IFT_AV	IFT_R	IFT_L	CA_SD	CA_AV	CA_R	CA_L	MethodTy	CaptureTi	Caption	NO
145.5	72.75	0	0	0	0	0	0	0	0	0	0	0	0	0	Circle Fitti	2022-05-3(	1-1	1
8.912346	0.99	0	5.534079	0.204891	0	12.72846	1.540383	0	9800000	0.326667	62.6328	151.3415	120.0251	182.6579	Young-La	2022-05-3(	1-2	2
145.5	72.75	0	0	0	0	0	0	0	0	0	0	0	0	0	Circle Fitti	2022-05-3(	2-1	3
21.77243	5.1	0	10.29132	0.906628	0	18.17466	4.108983	0	9800000	0.970019	91.97478	134.485	88.49762	180.4724	Young-La	2022-05-3(	2-2	4


CA_L=0.000° CA_R=0.000° CA_AV=0.000°


CA_L=139.992° CA_R=139.992° CA_AV=139.992°

S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
AW	SFE	V_AV	V_R	V_L	S_AV	S_R	S_L	IFT_AV	IFT_R	IFT_L	CA_SD	CA_AV	CA_R	CA_L	MethodTy	CaptureTi	Caption	NO
17.0266	3.32	0	0	0	0	0	0	0	0	0	0	139.9922	139.9922	139.9922	Circle Fitti	2022-05-3	1-1	1
51.62035	18.88	0	2.265938	2.134785	0	6.664804	6.478954	0	32.66667	14.67899	10.91775	106.8844	101.4255	112.3433	Young-Lap	2022-05-3	1-2	2
17.0266	3.32	0	0	0	0	0	0	0	0	0	0	139.9922	139.9922	139.9922	Circle Fitti	2022-05-3	2-1	3
145.5	72.75	0	0	0	0	0	0	0	0	72.8	0	0	0	0	Young-Lap	2022-05-3	2-2	4

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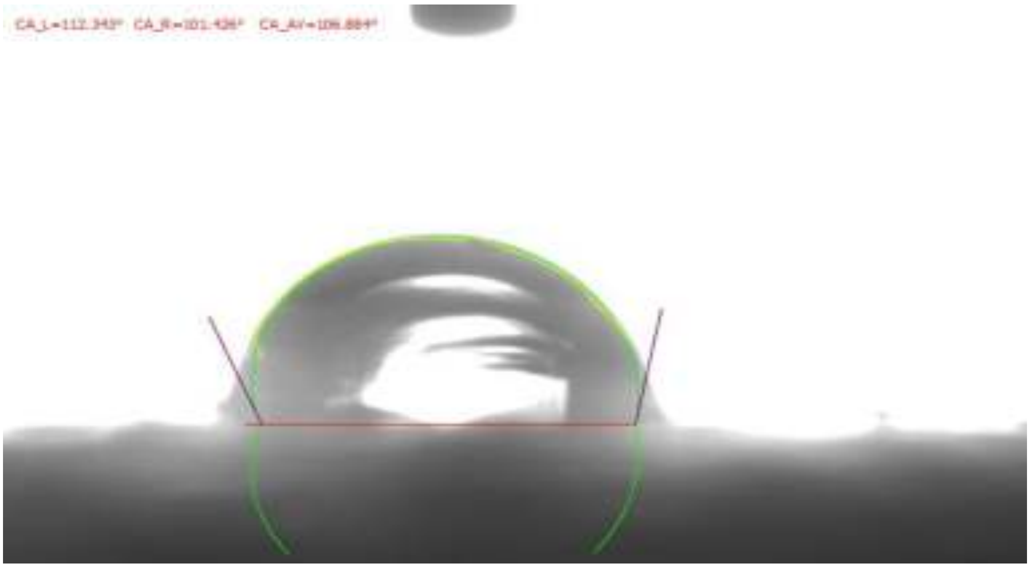
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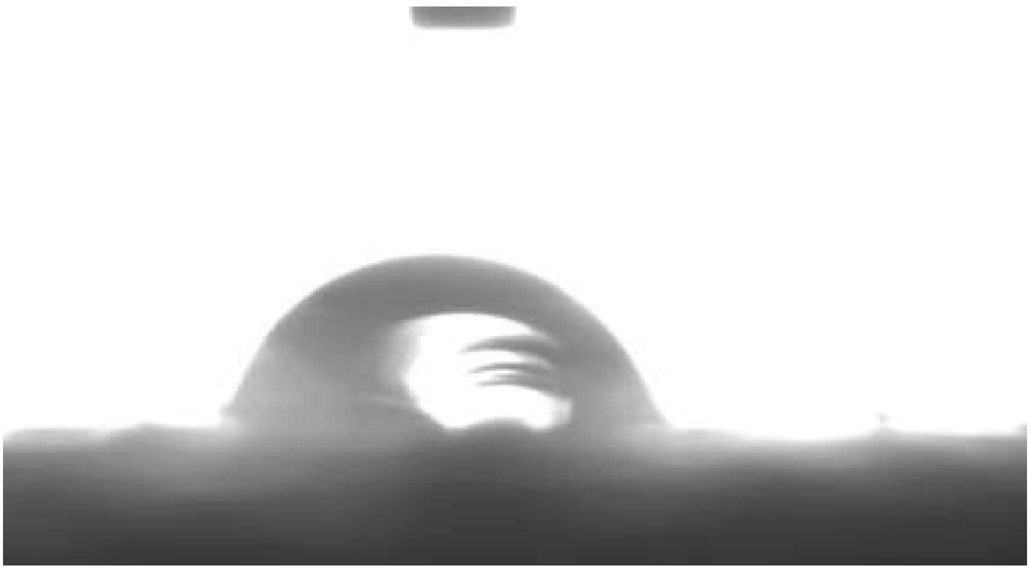
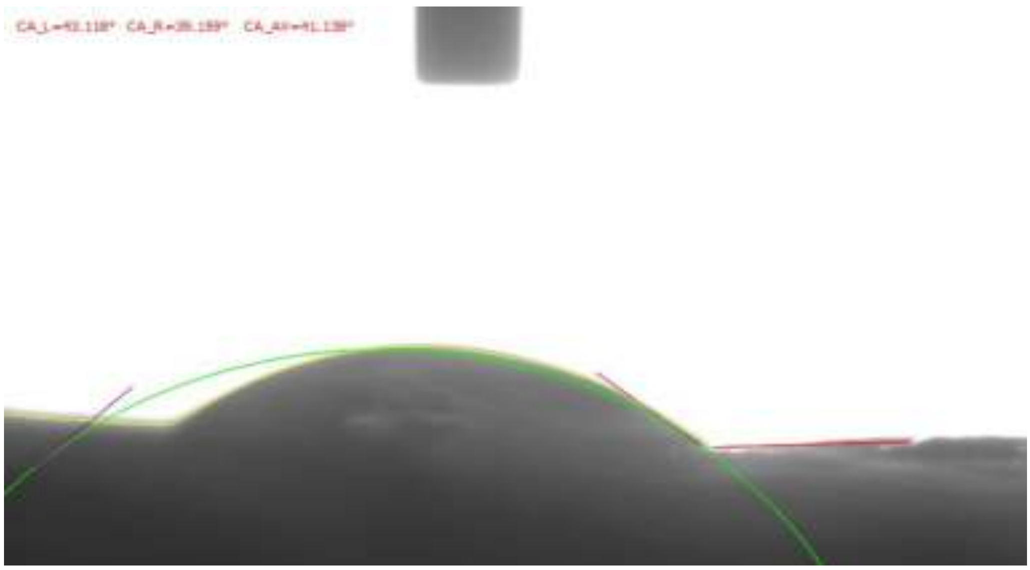
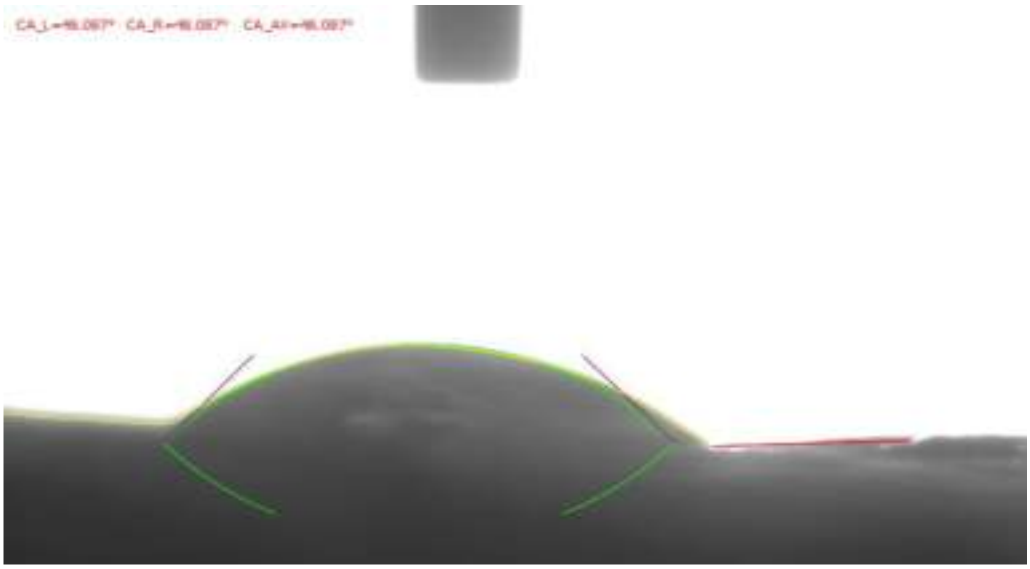
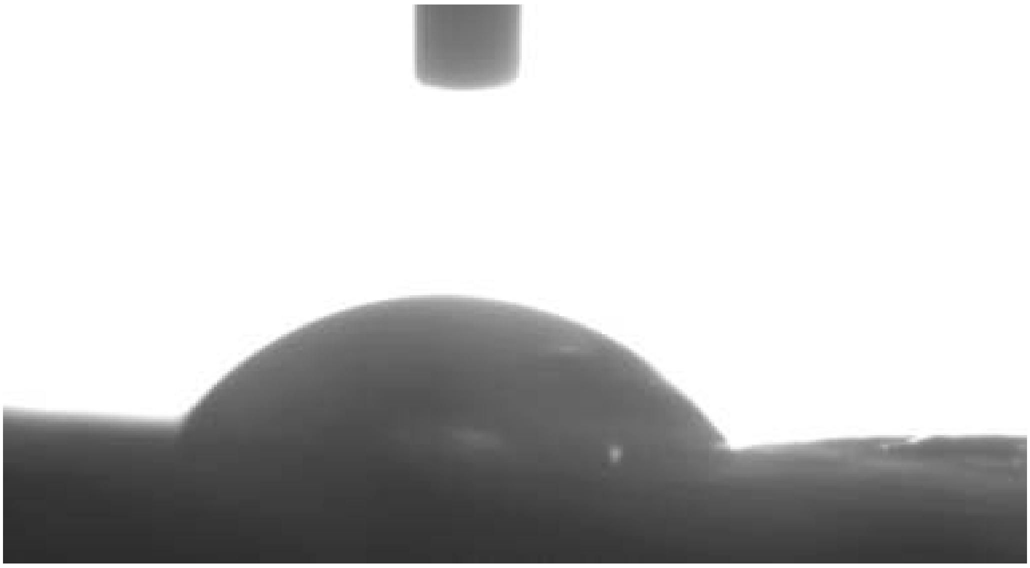
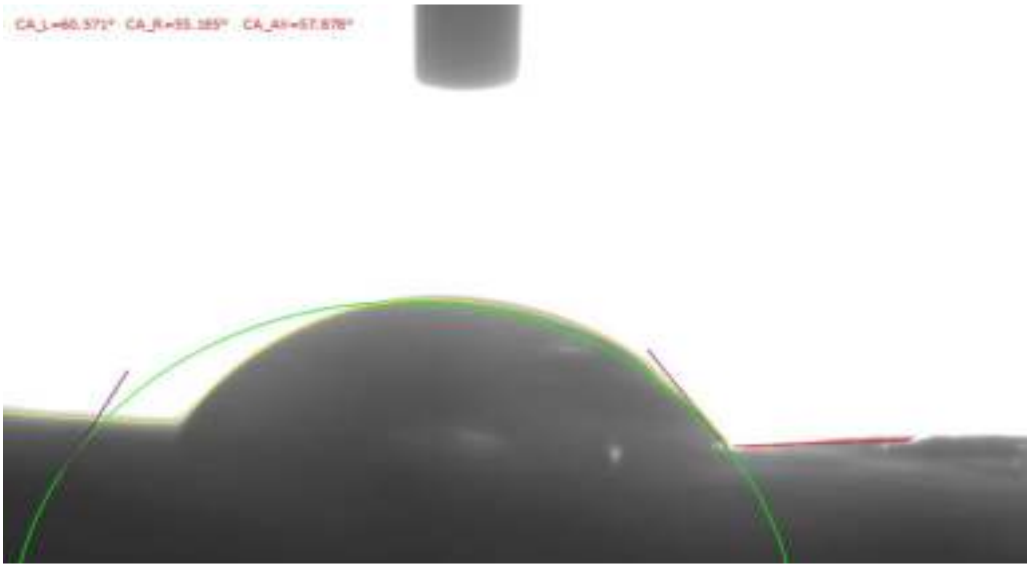


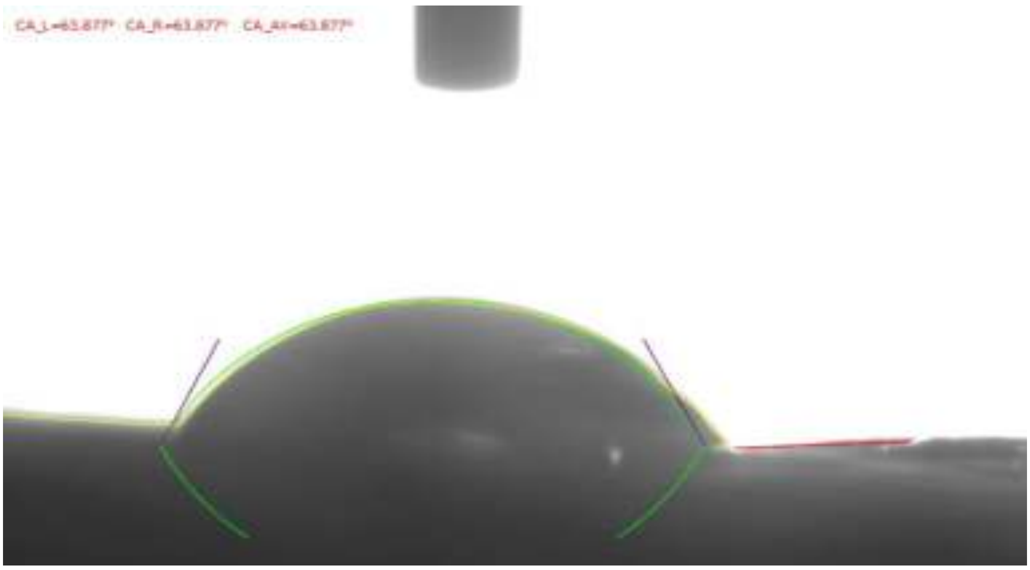


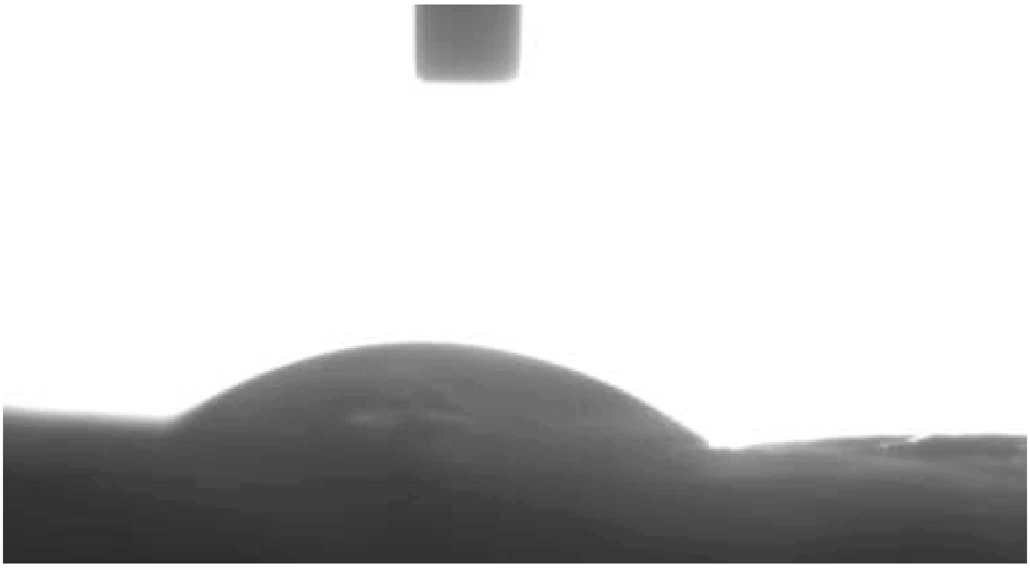


S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
AW	SFE	V_AV	V_R	V_L	S_AV	S_R	S_L	IFT_AV	IFT_R	IFT_L	CA_SD	CA_AV	CA_R	CA_L	MethodTy	CaptureTi	Caption	NO
111.4333	49.07	0	0	0	0	0	0	0	0	0	5.386082	57.87764	55.1846	60.57068	Circle Fitti	2022-06-0:	1-1	1
104.7819	45.44	0	2.623318	2.623318	0	7.759485	7.759485	0	9800000	9800000	0	63.87695	63.87695	63.87695	Young-Lap	2022-06-0:	1-2	2
127.5397	58.71	0	0	0	0	0	0	0	0	0	3.959498	41.13834	39.15859	43.11809	Circle Fitti	2022-06-0:	2-1	3
121.3468	54.82	0	1.480859	1.480859	0	5.940709	5.940709	0	9800000	9800000	0	48.08737	48.08737	48.08737	Young-Lap	2022-06-0:	2-2	4

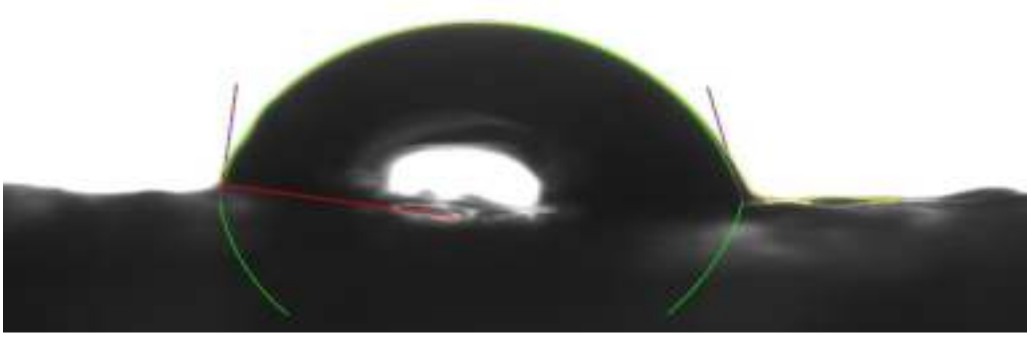



CA_L=60.571° CA_R=55.185° CA_Av=57.878°

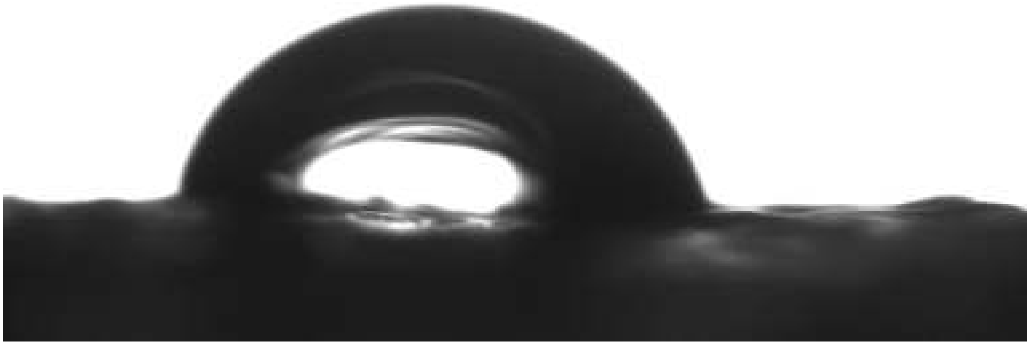

CA_L=63.877° CA_R=63.877° CA_Av=63.877°

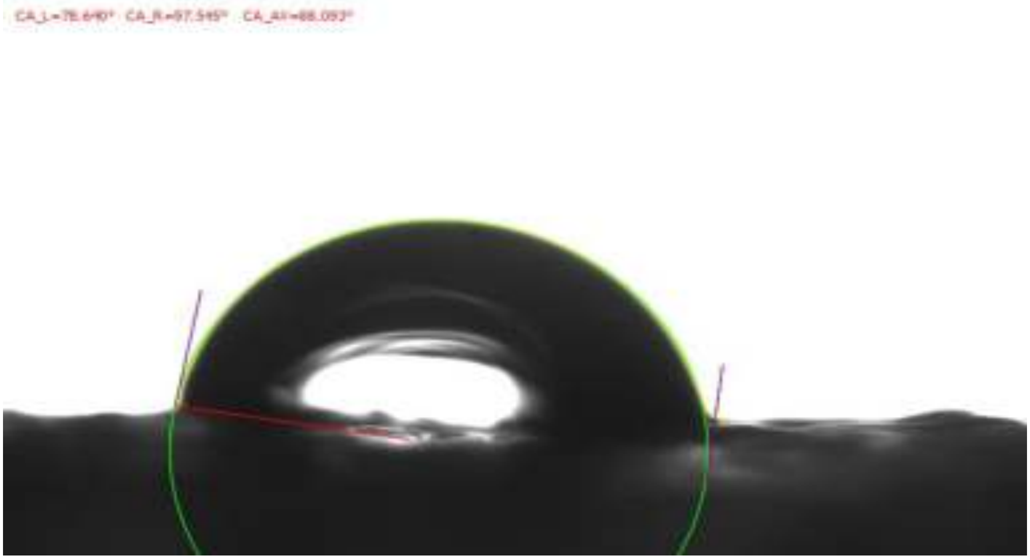


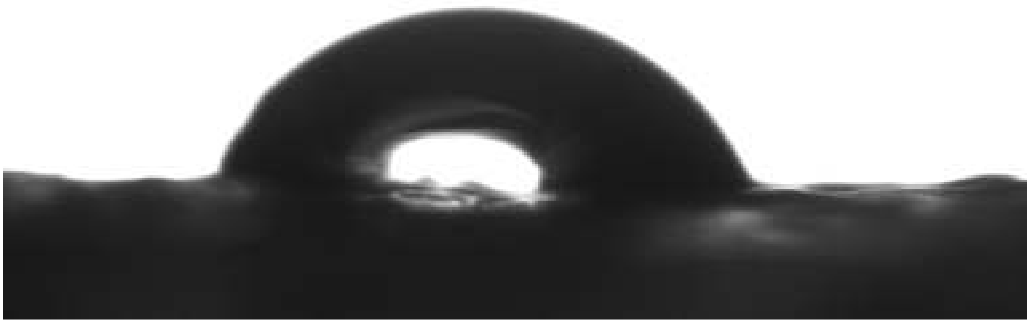
CA_L=82.485° CA_R=75.783° CA_AV=79.134°

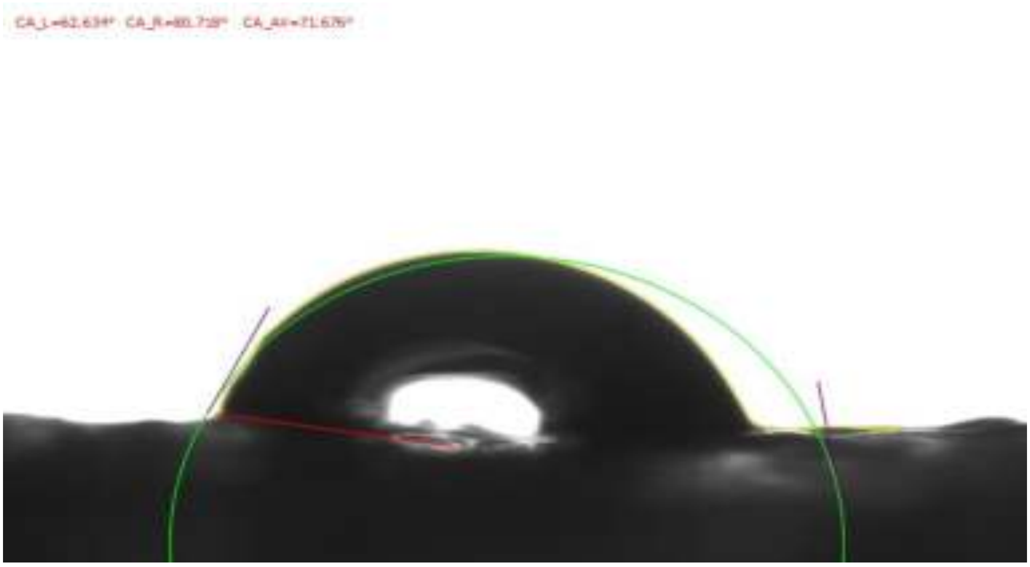


S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
AW	SFE	V_AV	V_R	V_L	S_AV	S_R	S_L	IFT_AV	IFT_R	IFT_L	CA_SD	CA_AV	CA_R	CA_L	MethodTy	CaptureTi	Caption	NO
75.17113	30.38	0	0	0	0	0	0	0	0	0	18.90529	88.09283	97.54548	78.64019	Circle Fitti	2022-06-0	1-1	1
79.33416	32.44	0	3.872323	3.813401	0	9.506669	9.393916	0	9800000	96.67555	3.281652	84.8074	83.16657	86.44823	Young-Lap	2022-06-0	1-2	2
95.62194	40.64	0	0	0	0	0	0	0	0	0	18.08449	71.67595	80.7182	62.63371	Circle Fitti	2022-06-0	2-1	3
86.46412	35.99	0	3.346934	3.165218	0	8.737317	8.3562	0	9800000	33.97375	6.702692	79.13414	75.78279	82.48549	Young-Lap	2022-06-0	2-2	4




CA_L=78.640° CA_R=97.545° CA_AV=88.093°





Sample	1	2	3	4	5	average
PS	**62.7**	**58.8**	**60.2**	**59.2**	**59.5**	**60.1**
PS+1 CNT	**59.7**	**58.3**	**57.1**	**56.1**	**55.2**	**57.3**
PS+2 CNT	**58.5**	**58.8**	**57.4**	**60.8**	**53.2**	**57.8**
PS+3 CNTs	**61.3**	**59.4**	**58.8**	**60.5**	**57.6**	**59.5**

Chapter Four

Conclusions and Recommendations

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Conclusions and Recommendations

4.1 Conclusions

1. The D.C electrical conductivity of the polystyrene increases by increasing the carbon nanotubes concentrations.
2. The dielectric constant decreases with increase the frequency and increases with increase the CNTs wt. % content.
3. The dielectric loss decreases with increase the frequency and increases with increase the CNTs wt. % content.
4. The A.C electrical conductivity of composites is increasing with increasing frequency of applied electrical field and CNTs wt. % content.
5. The absorption coefficient, extinction coefficient, refractive index and real and imaginary parts of dielectric constants are increasing with increase the CNTs wt. % content.

4.2 Recommendations

There is a wealth of other potential applications for carbon nanotubes, such as solar energy harvesting; Nanofilters supports catalyst and coatings of all types. There will almost certainly be many unexpected applications for this wonderful material to emerge in the coming years, which may be the most important and valuable of all. Several researchers are investigating conductive and/or waterproof paper made of carbon nanotubes. Carbon nanotubes have also been shown to absorb infrared light and may have applications in the I/R optics industry .

References

1- Wang, X., Li, Q., Xie, J., Jin, Z., Wang, J., Li, Y., ... & Fan, S. (2009). Fabrication of ultralong and electrically uniform single-walled carbon nanotubes on clean substrates. *Nano letters*, *9*(9), 3137-3141.

2- م. م نجلاء باقر كمر. (2020). دراسة نظرية للعلاقة بين نصف القطر وفجوة الطاقة للأنابيب النانوية الكربونية أحادية الجدران تحت تأثيرعملية التشويه الميكانيكي المرن *DIRASAT TARBAWIYA*, *13*(52).

3- Hill, D. E., Lin, Y., Rao, A. M., Allard, L. F., & Sun, Y. P. (2002). Functionalization of carbon nanotubes with polystyrene. *Macromolecules*, *35*(25), 9466-9471.

4- Kaseem, M., Hamad, K., & Ko, Y. G. (2016). Fabrication and materials properties of polystyrene/carbon nanotube (PS/CNT) composites: a review. *European Polymer Journal*, *79*, 36-62.

5- **"Nanotechnology: Basic Science and Emerging Technologies"**, M. Wilson *et al,* Chapman and Hall (2002) ISBN 1-58488-339-1

6- نيوجي ، إس وآخرون. (2002). كيمياء الأنابيب النانوية الكربونية أحادية الجدار. Acc. Chem. Res.2002، 35، 1105-1113

7- ساجد ، م. وآخرون. (2016) الأنابيب النانوية الكربونية من التوليف إلى *في الجسم الحي* التطبيقات الطبية الحيوية. المجلة الدولية للصيدلانيات 501 (2016) 278-299.

8- إيتمادي ، إيه وآخرون. (2014). الأنابيب النانوية الكربونية: الخصائص والتوليف والتنقية والتطبيقات الطبية. رسائل البحث النانوية 2014 ، 9: 393..

9- جروبرت ، ن. (2007). الأنابيب النانوية الكربونية - تصبح نظيفة. Materialstoday Volume 10 ، الإصدارات 1-2 ، الصفحات 28-35..

10- هاريك ، في م. (2017). هندسة الأنابيب النانوية الكربونية وآليات البلعمة والتأثيرات السامة. توكسيكول ليت 2017 ، 273: 69-85..

11- هاريك ، في م. (2017). هندسة الأنابيب النانوية الكربونية وآليات البلعمة والتأثيرات السامة. توكسيكول ليت 2017 ، 273: 69-85..

12- Farshidfar A., Haddadiv. and Nazokdast H., 2006,"Electrical and Mechanical properties of conductive carbon black/polyolefin composites mixed with carbon fiber, composites convention and Trade show American composites Mamufactarers Association, St. Louis., Mo USA.

Tomasz Pingot, Martyna Pingot and Marian Zaborski , 2011,"THE -13 EFFECT OF CARBON FILLERS ON ELASTOMER COMPOSITE PROPERTIES", International Conference of Multiphase Polymers and Polymer Composites: From Nanoscale to Macro Composites", ParisEst, Creteil Uniersity, Paris, June, France.

14-Hamzah M., Saion E. , Kassim A. , Mahmud E. and Shahrim I., 2009, J. for the advancement of sci. Vol. 1, No. 1, P(9-14).
15- Hamzah M. , Saion E., Kassim A. and Yousuf M. , 2008, "Temperature dependence of AC Electrical conductivity of PVA-PPy-FeCl3 composites polymer Films", MPJ. Vol. 3, No. 2 ,p(24-31) , Malaysia.
16- Raghavendra S.C, Revanasiddappa M., Khasim S. and Vishnuvardhan T. K. , 2007, J.Bull. Korean chem.. Soc. Vol. 28 , No.7, P(1104-1108) .

17- Vishnuvardhan T. K., Kulkarni V. R., Basavaraja C.and Raghavendra S.C., 2006, J.Bull. Mater. Sci. Vol. 29 , No. 1, pp. 77-83.
18- Shui G. , Hu J. , Qiu M. , Wei M. and Xiao D. ,2004, J.Chinese chem.. letters, Vol. 15 , No. 12 ,pp 1501-1504 ..
19- Hutagalwng. S. D. and Lee. B. Y. ,2007, Proceeding of the 2nd international conference Nano/Micro Engineered and Molecular systems, January, Bangkok,Thailand.
20- Scholz. S.M, Carrot.G and Hilborn.J ,2008, "Optical properties of Gold Containing poly (Acrylic Acid) composites" , Lausanne, Switzerland.
21- Ahmed R.m. , 2008, "Optical study on poly(methyl methacrylate)/poly(vinyl acetate)", Zagazig Uni., Zagazig, Egypt, E-mail-rania 8_7@hotmail. com.
22- Shui G. , Hu J. , Qiu M. , Wei M. and Xiao D. ,2004, J.Chinese chem.. letters, Vol. 15 , No. 12 ,pp 1501-1504 .