[*]Electrical properties of polyaniline / multi-walled carbon nanotubes nano films

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[a]Raheem G. Kadhim, [b]Mohammed H. Shinen,[ac]Mohammed S.Abdali

[a]Department of Physics, College of Science ,University of Babylon, Iraq
[b]Department of Physics, College of Science ,University of Babylon, Iraq
[c]Department of Environmental, College of Science ,University of Al-Qadisiya, Iraq
E-mail address: [a]Raheemnano2015@gmail.com , [b]mohammed.shinen@yahoo.com ,[c]mohammed.sami68@yahoo.com

ABSTRACT :

In this research we study the electrical properties of polyaniline (PANI) nano films pure and doped with multi-walled carbon nanotubes (MWCNTs) and which included direct electrical conductivity (σ_{dc}),activation energy and the hall effect with ratio (1%, 3% and 5%) prepared by spin coating deposited on glass substrate at room temperature.

The results showed that (PANI) has conductivity about of (7.136×10^{-7} $(\Omega.cm)^{-1}$) at room temperature; and this conductivity increased with increasing of doping ratio, also with increasing of temperature as well as the results showed throughout the study that (PANI) has one activation energy and this energy decreased with increasing of doping ratio. the hall effect showed that the (PANI) its p-type.

Key words: Electrical properties; Polyanilin; nano films; Carbon nanotubes
* The Research in Apart of an Ph.D. Thesis in The Third Researcher.

Subject Classification: QC 170-197

1- **Introduction :**

Polymers of unique composition have the properties of semiconductors, while mainly commercial polymers are insulator. known that polymers are simply shaped , chemists and physicists happening median the twentieth irregular double century to conduct studies designed to expand conductor polymers characterized by the bonds [1] .

Polymeric materials can be synthesized and processed into different shapes according to the required application such as thin films , polymer have many advantages to the electrical application due to their simple synthesis technology , relatively low cost materials and can be deposited on different substrates , moreover, they have special characteristic that mode them very important , such that ,they have a wide range of electrical conductivity [10^{-24}-10^{6} S/cm][2,3].

The electrical conductivity of polymers related with free ions which are not chemically linked to the large molecules, Conductive polymer is broadly used in microelectronics engineering, the magnitude, these microelectronics application is that it has physical properties modified to a particular request and recognize the mechanisms controlling these properties.[4 ,5].

Polyaniline is one of conductive polymers, a kind of p-type and his behavior resembles the behavior of semiconductors[6]. Also it features properties photoelectric task could be used in industrial applications[7]. It is used in the solar cell industry and in printed electrical panels for panels electrical appliances Maps[8,9] .

2- MATERIALS AND METHODS

2.1-Preparation of samples

The thin films of (Polyaniline) were synthesize by using spin coating technique that the polymer is dissolved in (DMF) and deposited on substrate off glass .

2.1.1-D.C Electrical Conductivity :

There are two ways to calculate the D.C Electrical Conductivity :

a- Interdigitated finger Electrode

b- Deposition polar

a - Interdigitated finger Electrode

Consisting of poles individually-like comb teeth and be very sensitive to the thin films in solid-state physics which are small and distinctive size and dimensions are measured in nano-meter , as in Figure (1) [3,10]. Which shows that the electrodes consist of aluminum in the form of lines on the base of the glass, and can perform calculations using the following relationship

$\sigma_s = [I/V]\,[L/Wt\ell]$ ………………….. (1)

Where(t) represents the thickness of polymer, W the distance fingers (10mm), ℓ number of fingers is to be (10), and L the space between electrodes (100µm).

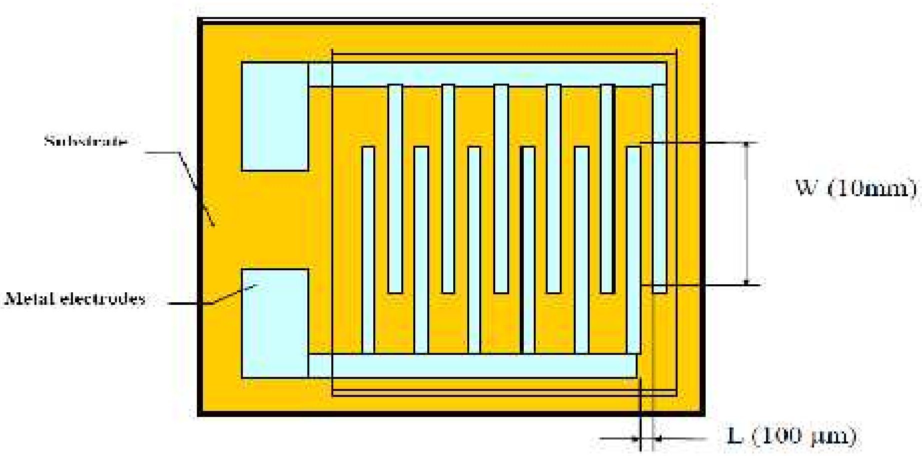


Fig.(1)A schematic diagram of interdigitated finger electrode

b - Deposition polar

Masks have been designed for this technology using thin aluminum material and forms suitable and as in shape (2) and purpose is to determine the geometry of the electric pole and raise these masks after the completion of the deposition process.

Electrical conductivity in the semiconductor In this technique given the following relationship[11].

R: resistant membrane practically measured (Ω).
A: pole width (cm).
L: the distance between the opposite poles (cm).

It resistivity account that has been The continuous conductivity Account (σ_{dc}) of calculating the value of inverted resistivity, namely that[13].

$$\pm_{dc} = 1/\,^{\circ} \quad ....(4)$$

Based on the equation (2) painted a graphic relationship between (Lnσ and (1000 / T)) and so could account activation energy which is equal to the slope of the line extracted from the graph multiplied of Boltzman's constant

$$\pm = \pm_o EXP(\frac{-E_a}{k_B T}) ....(2)$$

As:
Ea: activation energy(eV). T: the absolute temperature.
Kβ: Boltzmann's constant. $\sigma_{\circ}$:constant.

The continuous connectivity membranes prepared account after measuring the resistivity of membranes (ρ) for each temperature starting from room temperature down to the point (60c^{o}) using the following relationship [12]

$$^{\circ} = \frac{RAT}{L} \quad ....(3)$$

As:

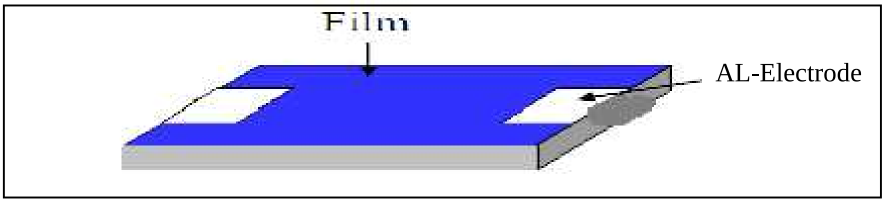


Figure (2) shows an illustrative scheme of poles precipitated on the sample to be measured

The electrical properties of polianylyne are measured by digital electrometer type Keithley (616) and electrical oven was used, to measure a current as a function of the applied voltage as show in Figure(3).

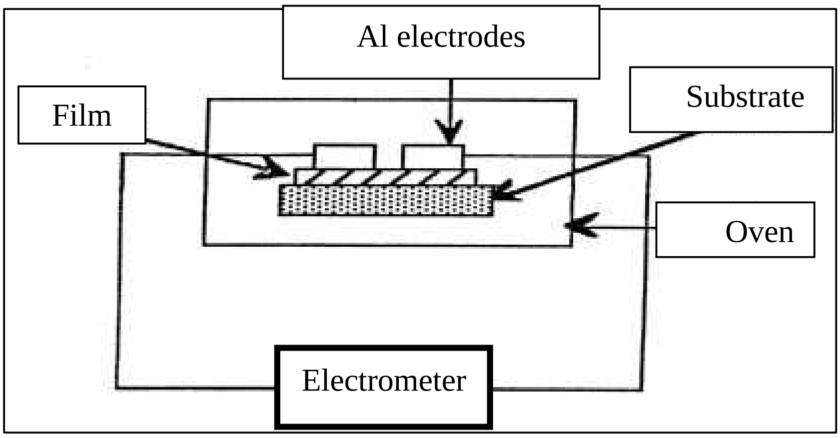
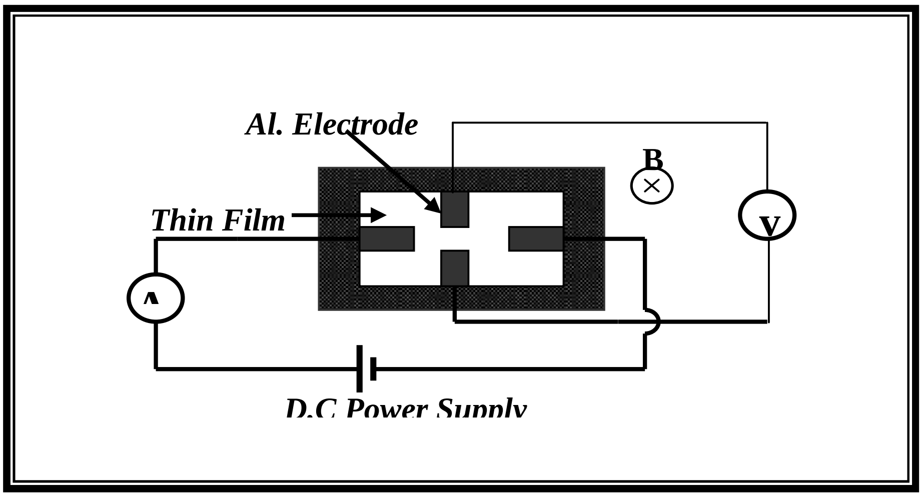


Fig.(3) circuit used to measure the continuous electrical conductivity

2.2-Hall effect :

Hall effect known as the difference in the distribution of the current in the conductive or semi-conductive segment due to the magnetic field [12,13] which shed a magnetic field on a conductor carrying an electric current direction perpendicular to the direction of current flow generates a delinquency charge carriers aside and cause the generation of electric driving force over the connector direction perpendicular to the direction of both the current and the magnetic field, Figure (4) shows an electrical circuit for measuring the Hall effect



Figure(4): Illustrative scheme of the Department of measurement Hall Effect

And the hall effect has been measured according to the circuit in Figure (5) which consists of D.C. power supply with (0 – 40) volt and two digital electrometers (HMS-3000) to measure the current and voltage.

Fig. (5): Set-up and photograph illustrate the Hall effect.

The Hall effect in semiconductors measurements are given the following relationship [14].

$$R_H = -(\frac{1}{ne}) = \frac{V_H.t}{I_x.B_z} \quad \ldots\ldots\ldots\ldots(5)$$

It represents
RH: Hall coefficient. n: the concentration of electrons.
e: electron charge. t: the thickness of the membrane.
Ix: current flowing in the membrane. Bz: the intensity of the magnetic field.
and from this relationship has also been the Concentration of the majority carriers account, using the following relationship was Hall mobility of these carriers account [13].

$«_H = |R_H| ±$ ………… (6)

As it represents:
Hμ Mobility Hall
σ electrical conductivity

3 -Results and Discussion:

3.1-The D.C Conductivity and Activation Energy

Measurement results showed that polyaniline has electrical conductivity up to (7.13646E-07(Ω.cm)$^{-1}$) at room temperature and that this conductivity increases with increasing temperature, As for the membranes vestiges we note there is also an increase in the conductivity values with the increase in the proportion of doped, This can be explained by the increase that led to the formation of impurity donor levels Near the conduction band, When the activation energy calculation we found that there was a single activation energy and this shows the transition in a way thermal stimulation at the border granular mechanical occurrence, As for the membranes vestiges, the value of the activation energy decreases with increasing the proportion of doped As shown in Table (1) , This can be explained that increasing the proportion of impurities led to the approach of the Fermi level more towards the conduction band, as is evident in Figures (6,7).

Table1:D.C.conductivity parameters for (PANI: MWCNTs)films for various ratios

Sample	Activation energy $E_{a\ (eV)}$	Electrical conductivity $\sigma_{d.c}$ (Ω.cm)$^{-1}$
pani	0.014221	7.136×10^{-7}
pani : cnt(1%)	0.014002	1.25×10^{-6}
pani : cnt (3%)	0.0138	1.312×10^{-6}
pani : cnt (5%)	0.0136	1.352×10^{-6}

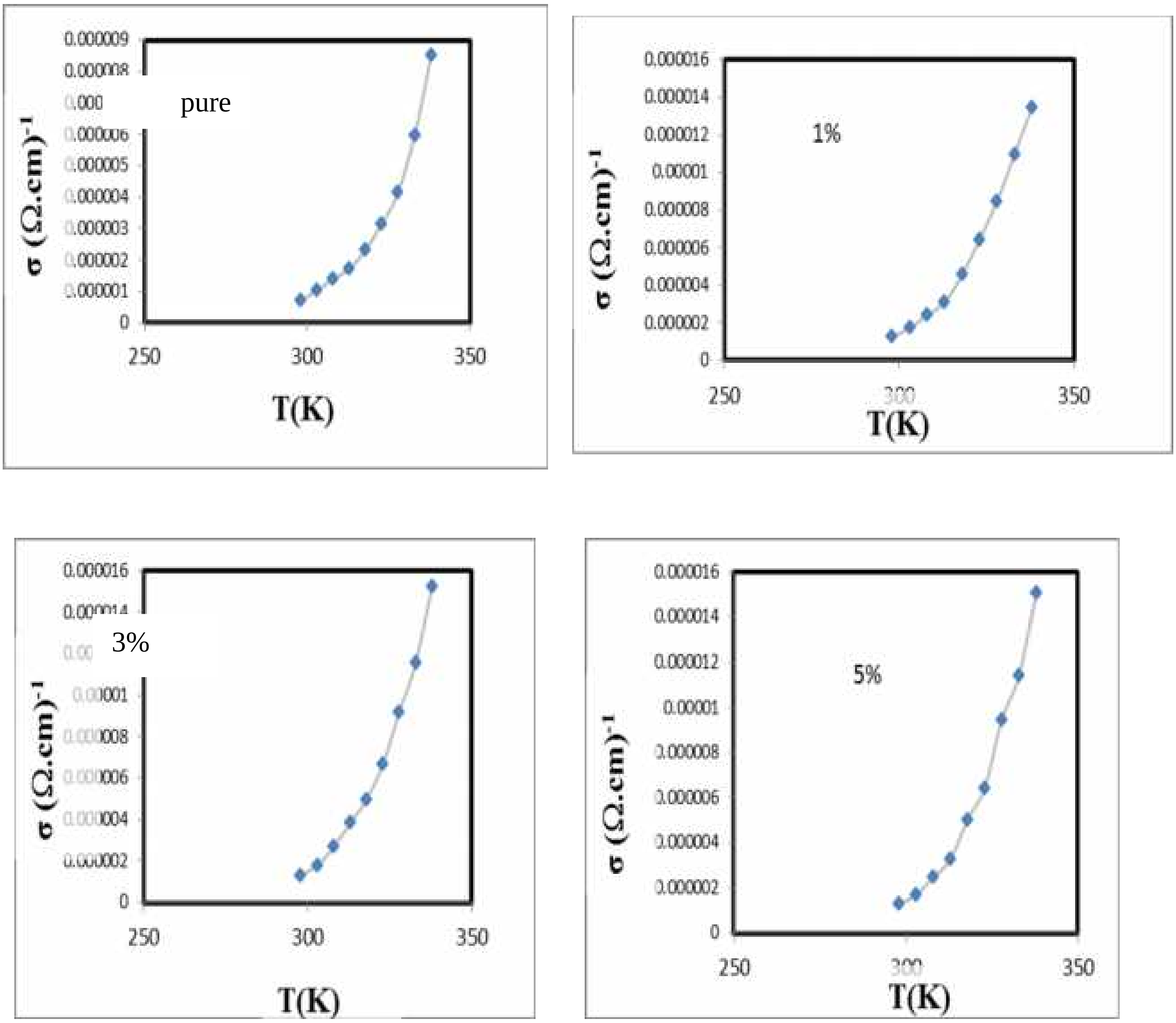


Figure 6 : Variation of $\sigma_{D.C}$ versus temperature for (PANI: MWCNTs)

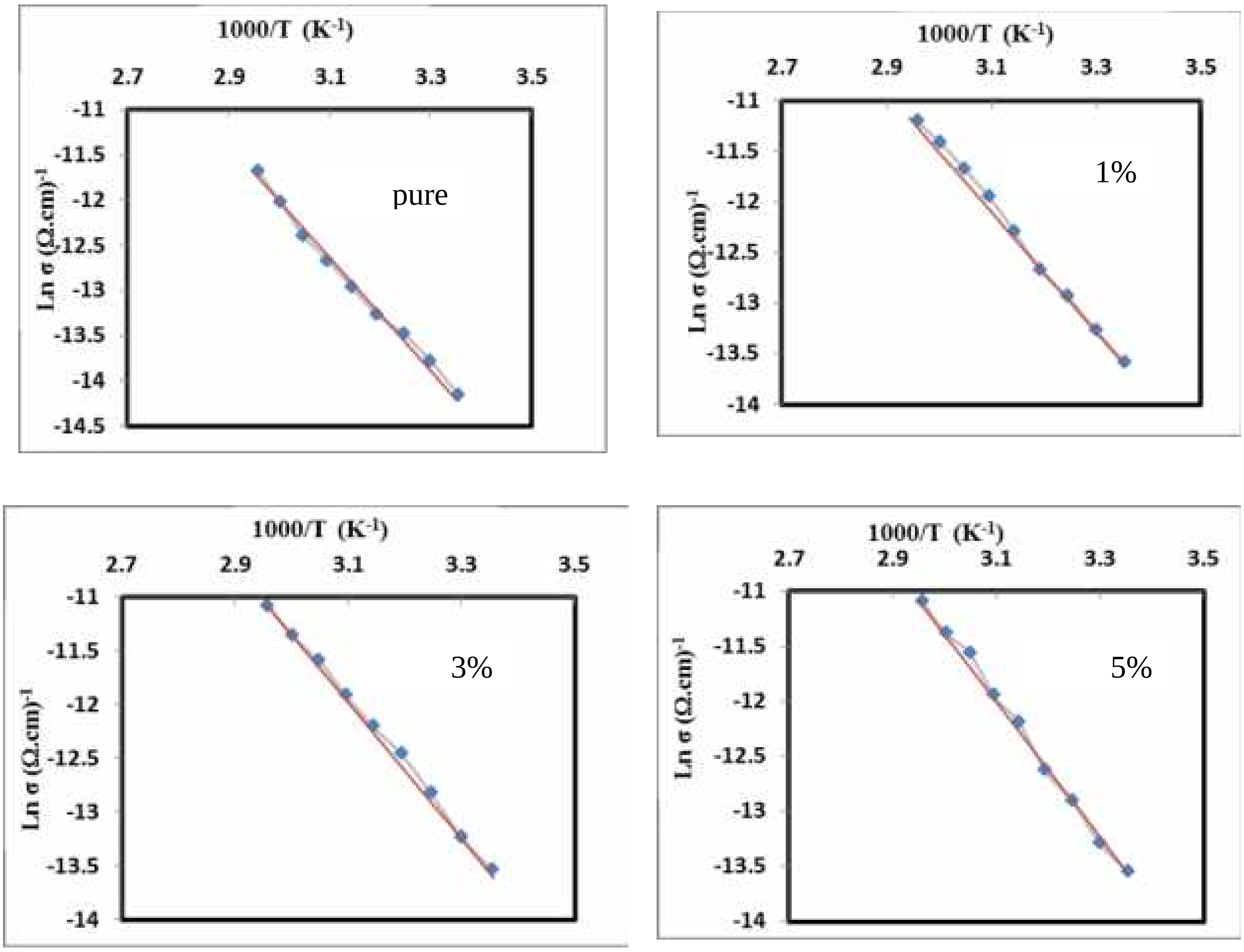


Figure 7 : Ln±=versus 1000/T for (PANI: MWCNTs)

3.2- Hall Effect

The results of the measurements of the Hall effect that all membranes prepared is the p-type through the positive sign of the Hall coefficient , The results also showed that (PANI) has a value of mobility (1.22×10^2 $cm^2/V.s$) at room temperature. in membranes vestiges there was a clear increase in the concentration of carriers and a decrease in the values of mobility at room temperature with increasing doping ratio as in the table (2), This was due largely to an increase in the concentration of carriers formed near the conductive band, which in turn lead to an increase the number of donor atoms of electrons capable of ionization within the thermal energy does not exceed the value of topical levels (K_BT), As for the decrease in mobility shall be due to the increased concentration of carriers.

Table 2: Hall parameters for (PANI/ MWCNTs) films at different ratios

Sample	RH (cm3 / C)	nH (1 / cm3)	ρ (Ω.cm)	μH (cm ^{2}/ V.s)	$\sigma_{R.T}$ $(\Omega.cm)^{-1}$
Pani pure	5.3×10^{7}	1.1×10^{11}	4.3×10^{5}	1.22×10^{2}	2.2×10^{-6}
pani:cnt(1%)	1.69×10^{7}	3.6×10^{11}	3.38×10^{5}	5.09×10^{1}	3.01×10^{-6}
pani:cnt (3%)	6.07×10^{6}	5.2×10^{11}	2.8×10^{5}	1.5×10^{1}	4.5×10^{-6}
pani:cnt (5%)	4.5×10^{6}	7.7×10^{11}	1.8×10^{5}	0.98×10^{1}	5.44×10^{-6}

7. Conclusions:

The summarized results from this work are the following:

1. It is found through the study that these polymers appear a continuous change in the Electrical properties as a result of adding (carbon nanotube) to the polymer

2. The addition of carbon nanotube to (PANI) led to the improvement Electrical properties.

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الخواص الكهربائية لأغشية البولي أنيلين النانوية\ انابيب الكاربون النانوية المتعددة الجدران*

تاريخ الاستلام 2016/10/5 تاريخ القبول 2016/12/20

الخلاصة:

في هذا البحث تم دراسة الخواص الكهربائية لأغشية البولي أنيلين النقية والمشوبة بأنابيب الكاربون النانوية المتعددة الجدران النانوية والتي تضمنت التوصيلية الكهربائية المستمرة(σdc), وطاقة التنشيط وكذلك تأثير هول وبنسب تشويب (%5,%3,%1) والتي حضرت بتقنية طلاء البرم(spin coating) وبدرجة حرارة الغرفة

تبين من النتائج أن البولي أنيلين يمتلك توصيلية بحدود $(7.136\times10^{-7}\ (\Omega.cm)^{-1})$في درجة حرارة الغرفة وان هذه التوصيلية تزداد مع زيادة نسبة التشويب و مع زيادة درجة الحرارة وكذلك تبين من الدراسة ان البولي أنيلين يمتلك طاقة تنشيط واحدة وان هذه الطاقة تقل مع زيادة نسبة التشويب.كما وان قياسات تأثير هول بينت أن البولي أنيلين من النوع الموجب (P-type)

مفاتيح البحث: الخواص الكهربائية , اغشية بولي انيلين النانوية , انابيب الكاربون النانوية

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