

## **THE EFFECT OF CARBON ON THE ELECTRIC PROPERTIES OF POLYETHYLENETEREPHTHALATE**

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**THAMIR SALMAN BACHARI**

**POLYMER RESEARCH CENTRE- MATERIALS SCIENCE  
DEPARTMENT-BASRAH UNIVERSITY**

E-mail: [thamir\\_bachari@yahoo.com](mailto:thamir_bachari@yahoo.com)

### **ABSTRACT:**

The electrical properties of polymer bulk films have done from prepared PET (polyethylene terephthalate) of water drinking bottle as paste and mixed with different percentages by weight (wt%) Carbon (C) on clean glass substrates. This investigation exhibits dependence on the structure of the polymer. The polymer bulk strip films showed different electrical properties, which depend on the film thickness and the applied voltage, PET characterization and diagnosis were carried out by infrared spectrophotometer (IR) and differential scanning calorimeter (DSC). The I-V characteristics of the films were measured at applied voltage (150) volt d.c. and the effect have been discussed, the electrical resistivity ( $\rho$ ) and the electrical conductivity ( $\sigma$ ) were measured depend on the percentage of film constituent.. The calculated activation energy is equal to  $5.6 \times 10^{-4}$  eV at PET0.02C0.002.

**Keywords:** PET, C, Bulk films, IR, DSC, Electric conductivity, Activation energy.

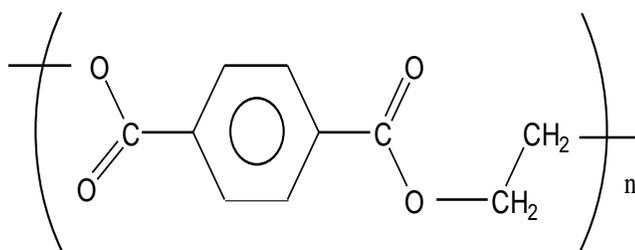
### **1- INTRODUCTION:**

Films prepared by mixing bulk PET filled with carbon (C). polymer exhibit variety of electric properties reflecting their structure and molecular motion. Fig.(1). Shows the chemical structure of PET[1]. Most polymers are highly electric insulator, some polymers show metallic conduction[2]. Transport and conversion are the characteristics of polymer constituents with graphite, which show conductivity variation with temperature. The development of intrinsically conductive polymers has benefited immensely from the contribution of synthetic chemists[3]. In case of metals, the resistivity depend on collisions, quantum mechanics tells us that electrons behave like waves. One of the effect is that electrons do not scatter from a perfect lattice, they scatter by defects which can be atoms displaced by lattice vibration, vacancies and interstitials, dislocations, grain boundaries and impurities[4]. The application of potential difference (voltage) causes the movement of electrons and when electrons are free to move there is flow of current. Metals can be thought of as a collection of atomic nuclei existing in a sea of electrons and when voltage is applied the electrons are free to move and to conduct current. Polymers and atoms that make them up have their electrons tightly bound to the central long chain and side groups

through “covalent” bonding. Covalent bonding makes it much more difficult for most conventional polymers to support the movement of electrons and therefore they act as insulators. Not all polymers behave the same when they subjected to voltage and plastic can be classified as “polar” or “non-polar” to describe their variations in behavior, the non polar plastic are truly covalent and generally have symmetrical molecules. In their materials there are no polar dipoles present and the application of electric field does not try to align any dipoles, most plastic are electric insulator (poor conduction of electricity) and resist the flow of current. This is one of the most useful properties of plastics and makes much of our modern society possible through the use of plastic as wire coatings, switches and other electrical and electric products despite this dielectric breakdown can occur at sufficiently high voltages to give current transmission and possible mechanical damage to the plastic[5].

The conventional method of preparing electrically conductive polymer composites (CPCS) is by admixing conductive solid fillers such as metal particles, carbon block, graphite or carbon nanotubes into the common polymer, on the other hand conductive polymers were also expected to yield numerous potential applications over the last decades[6]. Other methods were used melt spinning processes and coating process, in order to obtain conductance polymer for example in melt spinning process poly aniline (PANI), Polypyrole (PP) and Graphite were used to obtain polypropylene based fibers with specific electrical and mechanical properties[7].

In addition to its fundamental scientific aspects, the study of electrical conduction mechanism between two metallic electrodes placed in rarefied atomsphere offer valuable practical means of improving the performance of high vacuum (HV) apparatus. Corona occurring at the interface of an insulator and metal can damage or reduce the life of an insulating system. In general inorganic insulating materials are more resistance to the damaging effect of corona than organic insulating materials. Corona also generates electromagnetic interface and librates zone, a toxic and oxidant gas[8]. The thickness of an insulating material plays a role in determining its breakdown voltage, other-wise known as dielectric strength, specific dielectric strength[9].



**Fig.(1). Chemical Structure of PET.**

## **2- Methods:**

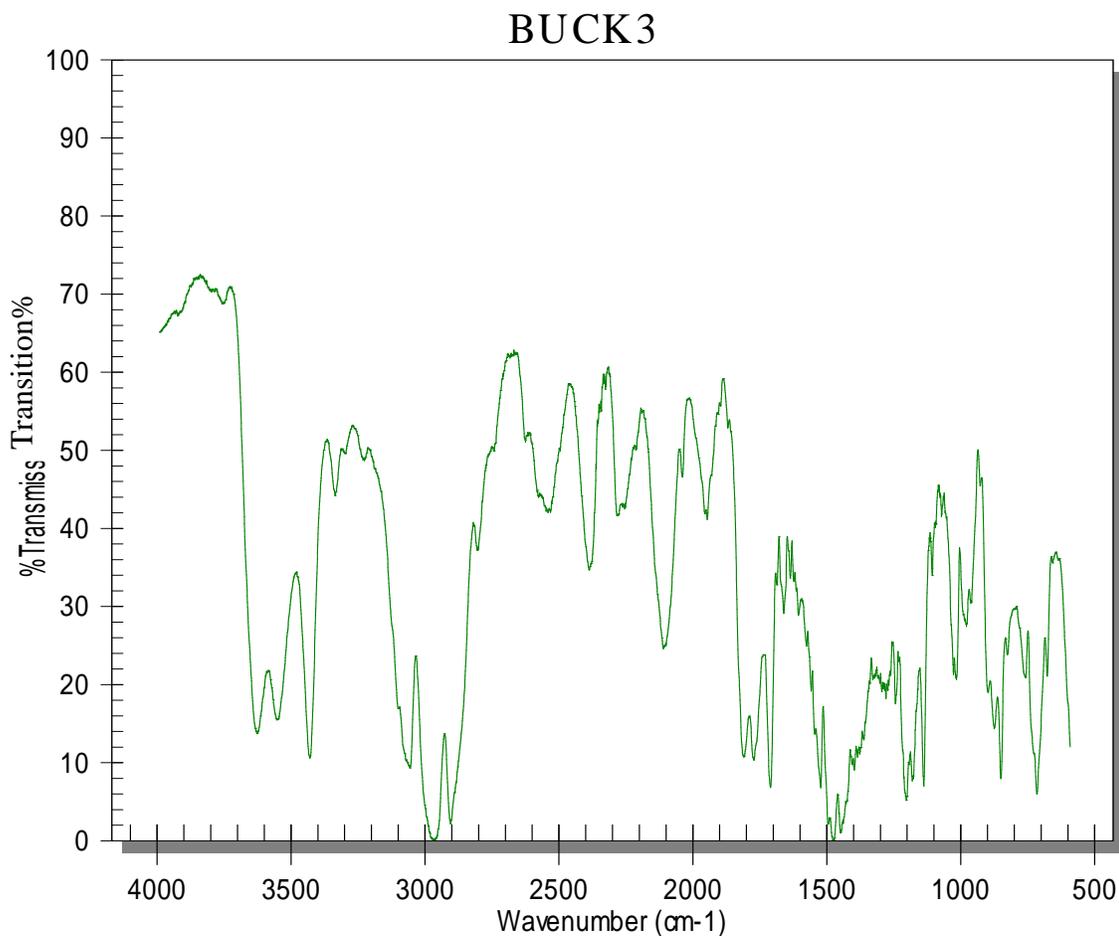
### **2-1- The Preparation of PET:**

Weight 25g of PET flacks from local water drink bottles by using electric sensitive balance sort Sartorius made in Germany, which have been put in Tri-neck flask round 500 ml in capacity, which is fixed by stand on a heater and drop 25% NaOH, Klaus Englert (EMC, Laboratory Germany) solution of PH14 on the amount 25 gm. of PET the flacks. A stirrer Gallenkump Cat. No. 56 425 made in England, have inserted into the vertical neck B24 (24 mm.in diameter), a thermometer have inserted in the side neck B19 (19 mm. in diameter) and a condenser have inserted in the other side neck B19 (19 mm. in diameter), which was connected to a path of cold water with pump gw 220 v 50 HZ and 0.6A to, to ensure efficient condensation. Electric heater (The Numeral controls Electric Heated) have been used, the system was run at 100-130°C of the heater for six hours, until complete reaction of PET flacks with NaOH was occurred and precipitate at the the flask round bottom, and filtered at 100°C by using Whitman filter paper chart 10.0 cm. made in England by W&R BALSTON LIMITED. While the solution was collected into flask, left the precipitate over night to be dried and have etched into Petri dish. The precipetate white powder have emplaced again into the flask round, this is reacted with 25 mil. of ethylene glycol (Gainland Chemical Company, U.K.) and 0.3 parts of zinc chloride (Merck, Darmstadt, Germany)[10] and reflexes for 6 hours and filtered at 100°C by using Whitman filter paper chart 10.0 cm. Left the precipitate to be dried over night, which is a white paste like substance of PET with PH10 by the detection with indicator paper Mecherey-Nagel, Germany, while the solution was collected into flask, and the prepared PET was collected into plastic container.

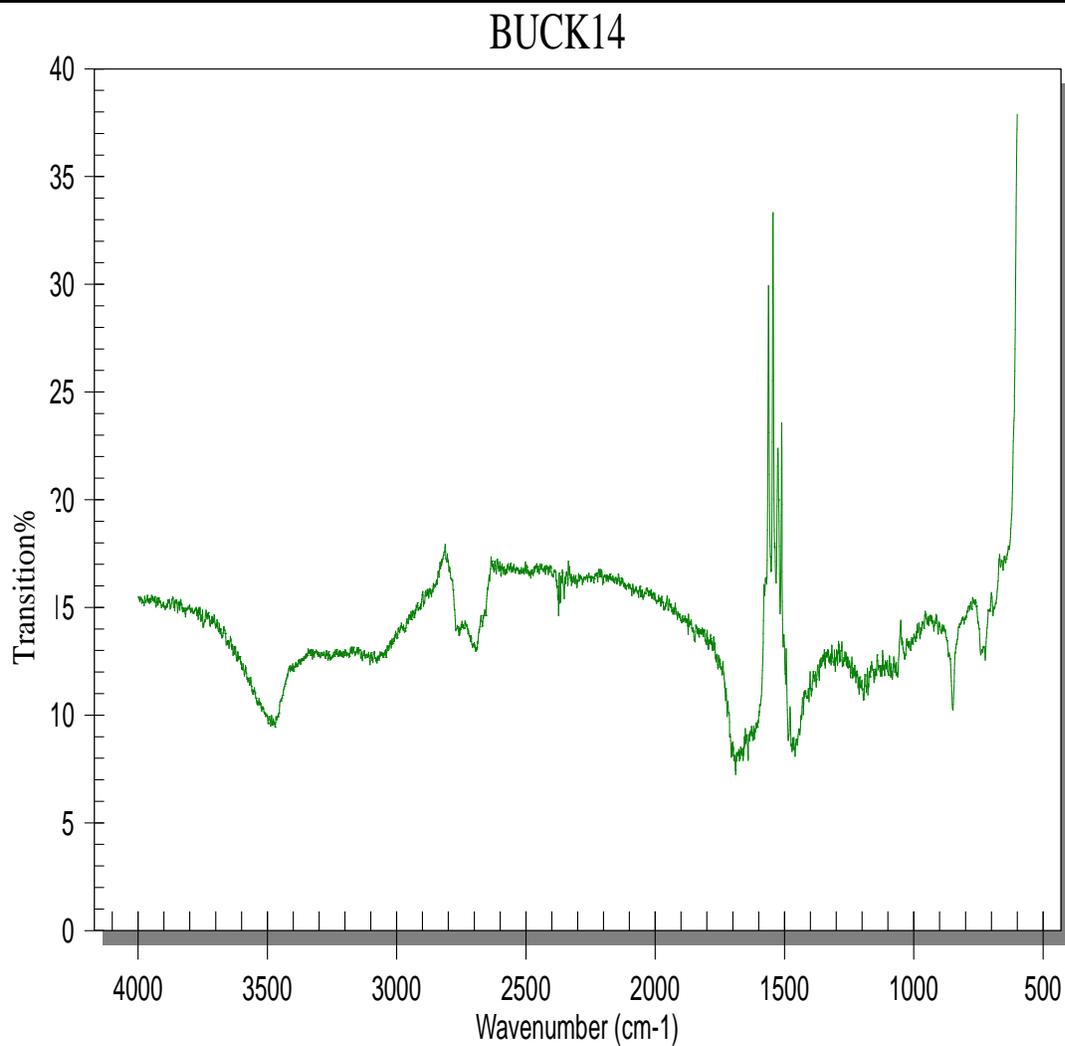
### **2-2- The Diagnosis of PET:**

PET flake and the prepared PET were examined by IR spectrophotometer, Type Buck scientific, Model 500 U.K. The PET bottles flake give an explanation that most of the ester groups encountered in polymers give rise to characteristics bands at 1150-1200  $\text{cm}^{-1}$ . as shown in Fig.(2). This is also a typical example, with particularly strong peak at 1050-1060  $\text{cm}^{-1}$  these are specific for terephthalate group. Coupled with band at 730  $\text{cm}^{-1}$  this lead to the clear identification of polyethylene terephthalate such as (terylene)[11]. It should be noted that 730  $\text{cm}^{-1}$  is an a typical frequency for  $\rho$ -distributed aromatic and this is a consequence of the interaction between polar ester group and benzene ring. It is easy to distinguish between terylene and other commonly encountered material of this type, poly-bis-1,4-hydroxymethyle terephthalate, by inspection of the region 900 to 1000  $\text{cm}^{-1}$ . The spectrum of terylene is sensitive to the degree of crystalline of the sample and this factor, if there is interaction between adjacent chains in order crystalline regions of polymers there may be some changes in vibration modes and a new bands may appear in the infrared spectra. The carboxylic acid can be indicated at 1700-1725  $\text{cm}^{-1}$  and end group content was evaluated at the absorbencies 3440 and 824  $\text{cm}^{-1}$ [12] The Chemical structure of PET is shown in Fig.(1). In Fig.(3). The IR spectroscopy of the prepared PET powder with NaOH only was examined with KBr, the functional group (carbonyl group) in which the second of these peaks is the C=O stretching mode of a carbonyl compound and it is precise position at 1680  $\text{cm}^{-1}$  suggest a saturated ester. The success of infrared (IR) spectroscopy in the characterization of organic compounds is the results of the almost general validity and applicability of concept group frequencies, such as carbonyl group. Aromatic

absorption occurs at  $1600\text{ cm}^{-1}$ . Conformation is also occurs with PET by Infrared spectroscopy both trans and gauche conformation and to the O-H end group of the molecules, a method is proposed that can discriminate otherwise similar the PET fibers. The absorbencies at  $1200$  and  $860\text{ cm}^{-1}$  relative, respectively, to the gauche and trans conformers. [11]. The carboxylic acid can be indicated at  $1700\text{-}1725\text{ cm}^{-1}$  and end group content was evaluated at the absorbencies  $3440$  and  $824\text{ cm}^{-1}$ . [13] as in Fig.(3).



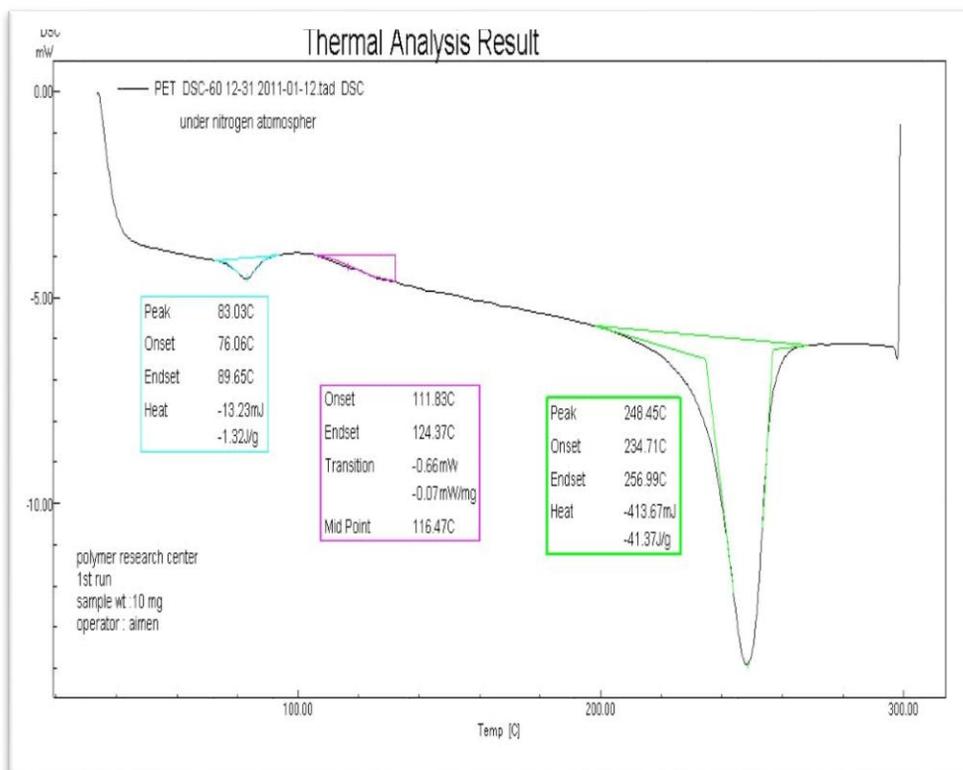
**Fig.(2). IR Spectroscopy of PET Flake.**



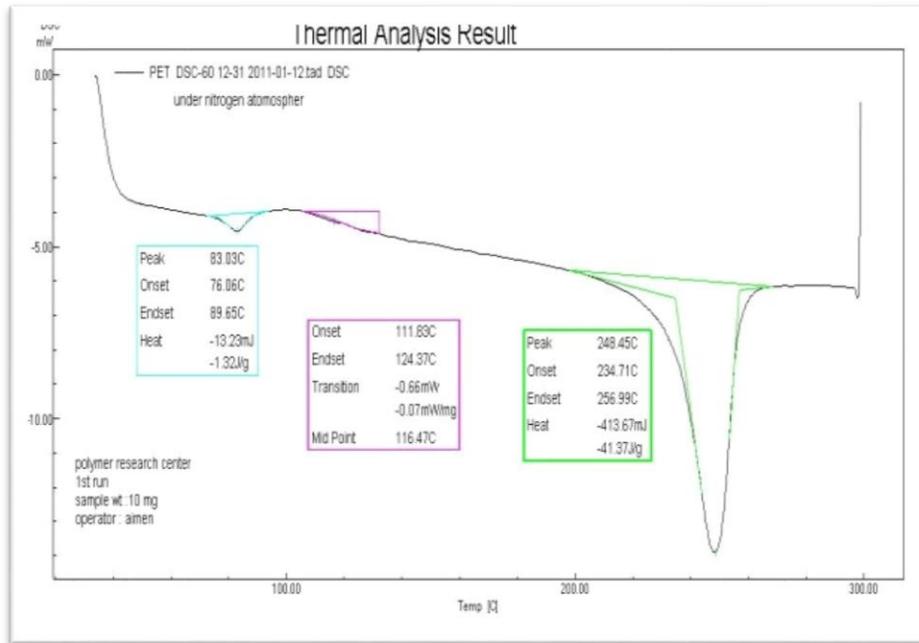
**Fig. 3 The IR spectroscopy of prepared poly ethylene terephthalate**

**2-3- The DSC measurements’:**

Differential scanning calorimeter, by using DSC-60 sort DELL, Type SHIMADZU No. C30454801026 SA. The heat rate is 20°C/min. the endothermic process in Fig.(4). For PET flake, T<sub>g</sub> on the curve, the linear section below and above T<sub>g</sub> are colored red is equal to 116.47°C, the heat flow is -0.66 mW (-0.07 Mw/mg) and T<sub>m</sub> is 284.45°C, the heat capacity is -413.67 mJ (-41.37 J/g) The T<sub>m</sub> in the endothermic process of Fig.(5), for prepared PET in the reaction with NaOH only (dry powder) was 116.36 °C, which is the same as T<sub>g</sub> in Fig.(6), the heat capacity is -1.30 J (130.4KJ). [14].



**Fig.(4). DSC measurements of PET Flake.**



**Fig. (5) DSC of prepared PET powder reaction with NaOH**

Strip films have been prepared of PET with carbon (available in local market) [15]. Weights of PET paste and carbon have been measured by electric sensitive balance Sartorius made in Germany, on clean glass substrate were cleaned by ethanol for 5 minutes and rinse with water then dried by oven sort (SIMFER) (trade mark) at 80 °C for one hour, to be ready for preparing the bulk films. PET and carbon were mixed and put on the cleaned substrate as strip bulk films as indicating in Table-1-. And left over night to be dried after connected to the electric circuit as in Fig.(6), these were hold in box to prevent any effect from the environment, a Venire, Type Caliper Certificate, is used for measurements the thickness of the bulk films after the electrical measurements were completed. The electric resistivity can be calculated using the equation[16]:

$$\rho = \frac{V \cdot A}{I \cdot \tau} \text{----- (1)}$$

where V is the voltage crossed the film, I is the current pass through the film, A is the area of the electrode, was measured by micrometer Type STRRETT.Co.LTD. and  $\tau$  is the thickness of the film. The electrical conductivity  $\sigma$  can be measured from the above equation:

$$\sigma = \frac{1}{\rho} = \frac{\tau}{RA} \text{----- (2)}$$

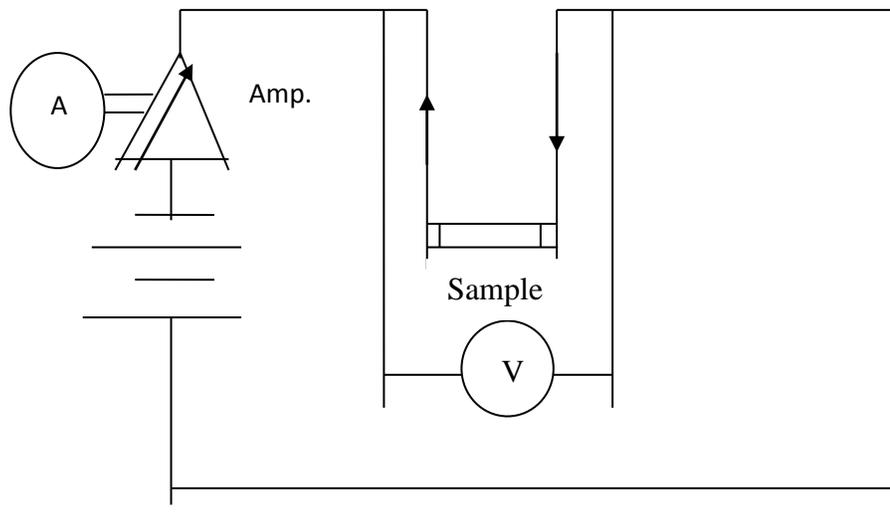
Where  $\tau$  is the thickness of the film, A is the area of the electrode =  $\pi D^2/4$ [17]. and R is the resistance of the film.

Schematic diagram of the circuit in Fig (5). is used to measure the electrical properties of the films as indicating in table-1-, which consists of power supply sort LEYBOLD - HERAEUS, Amplifier sort Phywe made in Germany, ammeter for low current measurements, sort Phywe, made in Germany and ASWAR trade mark digital AVΩ meter ,is used as voltmeter, The activation energy was calculated using equation[18]:

$$\sigma = \sigma_0 \exp - \frac{E}{KT} \text{----- (3).}$$

where  $\sigma_0$  pre-exponential factor, E is the activation energy of the film and k is the Boltzmann's constant is equal to  $1.380 \times 10^{-23} \text{J/}^\circ\text{k}$ .

The specimen is put in open round . under high vacuum by using high vacuum pump Edwards made in U.K. and left to the next day to be dried, which is evacuated again for 30 minutes, Isomental Volin heater Europe Union was used for heating PET0.02C0.002 composite a thermometer is used to measure the temperture which is put in the middle neck of the round and the other two necks where tightly closed to prevent air into the round, the same circuit in Fig.(6) is used in measuring the electrical properties. The data was listed in Table-2-. The current and the voltage cross different films were measured, from which the effect was skeched before breakdown voltage. The calculated electrical resistivity and the electrical conductivity as in Table 3.



**Fig.(6). Schematic Diagram of the Electric Measurements.**

**Table-1-Labeling of films composites.**

Label	Composite constituents	thickness cm	Electrod area(A)cm <sup>2</sup>
PET0.02C0.002	0.02PET+10% wtC	0.09	3.846x10 <sup>-5</sup>
PET0.03C0.0015	0.03PETG50% wtC	0.09	3.846x10 <sup>-5</sup>
PET0.1C0.001	0.1PET+1% wtC	0.09	3.846x10 <sup>-5</sup>
PET0.1C0.005	0.1PET+5% wtC	0.093	3.846x10 <sup>-5</sup>
PET0.05C0.0025	0.05PET+5% wtC	0.09	3.846x10 <sup>-5</sup>
PET0.02C0.002	0.02PET+10% wtC	0.02	3.846x10 <sup>-5</sup>

**Table 2 I-V Characteristics of Film Composites.**

<b>PET0.02 C0.002</b>		<b>PET0.03 C0.0015</b>		<b>PET0.1 C0.001</b>		<b>PET0.1 C0.005</b>		<b>PET0.05 C0.0025</b>	
Vmv	InA	Vmv	InA	Vmv	InA	Vmv	InA	Vmv	InA
0.8	0.02	0.3	1	160	0.6	26.8	0.4	1.5	0.2
0.668	0.2	66.8	0.4	123.9	1.8	38.7	0.22	28	0.35
0439	0.8	64.8	0.07	107.1	6	16.5	10	23.3	0.6
260.2	4	55.1	0.08	104.1	8.6	12.7	12	18.6	1.3
144.7	10	38.7	0.22	79.2	9.6	29.9	21.5	13.5	9
115	100	34.4	0.23	44.9	10.2	37.5	155	9.4	52
113.2	120	28.5	0.5	27	207	3.8	152.5	8.9	200
73.3	126	12.5	10	27.3	303	38.4	752	9	570
66.8	130	2	10.8	20	330.7	38.9	1425	8.6	1500
62.1	135	8.6	12	14.4	470.9	39	2252	8.5	1600
36.2	400	39.4	1500	17.2	450	39	50000	8.3	1900

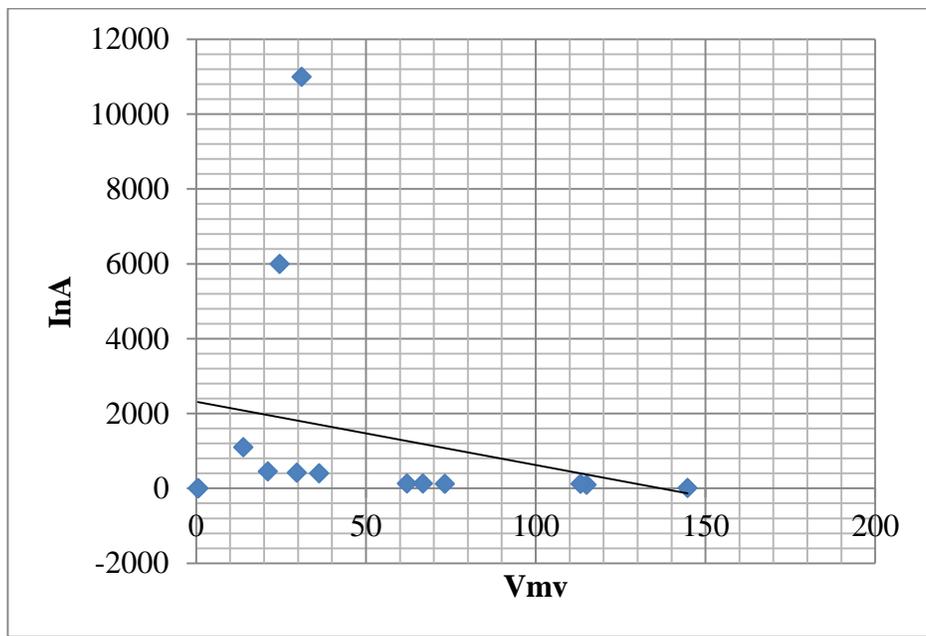
29.7	420	39.4	3500	12	560.9	118	50000	8	5600		
17.6	1100	58.7	5000	12.8	710	37.6	55000	7.6	29800		
21.1	450	39.4	4400	8.8	1610	34.7	75000	7.6	27800		
24.6	6000	34.4	4600	8.2	2110	34.2	125000	7.4	29800		
31.1	11000	34.4	4800	9.4	24610	9.6	51000	7.3	30000		
PET0.02 C0.002											
Vmv	2.2	2.41	0.9	0.8	0.3	0.5	0.4	1.1	0.6	0.7	0.9
InA	0.05	0.07	0.05	0.08	0.5	2	4	50	12	100	110
Vmv	6.6	2.7	0.7	1.3	0.3						
InA	120	40	100	400	300						

**Table3 The Electric Resistivity and Electrical Conductivity of the Composite Films.**

<b>PET0.02 C0.002</b>			<b>PET0.03 C0.0015</b>			<b>PET0.1 C0.001</b>		
RΩ	ρΩcm	σScm <sup>-1</sup>	RΩ	ρΩcm	σScm <sup>-1</sup>	RΩ	ρΩcm	σScm <sup>-1</sup>
4x10 <sup>7</sup>	1.7x10 <sup>3</sup>	5.84x10 <sup>-4</sup>	3x10 <sup>7</sup>	2.8x10 <sup>6</sup>	3.4x10 <sup>-7</sup>	26x10 <sup>7</sup>	1.1x10 <sup>6</sup>	8.7x10 <sup>-7</sup>
3.34x10 <sup>6</sup>	1.4x10 <sup>3</sup>	7x10 <sup>-4</sup>	16.7x10 <sup>7</sup>	7.1x10 <sup>6</sup>	1.4x10 <sup>-7</sup>	6.8x10 <sup>7</sup>	2.9x10 <sup>4</sup>	3.4x10 <sup>-5</sup>
5.48x10 <sup>5</sup>	2.3x10 <sup>2</sup>	4.26x10 <sup>-3</sup>	92.4x10 <sup>7</sup>	3.9x10 <sup>6</sup>	2.5x10 <sup>-7</sup>	1.7x10 <sup>7</sup>	7.6x10 <sup>3</sup>	1.3x10 <sup>-4</sup>
65x10 <sup>6</sup>	2.7x10 <sup>5</sup>	3.59x10 <sup>-6</sup>	68.8x10 <sup>7</sup>	2.9x10 <sup>5</sup>	3.3x10 <sup>-6</sup>	1.2x10 <sup>7</sup>	5.1x10 <sup>3</sup>	1.9x10 <sup>-4</sup>
14.47x10 <sup>6</sup>	6.1x10 <sup>4</sup>	1.61x10 <sup>-5</sup>	17.5x10 <sup>7</sup>	7.5x10 <sup>4</sup>	1.3x10 <sup>-5</sup>	8.2x10 <sup>6</sup>	3.5x10 <sup>3</sup>	2.8x10 <sup>-4</sup>
1.15x10 <sup>6</sup>	4.9x10 <sup>3</sup>	2.03x10 <sup>-4</sup>	14.9x10 <sup>7</sup>	6.3x10 <sup>4</sup>	1.5x10 <sup>-5</sup>	4.4x10 <sup>6</sup>	1.8x10 <sup>3</sup>	5.3x10 <sup>-4</sup>
0.94x10 <sup>6</sup>	4x10 <sup>3</sup>	2.48x10 <sup>-4</sup>	57x10 <sup>6</sup>	2.4x10 <sup>4</sup>	4.1x10 <sup>-5</sup>	1.3x10 <sup>5</sup>	55.695	1.7x10 <sup>-2</sup>

0.61x10 <sup>6</sup>	2.6x10 <sup>3</sup>	3.83x10 <sup>-4</sup>	1.25x10 <sup>6</sup>	5.3x10 <sup>2</sup>	1.87x10 <sup>-3</sup>	9x10 <sup>4</sup>	38.5	2.59x10 <sup>-2</sup>
0.507x10 <sup>6</sup>	2.1x10 <sup>3</sup>	4.61x10 <sup>-4</sup>	1.85x10 <sup>5</sup>	79.145	1.26x10 <sup>-2</sup>	6.0x10 <sup>4</sup>	25.824	3.8x10 <sup>-2</sup>
0.46x10 <sup>6</sup>	1.9x10 <sup>3</sup>	5.09x10 <sup>-4</sup>	7.16x10 <sup>5</sup>	3x10 <sup>2</sup>	3.26x10 <sup>-3</sup>	3x10 <sup>4</sup>	13.069	7.6x10 <sup>-2</sup>
0.23x10 <sup>6</sup>	9.8x10 <sup>2</sup>	1.01x1 <sup>-3</sup>	2.6x10 <sup>4</sup>	11.226	8.9x10 <sup>-2</sup>	3.8x10 <sup>4</sup>	16.32	6.1x10 <sup>-2</sup>
0.1x10 <sup>6</sup>	4.2x10 <sup>2</sup>	2.33x10 <sup>-3</sup>	72.4x10 <sup>7</sup>	3x10 <sup>5</sup>	3.2x10 <sup>-6</sup>	2.2x10 <sup>4</sup>	9.779	0.102
16x10 <sup>3</sup>	6.83	1.46x10 <sup>-1</sup>	11.7x10 <sup>3</sup>	5.017	0.199	2.1x10 <sup>4</sup>	9.143	0.109
46x10 <sup>3</sup>	20	0.5x10 <sup>-1</sup>	8.95x10 <sup>3</sup>	3.827	0.261	1.8x10 <sup>4</sup>	7.698	0.129
41x10 <sup>2</sup>	1.752	0.57	7.4x10 <sup>3</sup>	3.196	0.312	3.8x10 <sup>3</sup>	1.659	0.602
28x10 <sup>2</sup>	1.208	0.827	7.1x10 <sup>3</sup>	3.042	0.328	4.3x10 <sup>2</sup>	0.185	5.381
PET0.1C0 .005			PET0.05 C0.0025			PET0.0 2C.002		
RΩ	ρΩcm	σScm <sup>-1</sup>	RΩ	ρΩcm	σScm <sup>-1</sup>	RΩ	ρΩcm	σScm <sup>-1</sup>
6.7x10 <sup>7</sup>	2.8x10 <sup>4</sup>	3.5x10 <sup>-5</sup>	7.5x10 <sup>6</sup>	3.2x10 <sup>3</sup>	3.1x10 <sup>-4</sup>	44x10 <sup>6</sup>	1.8x10 <sup>4</sup>	5.31x10 <sup>-5</sup>
17.3x10 <sup>7</sup>	7.4x10 <sup>4</sup>	1.3x10 <sup>-6</sup>	80x10 <sup>6</sup>	3.4x10 <sup>4</sup>	2.9x10 <sup>-5</sup>	34x10 <sup>6</sup>	1.4x10 <sup>4</sup>	6.7x10 <sup>-5</sup>
1.65x10 <sup>6</sup>	7x10 <sup>2</sup>	1.41x10 <sup>-3</sup>	38.8x10 <sup>6</sup>	1.6x10 <sup>4</sup>	6.02x10 <sup>-5</sup>	18x10 <sup>6</sup>	7.6x10 <sup>3</sup>	1.2x10 <sup>-4</sup>
1.05x10 <sup>6</sup>	4.5x10 <sup>2</sup>	2.21x10 <sup>-3</sup>	14.3x10 <sup>6</sup>	6.1x10 <sup>3</sup>	1.63x10 <sup>-4</sup>	10x10 <sup>6</sup>	4.2x10 <sup>3</sup>	2.3x10 <sup>-4</sup>
1.39x10 <sup>6</sup>	5.9x10 <sup>2</sup>	1.62x10 <sup>-3</sup>	1.5x10 <sup>6</sup>	6.4x10 <sup>2</sup>	1.55x10 <sup>-3</sup>	6x10 <sup>5</sup>	2.5x10 <sup>2</sup>	3.8x10 <sup>-3</sup>
2.41x10 <sup>5</sup>	1x10 <sup>2</sup>	9.67x10 <sup>-3</sup>	1.8x10 <sup>5</sup>	77.258	1.2x10 <sup>-2</sup>	2.5x10 <sup>5</sup>	1x10 <sup>2</sup>	9.3x10 <sup>-3</sup>
2.49x10 <sup>4</sup>	10.649	9.38x10 <sup>-2</sup>	4.4x10 <sup>4</sup>	15.557	0.064	1x10 <sup>5</sup>	4.2.738	2.3x10 <sup>-2</sup>
5.1x10 <sup>4</sup>	21.824	4.58x10 <sup>-2</sup>	1.5x10 <sup>4</sup>	6.748	0.148	5x10 <sup>4</sup>	21.369	4.6x10 <sup>-2</sup>
2.7x10 <sup>4</sup>	11.666	8.57x10 <sup>-2</sup>	5.7x10 <sup>3</sup>	2.004	0.498	2.2x10 <sup>4</sup>	9.402	0.106
1.73x10 <sup>4</sup>	7.4	0.351	5.3x10 <sup>3</sup>	2.27	0.440	7x10 <sup>3</sup>	2.991	0.334
7.8x10 <sup>2</sup>	0.333	2.999	4.3x10 <sup>3</sup>	1.867	0.535	8.1x10 <sup>3</sup>	3.496	0.285
2.36x10 <sup>3</sup>	1.008	0.991	1.4x10 <sup>3</sup>	0.61	1.637	5.5x10 <sup>4</sup>	23.506	4.25x10 <sup>-2</sup>
6.83x10 <sup>2</sup>	0.292	3.422	2.5x10 <sup>2</sup>	0.108	9.174	6.7x10 <sup>4</sup>	28.848	3.4x10 <sup>-2</sup>
4.62x10 <sup>2</sup>	0.197	5.057	2.7x10 <sup>2</sup>	0.116	8.558	3.2x10 <sup>3</sup>	1.389	0.719

$2.7 \times 10^2$	0.116	8.551	$2.48 \times 10^2$	0.106	9.422	$8 \times 10^3$	1.573	0.635			
$1.88 \times 10^2$	0.077	12.846	$2.43 \times 10^2$	0.103	9.615	$1 \times 10^3$	0.427	2.339			
PET 0.02 C0.002											
$\text{Ln}\sigma$	-9.114	-9.584	-8.948	-8.360	-5.480	-4.671	-3.7	-3	-2.24	-1	-1.2
$10^3/T \text{ } ^\circ\text{K}^{-1}$	3.424	3.412	3.4	3.246	2.832	2.801	2.68	2.68	2.67	2.67	2.668
$\text{Ln}\sigma$	-3.15	-3.35	-0.31	-1.22	1.6						
$10^3/T \text{ } ^\circ\text{K}^{-1}$	2.668	2.665	2.638	2.638	2.5						



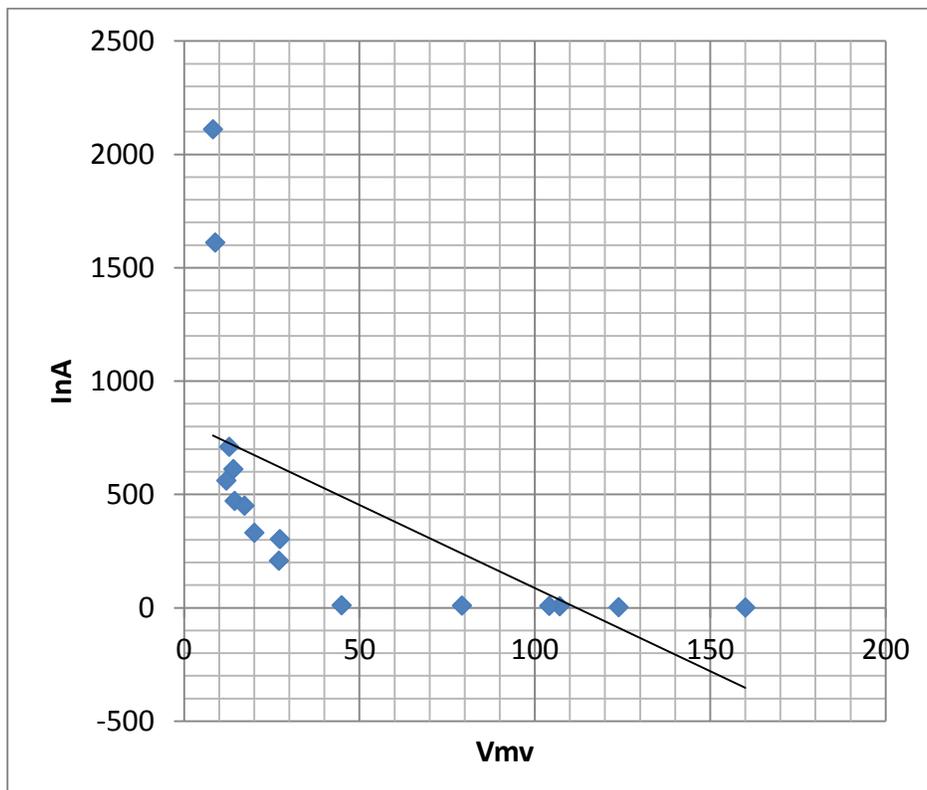
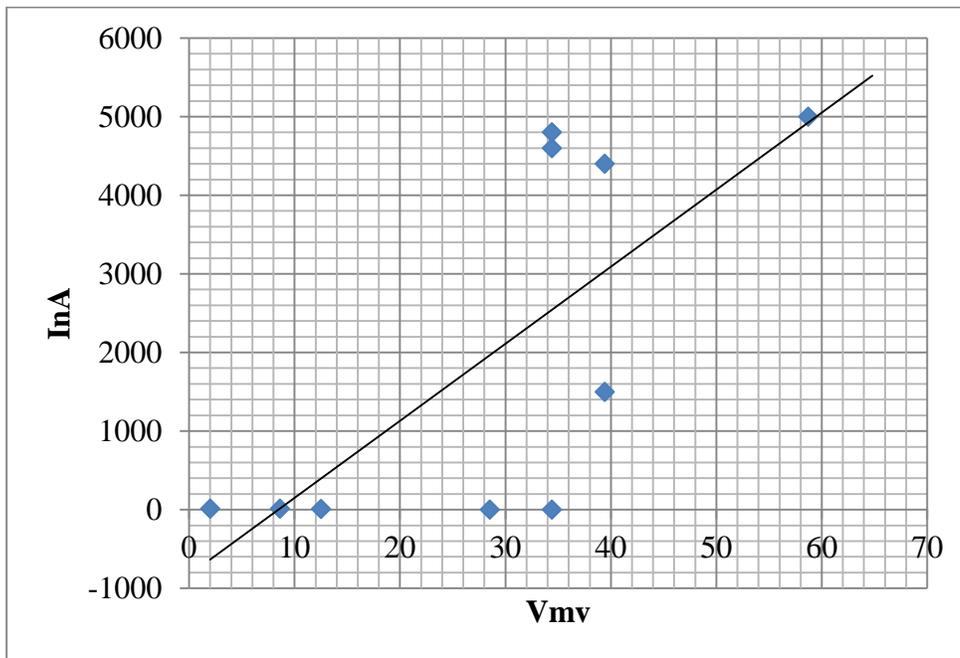
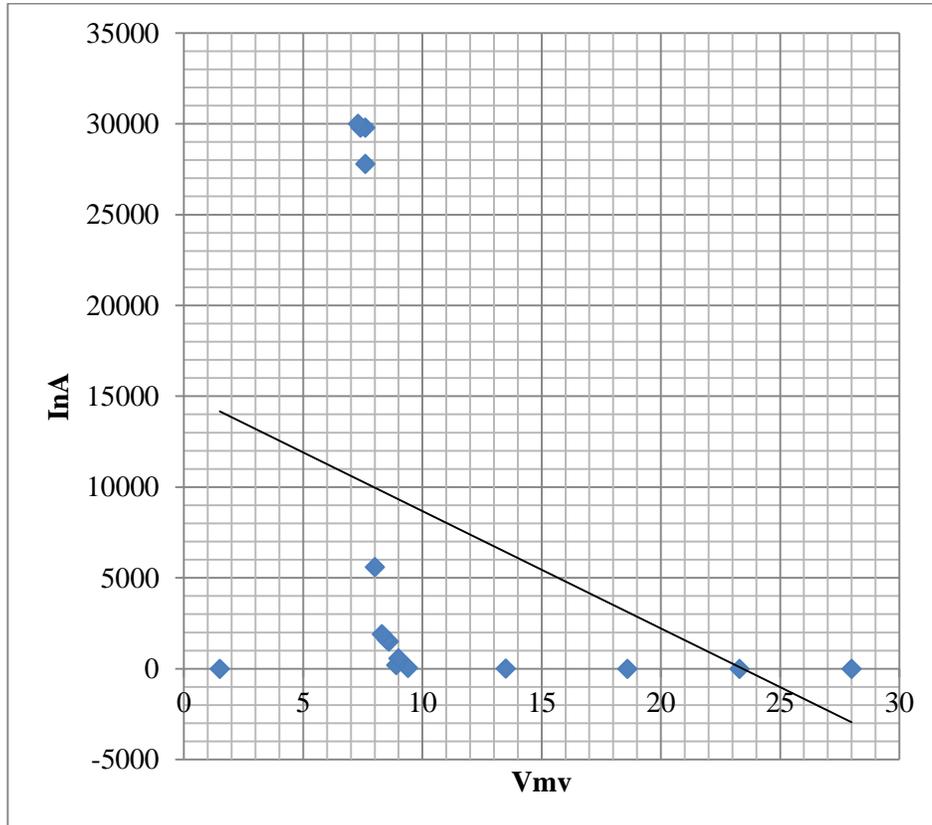
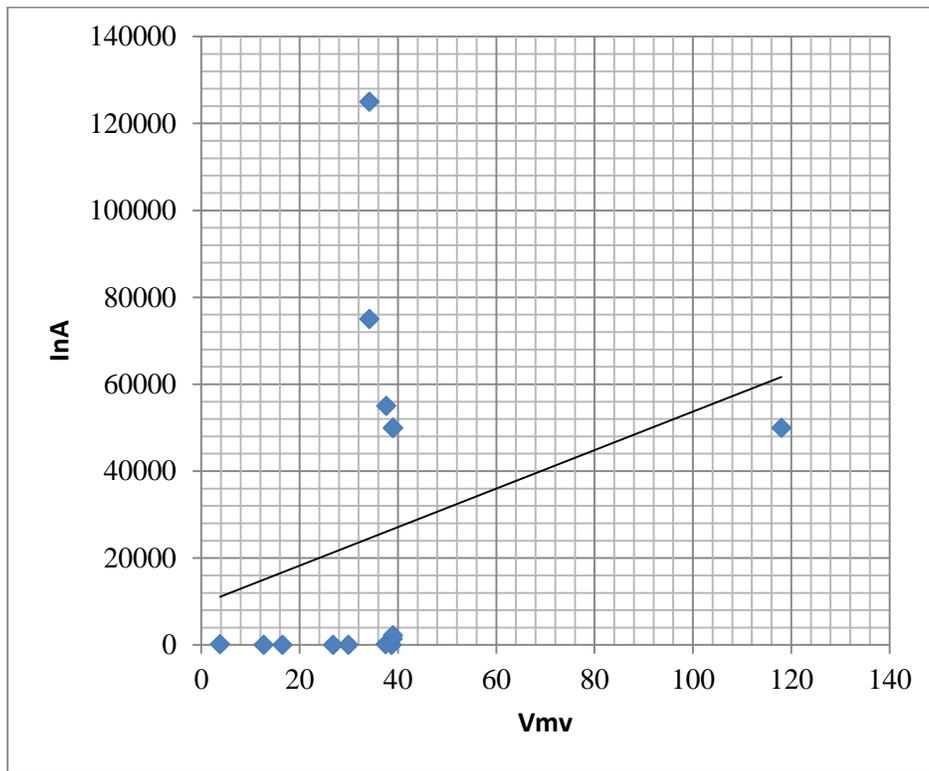
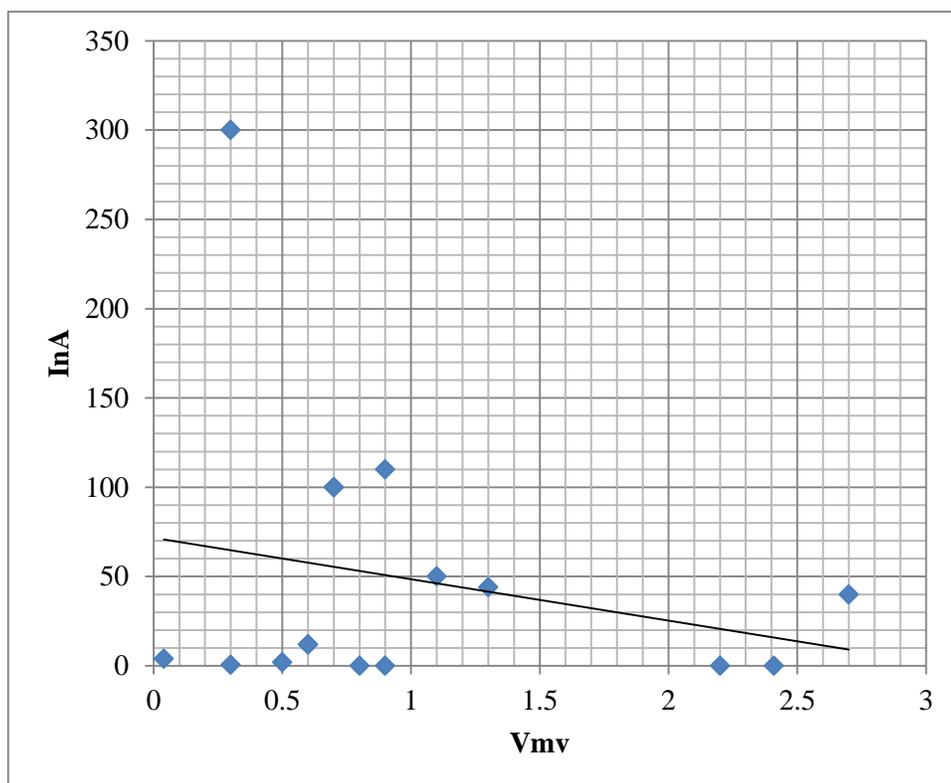
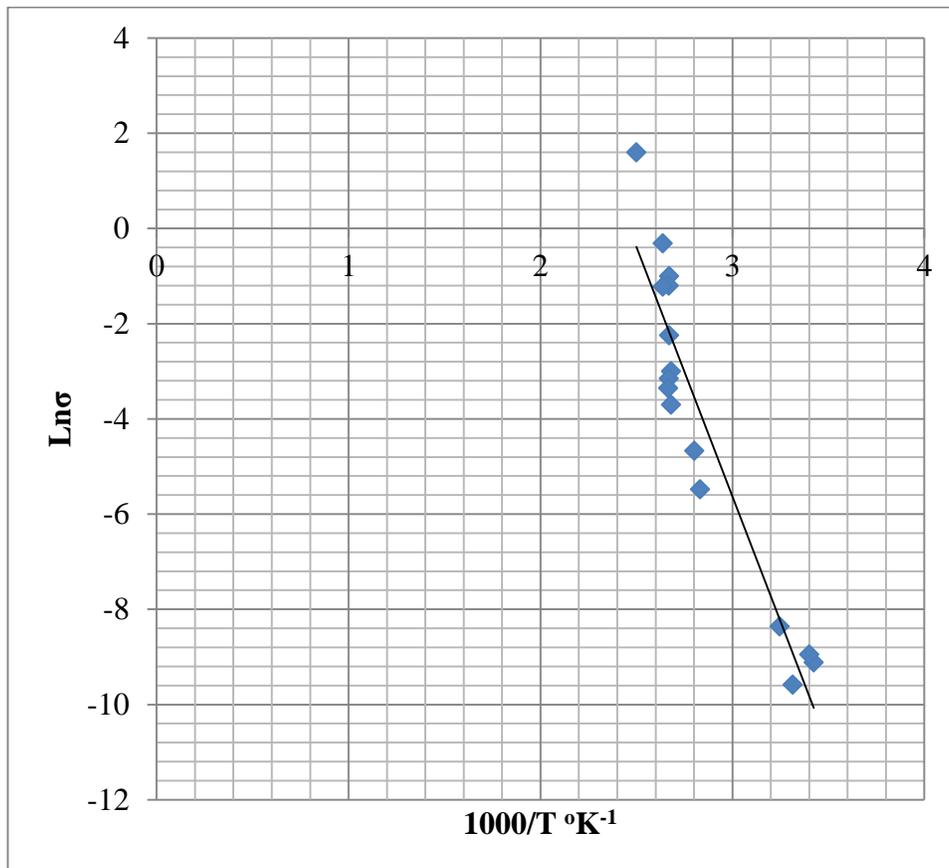


Fig.(9). I-V characteristics of PET0.1C0.001.







**Fig.(13). Arrhenius Plot of PET0.02C0.002.**

### 3- Results and Discussions:

Figures (6, 7, 8, 9, 10 and 11) shows the I-V characteristics curves of six composites, PET0.02GC.002, PET0.03C0.0015, PET0.01C0.001, PET0.1C0.005, PET0.05C0.0025, and under vacuum PET0.02C0.002. The shapes of plots obtained from Table-2- the I-V characteristics depends on applied field the linearity of the graph obtained in which some of the points were shifted from the straight line for the bulk sample of PET0.02C0.002 wt% in time of measurements 100 min. as shown in Fig.(7). because of the instability of low current passes through the sample. For PET0.03C0.0015 As C increased to 5wt% of PET, the linearity of the graph was rather instable but shows points become more close to the straight line obtained between the current and voltage and is covered by Ohm Law[19] as shown in Fig.(8). For PET0.01C0.001 with C 1wt% of PET the current passes through the sample shows there is no decrease in stability in the composite[20], at the beginning of the measurements and the current increased with time after 67 min., as in shown Fig.(9). The current passes through the sample become rather instable for PET0.1C0.005 as C5wt% of PET and increased with time of measurements 80 min. in the range indicated from which a straight line was obtained, the

experiment controlled by the source measurement unit allowing the measurement of the currents in nA to  $\mu\text{A}$  range[19] as shown in Fig.(10).

For PET0.05C0.0025 increased current with time of measurements 70 min. and thickness of the bulk film was 0.09 cm. gave a significant dependant of linear graph obtained on film thickness as shown in Fig.(11). Electric measurements of polymeric composites, these materials are typically disordered structures consisting randomly arranged filler dispersed in polymer medium[20].

For PET0.02C0.002 under vacuum measurement, I-V characteristics give significant dependant of the composite on the temperature, and the current increased to 300 nA at 106 min. as shown in Fig.(12)

From Table 3: For PET0.02C0.002 using equation 1 the electric resistivity decrease from  $1.8 \times 10^3 \Omega \cdot \text{cm}$  -  $1.208 \Omega \cdot \text{cm}$ . and by applying equation 2 the electric conductivity increase from  $5.8 \times 10^{-4} \text{ S} \cdot \text{cm}^{-1}$  -  $0.827 \text{ S} \cdot \text{cm}^{-1}$ , respectively, the electric conductivity increase by three orders of magnitude, at applied voltage (12.9-0.4) volts and the voltage across the film are (267-38) mv. In time interval 100 minutes.

For PET0.03C0.0015, the amount of mixing PET increase by 15% and C decrease to 75wt% with respect to the first column, the electric resistivity decreases from  $2.8 \times 10^6 \Omega \cdot \text{cm}$  to  $3.042 \Omega \cdot \text{cm}$ . at applied voltage (142-0) volts d.c. and the voltage across the film is (66.8-34.2) mv. The electrical conductivity increase from  $3.4 \times 10^{-7} \text{ S} \cdot \text{cm}^{-1}$  -  $0.328 \text{ S} \cdot \text{cm}^{-1}$ , by six orders of magnitude as at time interval 73 minutes. The atoms in insulating materials have very tightly- bound electrons, resisting free electron flow very well. However, insulators cannot resist indefinite amount of voltage. With enough voltage applied, any insulating material will eventually succumb to electric “pressure” and electrons flow will occur. However, unlike the situation with conductors where current is a linear proportion to applied voltage (given a fixed resistance), current through an insulator is quite nonlinear; for voltage below a certain threshold level, virtually no electrons will flow, but if the voltage exceed that threshold, there will be a rash of current. Once current is forced through an insulating material, breakdown of that material’s molecular structure has occurred. After break down, the material may or may not behave as an insulator any more, the molecular structure have been altered by breach. There is usually a localized “puncture” of the insulator medium where the electrons flowed during breakdown. Thickness of an insulator material plays a role in determining its breakdown voltage, otherwise known as dielectric strength-specific dielectric strength [9].

PET0.1C0.001, the resistivity increases from  $1.1 \times 10^6 \Omega \cdot \text{cm}$ . to  $0.185 \Omega \cdot \text{cm}$ . and the electrical conductivity increases from  $8.7 \times 10^{-7} \text{ S} \cdot \text{cm}^{-1}$  to  $5.81 \text{ S} \cdot \text{cm}^{-1}$ , by six orders of magnitude. The measured voltage across the film is (160-9.4) mv. at time interval 67 minutes. the applied voltage is (166-0.4) volts d.c.

PE 0.1C0.005, there is decrease in the electrical resistivity from  $2.8 \times 10^4 \Omega \cdot \text{cm}$  to  $0.077 \Omega \cdot \text{cm}$ . and the electric conductivity is  $3.5 \times 10^{-5} \text{ S} \cdot \text{cm}^{-1}$  increases to  $12.846 \text{ S} \cdot \text{cm}^{-1}$ , by six order of magnitude the applied voltage is (142-0) volts and time interval 80 minutes. Because the electrical insulating quality inherent in most polymers has long been exploited to constrain and to

sustain and protect currents flowing along chosen paths in conductors and to sustain high electric fields with-out breakdown[21].

For PE 0.005C0.0025, by weight, obviously the percentage is decreased for PET by 25% wt and C by 125% as in the first column. The electrical resistivity decreases from  $3.2 \times 10^3 \Omega \cdot \text{cm}$ . to  $0.103 \Omega \cdot \text{cm}$ . and the electrical conductivity increases by five orders of magnitude from  $3.1 \times 10^{-4} \text{ S} \cdot \text{cm}^{-1}$ . to  $2.319 \text{ S} \cdot \text{cm}^{-1}$  the voltrage across the film is (390-7.1) mv. at time 70 minutes.

The development of composite solid film of PET and G matrix , for use at high voltage requires considerable care with processing technology. In application of high voltage above 300 volts across the film can result in electric spark break down being initiated in pockets of air trapped within the sealed unit, causing localized damage to the polymer film and metallization, and considerable generation of heat[22].

The effect of film process and thickness on quality and quantity of ordering; and the complex of ordered structure of the film is a function of depth, which exhibits a variety of order ranging, both thickness and heating rates during curing, improve amount of order[10].

PET0.02C0.002 , the measurements is carried out under high vacuum. The temperature raised from  $19^\circ\text{C}$  to  $125^\circ\text{C}$ , which were measured by thermometer at applied voltage varied between (18.22 volts to 4.5mv then raised to 257mv), there is decrease in electrical resistivity from  $1.8 \times 10^4 \Omega \cdot \text{cm}$ . to  $0.427 \Omega \cdot \text{cm}$ . the electrical conductivity increases from  $5.31 \times 10^{-5}$  to  $2.339 \text{ S} \cdot \text{cm}^{-1}$ . In time interval 106 minutes.

The temperature acts to increase the electrical conductivity by five orders of magnitude. Thermal treament may result in thermal degradation , but enhance the performance of composite[23]. But the effect of C, according to the first column the behavior of the composite as the voltage across the film varies from 2.2 to 0.3 mv shows definite change in in electrical conductivity.

(PET0.02C0.002 under vacuum), the effect was illustrated before breakdown voltage. Fig.(13) shows the Arrhenius plot of PET0.02C0.002 between  $\text{Ln}\sigma$  and  $1000/T \text{ } ^\circ\text{k}^{-1}$ , using equation 3, the calculated activation energy is  $5.6 \times 10^{-4} \text{ ev}$ . and  $\sigma_0$  is equal to  $6.082 \text{ Scm}^{-1}$ . By extrapolation method of Fig.(13) before fitting. Insulators suffer from the phenomena of electrical breakdown when the electric field applied across an insulating substance exceed in any location the threshold breakdown field for that substance, which is proportional to the band gap energy, the insulator suddenly turns into resistor, some time with catastrophic results. During electrical breakdown, any free charge carrier being accelerating by the strong field , electric field will have enough velocity to hit electrons from ionize any atom it strikes. These freed electrons and ions are in turn accelerated and strike other atoms, creating more charge carrier in a chain reaction[24]. For glass transition temperatures indicated in Fig. (4) is the liquid state transition temperature, for short (glass transition) is the reversible transition in amorphous region within semi crystalline materials from a hard and relatively brittle state into a molten or rubber-like state. Amorphous solid that exhibits a glass transition is called a "glass". For PET is  $70^\circ\text{C}$ , the measured value in this investigation is  $92.36^\circ\text{C}$ , for prepared PET, despite the massive change in the physical properties of material through its glass transition, the transition is not itself a phase transition of any kind; rather it is a laboratory phenomena extended over a range of temperature and defined by one of several conventions such conventions include a constant cooling rate

(20°K/min.). above  $T_g$ , a noncrystalline polymer material behaves rubbery, or like viscous fluid depending on the molecular weight and how much the temperature exceeds the glass transition temperature. Below  $T_g$ , a bulk polymer is described as a glass that is more or less brittle (remaining flexibility might be provided by side-chains) depending on the structural complexity and how much it is cooled down. Any influence on the glass transition due to interfacial interactions neglected even for films thinner than bulk radius of gyration. The major reason for such 'free' boundary conditions originates from classical mean-field theories, or molecular dynamic simulations. It is assumed that interfacial interactions are completely screened within a distance corresponding to the persistence length of the polymer. Thus, confinement effects due to the interfacial interactions, such as pinning of molecules at substrate surfaces, are only considered up to 0.6 to 1 nm distance[25].

#### **4- Conclusions:**

The development of composite solid film of PET and C matrix, for use at high voltage requires considerable care with processing technology. In application of high voltage above 100 volts across the film can result in electric spark break down being initiated in pockets of air trapped within the sealed unit, causing localized damage to the polymer film and metallization, and considerable generation of heat. The I-V characteristics effect describes how, in a large electric field, the electron doesn't need as much thermal energy to get into the conduction band (since part of this energy comes from being pulled by the electric field), so it does not need as large a thermal fluctuation and will be able to move more frequently. Carbon can be conducted electricity due to the vast electron delocalization within the carbon layers (a phenomenon called aromaticity). These valence electrons are free to move, so are able to conduct electricity. However, the electricity is only conducted within the plane of the layers, thus it does not conduct in powdered form. The results shows that carbon particles dispersed better in PET matrices where as the conductive percolation threshold of PET wt%C was higher, more over carbon filler reflecting the effectiveness as an annealing agent. A true insulator is a material that does not respond to an electric field and completely resist the flow of electric charge. In practice, however, perfect insulators do not exist. Therefore, dielectric materials with high dielectric constant are considered insulators. In insulating material valence electrons are tightly bonded to their atoms. These materials are used in electrical equipment as insulators or insulations. Their function is to support or separate electrical conductors without allowing current through themselves. The terms also refer to insulating supports that attach electric power transmission wires to utility poles or pylons. Some materials such as glass. Papers and Teflon are good insulators even though they may have lower bulk resistivity.

1-Within a high voltage, electrons can be freed from the atoms of an insulating materials, resulting in current through the material.

2-The minimum voltage required to "violate" an insulators by forcing current through it is called the breakdown voltage, or dielectric strength.

3-The thicker a piece of insulating material, the higher breakdown voltage, another factors being equal.

4-Specific dielectric strength is typically rated in equivalent units, volts per mil. Or kilovolts per inch (2.5 cm).

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تأثير الكربون على الخصائص الكهربائية للبولي أثلين ترفثاليت

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ثامر سلمان بجاري

مركز أبحاث البوليمر- قسم علوم المواد – جامعة الصرة

E-mail: [thamir\\_bachari@yahoo.com](mailto:thamir_bachari@yahoo.com)

الخلاصة:

تم بحث الأغشية البوليمرية المحضرة من البولي أثلين ترفثاليت مع الكربون التي تم دراسة خصائصها الكهربائية أظهرت اعتماد الخصائص الكهربائية على النسب الوزنية لتكوين البوليمر المحضر. أن شرائح الأغشية الحجمية أظهرت خصائص كهربائية مختلفة، التي تعتمد على سمك الغشاء والفولتية المجهزة. مميزات وتشخيص البولي أثلين ترفثاليت باستخدام جهازي مطياف الأشعة تحت الحمراء والمسح الحراري التفاضلي. أن قياس المقاومة والتوصيلية الكهربائية اعتمادا على أساس النسب لمكون الشريحة. مميزات التيار- الفولتية عبر الأغشية التي تم مناقشتها وسجلت عند الفولتية المجهزة 150 فولت مستمر ومناقشة التأثير الحاصل. تم حساب طاقة التنشيط التي تساوي  $5.6 \times 10^{-4}$  إلكترون-فولت عند المكون PET0.02C0.002.

الكلمات المفتاحية: البولي أثلين ترفثاليت، الكربون، طيف الأشعة تحت الحمراء، المسح الحراري التفاضلي، التوصيلية الكهربائية، طاقة التنشيط.