JOURNAL OF KUFA – PHYSICS Vol.1 No.1
A Special Issue for the 2nd Conference of Pure & Applied Sciences (11-12) March 2009

Electrical and optical Properties of Poly(Crystal Violet Terephthalate)(PCVT)

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Abstract:

An analysis was carried out to examine the conduction mechanism in poly crystal violet terephrthalate (PCVT) synthesized by condensation polymerization .Electrical measurement including (current-voltage) characteristics .The effect of temperature on conductivity with range(300-368)K ,also investigated the activation energy (Ea) was estimated from conductivity as a function of reciprocal temperature about 0.47eV.The deviation from Ohm's law has been analyzed in term of hopping available range conduction theories .Hopping conducting mechanism was concluded to be the most probable one interpreting the behavior of charge transport that was supplied by injector electrodes .Optical properties of polymer was also investigated by using thin film of polymer on a glass substrates .The type of transition and energy gap determined depending on data of absorption spectrum of this sample . Indirect allowed band gap can be calculated equal to about 1.56eV and phonon energy assistance in transition about 0.06eV. The value of energy gap indicated that polymer have semiconductive properties.

1. Introduction

Studying the electric properties of polymers have become a great interest in the past few years because these materials have many industrial uses ,especially in electric and electronic applications .A great interest have been explored in the field of conductive and semiconductive polymeric materials due to the fast progress in the molecular electronic application [1-7].

Conducting polymers have practical viewpoints . Conduction in polymer has been extensively with some conflict of interpretation [8].Several studies were carried out on the conduction mechanisms for metal free polymer metal dyes such as CuPc,ZnPc,CoPc and FePc [9-12] . Different methods exist to deposit polymer into a substrate . The most common are spin-coating, electrochemical deposition , dip-coating and drop-coating ,however , deposition method like thermal evaporation ,Langmuir-Blodgett(LB) and self assembly techniques have also been described [13-15].in the present work is to study electrical and optical properties of a new polymer derived from dye.

2. Experimental procedures

Aluminum and glass substrates (76x26mm) were thoroughly cleaned before deposition process by immersing it in cleaning solution for 5hr's then washed several times by distilled water and dried .Thin film was prepared by casting the dilute polymer solution with DMSO solvent on aluminum and glass substrates .Aluminum substrates supported by lower aluminum electrode deposition by evaporation method under low pressure 10^{-6} torr then dried at R.T for 3hr's .Aluminum electrode was evaporated as upper electrode through a circular mask with area 0.03cm^2 to obtain sandwich configuration . Current-voltage characteristics measured with Ammeter model MEGOHMMETER(IM6) at the range (10^{-12}-10^{-4}A) were carried out in dark and electrically shielded box. The films thickness were measured by micrometer model köller with the range (1-1000μm) .Voltmeter model SC-Multi LOGGER IWATSU Electrical Co.LTD., Regulator DC Power supply electronic CORP Japan with the range (0.1-60V)

3. Results and discussion

3.1 Electrical properties

All samples were enclosed in grounded aluminum screen box with temperature controlled system .The sample temperature was measured with a thermocouple placed near the sample .Figure (1) shows the X-Ray Diffraction (XRD) of polymer at different temperature ranges (298,323 and 373K) .PCVT films casted on a glass substrate after 1hr duration. The Figure shows that the polymer has amorphous structure at different temperatures related to anhomogounous of morphological structure . A complete removal of the solvent was impossible in this type of treatment, because of DMSO solvent may remain with in the polymer chains and may form crosslink bridges between the polymer chains. Figure(2) shows plots of current versus applied voltage on a log-log scale at different temperature range (300-368)K .At low field region (0.1-1)V the current shows Ohmic behaviour ,indicating that thermally generated charge carriers are effected by the current limits [16] . The bulk conductivity of PCVT film in the Ohmic region was measured at R.T and found to be equal to about $3.15x10^{-7}$ S/cm .The current increases with increasing temperature and applied voltage ,that means PCVT film has a conductivity of positive temperature coefficient, which is identifying the characteristics of semiconductor materials .Figure(3) shows the relationship between conductivity and the reciprocal temperature (10^3/T) where the conductivity was observed to increase about two orders of magnitude with increasing temperature from R.T to 368K with activation energy (Ea) about 0.47eV .The non Ohmic behaviour indicates that the injected electrode carriers are greater than the thermally generated charges, therefore , different conduction mechanism can be occured to explain the charge transfer . The relationship between (10^3/T$^{1/4}$) and (10^3/T$^{1/3}$) and conductivity as shown in Figure(4) and Figure(5) respectively confirms the hopping mechanism process [17] .The theory of variable range hopping has been successfully uses in describing the transport properties in a variety of disordered semiconductors, as well as in conducting polymers ,despite the many approximations and simplifications modes in deriving the equation[18] .In this study ,other possible conduction mechanism such as ionic ,space charge limited current were also tested before excluded from our discussion .The possible existing of Schottky or Poole – Frenkle effect can be investigated from the relationship between current and squire root of electric field (E$^{1/2}$).A non linear behaviour was obtained at high electric field as shown in Figure (6) ,also (current – voltage)characteristics does not obey the general ionic relationship which is applied for ionic conduction as shown in Figure(7) [19].

3.2 Optical absorption measurement

The variation of optical absorptance with wavelength of the sample is shown in Figure(8),the optical data were analyzed from the classical relation for near edge optical absorption in semiconductor [20] :

$$\alpha h\nu = A(h\nu - E_g \pm E_p)^n \qquad \ldots\ldots\ldots\ldots\ldots(1)$$

Where α , h ,ν , A , E_g , E_p are the linear absorption coefficient , Plank's constant ,the frequency ,constant ,energy gap between valance band and conduction band , phonon absorption (+) or phonon emission (-) energy and n constant, where the value of n limite the type of transition.

Absorption coefficient (α)can be calculated by the formula[21]:

$$\alpha = \frac{2.303}{d}(A' + \log(1-R)^2) \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

where d,A' and R are the thickness ,absorptance and reflectivity respectively .

The absorption coefficient after correcting the reflection losses is plotted against photon energy is shown as Figure(9) .The energy gap (Eg) was calculated dependent on analytical absorption coefficient edge(α).Indirect electronic transition can be observed where $\alpha \leq 10^4 cm^{-1}$. In this transition the electron transition from maximum valance band to conduction band did not occur at the same wave vector (k') [21].Figure(10) show the variation of $(\alpha h\nu)^{1/2}$ versus photon energy . the figure has two straight lines ,the straight line in high photon energy is due to transition associate with phonon emission and phonon energy intercept at (Eg+Ep) ,when $(\alpha h\nu)^{1/2} = 0$,other line is corresponds to the phonon absorption process and the phonon energy intercept at (Eg-Ep) .The indirect band gap energy (Eg) is calculated about 1.56eV and the phonon energy Ep is about 0.06eV .

4. Conclusion

New polymer derived from organic dye (PCVT) has been prepared as a thin film by cast method to investigate the electric conduction mechanism and optical properties .It is shown from the electrical and optical experimental results that the polymer has a semiconductor property .Its conductivity is in the order of magnitude of 3.15×10^{-7} S/cm .The DC electric conductivity of the polymer shows typical Arrhenius-type dependence on means of hopping conducting mechanism .Optical studies indicate that this polymer has indirect band gap with value of about 1.56eV .

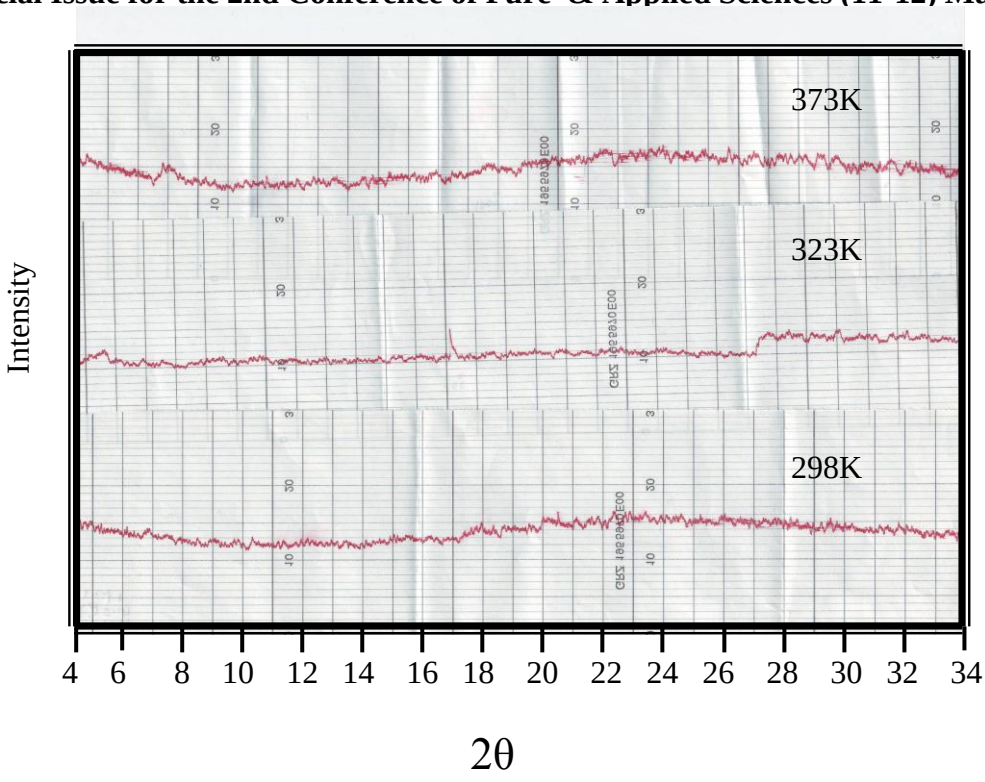
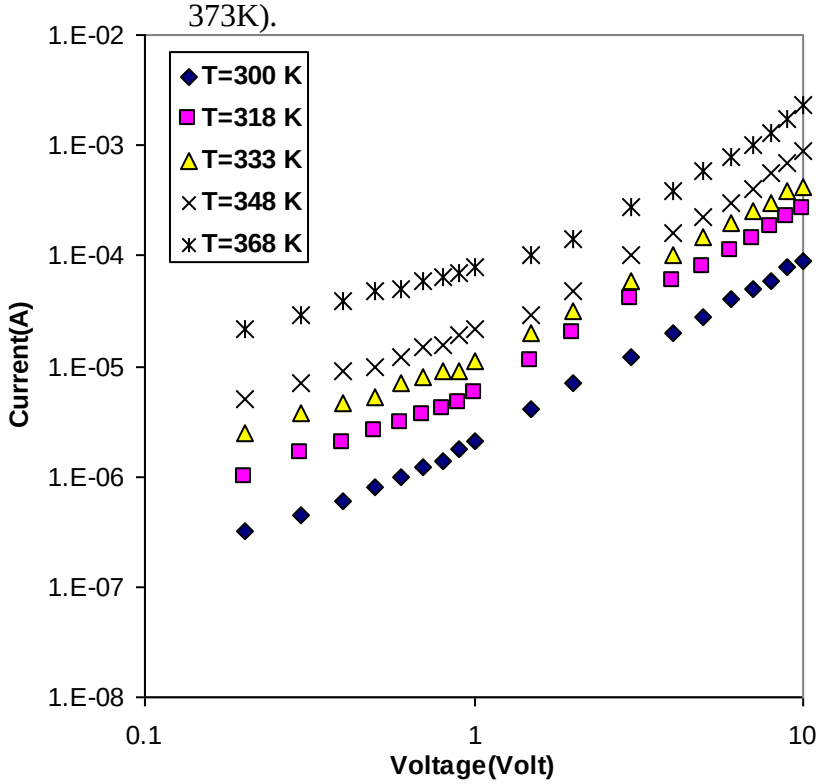
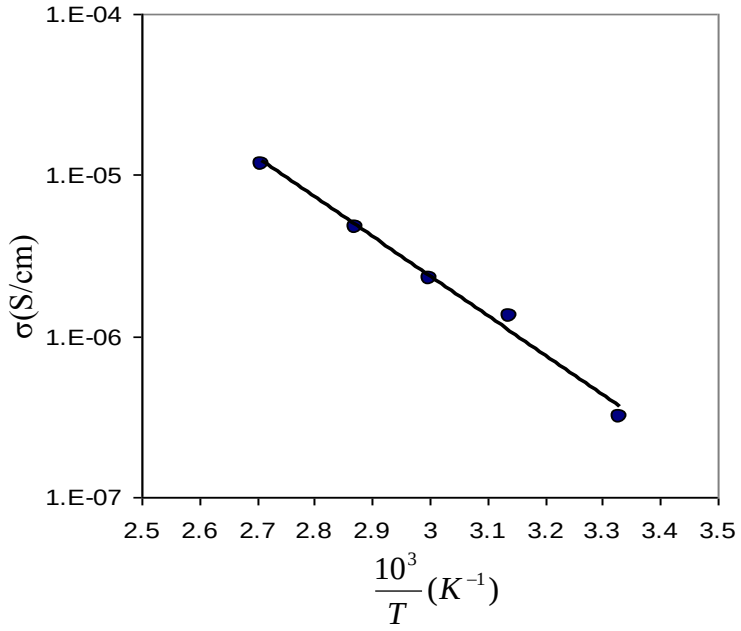


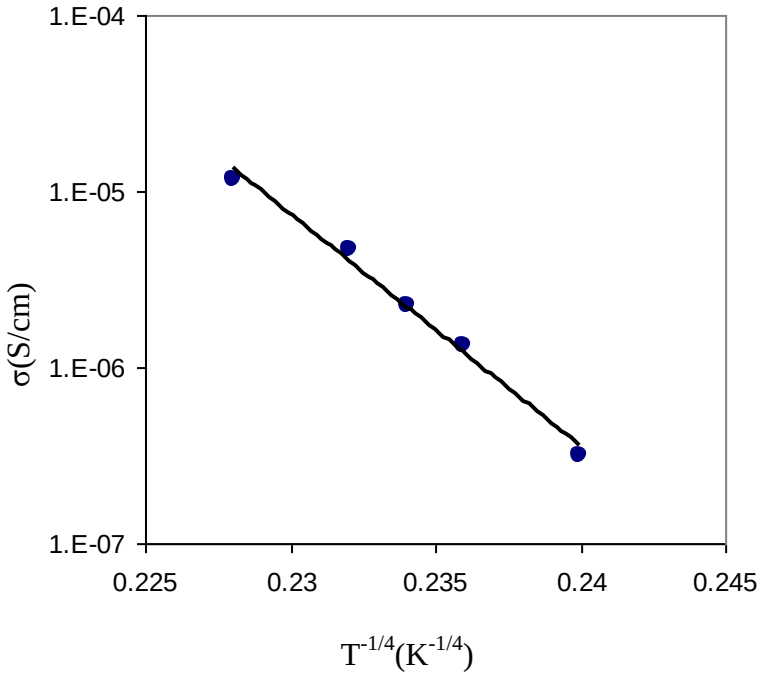
Figure (1): XRD of PCVT at different temperature (298,323 and 373K).



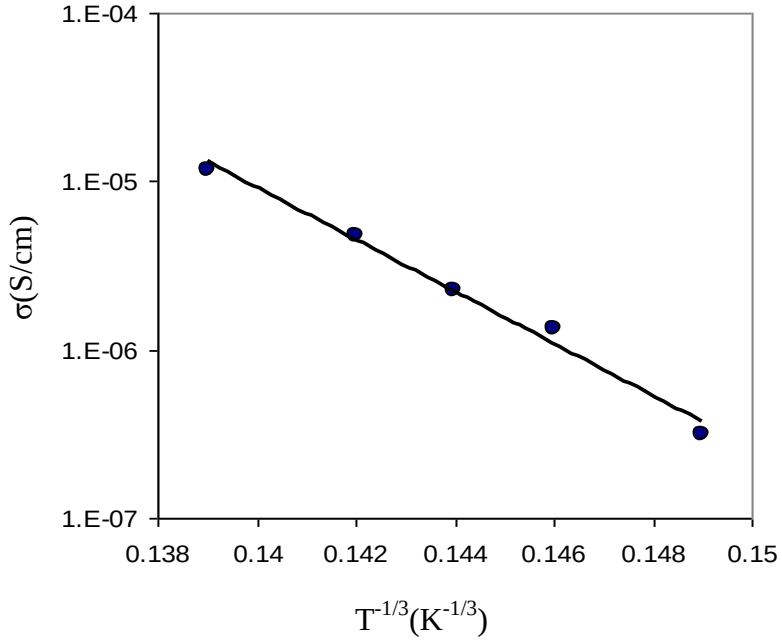
Figure(2) :The (current-voltage) characteristics of PCVT at different temperature.



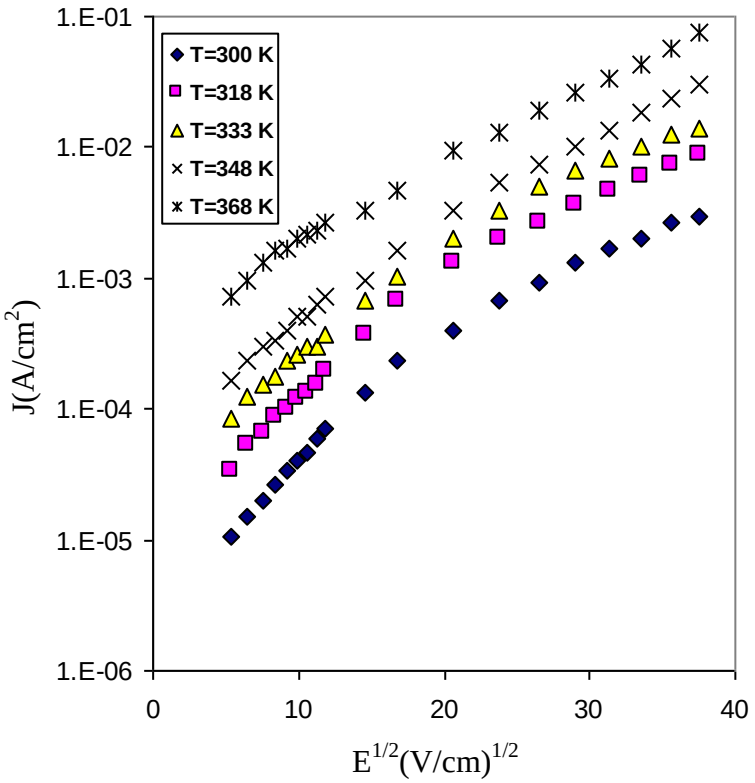
Figure(3): The relationship between conductivity and reciprocal temperature.



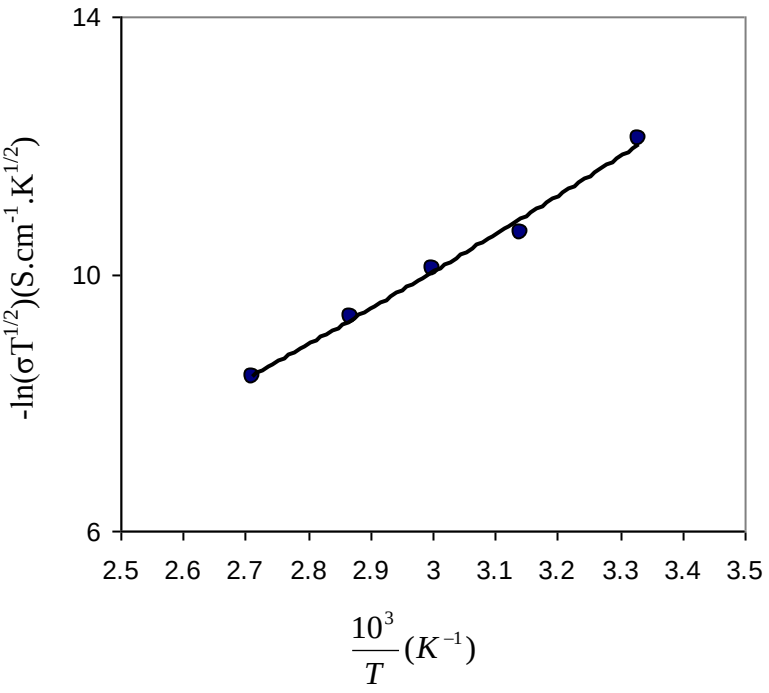
Figure(4) : The relationship between conductivity and $(10^3/T^{1/4})$.



Figure(5): The relationship between conductivity and ($10^3/T^{1/3}$).



Figure(6) : The relationship between current and $E^{1/2}$ at different temperature.



Figure(7) : The relationship between ($\sigma T^{1/2}$) and reciprocal temperature.

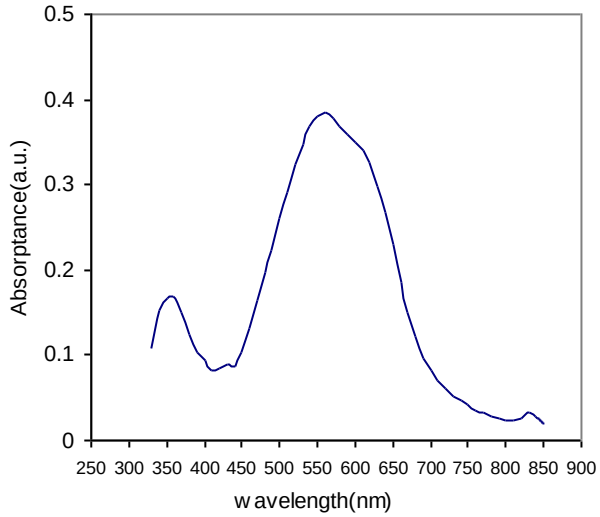


Figure (8): The relationship between absorptance and wavelength.

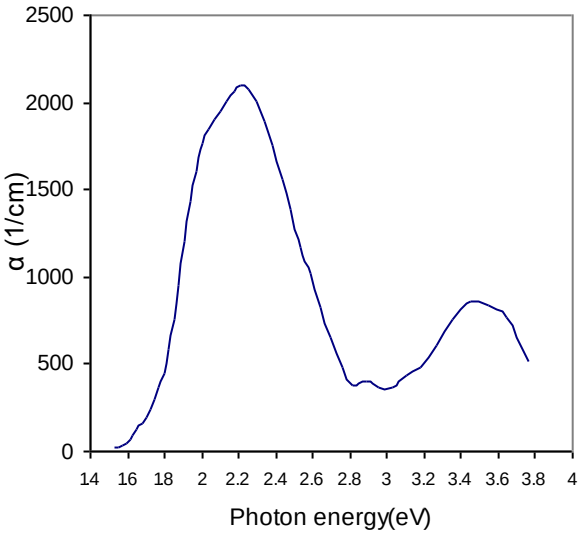
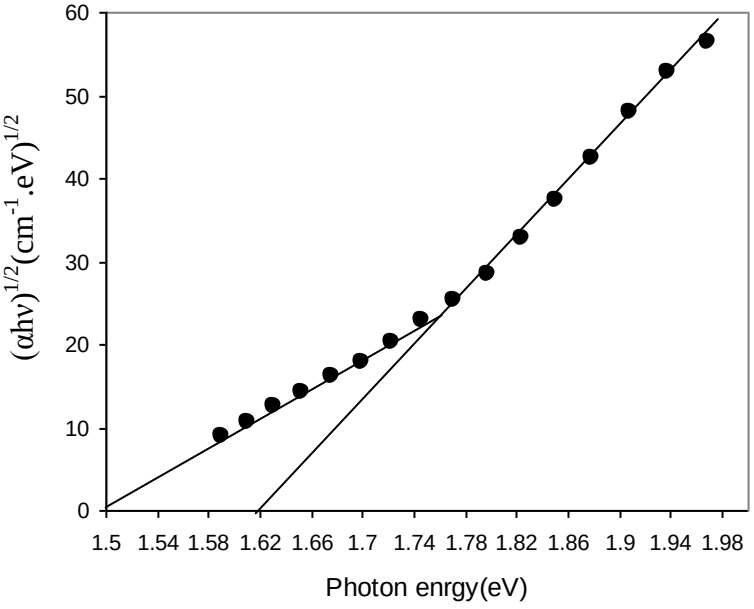


Figure (9): The relationship between absorption coefficient and photon energy.



Figure(10): The relationship between $(\alpha h\nu)^{1/2}$ and photon energy.

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الخلاصة:
درست الخواص الكهربائية والضوئية لبولي كريسيال فيوليت ترفثاليت (PCVT)المحضر بالبلمرة التكثفية .تضمنت دراسة الخواص الكهربائية للبوليمر المحضر على هيئة ألمنيوم / بوليمر /ألمنيوم دراسة ميزة(التيار –الفولتية) و ميزة (التوصيلية – درجة الحرارة) عند مدى درجات الحرارة يتراوح بين (300-368K) .تم حساب طاقة التنشيط المرافقة لعملية انتقال حاملات الشحنة عند المنطقة الاومية والتي كانت بحدود 0.47eV.درست ميكانيكية انتقال حاملات الشحنة للبوليمر المحضر حيث كانت من نوع الانتقال الالكترونية بالقفز عند المجالات الواطئة من ناحية أخرى أثبتت الخواص الضوئية للأغشية البوليمرية المرسبة على قواعد من الزجاج أن البوليمر يمتلك فجوة طاقة غير مباشرة مقدارها 1.56eVوطاقة الفونون المرافق لعملية الانتقال هي بحدود 0.06eV. قيمة فجوة الطاقة الضوئية تشير إلى أن البوليمر يمتلك خواص أشباه الموصلات .