Study of Electrical Conduction Mechanism of Polyblend Poly Urethane / Crystal Violet Dye (PU/CV)

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Abstract:

The electrical conduction mechanism of polyurethane(PU) was doped with a crystal violet (CV) at weight ratio of 1:3,Electrical measurements including (current-voltage) and (conductivity-temperature) characteristics at a temperature range of (311-393)K .The result shows that the sample has a semiconductor behavior as its conductivity increases with the increasing temperature and the value of dark conductivity at R.T estimated from Ohmic region was about $4x10^{-9}$ S/cm .The required energy to move electrons from valence band to conduction band can be estimated to be about 0.92eV.The deviation from Ohmic law was been analyzed in terms of variable range hopping (VRH) conduction theories.

Keywords: Polydye; Conduction mechanism; Electrical conductivity; Polyurathane; crystal violet dye.

دراسة ميكانيكية التوصيل الكهربائي لخليط متعدد من البولي يوريثان / صبغة البنفسج البلوري(PU/CV)

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الخلاصة:

درست الخواص الكهربائية لأغشية رقيقة من البولي يوريثان المطعم بصبغة البنفسج البلوري وبنسب وزنية 3:1. رسب البوليمر على قواعد من الألمنيوم . حللت القياسات الكهربائية والتي تتضمن العلاقة بين التيار والفولتية والعلاقة بين التوصيلية ودرجة الحرارة في المدى بين ^{o}K (311-393). أثبتت النتائج أن البوليمر يسلك سلوك شبه موصل حيث تزداد التوصيلية مع ازدياد درجة الحرارة وقيمة التوصيلية هي بحدود $4x10^{-9}$ S/cm .تم حساب طاقة التنشيط للبوليمر ووجد أنها تساوي 0.92 eV. درست ميكانيكية انتقال حاملات الشحنة للبوليمر المحضر حيث كانت من نوع الانتقال الالكترونية بالقفز عند المجالات الواطئة.

الكلمات المفتاحية: متعدد صبغة ; ميكانيكية التوصيل; التوصيلية الكهربائية; بولي يوريثان; صبغة البنفسج البلوري.

1. Introduction

Polymer films have been extensively investigated in the last few years due to their potential applications in LEDs, Sensors and Photovoltaic devices[1-3].Many researches have carried out studies on the conduction mechanism of the polymer thin films achieved using many different ways , Ali et.al. [4,5] have

used Schottky mechanism in polyvinyl alcohol grafted Rhodamine B ,while space charge limited current when reaction Phathalic anhydride reaction with Fluorescien dye in acidic medium .

Thin organic films have attractive features and being widely investigated for their using in electronic devices . The major advantage of organic materials over inorganic semiconductors is that they can be deposited by evaporation , spin – coating , screen printing , and casting . These deposition methods are simpler and cheaper than most of those that used in inorganic semiconductors . Crystal violet or Gentian violet or Methyl violet (10B) is a triphenyltmethane dye as shown in Fig. (1). The dye used as a histological stain in Gram's Method of classifying bacteria .Crystal violet has antibacterial, antifungal, and anthelmintic properties and was formerly important as a topical antiseptic. The medical use of this dye has been largely superseded by much modern drugs, although it is still listed by the World Health Organization. When the dye dissolved in water the it has a blue-violet color with an maximum absorbance at 590 nm and an extinction coefficient of 87,000 $M^{-1}.cm^{-1}$**,** [6,7]**.** The electrical conduction properties of thin polymer films have been extensively studied in recent years to understand the nature of charge transport in these materials [8] . The objective of this study is to investigate the organic dye CV influences on electrical properties of polyurethane.

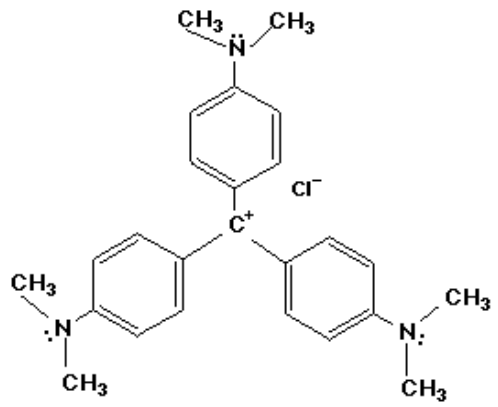

Fig. (1) Structure of crystal violet

2. Experimental Part

1 gm of PU/CV was dissolved in 5ml of pure ethanol and mechanical stirring on meganitic stirre for 15 min was achieved .The mixture is very good soluble , to extract it of any material poor solubility, filter paper was used .Aluminum substrates was used to study the electric conduction mechanism of (PU/CV) .The aluminum substrates were ultrasonically cleaned in distilled acetone, deionized water .After the cleaning the substrates, polymers as thin film have been deposited on aluminum substrates at normal equilibrium condition using cast method from solution technique[9].

All substrates transferred to the chamber of thermal evaporation model varian 3117 to evaporate the front upper aluminum electrodes under vacuum of 10^{-5}torr at circular shape with area of $0.2cm^2$.The sample and electrodes were enclosed in an oven whose temperature was controlled by proportional controlled ,and a regulated voltage range from (1-60V) was supplied by power supply model hp 6443B .The current was measured by ammeter and voltmeter model SC-MultiLOGGER IWATSU Electric Co.LTD. A schematic

diagram of electrical properties measurement is shown in Figure (2).

3. Result and Discussion:

The electrical measurement of PU/CV was conducted at a steady state condition . Figure (3) shows the relationship between the current and applied voltage at different temperature range (311-393K).At law voltage (≤10V) Ohmic conduction mechanism was observed clearly which indicates that the charge carriers are thermally generated , and charge carriers which are effected by current limits [10] ,from the Ohmic region the dark conductivity can be estimated at R.T which was about $4x10^{-9}$ S/cm .At high applied voltage (≥10V), non-Ohmic behavior can be notice which indicates that the injected electrode carriers are greater than the thermally generated charge . Figure(4)shows the temperature dependence of the conductivity of the sample which indicates that it is fitted to Arrhenius law [11] :

$$\sigma_{dc} = \sigma_o e^{\frac{-Ea}{k_B T}} \quad \text{..... (1)}$$

Where :σ_o is the pre –exponential rate corresponding to 1/T=0,Ea is the activation energy ,K_B is the Boltzmann's constant and T is absolute temperature. The polymer has a semiconductor behavior where the conductivity increases with increasing temperature due to delocalized π-electrons [4],from this Figure, it can be estimated that the activation energy (Ea) from the slope of the straight line, it found to be 0.92eV.Mott's conduction mechanism (variable-range hopping) VRH , which was successfully applied to this polymer according to the equation [12] :

$$\sigma = Ae^{-BT^{\frac{-1}{n}}} \quad \text{..... (2)}$$

Where A,B and n are constants ,the value of the exponent (n) determines the nature of the conduction mechanism. Experimentally, DC conductivity measurement was carried out for the sample shows that the temperature dependence of the DC conductivity obeys lnσ(T) versus $T^{-1/4}$ in Figure(5), which is consistent with a charge transport process governed by the theory of (VRH) that has been successfully used in describing the transport properties in a variety of disorder semiconductors. In this study another possible conduction mechanisms such as ionic ,space charge limited current, Schottky and Poole-Frenkel effect and tunneling were also studied to identify the proper investigation. Figure (6) shows the relationship between ln(σT) and 10^3/ T,where the linear relation can exclude the ionic mechanism from our speculated [13] .The possible existing of Schottky or Poole –Frenkel effect can be investigated from the relationship between current and square root of electric field ($E^{1/2}$) . A nonlinear behavior was obtained at high electric field as shown in Figure (7) ,also (current – voltage) characteristics does not obey the general space charge limited current .Moreover, the range of thickness for films under study were out of range satisfying tunneling mechanism[14].

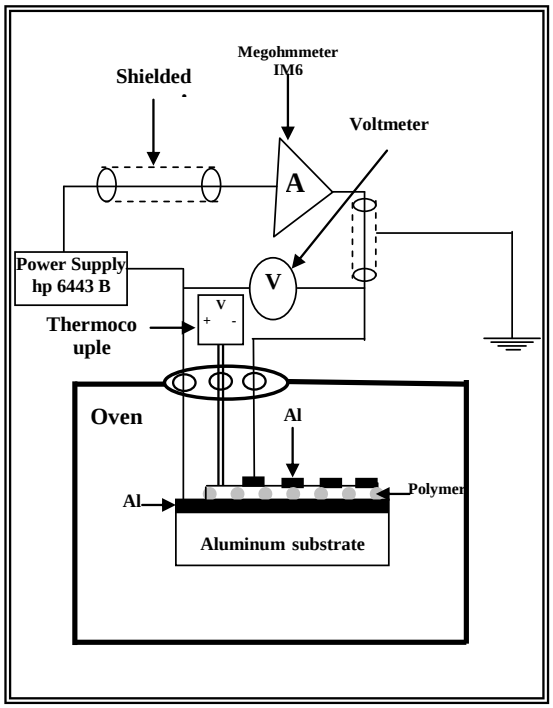

Figure (2): Schematic diagram of the electric circuit measurement

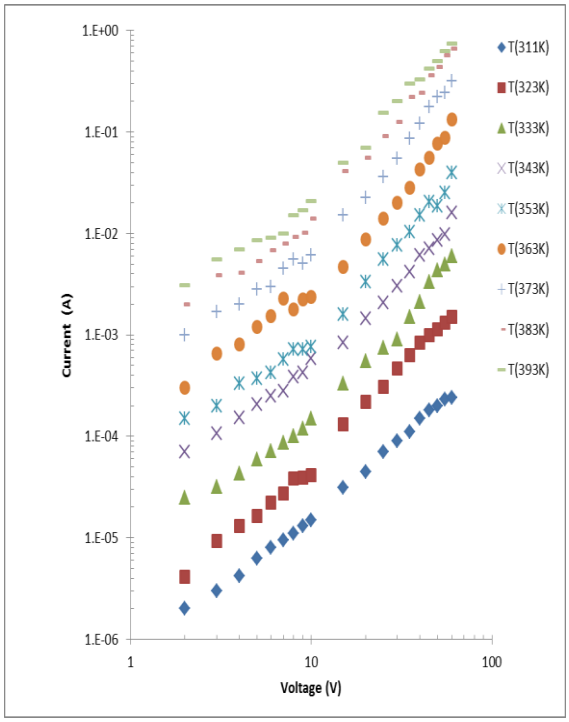

Figure (3):The (current-voltage)characteristics at different temperature range (311-393K).

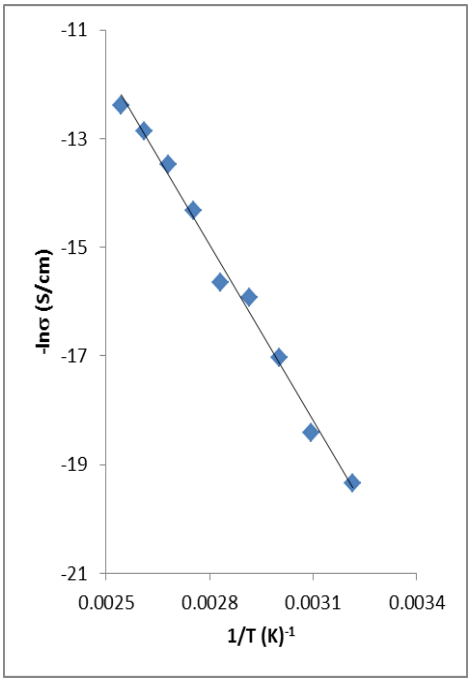

Figure (4):The relationship between -lnσ(T) and 10^3/T .

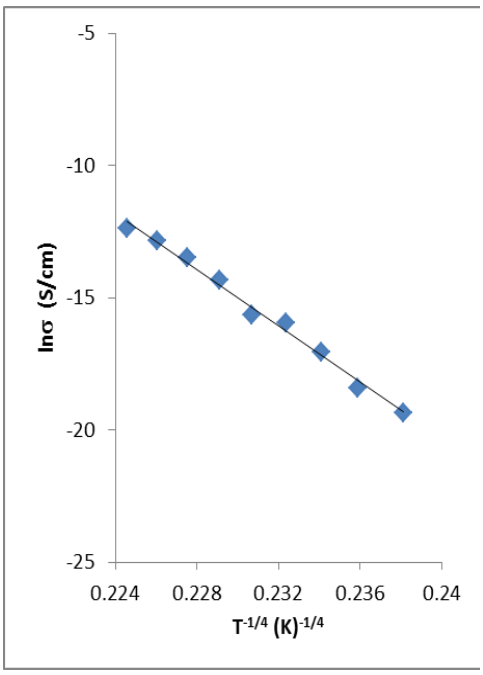

Figure (5):The relationship between lnσ(T) and T

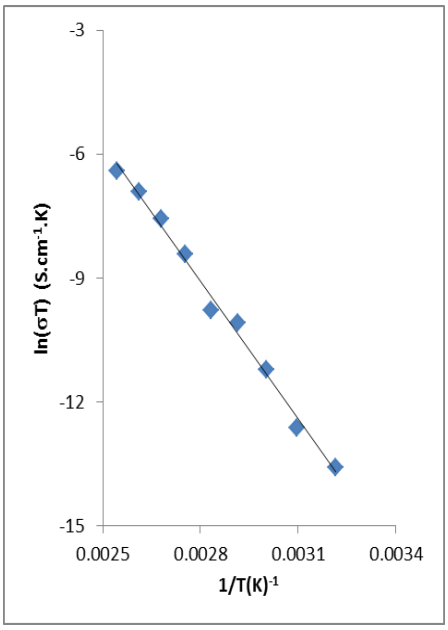

Figure (6):The relationship between –ln(σ T) and 10^3/ T .

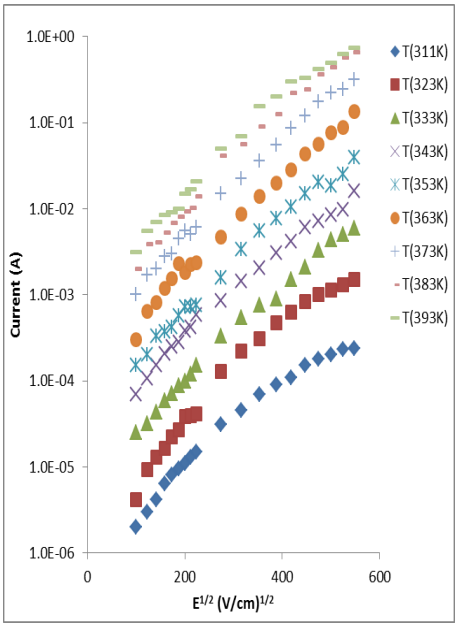

Figure (7):The relationship between current and square root of electric field ($E^{1/2}$) .

4. Conclusions

The electrical properties of polymer blend (PU/CV) films has been carried out. It is shown that this polymer has a simeconducting property. Its conductivity is in the order of magnitude $4x10^{-9}$ S/cm. The DC electrical conductivity of the polymer shows typical Arrhenius -type dependence on temperature and its behavior can be explained by means of hopping conduction mechanism. The current - voltage characteristics for the polymer could be interpreted in terms of both Schottky and Pool -Frenkel effects.

5. Reference

[1] B. Adhikari and S. Majumdar," Polymers in sensor applications"Progress in Polymer Science, 29, 7, (2004), P. 699–766.

[2] S. Hameed, P. Predeep andM.R.Baiju "Polymer Light Emitting Diodes - A Review on Materils and Techniques" , Rev.Adv.Mater.Sci. 26(2010)P. 30-42.

[3] A. Breeze, A. Salomon, D. Ginley and B. Gregg,"Photovoltaic Cells Based on Conducting Polymers and Perylene Diimides" National Renewable Energy Laboratory,(2001).

[4] A.Q. Abdullah, "Synthesis and Characterization of Electrical Properties Polyvinyl alchol grafted Flourescien dye and Polyvinyl alchol grafted Rhodamine B dye and Their Application in Schottky Diode" M.Sc Thesis, Basrah University , Basrah, Iraq, (1998).

[5] Ali Q.Abdullah, Karema M. Ziadan and Salah Sh.Al-Luaibi, Electrical Properties of New Polymeric Dyes (PFT), Iraqi J. Polymers, Vol.11, No.2, (2007) 84-97.

[6] Adams E. Q., and Rosenstein L. (1914).The color and ionization of crystal violet, J. Amer. Chem. Soc., 36(7), pp.1452- 1437.

[7] Mahasin Al-Kadhemy F. H., Abaas W.H.(2012) Absorption spectrum of crystal violet in chloroform solution

and doped PMMA thin films",Atti Della, Fondazione Giorgio Ronchi, 3, pp.359-367.

[8] Po-Tsun.T.C.Chang,Shuo-Ying Yan,Chun-Huai Li and S. M. Sze, Electrical Transport Phenomena in Aromatic Hydrocarbon Polymer, Journal of the Electrochemical Society,150(2)F7-F10 (2003).

[9] M.Kaneko and D.Wohrle"Polymer-Coated Electrodes:New Materials for Science and Industry",Advance in Polymer Science,Speringer-Verlage Berlin Heidelberg,84, (1988) 147.

[10] Ali Q.Abdullah,Karema M.Ziadan and Salah.Sh.H.AL-L'aibi ,"Electrical Conduction Mechanism for Poly(1,4 – DIAZOPHENYLENE-BRIDGED – TRIS (8-HYDROXY- QUINOLINE) ALUMINUM (PDPAlq3)",Iraqi J.Polymers,Vol.12,No.1,(2008) ,95-108.

[11] P.P.Korniychuk,A.M.Gabovich,K.Singer,A.I. Voitenko and Y.A.Reznikov,"Transient and Steady Electric Currents Through a Liquid crystal Cell",Liquid Crystals,(2010),37,9,P.1171-1181.

[12] N.F.Mott,E.A.Davis,"Electronic Process in Non-Crystalline Materials, Clarendon Press,Oxford,(1971).

[13] C.K.Chaing,G.T.Davis and C.A.Harding,Soild State Ionic,18,300,(1986).

[14] A.Q.A.Al-Assadi" Synthesis and Study of optical and Electrical Properties for Some New Organic Dyes and Their Promising Applications as Light –emitting Diodes"Ph.D Thesis ,University of Basrah,College of Science,Basrah,Iraq,(2007).