ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Study of the Electrical Characteristics of Poly Para-Amino Benzaldehyde as Schottky diode Solar Cells application

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Manuscript Info

Manuscript History:

Received: 15 August 2015
Final Accepted: 19 September 2015

Key words:

PPAB polymer, Solar cells, Schottky diode, electrical characterization

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Abstract

Organic polymer semiconductors as new materials for solar cells (solar energy conversion) have been explored. In this study Schottky diode solar cells of Poly Para-Amino Benzaldehyde (PPAB) doped with (0.5) of Oxonium salt (AsF_6), were fabricated at room temperature by cast technique.

The current-voltage characteristics of the (Cu / PPAB / Al) structure was investigated under light (illumination) and dark conditions, and can be explained in terms of the charge transport mechanism operating in sample at different voltage regions and at different temperatures (303 – 343K).

The electrical conductivity as a function of reciprocal absolute temperature (1/T) under illumination condition was investigated. It was found to be increases when temperature increase from ($1.3x10^{-11}$ S/cm) at 303K to ($1.5x10^{-9}$ S/cm) at 343K. This behavior indicates that the sample behaves as semiconductor material. The activation energy was obtained from the curve at room temperature as (0.53 eV), while the barrier height (Φ_{Bn}) was obtained at room temperature (303K) as (1.61 eV) and (5.73 eV) at (343K).

The electrical parameters [ideality factor (n), series resistance (R_s), saturation current (I_s)], of the device are measured at different temperature.

1- Introduction

The consumption of energy has been increasing over the years. Traditionally energy is supplied from fossil fuels and nuclear energy. These energy sources are limited and will have serious scarcity in future generations. Renewable energy sources will play a key role in supplying electricity to future generations. Bio mass energy, geo thermal energy, wind energy and solar energy are the main renewable energy sources utilized today. The sun is the most sustainable and reliable energy source. This resource makes photovoltaic devices an obvious candidate for energy consumption. Furthermore, this method of energy conversion has environmental benefits. The amount of energy received from the sun by earth per day is very large and 1000 times greater than the world's energy needs. However, only a small percentage of the energy is being utilized for world energy needs. This difference leads to efforts to improve existing technologies [Laxman, 2011].

Photovoltaic cells harvest solar energy from the sun and convert it into electrical energy. The conversion of energy into electrical energy is an important challenge. Traditionally, the solar cell industry has been dependent on inorganic solar cells. Silicon and CdTe are the main semiconductors employed for the fabrication of inorganic solar cells. Inorganic silicon solar cells have achieved efficiencies of 25% [Zebaze, 2011], but the high cost of silicon solar cells has led to the investigation of low-cost alternative photovoltaic materials and devices [Guirong et al, 2002].

Many improvements have been taken and new materials for solar cells have been explored over the years. Research has now reached the stage of using organic polymer semiconductors in many optoelectronic devices including organic light-emitting diodes (OLED), organic transistors (OFET), and solar cells [Pfeiffer et al 2006, Wudyalew, 2007]. The low cost, mechanical flexibility, lightweight, large scale, fast production and easy modification of properties make organic solar cells a replacement for the high cost inorganic solar cell [Wohrle et al, 1991].The metal/organic semiconductor Schottky junction as an alternate to the metal/inorganic semiconductor junction has been developed, which has opened the new possibility of replacing conventional inorganic devices by organic ones [Brabec et al 2003, Syed et al, 2001].

In the present work, we have fabricated and investigated a new type of Schottky diode solar cells based on preparing of poly para-amino benzaldhyde (PPAB) films by cast technique. The electrical properties of (Cu / PPAB / Al) structure have been studied under dark and illumination conditions in the temperature range from 303 to 343K.

2- Experimental Details

(0.5 mg) of Poly Para-Amino Benzaldehyde (PPAB) dissolved in Dimethylformamide (DMF), and the same amount (0.5 mg) of Oxonium salt (AsF_6) as dopant material was dissolved in the same solvent (DMF). Then the same volumetric rate of (0.5 gm) was taken from each solution and stirred on the magnetic stirrer for one hours until completely mixed to form viscous solution. The solution then, precipitated as thin film (1.55 µm thickness) on Al layer precipitated on a glass slide which used as substrate after washed in acetone, then methanol, DI water and finally dried by blowing nitrogen gas. The (PPAB) film were removed to a desiccator (dust free chamber) and left to dry and to evaporate the solvent slowly at the lab temperature for three days after which they were removed and the electrodes were deposited to complete the structure. Thin layer of copper precipitated in a vacuum chamber maintained at (10^{-4} Torr), in circles shape and in an area of ($0.03 cm^2$).

Electrical measurements of (Cu / PPAB / Al) structure were performed under darkness and illumination condition over a voltage range appropriate to the thickness of the sample, using a stabilized power supply and a ketihley digital electrometer (model 614). Sample temperatures were varied using a heater and a temperature control unit. Temperature was measured by means of a chromel/alumel thermocouple mounted in close proximity to the specimen of interest and could be read out on a keithly 871 digital thermometer display.

3- Results and the Discussion

It is recognized that the Ohmic contact is required in all typical semiconducting pattern. Ohmic contact is a typical semiconducting zone where the current-voltage curve should be linear and symmetrical. If the relation between the current and voltage is nonlinear and non-symmetrical, then this kind of contact is called Schottky conductivity [Pfeiffer et al, 2006].

According to the classical theories, on p-type and n-type doping of an intrinsic material new energy levels are introduced in the band gap close to the band edges. This changes the chemical potential of electrons in the material (the work function) as described by the fermi level. If a semiconductor is brought into contact with another material having a different work function the electrochemical potentials (fermi levels) equilibrate by building up space-charge layers at the interface. Due to its low charge-carrier density, this space charge region is formed almost completely within the semiconductor in contact to a metal electrode of dissimilar work function.

The electrical properties of Schottky conductivity is analyzed assuming thermionic emission theory of Schottky barrier model. This theory assumes that the current is controlled by the transfer of charge carriers through the interface region and the current will be a function of the used biased voltage.

The electrical conductivity (σ) of the inorganic and organic materials can be expressed as :

$$\boldsymbol{\sigma = \sigma_0 \exp [- E_a / K_B T]} \quad \_\_\_\_\_\_\_\_\_\_\_\_ (1)$$

Where σ is the conductivity at temperature T, σ_0 : is a pre-exponential factor (electrical conductivity at absolute zero temperature, K_B: Boltzmann constant, $E_{a:}$ is the thermal activation energy. T: an absolute degree.

The usual way to get the activation energy is the relationship between the logarithm of the electrical conductivity and inverted absolute temperatures (1/T) which is linear. As for ideality factor (n) can be compensated in the following equation:

$$\mathbf{n = q / K_B T [dV /d (Ln\ I)]} \quad \_\_\_\_\_\_ (2)$$

where q is the electronic charge, dV /d(Ln I) is the slope of linear region of Ln I vs. V plots.

The barrier height (Φ_{Bn}) is calculated from the following relationship [Williams et al, 1988]:

$$\boldsymbol{\Phi_{Bn} = (K_B T / q) \ Ln \ [A^* T^2 / J_S]} \quad \_\_\_\_\_\_ (3)$$

Where J_S is the current density, A* is the effective Richardson constant, and from a linear fit of the (Ln I) vs. V plots, the experimental values of n and (Φ_{Bn}) were calculated by the slopes and intercepts of linear fit.

Figures (1) and (2) show the relationship between the current and the voltage at different temperatures (303 – 343K^o) in the dark and illumination conditions. The relationship (I-V) is not linear and we can observe the effect of light on the electrical properties quite clear**.**

Figures (3) and (4) explain the relationship between the current and the voltage for the forward and reverse bias at the room temperature and in the both conditions (light and darkness)**.**

The relationship (I-V) is not linear too and the appearance of the effect of light on the electrical properties provides the piece of information that this material is efficient for use in photovoltaic applications such as a solar cells and that the conductivity charge is represented by the electro-hole carriers as in the inorganic semiconductors**.**

The properties of (I-V) of this device show the influence of timing, which refers to the formation of depletion layer when connecting a semiconductor with metal. At the voltage more than (5 volt), the current becomes linear in the light and darkness curve which proves that the typical resistance is the one prevailing in volumetric resistance of the inorganic semiconductor [Syed et al, 2000]**.**

The other parameters that gives the description of Schottky diode are the ideality factor (n) and the saturation current (I_s). The (n) and (I_s) values can be estimated at room temperature from the relationship (LnI - V) (Figure 5) and according to the relation (2) as (2.51) and (1.2 x 10^{-10} Amp) respectively. The value of (n) was a little bit higher than the practical value reported in the literature which ranged between (1- 2), and they fall within the value gained from the polymeric materials, such as the polyethylene polymer doped with iodine vapors which is nearly (4.46) [Miyauchi et al, 1989]. The high value of (n) reflects the amount of recombination of charge carriers in the depletion region; while the low value of (n) reflects the amount of reduction in the recombination process of the charge carriers. However, in our (Cu/PPAB/Al) cells, the measured value of n is larger than two and therefore tunneling, recombination-generation currents in the depletion region and recombination through interface states at the (Cu/PPAB/Al) junction are expected to play important roles [Singh et al, 2003].

Figure (6) shows the relationship between (dV/dLnI) and (I), where the slope of the straight line is the series resistance (R_s), which were about (4.04 k ohms), which is within the common range of inorganic semiconductors [Caglar et al, 2008]. Figure (7) shows the relationship between the (electrical conductivity) and inverted absolute temperature, and from the slope the activation energy is gained, which was about (0.53 eV). It is observed that the electrical conductivity of the diode owns positive thermal coefficient; which indicates that the sample behaves as semiconductor material.

Figure (8) shows the relationship between [Ln (I/T^2)] and inverted absolute temperature (1000/T)K^{-1} under illumination condition. It is observed that the barrier height changed with temperature. As a result we can get the two values of the barrier height : the first is (1.61 eV) at room temperature and the other value is (5.73 eV), at the high temperature (343k**)**.

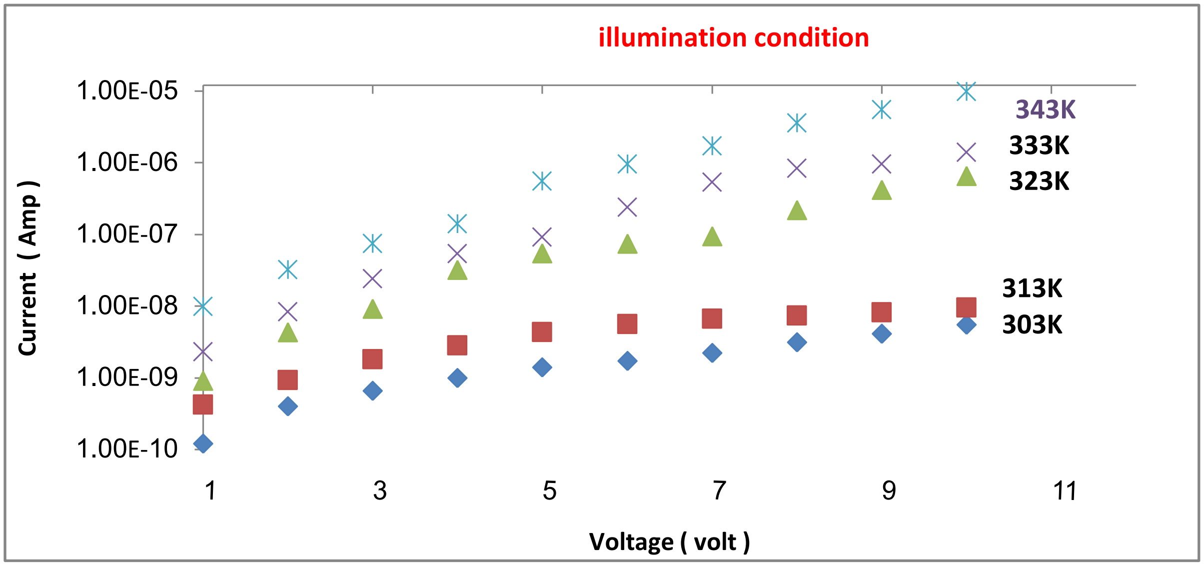

Figure (1): Current – voltage characteristics for (Cu/PPAB/Al) structure at different temperatures (303-343K) under illumination conditions.

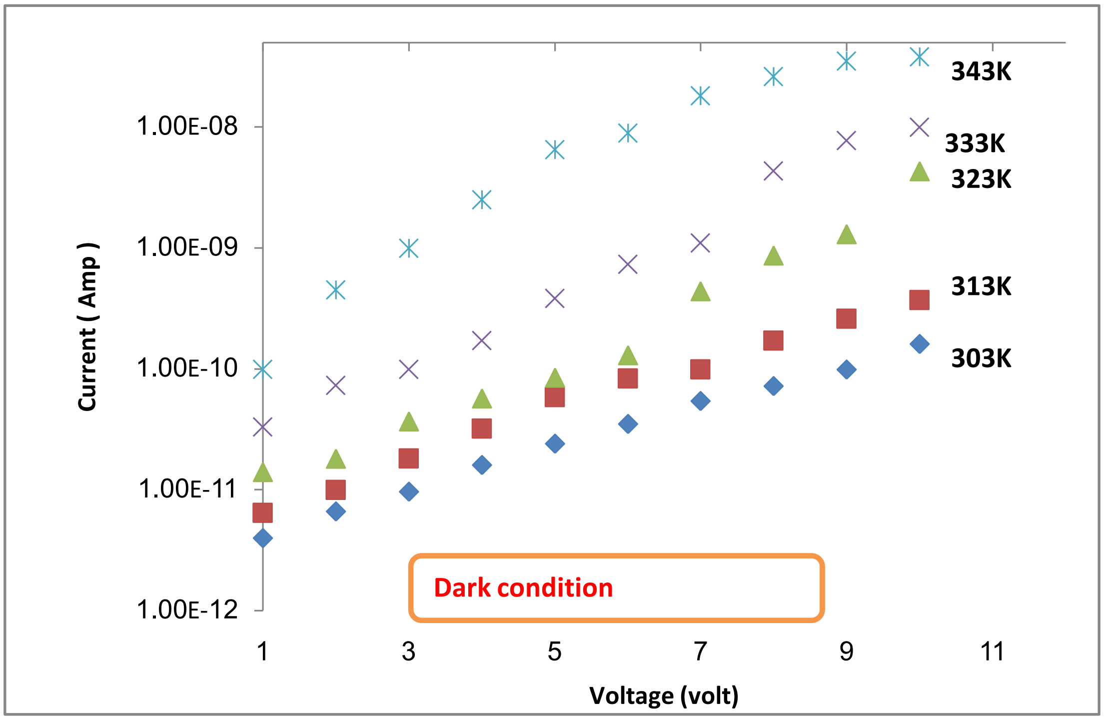

Figure (2): Current – voltage characteristics for (Cu/PPAB/Al) structure at different temperatures (303-343K) under dark conditions.

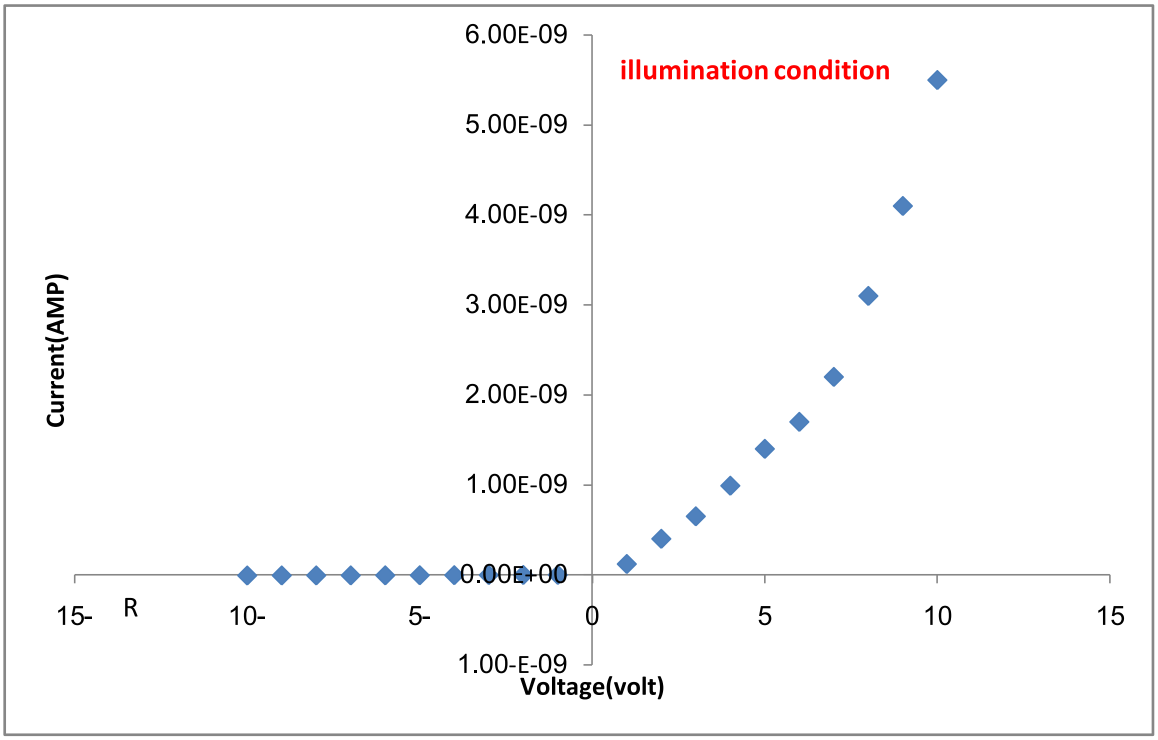

Figure (3): Current as function of voltage) (forward and reverse biases for (Cu/PPAB/Al) structure under illumination conditions.

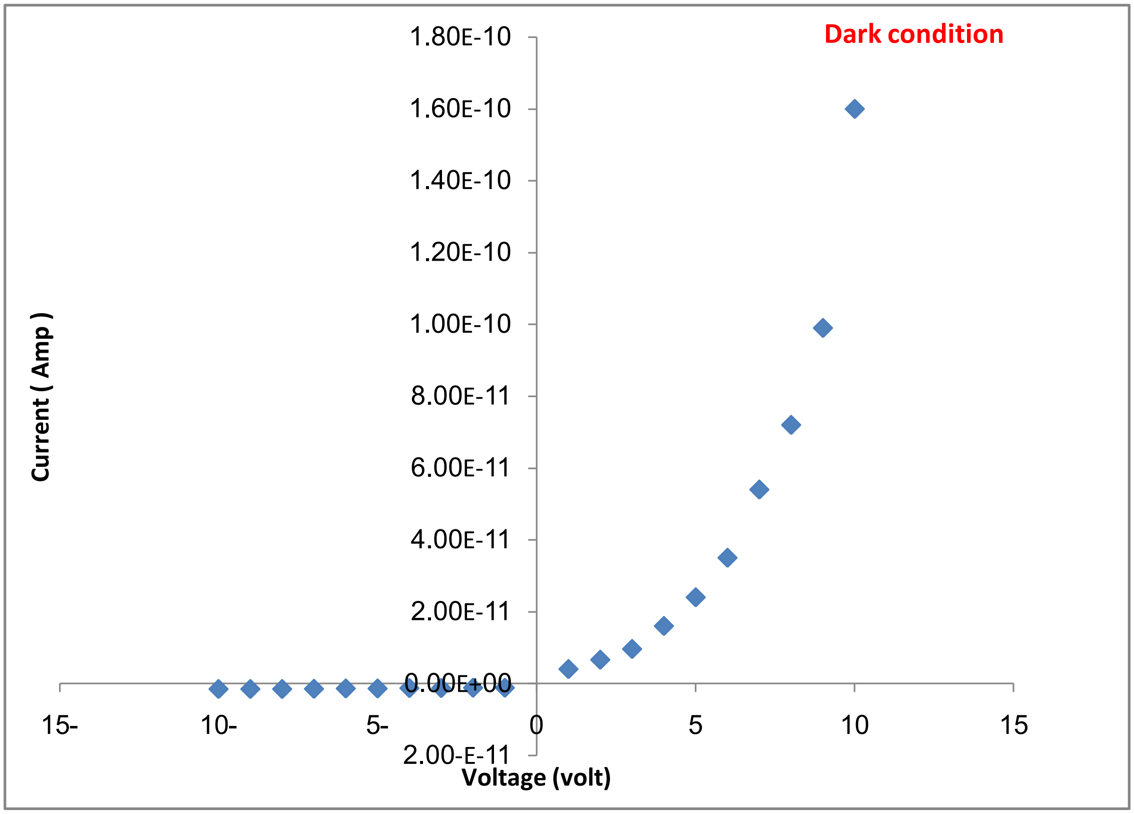

Figure (4): Current as function of voltage (forward and reverse biases) for (Cu/PPAB/Al) structure under dark conditions.

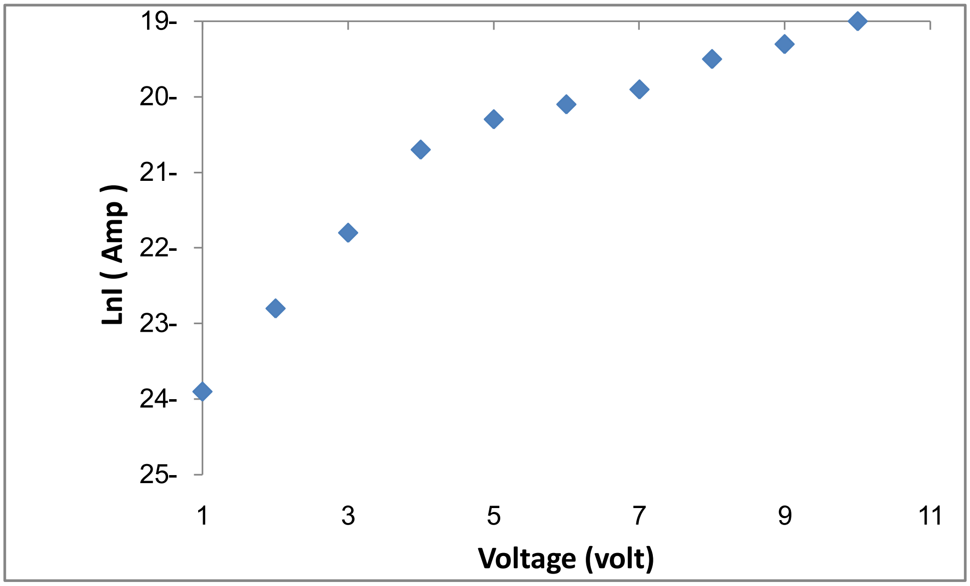

Figure (5): Current density as function of voltage for (Cu/PPAB/Al) structure at room Temperature under illumination condition.

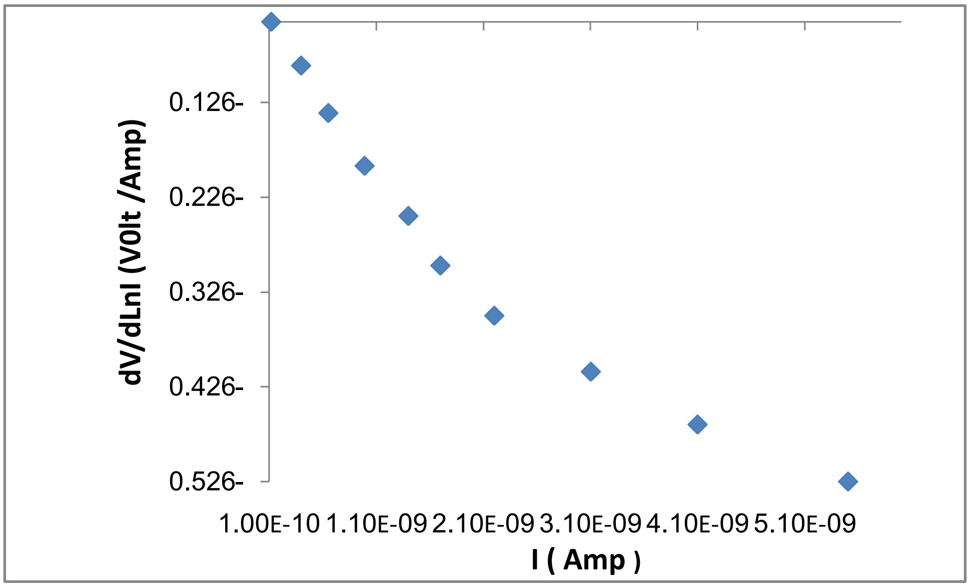

Figure (6): The characteristics of (Cu/PPAB/Al) structure at room temperature under illumination condition.

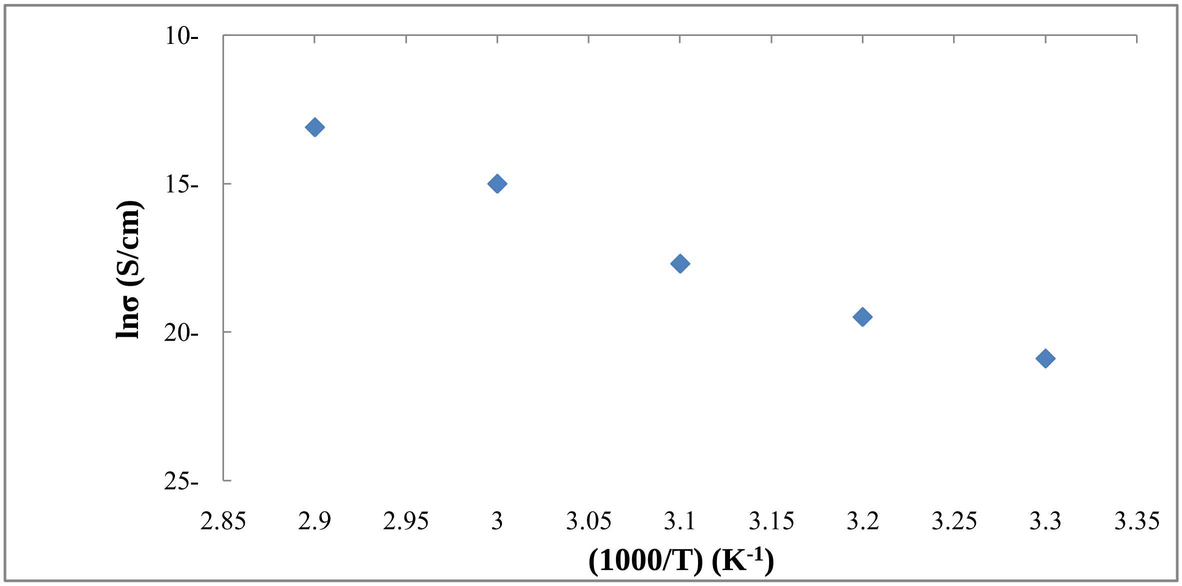

Figure (7): Dependence of conductivity on reciprocal temperature for (Cu/PPAB/Al) structure under illumination condition.

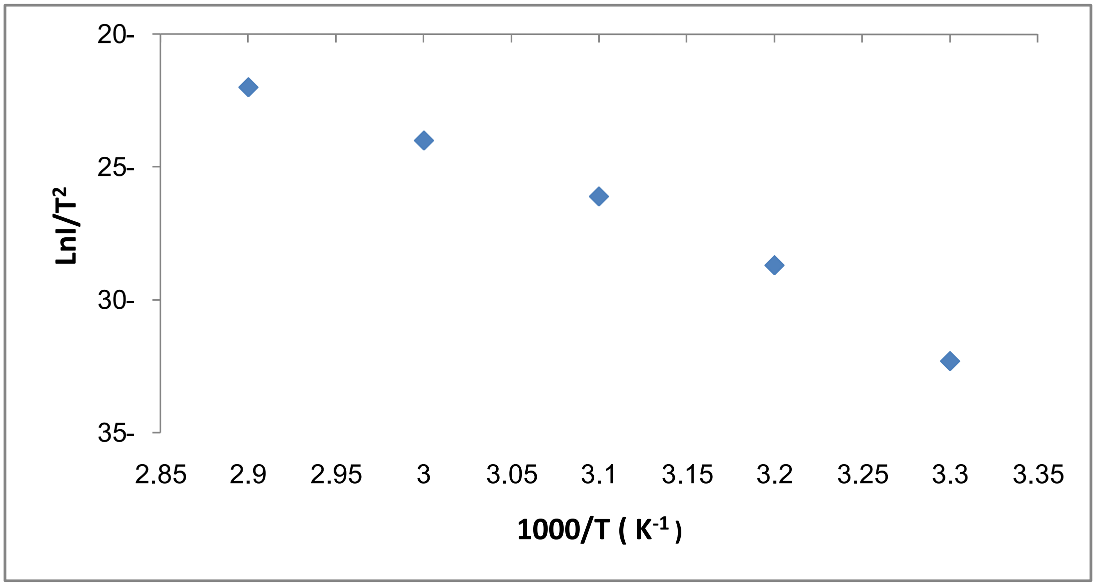

Figure (8): (Ln I/T^2) vs (1000/T) for (Cu/PPAB/Al) structure under illumination conditions.

4- Conclusions

In brief, Poly Para-Amino Benzaldehyde (PPAB) deped with (0.5) of Oxonium salt (AsF6), have been used to prepared Cu/PPAB/Al structure as Schottky Diode solar cells using casting technique .

The current-voltage (I-V) characteristics of schottky Diode solar cells at different temperature (303-343K^0) have been investigated under dark and illumination condition, which show ohmic behavior at all applied voltage.

The electrical conductivity have been studied under illumination condition and it was found to be increases with temperature increase.

The activation energy, and other electrical parameter was obtained which indicates that the sample behaves as semiconductor material, and can be used in photovoltaic applications.

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