Temperature and Doping Dependencies Junction Of Polythiophene Schottky Barrier

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Abstract

The junction between polythiophene, a conducting polymer formed by electrochemical polymerization, and n-type silicon was studied the temperature and doping dependencies were observed in the junction characteristics. The increase of junction temperature leads to increase the saturation current, the barrier height, and decrease of the ideality factor for junction. While the reduction in doping concentration causes a decrease in the forward current. The results were explained according to the conventional Schottky diode theories.

Introduction

The organic conducting polymers are widely used recently in the fabrication of the electronic , photonic elements ,and in other applications.

The polymers were used in the electronic devices , as homojunction with n- and p-type conducting polymers(1) , heterojunction detween conducting polymers and inorganic semiconductors (2) , and Schottky barrier between metals and semiconducting polymers(3) , In other hand , the conducting polymers used to synthesis solar cells (4) , and liquid junction (5). More recently, it were used to fabricate the field effect transistor (FET) (6,7) , and light emitting diode (LED) (7,8) .

Among various organic conducting polymers polythiophene (PT) and its derivatives are very attractive, because they are more stable from other polymers such as polyacetlyene, high conductive and can be doped either by donor (acceptor) giving n-type (p-type) semiconductor and even metallic regime, etc.

Previously the temperature dependence of I-V characteristics of conductive polymeric contacts was studied. For example poly (3- alklthiophene) Al (9) ,and n-cds (n-tio2) (10) . and in our previous work, we have studied the polypyrrole

Preparation and characteristics of PT/ n-Sijunction. We found that the PT/ n-Sijunction. behaves as the Schottky barrer diode, and the TP behaves as metal with the high work function (11). In this paper, the temperature dependet of I-V characteristic in forward bias of PT/ n-Si Schottky barrier was reported the effect of NE3 on I-V characteristic was studied also.

Experimental Method

The junction Fabrication was achieved by electrochemical method using one compartment cell with two electrodes. The working electrode was an n-type silicon wafer of adout (1Ω.cm) resistivity and a pt foil as a counter electrode. The electrolyte solution was a 0.2 M thiophene monomer, and 0.2 M tetrabutylammoniun perchlorate ($TBAClO_4$) in dichloromethane (CH_3Cl_2) .The detailed method for sample preparation and characteristic for polythiophene was reported previously (12) the silicon wafer was cleaned carefully by a method described by wahak (13).The reduction of doping (or conductivity) of polymer films. have worked out via putting the PT/n-Si in NH_3 solution for different times .

The I-V characteristic of PT/n-Si was measured by a simple ciruit consisting on. The regulated power supply, two digital multimeters and I-V Curve tracer (Tecktronix type576). The junction was attached directly with heater surface and held by sandwich configuration on it. The temperature of junction is adjusted by the control of voltage which is supplied to heater coil by the regulator power supply .The temperature is measured by a Copper-constantan thermocouple .The junction is put under vacuum through the measurements.

Results and Discussion

Figure (1) shows the I-V characteristics of PT/n-Si junction at different temperatures. The figure, shows that higher temperatures leads to decrease the junction potential barrier (means that the forward voltage needed to cause current to flow is reduced)

The standard thermoionic theory was used to calculate the junction Parameters, Which stated that (14) ,

$$I = I_s \exp(qV/nkT) \qquad [1]$$

$${}_B/KT) \quad [2] \ \Phi \ I_S = A^* T^2 \exp\ (-$$

Where, I_s: the saturation current, V: the applied voltage , n : ideality factor, A*:

Richardson constant, $Ø_B$: the barrier height, q : the electron charge, k: Boltzman's Constant, and T: the temperature.

Figure (2) , shows the plots of the same data as in figure (1) but on semilog scale , which was fitted with equation [1] the extroplathon of the linear parts of the curves in figure (2) , to zero voltage gives the saturation current at various temperatures . The values of the saturation current which were extracted from figure (2) were plotted on a semilog scale (figure (3)) .It appears from it that the saturation current fits well with the straightline . The similar behaviour of I_s with temperature was reported for other polymeric contacts also [2] . The temperature dependenc of I_s could be explained by the variation of the gap state or the built in voltage with temperature (2) in addition to the increase in the minority charge carriers in silicon because of the temperature raising. The barrier height of the junction different temperatures can be obtained from equation [2], by assuming the $A^* = 120\ A/K^2 . cm^2$, the quality factor can be calculated from the linear portions of figure (2) at low forward voltage. Also, in the region far from the biasing voltage, the properties of junction is attributed to bulk property for materials, so that, we could found the resistivity of polymer films, that is a series resistance for the junction . The temperature dependencies of the , n , $Ø_B$, R_S are shown in the figures (4) & (5), respectively.

The combination of multistep tunnel recombination mechanism of majority carrier through the junction can therefore explain the variation in the quality factor.

Although, the barrier height does depend on the temperature in conventional **Schottky diode [14] . The barrier height increases with temperature raising (fig.4) , for PT/n-Si junction This increase may be due to (2):**

- An increase . in charge carries n each of n-Si and PT by thermal activation,
- An increase in the thermal emission via the barrier in according to eq. [2] The similar results are observed in the PPY/ n-Si diode (15).

The slope of figure (5), gives the activation energy conduction E =0.095 eV, comparing this value to the results from four probes method , we found an agreement within 0.065 %.

The general behaviour of all above results in figures (1-5) like other polymeric contacts synthesis from polymer with inorganic semiconductors or with the metals [2,9,10].

The results in previous studies of polymeric materials at higher temperatures shows the anomalous behaviour like:

1- The absorption spectrum of poly (3- alkylthiophene) shifted to higher energy. This change can be understood by the increase in the bandgap for polymer (7,16) .

2- At high dopant concentration, the metallic behaviour was observed like, positive thermopower, negative dielectric constant (7).

3- the optical spectrum of doped conducting polymers resemble those of free- carrier absorption in metals, although the conductivivty decreases slowly in this regime (7) .

To explain the above results the following model was suggested (7, 17)

The imperfection (either chemical or conformational defects) cuts the delocalized π-electron system into shorter segments and decreases the value of the conjugation length much below the chain length The optical absorption of the disorderd polymer chains resembles that of shorter oligomers These studies suggest that the lowest transition energy of oligomers is roughly proportional to the length (1) of the molecule. i.e.

$$E_g\ (l) = A + \frac{B}{l}$$

where A and B are constants

so that , heating causes a shortening of the π-conjugation length and therefore increases bandgap, this is consistent with the above results in point (1) .

In an inorganic semiconductors, experimental results show that the bandgaps of most semiconductors decrease with the increase of temperature . e ,g. , the Si bandgap at room temperature is l . 12 eV, while at 0 k is l, 17 ev; But for other semiconductors like, Pbs which its bandgap increase from 0.286 eV at 0 K TO 0.41eVat 300k (13). And the temperature dependent of diode characteristies can be explained by the increase in carriers concentration with temperature raising which leads to the increase in the current flow (18) .

The effect of conductivity (Bandgap) of Polythiophene Polymer on the I-V characteristics is as Follows .The conductivity of PT was reduced by the method describrd in the experimental section . Figure (6) shows the effect of dipping time in NH_3 on I-V characteristics . Obviously figure (6) revealed that the forward current decreases with the increase of the dipping time in NH_3 .As pointed out in the previous studies, the NH_3 decreases the conductivity (the bandgap increases) of Polythiophene (12) . From the above discussion, we have two important results : First, at ahigher temperature the bandgap of polymer increases and the forward current increases also. Second, the decreases of conductivity by dipping in NH_3 leads to decrease the forward current . The mismatching between the above two results, makes us conclude the increase of the forward current arises from other mechanisms which take place in polymer film .As mentioned above, the band gap is increased by heating (see eq.3) , the main reason affected on this precess is the rotation of side group. Since the PT does not contain side group we thought that this process does not occur in it. Therefore, the increase in forward current is due to an excess of charge curries generated by heating. This conclusion is enhanced by the behaviour of resistance with the temperature as in fig. (5) .

In conclusion, there are similar behaviours between all polymeric contacts characteristics at higher temperatures. Many effects may take place in these temperatures, the selection of one from these effects depends on the type of the polymer in the molecular structure, and requires to take into account all conduction mechanisms, environmental, synthesis and measurements conditions.

Finally, the temperature dependent effect of I-V characteristics for PT/ n-Si may be used as a temperature sensor and in other applications.

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دراسة الاعتماد الحراري والتشويب على خواص ثنائي حاجز شوتكي في البولي ثايوفين

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الخلاصة

درس الاعتماد الحراري والتشويب على مميزات ثنائي شوتكي المحضر من البوليمر الموصل (البولي ثايوفين) على بلورة من السليكون نوع سالب (n-type) . لوحظ اعتماد واضح لهذه الخواص على الحرارة ونسبة التشويب . وجد ان ارتفاع درجة حرارة الوصلة يؤدي الى زيادة في تيار الاشباع وحاجز الجهد ونقصان في قيمة عامل الجودة . بينما يؤدي تقليل نسبة التشويب الى نقصان في قيمة التيار الامامي للثنائي . وقد فسرت النتائج بالاعتماد على ات التقليدية لهذه الثنائيات .