Study the Effect of Thickness of Polyaniline nano-films on the Current Density-Voltage (J-V) characteristics

Mohammed Hamid Said
Collage of Pharmacy ,University of Babylon, Iraq.
Mohammed Hadi Shinen **Hani Mahmood Hussien**
College of Basic Education, University of Babylon, Iraq
Hanim572003@yahoo.com

Abstract

Polyaniline (PANI) was used as a basic material in this research where nano-films of Polyaniline were deposited on n-type silicon wafers. The thickness of the PANI films was controlled by the spin coating process. Different thickness of PANI(225,107, 90, 74 and 61)nm were obtained by using different spin speed(1000, 2000, 3000, 4000 and 5000) rpm, respectively. The current density-voltage(J-V) characteristics were achieved in both light (100 mw/cm^2) and dark conditions. The parameters of the photovoltaic samples, that is, open circuit voltage (V_{oc}) ,short–circuit current density (J_{sc}) ,fill factor (FF),and energy conversion efficiency (η) were calculated. sWe found that the best thickness of PANI film is 107 nm to get best energy conversion efficiency, short–circuit current density and maximum power point .

Key words: polyaniline , nano – films , current density.

الخلاصة:

استخدم البولي انيلين كمادة أساسية في هذا البحث حيث تم ترسيب أغشية نانوية من الانيلين على شرائح من السليكون نوع n. تم الحصول على سمك مختلف من أغشية البولي انيلين وهي(225و107 و90و74و61) nm من خلال استخدام سرع مختلفة من البرم وهي(1000 و2000 و3000 و4000 و5000)rpm على الترتيب .تم الحصول على منحنيات كثافة التيار– الفولتية (J-V) بظرف الضوء 100 (mw/cm^2) والظلام .تم حساب معلمات خرج الخلية الشمسية وهي فولتية الدائرة المفتوحة (V_{oc}) وكثافة تيار دائرة القصر (J_{sc}) وعامل الملئ(F.F) وكفاءة التحويل(η) . وجدنا ان استخدام البولي انيلين ذو سمك 107 nm يؤدي إلى الحصول على أفضل النتائج من حيث كفاءة التحويل و كثافة تيار دائرة القصر والقدرة العظمى الخارجة.

الكلمات المفتاحية : بولي انيلين ، اغشية نانوية ، كثافة التيار

Introduction

Polyaniline (PANI) has been known for more than one hundred years in its 'aniline black' form, an undesirable black deposit formed on the anode during electrolysis involving aniline and among the conducting polymers. Polyaniline (PANI) is the most promising polymer due to its simple synthesis, controllable electrical conductivity, and good environmental stability(Ajayan *et al.*, 2003). Conductive polymers are organic polymers that conduct electricity, such compounds may be true metallic conductors or semiconductors, the biggest advantage of conductive polymers is their processibility , conductive polymers are also plastics (which are organic polymers) and therefore can combine the mechanical properties (flexibility, toughness, malleability, elasticity, etc.) of plastics with high electrical conductivities and their properties can be fine-tuned using the exquisite methods of organic synthesis(Heeger *et al*,1988).

Among the conducting polymers**,** the use of conducting polypyrrole and Polyaniline blends and composites in rechargeable batteries, dielectric films in capacitors, coating of these conducting polymers to cover conductors in rotating machines, solid dielectric cables, surge suppressors. Schottky diodes and organic field effect transistors are very promising also these materials can also be used as electrodes in electrochemical devices (Khan *et al*, 2009). Organic semiconductors are at the top of the considerable interest due to the possibility to make electronic devices on flexible materials (for example plastic or paper) using cheap technological processes such as spin coating and printing. In order to improve efficiency of an organic semiconductor device, it is important to have a comprehensive knowledge of charge transport mechanism, because it is one of the main factors affecting in the device characteristics (Forrest, 2004; Misra *et al*, 2007).

One important way to convert solar radiation into electricity occurs by the photovoltaic effect which was first observed by Becquerel, it is quite generally defined as the emergence of an electric voltage between two electrodes attached to a solid or liquid system upon shining light onto this system. Practically all photovoltaic devices incorporate a pn-junction in a semiconductor across which the photovoltage is developed and these devices are also known as solar cells (Goetzbergera *et al*, 2003). Recently polymer semiconductor materials have been investigated due to their attractive applications in optoelectronic devices, such as organic thin-film transistors, photovoltaic cells, and organic light-emitting diodes (Vardenya *et.al,* 2005; Yoshida *et.al*,2003).

Many articles on PANI/crystalline Si layer structure heterojunctions were fabricated(Laranjeira *et al*,2002;Saglam *et.al*,2004;Ashery *et al*,2008).(Wang and Schiff, 2007) have fabricated heterojunction solar cells using HCl-doped polyaniline on crystalline n-type Si and found that open circuit voltage for these cells with high-conductivity PANI saturated at 0.51V. (Haitham, 2009) fabricated polymer-on-silicon solar cells by coating different silicon substrates with conductive polyaniline layers where he used different substrates with different resistivities and he performed electrical measurements in both illumination and dark conditions to study the characteristics of photogenerated carriers in the polymer layer contributing to the output of such solar cells. The aim of this work is to fabricate sells of nano-films of Polyaniline (PANI) deposited on silicon wafers by the spin coating process with different thickness and studying the current- voltage(I-V) characteristics.

Experimental Work

Nano-films of Polyaniline (PANI) were deposited on silicon wafers with 1mm thick (n-type silicon) by using spin coating (model 4000) electronic system. The thickness of the PANI films can be controlled by the spin coating process as following:

Spin speed (rpm)	Thickness of PANI film(nm)
1000	225
2000	107
3000	90
4000	74
5000	61

The wafers of silicon (1mm thickness) were ultrasonically cleaned in isopropanol and then dried at 150◦C. The wafers were etched in HF (40%) to remove native oxide then rinsed in double distilled water and dried. Aluminum metal was deposited onto the back contact using vacuum coating machine (Edward vacuum evaporation) while PANI side has been coated with five circular gold electrode and the area of each one is 0.0314 mm^2, as shown in figure 1,so that the average J-V characteristics were taken.

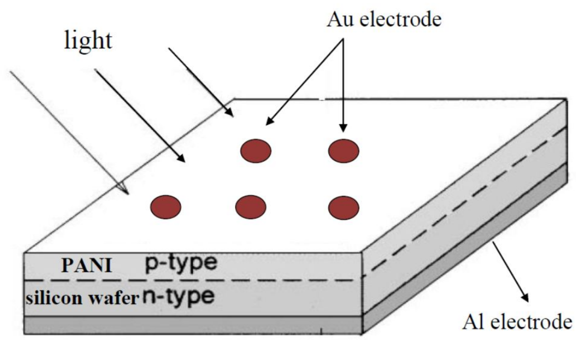

Figure 1:Schematic of PANI/Si samples.

The current-voltage(I-V) characteristics were performed by using Kiethley 6517 A Elecrometry/High resistance. Measurements achieved in both light (100 mw/cm^2) and dark condition. The photovoltaic samples parameter, that is, open circuit voltage (V_{oc}),short–circuit current density (J_{sc}),fill factor(FF), and energy conversion efficiency (η) were calculated .

Results and Discussion

The current density-voltage (*J-V)*characteristics curves under darkness and illumination are shown in figures 2,3,4,5 and 6. All figures illustrate effect the thickness of PANI film on *J-V* behavior and photo-carriers generated throughout the polyaniline should not contribute to the saturation current, and indeed the thicker film might have optically filtered some of the photons. It may be that the polyaniline film has different properties for the different thicknesses, at least near the Si-PANI interface.

The current density-voltage characteristics of the samples under illumination are quite different where under forward bias the principal effect appears to be that the high resistivity substrate led to a significant series resistance.

Figures 2,3,4,5 and 6 show that the maximum photocurrent is not reached at 0 Volts, i.e., under short circuit conditions, but only at more negative bias, corresponding to a higher internal field. This happens in organic solar cells where the polaron pair dissociation is more difficult, e.g. if the active layer is thicker, and therefore at the same (external) voltage the (internal) field at zero bias is lower (Limpinsel *et.al*,2010).

The *J-V* curves can be separated into three regions: (i) at reverse bias and at forward bias up to about 0.6V, the characteristic is nearly symmetrical and is governed by a “leakage” current through the shunt resistance; (ii) at bias corresponding to flat-band conditions, the injection starts, and the exponential region can be distinguished; (iii) the saturation due to the series resistance is observed at higher bias.

The dark currents are fairly similar; there is slightly less dark current for the thicker PANI. Under illumination, all samples show a saturated reverse-bias current. It is surprised that the diode with the thicker polyaniline film has a larger saturation current. Under forward bias, the principal effect appears to be that the high resistivity substrate led to a significant series resistance. Interestingly, under reverse bias the high resistivity substrate shows a substantially larger reverse bias current. This presumably corresponds to an increased diffusion length in the higher resistivity substrate.

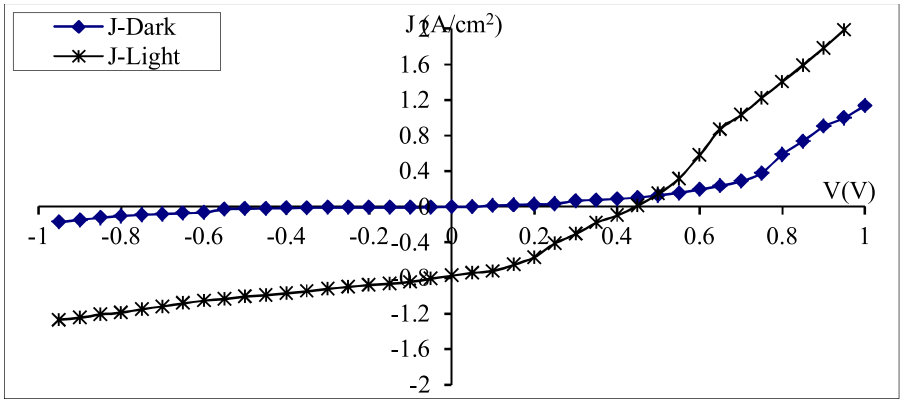

Figure 2: *J-V* characteristics for Si/PANI under Light and darkness, the nano-polyaniline layer was 225 nm thick.

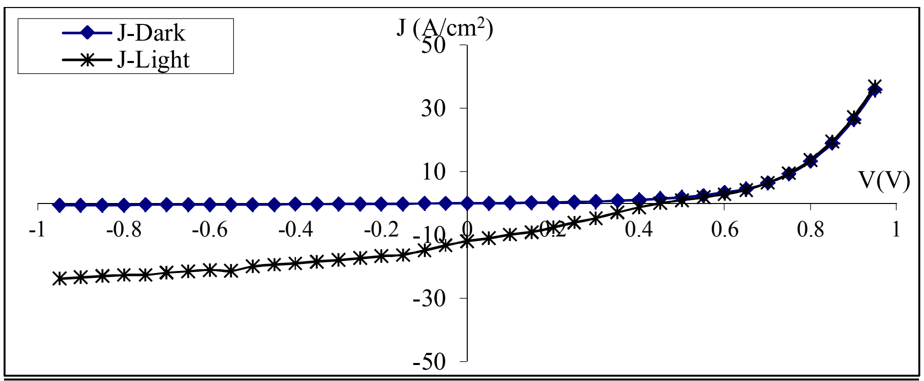

Figure 3: *J-V* characteristics for Si/PANI under Light and darkness,the nano- polyaniline layer was 107 nm thick.

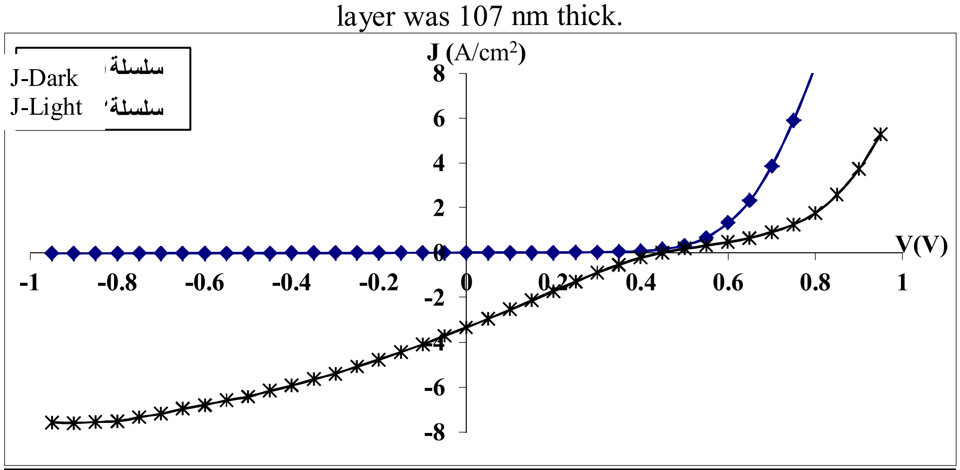

Figure 4: *J-V* characteristics for Si/PANI under Light and darkness,the nano- polyaniline layer was 90 nm thick.

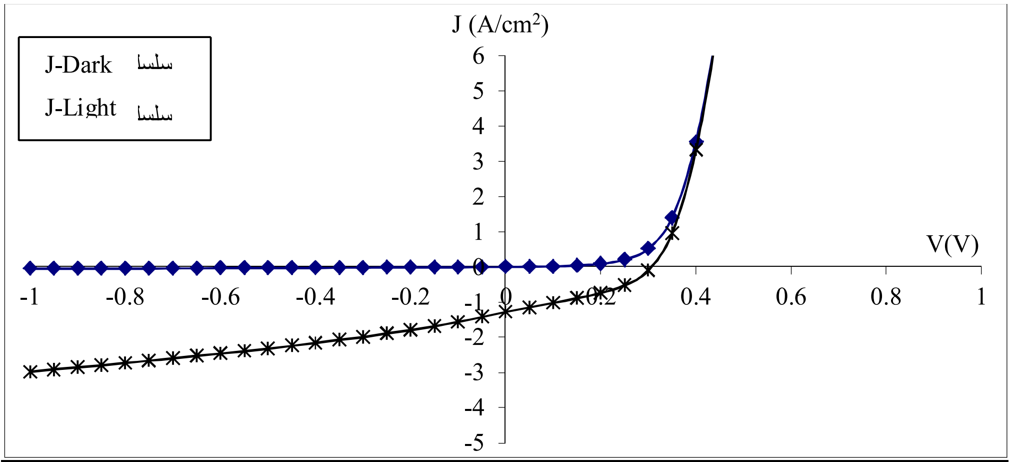

Figure 5: *J-V* characteristics for Si/PANI under light and darkness, the nano- polyaniline layer was 74 nm thick.

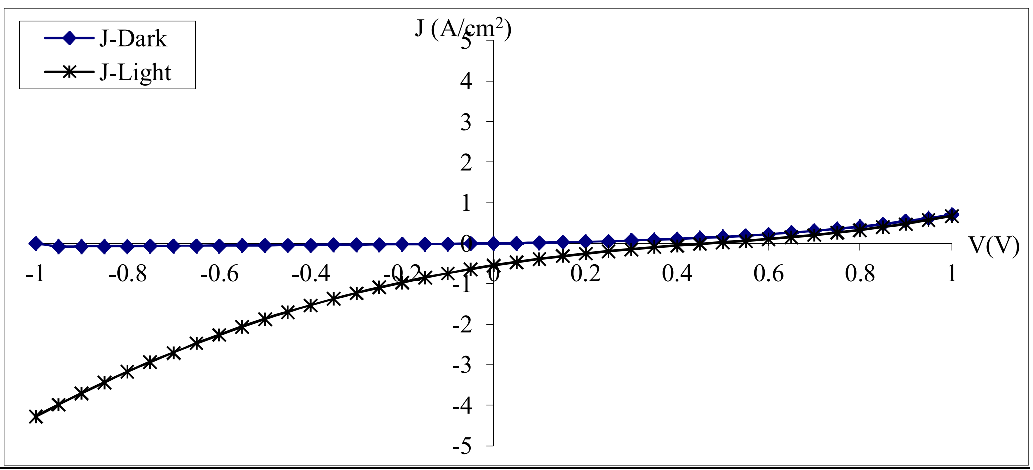

Figure 6: *J-V* characteristics for Si/PANI under Light and darkness, the nano- polyaniline layer was 61 nm thick.

The obtained values of photovoltaic cell characteristics, that is, open-circuit voltage (V_{oc}), short-circuit current density (J_{sc}), fill factor (F.F), and energy conversion efficiency (η) are presented in Table 1.The highest J_{sc} , V_{oc}, and efficiency of these samples obtained using PANI film of 107nm are 10.5 mA/cm^2 ,450 mV, and 1.045 %, respectively, these values are better than obtained by (Morse *et. al* , 2012) .

A high fill factor (strongly curved *J-V* characteristic) is advantageous and indicates that fairly strong photocurrents can be extracted close to the open-circuit voltage. In this range, the internal field in the device that assists in charge separation and transport is fairly small. Consequently a high fill factor can be obtained when the charge mobility of both charges is high.

Conclusion

The current density-voltage (J-V) characteristics depend on thickness of polyanilane nano films that result in different parameters of the photovoltaic samples. We found that the best thickness of PANI film is 107 nm to get best energy conversion efficiency, short –circuit current density and maximum power point.

Table 1: Photovoltaic characteristic parameters of Si/PANI samples.

Parameter	Thickness of nano-PANI film				
	61nm	74 nm	90nm	107 nm	225 nm
V_{oc}(mv)	450	300	440	450	450
J_{sc}(mA/cm^2)	0.54	1.3	3.5	10.5	0.774
V_p(mv)	200	190	200	190	280
J_p(mA/cm^2)	0.25	0.8	1.5	5.5	0.45
P_{mx}(mw/cm^2)	50	1	300	1050	126
F.F	0.205	0.3897	0.1948	0.221	0.3617
ɳ	0.498	0.152	0.3	1.045	0.126

References

Ajayan,P. M.; Schadler, L. S. and Braun,P. V. 2003 In Nanocomposite Science and Technology .Wiley-VCH, Weinheim.

Ashery,A.; Farag, A. A. M. and Salem, M. A. 2008. Fabrication and characterization of in situ polymerized n-polyaniline films grown on p-Si heterojunctions. Microelectronic Engineering; 85(11): 2309–2315.

Forrest,S.R. 2004. The Path to Ubiquitous and Low-cost Organic Electronic Appliances on Plastic Nature. 428: 911 – 918.

Goetzbergera, A.; Heblinga, C. ; Hans-Werner, S. 2003. Materials Science and Engineering . R ;40: 1–46.

Heeger,A. J.;Kivelson,S.; Schrieffer, J. R. and Su, W. P. 1988. Reviews of Modern Physics. 60:781.

Khan, A. S. 2009. Preparation,Characterization and Studies of Conducting Polymer Composites and Blends. Ph.D. thesis ,Quaid-I- Azam Univerity , Pakistan.

Laranjeira,J.M.G.;Khoury,H.J. ; de Azevedo,W.M.;da Silva,E. F. and de Vasconcelos, E.A. 2002. Fabrication of high quality silicon-polyaniline heterojunctions. Applied Surface Science; 190(1–4): 390–394.

Limpinsel, M. , Wagenpfahl, A.,Mingebach, M. and. Deibel, C. 2010, Photocurrent in bulk heterojunction solar cells. Phys. Rev. 81:6-12.

Mikhlif , H. M. 2009. Illumination and Dark Current-Voltage Characteristics of Polymer-Silicon Heterojunction Solar Cells. IJAPLett; 2 (1):15-18.

Misra, A.; Kumar, P.; Kamalasanan, M. N.; Chandra, S. 2006.White Organic LEDs and Their Recent Advancements Semiconductor Science and Technology; 21:R35 – R47.

Morsi, I.,. Ebrahim ,Sh. and Soliman, M. 2012 Construction and Study of Hetreojunction Solar Cell Based on Dodecylbenzene Sulfonic Acid-Doped Polyaniline/n-Si. International Journal of Photoenergy .Volume 2012:1-6.

Saglam, M. ; Biber, M.; akar, M. C and Turut, A. 2004. The effects of the ageing on the characteristic parameters of polyaniline/ptype Si/Al structure. Applied Surface Science; 230(1–4): 404–410.

Vardenya,Z.V.;Heeger, A. J. and Dodabalapurc, A. 2005. Fundamental research needs in organic electronic materials. Synthetic Metals; 148: 1–3.

Wang,W.and Schiff, E. A. 2007. Polyaniline on crystalline silicon heterojunction solar cells. Applied Physics Letters; 91: 3-6.

Yoshida, M.;Uemura,S.; Kodzasa,T.;Ushijima, H. and Kamata, T. 2003 High performance organic FET with double-semiconductor layers. Synthetic Metals;137(1–3): 893–894.