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Voltage dependent photocurrent characteristics of Al/PTCDA/*p*-type Si structures in the light intensity range of 20-100 mW/cm^2

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In this study, The PTCDA solution was coated on the p-Si semiconductor by Spin Coating method to form a very thin film layer. The photoelectric/photovoltaic values of Al/PTCDA/p-type Si structures were investigated in the light intensity range of 20 mW/cm^2 and 100 mW/cm^2 using current-voltage measurements. Thus, the fundamental photovoltaic values such as open circuit voltage (V_{oc}), short circuit current density (J_{sc}), maximum current density (J_{max}), maximum voltage (V_{max}) and maximum power (P_{max}) were acquired as 0.176 V, 1.057×10^{-3} A/cm^2, 7.580×10^{-4} A/cm^2, 0.112 V, 8.484x10^{-5} W; 0.159 V, 4.586×10^{-3} A/cm^2, 2.700×10^{-3} A/cm^2, 0.079 V, 2.1584x10^{-4} W under 20 mW/cm^2 and 100 mW/cm^2 light intensity, respectively. According to the obtained results, the experimental results showed that the electrical properties of Al/PTCDA/*p*-Si structures will improve depending on the light intensity and thus this structure can be developed for photovoltaic applications.

Keywords: *Photovoltaic, Power, Current density, PTCDA, p-Si.*

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1. Introduction

Investigating the light sensitivity of semiconductor structures used in photovoltaic device manufacturing is an important factor. In recent years, semiconductor structures with polymer or oxide interlayers have attracted much more attention due to their suitability for use in photovoltaic applications. Thus, depending on the developing electronic technology, photovoltaic devices are known as indispensable circuit elements today. Therefore, it is very important to investigate the effects of semiconductor circuit elements depending on light intensity. Because the presence of any polymer or oxide layer between the metal and semiconductor layers can change the state of the carrier charges from metal to semiconductor or from semiconductor to metal. In this study, we used perylenetetracarboxylic dianhydride (PTCDA) semiconductor thin layer as the interface layer. Our main aim in this study is to investigate the photovoltaic behavior of Al/PTCDA)/p type Si structure under different light intensities (from 20 mW/cm^2 to 100 mW/cm^2 with 20 mW/cm^2 steps). When we look at the literature, there are many studies on the photovoltaic properties of semiconductor structures [1-7]. For example, in our previous study [4], we studied the photoelectric properties of Al/PDCDA/p-Si structure only in the dark and at room temperature. However, in this study, we examined the main photoelectric properties (such as V_{oc}, J_{sc}, J_{max}, V_{max} and P_{max}) of the same structure under different light intensities (from 20 mW/cm^2 to 100 mW/cm^2). It was observed that the basic photovoltaic properties of the Al/PTCDA/p-Si structure changed depending on the light and there was an increase in charge transitions due to the increase in light intensity [5-7]. This means that the Al/PTCDA/p-Si semiconductor structure is very sensitive to light intensity and its photo-properties change. Experimental studies have shown that

Al/PTCDA/*p*-Si semiconductor structures can be used for photovoltaic cells and their applications.

2. Methods and Materials

In this study, Si and PTCDA semiconductor materials used were purchased. The Si crystal used in the preparation of photodiodes has a thickness of ≈520 µm in the [100] direction and a resistive structure of 5–10 Ω-cm. Firstly, the wafer cleaned using the RCA1 cleaning process to remove contaminants from the semiconductor surfaces [8]. To make ohmic contacts, Al metal (99.99 percent) was evaporated at roughly 10^{-6} Torr in a thermal evaporation system. After, the solution of PTCDA thin organic layer were prepared in chloroform. The semiconductor wafer front faces were coated PTCDA solutions with spin speed of 1000 rpm for 30 s by spin coating method (6800 Spin Coater Series). Following these procedures, to make a rectifier Al metal contact with diameter of 1.5 mm (rectifier contact area=1.76×10^{-2} cm^2) at 10^{-6} Torr pressure Al (% 99.99) metal was thermally evaporated on the surface of organic layer-semiconductor pieces. The current-voltage (*I-V*) measurements of the Al/PTCDA/p-Si semiconductor structure in the dark and in daylight were made using a Keithley 2400 Source-Meter at room temperature. The general measurement setup of the Al/PTCDA/*p*-type semiconductor structure was obtained as shown in Fig. 1.

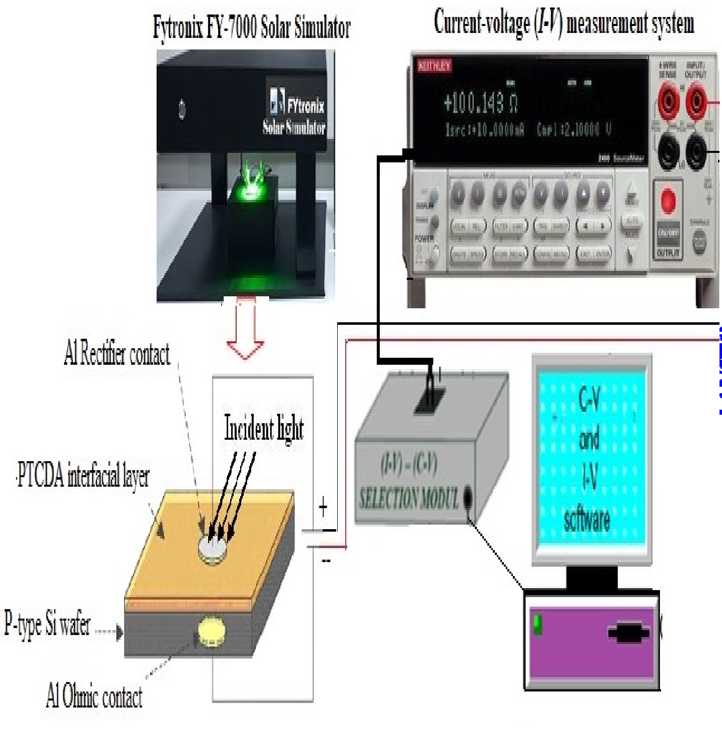

Fig.1. The general measurement setup of Al/PTCDA/*p*-semiconductor structure

3. Results and Discussions

Figs. 2-6 shows the current density-voltage (*J-V*) and power-voltage (*P-V*) curves of Al/PTCDA/*p*-type Si semiconductor structure under light intensity of 20, 40, 60, 80 and 100 mW/cm^2, respectively. In Figs. 1-6, *J-V* curves are shown in blue and *P-V* curves are shown in red. The basic photovoltaic parameters of the Al/PTCDA/p-Si semiconductor structure for each light intensity value are calculated from *J-V* measurements and given both in Table 1 and in the Figs. 1-6, respectively.

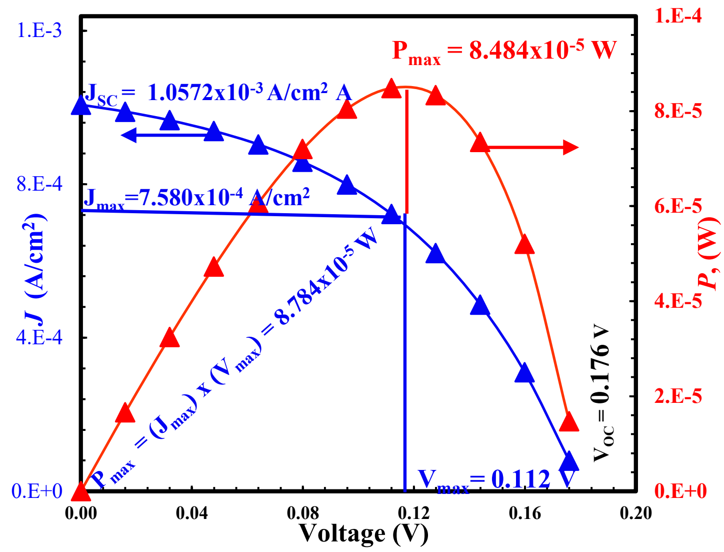

Fig. 2. The ***J-V*** and ***P-V*** plots of the Al/PTCDA/p-type Si structure under 20 mW/cm^2 light intensity

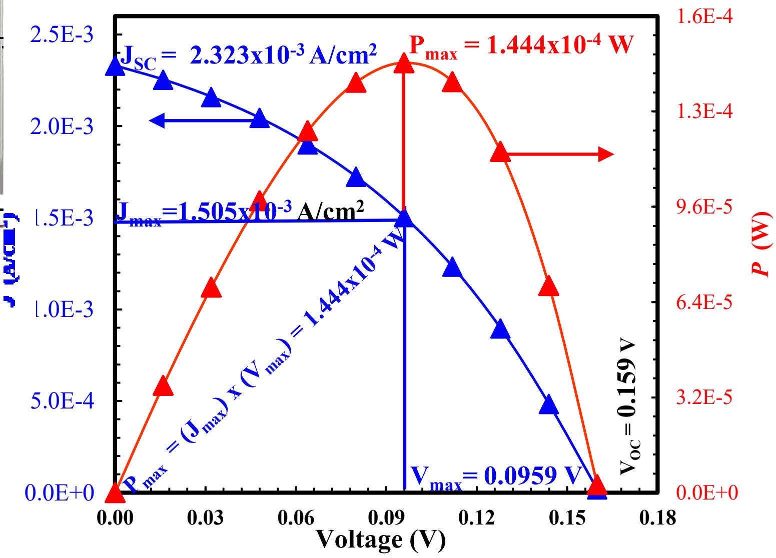

Fig. 3. The ***J-V*** and ***P-V*** plots of the Al/PTCDA/p-type Si structure under 40 mW/cm^2 light intensity

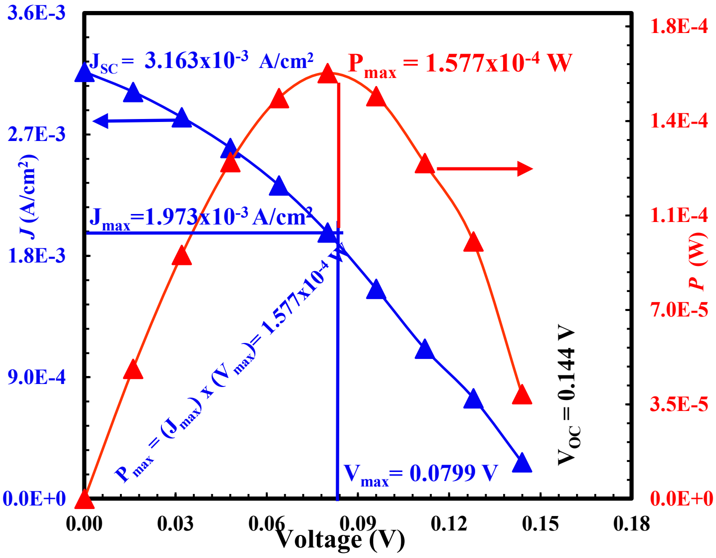

Fig. 4. The ***J-V*** and ***P-V*** plots of the Al/PTCDA/p-type Si structure under 60 mW/cm² light intensity

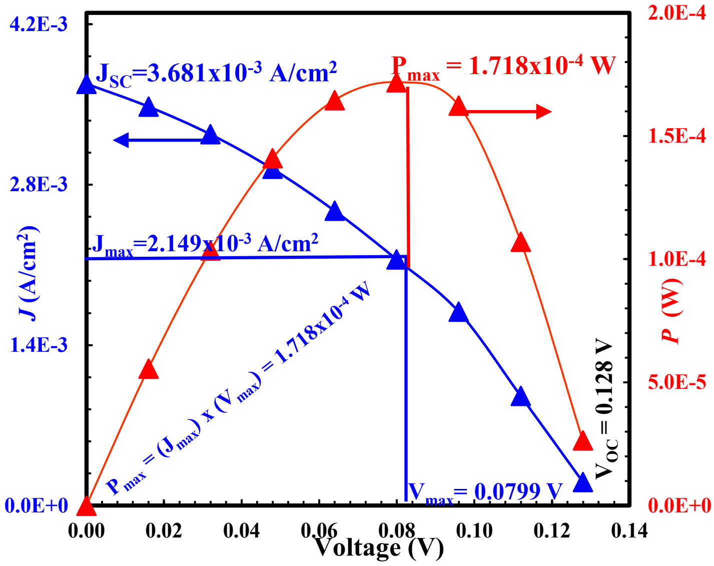

Fig. 5. The ***J-V*** and ***P-V*** plots of the Al/PTCDA/p-type Si structure under 80 mW/cm² light intensity

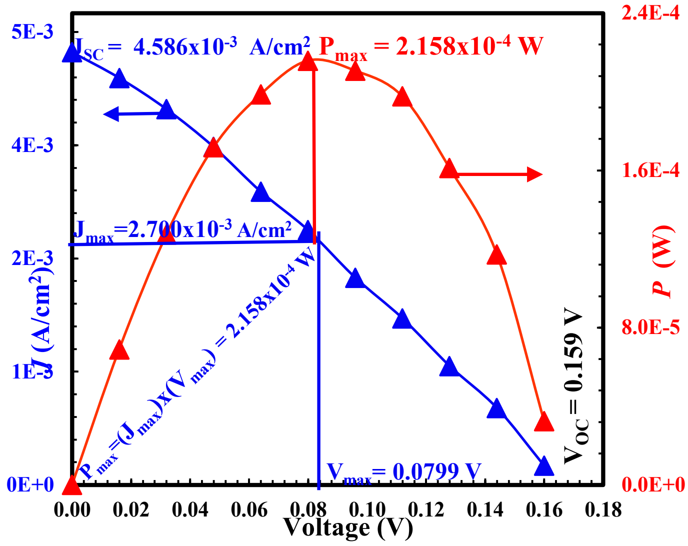

Fig. 6. The ***J-V*** and ***P-V*** plots of the Al/PTCDA/p-type Si structure under 100 mW/cm² light intensity

Table 1. *The main photovoltaic values of the* Al/PTCDA/*p*-Si structure

Intensity (mW/cm²)	V_{max} (V)	V_{oc} (V)	J_{sc} (A/cm²)	J_{max} (A/cm²)	P_{max} (W)
20	0.112	0.176	1.057×10^{-3}	7.580×10^{-4}	8.784×10^{-5}
40	0.096	0.159	2.323×10^{-3}	1.505×10^{-3}	1.444×10^{-4}
60	0.0144	0.144	3.163×10^{-3}	1.973×10^{-3}	1.577×10^{-4}
80	0.0799	0.128	3.681×10^{-3}	2.149×10^{-3}	1.718×10^{-4}
100	0.799	0.159	4.586×10^{-3}	2.700×10^{-3}	2.158×10^{-4}

As seen in Figs. 2-6 and Table 1, the photo voltaic values show a regular increase with the increase in light intensity. That is, the experimental results show that the V_{OC}, J_{SC} and P_{max} values of the Al/PTCDA/p type Si semiconductor structure at 20 mW/cm² light intensity are 0.176 V, 1.0572×10^{-3} A/cm² and 8.484×10^{-5} W, respectively, while at 100 mW/cm² light intensity, the V_{OC}, J_{SC} and P_{max} values increase to 0.159 V, 4.586x10 A/cm² and 2.158×10^{-4} W, respectively. This is evidence that the charge carriers increase with the light intensity [5-10]. It is very important that the maximum power values are high, especially due to the increasing light intensity. Therefore, these photovoltaic values are very good in performance and efficiency of our semiconductor device.

4. Conclusion

We investigated the light intensity dependent fundamental photovoltaic properties such as open circuit voltage (V_{oc}), short circuit current density (J_{sc}), maximum current density (J_{max}), maximum voltage (V_{max}) and maximum power (P_{max})

of Al/PTCDA/*p*-type Si semiconductor structure using current-voltage (*I-V*) measurements. This means that as the photovoltaic values of the semiconductor device increase depending on the light intensity, the number of charge carriers moving from the valence band to the conduction band also increases. Thus, the experimental results show that Al/PTCDA/*p*-type Si semiconductor structure can be used as a photo sensor and optoelectronic device in light applications.

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