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Organic Photovoltaic Device Characterization for Binary P3HT- PCBM and Ternary P3HT-P3OT-PCBM Blends

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Abstract – Organic photovoltaic devices using P3HT: PCBM, P3HT:P3OT: PCBM as an active layer on ITO coated glass substrates were made-up and characterized. Different devices were produced of the same sample in the same conditions and the characteristics were compared with that of a standard thin film polycrystalline silicon solar cell. It was found that the device fabricated from the samples prepared improves the short circuit current (Isc) compared to the silicon solar cell. The Open circuit voltages for the binary devices were also high. But the open circuit voltages (Voc) for the ternary devices and the efficiency were lowest for the Samples**.**

Index Terms – Organic solar cells; Spin Coating; binary P3HT-PCBM blend layer, ternary P3HT-P3OT-PCBM layer

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1 INTRODUCTION

With the advanced utilization rate of fossil fuels, resources are about to diminish in a few decades but the demand for energy usage is constantly increasing. To meet up the higher energy demands, different renewable sources are being used with more attention on solar energy because of its limitless accessibility. The solar energy is collected using solar cells. The first type of solar cells manufactured were the silicon based solar cells which had an efficiency of 27% in theory and 24% practically.[2] The silicon based cells make use of photovoltaic effect.[3] These cells are also known as PV cells. There are different types of solar cells: crystalline silicon based and polycrystalline thin film and bulk organic.[4] With the bridging of practical and theoretical values of efficiency for silicon based cells, the demand for another type of solar cells increased.[5] The organic solar cells were first fabricated and demonstrated by C.W. Tang.[6] The organic solar cells with different organic compounds were fabricated and characterized in the succeeding years. So far, an efficiency of 3-9 % has been achieved. [7]

Organic materials also find application in numerous electronic devices.[8] When used as an active element in optoelectronic devices it is called as Organic Light Emitting Diode (OLED) while with transistors as Organic Field Effect Transistors (OFET). [9–12] An organic cell is fabricated by depositing different layers on a glass substrate. The cells can be of different types such as single layer, double layer, and blend layer type. [13] Each of these has its own advantages and disadvantages. Different procedures are also used to fabricate a cell; for solid source, we can use vacuum evaporation technique.[14] For liquid organic material which is the source in the current work, we use a spin coating method. Detailed studies on the preparation procedures and annealing conditions of devices are published elsewhere.[9,10,13,15]

Here, we have used a polymer based organic solar cell. Out of many commercially available compounds, we have used PEDOT (polyethylene dioxythiophene) and PSS (poly styrene sulfonic acid) as a conducting layer over ITO (Indium tin oxide) coated glass substrate while a blend of P3HT (poly (3-hexylthiophene)) and PCBM ([6, 6]-phenyl-C61- butyric acid methyl ester) is used as the active material. In the way a blend of P3HT, P3OT and PCBM in ternary form [16] is also used as active material. P3HT acts as the donor polymer and PCBM as the acceptor in the active layer. Although, there are three different architectures single layer, blend layer and double layer, we have used blend layer architecture due to a large interface area if the molecular mixing occurs on a scale that allows good contact between alike molecules and most excitons to reach the Donor /Acceptor interface. [11] The polymer P3HT/PCBM was used because there was no other alternative way to get other organic compounds.

2 EXPERIMENTAL Procedure

MATERIALS USED

An ITO coated glass substrate has been used as the substrate for the polymer based organic solar cell. As a smoothening layer for hole transportation, PEDOT: PSS was used. The active materials used were P3HT-PCBM and P3HT-P3OT-PCBM blends. The active layer was a blend layer and thus was referred as blend layer architecture. The materials are shown in the figure 1 below.

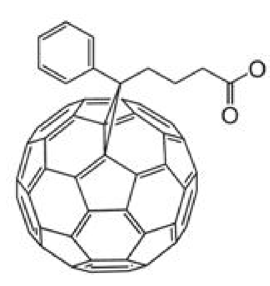

Figure 1, Structure of PCBM

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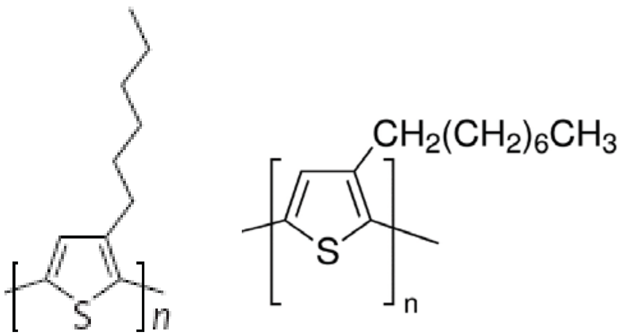

Figure 2, Structure of P3HT and P3OT respectively.

FABRICATION PROCEDURE

The structure of the fabricated device is Al/ P3HT: PCBM/PEDOT: PSS/ITO/Glass. Indium Tin Oxide coated glass substrates were patterned after cutting using by cutter. First, we covered the part of the substrate where we want to use ITO as the bottom electrode with thick plaster which is resistant to hydrochloric acid (HCl) then we exposed the un-covered part to 80% HCl evaporation in beaker for 40 minutes to etch away the exposed ITO. After removing we patterned the ITO glass into 15x15 mm2.

We have prepared P3HT: PCBM solar cell (sample) with three different devices. In the same manner for P3HT: P3OT: PCBM, two samples, four devices for each. The value of the Jsc (short circuit current density) of each of the device is much better compared to the standard thin film silicon solar cell. The open circuit voltage for P3HT: PCBM is also much better. But the FF (fill factor) and PCE (power conversion efficiency) are less (Table 1, 2 &3).

Electrical characterization of the devices was performed using a Linear Sweep Voltammetry and a solar simulator with a source operating at an intensity of 100mW/cm2.

3. RESULTS AND DISCUSSION

Figure 3 shows the characteristics of the P3HT: PCBM organic solar cell representing the three devices fabricated using the blend.

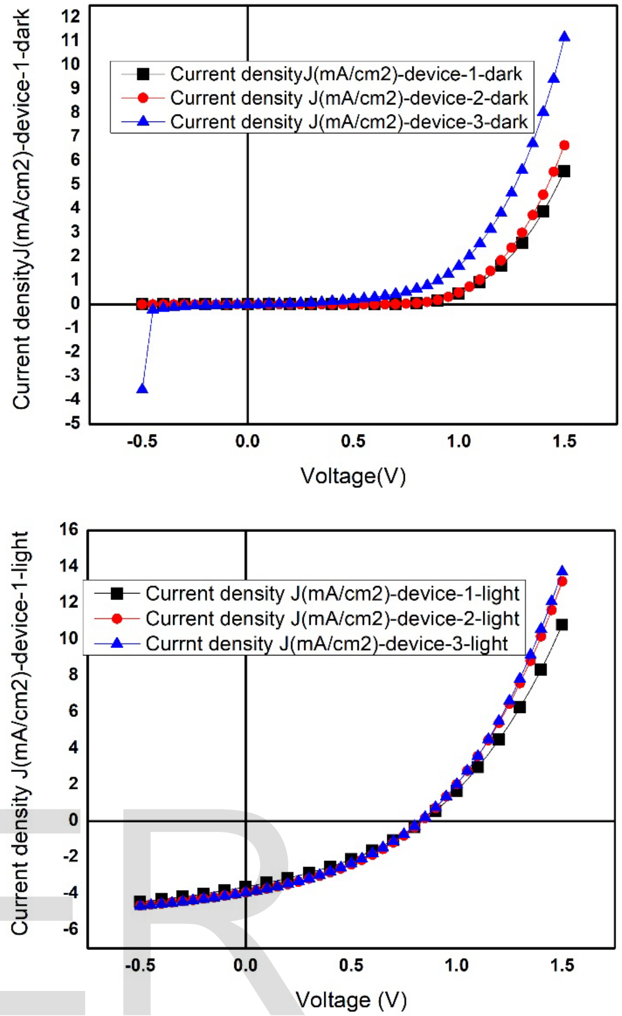

Figure 3, Electrochemical Analyzer: Model, CHI630A Jsc-v curve of binary blends of RR-P3HT-PC61BM (10 mg/ml) in 1,2-dichlorobenzne) in dark and illumination repectively.

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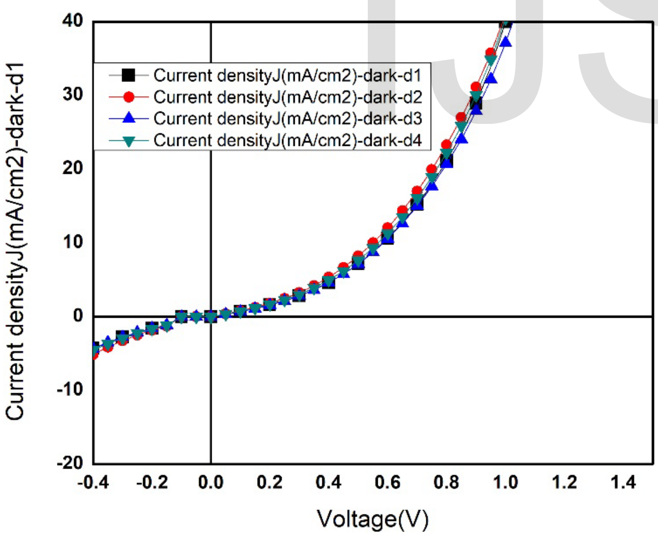
Table 1 COMPARISON OF PARAMETERS OF THE P3HT: PCBM SAMPL SOLAR CELL WITH STANDARD THIN FILM SILICON SOLAR CELL

No	Device	Voc [V]	Jsc [mA/cm2]	FF (%)	PCE (%)
1	P3HT-PC61BM, oDCB	0.8406	3.6253	34.61	1.0547
2	P3HT-PC61BM, oDCB	0.8348	3.9334	36.44	1.1964
3	P3HT-PC61BM, oDCB	0.8294	3.9448	3.9480	1.1685
	Standard thin film silicon cell	0.63	0.04	54	8.4

Figure 4 below shows the characteristics of the P3HT: PCBM-P3OT (10%) organic solar cell representing the four devices fabricated using the blend.



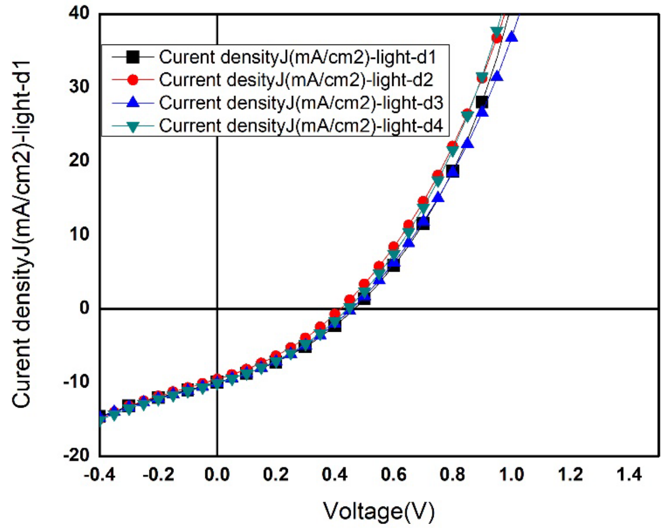
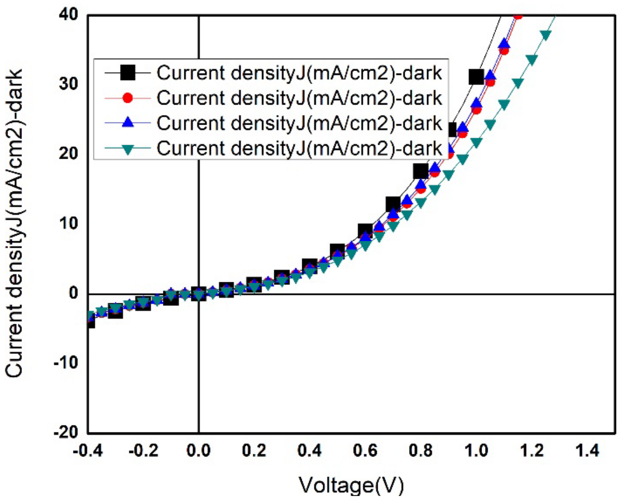


Figure 4 Electrochemical Analyzer: Model; CHI630A Jsc-V curve of ternary blends of RR-P3HT-PC61BM-P3OT 10% (10 mg/ml) in 1,2-dichlorobenzne in dark and illumination repectively

TABLE 2. COMPARISON OF PARAMETERS OF THE P3HT: PCBM SAMPLE 2 SOLAR CELL WITH STANDARD THIN FILM SILICON SOLAR CELL

No	Device	Voc [V]	Jsc [mA/cm2]	FF (%)	PCE (%)
1	P3HT-PCBM-P3OT	0.4662	9.9595	33.8310	1.5697
2	P3HT-PCBM-P3OT	0.4194	9.5413	32.9950	1.3203
3	P3HT-PCBM-P3OT	0.4571	10.0190	33.4410	1.5314
4	P3HT-PCBM-P3OT	0.4433	10.05	33.669	1.4999
	Standard thin film silicon cell	0.63	0.04	54	8.4

Figure 5 below shows the characteristics of the P3HT: PCBM-P3OT (15%) organic solar cell representing the three devices fabricated from the sample.



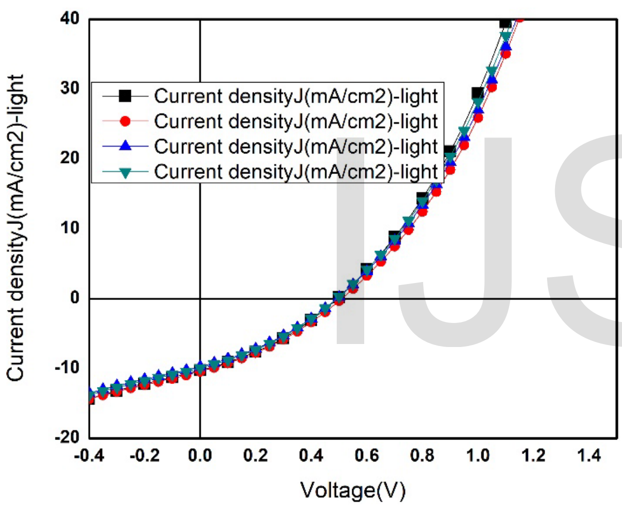


Figure 5 Electrochemical Analyzer: Model; CHI630A Jsc-V curve of ternary blends of RR-P3HT-PC61BM-P3OT 15% (10 mg/ml) in 1,2-dichlorobenzne in dark and illumination

TABLE3. COMPARISON OF PARAMETERS OF THE P3HT: PCBM-P3OT (15%) SAMPLE SOLAR CELL WITH STANDARD THIN FILM SILICON SOLAR CELL

No	Device	Voc	Jsc	FF	PCE
1	P3HT-PCBM-P3OT	0.4943	10.2840	33.5350	1.7047
2	P3HT-PCBM-P3OT	0.5097	10.4420	32.9680	1.7545
3	P3HT-PCBM-P3OT	0.4928	9.7471	33.3540	1.6022
4	P3HT-PCBM-P3OT	0.4910	9.9466	33.4150	1.6318
	Standard thin film silicon cell	0.63	0.04	0.54	8.4

The solar cell parameters of the fabricated devices from the binary samples P3HT-PCBM are tabulated in the table 1. In this case it was found that the procedure improves the short circuit current (Jsc) for the deposited samples and the open circuit voltage (Voc) is also high. But the efficiency and the fill factors are very low for the sample compared to the standard.

The solar cell parameters of the fabricated devices from the ternary samples P3HT-PCBM-P3OT (10%) and P3HT-PCBM-P3OT (15 %) are tabulated in the table 2&3. In these devices also, the same improvement in short circuit current was observed. But the open circuit voltage in both tables (2&3) for the samples are very low.

A detailed study on these types of solar cells and procedures may yield organic solar cells with more efficiency.

4. CONCLUSION

We have prepared P3HT: PCBM solar cell (sample) with three different devices. In the same manner from the ternary sample P3HT: P3OT: PCBM. The value of the Jsc (short circuit current density) of each of the device is much better compared to the standard thin film silicon solar cell. The Voc (open circuit voltage) is also high for the binary case but the FF (fill factor) and PCE (power conversion efficiency) are less comparable, much lower than that of the standard thin film silicon solar cell. The open circuit voltage in the ternary samples are also lower. (Table 2&3).

A detailed study on these types of solar cells and procedures may yield organic solar cells with more efficiency.

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