PREPARATION AND CHARACTERIZATION OF P3HT-PCBM ORGANIC SOLAR CELLS

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Abstract - Organic solar cells using P3HT: PCBM as an active layer on ITO coated glass substrates were fabricated and characterized. Different air annealing procedures and cathode materials were tried and the characteristics were compared with that of a standard thin film polycrystalline silicon solar cell. It was found that the sample prepared with post-deposition air annealing at 130 ^{o}C improves the open circuit voltage (Voc) considerably. Besides, short circuit current (Isc) and the efficiency (η) were highest for the sample with a non annealed active layer. Series resistance (Rs) for this sample was lowest, but 10^3 times higher than that of the silicon solar cell, which in turn may have reduced the efficiency value for the organic cell compared to silicon.

***Keywords** – Organic solar cells; Spin Coating; Photolithography; P3HT:PCBM blend layer; Air annealing.*

I. INTRODUCTION

With the higher consumption rate of fossil fuels, resources are about to deplete in a few decades but the demand for energy usage is continuously increasing. To meet the higher energy demands, different renewable sources are been used with more focus on solar energy because of its unbound availability. The solar energy is harvested using solar cells. The first type of solar cells manufactured were the silicon based solar cells which had an efficiency of 27% theoretically and 24% practically. The silicon based cells make use of photovoltaic effect. Such cells are also known as PV cells. There are different types of solar cells: crystalline silicon based and polycrystalline thin film and bulk and organic. With the bridging of practical and theoretical values of efficiency for silicon based cells, the demand for another type of solar cells augmented. The organic solar cells were first fabricated and demonstrated by C.W. Tang [1]. The organic solar cells with different organic compounds were fabricated and characterized in the succeeding years. So far, an efficiency of 5-6% has been achieved [2-5].

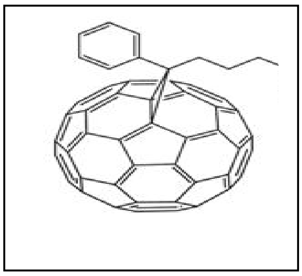
Organic materials find application in numerous electronic devices also. When used as an active element in optoelectronic devices it is called as Organic Light Emitting Diode (OLED) while with transistors as Organic Field Effect Transistors (OFET) [6-9]. An organic cell is fabricated by depositing different layers on a glass substrate. The cells can be of different types such as single layer, double layer, blend layer and laminated layer type [5]. 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. 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 [10-14].

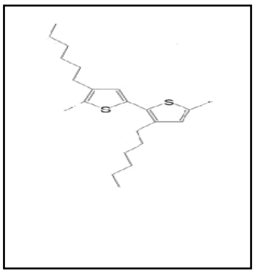
Here, we have used a polymer based organic solar cell. Out of many commercially available compounds, we have used PEDOT (polyethylene dioxythiophene) and PSS (poly styrene sulfonic acid) as a conducting layer over ITO (Indium tin oxide) coated glass substrate while a blend of P3HT (poly (3-hexylthiophene)) and PCBM ([6, 6]-phenyl-C_{61}-butyric acid methyl ester) is used as the active material. . P3HT acts as the *p*-type donor polymer and PCBM as the *n*-type acceptor in the active layer. Although, there are four different architectures-single layer, blend layer, double layer and laminated device, 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 [5]. The polymer P3HT/PCBM is preferred over other organic compounds because of its higher efficiency and low processing cost. The advantages of using polymer PV cells are that they offer mechanical flexibility, durability and unlimited potential from advances in organic chemistry. The performance of these cells is limited by low carrier mobility & short exciton diffusion lengths of polymers.

II. EXPERIMENTAL PROCEDURE

A. 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 is used. The active material used is P3HT-PCBM blend. The active layer is a blend layer and thus is referred as blend layer architecture. The source materials of research specified above are commercially purchased from Sigma-Aldrich.





(1a)
(1b)
Figure. (1a): Structure of P3HT, (1b): Structure of PCBM.

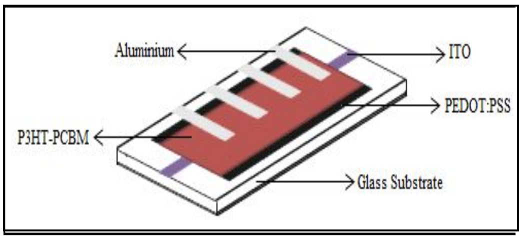


Figure 2: Architecture of P3HT: PCBM based organic solar cell fabricated.

As negative electrode, different elements have been used such as – aluminium and calcium. The organic compounds so chosen are commercially cheap as compared to other organic compounds available in the market.

B. Fabrication Procedure

The structure of the fabricated device is Al/ P3HT: PCBM/PEDOT: PSS/ITO/Glass. Indium Tin Oxide coated glass substrates were cleaned in an ultrasonic cleaner and patterned by photolithography. ITO was used as the anode. Each substrate was then treated with UV light to improve the wettability of diluted PEDOT: PSS in deionized water. PEDOT: PSS was then spin coated on these substrates using Holmarc spin coater and then annealed in air for 10mints. A blend of P3HT: PCBM was made in chlorobenzene in the ratio 10mg: 10mg: 1ml and filtered using a micro-syringe. Then it was spin coated on the PEDOT: PSS layer. Final contact material aluminium was thermally evaporated in a vacuum of around 2×10^{-6} Torr through a shadow mask to form the cathode. Thermal evaporation was done in a Hind Highvac vacuum coating unit.

We have prepared P3HT: PCBM solar cells with different post deposition conditions such as air annealed (130^{o}C) active layer (sample 1), Non-annealed active layer (sample 2), with Ca electrode and air annealed at 100^{o}C (sample 3). The reason for using Ca electrode is that work function of Ca is very low. This gives higher built-in voltage which will eventually help in improving the Jsc (Current Density) of the solar cell. The layer of Al is used as a protective layer to Ca to avoid its oxidation [14].

Electrical characterization of the devices was performed using a Keithley 2400 digital source meter and a solar simulator with xenon DC 350 (Autosys) operating at an intensity of 100mW/cm^2.

C. Precautions

The cell shall not be exposed much to air directly during the process of fabrication as they are degradable. Presence of dust particles or of any other foreign material is avoided by filtering the solutions.

III. RESULTS AND DISCUSSION

Figure 3 shows the dark characteristics of a typical non annealed P3HT: PCBM solar cell fabricated.

Shown in figure 4 is the characteristic of the P3HT: PCBM organic solar cell in the presence of light.

We have prepared P3HT:PCBM solar cells with different post deposition conditions such as air annealed

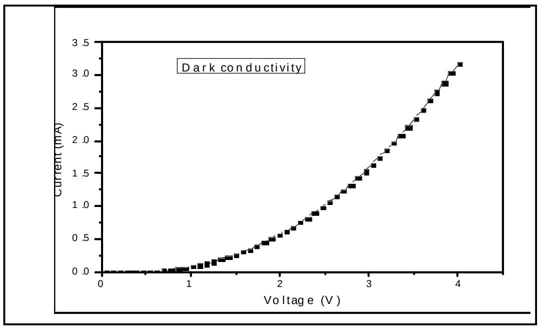


Figure 3: Dark Characteristics of Organic Solar Cell.

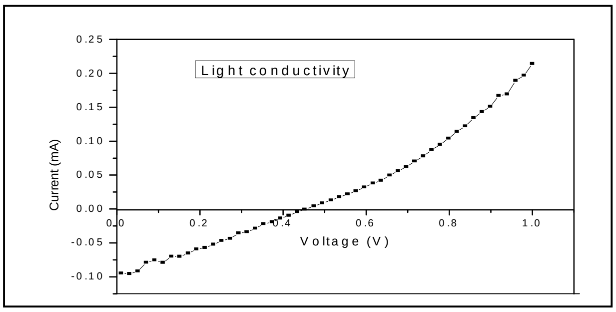


Figure 4: Light characteristics of a typical non annealed P3HT: PCBM solar cell fabricated (Sample 2).

(130^{o}C) active layer (sample 1), Non-annealed active layer (sample 2), with Ca electrode and air annealed at 100^{o}C (sample 3). All the samples were with a small active area of 0.06 cm^2. The solar cell parameters of all the fabricated devices are tabulated in the table 1.

It is found that air annealing at 130 ^{o}C improves the open circuit voltage (Voc) considerably for the deposited samples and the short circuit current (Isc) and the efficiency (η) were highest for the sample with non annealed active layer. Besides, series resistance (Rs) for this sample was lowest, but 10^3 times higher than that of the polycrystalline thin film silicon solar cell purchased. Fill factor values were almost similar for all the samples including the silicon sample. Following are the parameters calculated for the standard polycrystalline thin film silicon solar cell: Area of the active cell = 4 cm^2, V_{oc} = 0.63 V, I_{sc} = 0.04 A, FF = 0.54, η = 8.4 %. Shown in figure 5 is the *IV* characteristic of a standard thin film silicon solar cell.

A detailed study on these types of solar cells and annealing procedures like vacuum annealing for crystallization of active layers and optimum series resistance may yield organic solar cells with more efficiency and is underway in table 1s.

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

Sample	Device	Voc (V)	Isc (A)	FF	η (%)	Rs (Ω)
1	Air annealed (130°C) active layer	1.01	0.84 x 10^{-6}	0.413	0.01	6 M
2	Non-annealed active layer	0.46	100 x 10^{-6}	0.48	0.4	0.005 M
3	with Ca electrode and air annealed (100°C)	0.75	1.37 x 10^{-6}	0.37	0.01	0.5 M
4	Standard thin film Silicon solar cell	0.63	0.04	0.54	8.4	5

IV. CONCLUSION

We have prepared solar cells using P3HT: PCBM active layer in different post deposition conditions. We have compared the parameters with a standard silicon solar cell. It is found that air annealing at 130 °C improves the open circuit voltage (Voc) considerably for the deposited samples and the short circuit current (Isc) and the efficiency (η) were highest for the sample with non annealed active layer. Besides, series resistance (Rs) for this sample was lowest, but 10^3 times higher than that of the silicon solar cell. A detailed study on these types of solar cells and annealing procedures like vacuum annealing for crystallization of active layers and optimum series resistance may yield organic solar cells with more efficiency.

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