

# The Fabrication of Bulk Heterojunction P3HT: PCBM Organic Photovoltaics

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**Abstract.** Bulk heterojunction Organic photovoltaic (OPV) devices are gaining a lot of interest due to their potential for ease of processing and lower manufacturing cost sustainable energy generation. In consequence, the number of studies into the properties and characteristics of organic solar cell devices has been increased to improving their power conversion. A further advancement over past decade has shown that improved efficiency could be obtained by mixed of poly(3 - hexylthiophene) (P3HT) and [1] - phenyl - C61-butyric acid methyl ester (PCBM) as an active layer. A series of optimizations of this P3HT: PCBM blends, such as the mixture ratio variation, the annealing treatments, and solvent treatment, have been emerged to improve the efficiency of the OPV. As a result, significant improvements were achieved. Here, we report the fabrication heterojunction devices of 2.9 % efficiency. This result has been achieved using the configuration of a typical heterojunction solar cell modules consists of layered glass/ITO/PEDOT: PSS/active layer/cathode interlayer

**Keywords.** Bulk heterojunction, efficiency, OPV, P3HT, and PCBM.

## 1. Introduction

Renewable energy sources are recognized as a technology that plays a significant role in lowering the global warming effect by reducing CO<sub>2</sub> emissions to the atmosphere. The trend of industries reveals that renewable energy investment has been increasing which reflect the urgency of study into these type of energy source. The capacity of the renewable power generating showing a largest annual enhancement ever in 2016, with an estimated capacity added of 161 GW [1, 2]. Compare to 2015; the total renewable power capacity increased up to nearly 2.017 GW at years end [1]. Solar cells indicated for the first time contributed to greatest additional energy capacity than any other generating technology (34 %)[2].

Today, crystalline silicon solar cells dominate the solar power market. Global production of this type photovoltaics and modules rose significantly. This technology has been impacting the world which encourages the expansion of energy source from fuel to green energy. Recently, silicon solar cells have reached a conversion efficiency of 25.6 % [3]. However, the shortcoming facing researcher of this type photovoltaics is not only their efficiency conversion but also the expensive of fabrication cost, both regarding energy and money.

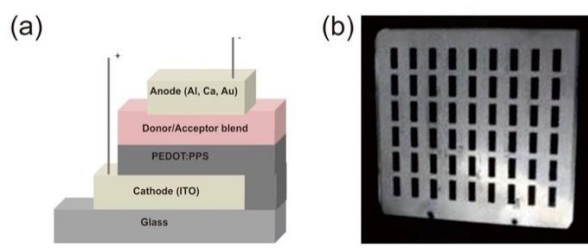


One solution that possibly overcomes these drawback is organic photovoltaics (OPV) [4, 5]. In most straightforward term, an organic photovoltaic is a device that deals with organic materials for absorption of light and transport of charge in producing electricity directly from the sun by the effect of photovoltaics. Here we report the fabrication of OPV using blended of poly(3- hexylthiophene) (P3HT) and [6,6]-phenyl-c61-butyric acid methyl ester (PCBM) as an active layer. Investigation of this P3HT: PCBM mixed, using UV-VIS spectroscopy is also presented.

## 2. Materials and methods

### 2.1. Device Fabrication

The structure of the OPV based P3HT: PCBM that was used in this research is shown below in Figure 1a. The anode consisted of glass slides pre-patterned with indium tin oxide (ITO) were obtained from Kintec Company, Hong Kong. The ITO glasses were prepared using the following cleaning procedure: (1) ITO substrate was immersed in acetone for 5 min and then sonicated for 20 min. (2) Each substrate was then dried under a flow of Nitrogen. (3) Furthermore, the substrates were then stored in isopropyl alcohol (IPA) for sonication for further 15 min. (4) The glasses were then again dried under a Nitrogen flow. (5) Finally, the pre-cleaned substrates were put in the UV – ozone for 10 min ready for use. A 70 nm layer of poly(3,4-ethylene dioxythiophene)/ poly(styrene sulfonate) (PEDOT: PSS) were deposited on the top of the ITO pattern and were annealed at 140 °C for 30 min. This layer seals the anode layer from oxygen and prevents the immigration of electron to the cathode. Also, the PEDOT: PSS film acts as a layer for hole transport [7]. A weight ratio of 1:1 was used for P3HT (sanitized in the COE of Newcastle University) and PCBM (purchased from Lumtec) blends. The solution of P3HT: PCBM blends (20 mg/mL in  $\text{CHCl}_3$ ) was stir sonicated for 25 min and then immediately spin coated at 2000 rpm for 1 min resulting in a 70 nm thick of an active layer. The P3HT: PCBM blended films were dried at 140 °C for 4 min and then introduced to a nitrogen glove box, where they are placed into a substrate holder for cathode evaporation, as shown in Figure 1b. This holder can accommodate 54 substrates.



**Figure 1.** (a). The structure of bulk heterojunction OPV, (b). The sample holder

Aluminium/Al electrodes were then evaporated onto the central region of the slides at a deposition rate of 2 A/s and a pressure lower than ( $2 \times 10^{-6}$ ) Torr. The final thickness of this Al electrode was 110 nm.

### 2.2. Device Characterization

During this project, A Varian Cary 6000i UV-vis spectrophotometer with a scanning wavelength of 200 nm to 900 nm was used to obtain the absorption of the P3HT: PCBM blend films. The relevant films were spin cast on quartz substrates. A critical procedure was performed before any measurement which is a baseline reference scan with no sample present to remove artifacts introduced by spectrophotometer.

AM 1.5 solar simulator product in a nitrogen atmosphere is used in obtaining a spectrum of light approximating natural sunlight to test OPV devices. For this testing, the instrument is used to get the electrical characteristics of the cells which lead to the quality of the photovoltaic device. The solar simulator consists of three main components: associated power supply and a light source; filters and

optics to modify the output beam to meet the classification requirements; and the necessary controls to operate the simulator and adjust irradiance. The filter was used for changing the Xenon (Xe) lamp spectrum to be more like sunlight. The target irradiance is  $1000 \text{ W/m}^2$  (1 sun). Finally, the current, voltage and irradiance signals are recorded by the system simultaneously. The power efficiency and fill factor are determined directly by Labview software. To obtain I-V data, we used the following step. The cell was loaded into a holder and then connected to a Keithley 2400 Sourcemeter to systematically sweep the potential between the two electrodes of the devices. During this process, the current produced by the device under test was recorded, and I-V curve was then generated.

### 3. Results and discussion

#### 3.1. Absorbance Characteristic

Figure 2 showing the UV-vis absorbance spectrum of the bulk P3HT: PCBM film as a spin-coated film and indicated that the UV-vis spectra of the film presenting the expected typical spectra with a superposition of both component which PCBM-based bands and absorption P3HT-based band [8, 9]. It establishes that the absorption P3HT-based peak at 520 nm provides information on conjugation degrees of the polymer chains while the presence of the relative size of the P3HT vibronic shoulder at 610 nm indicated the degree interchain order [9–11].

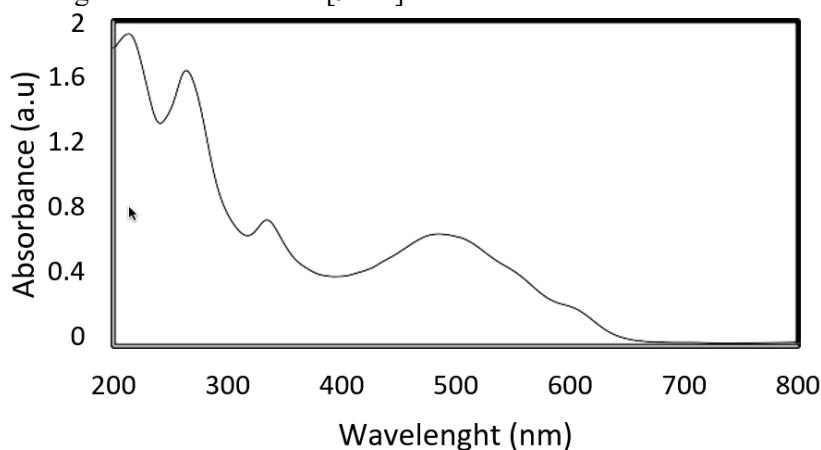
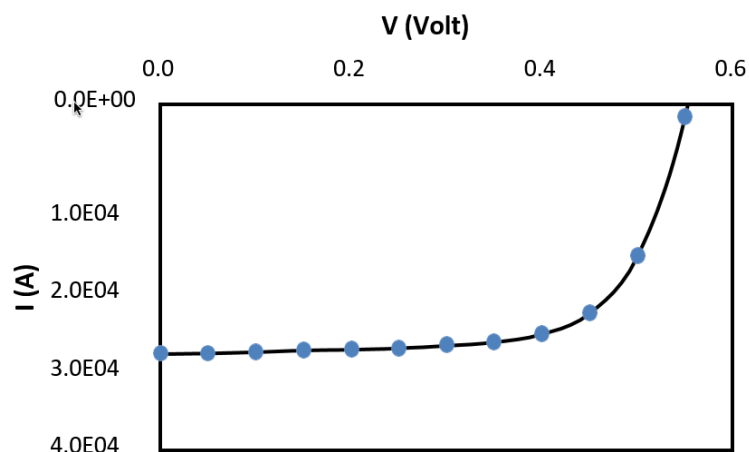


Figure 2. The UV-vis absorbance spectrum of the bulk P3HT: PCBM film

#### 3.2. Bulk Heterojunction OPV Characteristic

Bulk heterojunction P3HT: PCBM were fabricated with a layer structure of glass /ITO/ PEDOT: PSS /P3HT: PCBM/ Ca/Al. Current versus voltage (I-V) characterization as shown in Figure 3 has been performed under AM 1.5 simulated with the key parameters is listed in Table 1.

The device performance is showing a power conversion efficiency (PCE) of 2.9%, short-circuit current density ( $J_{sc}$ ) of  $-7.6 \text{ mA}\cdot\text{cm}^{-2}$ , open circuit voltage ( $V_{oc}$ ) of 0.6 V, and fill factor (FF) of 0.7. The characteristics of this cell are comparable to those obtained for devices fabricated with unannealed P3HT: PCBM organic solar cells [11, 12]. The low  $V_{oc}$  can be associated with the interface between the P3HT and PCBM molecules [5, 13] and the loss charge carriers at the electrodes. Also, The Fill Factor that appeared is lower than the ideal value could be assigned to the voltage dropping due to the high of the series resistant and the current leakage through the shunt resistant of the device [5, 14].



**Figure 3.** IV curve of the bulk heterojunction P3HT: PCBM

**Table 1.** The key parameters of the OPV

Parameter	Value
Efficiency (%)	2.9
$V_{oc}(V)$	0.6
$I_{sc}(A)$	$-2.9 \times 10^{-4}$
$J_{sc}(mAcm^{-2})$	-7.6
Fill Factor	0.7

#### 4. Conclusions

In conclusion, we have produced a bulk heterojunction P3HT: PCBM organic photovoltaics devices with the efficiency of 2.9 %. Absorbance characteristic of polymer P3HT/PCBM film for use in thin-film electronics is also presented, which shows the expected typical spectra with a superposition of both components which PCBM-based bands at 260 nm and 330 nm and absorption P3HT-based band at 520 nm. These results could be an essential milestone in evaluating the performance of bulk heterojunction P3HT: PCBM organic solar cells for further improvement.

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