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Investigations of the incident light angle effect on the organic photovoltaics devices performance using varied acceptor ratio

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Abstract

Organic photovoltaic devices (OPV) have received great attention in the last decades, due to their advantages in fabrication processes and the low cost of organic material. In this report, the active layer of the device is prepared from poly (3-hexylthiophene) (P3HT) (20 K): (phenyl C61 butyric acid methyl ester) (PCBM) with various acceptor ratios (1:0.5–2). The surface morphology of the active layer thin films was investigated by analysing their optical microscope image using Image J software. The active layer thin films were characterized optically to calculate the optical properties of the active layer. The internal absorption of the device is calculated using the optical modelling technique. Then, optical modelling is utilized to optimize the device performance based on changing the donor: acceptor ratio and predicting the internal quantum efficiency (IQE) of the devices. The optimum current density values of the device (*Jsc*) were found to vary in about (11–14 mA cm^{-2}) compared with the measured data (3.8–8 mA cm^{-2}). The internal quantum efficiency (IQE) was identified from measured and modelled *Jsc* and its percentage confirmed that the best blending ratio of P3HT: PCBM is (1:0.8–1), associated with the IQE percentage 54%–45%. Additionally, the effect of incident light angle was examined by using optical modelling technique and the findings revealed that the current density *Jsc*, gradually increased with the incident angle between (0–45) degrees and then suddenly decrease at the angle of 60 degrees due to the reflection that occurs at Air/glass interface at large angles.

1. Introduction

In the academic and industrial field, bulk heterojunction (BHJ) organic solar cells (OSCs) devices have attracted great attention due to their application in fabricating large-scale OPV, lightweight, flexible, and low-cost solar cells [1, 2]. The main advantage of using organic photovoltaic materials is the potential to apply or paint the photoactive layer ink onto the large flexible substrates [3]. In general, the organic BHJ solar cells devices contain two electrodes (anode and cathode), and between them, the photoactive layer is placed, which is a blend of donor and acceptor material. The organic photovoltaics materials can be classified into two classes, polymer or small molecular material cells [4]. The donor (polymer) material represents the main light absorber in the device as it absorbs 70%–80%, in contrast to an acceptor (small molecular) that absorbs around 20%–30% [5]. Nowadays, the highest efficiency of organic cells is recorded (18.2%) achieved by Liming Ding and his group based on his study published in 2021 [6].

When the light incident passes through the device, the free charge career will be generated according to the following internal charge generation process: Light absorbs by the active material to create a pair of hole-electron at critical conditions called (exciton) (1) (see figure 1). The exciton will then diffuse toward the interface between the donor/acceptor materials (2). After that, the exciton will dissociate due to the offset between the energy level of donor/acceptor material to create a free hole and electron followed by charge transport (3) and (4), and charge extraction (5) at the electrode of the device. As it's aware the real device is not an ideal system so the generated charge will be governed by the charge carrier recombination process (6), which occurred due to the morphology defects in the active layer [7, 8].