Stability analysis of organic solar cells fabricated with PTB1:PCBM in accordance with established ISOS-D1 protocols

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The fabrication of organic solar cells (OSC) in the last ten years has attracted interest due to potential application in the different fields [1, 2]. Actually, the polymers of low-band gap are being used as promised materials to increase the power conversion efficiency (*PCE*). However, the degradation of performance in OSCs such as power conversion is a crucial point and has been seldom studied [3, 4]. ISOS-D1 protocols in the last years have been applied to quantify the lifetime in OSC [5]. Using these protocols is possible to compare the lifetime from other similar devices.

In this work, we fabricated bulk heteterojuction (BHJ) OSC using as polymeric material of low-band gap Poly((4,8-bis (octyloxy) benzo (1,2-b:4,5-b') dithiophene-2,6-diyl) (2-((dodecyloxy) carbonyl) thieno(3,4-b) thiophenediyl)) (PTB1) in combination with [6,6]-phenyl C_{61}-butyric acid methyl ester (PCBM) material. The samples were exposed under nitrogen and air environment and encapsulation conditions. To analyze the degradation process in OSC was applied ISOS-D1 protocols. From the parameters got of current density-voltage characterization (i.e. open circuit voltage (V_{OC}), short circuit current density (J_{SC}), fill factor (*FF*) and *PCE*) were used to follow stability process on the OSC during 5300 h. The normalized *PCE* parameter versus time was studied and they are then related to the possible predominant degradation mechanisms that are present in the device [6].

The OSC structure was manufactured with the stack ITO (120 nm) / PEDOT:PSS (40 nm) / PTB1:PCBM (90 nm) / Ca (25 nm) / Ag (100 nm) as is shown in Fig 1. Three groups of devices were prepared to study the degradation process of their electrical characteristics under 3 different environments: a) in electronic grade 99.999% N_2 (H_2O < 0.1 ppm, O_2 < 0.1 ppm), b) in ambient conditions (60 ± 5% RH) and c) encapsulated. A light intensity of 100 mW/cm^2 was used to test the organic solar cell devices under illumination. In addition *J–V* dark curves were collected for all the photovoltaic devices. Active area used in OSC was 0.09 cm^2.

Fig. 2 is shown the *J–V* curves under illumination for samples under encapsulation. The average performance parameters for all devices such as V_{OC}, J_{SC}, *FF* and *PCE* just after fabrication were 577±8 mV, 11.4±0.7 mA/cm^2, 67.1±3.7% and 4.4±0.2%, respectively. In accordance with ISOS-D1, the lifetime (T_{S80}) for samples under nitrogen, air and encapsulation was 1000 h, 4 h and 48 h, respectively as is shown in Fig. 3. The mechanism responsible for the slow degradation in devices exposed under N_2 was identified to the intrinsic chemical reactions of the polymeric materials. Samples under air environment, the mechanisms responsible for the extremely rapid degradation were associated to chemical reaction of the active layer and/or electrodes with water and oxygen that diffuse into devices. Water was the dominant degradation mechanism. Finally solar cells under encapsulation the main mechanism was associated with the oxygen that takes place product of the encapsulation. The main source of oxygen in these conditions might be the encapsulating/sealing material (EPT-HM), as it contains oxygen in its molecular structure. These results show that the procedure followed in this work under ISOS-D-1 protocols has permitted to gain knowledge of the main degradation mechanisms of the PTB1 donor polymer in the solar cells and thus to improve their reliability and durability.

Acknowledgements

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Figures

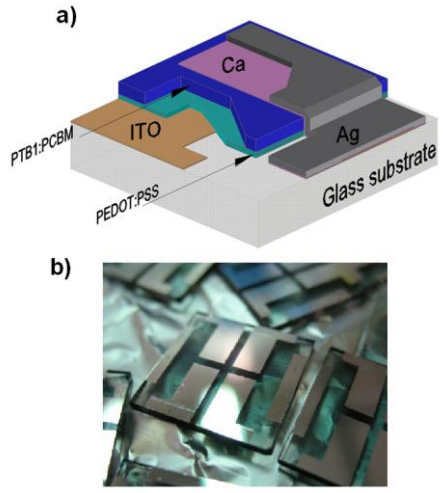

Figure 1 a) Schematic structure PTB1:PCBM of organic bulk heterojunction solar cell, b) physical representation of device.

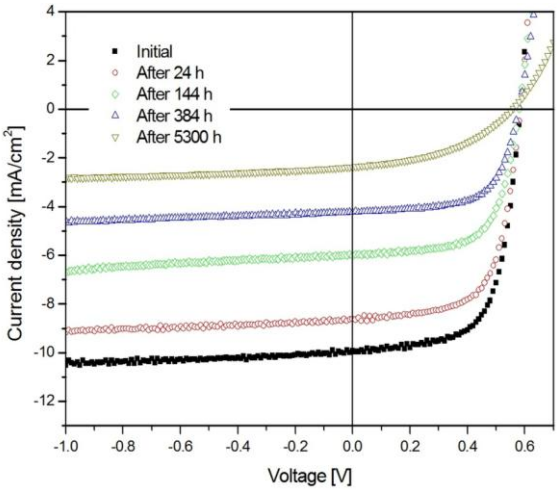

Figure 2 Illuminated *J–V* curves of PTB1:PCBM solar cells under encapsulation during 5300 h.

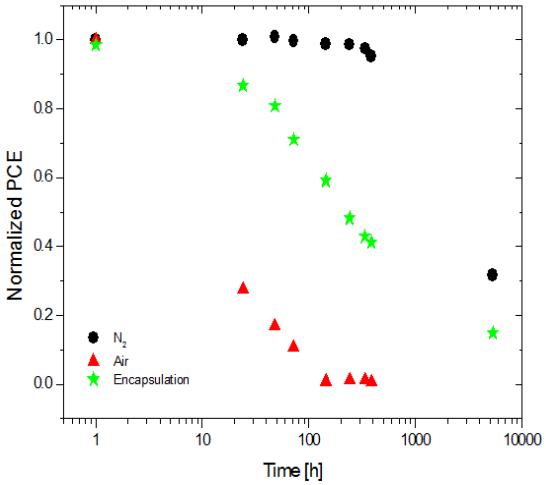

Figure 3 Stability *PCE* normalized versus time from organic solar cells under N_2, air and encapsulation.