

# Elucidating the origin of the improved current output in inverted polymer solar cells



P. Morvillo\*, R. Ricciardi, G. Nenna, E. Bobeico, R. Diana, C. Minarini

ENEA, P.le E. Fermi 1, 80055 Portici, Italy

## ARTICLE INFO

### Article history:

Received 23 December 2015

Received in revised form

19 February 2016

Accepted 22 March 2016

Available online 6 April 2016

### Keywords:

Polymer solar cells

Inverted architecture

Impedance spectroscopy

## ABSTRACT

In this work, we compared the photovoltaic performance of standard and inverted polymer solar cells with the aim to elucidate the origin of the different current output. We realized devices with both architectures using a blend film of poly[(4,8-bis-(2-ethylhexyloxy)-benzo[1,2-b:4,5-b']dithiophene)-2,6-diyl-alt-(4-(2-ethylhexanoyl)-thieno[3,4-b]thiophene)-2,6-diyl]//[6,6]-phenyl C<sub>71</sub> butyric acid methyl ester (PBDTTT-C:[70]PCBM). The standard cell sequence is ITO/PEDOT:PSS/PBDTTT-C:[70]PCBM/Ca/Al and the inverted one is ITO/ZnO/PBDTTT-C:[70]PCBM/MoO<sub>3</sub>/Ag. The inverted architecture shows better performances compared to the standard one mainly in terms of current output. The optical modeling has revealed that this architecture allows more photons to be absorbed in the blend film, giving rise to an higher current output, although the observed improvement cannot be completely attributed to the calculated higher absorption of the incoming light. By using the impedance spectroscopy analysis, we found that the inverted device architecture has higher values for the interface trap time constant and the density of interface states. Both parameters contribute to retain the charge collection efficient, compared to the standard configuration, despite the increased charge carrier density and to further improve the current output.

© 2016 Elsevier B.V. All rights reserved.

## 1. Introduction

Polymer solar cells (PSCs) have attracted an increasing attention in the last years due to the possibility to realize lightweight, flexible and large area devices using low cost roll-to-roll fabrication methods [1–3]. The most promising device architecture is based on the bulk heterojunction (BHJ) structure where the photoactive layer is a nanoscale interpenetrating network of conjugated polymer donor and fullerene derivative acceptor [4–6]. Recently, the performance of PSCs has significantly increased thanks to the development of new photoactive materials, the optimization of device fabrication conditions, the development of new device structures and the engineering of contact interfaces [7]. Actually, power conversion efficiency (PCE) surpassing 10% has been achieved for single-junction devices [8].

Two device architectures are mainly used to build PSCs, the so-called standard structure, where the transparent conductive anode (i.e. indium tin oxide, ITO) is covered by a thin hole conducting layer, such as poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT:PSS), the photoactive layer and a low-work-function metal

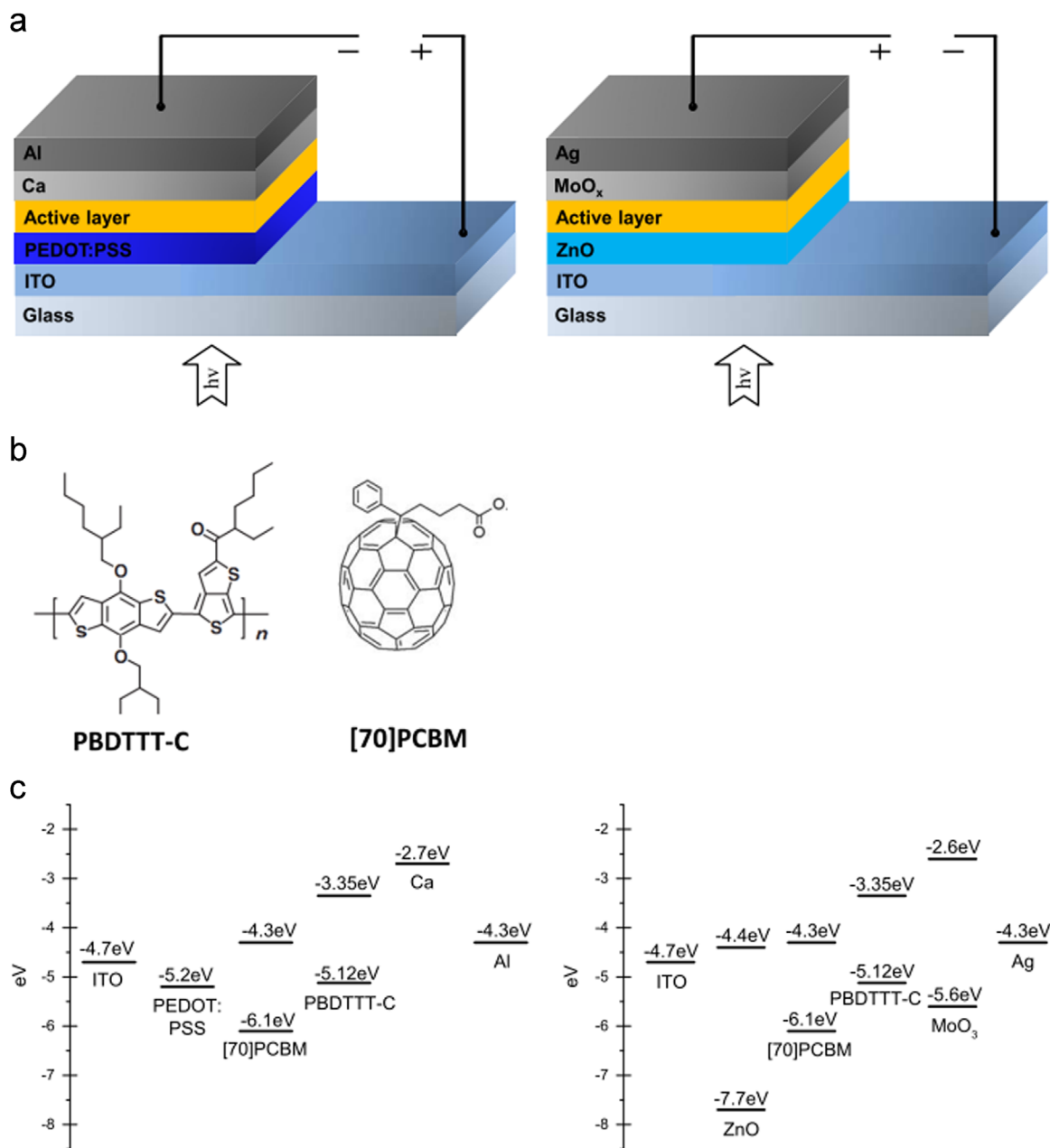
(usually Ca/Al) and the inverted one, where the charge-collecting nature of the electrodes is reversed, i.e. the ITO electrode, covered by a n-type metal oxide such as titanium oxide or zinc oxide, is used as the cathode and a p-type metal oxide, such as MoO<sub>3</sub>, with an high-work-function metal, typically Ag, is used as the anode [1]. The anode and cathode interface materials commonly used in the standard configuration, are susceptible to degradation leading to a limited device stability. The back metal contact (Ca/Al) is air sensitive [3,9] while the PEDOT:PSS, due to its hygroscopic and acidic nature, can deteriorate the active layer or the bottom electrode [10,11].

Moreover, the inverted architecture can benefit from the vertical phase separation of the photoactive blend: in fact the electron conducting phase (i.e. fullerene) is mainly concentrated on the bottom while the hole conducting phase (i.e. polymer) on the top [12–14]. In terms of performance, it has been shown that usually devices realized with the inverted structure have an higher short circuit current density ( $J_{sc}$ ) compared to the standard ones realized with the same photoactive layer [14–19], although in some case the PCEs of the devices are limited by a lower fill factor (FF) and/or open circuit voltage ( $V_{oc}$ ) (especially for P3HT:PCBM based PSC) [16–19].

It is worth to note that the performance and the stability of a certain device architecture is strongly related to the interlayers and the electrodes used to build the cell, i.e. the inverted

\* Correspondence to: ENEA, SSPT-PROMAS-NANO, Piazzale E. Fermi 1, 80055 Portici, NA, Italy. Tel.: +39 0817723260; fax: +39 0817723345.

E-mail address: [pasquale.morvillo@enea.it](mailto:pasquale.morvillo@enea.it) (P. Morvillo).



**Fig. 1.** (a) Device architecture of the standard and inverted polymer solar cells. (b) Chemical structures of PBDTTT-C and [70]PCBM (major isomer). (c) Energy level diagrams of the employed materials.

architecture has nothing of intrinsically “magic” compared to the standard one.

Although recent studies have addressed the superior current output of the inverted PSCs compared to the standard ones in terms of improved light harvesting and better charge collection [14,15], it is not completely elucidated the contribution of these two factors.

In order to clarify these issues, we realized PSCs with standard (glass/ITO/PEDOT:PSS/blend/Ca/Al) and inverted (glass/ITO/ZnO/blend/MoO<sub>3</sub>/Ag) architectures (Fig. 1). The photoactive layer was a BHJ of poly[(4,8-bis-(2-ethylhexyloxy)-benzo[1,2-b:4,5-b']dithiophene)-2,6-diyl-alt-(4-(2-ethylhexanoyl)-thieno[3,4-b]thiophene)-2,6-diyl] (PBDTTT-C) and [6,6]-phenyl C<sub>71</sub> butyric acid methyl ester ([70]PCBM). PBDTTT-C is a copolymer of benzodithiophene and thieno-thiophene units with an interesting range of light absorption (~850 nm) and shows PCE up to 6% when used as donor material in standard PSC [20]. This polymer was selected for the

better reproducibility of the corresponding devices. All the devices were characterized by external quantum efficiency (EQE) and current–voltage (*I**V*) measurements in dark and under different illumination levels.

The optical modeling of both device architectures was performed with the purpose to quantify the amount of absorbed light inside the photoactive layer while the impedance spectroscopy (IS) was employed in order to elucidate the charge injection processes across the different interfaces. The IS has been extensively applied for the study of the electrical processes in organic devices in dynamic regime [14,16,21,22]. Usually, the injection process is provided by the kinetics of filling and releasing of the states at metal–organic interface [23] and organic–organic interface [24,25] and, in particular, at the interface between the electrodes (or the injection layer) and the transporter layers which can be modified both doping the hole injection materials and applying surface treatments to the anodic contact [26–28].

Download English Version:

<https://daneshyari.com/en/article/77576>

Download Persian Version:

<https://daneshyari.com/article/77576>

[Daneshyari.com](https://daneshyari.com)