Journal of Industrial and Engineering Chemistry 24 (2015) 206–210

Contents lists available at ScienceDirect

Journal of Industrial and Engineering Chemistry

journal homepage: www.elsevier.com/locate/jiec

Efficient inverted-structure polymer solar cells with reduced graphene oxide for anode modification

Tae-Woon Kang [a], Yong-Jin Noh [a], Seok-Soon Kim [b], Han-Ik Joh [c], Seok-In Na [a,*]

[a] Professional Graduate School of Flexible and Printable Electronics, Polymer Materials Fusion Research Center, Chonbuk National University, 664-14, Deokjin-dong, Deokjin-gu, Jeonju-si, Jeollabuk-do 561-756, Republic of Korea
[b] Department of Nano & Chemical Engineering, Kunsan National University, Kunsan, Jeollabuk-do 753-701, Republic of Korea
[c] Institute of Advanced Composite Materials, Korea Institute of Science and Technology, San 101, Eunha-ri, Bongdong-eup, Wanju-gun, Jeollabuk-do 565-905, Republic of Korea

ARTICLE INFO

Article history:
Received 1 August 2014
Received in revised form 15 September 2014
Accepted 27 September 2014
Available online 5 October 2014

Keywords:
Polymer solar cells
Conjugated polymers
Interfacial layer
Graphene
Reduced graphene oxide

ABSTRACT

Enhanced cell-efficiency of inverted bulk-heterojunction based polymer solar cells (PSCs) was achieved by anode modification with reduced graphene oxide (rGO). The rGO thin film was obtained with spin-coating of a cost-effective rGO solution dissolved in ethanol on top of the organic photoactive layer, and the effects of the rGOs as a new interlayer on device-performances of inverted-structure PSCs were investigated. The inverted PSC with r-GO showed a remarkable enhancement in power conversion efficiency compared with the cells with no interfacial layers. In particular, the inverted device with r-GO showed highly comparable efficiencies and superior PSC-stability to conventional PEDOT:PSS-based inverted PSCs.

Introduction

Bulk-heterojunction (BHJ) polymer-based solar cells (PSCs) have been highly attractive as a promising energy source due to their cost-effective and large-area power generation ability [1–8]. However, for real commercialization, the PSCs should have a relative competitiveness in efficiency, cost, and stability compared with other solar cells [6–8]. To this end, an inverted cell-structure to provide better PSC-stability and design-flexibility has been developed in which an anode interfacial layer between the high work-function metal anode and the BHJ and a cathode interfacial layer between the indium tin oxide (ITO) cathode and the BHJ are used for effective hole and electron collection and the replacement of poly(3,4-ethylenedioxythiophene): poly(styrenesulfonate) (PEDOT:PSS) and low work-function metal to induce a poor device-stability [9,10]. To be a successful inverted configuration for high-performance inverted devices, many efforts on electrode modification using various interfacial materials have been devoted [9–13].

Chemically converted graphene oxide (GO) and reduced GO (rGO) could also be an efficient interfacial modifier for high-performance inverted PSCs, because they can be simply available in large quantities by chemical synthetic processes and also can provide a low-cost solution processability [14–19]. In particular, in inverted PSCs with metal cathodes, Gao et al. [18] reported that a GO layer can effectively modify the active layer/metal anode interface, resulting in significantly improved PSC-efficiencies. However, typically, GO has an insulating property, and thus showing a high GO-thickness dependency on cell-efficiency [15–18], which indicates that the rGO, the reduced form of GO having a better conductivity and charge transport, can be considered as a better interfacial layer for inverted PSCs [17,20]. However, to date, there have been no efforts for using rGO as interfacial layers in inverted PSCs.

In this paper, we demonstrate that a solution-processed rGO film can effectively serve as an interfacial material (IFL) for high-performance inverted-structure PSCs. As the BHJ/metal interface modifier, the rGO was prepared with a 4-(trifluoromethyl) phenylhydrazine reductant, which was recently introduced as an effective reductant to provide more improved conductivity, work function, and film-uniformity than conventional hydrazine-based rGOs [21]. We investigated the effects of the rGOs as a novel IFL on inverted PSC-performances. As a result, the inverted PSC with

* Corresponding author. Tel.: +82 63 270 4465; fax: +82 63 270 2341.
E-mail addresses: nsi12@jbnu.ac.kr, seokinna@gmail.com (S.-I. Na).

http://dx.doi.org/10.1016/j.jiec.2014.09.030
1226-086X/

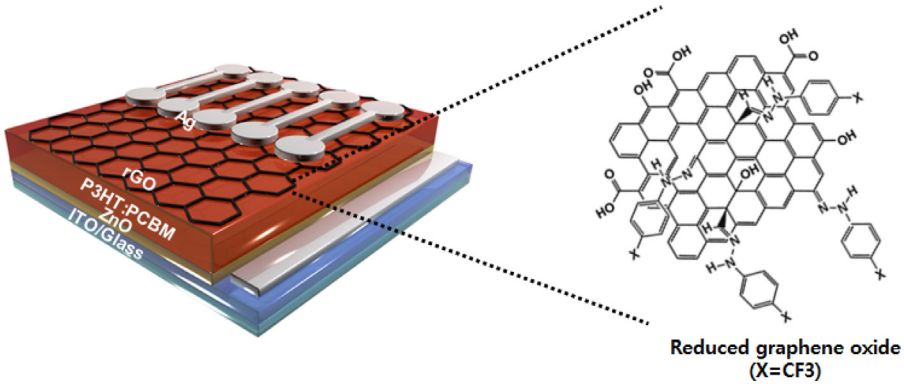

Fig. 1. Device-structure of the inverted PSC with a rGO interfacial material (the left image) and the chemical structure of the rGO (the right image).

r-GO showed a remarkable enhancement in power conversion efficiency compared with the cells with no interfacial layers. In particular, the inverted device with r-GO showed highly comparable efficiencies to conventional PEDOT:PSS-based inverted PSCs and better PSC-stability than PEDOT:PSS-based solar cells.

Experimental

The PSC-configuration with the inverted structure and the chemical structure of the rGO are shown in Fig. 1. To prepare inverted solar cells, ZnO solution was fabricated with a 0.75 M zinc

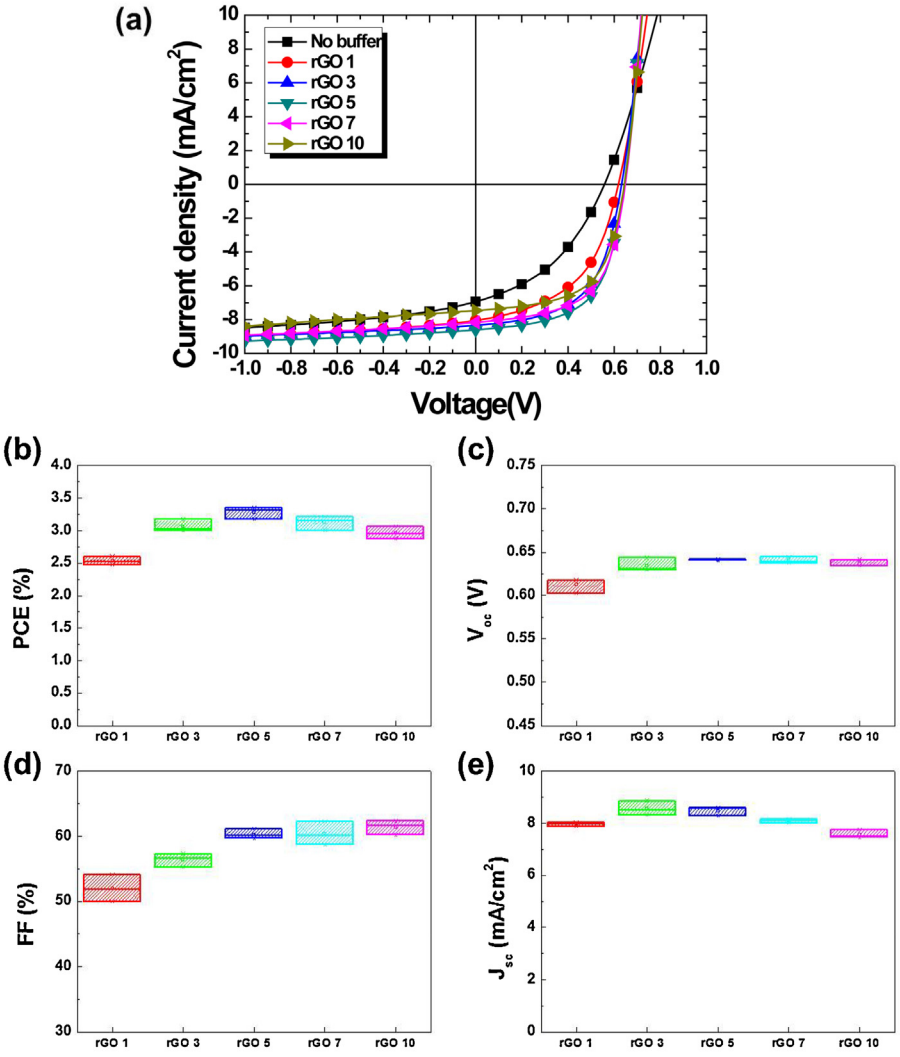

Fig. 2. (a) The representation *J*–*V* curves of the inverted PSCs with no IFL and rGO layers. Comparison of (b) PCE, (c) V_{oc}, (d) FF, and (e) J_{sc} of devices with rGOs.