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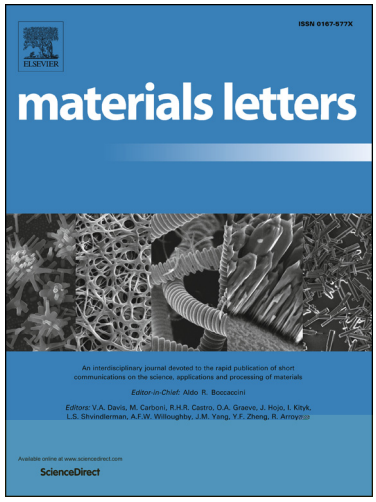

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Multi-walled carbon nanotube incorporated Nanoporous Titanium Dioxide electrodes for Hybrid Polymer Solar cells

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Abstract

This study focuses on incorporating Multi-walled carbon nanotubes (MWNT) in nanoporous titanium dioxides (TiO_2) thin film for enhancing the performance of hybrid Poly(3-hexylthiophene)(P3HT)/ TiO_2 solar cells. MWNTs were successfully incorporated in the nanoporous TiO_2 electrodes either by systematically blending or dipping prior to the deposition of P3HT. Current density–voltage (J-V) characteristic of the corresponding fabricated devices showed that the short-circuit current density (J_{SC}) and fill factor are strongly influenced by the amount of MWNT incorporated into TiO_2 nanoparticles. Solar cells with optimum amount of MWNT incorporated by blending in nanoporous TiO_2 layer showed a factor of two efficiency enhancement, mainly due to improvement in J_{SC} compared to the corresponding control device. Further increment in MWNT reduces the efficiency mainly due to a sharp drop in fill factor and $V_{OC,}$ which can be attributed to shunting by excess amount of MWNTs. Devices with MWNT dip-coated TiO_2 and polymer too showed enhanced efficiency over 2.5% under AM 1.5 illumination (100 $mWcm^{-2}$), which is a factor of three higher than the corresponding control device.

Keywords: Carbon nanotubes; Electrical properties; Hybrid solar cell; P3HT; TiO_2

Introduction

Nanoporous TiO_2 electrodes, are promising electron acceptor materials for low-cost polymer based solar cells due to its stability, electron transport properties, the possibilities for controlling surface morphology and low cost. . In polymer-metal oxide hybrids, energy offset at the metal oxide-polymer interface provides the necessary driving force to dissociate the charge carriers from the photogenerated excitons produced in the polymer. The dissociated charges are transported towards the electrodes by a potential gradient created by asymmetry of the work-function of the electrodes. It is unavoidable that some of the excitons will recombine before charge separation (geminate recombination) or during charge collection when they traverse through the layers of the cell (interfacial recombination). The performance of the solar cells is dependent on the competition between geminate recombination and interfacial charge transfer which is key for exciton dissociation, and the competition between interfacial recombination and charge transport which is the key for charge collection.

the TiO_2 nanoparticle matrix can produce low resistive paths for separated electrons towards anode which effectively reduces the interfacial recombination. The V_{OC} experiences no significant changes up to 0.015wt% MWNT content and drops significantly with further increment. This ensure that the The fill factor also remains unchanged up to 0.03wt% MWNT content, and a sudden drop is observed with 0.04wt% content. The drop in fill factor with high MWNT loaded devices also ensure the increased rate of recombination at high MWNT content. The overall efficiency of the TiO_2:MWNT/P3HT solar cell is optimized when MWNT in TiO_2 is 0.02 wt.%, which is nearly by about a factor of two compared to the control cell. The efficiency enhancement in our devices are mainly due to enhanced J_{SC} and fill factor, which could have resulted from improved electron mobility in MWNT incorporated nanoporous TiO_2 film [10]. The TiO_2:MWNT structure is expected to provide fast charge transport as well as charge collection from dead zones providing additional dissociation sites at MWNT/Polymer interface

Figure 3(a) and (b) shows the J-V and EQE curves of TiO_2:MWNT(0.02%)/P3HT and TiO_2/MWNT/P3HT devices with corresponding TiO_2/P3HT control devices. Fig.3(a) shows that the TiO_2:MWNT(0.02%)/P3HT device suffer lower fill factor and V_{OC} compared to the control device. There is no significant changes in the fill factor and V_{OC} of dip coated TiO_2/MWNT based device. However, a threefold increment in PCE is observed with the incorporation of MWNTs which is solely as an effect of increased J_{SC} (See Fig S3 in Supp. info. For full data). This could be due to evenly distributed MWNT bundles over the surface as found in Figure 1(c). Fig 3(b) shows the EQE spectra of both blended and dipped devices with corresponding control device, and it confirms that the MWNTs have no effect on altering absorption feature of TiO_2. The increased J_{SC} in TiO_2/MWNT/P3HT devices can be explained by π-π stacking of P3HT molecules in the MWNT surface, which provides a well-aligned carrier transport pathway [11] in addition to increased electron transport in TiO_2 nanoporous electrode.

Conclusion

It has been shown that the performance of the TiO_2/polymer solar cells can be significantly improved by adding MWNTs in porous TiO_2. Device with optimum amount of MWNT incorporated TiO_2

nanocollidals enhanced the overall efficiency by about a factor of two compared to the control device. Device with dip-coated MWNT enhanced overall PCE by a factor of three, mainly due to increase in short circuit current density. This improvement may be due to the enhanced number of percolation routes in MWNT incorporated solar cells, which reduces the back electron transfer and hence minimizes the losses and the aligned P3HT chains around MWNT due to π-π interaction.

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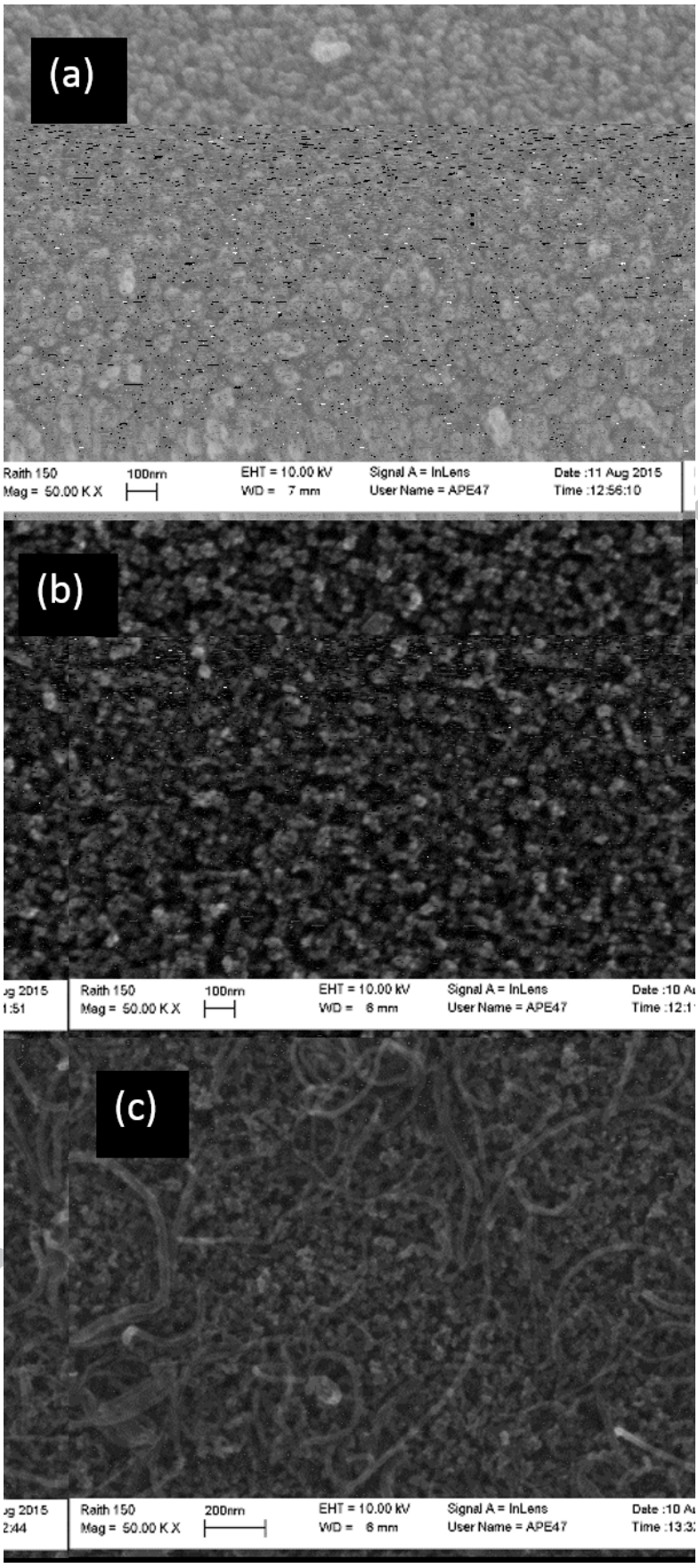
Figure 1: SEM images of (a) TiO_2 nanoporous layer, (b) TiO_2: MWNT (0.02 wt. %) blend and (c) TiO_2 /MWNT nanoporous film

Figure 2:(a) J-V characteristics and (b) variation of J_{SC}, V_{OC}, fill factor and PCE of TiO_2:MWNT/P3HT solar cells fabricated with different MWNT content in the TiO_2 layer (See Fig S2 in Supp. info. For full data).

Figure 3:(a) J-V in dark and under AM 1.5 conditions (100 $mWcm^{-2}$) and (a) EQE spectra of TiO_2:MWNT(0.02%)/P3HTand TiO_2/MWNT/P3HT devices with corresponding TiO_2/P3HT devices.

Highlights

- MWNTs were successfully in cooperated into the nanoporous TiO_2 electrodes
- The Efficiency of solar cells were doubled when TiO_2 is doped with 0.02 % MWNT
- Efficiency enhanced over 3 folds when TiO_2 electrode is dipped into MWNT suspension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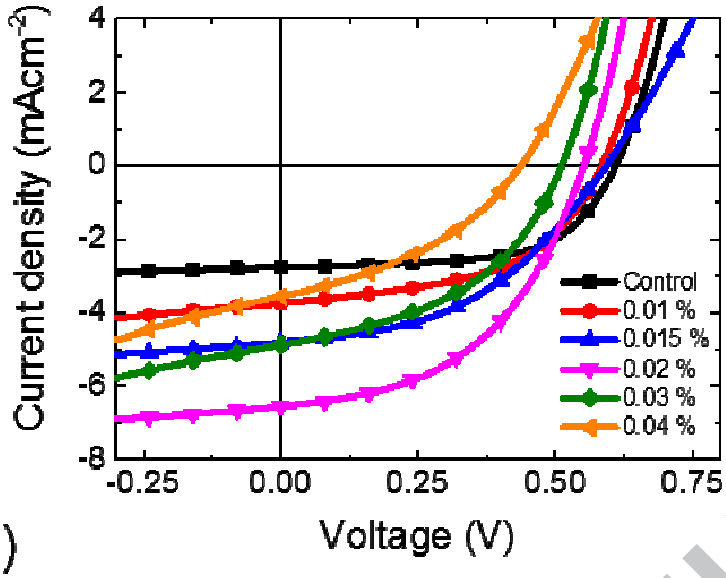
(a)



(b)