Solar Energy 137 (2016) 531–550

Contents lists available at ScienceDirect

Solar Energy

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

Review

Application of graphene in dye and quantum dots sensitized solar cell

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ARTICLE INFO

Article history:
Received 18 January 2016
Received in revised form 26 August 2016
Accepted 29 August 2016

Keywords:
DSSC
Electrical conductivity
Graphene
PCE
QDSSC
RGO

ABSTRACT

The incorporation of graphene-based materials into solar cell represents a cost-effective option to boost its stability, optical transmittance and the overall performance. Graphene has been used as transparent window and counter electrodes, interface layers, hole/electron transport material and also as a buffer layer to slow-down charge recombination in solar cell. Prioritized concern for efficient graphene-based material for dye sensitized solar cell (DSSC) and quantum dots sensitized solar cells (QDSSC) has been motivated by the quest for efficient and low-cost solar cell. Conventional organic dye in DSSC was replaced with stronger light absorber quantum dots (QDs) material in QDSSC to absorb wider spectral wavelength so as to improve photo response in the solar cell. In this review, the application of graphene in DSSC and QDSSC was discussed. Promising properties of graphene has shown to enhance various layers of a solar cell. Although layer-by-layer chemical process can detach sections of graphene, this can be improved by doping. Conversion of graphite to graphene enhances the conductivity of photoexcited electrons, electron mobility and reduces the recombination rate of electron/hole pairs. The tunable bandgap properties and excellent thermal and mechanical stability of graphene facilitate the transfer of electrons. RGO improves electron lifetime by increasing the chemical capacitance and decreasing the resistance.

Contents

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http://dx.doi.org/10.1016/j.solener.2016.08.055

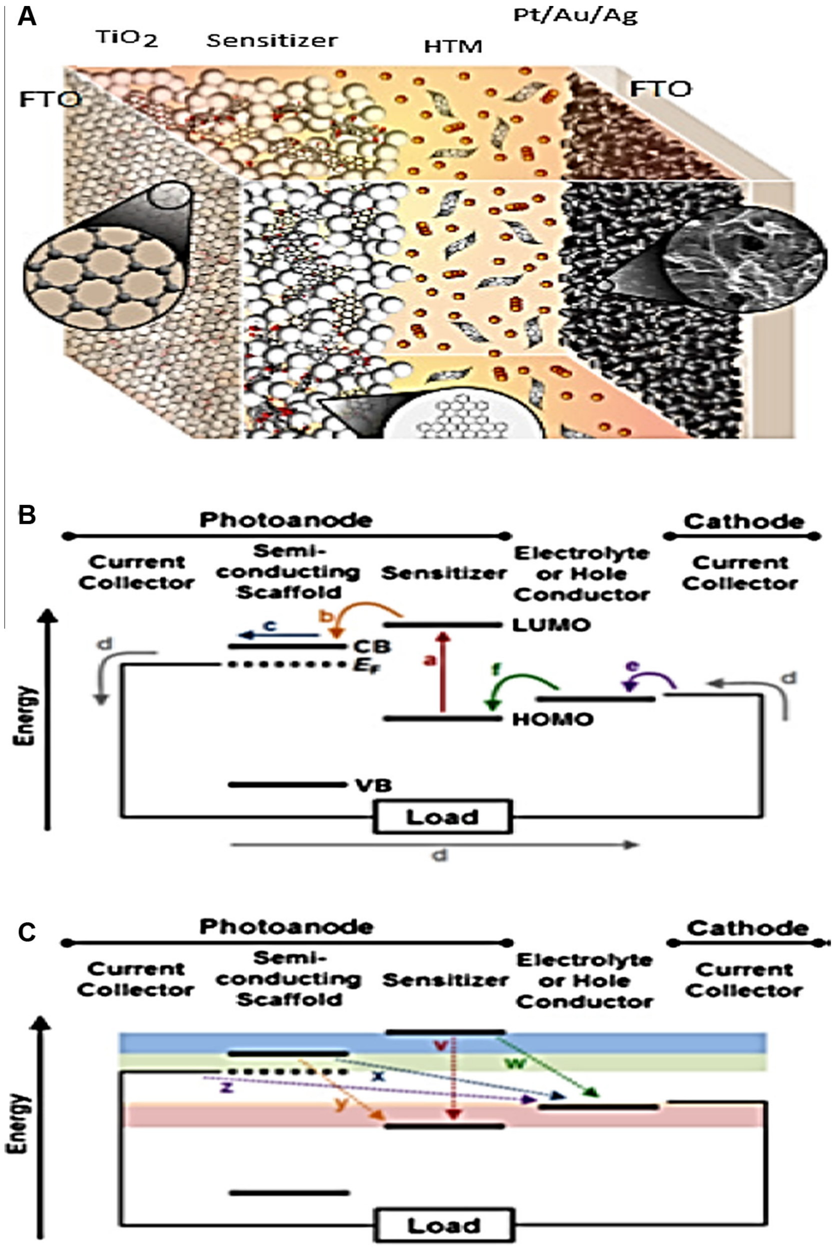

Fig. 1. Basic structure of dye and quantum dot sensitized solar cells. (A) shows the layers of the solar cell cell comprising FTO as the transparent electrode, TiO_2 as the transparent conducting oxide, the sensitizer (dye/QDs), the HTM as the electrolyte, and Pt/Au/Ag as the conductive sheet. (B) represents charge transfer pathway with CB = conduction band; VB = valence band; EF = Fermi energy level of the semiconductor; LUMO = lowest unoccupied molecular orbital; HOMO = highest occupied molecular orbital of the sensitized solar cell. Electron pathway indicated using arrow; a, b, c, d, e, and f denotes steps involved in charge transfer. Traditionally, at least either side of the sensitizer layer utilizes a transparent conducting electrode as shown in (A). The Fermi energy level is close to the CB owing to high level of electron doping. The area denoted with (C) depicted notable recombination pathways indicated using arrow; v, w, x, y, and z respectfully. The colored arrows represent voltage drop with respect to charge transfer. Updated version presented in Roy-Mayhew (2013). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

1. Introduction

Graphene is a two-dimensional one-atom thick material that exhibits high thermal conductivity at room temperature ($\sim 5 \times 10^3$ W m^{-1} K^{-1}), high charge/hole mobility (2×105 cm^2 V^{-1} s^{-1}) and charge carrier concentration (10^{13} cm^{-2}). Exceptionally, electron and hole carrier half integer quantum Hall effect in graphene has shown to be attractive in material science and physics (Wu et al., 2007; Chen and Tao, 2009; Dreyer et al., 2009; Park and Ruoff, 2009; Chen et al., 2012). The chemistry of electrically insulating graphene oxide (GO) incorporating functional reactive oxygen covalently attached to the GO has shown to be suitable for solar cell application (Dreyer et al., 2009). Reduced GO has outstanding electrical conductivity and electron/hole mobilities to significantly absorb a fraction of incident light energy ($\alpha = 2.3\%$) to improve the performance solar cell (Li et al., 2011; Zhang et al., 2012, 2011). The small overlap existing between the valence and conduction band of graphene supports its outstanding electrical conductivity. However, it has been demonstrated that graphene-based DSSC has theoretical photon conversion efficiencies (PCE) exceeding 24% in a stacked structure (Yong and Tour, 2010). The performance of graphene-based materials