Digest Journal of Nanomaterials and Biostructures Vol. 4, No. 4, December 2009, p. 723-727

PERFORMANCE OF NANO STRUCTURED DYE-SENSITIZED SOLAR CELL UTILIZING NATURAL SENSITIZER OPERATED WITH PLATINUM AND CARBON COATED COUNTER ELECTRODES

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Dye sensitized solar cell (DSSC) fabrication procedure has been employed using natural pomegranate juice for sensitization of nanocrystalline TiO_2. Platinum and graphite coated electrodes were prepared by pulse current electrondeposition and soot staining method for use as counter electrodes. Photovoltaic parameters like short circuit current (I_{SC}), open circuit voltage (V_{OC}) and fill factor (FF) were evaluated for fabricated cells. Although the fill factor for both cells was found to be 45%, I_{SC} and V_{OC} for cells operating with carbon and platinum coated counter electrodes were increased from 360 to 400 mV and from 175 to 200 μA respectively. Overall conversion efficiencies of fabricated DSSC found to be 1.5 % for cell operated with platinum electrodeposited and 0.9 % for carbon coated counter electrodes.

(Received November 8, 2009; accepted November 16, 2009)

Keywords: Dye sensitized solar cell, phovoltaic performance, pomegranate juice, Platinum electrodeposition, Carbon counter electrode.

1. Introduction

Dye-sensitized solar cells (DSSCs) [1] have attracted much attention for the last more than a decade. The DSSC consists of a dye-covered, nanoporous TiO_2 (titanium dioxide) layer and an electrolyte containing a redox mediator (I^-/ I_3^-) encapsulated between two glass plates as shown in Fig. 1.

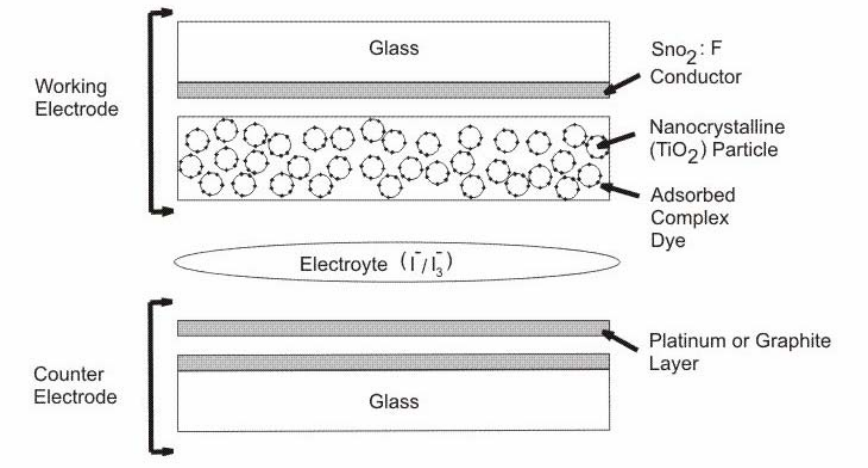

Fig.1 Schematic of a dye solar cell.

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On the surface of the TiO_2, a monolayer of dye molecules is adsorbed. The huge nanoporous surface allows for an adsorption of a sufficiently large number of dye molecules for efficient light harvesting. Front and counter substrates are coated with a transparent conducting oxide (TCO). Fluorine doped tin oxide (FTO) is most commonly used. The TCO glass at the counter electrode is coated with few atomic layers of carbon or platinum, in order to catalyze the redox reaction with the electrolyte.

Electron kinetics in the nanocrystalline TiO_2 layer plays an important role in the operation of a dye solar cell. The electron injection from the excited dye to TiO_2 takes place in femtoseconds while the time scale for the back electron transfer is several orders of magnitude slower, indicating the charge separation achieved on kinetic grounds. The dye regeneration process occurs in nanoseconds scale explaining the efficient operation of the dye solar cell since the oxidized dye should be reduced to its ground state as fast as possible. The injected electrons to TiO_2 hop through the colloidal structure and finally arrive at the conducting glass collector [2], [3] and [4].

The adsorption of the dye to the nc-TiO_2 surface usually takes place via special anchoring groups attached to the dye molecule. The high efficiency of the dye sensitized solar cell is accomplished by coating the internal surfaces of the porous TiO_2 electrode with special dye molecules tuned to absorb the incoming photons [5] and [6].

Our aim was to investigate the performance of a sensitized solar cell with natural pomegranate juice operated with two different counter electrodes.

2. Experimental

2.1. Materials

Transparent conductive oxide coated glass (TCO 10-10, 2 cm × 2 cm) and Ti-Nanoxide D were purchased form Solaronix. Dinitroamine Platinum (II) was procured from Johnson Matthey Catalysts for platinum electrodeposition. Acetonitrile, sodium carbonate and sodium acetate (Aldrich) were used for electrolyte preparation.

2.2. Preparation

Ti-Nanoxide was deposited on TCO glass having resistance of 10 Ohm/cm^2 by tape casting technique and sintered in 450°C for 30 minutes. The working electrode (TiO_2 electrode) was immersed in freshly squeezed pomegranate juice for 12 hours. Pt counter electrode was prepared on TCO glass by pulse current electrodeposition method [7]. Electrodeposition was carried out using an aqueous solution of 16 ml of Dinitroamine Platinum (II), 100 gr of sodium carbonate and 40 gr of sodium acetate in 1000 ml of distilled water. Pt electrode was prepared by current density of 0.2 A / dm^2 with the 10 s on-time and 10 s off time at room temperature. TCO glass, Pt wire and Ag/AgCl were used as the working, counter and reference electrodes respectively. Carbon coated counter electrode was prepared on TCO glass by soot staining method. The TCO glass was placed on top of a burning candle to apply a light carbon film to the entire conductive side of the plate. Electrolyte solution was prepared by taking the proportionate quantity of 0.5 mol KI and 0.05 mol of iodine in 20 ml acetonitrile solvent [8].

2.3. DSSC assembly

The immersed TiO_2 electrode in pomegranate juice was removed and rinsed with ethanol and was dried at 80°C for 10 minutes. The stained TiO_2 films and the Pt counter electrodes were assembled into sealed sandwich-type cells by heating with a hot-melt of ionomer films (Surlyn 1702, Du-Pont) used as spacers between the electrodes. A drop of electrolyte solution was put on each of the drilled holes in the counter electrodes of the assembled cells.

2.4. DSSC performance

Photoresponse of the DSSC was evaluated by recording I–V characteristics with a 10 kΩ potentiometer as a variable load as shown in Fig .2.

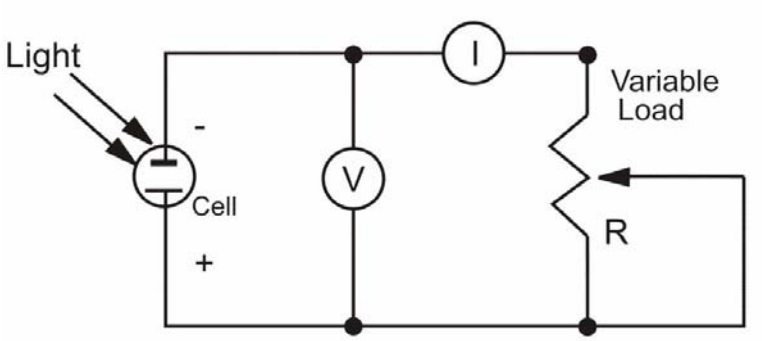

Fig.2 Experimental setup for measuring the current– voltage characteristics.

The I–V characteristics of the fabricated solar cells were measured under illumination (area of 1 cm^2). For illumination, tungsten halogen lamp [OSRAM, Germany] was used with and incident light of 300 W/m^2.

3. Results

The sponge-like structure in SEM image of the top view of TiO_2 film coated on TCO electrode is shown in Fig.3. The film is about 12 μm thick and the spherical TiO_2 nanoparticles are homogenously distributed within the TiO_2 layer. No fracture on the surface and no gaps between the coatings were observed, indicating excellent inter-particle connectivity and inter-layer attachment.

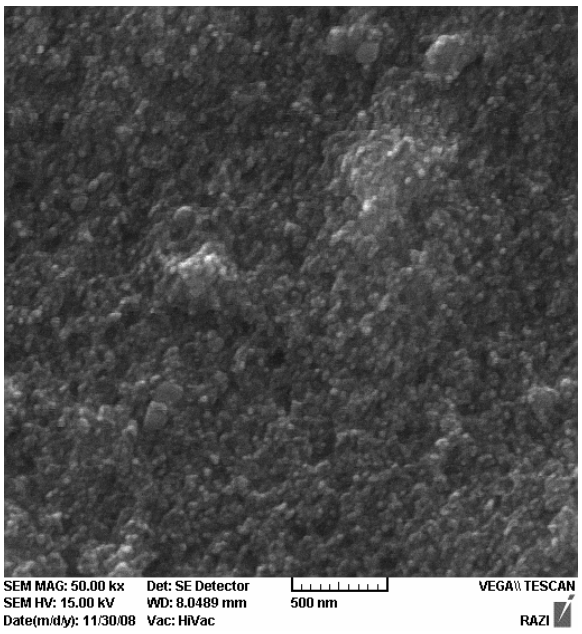

Fig.3 Top view of SEM micrographs of TiO2 film coated on FTO glass.

Pomegranate juice mainly contains cyanin derivatives and exists as flavylium at natural pH. Flavylium is red in color and strongly bond with Ti^{4+} via emanating H_2O molecule [9]. The absorption spectra of nanocrystalline TiO_2 covered with freshly squeezed pomegranate juice is illustrated in Fig.4. An intense absorption band in visible region with a peak at 522 nm is observed caused by chelation of flavylium with TiO_2 [10].

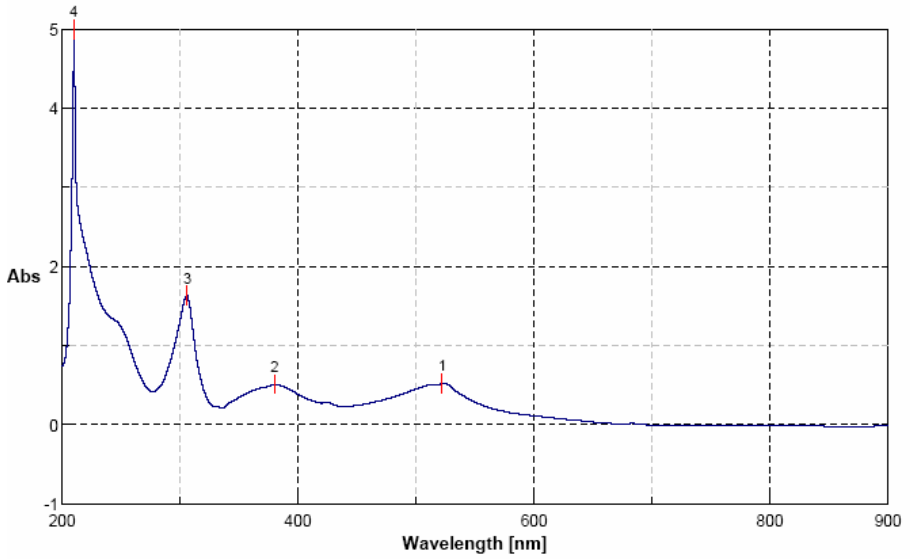

Fig.4 Spectral response of TiO_2 electrode coated with pomegranate juice.

The I-V curve for two fabricated cells is shown in Fig .5.

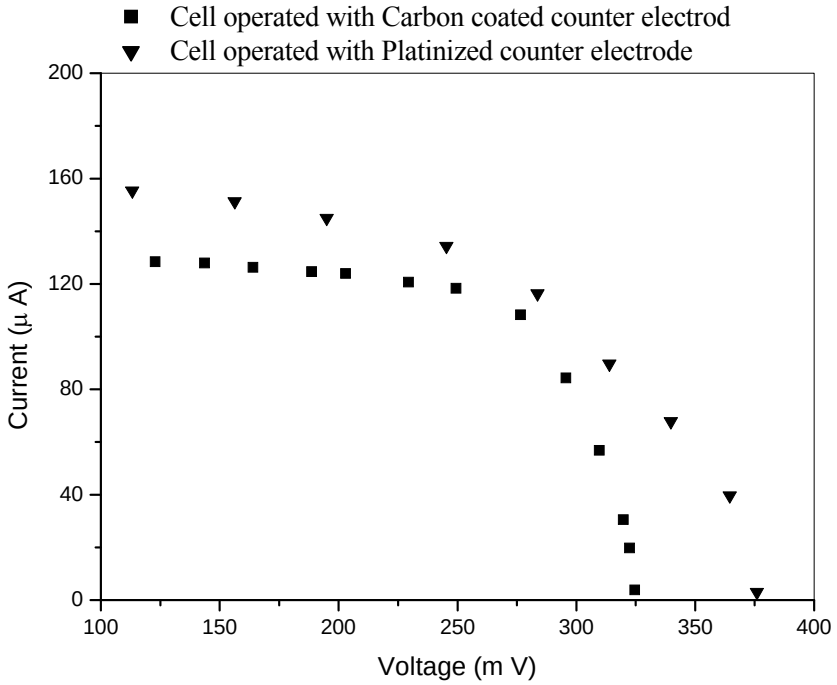

Fig.5 Photovoltaic response of fabricated DSSCs under illumination.

The values of V_{OC}, I_{SC}, FF and cell efficiency (η) for both cells of active area 1 cm^2 illuminated by a halogen lamp with an incident light of 300 W/m^2 are shown in table 1. As seen in table 1 the FF values for both cells are equal, indicating the types of counter electrode used in this work have no effect on FF. The use of platinum deposited counter electrode facilitates the electron transfer process to regenerate the electrolyte in the cell explaining the higher I_{SC} and V_{OC} values over the carbon coated counter electrode.

Table1. Photovoltaic performance for fabricated cells.

DSCC	V_{OC}	I_{SC}	FF%	η
Operated with Carbon Coated Electrode	360	175	45	0.9
Operated with Platinum Coated Electrode	400	200	45	1.5

4. Conclusion

Natural pomegranate juice was used as sensitizer in dye-sensitized solar cell. Although the photovoltaic performance of fabricated DSSCs operated with Platinum coated over carbon coated counter electrode has shown an increase in I_{SC}, V_{OC} and cell conversion efficiency, it was shown that the type of counter electrodes used in this study has no effect on fill factor of fabricated natural DSSCs.

Acknowledgment

This research is financially supported by Iranian Research Organization for Science and Technology (IROST), Iran. The author would like to thank Dr K. Shirvani for his help in preparing platinum electrodeposited counter electrode.

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