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FABRICATION AND INVESTIGATION OF FLEXIBLE DYE SENSITIZED NANOCRYSTALLINE SOLAR CELL UTILIZING NATURAL SENSITIZER OPERATED WITH GOLD COATED COUNTER ELECTRODE

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Flexible Dye-sensitized solar cells were assembled using flexible transparent electrodes as substrates, nanocrystalline TiO_2, an electrolyte based on I_3^-/I^-, dye molecules and a counter electrode. In this study has been employed natural pomegranate juice for sensitization of nanocrystalline TiO_2 and gold layer as counter electrode was prepared by sputtering method on conducting substrates polymer. Photovoltaic parameters like short circuit current (I_{SC}), open circuit voltage (V_{OC}) , fill factor (FF) and Overall conversion efficiencies(η) for fabricated cell were 3.50mA, 600mV, 60% and 1.26 % under 100 mW/m^2 illumination respectively.

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Keywords: Flexible dye sensitized solar cell, nanocrystalline TiO_2, natural sensitizer, sputtering method.

1. Introduction

Dye-sensitized solar cells (DSSCs) have attracted much attention for the last more than a decade since they were developed by Gratzel in 1980s [1-6] because of their low-cost, environment friendliness and high conversion efficiency of solar energy into electrical energy compared to silicon cells [7-9]. Flexible DSSCs, based on the substrates of indium tin oxide (ITO) coated polyethylene terephthalate (PET), substituting for rigid glass substrates, are regarded as one possible breakthrough in the field of DSSC regarding their commercialization, because flexible DSSCs have presented great advantages of low cost of production and wide application[10]. Conductive plastic substrates, such as ITO/PET can be processed by a continuous process like roll-to-roll production for porous nanocrystalline film coating, therefore, greatly decreasing the production cost of the solar cells. In addition, it is light weight, having portable character [11]. A prototype of a flexible DSSC was already demonstrated in 1998 and is shown in Fig.1 [12].

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Fig.1. a 4 cell module of a flexible DSSC

Fig. 2 shows a typical flexible DSSC that contains of five components: 1) a flexible transparent conducting oxide (TCO) substrate 2) a nanocrystalline network of a wide band gap semiconductor (usually TiO2), 3) a sensitizer, 4) an electrolyte, and 5) a counter electrode (CE) such as golde, graphite or platinum [13].

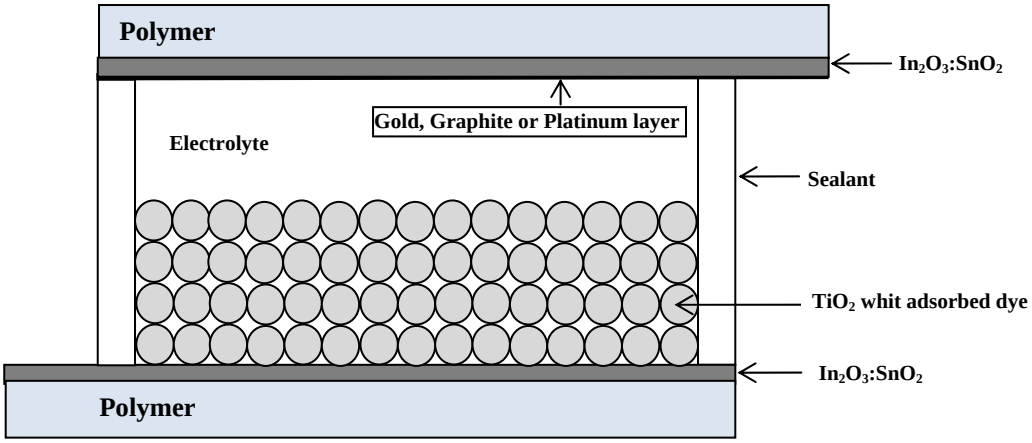


Fig.2. Schematic of flexible DSSC

The total efficiency of the flexible DSSC depends on the optimization and compatibility of each of these constituents [14,15].Using the very high surface area, which is provided by the nanocrystalline particles of TiO_2, DSSC allowed for an adsorption of a sufficiently large number of dye molecules for efficient light harvesting[16]. Electron kinetics in the nanostructure TiO_2 layer on TCO plays an important role in the operation of a dye solar cell. The excitation of the dye upon irradiation is followed by injection of the resulting electrons into the conduction band (CB) of the semiconductor, from where they reach the cell photoelectrode. The electron injection from the excited dye to TiO_2 takes place in femtosecond while the time scale for the back electron transfer is several orders of magnitude slower, indicating the charge separation in this cells achieved on kinetic grounds. Regeneration of dye electrons occurs through electron donation from a redox electrolyte in contact with the dye. This typically occurs through an organic solvent containing an iodide/triiodide couple. Triiodide is reduced in turn at the counter electrode, while electron migration from the photoelectrode to the counter electrode completes the circuit. The voltage generated is equal to the difference between the Fermi level of the electron in the solid TiO_2 and the redox potential of the electrolyte [17, 18].

Our aims was to fabricated flexible dye sensitized solar cell and investigate the photovoltaic performance of with natural pomegranate juice and gold counter electrode operated.

2. Experimental

2.1. Materials

Transparent conductive oxide coated polymer (ITO, In_2O_3:SnO_2 2.5 cm × 2.5 cm), Ti-Nanoxide D-L series, Electrolyte MPN-100 and sealant (Amosil 4) were purchased from Solaronix.

2.2. Flexible DSSC fabrication

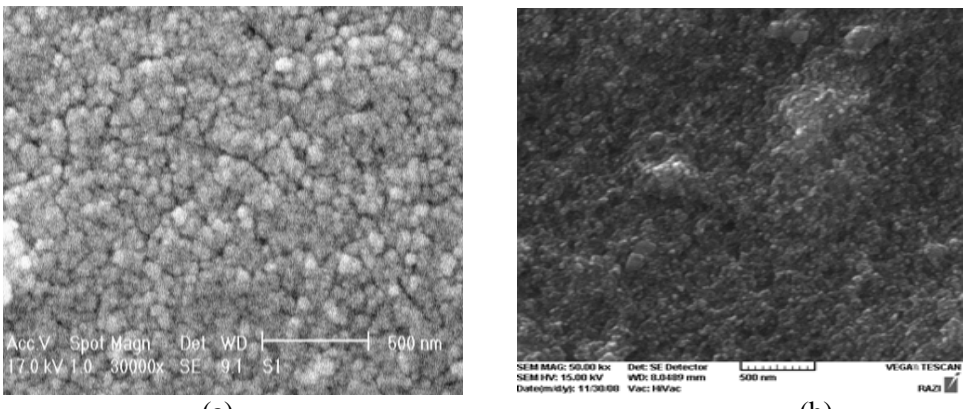
For preparation of photoelectrode, normal doctor blade technique was applied to fabricate the TiO_2 film [19]. Firstly, ITO with surface resistivity ~60 Ω/sq were sonicated (Elmasonic E 60H) with acetone and ethanol (50:50 V/V %) at 60°C for 1 h. Subsequently, TiO_2 paste was sonicated for 1 h to form an easily mobilized gel and then a little of the gel was spread onto a transparent flexible substrates in advance surrounded with a adhesive 3M tapes (having a thickness of ~50 μm) as spacers. The prepared photo electrode was placed in the oven (Memert UFE 500) and sintered at 120°C for 24 hours. The photoelectrode were sensitized by immersing them in pomegranate juice for 24 h. Gold layer was applied on ITO polymer by sputtering method [20]. Gold counter electrode with 30 nm thickness was prepared by reactive sputtering (SCDOOS model) under 14 mA for 240 s [16]. The immersed TiO_2 electrode in natural dye was removed and rinsed with ethanol and dried at room temperature for 1 h. The dye-covered nanocrystalline TiO_2 film and the counter electrodes were assembled into sealed sandwich-type cells applying one drop of electrolyte (MPN-100) and sealing with Amosil 4.

2.3. DSSC performance

The photocurrent-voltage characteristics were measured with a potentiostat (chi660a) under illumination. A 1000 W Xenon lamp was employed as the light source in conjunction with an IRA-25S filter (Schott, USA) to get rid of the UV light. The light intensity corresponding to AM 1.5 (100 mW/cm2) was calibrated using a standard silicon solar cell.

3. Results and discussion

Fig.3 shows scanning electron microscopy (SEM Philips XL30 model) image of the surface nanocrystalline TiO_2 film coated on ITO electrode before and after sintering process. The film is about 8 μm thick and the spherical TiO_2 nanoparticles were homogenously distributed within the TiO_2 layer and sponge-like structure of electrode after sintering process. As it is shown in Fig.3 no fracture on the surface of the coated layer after sintering is seen indicating excellent inter-particle connectivity.



(a) (b)

Fig.3 SEM images of SEM photographs of the TiO_2 electrodes (a) before and (b) after sintering.

To investigate the morphological characteristics of nanocrystalline TiO_2, atomic force microscopy (AFM) was used. Detailed surface characteristics were obtained in the corresponding AFM images (1 µm × 1µm surface plots), shown in Fig. 4. Analysis of the AFM images confirmed that the TiO_2 films consist of interconnected grain particles with an average diameter of 33.27 nm. The fractal TiO_2 films are endowed with a high real surface extension, which could be very beneficial for the photosensitization process, as a large amount of surface sites is available for the binding of the natural dye molecules. [21]

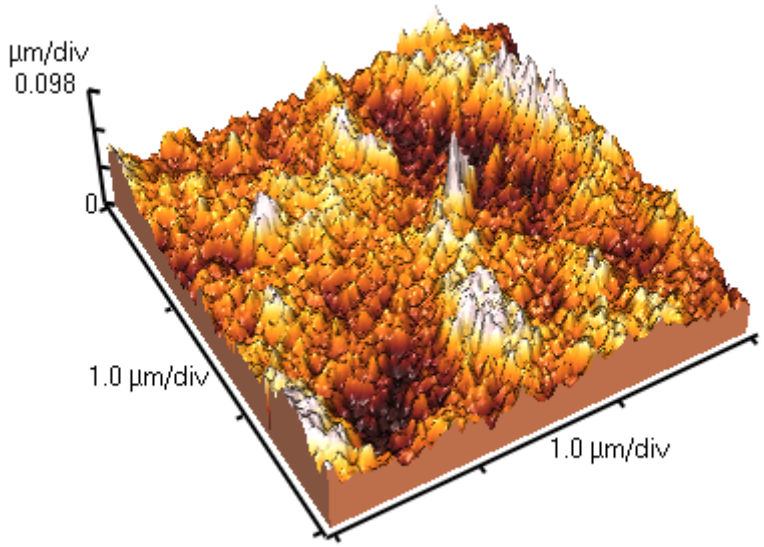


Fig. 4 Three-dimensional surface plot AFM picture of the nanocrystalline TiO_2 film

Pomegranate juice mainly contains cyanin derivatives and exists as flavylium at natural pH[22]. Flavylium is red in color and strongly bond with Ti^{4+} via emanating H_2O molecule [23]. The absorption spectra of nanocrystalline TiO_2 covered with freshly squeezed pomegranate juice is illustrated in Fig.5. An intense absorption band in visible region with a peak at 522 nm is observed caused by chelation of flavylium with TiO2 [24].

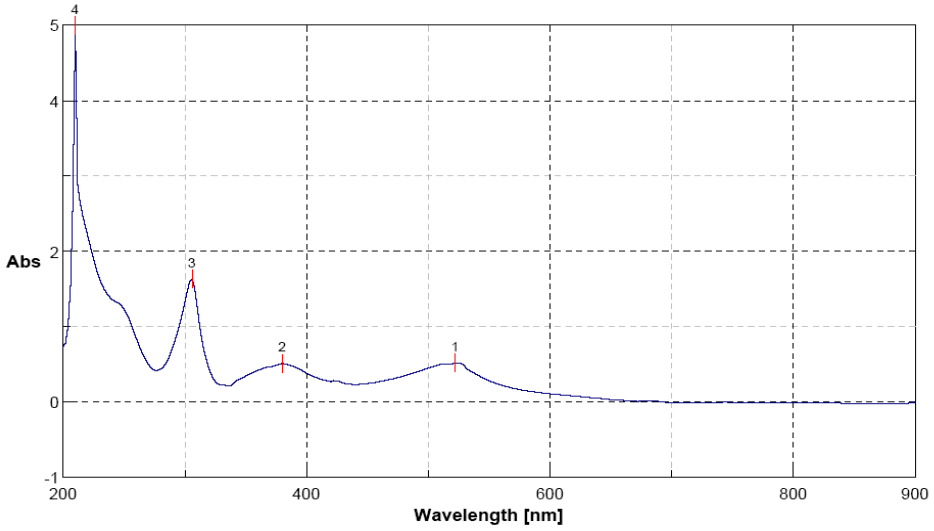


Fig.5 Spectral response of TiO_2 electrode coated with pomegranate juice.

The I-V curve for two fabricated cells with pomegranate juice and gold counter electrode is shown in Fig .6.

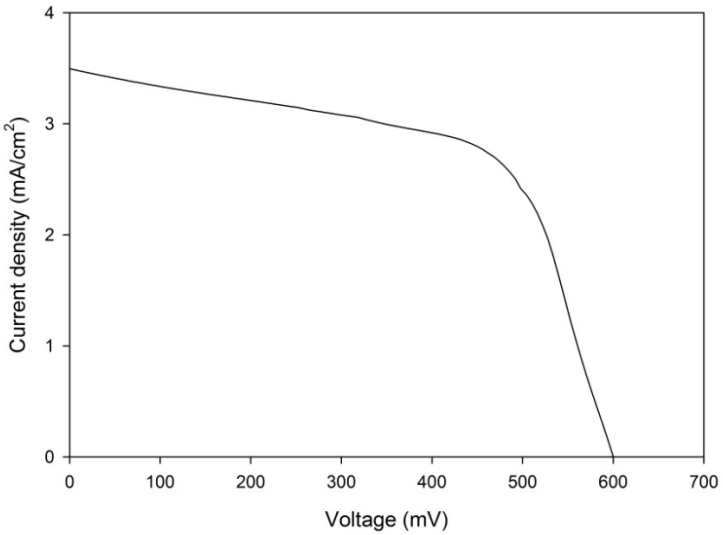


Fig.6 Photocurrent–voltage characteristics for fabricated cell measured under illumination of 100mW/cm2 (AM 1.5).

Fill factor and conversion efficiency for fabricated cell is calculated from Eq.2 and 3 [25].

$$FF = \frac{Imax \times Vmax}{Isc \times Voc} \tag{2}$$

$$\eta = \frac{Isc \times Voc \times FF}{\text{Light intensity}\left(\frac{mW}{cm2}\right)} \tag{3}$$

The values of V_{OC}, I_{SC}, FF and cell efficiency (η) for fabricated cell operated with pomegranate juice and gold sputtered counter electrode of active area $1cm^2$ illuminated by a halogen lamp with an incident light of $100\ mW/cm^2$ is summarized in Table1.

Table. 1 Photovoltaic performance for fabricated cell

Fabricated flexible DSSC	**V_{OC} (mV)**	**I_{SC} (mA/cm^2)**	**FF %**	**η %**
Cell operated with gold counter electrode	600	3.50	60	1.26

4. Conclusions

Natural pomegranate juice as natural photosensitizers was used in flexible dye-sensitized solar cell. Furthermore we have fabricated a gold counter electrode for flexible DSSC using sputtering method as an electron catalysis layer. Although previous research have shown that overall conversion efficiency for DSSC with Pt counter electrode is higher than other electron catalysis materials, but platinum is more expensive than gold. Therefore replacing platinum with gold could be an alternative to make industrialized flexible DSSC less costly in the future.

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