

# Natural pomegranate juice as photosensitizers for dye-sensitized solar cell (DSSC)

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The dye-sensitized solar cells (DSSC) were assembled by using natural dyes extracted from pomegranate juice as sensitizer for nanocrystalline  $TiO_2$ . The natural dye, adsorbed onto the semiconductor surface, absorbs visible light and promotes electron transfer across the dye/semiconductor interface. Platinum coated electrodes were prepared by pulse current electrodeposition for use as counter electrode. Photovoltaic parameters like short circuit current ( $I_{sc}$ ), open circuit voltage ( $V_{oc}$ ), fill factor (FF) and Overall conversion efficiencies( $\eta$ ) for fabricated cell were 2.2  $\mu A$ , 370 mV, 45% and 1.5 % under 100  $mW/cm^2$  illumination respectively. The use of a natural product as the semiconductor sensitizer enables a faster and simpler production of cheaper and environmentally friendly solar cells.

(Received March 28, 2011; accepted April 11, 2011)

**Keywords:** Dye sensitized solar cell (DSSC), Natural pomegranate juice, Phovoltaic performance

## 1. Introduction

The Sun provides approximately 100000 terawatts to the Earth which is about 10000 times more than the present rate of the world's present energy consumption. Photovoltaic cells are being increasingly used to tap into this huge resource and will play key role in future sustainable energy systems. So far, solid-state junction devices, usually made of silicon, crystalline or amorphous, and profiting from the experience and material availability resulting from the semiconductor industry, have dominated photovoltaic solar energy converters [1]. However, the cost of photovoltaic electricity production is still too high to be competitive with nuclear or fossil energy. The recently discovered cells based on mesoscopic inorganic or organic semiconductors commonly referred to as 'bulk' junctions due to their three-dimensional structure are very attractive alternatives which offer the prospect of very low cost fabrication. The prototype of this family of devices is the dye-sensitized solar cell (DSSC), which accomplishes the optical absorption and the charge separation processes by the association of a sensitizer as light-absorbing material with a wide band gap semiconductor of mesoporous or nanocrystalline morphology. Dye-sensitized solar cells (DSSCs) are devices for the conversion of visible light into electricity based on the photosensitization of wide band-gap metal oxide semiconductors [2]. 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

[3]. 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 [4, 5].

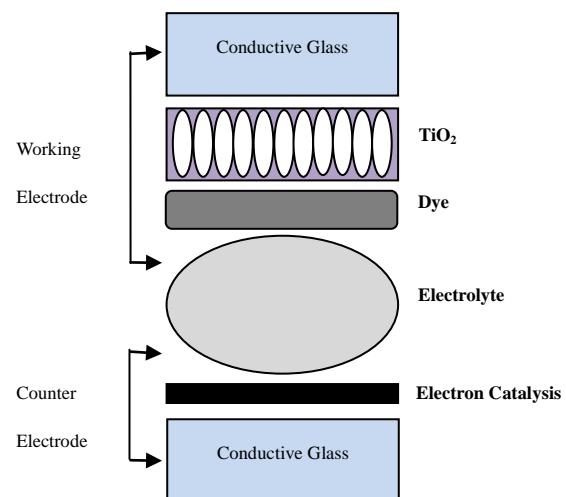


Fig. 1. Schematic of a dye solar cell.

Usually, the photoanode is prepared by adsorbing a dye (S) on a porous  $\text{TiO}_2$  layer. By this approach, the dye extends the spectral sensitivity of the photoelectrode, enabling the collection of lower energy photons. Due to its crucial role in such systems, considerable efforts have been directed towards the development and improvement of new families of organic dyes [6] and of metal complexes, the most efficient so far being Ru(II) [7] and Os(II) [8] polypyridine dyes, which couple broad spectral sensitivity to almost ideal ground and excited state thermodynamic and kinetic properties. Since the preparation of synthetic dyes normally requires multistep procedures, organic solvents and, in most cases, time consuming chromatographic purification procedures, there is interest towards the possible use of natural dyes which can be easily extracted from fruits, vegetable and flowers with minimal chemical procedures [9].

Our aim was to investigate the photovoltaic performance of dye sensitized solar cell sensitized with natural pomegranate juice as photosensitizer.

## 2. Experimental

### Materials

Transparent conductive oxide coated glass (TCO 10-10, 2 cm × 2 cm) and Ti-Nanoxide D were purchased from 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.

### Preparation

Ti-Nanoxide was deposited on TCO glass having resistance of 20 Ohm/cm<sup>2</sup> by tape casting technique and sintered in 450 °C for 30 minutes. The working electrode ( $\text{TiO}_2$  electrode) was immersed in freshly squeezed pomegranate juice for 12 hours. Pt counter electrode was prepared on TCO glass by pulse current electrodeposition method. Electroposition 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<sup>2</sup> 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. 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].

### DSSC assembly

The immersed  $\text{TiO}_2$  electrode in pomegranate juice was removed and rinsed with ethanol and was dried at room temperature. The stained  $\text{TiO}_2$  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 cell.

### DSSC performance

Performance of the DSSC was evaluated by recording I-V characteristics with a 10 kΩ potentiometer as the variable load under 100 mW/cm<sup>2</sup> illumination as shown in Fig. 2.

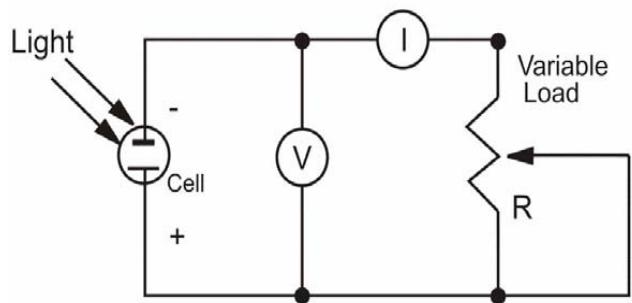


Fig. 2. Experimental setup for measuring the I-V characteristics.

## 3. Results and discussion

### Characterization of nanostructure $\text{TiO}_2$

The sponge-like structure in SEM image of the top view of  $\text{TiO}_2$  film coated on TCO electrode is shown in Fig. 3. The film is about 12 µm thick and the spherical  $\text{TiO}_2$  nanoparticles are homogenously distributed within the  $\text{TiO}_2$  layer. No fracture on the surface and no gaps between the coatings were observed, indicating excellent inter-particle connectivity and inter-layer attachment.

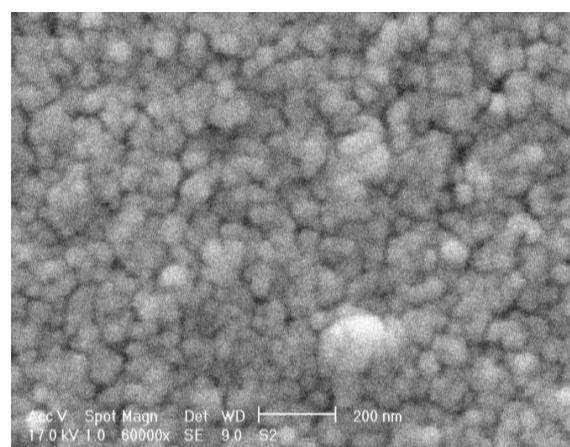


Fig. 3. Top view of SEM image of  $\text{TiO}_2$  film coated on FTO glass.

### Spectral response of photoelectrode in UV-Vis region

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. 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 555 nm is observed caused by chelation of flavylium with  $TiO_2$ .

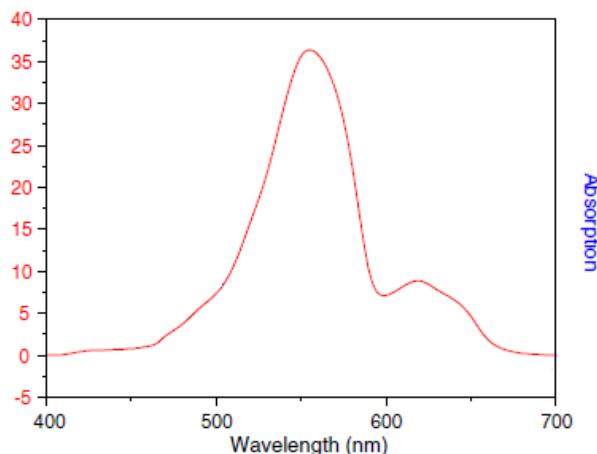


Fig. 4. Spectral response of  $TiO_2$  electrode coated with pomegranate juice.

### Performance of fabricated cell

The I-V curve for fabricated cell with natural pomegranate juice as dye and platinum as counter electrode is shown in Fig. 5.

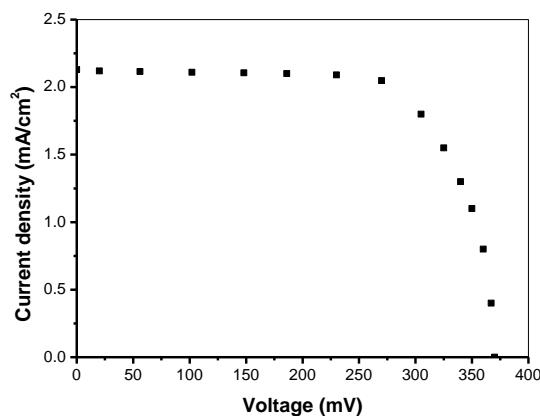


Fig. 5. Photovoltaic response of fabricated DSSC.

The values of  $V_{OC}$ ,  $I_{SC}$ , FF and cell efficiency ( $\eta$ ) for fabricated cell operated with Gold sputtered counter

electrode of active area  $1\text{ cm}^2$  illuminated by a halogen lamp with an incident light of  $1000\text{ W/m}^2$  is summarized in Table 2.

Table 2. Photovoltaic performance for fabricated cell.

Fabricated DSSC	$V_{OC}$ (mV)	$I_{SC}$ (mA/cm <sup>2</sup> )	FF %	$\eta$ %
Cell Fabricated	370	2.2	45	1.5

### 4. Conclusions

Natural pomegranate juice was used as sensitizer in dye-sensitized solar cell. Because of the simple preparation technique, widely available and low cost Natural pomegranate juice as an alternative sensitizer for dye-sensitized solar cell is promising. Moreover we have fabricated a platinum counter electrode for DSSC using Electron deposition method as an electron catalysis layer.

### Acknowledgments

This research is financially supported by Iranian Research Organization for Science and Technology (IROST), Iran.

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