Investigation of Electrical Properties of Dye Sensitized Solar Cells Based on Thin Film Electrodes

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Abstract. For electricity production with zero emission Dye-sensitized solar cells (DSSC) shows a great potential having a low cost fabrication solar cell devices. In this research, we have used two types of modified titanium dioxide (TiO_2) nanoparticles as photoanodes for DSSC, such as commercial TiO_2 paste, and synthesis TiO_2 paste. These TiO_2 compact layers were coated on FTO (Fluorine doped Tin Oxide) coated conductive glass substrates using doctor blade technique. Then, a freshly prepared solution of iodide – triiodide, and Ruthenium (II) dye (N_{719}), were used as electrolyte and the dye, respectively. A platinum (Pt) coated FTO was used as a counter electrode. The J-V characteristics for all the devices were obtained under light evaluating their performance and to calculate the power conversion efficiency.

INTRODUCTION

Dye sensitized solar cells (DSSCs) offers a possibility to lower the overall manufacturing cost due to their unique design, structure and having abundantly available cost efficient materials [1, 2]. One of the most promising third-generation DSSCs techniques, Mesoporous is based on nanocrystalline titanium dioxide and dye molecules. Due to easy fabrication techniques, lesser cost and light weight, DSSCs have attracted extensive interest. Photo anodes (wide band gap semiconductors), Sensitized dye, redox electrolyte (including redox couple like iodide/triiodide) and counter electrodes (conductive glass coated with Pt) are the key components of the DSSCs. Among these components the photo anode has always been the central interest of the researchers. Unlike to the Gratzel and O'Regan, many researchers have investigated different semiconductor materials like as ZnO, SnO_2 and ZrO_2 etc. However TiO_2 nanoparticles have been proven the most promising semiconducting material [3]. Other than TiO_2 nanoparticles, TiO_2 nanotubes, nanowires, nanorods, core-shell structures and nanosheets has been investigated by many researchers in order to increase the conversion efficiency of DSSCs. However the outcomes were not as efficient as TiO_2 nanoparticles [4]. As the sunlight is incident on DSSC, electrons of the dye get excited by absorption spectra of photons from the lower energy state to the higher excited state. Now the excited electron , which are present in conduction band of the TiO_2 get diffuse through the mesoporous TiO_2 film into the conductive substrate[5]. The photo generated majority carriers transferred to the counter electrode. Regeneration of the reduced dye sensitizer with the help of reversible redox couple established continued conversion of light energy. The dye that is synthesized from natural plants is very important in DSSC, which acts as a photon absorber [6, 7]. In this work, DSSCs were fabricated using TiO_2 electrode as a photoanode and Pt electrode as a counter electrode, here photoanode electrode was used with the commercial and synthesis TiO_2 paste and solar cell performance was analyzed. We have examined the development of the device performance like short-circuit current density (J_{sc}), open circuit voltage (V_{oc}) and solar energy-to-electricity conversion efficiency (η).

EXPERIMENTAL DETAILS

Before the photoanode films were prepared, TiO_2 paste was synthesized by reacting 200mg TiO_2 nanopowder, 40mg ethyl cellulose and few drops of α- terpinol. These all were grind using mortar pestle until a uniform smooth paste was formed. TiO_2 paste also obtained from Sigma-Aldrich.com and denoted as commercial TiO_2 paste. A diagrammatic assortment of DSSC device is mentioned in Fig 1. As displayed in the diagram, a typical DSSC is included four general parts: (a) photo-anode (wide band gap metal oxide) (b) photo- sensitizer (c) electrolyte (redox couple) (d) counter electrode. Fluorine doped Tin Oxide (FTO) coated glass substrates were used for fabrication of devices [8]. FTO substrates were cleaned in an ultrasonic bath with acetone and ethanol solution. A scotch tape was put on the conducting side of FTO, then, TiO_2 films were deposited using doctor blade method. The as-produced films were annealed at 450^{o}C for 30 min. The TiO_2 films were immersed in a N719 dye for 24 hours. The Pt-coated films, as counter electrodes, were deposited on the FTO substrates by doctor blade method and annealed at 450^{o}C for 30. The TiO_2 films were modified as dye-loaded photo anodes and Pt film counter electrodes. Each sandwich cell was held in place with the help of two heavy-duty clips on both opposite ends [9, 10]. In acetonitrile the liquid electrolyte of LiI and I_2 was introduced to one edge of each 1.1 cm^2[11, 12]. Figure 1.exhibits the diagram of device and related energy level diagram.

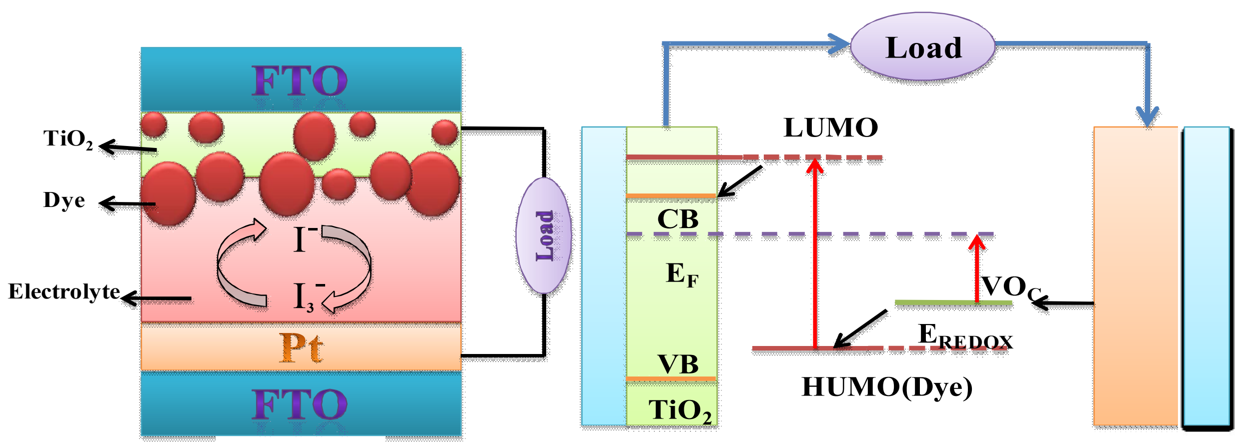

FIGURE 1. DSSC device structure and related energy level diagram.

RESULTS AND DISCUSSION

The photovoltaic performance of the DSSCs based on Titanium Dioxide thin film photoanode were investigate under a simulated solar irradiation of 100mW cm^{-2} (AM 1.5G)[13]. Figure 2 (a), (b) display the measured I-V characteristics of solar cell based on commercial TiO_2 films and synthesis TiO_2 films under light at room temperature. The corresponding photovoltaic parameters open circuit voltage (Voc), short circuit current (Jsc), fill factor and conversion efficiency (η) for DSSCs for the both TiO_2 films has been summarized in Table 1. From the obtained results, we found that photovoltaic parameters (V_{oc}, J_{sc} and FF) shows variation as mentioned in the table 1. The performance of the fabricated cell is reasonably good when compared both of the cells. Its efficiency may appear to be low for any practical application, but the performance of the cells is comparable to similar low-cost DSSC technology available today[14, 15]. The major point is that the films were applied in a single step. On the other hands the cell stability is different factor for its application. Which depends strongly on other factor like dye and electrolyte coupling.

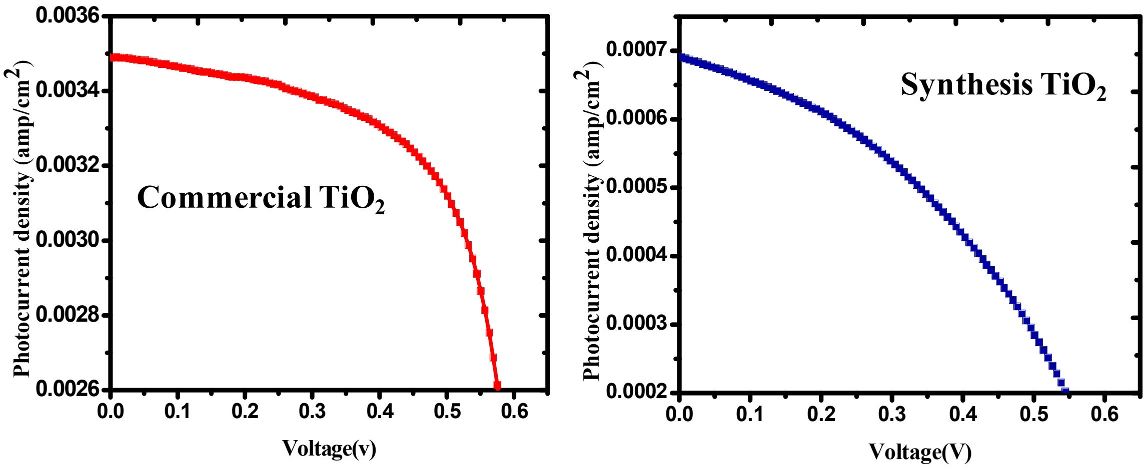

FIGURE 2. The J-V curves of DSSCs based on different TiO_2 films **(a)** commercial TiO_2 **(b)** synthesis TiO_2.

TABLE 1. The photovoltaic parameters of DSSCs based on commercial TiO_2 and synthesis TiO_2films photoelectrodes.

Photoanode	Jsc(amp/cm$_2$)	Voc(V)	FF	η (%)
Commercial TiO_2	3.17673528	0.72503843	62.7262	1.4447
Synthesis TiO_2	0.62923758	0.60552774	41.2786	0.1573

CONCLUSIONS

In this paper, DSSCs were fabricated successfully with two types of TiO_2 films electrodes. The performance of DSSCs showed that the higher energy conversion efficiency of commercial and synthesis both TiO2 electrodes has been achieved 1.4% and 0.15% respectively. The photovoltaic properties of DSSCs devices examined that the power conversion efficiency between both TiO_2 films was good and not so relatively high, but with the help of this methodology we can improve photovoltaic parameters performances. However we believe that we have achieved considerable efficiency even it has been manufactured in simple laboratory conditions, but significant enhancement in cell performance can be obtained. On the other hand the efficiency of DSSCs can be improved with evaluation of used electrolyte and dye, and their sources can be achieved through in our immediate environment.

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