Journal of Fundamentals of Renewable Energy and Applications

Shah et al., J Fundam Renewable Energy Appl 2017, 7:4
DOI: 10.4172/2090-4541.1000234

Research Article Open Access

Dye Sensitized Solar Cells Based on Different Solvents: Comparative Study

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Abstract

Solution of Z907 dye in two different solvents, namely ethanol (EtOH) and chloroform ($CHCl_3$) are prepared and utilized in dye-sensitized solar cells (DSSCs). The effects of dye solvents on the performance of these cells have been investigated and the results are represented. The DSSCs that used EtOH as a dye-adsorption solvent showed an improved solar cell efficiency relative to the DSSCs that used $CHCl_3$. For dye-adsorption solvents, the highest conversion efficiency of 1.40% is achieved using $CHCl_3$ and 0.15% for EtOH, respectively. Photo- and electrochemical tests of Z907 dye in ethanol, adsorbed on the TiO_2 surface showed low dye loading and coverage on the surface, shorter electron lifetime and the greater resistance in the TiO_2/dye/electrolyte interface, publicized to the dye aggregation at the TiO_2 surface, which decreased the solar cell performance of the DSSCs.

Keywords: Energy conversion; Ruthenium dye; Dye sensitized solar cells; Sensitizers; Solvent effects

Introduction

The increase in the consumption of energy and its bad effect on environment, have led us to find more and more renewable energy sources. In this scenario the solar energy is famous and well known candidate. Gratzel or dye sensitized solar cells (DSSCs) are the third generation of solar cell and are feasible alternative to inorganic solar cells because of their easy and lower cost of production [1] and exhibit commercially pragmatic energy conversion efficiency [2]. Since the dye plays an important role in absorbing visible light and transferring photon energy into electricity, much attention has been paid to survey the effective sensitizer dyes [3]. The dye-sensitized solar cells (DSSC) which belong to the thin film group emerged as a new class of low cost energy conversion devices with simple manufacturing procedures [4]. The light to current conversion efficiency in DSSCs is achieved by injection of electron from valance band of excited dye into the conduction band of the semiconductor oxide, followed by dye regeneration with the help of electrolyte and moving hole to the counter electrode shown in (Figure 1). Extensively large amount of work has been done on dye molecule [5-7], semiconductor TiO_2 electrodes [8-10], counter electrodes [11] and electrolytes [12,13] to improve the DSSCs efficiency and stability. The design of organic dyes (i.e., geometric structures, molecular orbital energy, absorption profiles, and aggregation states of the dye) [14,15], reduction of the rate of charge recombination and the lack of electron donating moiety in the oxidized organic dye have also been proposed to have a great influence on output of DSSCs [16,17]. Thus, there is an intense need to design the molecular structure of organic dye or dye solvents to prevent dye aggregation (Figures 1 and 2).

In this Communication, the effect of chloroform and ethanol (as solvent for Z907 dye based DSSCs) on the absorption and solar cell performance are studied and evaluated. The synthesis and characterization of DSSCs composed of ITO, TiO_2 (dense and nonporous films), Z907 dye as sensitizers in DSSCs are investigated. The chemical structure of Z907 is shown in (Figure 2). The current-voltage results obtained are summarized in (Table 1). The device using chloroform as dye absorption solvent gives photon to current conversion efficiency of 1.40% higher as compared to similar device using ethanol, under full sun illumination (AM1.5, 100 mW/cm^2).

Experimental Section

Fabrication

Two devices are prepared with a standard procedure, firstly ITOs glass substrates are cleaned by treating them with washing powder, ethanol and IPA. The semiconductor TiO_2 dense and nonporous layers are pasted by spin coating and doctor blade techniques respectively, reaching a thickness of approximately 20 nm for dense layer and 30 µm for TiO_2 nonporous layer and then annealed for 45 mins in carbolated furnaces on 450°C. After that two photo electrodes are dipped in two different beakers with first have Z907 dye solution in ethanol as solvent and second in chloroform with 3×10^{-4} M for both solutions for a night. Both working electrode and carbon coated counter electrode are sealed together using binding clips as shown in (Figure 3). Finally, the Iodine/Iodide-based liquid electrolyte is injected in between the electrodes through injection by capillary action (Figures 3 and 4).

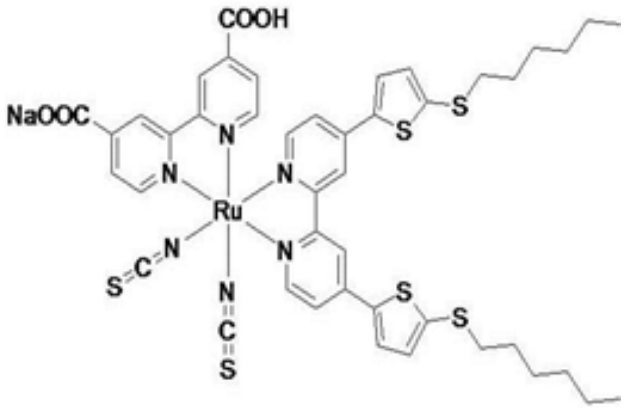

Figure 1: Systematic diagram of DSSC.

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Received July 13, 2017; **Accepted** July 25, 2017; **Published** August 02, 2017

Citation: Shah ZA, Zaib K, Khalid M,saeed M (2017) Dye Sensitized Solar Cells Based on Different Solvents: Comparative Study. J Fundam Renewable Energy Appl 7: 234. doi:10.4172/20904541.1000234

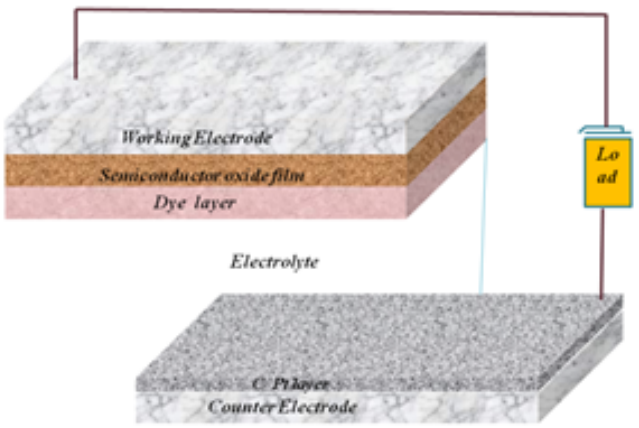

Figure 2: Chemical structure of Z907 dye.

	Voc (V)	Isc (mA)	Area (cm^2)	Jsc (mA/ cm^2)	Fill Factor (%)	Efficiency (%)
Dye in Ethanol	0.29	0.131	2	0.065	81.1	0.15
Dye in Chloroform	0.62	0.88	2	0.44	50.5	1.40

Table 1: I-V Parameters for DSSCs in ethanol and chloroform.

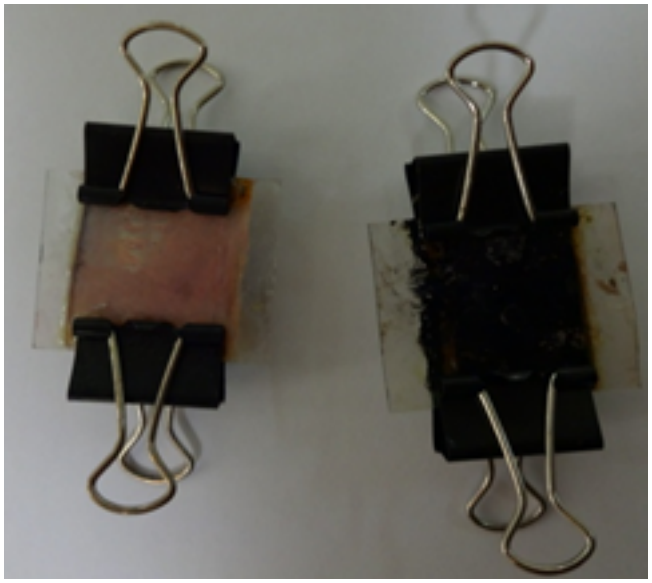

Figure 3: DSSCs hold together by binding clips.

Results and Discussion

The photovoltaic response of the Z907 based DSSCs for two selected dye absorbent solvents have been investigated. Specifically, current-voltage (I-V) characterization is investigated through KEITHLEY 2420 source meter shown in Figure 4 and I-V curve given in (Figure 5), measured under 1000 W/m^2 while other cell parameters such as Short circuit current (I_{sc}), Open circuit voltage (V_{oc}), current density fill factor (FF), efficiency (η) are measured through I-V curves and formulae and are summarized in (Table 1). The use of $CHCl_3$ as adsorption solvent increases the photovoltaic efficiencies that show the large dye loading from $CHCl_3$ solution on the TiO_2 surface rather EtOH.

Figure 4: Keighley 2420 Source meter.

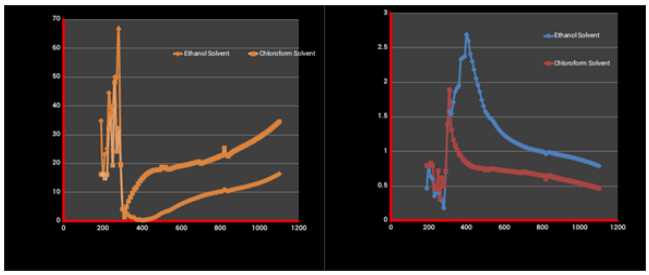

Figure 5: Measured I-V curves for $CHCl_3$ and EtOH as dye absorbent solvent.

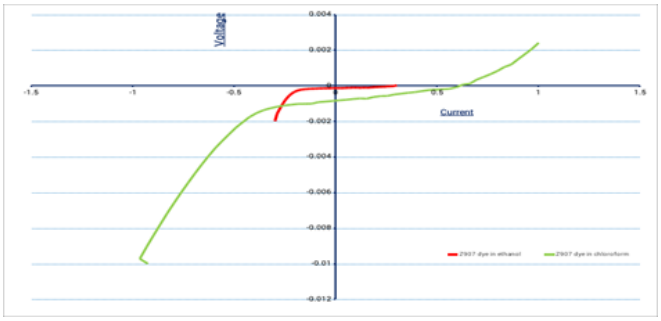

Figure 6: Transmittance and absorption spectra for ethanol and chloroform.

Efficiency

Efficiency is one of the most important representative parameter of the overall cell performance defined by the formula below:

$$\text{Efficiency } (\eta) = (V_{oc} \times J_{sc} \times FF)/P_{in}$$

UV transmittance and absorbance spectra are recorded on a SPECORD 200 as shown in (Figure 6). The Z907 dye is dissolved in $CHCl_3$ and EtOH to prepare dye solution and the concentrations of solutions used are set as 3×10^{-4} M. Their spectroscopic data characterize all of their chemical structures. In the range of 300-650 nm, Z907 dye in $CHCl_3$ as compared to EtOH exhibited broad absorption. The n-π^* and localized π-π^* transitions attributes by short wavelength region i.e., from 280-340 nm while the long wavelength region i.e., 390-510 nm,

attributes charge transfer transitional energy of the delocalized π-π* transition and results in donor-π-acceptor system. With respect to $CHCl_3$, the absorption band is relatively blue-shifted using EtOH. This action is due to the solvent effect (Table 1). The charge transfer absorption band is destabilized in ethanol like solvents because of hydrogen bonding interactions between the donor and/or acceptor moieties and ethanol [18,19] while $CHCl_3$ is less polar than EtOH and thus transfer absorption band is more favourable for it (Figures 5 and 6).

Conclusion

Two DSSCs are fabricated and are constantly soaked in Z907 dye solution during the whole night hours. The UV spectra and photovoltaic performance of two devices are tested in $CHCl_3$ and EtOH solution as dye adsorption solvents, and it is found that the Photovoltaic performances are influenced by the dye adsorption solvent. The highest photon to current conversion efficiency of 1.40% is obtained for $CHCl_3$, as a dye solvent. The conversion efficiency of the DSSC is found strongly dependent on the kind of solvent used, because dye solvent directly affects the loading of dye and charge moieties in DSSCs.

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