

FACTORS CONTROLLING TRANSPARENCY TO THE EFFICIENCY OF PHOTOVOLTAIC RATION BY SUITABLE DYE SELECTION USING DYE-SENSITIZED SOLAR CELLS

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ABSTRACT

Dye synthesized solar cell (DSSC) is a great promising inexpensive renewable source of energy that have a big profile of application specially the transparent solar cell. Transparent DSSC is the core focus of this paper. The transparent solar cell was prepared using titanium dioxide (TiO₂) nanoparticles as a counter electrode. The method for depositing TiO₂ is screen printing. The design of the solar cell followed the traditional way containing Fluorine doped Tin Oxide (FTO) glass, TiO₂, electrolyte, Platinum (PT) as a counter electrode, and N719 dye. The results indicated that the thickness of TiO₂ thin film is 2.926 [μm] and 75% transparency before the assembly of the whole cell. On the other hand, the achieved transparency of the solar cell after the assembly was 70% and the efficiency is 3% using screen printing. This paper studies the variables that affect the transparency and the efficiency at the same time and suggest ways to improve the quality of transparent solar cell by selecting a suitable dye.

Keywords: DSSC; Transparent Solar cell; transparent dye; photovoltaic; titanium dioxide

INTRODUCTION

Transparent photovoltaic have attracted much attention as a promising source of renewable energy to decrease the reliance on fossil and nuclear industries. In the earlier period, a lot of attempts have been committed to the improvement of photovoltaic especially organic photovoltaic (OPV). [1] There are many challenges facing the researchers in the way to develop technologies that convert solar energy to electricity equally efficient to fossil fuel. [2] Some of these challenges are cost of fabrication, materials, lifetime, and space to place the solar cell. Transparency is a main property of glass that is not shared with currently commercialized solar cells. This creates a problem since the transparent glass in most applications is necessary to provide light to

users within. It is therefore highly desirable to transfer the transparency property to solar cells. This brings the need to make transparent solar cell and can be implemented in buildings, cars, trains, airplanes, and electronic devices. Therefore, transparent solar cell is desired to be fabricated to solve the problem of space. However, transparency characteristic is just the total opposite of the solar cell fundamental. This is to absorb the light and not to let it pass through. A wide number of researchers are working on this feature and trying to construct a transparent solar cell in different directions. This research is focused on finding factors that influence the maintenance of high transparency with better efficiency of the transparent photovoltaic through selecting suitable dye using DSSC design for the cell and Titanium dioxide for the photo anode. The photo catalytic property of Titanium dioxide is useful for converting the solar energy into chemical energy to oxidize the material [3]. In addition to that Titanium dioxide (TiO₂) properties varies, such as super-hydrophilicity, oxidization, nontoxic, chemical stability, can be used for a long time, low cost and transparent to visible light [4].

MATERIALS

Fluorine doped Tin Oxide (FTO) Glass - Substrates (Kaivo, China), Acetone and ethanol, deionized (DI) water for cleaning the FTO glass, TiCl₄ for photo anode coating before TiO₂. Materials to make the electrolytes - Acetonitrile (solvent), Iodine (I₂) (QRëC, New Zealand), Lithium iodide crystalline powder 99.9% trace metals basis (LiI) (Aldrich, USA), 4-tertButylpyridine 96% (Aldrich, USA), Ethyl-methyl-Imidazolium iodide (Aldrich, USA). Dyes selections SQ2: C₅₂H₇₂N₂O₆ (kyutech, Japan) and Tastca: C₃₀H₂₂N₂O₂ (kyutech, Japan). TiO₂ transparent (Aldrich, USA), Ti-Nanoxide T/SP (Solaronix, switzerland). TiO₂ transparent (Aldrich, USA), Ti-Nanoxide T/SP (Solaronix, switzerland).

EXPERIMENTAL

The experiment starts with cleaning process for all samples. It is then followed by deposition of the transparent paste and immersing of the samples in different dyes. Finally the samples were combined together.

Cleaning process

All the experiments in this paper use FTO glass as a substrate. The samples are cut in (2x2) cm² size. And cleaned with soap and water, and then cleaned in an ultrasonic bath in Deionized (DI) water, followed with Acetone and Isopropanol. The samples are blow dried. This cleaning process makes the substrates suitable for preparing the samples.

Deposition of photo anode and counter electrode

TiO₂ transparent paste is deposited on FTO glass using screen printing board [5] (characterization : 90 T-mesh/cm (230T mesh/inch), 60 µm mesh opening, 50 µm thread diameter, 29.8% open surface, 20 µm fabric thickness, 24.5 (cm³)(m⁻²) theoretical paste volume, (17cm³)(m⁻²) k/k volume, 48gm⁻² weight). The amount of

paste is enough to cover the 1x1 active area of the sample. The resulted thickness expected is between 2.5 μm and 3 μm . As for the counter electrode after depositing Pt on the FTO glass the samples were exposed to 450 C in the furnace for 30 minutes (2 hours rising up and 2 hours declining while 30 minute is at 450 C settled). Then, the samples were ready to be immersed in dye.

Different type of dyes

Four samples were prepared and immersed in 3 types of dyes. The first sample was immersed in the SQ-5: blue, the second one in TASTCA: Yellow, and the third one in a cocktail dye containing a mixture of both, the fourth sample was placed in the TASTCA dye and then SQ-5 dye. All samples were immersed in the dyes for 5 hours. Combining the cell in DSSC assembling was done following the conventional method reported in [6]. After taking the electrode TiO_2 glass out of the dye solution, it was cleaned with some ethanol and air-dried for 10 minutes. The electrolyte was prepared out of Acetonitrile solvent 10ml, I_2 0.05M, LiI 0.1M, 4-tert-Butylpyridine 0.5M, and Ethyl-methyl-Imidazolium iodide 0.6M. The photoanode covered with dye while the counter electrode was covered with Pt, were assembled in a sandwich form using polymer sheets with a 25 μm thickness on a hot plate. For depositing the electrolyte, a small space left open as shown in Figure 1. In this experiment, no hole is made in the counter electrode. Finally, 1-2 drops of the electrolyte were added from the open corner of DSSC and the cell was sealed using Epoxy resin to finish the assembling of the cell.

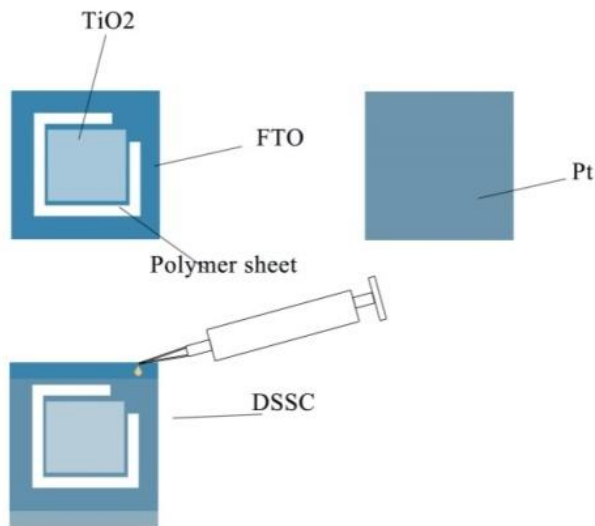


Figure 1: DSSC assembling

RESULTS AND DISCUSSION

Before combining the cells a transmission and absorption test was performed to measure the amount of transmitted light through the photo anode after depositing the paste. Table 1 demonstrates the absorption peak for each dye at a specific wavelength. The test was performed after every sample immersion (for an hour in each dye). The

samples were coated with the transparent paste of TiO₂ using screen printing. It is notable in Table 4.2 that the absorption of the TASTCA dye increased with immersion time up to a maximum of 5 hours, after which the absorption stabilized and eventually dropped. To the contrary, the SQ-5 dye needed 2 hours to be fully absorbed at this thickness and any more than that decreased the absorption of the dye. An absorbance of 2.3% was obtained after 2 hours of immersion in the blue dye. For the dye cocktail, a 50%-50% combination of SQ-5 and TASTCA dyes, the result was green in color and it needed a maximum of 3 hours to obtain a good absorption of up to 0.6 for blue at 668 nm and 0.98 for yellow at 338 nm. The combination of more than one dye, in order to obtain good absorption, can be performed in another manner. This alternate method starts by immersing the samples in SQ-5 for a period of time, followed by a cleaning with ethanol and immersion into the TASTCA for five hours. The last sample was immersed in SQ-5 then TASTCA. Table 2 demonstrates that for the sample resulting from dye SQ-5 then TASTCA, it is best to keep the photo anode in SQ-5 for only 1 hour instead of 2 since the absorbance dropped from 0.84 to 0.56 if left in the dye for more than 1 hour. Furthermore, this sample should then keep the photo anode in the TASTCA dye for 5 hours, as the absorbance increased to 1.17. For the second sample

Table 1: photo anode absorbance results

Dye type	Wavelength of the peak (nm)					A%				
	1h	2h	3h	4h	5h	1h	2h	3h	4h	5h
TASTCA (yellow)	383	347	349	410	455	0.3663	1.0	0.95	1.3	0.16
SQ-5 dye (blue)	673	668	671	662	690	2.45	2.4	2.3	2.23	0.8
TASTCA&SQ-5 (Blue + yellow= green)	670 /337	670/339	668/338	667/416	658/457	0.5773 / 0.8778	0.49/0.77	0.62/0.98	0.58/0.96	0.25/0.7
SQ-5 then TASTCA (Blue then yellow)	664	670	671	668	667	0.84	0.56	0.56	0.37	0.3
	347	350	412	409	450	0.5	0.4	1.17	1.22	0.3

the efficiency is tested using the solar cell analyzer with light intensity of 100 [mW/cm²] (1 kW/m², one-sun of illumination), Cell temperature of 25 °C and a mask with 0.2025 (cm²) open area. The resulted efficiency is presented in the table 1 bellow. Which shows that the height obtained efficiency was 3.02 using TASTCA dye. SQ-5 and TASTCA cocktail come in second place with efficiency of 2.9. However the transparency of this dye is not preferable to be used in a transparent solar cell. The last 2 dyes are SQ-5 and SQ-5/ have lower efficiency and as mentioned before they have also lower transparency.

Table 2: Efficiency test for solar cell using different dyes

Dye	SQ-5	TASTCA	SQ-5+TASTCA	SQ-5 then TASTCA
n%	2.2	3.02	2.9	2.17

CONCLUSION

In summary, in this research a transparent solar cell is constructed using DSSC design. The factors that control the transparency to efficiency ratio are possible to be maintained, in order to get a transparent solar cell that can be used in real life application. This paper discussed the used dye as a major factor that affects the transparency and the efficiency of a transparent DSSC. The test is made using samples of DSSC that used transparent commercialized titanium dioxide. Between the four types of dyes were used the most transparent one was the TASTCA with 75% transmission, and 3.02% efficiency, which is the highest efficiency compared with the rest of the samples using the other dyes. The resulted solar cell gives a light yellow reflected color. There are wide numbers of dyes with different color reflection with different efficiency effects. It is advisable in general to select the dye based on the absorption wave length that the dye obtains.

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