Fabrication Of Dye Sensitized Solar Cell Using Various Counter Electrode Thickness

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ABSTRACT: Dye Sensitized Solar Cell (DSSC) or better known as the 'Gratzel cell' is a low-cost solar cell belonging to the group of thin film solar cells. It is based on a semiconductor formed between a photo-sensitized anode and an electrolyte that forms a photo-electrochemical system. This paper discusses about the fabrication of a DSSC with the usage of recycled materials and organic dye. The DSSC is fabricated using 'Dr. Blade' method which revolves around the use of graphite from batteries and organic dye from rose extract. Results are based on electrical performance and characteristic of the fabricated TiO2 solar cell based on the graphite coating thickness. The required data are investigated in terms of fill factors, solar cells efficiency and UV absorption. Result shows that thinner layer of graphite coating have good potential as an alternative counter electrode material.

KEYWORDS: DSSC, dye, graphite, thickness, fill factor, efficiency

1. INTRODUCTION

A dye-sensitized solar cell (DSSC) or better known as the gratzel cell is a low-cost solar cell from the thin film solar cell group. It consists of few semiconductor materials that are formed between a photo-sensitized anode and an electrolyte thus creating a photoelectrochemical effect. The modern version of a dye solar cell was originally co-invented by Brian O'Regan and Michael Grätzel at UC Berkeley and this work was later developed by the aforementioned scientists at the École Polytechnique Fédérale de Lausanne until the publication of the first high efficiency DSSC in 1991 (O'regan and Grätzel). DSSC has various advantages features being that it is simple to make using conventional roll-printing techniques, is semi-flexible and semi-transparent which offers a variety of uses not applicable to glass-based systems, and most of the materials used are low-cost. In practice it has proven difficult to eliminate a number of expensive materials, notably platinum and ruthenium, and the liquid electrolyte presents a serious challenge to making a cell suitable for use in all weather. Although its conversion efficiency is less than the best thin-film cells, in theory its price to performance ratio should be good enough to allow them to compete with fossil fuel electrical generation by achieving grid parity (Tributsch 2004).

2. ADVANCE RESEARCH ON DSSC

M.C. Kao et al focused on the thickness of the TiO_2 Substrate by using sol gel and rapid thermal annealing method in the range of 0.5–2.0 μm. Based on the result despite having thicker TiO_2 film which has an easy adsorption of the N3 dye, thinner material (1.5 μm) has higher short-circuit current (Isc), open-circuit voltage (Voc) and transmittance value which could increase the incident light intensity on the N3 dye. Optimum power conversion efficiency (η) of 2.9% was also obtained through the TiO_2 film thickness of 1.5 μm (Kao et al 2009). Jiaguo Yu. et al fabricated the DSSC based on a double-layered composite films of TiO_2 nanoparticles and hollow spheres. Data was focus on nanoparticles/nanoparticles (PP), hollow spheres/hollow spheres (HH), hollow spheres/nanoparticles (HP), and nanoparticles/hollow spheres (PH) double-layered films in which shows an efficiency of 4.33, 4.72, 4.93 and 5.28%, respectively. High surface areas and the number of poresness in the TiO_2 hollow spheres are good in terms of adsorption of dye molecules and transfer of electrolyte solution (Yu and Shu 2011). By using the screen printing method, the DSSC with a thickness of 6-10 μm were characterized by Haiyan Zhang et al. Data was tested on its scanning electron microscopy images, X-ray diffraction and UV–vis absorption spectroscopy towards the effects of thickness on the photoelectric conversion performance of the fabricated DSSCs. photoelectric conversion efficiency rose from 5.52% through 8 printing layers to 6.49% by combining a moderate amount of graphene to TiO2. The results indicated that graphene not only enhances the transport of electrons from the film to the fluorine doped tin oxide substrates and reduces the charge recombination rate, but also reduces the electrolyte–electrode interfacial resistance, clearly increasing the photoelectric conversion efficiency (Zhang et al 2014). M.S. Liang et al has also fabricated the DSSC and characterized it by X-ray diffraction (XRD) analysis, scanning electron microscopy (SEM), electron diffraction X-ray (EDX) analysis, UV–vis spectrometry and a current-voltage (I-V) test. Result shows that thicker anatase TiO2 has better crystalline which leads to better solar cell efficiency whilst mesoporous TiO2 with an average pore size shows higher conversion efficiency and less size particle leads to a higher dye adsorption and increases the short circuit current density (Liang 2013).

3. DYE SENSITIZED SOLAR CELL (DSSC) STRUCTURE

Figure 1 shows three main parts of a DSSC. Firstly the layer of transparent conducting oxide called the ITO or FTO coated glass followed by an electrode normally a mesoscopic porous structure with a very high surface area usually TiO_2. The TiO_2 is usually annealed for a certain degrees Celsius and left to cool at room temperature. The electrode is than soaked with a high absorbance mechanism called the sensitizer or dye which is usually a photosensitive ruthenium-polypyridine dye, also known as molecular sensitizers and solvents (Sen 2008), for better absorption of photons from sunlight. This electrode is sandwich with a counter electrode usually from platinum or graphite and dips of electrolyte use in between the sandwiched solar cell to jumpstart the electron flow.

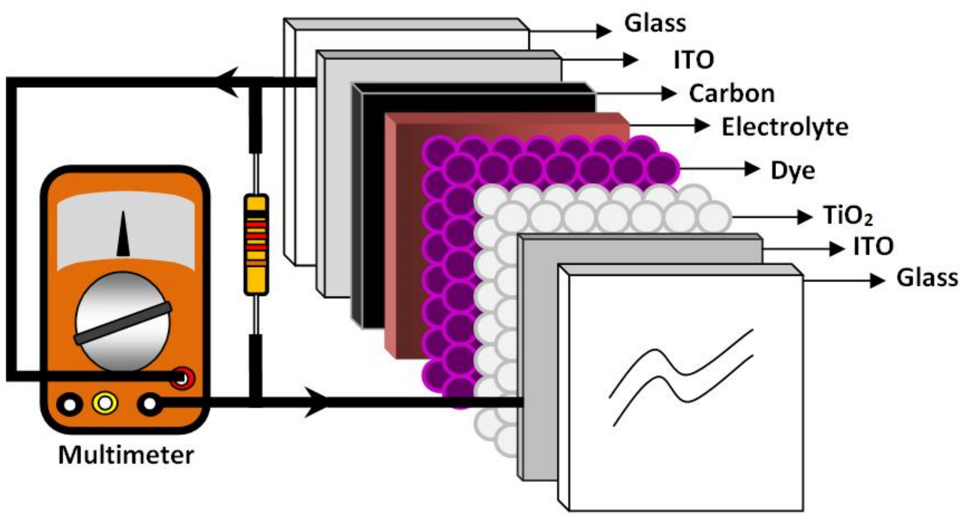

Figure 1 Schematic of the construction of Gratzel cell.

4. METHODOLOGY

4.1 Dye Sensitizer from rose extract

Fresh rose flowers of 30g are soaked with ethanol and then are mixed into 20 ml distilled water with a ratio of 1:1 at room temperature. These items are blended with distilled water for 15 minutes until the dye takes into an approximate fluid form and is dark maroon in color as shown as Figure 2. The mixture undergoes centrifuge at 3000 rpm for 25 minute at 25°C. Dropper been used to collect dye pigment at center of the test tube and is used for Ultraviolet-visible Spectroscopy (UV-Vis) measurement as well (Ahmad and Nafarizal2010).

Figure 2 Rose extract as dye sensitizer

3.5 g of (TiO2) nano-powder P25 is added with triton-X solution and the mixture is stir until homogenous as shown on Figure 3.

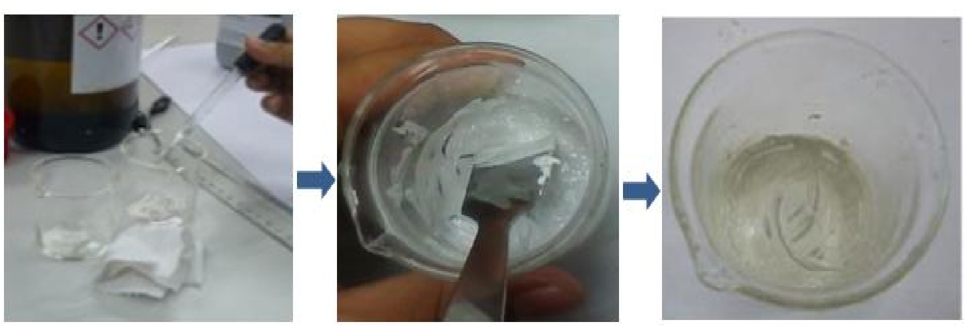

Figure 3 Preparation of TiO2 Paste

4.2 Fabrication procedure of Dye sensitized solar cells (DSSC) Dr. Blade Method

Scotch tape is applied on four corners of the conducting side of ITO glass; the scotch tape thickness is measured by using electronic digital caliper. The TiO_2 paste is added on to the ITO glass and is smeared with a razor blade on one side of the ITO glass. ITO glass is annealed on top of a hot plate to approximately 450 ºC for 30 minutes. After 30 minutes, the ITO glass is left to be cold at room temperature before it is soaked into the dye solution. As for the counter electrode, carbon from battery is smeared on to the ITO as TiO_2 using Dr. Blade's method. The TiO_2 and dye electrode is removed from the dye solution and is rinsed with ethanol to remove debris. The spacer is placed on the TiO_2 and dye electrode and some drops of the electrolyte solution is drip onto the TiO_2 and Dye layer. Both the electrode and counter electrode is combined facing each other by a binder clips. Using binder clip, the solar cell is sandwich together. The procedures are shown in Figure 4.

Figure 4 Steps of fabrication of DSSC using Dr. Blade

4.3 Procedure to record data of voltage and current indoor and outdoor

The fabricated solar cell is then tested under both the halogen lamp which simulates a light source and also under solar irradiance. The required parameters are taken as shown in Figure 5 and Figure 6.

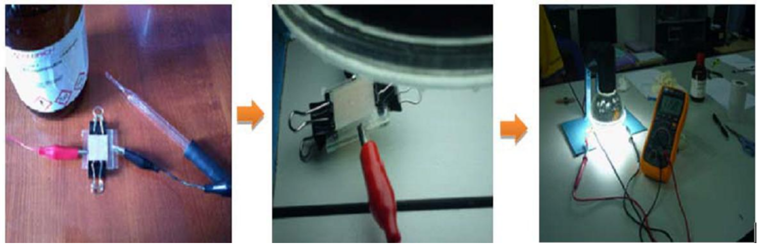

Figure 5 Indoor measurement by using halogen lamp

Figure 6 Outdoor measurement under solar irradiation

5. RESULT AND DISCUSSION

After fabrication, the DSSC are placed and measured under halogen lamp and solar irradiation ragging from 500-800W/m^2. The samples are measure in terms of Fill Factor (FF), Solar cells Efficiency (η) and UV-Absorption radius for the Rose flower extract. Table 1 shows the summary of results obtained from the indoor and outdoor testing using Dr. Blade methods. The sensitizer for both test uses dye extracted from rose petals.

Table 1: Summary of the Fabricated (DSSC) with Dr. Blade Method

TiO_2 Coating Thickness (µm)	**Graphite thickness (µm)**	**Dye**	**Test**	**FF**	**DSSC Efficiency, η%**
30	**30**	ROSE EXTRACT	Halogen lamp 512W/m^2	**0.85**	**0.06%**
	60			**0.86**	**0.11%**
	30		Irradiance 832W/m^2	**0.74**	**0.16%**
	60			**0.74**	**0.05%**

The TiO_2 coating thickness of 30µm was used for the electrode samples where else the counter electrode thickness is varied to 30µm and 60µm. Both samples are simulated and tested under a halogen lamp with 512W/m^2 and solar irradiance of 832W/m^2. Result shows that at 30µm of counter electrode thickness, the efficiency is higher compared to 60 µm and is the same with both test conditions. Despite having solar cell efficiency of below 1%, the fill factors shows promising data ragging from 0.7-0.86. This may be due to the usage of materials with long excitation diffusion length. Based on overall result, it shows that thinner coating thickness of graphite for the counter electrode has better performance and this may be due to the internal resistance of the semiconductor materials which is low compare to higher thickness material. In certain literatures, result shows that 10µm is the optimum thickness for a DSSC in TiO_2 coating but less describes the optimum thickness in the counter electrode region.

6. UV ABSORPTION OF ROSE EXTRACT

The spectrometer was used to determine the rate of absorption in the rose petal sensitizer which was used in DSSC fabrication. Figure 7 shows the absorbance rate of the rose dye is ragging from 400-600nm which is in the range of violet to almost red color in the spectrometry chart. Rose dye has the aspect of anthocyanin pigments in the region of 520 nm to 550 nm.

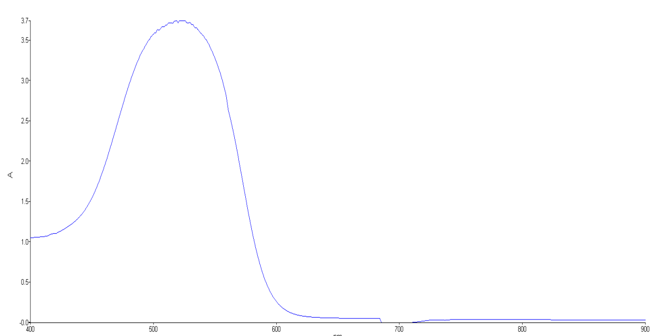

Figure 7 Graph of UV-Visible Transmittance for Rose Extract

The peak of this graph is 3.7 which is at 520nm wavelength. The chemical adsorption of the rose extract is a result of a chemical bound of hydroxyl at the surface of TiO_2 film which enhanced the adsorption molecules and increased the performance of dye sensitized solar cell (DSSC).

7. CONCLUSION

Based on the overall experiment, one could conclude that the electrical performance and characteristic of the fabricated TiO_2 solar cell based on the graphite coating thickness has been investigated. Graphite has potential to be use as a counter electrode material and replacing platinum which is expensive and scarce at times. Result also shows that the thinner the counter electrode thickness, the better the result in terms of fill factors having reached more than 50%. This might be due to usage of materials with long excitation diffusion length. The organic dye from rose extract shows potential application as a sensitizer because result shows that the peak absorbance rate is high and excites at shorter wavelengths.

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REFERENCES

O'regan, B., & Grätzel, M. (1991). A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO2 films. *nature*, *353*(6346), 737-740.

Tributsch, H. (2004). Dye sensitization solar cells: a critical assessment of the learning curve. *Coordination Chemistry Reviews*, *248*(13), 1511-1530.

Kao, M. C., Chen, H. Z., Young, S. L., Kung, C. Y., & Lin, C. C. (2009). The effects of the thickness of TiO 2 films on the performance of dye-sensitized solar cells. *Thin Solid Films*, *517*(17), 5096-5099.

Yu, J., Li, Q., & Shu, Z. (2011). Dye-sensitized solar cells based on double-layered TiO 2 composite films and enhanced photovoltaic performance.*Electrochimica Acta*, *56*(18), 6293-6298.

Zhang, H., Wang, W., Liu, H., Wang, R., Chen, Y., & Wang, Z. (2014). Effects of TiO 2 film thickness on photovoltaic properties of dye-sensitized solar cell and its enhanced performance by graphene combination. *Materials Research Bulletin*, *49*, 126-131.

Liang, M. S., Khaw, C. C., Liu, C. C., Chin, S. P., Wang, J., & Li, H. (2013). Synthesis and characterisation of thin-film TiO 2 dye-sensitised solar cell.*Ceramics International*, *39*(2), 1519-1523.

Sen, Z. (2008). *Solar energy fundamentals and modeling techniques: atmosphere, environment, climate change and renewable energy*. Springer Science & Business Media.

Ahmad, R., Ali, M., & Nafarizal, N. (2010). Fabrication and analysis of dye-sensitized solar cell using natural dye extracted from dragon fruit.*International Journal of Integrated Engineering*, *3*(3), 1-8.