Design and Construction of a Series and Parallel Connected Dye-Sensitized Solar Cell Module

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Abstract

A series and parallel connected dye-sensitized solar cell module has been constructed by using natural dyes extracted from teak leaves as sensitizer. This solar cell module was assembled with two 20-30 ohms conductive glasses (TEC 15, Dyesol) (one for TiO_2 coated electrode and another for carbon coated electrode), TiO_2 nano-powder (Degussa-P25 powder), iodide electrolyte solution and soft graphite pencil for carbon coating. It was found that the open circuit voltage V_{oc} was 1.565 V and the short circuit current I_{sc} was 0.294 mA.

Keywords: Dye-sensitized solar cell module, Natural dyes, TiO_2 nano-powder, V_{oc} , I_{sc}

Introduction

A photovoltaic module refers to an array of identical solar cells which are all interconnected in series or in parallel. In series connection, the voltage of the individual cells adds up, while the current of the module is the same as the current of single cell. Thus, to achieve a high utilizable voltage, cells must be interconnected in series forming a module. In parallel connection, the current of the individual cells adds up, while the voltage of the module is the same as the voltage of it single cell. Thus, to achieve a high utilizable current, cells must be interconnected in parallel forming a module. A module may contain several numbers of cells. In this work, an attempt was made to fabricate a dye-sensitized solar cell module using series connection and parallel connection.

The integrated series connection for DSSC modules can be designed in 3 ways: Z-connection, W-connection and Monolithic connection. Among these 3 ways, the Z-connection has been chosen as the favored type of integrated series connection because it was found in literature that the highest efficiencies can be attained with this design.

Fig. (1) schematically shows the construction of a series connection of Z-type. First the transparent conducting oxide (TCO) layer on the glass substrate is structured by laser scribing Fig. (1-a). Then, the TiO_2 layer, the silver lines and the glass frit are screen-printed on the substrate and dried. The glass frit is screen printed as a protective barrier on both sides of the silver lines Fig. (1-b). After sintering both electrodes are positioned on top of each other and fused at high temperatures. Thus, the glass frit forms a hermetic seal around the silver provided that the layer thickness of the glass frit and the silver match, the electrical Z-contact is formed during the glass fusing process.

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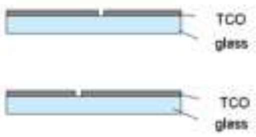

Figure (1-a)

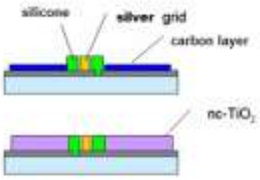

Figure (1-b)

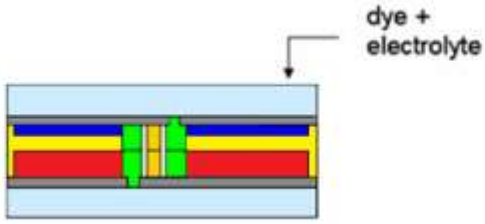

Figure (1-c)

Fig. (1) The Design for Z-connection of DSSC Module

Experimental Procedures

Substrate cleaning

The substrates were first dipped into Acetone with ultrasonic bath for at least 5 minutes to dissolve unwanted organic materials and to remove dust and contamination materials that are left on the substrates post manufacture. Another 5 minutes of ultrasonic bath in Methanol was followed in order to remove the acetone and materials that are not cleaned or dissolved by acetone. Finally, 5 minute ultrasonic bath in isopropyl alcohol (IPA) was needed to further remove the residual particles on the substrates. The cleaned substrates were then put inside the 90 °C oven and baked for at least 15 minutes followed by a quick nitrogen blow to ensure that the solvents were vaporized and that the remaining particles were removed.

Preparation of TiO_2 suspension

The 6g of TiO_2 nano-powder P25 was put in the mortar Fig. (2-a) and then 1mL nitric acid solution (pH3-4) was added to it while grinding with a pestle until a colloidal suspension with a smooth constancy was obtained Fig. (2-b). Some clear dishwashing detergent was then added. The mixture was kept to equilibrate at room temperature for about 15 minutes.

Fig. (2-a) Weighing TiO_2 nano-powder

Fig. (2-b) TiO_2 suspension

Preparation of TiO_2 film

First the design of a series and parallel connected DSSC module was drawn on the paper (Kay & Gratzel, 1993). Using a multimeter the conducting side was identified. For series connection, the two transparent conducting oxide (TCO) layers on the glass substrates were structured by laser scribing. By placing the conducting side of tin oxide coated glass plate up, the glass was taped with 3M Scotch tape, with a 0.5 cm wide strip on the top of the plate and 2 cm wide strip in the middle of the plate. Moreover, 0.5 cm wide gaps between the cells were taped by the tape. Fig. (3-a) shows the design putting TiO_2 paste on the glass.

Some titanium dioxide (TiO_2) suspensions were put on the glass and quickly spread over the surface using a glass rod (doctor-blade method). Fig. (3-b) shows TiO_2 paste coated on the glass. The tape was then carefully removed without scratching the TiO_2 coating (Fig.3-c). The coated plate was dried for 1 minute in a covered Petri dish. The glass plate was heated on the hot plate about 30 minutes until a white titanium dioxide coating was formed. The glass plate was then slowly cooled by turning off the hot plate (Fig.3-d). For series connection, the silver line was drawn in the middle of the glass substrate. For parallel connection, the tape was sandwiched between the cells as the spacer. The silicone was drawn as a protective barrier on both sides of the silver line.

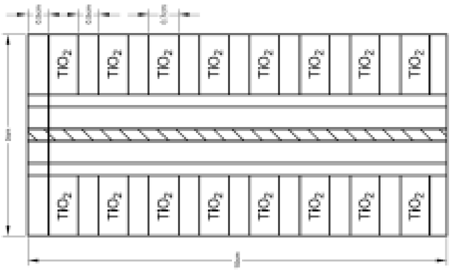

Fig. (3-a) The Design putting TiO_2 paste

Fig. (3-b) Spreading TiO_2 suspension on the glass

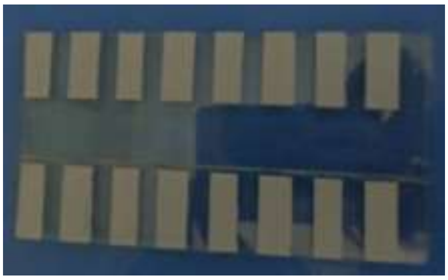

Fig. (3-c) TiO_2 coated plate

Fig. (3-d) Heating the glass on the hotplate

Extracting dye

In the fabrication of a series and parallel dye-sensitized solar cell module, the natural herbal extract dyes from teak leaves have been used as sensitizer. To extract dyes from the leaves, the leaves were ground in a mortar and then 2-3 mL of acetone was added (Fig.4-a). Then it was squeezed into the Petri dish (Fig.4-b). The colour of dyes was brownish red for teak leaves.

Fig. (4-a) Grinding the teak leaves in a mortar

Fig. (4-b) The dye solution extracted from teak leaves

Staining TiO_2 film

The dye solution was then poured into a rectangular shape plastic tray. The TiO_2 electrode was dipped into the dye solution with the coated side down for 24 hours until no white TiO_2 can be seen on either side of the glass (Fig.5-a). The glass plate then appeared as brownish red in color (Fig.5-b). It was first washed in H_2O and then in ethanol in order to remove water from the porous TiO_2. Any residue was wiped off with a tissue, blotting gently to dry it.

Fig. (5-a) TiO_2 electrode dipped into the dye solution

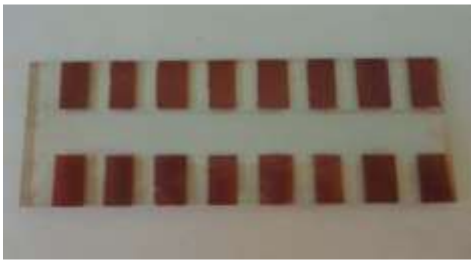

Fig. (5-b) Brownish red color glass plate

Preparation of Carbon-coated Counter electrode

Another glass plate was first washed with ethanol. Then, using a multimeter the conducting side was identified. By scratching thoroughly with a soft graphite pencil, a thin carbon coating was put on the conductive side of the glass plate as shown in Fig. (6). The silver lines were drawn in the middle of the TCO glass substrate coated carbon and dried. The silicone was drawn as a protective barrier on both sides of the silver line.

Fig. (6) Carbon coating electrode

Preparation of liquid electrolyte

0.5 M Potassium iodide was mixed with 0.05 M iodine in water-free ethylene glycol. 10 mL of ethylene glycol was put in a container. Then, 0.127 g of I_2 (Iodine) and 0.830 g KI (Potassium Iodide) was added to it. They were mixed together stirring with a clean glass rod. All the bottles and the containers were kept tightly capped when not in use.

Assembling the solar cell module

The carbon-coated glass plate was placed with the coated-face down on the TiO_2 coated glass plate. The two glass plates were stacked slightly off set sandwiching the spacer in between Fig. (7). The plates were bound together with the binder clips on each side of the longer edges (Romeo, 2002).

Then, two to three drops of iodide electrolyte solution was put on one edge of the plates. Each side of solar cell was then made slightly open and closed alternately so that the electrolyte solution was drawn in and wet the TiO_2 film, and thus making all the stained area to be in contact with the electrolyte solution.

Fig. (7) Assembling a series and parallel connected DSSC module

Results and Discussion

The properties of carbon were examined using RIGAKU-RINT 2000 X-ray Diffractometer. By using Scherrer equation, the average crystallite size of carbon powder was found to be 78.616 nm. Fig. (8) shows XRD pattern of carbon.

Nanosized titanium dioxide (TiO_2) semiconductor was also analyzed by XRD pattern. The X-ray diffraction pattern was recorded to different diffraction peaks corresponding to different planes. The resulting XRD pattern was found to be exactly coincided with the reference (78-2486) TiO_2 pattern (Meyers, 1997). This shows that the used TiO_2 nano-powder was pure with no other chemical impurities. The average crystallite size of TiO_2 was about 40.81 nm and anatase phase was observed. Fig. (9) shows XRD pattern of TiO_2 nano-powder (Smestad & Gratzel, 1998).

Fig. (10) shows the measuring pH for teak leaves dye solution with pH meter. It was found that the pH of teak leaves dye was 5.67.

The UV-Vis absorption spectrum in the wavelength range between 300 nm and 700 nm of liquid dye extracting with acetone from teak leaves was shown in Fig. (11). The absorbance peaks appeared at 413 nm and 663 nm and maximum absorbance A_{max} was 1.081 at 413 nm.

For a series and parallel connected dye-sensitized solar cell module, the open circuit voltage V_{oc} was found to be 1.565V and the short circuit current I_{sc} was found t0 be 0.294 mA asa shown in figure (12-a & b) respectively (Ngamsinlapasathian et al., 2000).

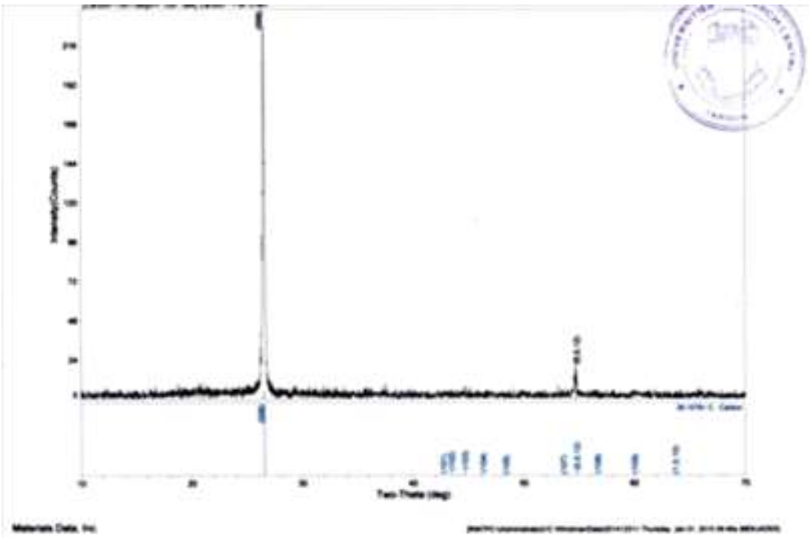

Fig. (8) XRD pattern of carbon powder

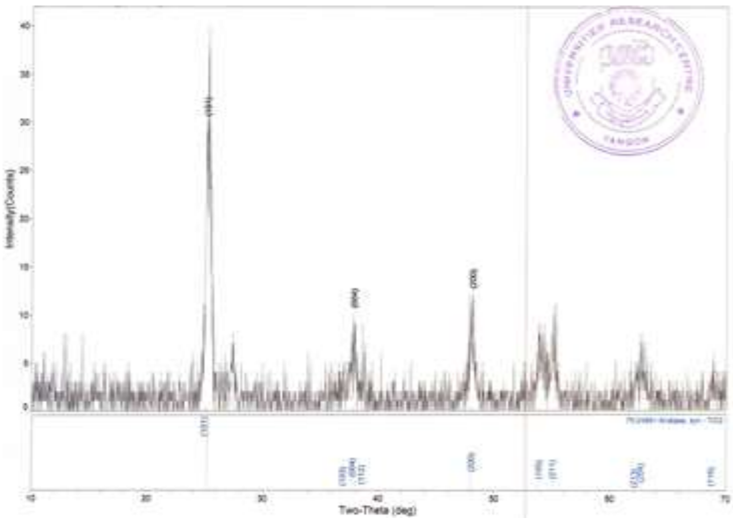

Fig. (9) XRD pattern of TiO_2 nano-powder

Fig. (10) Measuring pH for teak leaves dye solution with pH meter

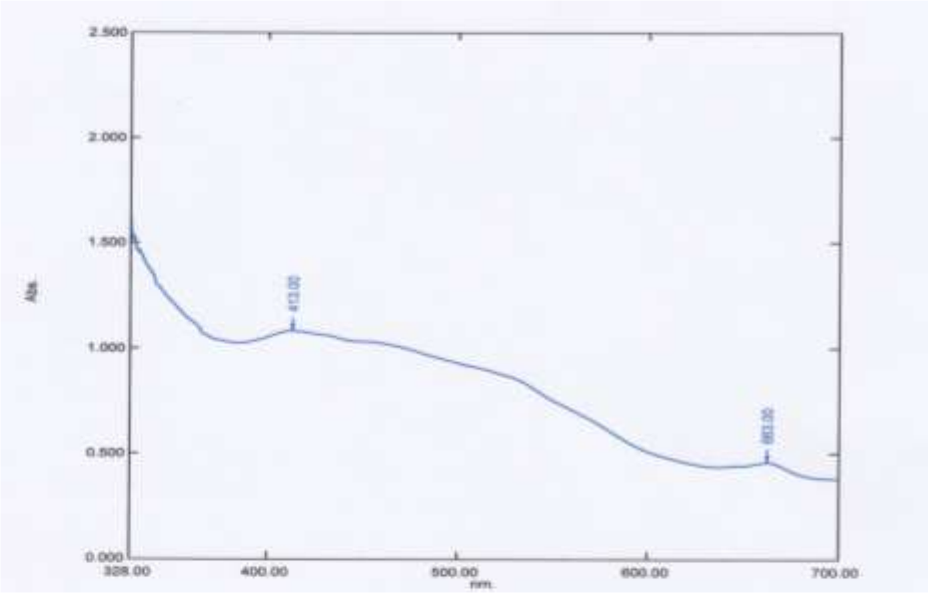

Fig. (11) UV-Vis absorption spectra of liquid dye extracting with acetone from teak leaves

(a) (b)

Fig. (12) Measuring the electrical output of a series and parallel connected DSSC module (a) for open circuit voltage (b) for short circuit current

Conclusion

The dye-sensitized solar cell is at present the only serious competitor to solid state junction devices for the conversion of solar energy into electricity. The use of natural herbal extract dyes as sensitizers for these devices could lead to achieve dye solar cells with higher efficiencies holding great potential for further cost reduction and simplification of the manufacturing. This research shows that natural herbal extract dyes from teak leaves can be used as low cost sensitizer in fabrication of dye-sensitized solar cell modules.

Although the efficiencies obtained with this natural dye are below the current requirements for large scale practical application, the results are encouraging and may boost additional studies oriented to the search of new natural sensitizers and to the optimization of solar cells components compatible with such dyes.

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