Sensors & Transducers, Vol. 27, Special Issue, May 2014, pp. 170-173

Sensors & Transducers

Fabrication and Characterization of Dye-Sensitized Solar Cells

Mohamed FATHALLAH, Ahmed TORCHANI and Rached GHARBI
Laboratoire des semi-conducteurs et Dispositifs électroniques, Ecole Supérieure des Sciences et Techniques de Tunis. 05 Av. Taha Hussein 1008, Montfleury, Tunis, Tunisie
Tel.: 216 24 193 149
E-mail: fath472001@yahoo.fr

Received: 31 December 2012 /Accepted: 10 August 2013 /Published: 26 May 2014

Abstract: Dye-sensitized solar cell (DSSC) constitutes a real revolution in the conversion of solar energy into electricity after 40 years of the invention of silicon solar cells. The working mechanism is based on a photoelectrochemical system, similar to the photosynthesis in plant leaves. The efficiencies of the DSSC are high as those obtained from amorphous silicon solar cells (10-11 %) and intensive efforts are done in different directions to improve this efficiency. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Dye-sensitized solar cell, TiO_2, electrolyte, I-V measurements, Fill factor, Efficiency.

1. Introduction

A solar cell is a device that converts photon energy into electrical current. In today's world, the mostly used solar cell is silicon based which is currently the most efficient one with approximately 25 % of efficiency. Nevertheless, it also has weakness. The weakness of this type of solar cell is the high production cost which makes it more costly than the source energy from fossil. Moreover, the fabrication of this type of solar cell itself is difficult due to the need of advanced clean room technology. With the development of nanotechnology, it appears that a breakthrough in solar cell technology can be achieved. One of these breakthroughs is the dye sensitized solar cell (DSSC) technology. This cell is extremely promising because it is made of low-cost materials and can be constructed without any advanced process technology, hence being accessible by researchers in developing countries [1, 2].

In DSSC type of solar cells, the light absorption and the separation of the electrical charges happens in different process. The light absorption process is performed by dye molecule, and the separation of the electrical charges is done by the nanocrystal semiconductor that has a wide gap. Overall DSSC photon to current conversion efficiencies (IPCE) over 10 % has been reached [3]. Recent developments in the area of sensitizers for DSSC have led to dyes which absorb across the visible spectrum leading to higher efficiencies. The recent development of an all solid-state heterojunction dye solar cell holds additional potential for further cost reduction and simplification of the manufacturing of dye solar cells [4].

The work reported here aims on demonstrating the fabrication and characterization of dye-sensitized solar cell as a low-cost cell in Tunisia. It also plays role as a preliminary study for DSSC in our laboratory.

2. Working Mechanism

By absorption of light, the dye molecule is excited from ground state to excited state as

Article number P_SI_496

described in Fig. 1. This leads to electrons being transferred into the conduction band of the semiconductor layer which leaves the dye in an oxidized state. The oxidized dye is reduced back by its ground state by donor electron that present in the iodide electrolyte. After reaching the TCO front electrode, the electrons pass through an external circuit and arrive at the counter electrode. The electrons are accepted by the electrolyte, catalyzed by the platinum on the counter electrode, and recombine with triiodide into diodide again. This process leads to the conversion of sunlight to electrical energy

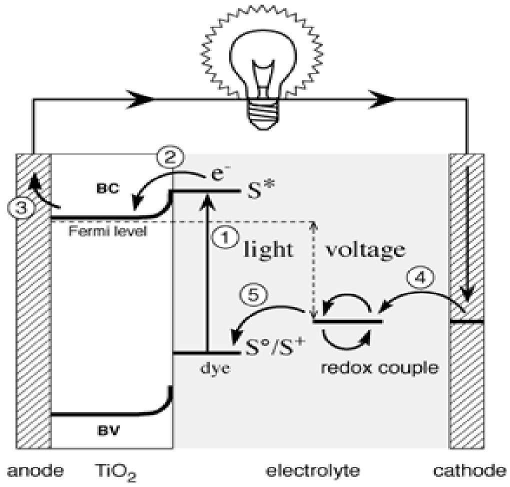
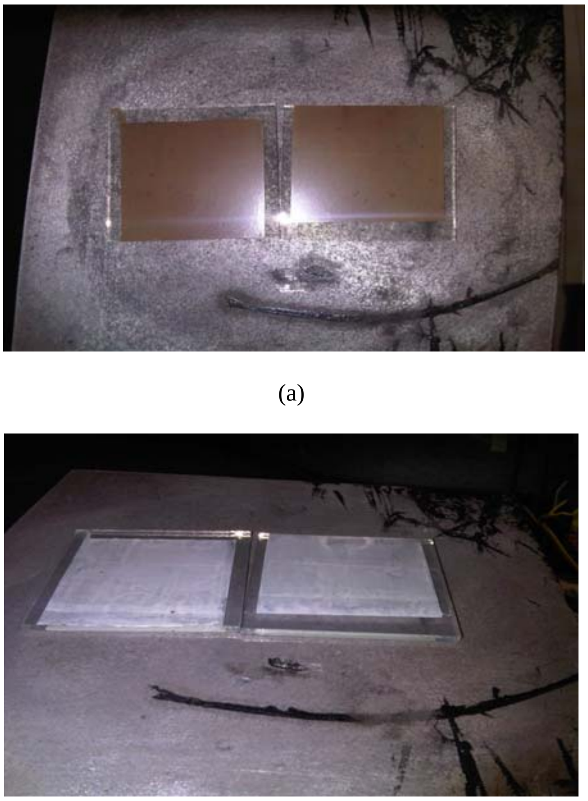


Fig. 1. Working mechanism of the DSSC.

3. The Fabrication of the DSSC

3.1. The Preparation of TiO_2 Films

1. First step is to clean TCO glass slides gently with ethanol and paper towel. And then, the conductive side of TCO glass was identified by using an ohmmeter.
2. After that the deposition area of the TiO_2 was defined as the surface of the conductive side of TCO glass by using scotch tape with 4 mm for one side, and 1mm for the two other sides, thus it will form an open area of 4.8×4.6 cm.
3. Then 3-5 drops of TiO_2 nanoxide D37 (size 37 nm) suspension was added above the deposition area that has been defined. Then, the suspension was spread smoothly by using glass stirring rod. This is known as the doctor blade method. Then, the slide was allowed to dry for 15 minutes before removing the tape.
4. Then the slide was put on a hot plate and heated first to100 °C and the film turns brownish and sometime releasing fumes (Fig. 2a). This is ensuring electrical contact and mechanical adhesion on the glass. The next step is to heat to 240 °C and maintain it for 1 hour until the film turns to yellowish-white (Fig. 2b). This is the sign that the sintering process is completed.
5. The last step is to allow the slide to cool down naturally to 70 °C and immerse it in a solution of ruthenium 535 with 20 mg for each 100 ml of ethanol and left for 5 hours.



(a)

(b)

Fig. 2. The film turns brownish at 100 °C (a) than yellowish-white at 240 °C (b).

3.2. The Preparation of the Counter Electrode

1. The counter electrode was also cleaned gently with ethanol and the conductive side of the TCO was identified.
2. Then, the entire conductive surface was coated using a polyester mesh with transparent Pt-catalyst T/SP and placed on hot plate for 10 mn at 100 °C and then heated to 200 °C for 1 hour and cooled naturally.

3.3. The Assembling Process of DSSC

1. The two electrodes were assembled together using binder clips and sealed with a sealing frame SX 1170 (Fig. 3).
2. When sealing the electrodes, two small holes should be left from which the electrolyte iodolyte AN-50 is introduced carefully to fill the space between the two electrodes and finally seal the two holes.

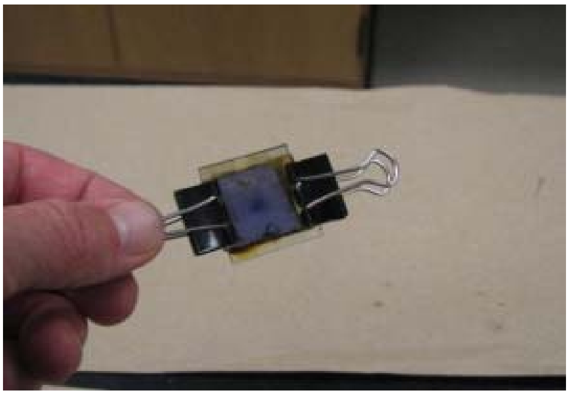


Fig. 3. The assembled DSSC.

4. Model of the Solar Cell

The basic model for a solar cell is the one-diode model as shown in Fig. 4.

The I-V relation in this circuit can be written as:

$$I(V) = I_L - I_0(e^{\frac{V_f - R_s I}{mV_T}} - 1) - \frac{V - R_s I}{R_{sh}}, \quad (1)$$

where I_L is the photocurrent; I_0 is the dark current; V_f is the solar cell voltage; R_s is the series resistance R_{sh} is the shunt resistance; m is the diode ideality factor.

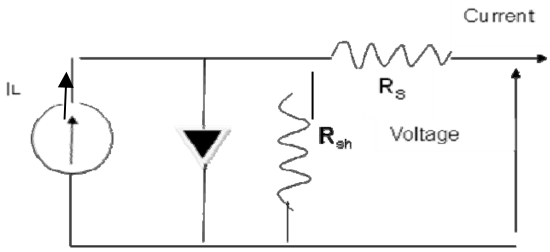


Fig. 4. Basic model for solar cells.

Assuming that the shunt resistance (R_{sh}) is high, and the series resistance (Rs) is small,

The I-V relation will reduce to:

$$I(V) \approx I_L - I_0(e^{\frac{v_f}{mV_T}} - 1), \quad (2)$$

where $V_T = \frac{K_B T}{e_0} \approx 26mV$ at room temperature (25 °C), T is the temperature (K); K_B is the Boltzmann's constant = 8.617 10^{-5} eV/K; e_0 is the elementary charge = 1.602 10^{-19}C. At open circuit ($R_L = \infty$, I=0, $V_f = V_{0C}$), we will get:

$$V_{oC} \approx mV_T \ln(1 + \frac{I_L}{I_0}), \quad (3)$$

At short circuit (RL =0, V_f =0, I =Isc), we get: $I_{sc} = I_L$.

The power delivered to the load of the solar cell is:

$$P \approx I_L V - I_0 \left[(e^{\frac{v_f}{mV_T}} - 1) \right] V, \quad (4)$$

The maximum power P_m delivered at $I=I_m$ corresponding to $V=V_m$.

5. Characterization of the DSSC

Fabricated cells were characterized using a variable load resistor through circuit shown in Fig. 5. The following parameters of the solar cell were determined by I-V measurements:

I_{sh}=13 mA, V_{OC}=0.395V, I_m=8.15 mA and V_m=0.19 V.

The fill factor is calculated:

$$FF = \frac{I_m V_m}{I_{sh} V_{OC}} = \frac{8.15 \times 0.19}{13 \times 0.395} = 0.30, \quad (5)$$

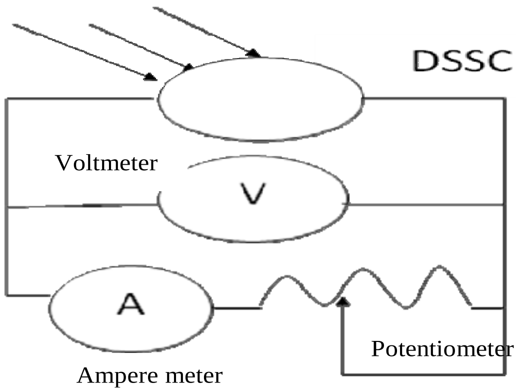


Fig. 5. The characterization circuit of DSSC.

With an incident light of 100 W/m^2 on a solar cell of 4.8×4.6 cm, the efficiency of the solar cell is:

$$\eta = \frac{P_m}{P_{in}} = \frac{V_m I_m}{P_{in}} = \frac{FF \times (V_{OC} \times I_{sh})}{P_{in}}, \\ = \frac{0.3 \times 0.395 \times 0.013}{0.0022 \times 100} = 0.7\% \quad (6)$$

6. Conclusion

We have performed the fabrication of DSSC using materials available in the market. The characteristics of the fabricated solar cell are measured and give open circuit voltage (V_{oc}) of 395 mV, short circuit current (I_{SC}) of 13 mA, maximum voltage (V_m) of 190 mV, maximum current (I_m) of 8.15 mA, fill factor FF of 30 % and efficiency η= 0.7 % when just assembled.

References

[1]. M. O'Regan and M. Gratzel, A low cost high efficiency solar cell based on dye-sensitized colloidal TiO_2 films, *Nature (London)*, Vol. 353, 1991, pp. 737-739.

[2]. Michael J. Cass et. al., Influence of Grain Morphology on Electron Transport in Dye Sensitized Nanocrystalline Solar Cells, *Journal of Physical Chemistry B*, Vol. 107, Issue 1, 2003, pp. 113-119.

[3]. Matt Law, et al., Nanowire dye-sensitized solar cells, *Nature Materials*, Vol. 4, 2005, pp. 455-459.

[4]. M. Gratzel, Review Dye-sensitized Solar Cell, *Photochemistry and Photobiology C*: *Photochemistry Reviews*, Vol. 4, 2003, pp.145-153.

___