Dye Sensitized Solar Cells Using Carbon Nanotubes and Natural Dye

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Abstract— **Technology is advancing to use energy which can be renewed and at the same time creating minimum pollution. Solar radiation is a clean and abundant source of energy. A dye sensitized solar cell (DSSC) can be a low cost solution to the energy applications. Dye sensitized solar cells were created with different material like carbon nanotubes(CNT) and graphite as counter electrodes. Natural dye was prepared from extracted pomegranate. The electrical behaviour (i.e. I-V characteristics) of these cells had been checked for different climates. These devices were studied for I-V characteristics at different light radiations.**

Keywords— **DSSC, counter electrode, carbon nanotubes, graphite, pomegranate**

I. Introduction

Solar energy is always preferred over the conventional energy sources because of its availability, abundance and cleanness. There are many applications of solar energy which can be easily implemented, quiet, and inexhaustible. Dye-sensitized solar cell (DSSC) is a low cost device because of its simple construction and availability of low cost materials that can work on its principle. It has light weight and can work at wide range of angles, even in low solar intensities.

The dye-sensitized solar cell (DSSC) is a reliable alternative to p–n junction PV devices in terms of technical as well as economical aspect and its working principle has been described by different researchers [1-2]. Won-Yeop Rho. et al [3] highlighted the efficiency of DSSCs using TiO2 nanotubes, which exhibit better electron transport. Lu-Ting Yan. et al [4] fabricated dye-sensitized solar cells in which ZnO/TiO2 composite film was created on transparent conductive glass substrate. They used various methods for creating the photoanode such as electrophoretic deposition, colloidal spray coating and screen printing. Many experimentations have been done on different parameters to improve performance of DSSCs[5-7].

II. DSSC Construction and Experimentation

Working principle of Dye sensitised solar cell is depicted in Fig. 1. This work involves four distinct DSSC prototypes. First cell was created using TiO_2 paste for the oxide layer and graphite as a counter electrode. The second one was created using carbon nanotubes(CNT) as the counter electrode. These two prototypes include extract from pomegranate juice (a natural dye) and conducting glass (FTO coated glass).

A. *Dye Preparation:*

Dye material should be such that its molecules can easily absorb the solar spectrum. It should have a long-term stabile behaviour to operate, a high redox potential and also roughness of the semiconductor surface. A natural dye from extract of pomegranate juice was created by crushing pomegranate. Acetic acid of 12 ml was added. The dye was then filtered using filter paper until it was turned to a completely red liquid.

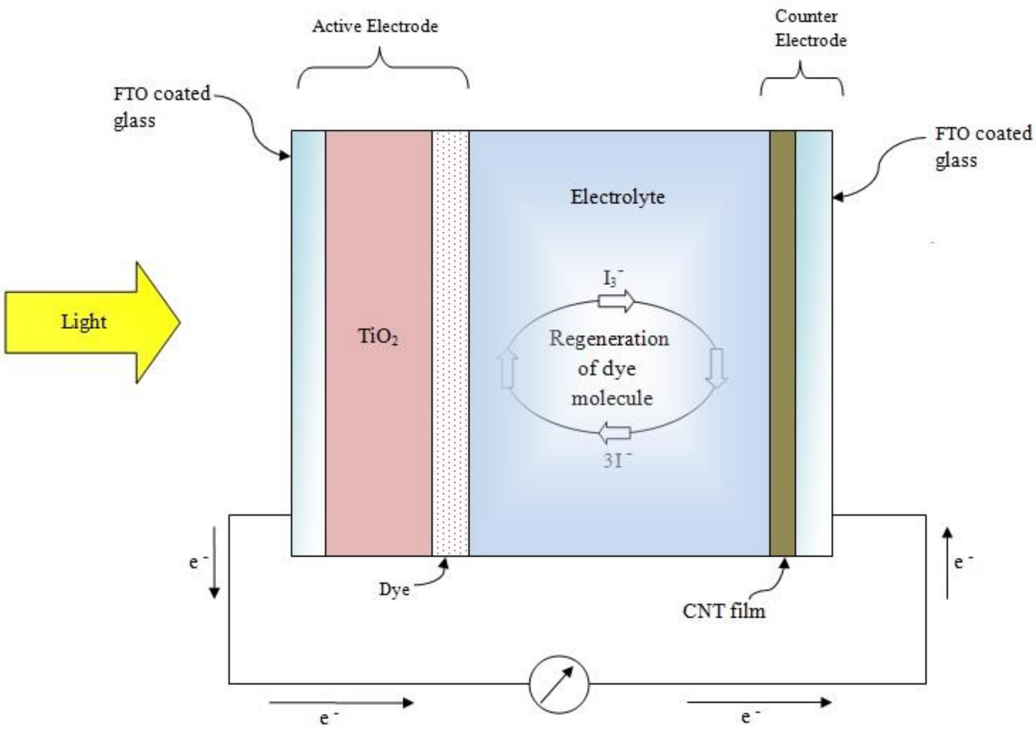

Fig. 1 Schematic illustration shows the proposed dye sensitized solar cells.

B. Conducting Glass and TiO_2 Layer

A conducting glass was used with an active area of 1.5 cm² and it is pre-coated with TiO_2 (Paste). The TiO_2 was prepared by mixing a proper amount of TiO_2 powder with adequate amount vinegar in it. It was mixed well till the required consistence is obtained. Generally, two types of conducting glasses are used, one is fluorine doped tin oxide (FTO) and other is Indium-doped conducting glass (ITO). Here, FTO coated glass plates were used with a thin film of TiO_2 deposited on the glass.

Fig. 2 FTO coated glass plate with reduced area

Fig. 3 TiO_2 Paste by using vinegar

Fig. 4 Active electrode of DSSC

C. Preparation of counter electrodes.

Counter electrodes are used to regenerate the electrolyte; photo-generated electrons from dye are transferred through the oxidized electrolyte diffusing towards the counter electrode. The function of counter electrode is to transport the electron that arrives from the external circuit back to the redox electrolyte system. Various materials have been used as counter electrodes. In this work, graphite and carbon nanotubes were used as counter electrode. Graphite was coated by using pencil, while CNT was coated by making paste using 1, 2-dichloro ethane solution as the same method used for TiO_2 paste.

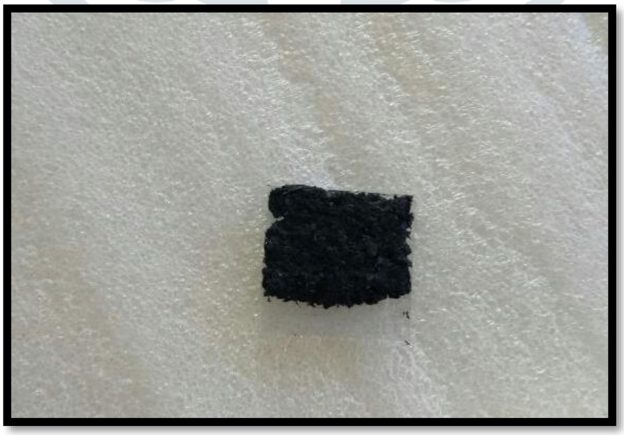

Fig. 5 counter electrode covered with CNT

D. Apply dye and electrolyte

After the preparation of active electrode and counter electrode the natural dye prepared in the first step was applied on the active electrode side. This natural dye helps the photon to lose its energy and to emit electron which will travel in the external circuit. An electrolyte is added to the TiO_2 side to replenish the electron lost by the dye, so that the reaction keeps on going.

E. Assembly of the cell

Two pieces of conducting glass one of which was coated with TiO_2 and another one was coated with carbon nanotubes or graphite. These two pieces of glass are bound together. A little indentation is left on both sides. To keep this system in this arrangement, the pieces were clipped together with paper clips. The above procedure gives the steps to make the DSSC's using oxide titanium, pre-coated on conducting glass.

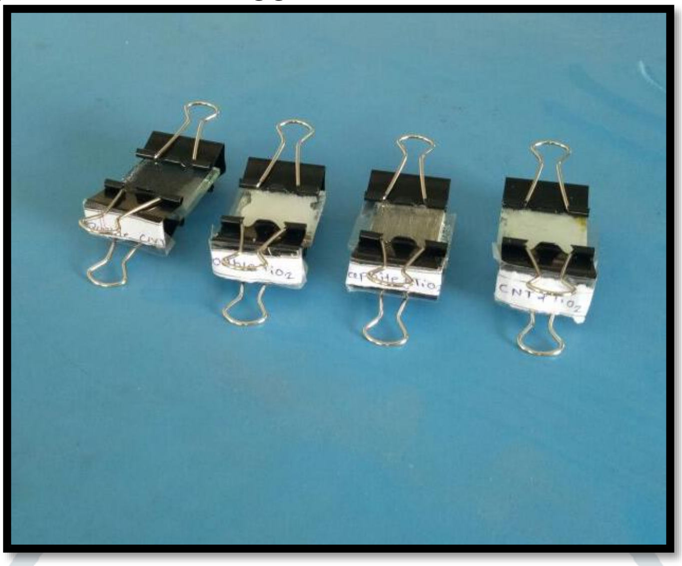

Fig. 6 Assembled DSSC

III. Results and Discussion

The first readings were taken at indoor conditions and second were taken in proper sunlight with the radiation level at 6.39kw/m² at noon 2.00 pm.

TABLE I
RESULT TABLE FOR DIFFERENT CONDITIONS

Sr. no.	Type of cell	Indoor voltage reading(mV)	Outdoor voltage reading(mv)	7W CFL bulb voltage reading(mV)	Cloudy weather voltage reading(mv)
1	TiO_2 +graphite	88.1	188.9	23.6	132.1
2	TiO_2 +CNT	69.6	157.7	12.2	103.7
3	TiO_2(Double)+CNT	74.3	164.5	15.7	111.4
4	TiO_2+CNT(double)	49.3	97.8	10.3	77.2

For carbon nanotubes' counter electrode, the variation in the output is not that effective. For single layer TiO_2 and single layer CNT the output goes up to 157.7 mV for outdoor and 69.9 for indoor condition, while for TiO_2 double layer the Output increases up to 164 mV in proper sunlight and 74.3 for indoor conditions. If we try to increase the thickness of the CNT layer, there is a downfall in the output voltage at around 97.8 mV for outdoor and 49.3 for indoor.

The second readings were taken in the illumination of a 7W CFL blub as a source of illumination at night 10.50 pm. The other set of reading were taken in cloudy weather with improper sunlight with the radiation level at 4.89kw/m² at morning 10.45 am.

It was observed that the output of multi meter for the first set of readings in the illumination of a 7W CFL bulb, the graphite cell gives high voltage of around 23.6 mV. For the cell with CNT as the counter electrode, single layers CNT have the output around 12.2 mV. While the cell with TiO_2 double layer and CNT single layer give an output voltage of around 15.7 mV. Increase in the thickness of the CNT layer causes the output to decrease up to 10.3 mV.

When there is a cloudy weather without proper sunlight and less illumination in this case, the cell with graphite as a counter electrode and TiO_2 as active electrode give high output voltage of around 132.1 mV. If CNT are use as the counter electrode, single layer CNT cell generates the voltage of 103.7 mV in the cloudy conditions. The double layer TiO_2 and single carbon nanotubes layer give the output of 111.4 mV. And the final cell with double layer CNT gives the reading of 77.2 mV.

IV. Conclusions

While discussing the solar energy, energy efficiency and particularly its cost, dye-sensitized solar cell shows a potential insight. Different combinations of DSSCs were created and checked the output of these cells under different conditions and circumstances. So, it can be concluded that the combination of graphite and TiO_2 layers was the dominating for all the circumstances. The use of SWCNT as the material for counter electrode can be used as the good alternative and can generate output. When the CNT layer is replaced with graphite, a maximum percentage increase in the cell output is around 27.0%. From the different variations, CNT with double layer thickness of TiO_2 give the maximum output but is still was not able to pass the graphite combination. The total increase in the percentage output of double layer TiO_2 is around 9.91%.

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