PHOTOVOLTAIC STUDIES OF DYE SENSITIZED SOLAR CELL WITH MODIFIED PEDOT: PSS AS COUNTER ELECTRODE

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ABSTRACT

A dye sensitized solar cell is one of the solar cells that use organic dyes to achieve photovoltaic properties. DSSCs are regarded as third generation solar cells. The photo electrode, counter electrode, electrolyte, and the dye are the major parts of a dye sensitized solar cell and all these have their own significance in the photovoltaic properties. The counter electrode plays an important role of gathering electrons that are generated at the photo-electrode and delivered through the external circuit, back to the electrolyte. Since the electrolyte is corrosive the counter electrode requires a high reaction rate to reduce the iodine in the electrolyte to an iodide ion. To fabricate the device in a cost effective way the researches turned towards carbon electrodes and conductive polymers. So in the present study we modified the counter electrode using MWCNTs and conducting polymers. Here we used Lawsone, a natural dye for the sensitization of nano crystalline TiO_2. DSSCs are fabricated with different counter electrodes and their photovoltaic characteristics are studied and the respective photovoltaic parameters are compared.

***Keywords:* Dye sensitized solar cell, Lawsone, Open circuit voltage, PEDOT: PSS, Short circuit current**

I INTRODUCTION

Nowadays the world energy consumption is increased more and more and the oil price is increased. Intensive research is focused on the development of alternative energies. Among them various researches are focused towards solar energy inorder to tap and use it for our daily functions without any harm to the humanity and life in the universe. One of the relevant areas in this field is dye-sensitized nano crystalline solar cells (DSSCs), [1] "the third generation solar cells". DSSC is a new class of low-cost solar cell that belongs to the group of thin film solar cells and offer enormous potential as an alternative renewable energy provider. It is one of the solar cells that use organic dyes to gain the efficiency in photo voltaic cells. It is also called 'Gratezel cell' after the Scientist who is the father of DSSC, inventor, the director of the Swiss Federal Institute of Technology in Lausanne, EPFL (Ecoles Polytechniques Federales de Lausanne). When the light incident on the photo-electrode the dye molecules from the photo electrode or the working electrode got excited from the HOMO layer to the LUMO layer [2] (Fig.1). The electron thus released from the excited dye molecule is transferred to the TiO_2 molecule and de-excited to the ground state. At the same time, the loss of electron in the dye is supplemented with one electron from the electrolyte and the electrolyte gets another electron from the counter electrode [3]. Such an electron transfer is formed throughout the life of the cell. Since the electron flow is between the ground state and the excited state, the electrons are moved by a process similar to water flow from higher level to lower level.

Many reports shows that maximum efficiency is obtained when platinum (Pt) sputtered over the FTO (Flurinated tin oxide coated glass) are used as the counter electrode. But the sputtering technique and the expenditure of Pt is very expensive. To reduce the cost, we must think about a material that gives considerable efficiency compared to Pt. From the literature survey it is confirmed that PEDOT: PSS can be used as counter electrode instead of costly platinum sputtered counter electrode. In the current study, the counter electrode is modified in four different ways. We have chosen MWCNTs [4] and studied their beneficial influence, with and without modification, when incorporated in the counter electrode on the photovoltaic properties of the DSSCs [5-6].

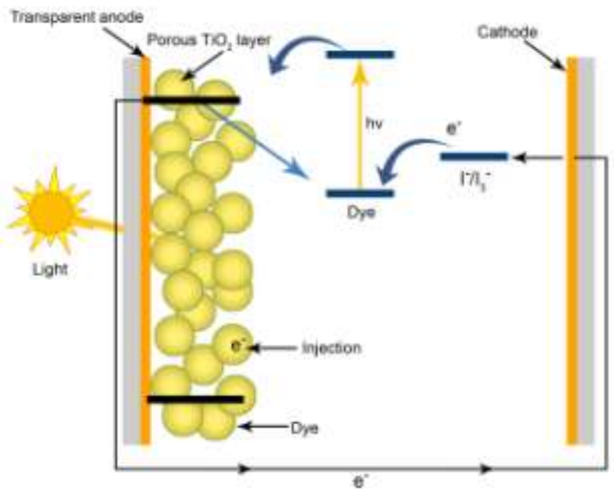
II EXPERIMENTAL

2.1. Materials

Fluoride doped tin oxide-coated glass substrate (FTO) having resistance of $10\Omega/cm^2$ is purchased from Solaronix, Switzerland. Titanium dioxide (Degussa P-25) and Lawsone (RB) with IUPAC name 2-hydroxy [1, 4]-napthoquinone, molecular formula $C_{10}H_6O_3$ and molar mass 174.15 g mol^{-1} are purchased from Solaronix and Hi-Media Laboratories Pvt. Ltd. Mumbai, India respectively. For electrolyte preparation, [7] polyethylene glycol (PEG) (MW 400) potassium iodide and iodine from Aldrich are procured and used without further modification. Poly ethylene dioxy thiophene: Poly styrene sulfoxide (PEDOT:PSS) is also from Aldrich. Other chemicals such as Dimethyl Sulfoxide (DMSO), 2-propanol, Acetonitrile and Titron X-100 are from Merck, India. Multi Wall Carbon nanotubes (MWCNTs) of length 1-2 micrometers and diameter 10-30 nm prepared by CVD process is purchased from Intelligent Materials Pvt.Ltd.

2.2. Preparation of photo-electrodes

The FTO glass plates are cleaned and rinsed with de-ionized water and 2-propanol, then sonicated in de-ionised water for 15 minutes and in propanol for 1 h. The FTO substrates are dried in air prior to make film. The TiO_2 paste is prepared by grinding the TiO_2 (P25 Degussa) powder purchased from Aldrich with 2ml of distilled water and sonicated for 30 min. The colloidal paste of TiO_2 is mixed with one drop of Triton X-100 by continuous stirring for 10min. Finally this paste of TiO_2 is coated over the cleaned FTO glass plate by doctor blade technique [8]. After air drying, the TiO_2-coated FTO films were sintered at 450^0C for 30 min. Then dipped in the solution of Lawsone dye (structure shown in Fig.2) solution for 12 h of sensitization at room temperature.



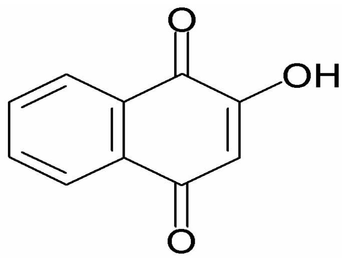


Fig.1: Structure of the fabricated cell **Fig.2. Structure of Lawsone**

2.3. Preparation of counter electrode

In the present work we tried to modify the PEDOT:PSS counter electrode in four different ways (P_1, P_2, P_3 and P_4). In P_1 counter electrode is made with PEDOT: PSS on a cleaned FTO glass plate by spin coating technique [9]. P_2 is by mixing PEDOT: PSS and DMSO in the ratio 3:1 and spin coated over cleaned FTO glass plate. P_3 is made by spin coating a mixture of PEDOT: PSS, DMSO (3:1) with 1 mg MWCNTs. The fourth electrode, P_4 is made by mixing PEDOT: PSS, DMSO and 1 mg f-MWCNTs. Then the prepared counter electrode is placed in an oven with 200^0C for 1 hour.

2.4. Preparation of electrolyte and assembling of DSSC

Electrolyte solution is prepared as reported in our work [9], by taking a proportionate quantity of 0.5 mol KI and 0.05 mol of iodine and PEG (MW 400) (0.14 mol) in 50 ml of acetonitrile solvent. The electrolyte is injected into the space between the photo-electrode and the counter electrode. Now the device is ready for characterization.

III RESULTS AND DISCUSSION

Photocurrent–voltage curves were measured using a Keithley Electrometer 2420. A solar simulator with 300 W Xe lamp with an AM 1.5 spectrum and an output power of 100 mW per cm^2 was used to illuminate the active area, 1 cm^2 of the photo electrode. For the DSSC using P_1 as counter electrode, the photocurrent- voltages are shown fig.3. It is plotted for three consecutive days. Both V_{oc} and J_{sc} is found to be decreasing. Figures 3, 4, 5 and 6 show the current-voltage characteristics of the fabricated devices for three consecutive days. Device with P_4 electrode gives maximum photo current and efficiency. As time passes the devices show decrease in photocurrent and efficiency which may be due to the corrosion of the dye and the counter electrode in the presence of the electrolyte. Decrease of the rate of change of V_{oc}, J_{sc} and efficiency of the devices with the four different counter electrodes is also studied and shown in figures 7, 8 and 9

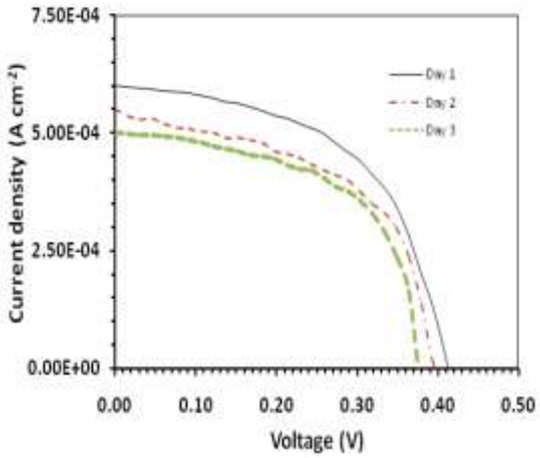


Fig.3: J-V characteristics of DSSC with PEDOT:PSS spin coated over FTO glass plate (P_1) as counter electrode.

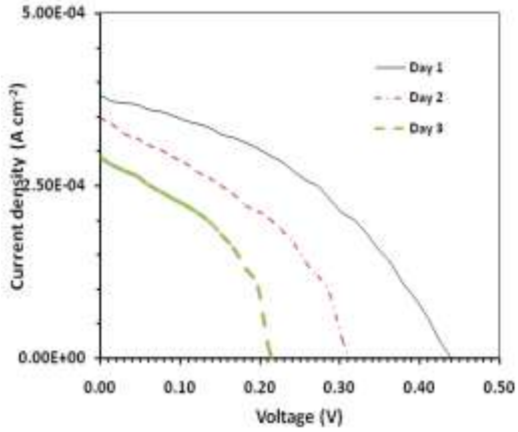


Fig.4: J-V characteristics of DSSC with PEDOT:PSS and DMSO(3:1) spin coated over FTO glass plate (P_2) as counter electrode.

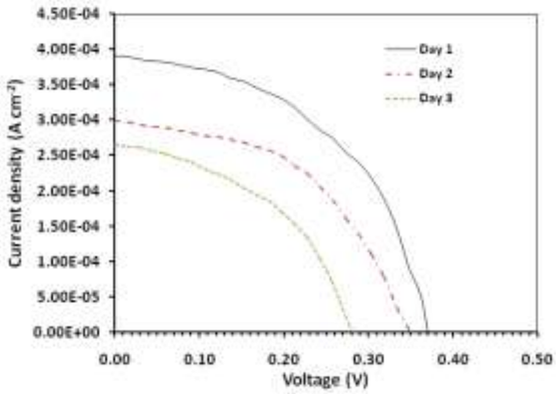


Fig.5: J-V characteristics of DSSC with PEDOT:PSS, DMSO (3:1) and MWCNTs is spin coated over FTO glass plate (P_3) as counter electrode

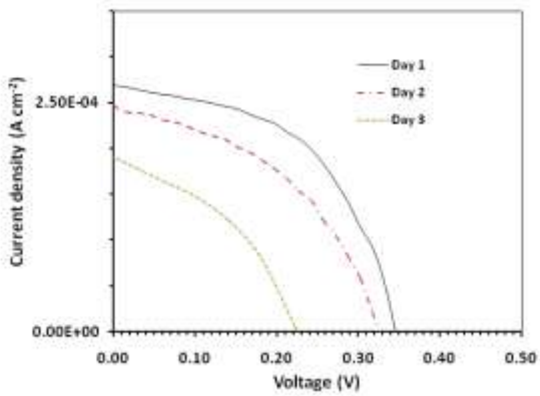


Fig.6: J-V characteristics of DSSC with PEDOT:PSS, DMSO(3:1) and fMWCNTs is coated over FTO glass plate (P_4) as counter electrode

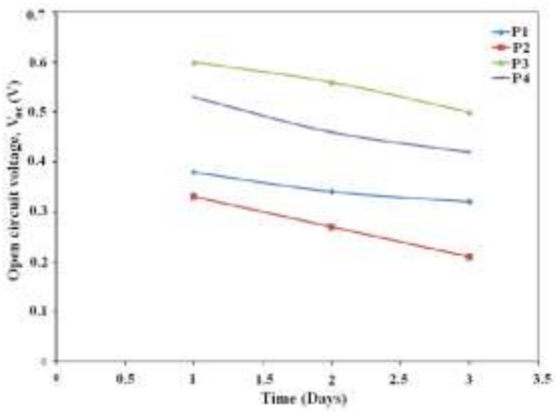


Fig.7: Rate of change of open circuit voltage

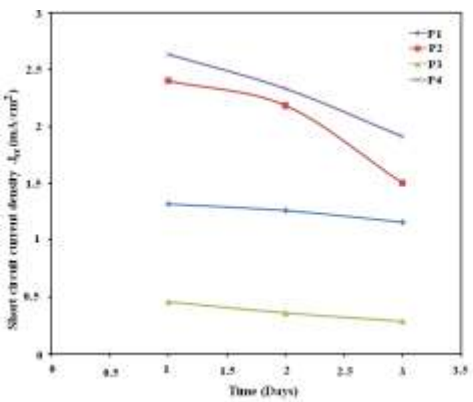


Fig.8: Rate of change of short circuit

For all the devices with different counter electrodes open circuit voltage, V_{oc} is found to be decreased exponentially with time and is evident from fig.7. Similarly rate of change of photocurrent density, J_{sc} decreases linearly and is shown in fig.8. J_{sc} of P_4 is greater because of the easy charge transfer to the electrolyte through fMWCNTs. In P_3 J_{sc} is µA region because the inter-connectivity between the PEDOT:PSS and MWCNTs is poor. Consequently the efficiency decreases.

This is shown in fig.9. This is because the Iodine electrolyte attacks both the electrodes as the time passes.

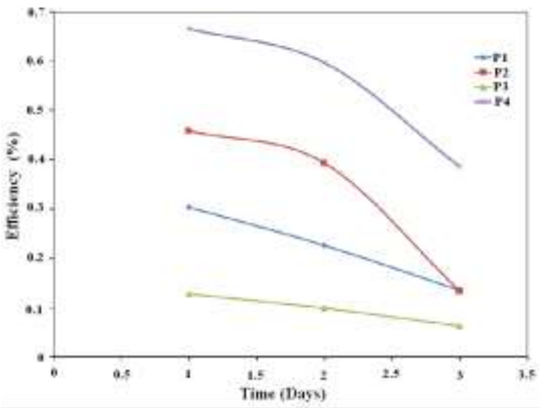


Fig.9: Rate of change of efficiency

IV CONCLUSION

We modified the PEDOT:PSS (Poly ethylene dioxy thiophene: Poly styrene sulphonate) counter electrode in four different ways using MWCNTs and a sandwiched type cell is made with Lawsone a natural dye and Iodine as electrolyte. Electrical characteristics are plotted and photovoltaic parameters are measured for three consecutive days. It is found that DSSC with fMWCNTs in PEDOT:PSS as counter electrode shows maximum J_{sc} (2.63mA/cm^2) and efficiency (0.6%).

ACKNOWLEDGEMENT

The authors would like to address their gratitude to Mr.N Pandurangan, Phytochemistry, School of Biotechnolgy for his help throughout the research work. We express our sincere thanks to Mr.Ranjith N.S, Senior Graphics Designer, ICTS, Amrita Vishwa Vidyapeetham for his support.

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