EXTENTED ABSTRACT

Material and Process Optimization in Dye Sensitized Solar Cell for Efficiency Enhancement

DEPARTMENT OF CHEMICAL ENGINEERING & TECHNOLOGY
INDIAN INSTITUTE OF TECHNOLOGY
(BANARAS HINDU UNIVERSITY)
VARANASI-221005
INDIA

Supervisor

Dr. Ravi P. Jaiswal

Submitted by

Juhi Singh

17041003

Introduction

Solar cells are photovoltaic devices that convert solar energy directly into electrical energy. It works on the principle of the photovoltaic (PV) effect in which it ejects electrons in the presence of sunlight which can be utilized to produce electricity. Solar cells can be classified into first, second, and third-generation cells. The first-generation cells—also called conventional, traditional, or wafer-based cells—are made of crystalline silicon. Second generation cells are thin film solar cells that include amorphous silicon, CdTe and CIGS cells. The third-generation solar cell consists of dye-sensitized solar cells, perovskite solar cells, and quantum dot solar cells.

Dye-Sensitized Solar Cells (DSSCs):

In 1993, Grätzel et. al. reported a 9.6% efficiency of cells, and then in 1997, they achieved 10% at the National Renewable Energy Laboratory (NREL). Dye-sensitized solar cells (DSSCs) have been explored intensively in recent years due to their predicted cost-effectiveness, customizable, transparency, high efficiency, compatibility with flexible substrates, as well as the capacity to work in low-light environments.

Motivation and Scope of the Present Work

In a DSSC cell, optimization of each step is needed to get maximum efficiency from the cell. Dye desorption is evident in DSSC, which lowers its performance significantly. Therefore, the Dye desorption challenge is addressed in this work.

Literature Survey:

Dye Desorption Challenge

To achieve high DSSC efficiency, it is necessary to stop dye desorption from the anode after adding the electrolyte to the cell assembly. Adding dye to electrolytes is a simple yet effective way to stop dye desorption. Hence dye desorption issues can be permanently removed from DSSC.

Research Gap

- Doctor's Blade Method is generally used to coat different layers, which do not give control over thickness and uniformity.
- Dye desorption issue in DSSC is not discussed and generally use of co-adsorbent is suggested.

Experimental Procedures

Fabrication of DSSC

1. **Cleaning of ITO/FTO:** The FTO glass substrate is sonicated for 15 minutes each in soap solution first, then in distilled water, then in acetone, and then in 2-propanol.

2. **Anode Preparation:**

a. **Pre-compact layer Coating:** The compact layer solution is coated on an FTO glass substrate using a spin coater at 2000 RPM for 30 sec then at 4000 RPM for another 100 sec. Then sintered at 450˚C in a furnace for 30 minutes.

b. **Transparent layer & Reflective layer Coating:** 100µl of transparent layer solution is coated on compact layer coated FTO using spin coater at 2000 RPM for 100 sec. Transparent layer coating is done two more times at the same RPM. Then, dried on the hot plate for 15 minutes at 100ºC.

100 µl of reflective layer solution is coated on dried FTO using spin coated at 3 steps with 1500 RPM for 20 sec, then 3000 RPM for 30 sec, and then 5000 RPM for 100 sec. Coated FTO is sintered at 450˚C in a furnace for 30 minutes

c. **<u>Post Compact layer Coating:</u>** 50µl of compact layer solution is coated on a reflective layer using a spin coater at 2000 RPM for 60 sec. FTO (the area where sealing will be done) is cleaned with IPA. Coated FTO is sintered at 450˚C in a furnace for 30 minutes.

d. **<u>Soaking in dye</u>:** Post compact layer coated FTO is taken out from the furnace at 150˚C and soaked in the dye solution for 10 to 12 hours in air-tight container.

3. **Cathode Preparation:** Plastisol paste is evenly spread on cleaned FTO using a glass rod. FTO is sintered at 450˚C for 15 minutes in a preheated furnace.

4. **Sealing and Electrolyte filling:** The EVA sheet is cut in a square shell (spacer) for the active area. The counter electrode is heated to150˚C for 10 minutes. The anode is placed over a spacer-counter electrode arrangement till the EVA sheet becomes transparent. Electrolyte solution is poured into a sealed DSSC assembly. Drills on the counter electrode are sealed with EVA solution.

Fig.1: Fabrication steps of DSSC

Results and Discussions

Dye Desorption in DSSC

When the electrolyte is poured over the anode before the J-V test of the DSSC, the color of the anode changed from dark red to light pink, which is shown in Fig.2.b. Electrolyte dissolves dye from anode into it, until chemical potential at both surfaces become equal.

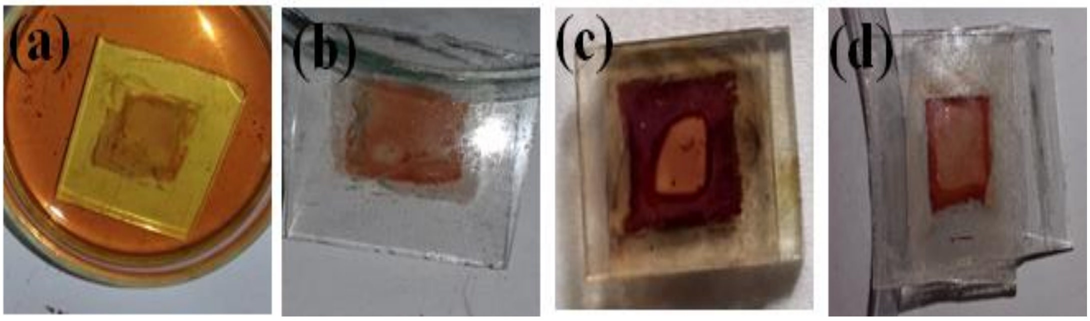

Fig. 2: Dye desorption images: (a) & (b) in the anode and (c) & (d) in the DSSC assembly

Addition of Dye in Electrolyte to Stop Dye Desorption

Dye-sensitized solar cell efficiency decreases from 9.18 % to 1.48 %. Short circuit current (Jsc) and fill factor (FF) decrease drastically as Jsc and FF depend on the amount of dye adsorbed at the anode. Open circuit voltage (Voc) also decreases significantly. The dye desorption problem needs to be addressed. JV plot of DSSC before dye desorption, after dye desorption, DSSC fabricated using 0.36 mg/ml and 0.66 mg/ml dye conc. of electrolyte is plotted and is shown in Fig.3. Sudden drop in efficiency of DSSC after dye desorption is also confirmed from the JV plot in the following Fig.3. No dye desorption of DSSC fabricated using 0.36 mg/ml dye conc. electrolyte (labeled as 0.36 DSSC) is further confirmed by a similar J-V curve of DSSC before dye desorption. Also, it is confirmed from the J-V plot of DSSC fabricated using 0.66 mg/ml dye conc. electrolyte (labeled as 0.66 DSSC) and table, that adding more dye to electrolyte will further decrease the efficiency of DSSC. Adding more dye to electrolyte after reaching optimum dye conc. to stop dye desorption, will hinder the electron transfer process and slow the electron transfer rate. Efficiency (η), Short circuit current (Jsc), Open Circuit voltage (Voc), and fill factor (FF) data for above mentioned cases are listed in the table. 1.

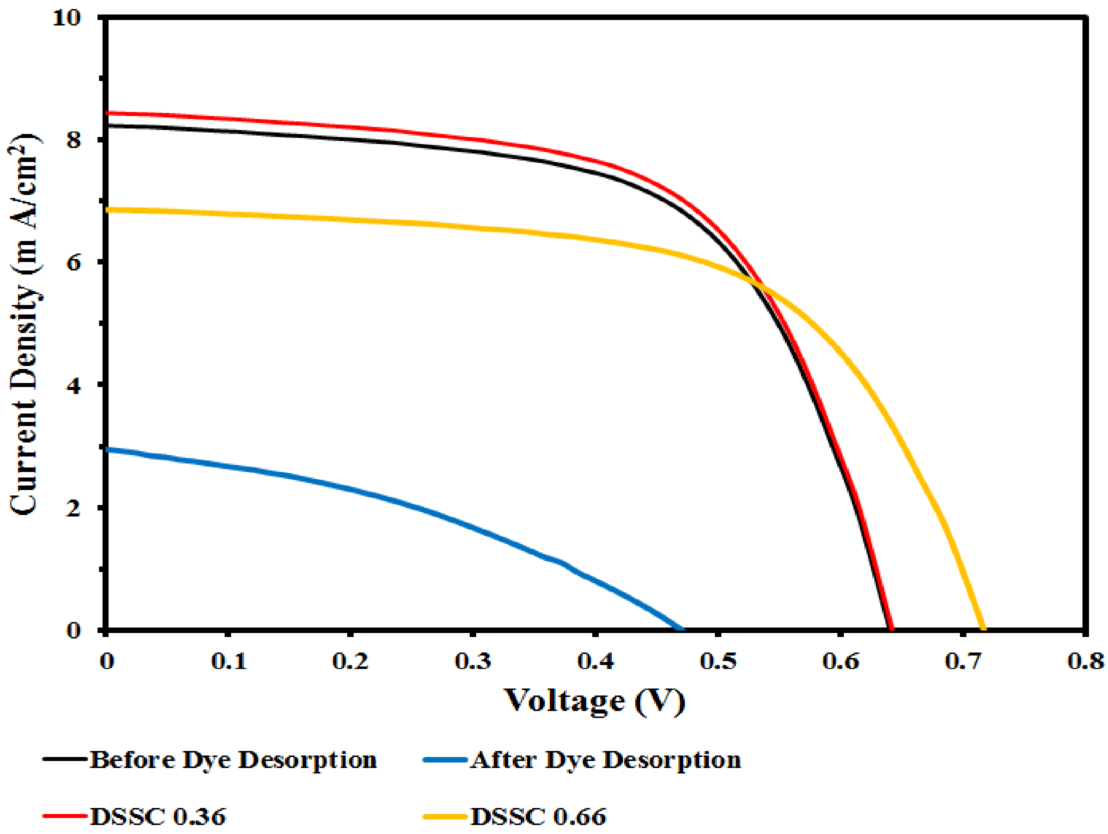

Fig.3: JV plot of DSSC before dye desorption, after dye desorption, DSSC fabricated using 0.36 mg/ml and 0.66 mg/ml dye conc. of electrolyte.

Table 1: Jsc, Voc, FF, and η for the different conditions of DSSC

Cell type	Jsc (mA/cm^2)	Voc (V)	FF	η
Before Dye Desorption	8.2	0.63	0.62	9.18
After Dye Desorption	2.9	0.48	0.36	1.48
DSSC 0.36	8.4	0.65	0.60	9.38
DSSC 0.66	6.9	0.71	0.62	8.63

Conclusions

A DSSC is fabricated with 9.18% efficiency, 8.2 mA/cm^2 Jsc, 0.63 V Voc and 0.62 FF. Dye desorption challenge is explained and addressed in this work. Dye desorption from anode continues till chemical potential of dye is equal at anode and in electrolyte, which reduces cell efficiency from 9.18% to 1.48%. To address this issue, dye was added in electrolyte (Optimum conc. 0.36 mg/ml) which stopped dye desorption completely.

Publications

1) Luminescent down-shifting natural dyes to enhance photovoltaic efficiency of multicrystalline silicon solar module- Solar Energy 206 (2020) 353–364, https://doi.org/10.1016/j.solener.2020.05.067- **PUBLISHED**

2) Direct Internal Cooling of a Crystalline Silicon Photovoltaic Module: Model Development and Experimental Validation- Solar Energy- **ACCEPTED**