Modified Dye Sensitized Solar Cells (DSSCs)

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***Abstract*— Sunlight is a renewable (sustainable) source of energy that is free from all kinds of environmental pollution. According to the world's interest in renewable energy, especially in 2020, it has become the main target of many projects. Egypt is considered a "sun belt" country of an average solar energy from 2,000 to 3,000 kWh/m2/year of direct solar radiation as stated in Egypt's Solar Atlas. This means that every square meter in Egypt gets annually from 2,000 to 3,000 kWh per year.**

Solar cells fabrication has passed through lots of improvements throughout generations. These developments are basically hindered by efficiency and high cost. Dye Sensitized Solar Cell (DSSC) is an inexpensive type of solar cells. In this project, a model of dye sensitized solar cells was fabricated using local and cost effective materials. The cost of the modified cell is 95% cheaper than that before modification. The main reason for that is using Soda-Lime glass coated with conductive type of polymer instead of the expensive FTO glass. A modified cell is fabricated with an area of 16x15 cm2. The total voltage then is about 560 mV. Although the efficiency of the modified cell is less than that before modification, but now it is available for any country to easily apply such project with affordable price.

***Keywords*— DSSC – solar cells – dye sensitized solar cells – renewable energy – electricity generation**

I. INTRODUCTION

DSSCs are photonic devices that convert visible light into electricity and are based on a porous thin film of a wide-bandgap semiconductor oxide modified by dye molecules. The manufacturing cost of DSSCs, which are 3rd -generation solar cells, is approximately 1/3 to 1/5 times that of silicon solar cells. This type of film enhances the light absorption due to its sponge-like characteristics and increased surface area.

The nanocrystalline material plays an essential role in electron injection and transport, determining the performance of the DSSCs. The overall conversion efficiency of DSSCs was reported to be proportional to the injection of electrons in wide-bandgap nanostructured semiconductors. To date, the certified efficiency record is approximately 11.1% for a small cell, and large-scale tests have clarified the great need for the commercialization of DSSCs. Thus, DSSCs have numerous advantages over silicon solar cells.

The main aim of the project is to fabricate an applicable model of DSSC using available, simple, and affordable materials.

II. MATERIALS AND STRUCTURE

- Transparent Conductive Substrate

DSSC is basically built up with two sheets of conductive transparent glasses to provide a substrate for the deposition of the semiconductor materials in addition to being also a current collector. Substrates must be of high transparency of more than 80% so that to allow the maximum amount sunlight to pass through the active area of the cell. The electrical conductivity of the substrates should be acceptable for efficient charge transfer in addition to eliminate energy loss. These two properties of substrate determine the efficiency of DSSCs.

FTO and ITO substrates are obtained from soda lime glass coated with fluorine tin oxide and indium tin oxide layers, respectively. The transmittance of ITO film is over 80% and sheet resistance 18 Ω/cm2, while FTO films are of 75% transmittance in the visible region and sheet resistance of 8.5/cm2.

Polymers can also be used as alternatives to glass substrates because of their flexibility and affordable prices. Murakami et al. used PET (polyethylene terephthalate) coated with ITO and obtained an efficiency of 3.8%.

- Mesoporous Semiconductor

The semiconductor, that provides a surface area for the adsorption of the dye, accepts electrons from the excited dye and conducts them to the external circuit to generate an electric current. The electron transfer rate that highly depends on the crystallinity, morphology, and semiconductor surface area affect the efficiency of DSSCs. Metal oxides as: titanium oxide (TiO_2), zinc oxide (ZnO), and stannic oxide (SnO_2) are used as semiconductor materials.

- Dye (Photosensitizer)

The main purpose of dye is to absorb light photons and transfer them to the conduction band of the semiconductor. It is chemically bonded to the porous surface of the semiconductor. An efficient photosensitizer should (i)show high absorption in the visible region (400 nm to 700 nm), (ii) Adsorb strongly on the surface of the semiconductor, (iii) Possess a high extinction coefficient, (iv) Be stable in its oxidized form allowing it to be rereduced by an electrolyte, (v)

Be stable enough to carry out ~108 turnovers, which typically correspond to 20 years of cell operation.

On the other hand, the performance of DSSCs greatly depends on the molecular structure of the sensitizers. Based on transition metals, photosensitizers have been shown to be the best so far. Photosensitizers are classified into: metal complex sensitizers, metal-free organic sensitizers, and natural sensitizers.

- Liquid electrolytes

Liquid electrolytes are classified into two types: organic solvent based electrolytes and room temperature ionic liquid electrolytes (RTIL).

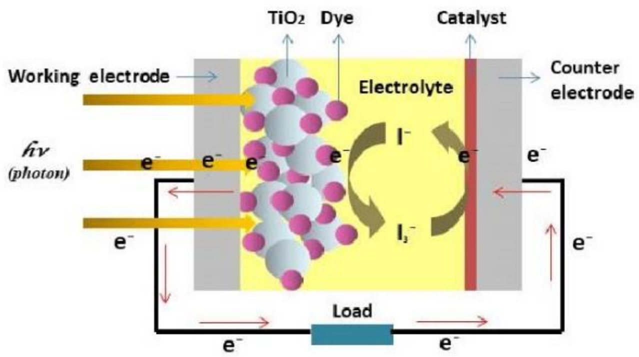


Fig. 1 Simplified structure of DSSCs

III. Working Principle

Basically, DSSC structure consists of three main parts; dye-sensitized photoanode, counter electrode, and redox electrolyte. The dye-sensitized photoanode absorbs light and charge injection. On the other hand, the counter electrode is for redox pair reduction and redox electrolyte or hole transporting material is for dye reduction. The working principle of DSSC is:

- First, light photons travel through the working electrode
- Second, light is absorbed by the dye to reach the excited state.
- Finally, the excited electrons are injected into the conduction band of semiconductor metal oxide then transfer to the external circuit.

IV. FABRICATION

The structure of DSSC after modification and its fabrication methods are:

- Soda Lime glass coated with a thin layer of Poly di-allyldimethylammonium to give the glass the required resistance and conductivity instead of high cost FTO. The glass resistance hence is 5 ohm.
- Mixture of (Scandium, Titanium dioxide, Triton, and Acetic acid) is added to the slide of the glass. Where; Scandium reduces the bandgab energy in order to prevent the electron from losing huge amounts of energy during its path between the two poles of the cell.
- The slide is soaked in Ruthenium dye for 24 hours.
- Another slide (cathode pole) of the glass is exposed to a candle to form carbon-based black particles on it.
- The two slides of the glass are fixed together.
- Iodide (electrolyte) is injected between the two slides.

Fig. 2 Fabrication method of DSSCs

V. TEST AND RESULTS

- Two models of DSSCs have been fabricated; one of dimensions (16*15cm and 3mm thick) and (6.5*2cm and 1mm thick).

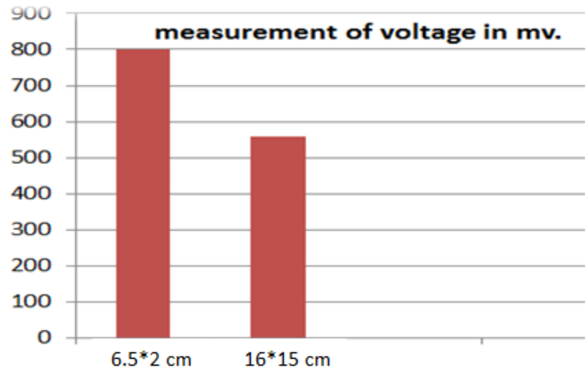


Fig. 3 Size test

- Another test was held under sunlight, florescent lamp, black and white sacs (resemble clouds), and at night.

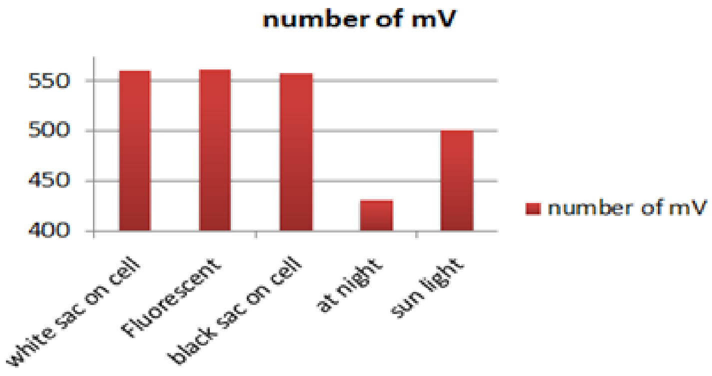
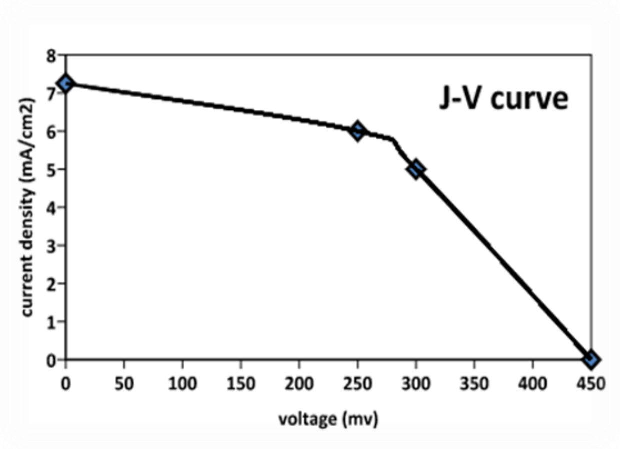


Fig. 4 Efficiency test



Voc, mv	Jsc, mA/cm^2	Fill factor, FF	P_{max} watt	η,%
540	7.25	0.81	0.31	3.14

Fig. 5 JV curve

$FF = V_{max} J_{max} / V_{OC} J_{sc}$ (1) $\eta = V_{OC} J_{sc} FF / I_s$ (2)

Where, Vmax and Jmax are voltage and current density for Maximum power output, respectively. Whereas, IS is the intensity of the incident light (mW/cm2)

VI. CONCLUSION

In this research study, dye sensitized solar cells are chosen among the other types of solar cells as they can be easily manufactured using simple tools in the laboratory. FTO and ITO glasses are replaced by soda Lime glass coated with the polymer mentioned in order to reduce the cost of the cell. Although the obtained voltage is reduced, its cost is reduced as well to about 95%. To raise the efficiency a little bit, Scandium is added to the mixture of TiO_2, Triton, and Acetic acid.

Two models of the cells have been fabricated one of area 240 cm^2 and the other of area 13 cm^2. The smaller one produced higher voltage because of the little loss of photon energy during its movement through the two poles of the cell.

The two models are applicable, affordable, sustainable, eco-friendly, and easy in fabrication.

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