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Construction of Solar Cells Using Organic Dyes

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Abstract

This work is mainly based on the fabrication and characterization of Dye Sensitized Solar Cell (DSSC) using organic dyes and to compare its efficiencies. DSSCs were made with glass plates coated with Titanium dioxide, Tartaric acid, dish washing liquid which is non -toxic and more efficient. Glass plates were coated with TiO_2, dishwashing liquid and Tartaric acid mixture as different blocks or cells and were dried for 24 hrs. Organic dye was prepared from beet root, henna, opuntia stincta, lawsone inermics extract. The as prepared dyes were coated on the TiO_2 coating and it is dried. Aluminium foil and copperwire were used as working electrodes and were mounted on each cell. The cells were connected in series. This is completely covered with another glass plate and it was clipped. The cell was kept on the terrace to have the optimum sunlight and its output voltages were measured and efficiencies were calculated and compared.

Keywords: DSSC; glass plates; dyes, voltage

Introduction

The energy and fuel crisis is the major concern in the world today. The demand for energy is growing day by day and many countries around the world have no alternative to increase the energy sources. So there is an urgent need of sustainable energy resources, such as the solar energy, which is considered as an environmentally friend, novel alternative and promising candidate to address this problem. However, solar energy has a limited application that directly related to its high cost. In present time, technology of solar cells based on crystalline silicon is facing a problem of silicon-based raw materials. So, low cost alternatives and hence new types of low cost solar cells are the need of the hour today.

In photoelectrochemical (PEC) solar cells, light energy may be converted into electrical and/or chemical energy. The efficiency of a solar cell device mainly depends upon its design and the properties of the photovoltaic materials included mainly on the light absorbers and their connections to the external circuit.

In 1972, Honda and Fujishima managed to split water into hydrogen and oxygen by illuminating titanium dioxide semiconductor electrodes [i]. Since titanium dioxide absorbs light mainly in the ultraviolet (UV) wavelength region, the efficiency in converting light energy to chemical and electrical energy is low. In order to form an efficient solar energy converter the semiconductor should have an energy band gap optimized for the spectral distribution of solar radiation and also exhibit chemical resistance against corrosion and dissolution. One way to increase the spectral response is to sensitize the semiconductor material with dye molecules.

In 1991, Grätzel and O'Regan presented an efficient dye-sensitized PEC cell containing a highly porous nanocrystalline titanium dioxide electrode sensitized with a monolayer of a ruthenium complex [ii-iii]. By this invention, high light absorption was achieved in the visible part of the solar spectrum. Dye-sensitized solar cells (DSSCs), a new type of solar cells, have attracted considerable attention due to their environmental friendliness and low cost of production. A DSSC is composed of a nanocrystalline porous semiconductor electrode-absorbed dye, a counter electrode, and an electrolyte containing iodide and triiodide ions. In DSCs, the dye as a sensitizer plays a key role in absorbing sunlight and transforming solar energy into electric energy. Numerous metal complexes and organic dyes have been synthesized and utilized as sensitizer.

Natural dyes can replace synthetic dyes since they can be easily extracted from fruits, vegetable and flowers with simple and direct chemical procedures, whereas the earlier normally requires many steps procedures, organic solvents and, purification procedures [iv-v]. The pigments are present in the different part of the plant including flowers petals, fruits, leaves, stems and roots.

Here we have constructed the DSSC with TiO2, ZnS and with dyes from the fruit of Opuntia Stricta and the leaves from Lawsonia inermis (Henna). Tartaric acid and the dishwashing liquid are used as fixers. The output voltages were measured and compared.

Opuntia Stricta

Prickly pear is an edible cactus plant that grows in the arid and semi-arid regions of the world. Broad, leaves and sharp spines characterize the prickly pear cactus, and the colorful into edible bulb-shaped fruits. It is grown mostly as a fruit crop, the plant is valued for its large, sweet fruits called fugs or tunas. The fruits are rich in dyes.

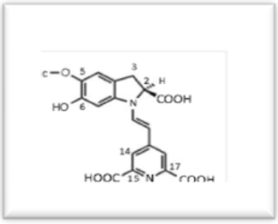


Figure 1. Opuntia stricta

Figure 2. Chemical formula

Lawsonia inermis

Figure 3 shows a schematic chemical structure of lawsone pigment in henna leaves. Henna's coloring properties are due to lawsone, (2-hydroxy-1,4-naphthoquinone) [32], also known as hennotannic acid, $C_{10}H_6O_3$, a burgundy organic compound that has an affinity for bonding with protein. Lawsone is primarily concentrated in the leaves. Fresh henna leaves will not stain color until the lawsone molecules are made available (released) from the leaves and they are smashed with a mildly acidic liquid. The lawsone will gradually migrate from the henna paste/solution into the outer layer of the skin and bind to the proteins in it known as keratin, creating a fast stain. Lawsone is a skin protective since it strongly absorbs UV light.

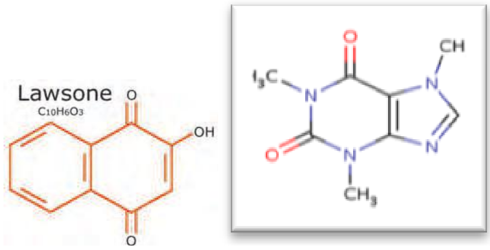


Figure 4. Chemical formula for Lawsonia inermis (Henna leaves)

PREPARATION OF DYE

The extract of the fruit Opuntia Stricta was taken in a beaker and it is stirred for one hour in the magnetic stirrer, and it is set for few minutes. The unwanted particles deposit at the bottom. It is filtered with filter paper. Then again it is stirred at a temperature of 70º C for one hour. After one hour, it is reduced to the room temperature and is washed with ethanol several times and was further used in the preparation of solar cells. The same procedure was followed to prepare the dye from Lawsonia inermis (Henna leaves).

U-V-Characterization

Ultra violet-visible characterization study was done for the as prepared dyes. It was observed that the absorption peaks occurred at 517nm, 381nm, 269nm and 246nm for opuntia stricta and the absorption peaks at 335nm, 288nm for lawsonia inermis. It matches with the wavelength absorption of the red oxide dye. Hence, it confirms that it is best suitable for the solar cell application.

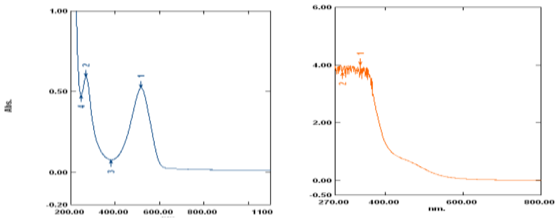


Figure 4(i) **Figure 4(ii)**

Figure 4. U-V Absorption spectra for (i) lawsonia inermis (ii) opuntia Stricta

PREPARATION OF PASTE

The paste to be coated was prepared as follows:

20 gms of TiO_2 was taken and it was mixed with 20ml of distilled water and 20ml of Ethanol. 1.5 gm of Tartaric acid was added to it. 5 drops of dishwashing liquid is added to mixture slowly and mixed well. This paste was used as a coating material for the solar cell.

CONSTRUCTION OF SOLAR PANEL

STEP: 1

A Glass plate was taken and is rinsed with water to remove unnecessary greases. Then the glass plate was cleaned with ethyl alcohol. 30cm x 22cm, 28cm x 20cm sizes of glass plates with 0.5mm thickness were purchased and were used for the construction of solar cells.

STEP: 2

The glass plates were equally divided into separate cells using cellotapes as shown in Fig 5(i)

STEP: 3

Titanium dioxide mixtures were then spread on the surface of each block and was dried for few hours as shown in Fig 5(ii).

STEP: 4

Then the as prepared dyes were coated over the TiO_2 mixtures and were dried for few hours. Several coatings of mixture were applied on the plates. Figure 5 (iii) shows the plate coated with dye from Opuntia Stricta and Lawsonia inermis

STEP: 5

After completely drying, the tapes were then removed carefully and are again dried for few hours.

STEP: 6

To prepare the working electrodes, aluminium foil and copper wire were cut about half of the size of the block. The aluminium foil and copper wire were mounted on each block layered with titanium dioxide mixture which will serve as the terminal point, where aluminium foil as the negative terminal and copper wire as the positive terminal as in Figure 5(iv)

STEP: 7

The connection of each block cell will be in series circuit which means the total voltage output is the sum of all the voltage on each block cell.

STEP: 8

Cover the prepared glass plate with another glass plate on same size and seal it with binding clips as in Figure 5(v) and now the cell is ready for use.

Figure 5(i)

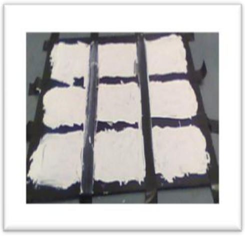


Figure 5(ii)

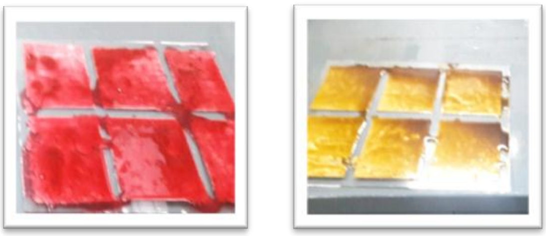


Figure 5(iii)

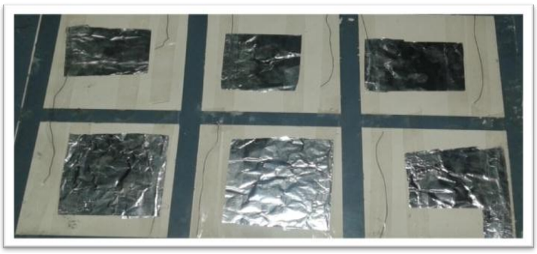


Figure 5(iv)

Figure 5(v)

EXPERIMENTAL OBSERVATIONS

The prepared cells were kept on the terrace at 9'0 clock everyday and the observations were made every one hour. The cells were placed inclined at an angle of 20°, facing east direction to receive optimum sunlight and were slowly moved to the direction of the sun. Output voltage was measured every one hour from 10.00 a.m. to 4.00 p.m. and the intensity of the sun was also recorded with sun meter. It was observed that, the output voltage increases gradually with time, and then decreases. The maximum output voltage was recorded between 11.00 a.m. to 12.00 noon.

Since the coated area of the cell is small, the output voltage measured was in millivolts, when the area of the cell is increased, the output voltage may increase. The observations were done from 16th February, 2017 to 10th March, 2017 as we received high intensity of sun light during these periods.

Observations

The cells were constructed with TiO_2, ZnS, as coating materials and its output voltages were measured and compared. TiO_2 was mixed with Tartaric acid, Dish washing liquid and was coated on the plate. Then the dye was coated on it and the output was measured

Table 1 Output voltages for two different cells for the dye Lawsonia inermis

Maximum intensity: 592w/m²

Time (hour)	Voltage (mV)	
	TiO_2	ZnS
10.00a.m	419	372
11.00a.m	507	419
12.00a.m	514	440
13.00p.m	521	475
14.00p.m	478	463
15.00p.m	462	353

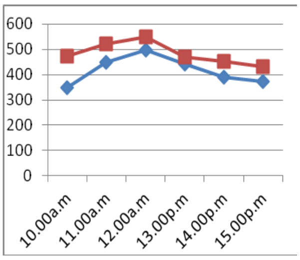
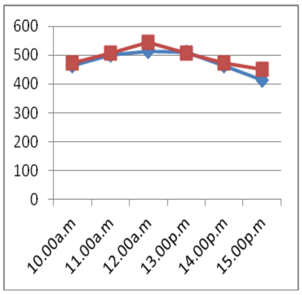


Table 2. Output voltages for two different cells for the dye Opuntia stricta

Maximum intensity: 602w/m²

Time (hour)	Voltage (mV)	
	TiO_2	ZnS
10.00a.m	419	372
11.00a.m	507	419
12.00a.m	514	440
13.00p.m	521	475
14.00p.m	478	463
15.00p.m	462	353



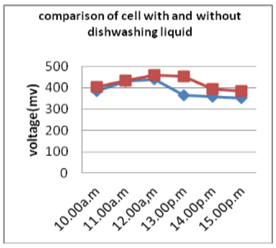


Figure 6 (i) Opuntia Stricta
Max.intensity: 592W/m²

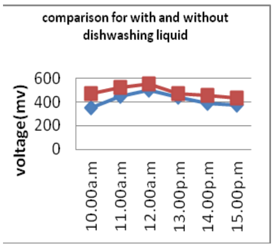


Figure 6(ii) Lawsone inermis
Max.intensity: 602W/m²

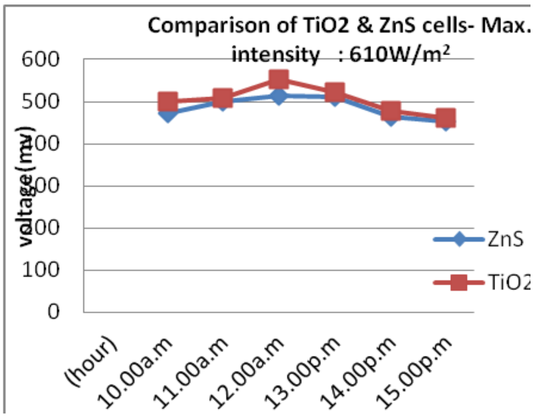


Figure 7 comparison of the cells for the dyes

From the observations, it was found that the cells coated with TiO_2 have more output voltages than the ZnS coated cells. The cells coated with the dye Lawsonia inermis give better output than opuntia stricta.

Conclusion

A simple solar cell was constructed with ordinary glass plates, easily available dyes and TiO_2 and ZnS materials. A good voltage output was got for the Lawsonia inermis dye with TiO2 as the coating material. The main disadvantage is that the dyes easily evaporate. This must be reduced with further improvements.

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