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# Fabrication of Dye Sensitized Solar Cell Using ITO / $TiO_2$ / ZNO / Natural Dye Sensitized

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## *Abstract*

***Dye sensitized solar cell have become a module of choice when arranged in series. Furthermore, the module can harness the sun's energy for man's use. The components that make up the cell were characterized which served as a good absorbance and the sensitized dye was able to absorb UV-ray.The solar cell produced had an open voltage of 0.334 V, at a fill factor of -44.4027, which further gave a short circuit current density of -0.000236. The efficiency was calculated to be 0.0035 ≈ 0.35 %..***

**Keywords:**Dye sensitized solar cell; ITO glass; spray pyrolysis; absorbance; efficiency

## 1.0 Introduction

Climate change is one of the major environmental problems that affect our society. At present annually more than 40 billion Tons of greenhouses gases are exhausted to atmosphere and the tendency is to the rise; the main reason for this situation is the high and uncontrolled use of fossil resource in energy generation. Developing an environmental friendly and reliable energy technology is a necessity. Solar energyemerged as possible solution to confront this problem. This technology permits a direct conversion of sunlight into electrical power without exhaust of both greenhouse gases and another polluting agent[1]. Actually silicon technology is market leader in photovoltaic technologies; however since a pioneering dye-sensitized solar cells (DSSCs) have become one important and promising technology in photovoltaic field. DSSCs have given rise to new solar cells generation being replaced with classical solid-state homo and hetero-junction device by a new concept with a nano-working electrode in photo-electrochemical cell [2].

Dye sensitized solar cells are a third generation technology in the area of photovoltaics. They are classified as a type of thin-film solar cell, meaning that they require only a small amount of material per cell compared to the first solar cells, making DSSCs lighter and more physically resilient than their first generation counterparts. They use a process similar to photosynthesis to produce electrical energy, making them an example of biomimicry [3].

Dye sensitized solar cells are a promising technology because they are inexpensive resilient, making them ideal for large scale and small scale application. However they have lower efficiencies than most other types of solar cells. This disadvantage is offset by their low cost and greater resilience and flexibility.

The basic idea of what a cell looks like at a magnified view is shown in the Figure 1.

The process by which the cell creates electrical energy can be represented by the following series of redox reactions [4]:

$$\text{Dye} + h\nu \rightarrow \text{Dye}^* \qquad (1)$$
$$\text{Dye} + TiO_2 \rightarrow TiO_2 + \text{Dye}^* \qquad (2)$$
$$TiO_2 + \text{CE} \rightarrow TiO_2\ \text{CE}^* + \text{Energy} \qquad (3)$$
$$\text{Dye}^* + I^- \rightarrow \text{Dye} + I_3^- \qquad (4)$$
$$I_3^- + \text{CE} \rightarrow I^- + \text{CE} \qquad (5)$$
$$\text{Overall } h\nu \rightarrow \text{Energy} \qquad (6)$$

Where hv represents light and CE represents electrode.

As illustrated when light is shined on the stained $TiO_2$ an electron from the conjugated system of the dye structure becomes excited equation (1). When an electron reaches a certain excitation state, the dye will give up the electron to the $TiO_2$ equation (2). And travel through the load to the platinized counter electrode, creating electrical energy equation (3). The iodide/triodide electrolyte solution reactivates the dye so it is able to undergo the process again by giving an electron back to the dye equation (4) and picking another electron up from the counter electrode equation (5).

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Oxide semiconductor materials have good stability under irradiation in solution. However, stable oxide semiconductors cannot absorb visible light because they have relatively wide band gaps. Sensitization of wide band gap oxide semiconductor materials, such as $TiO_2$, ZnO, and $SnO_2$, with photosensitizes, such as organic dyes, inorganic dyes, or natural dyes, that can absorb visible light has been extensively studied in relation to the development of photography technology since the late nineteenth century. In the sensitization process, photosensitizes absorbed onto the semiconductor surface absorb visible light and excited electrons are injected into the conduction band of the semiconductor electrodes.

## 2.0 Methodology

Dye sensitized solar cell were fabricated on transparent conducting under photovoltaic operation. The conductive glass is indium tin oxide (ITO) due to low cost and stability.

The $TiO_2$ Nano particles were fabricated by the aqueous hydrolysis of titanium alkoxides precursors, followed by autoclaving at temperature up to 240 °C to archive the desired Nano particles dimensions and crystalline (anatase). The Nano particles are deposited as a colloidal suspension by screen printing.

Note that the Indium tin oxide conducting glass should not be touched with bare fingers. When finger prints and other contamination are present we wash with ethanol, then dry using hair dryer.

**Cleaning the ITO Glass**

First the ITO was carefully washed with detergent and water, rinsed with distilled water. After rinsing with distilled water, the ITO glass was then placed in a chamber. Finally, methanol was poured in the chamber, and the chamber was placed in an ultrasonic cleaning device.

**Deposition of Zinc Oxide by spray pyrolysis**

A solution with 0.1 moralities was prepared by mixing zinc acetate salt of 99.9995 % purity with distilled and de-ionized water in a capillary tube. The solution was mixed with the magnetic stirrer for 15 mins. The surface tension of the obtained solution was deduced by the height of the solution in the capillary tube. Spray pyrolysis is the process in which the ZnO is deposited by spraying 10 ml of the zinc acetate solution on the conducting surface of the heated ITO, where the constituent reacts to form the chemical compound. The procedure is carried out in a fume chamber and gun.

The ITO was placed on heat; such that the conductive side faced up, the nozzle is fixed 5 cm from the ITO holder. When the ITO was heated to 260° C the solution was sprayed on it until it cools to 220° C. This process is repeated until the 10 ml zinc acetate was sprayed on the ITO.

**Titanium Deposition by screen printing**

First we stir well the Nano crystalline $TiO_2$ pastes before use, not shake unless bubbles could be formed. The $TiO_2$ paste was prepared by mixing titanium dioxide salt with 5 ml of acetic acid. The thickness of the adhesive tape will determine the thickness of the titanium dioxide deposited on the glass.We used scotch magic tape from 3m having a thickness of ~50 µm. This tape can be easily removed from the glass without leaving traces of adhesive materials.

The transparent pastes are made to give a layer of 2 -3 µm, for a single layer of tape. So a low dry-out of the solvent and a progressive heating is necessary to ensure optimal adhesion of the titanium dioxide layer onto the zinc oxide thin filmed ITO glass.

The deposition process itself consist of spreading out a given volume of ~10 ml/cm$^2$ of titanium dioxide paste with a rigid squeegee in a microscopic slide, preferably with polished edges. A glass rod could also do the job. We gently dry the electrode with a hair dryer till the solvent is evaporated with the Ti-nanoxide D paste, the electrode turns white or slightly translucent upon drying.

Note: There should be no signs of peeling off and also on the back side of the glass electrode and check if there are no air bubbles visible.

Approximately 2.0 g of $TiO_2$ salt was mixed with 10 ml of acetic acid. A $TiO_2$ layer was screen printed on the sprayed ZnO thin film, on the conducting side of the ITO glass and then annealed at 450° C for 30 mins.

**Annealing Process**

The annealing process allows the titanium dioxide Nano crystals to melt partially to gether in order to ensure electrical contact and mechanical adhesion on the glass. Good results have been obtained using a hot air blower to heat up the electrode at 450° C for about half an hour. While heating up the electrode first turns brownish, sometimes it releases fumes and later it turns yellowish-white due to the temperature dependent band gap narrowing in the pure titanium dioxide. This is the sign that the annealing process is completed and cooling rate is chosen to avoid cracking of the glass (cool down from 450° C to 60-80°C in 3 mins). The annealing process was carried out using the carbolyte machine.

**Sensitizer Impregnation**

The dye sensitizer is from a natural source, gotten from tomato seed. The extract was produced by crushing tomatoes into crude tomato juice. The crude juice was soaked in 2 ml of ethanol. With the aid of a chooser, we put the electrode slowly into the sensitizer solution with the conducting side already having ZnO and $TiO_2$ thin films facing down to the solution. After 15-20 minutes, when the electrode must have absorbed the dye, the electrode was brought out and then allowed to dry. When dried we rinsed the stained $TiO_2$ with ethanol, and allowed the ethanol to evaporate.

**Carbon Deposition**

The method used to deposit the carbon electrode is through the deposition of soot from a burning candle. Start with an ITO glass plate matching the size of the $TiO_2$ electrode being used for the assembly.

Light a candle and hold the piece of ITO glass, conductive side facing down, about 10 cm above the flame. The carbon from the combustion of wax is carried in the smoke and makes a black deposition on the conductive side of the ITO glass. A homogeneous gray to black layer was achieved. We allowed the glass plate to cool on a suitable surface before further processing.

**Sealing Electrodes**

When the electrodes are put together, the active sides of the anode and the cathode will be facing each other. In other words, the stained $TiO_2$ will face the carbon of the counter-electrode. The gap left between the two glass plates will be filled with electrolyte during the next step.

**Electrolyte Filling**

The gap between the two electrodes was now filled with electrolyte to complete the Dye Sensitized Solar Cell. This is performed by capillary effect in open cells.

We considered filling the cells with electrolyte as soon as the electrodes were put together so it will not be exposed to air for too long and possibly degrade.

We place a few drops of electrolyte at the interface of the two glass plates with a pipette, and allowed the liquid to be drawn into the cell by capillary effect. This operation was repeated until the entire internal surface of the solar cell was wetted with electrolyte.

**Completing the Cell**

Wipe off any excess liquid with a paper towel and manipulate the cell carefully to avoid skin contact with the electrolyte.

The Dye Solar Cell is now operational and will last until the electrolyte solvent evaporates.

Since the assembly is open to ambient air, the performance of the cell will decrease over time. This assembly however will give plenty of time to measure and demonstrate the electrical output of the photovoltaic device.

## 3.0 Results

**TABLE 1.1:** For the current to voltage in dark reaction

| Voltage_1 (V) | Current_1 (A) |
|---|---|
| +3.438494E-04 | -6.353009E-07 |
| +1.114312E-01 | +1.861659E-04 |
| +2.224305E-01 | +1.865597E-04 |
| +3.336730E-01 | +2.827760E-04 |
| +4.447159E-01 | +3.423128E-04 |
| +5.557644E-01 | +4.657056E-04 |
| +6.670106E-01 | +8.664844E-04 |
| +7.780282E-01 | +1.270817E-03 |
| +8.890325E-01 | +2.027389E-03 |
| +1.000162E+00 | +2.857973E-03 |

**TABLE 1.2:** For the current to voltage in light reaction

| Voltage_1 (V) | Current_1 (A) |
|---|---|
| -2.36E-04 | -1.45E-02 |
| 5.58E-02 | -1.33E-02 |
| 1.12E-01 | -1.20E-02 |
| 1.67E-01 | -1.01E-02 |
| 2.22E-01 | -7.89E-03 |
| 2.78E-01 | -5.24E-03 |
| 3.34E-01 | -2.71E-03 |
| 3.89E-01 | 5.77E-04 |
| 4.45E-01 | 3.98E-03 |
| 5.00E-01 | 7.00E-03 |

## 4.0 Discussion

From the graphs in Fig 2 and 3 the liquid dye sensitizer (from tomato) shows that at the wavelength set at 300 nm there is an absorbance of 3 % and shows decrease in absorbability as the wavelength increases (Fig 2). And also at a wavelength set at 300 nm there is a transmittance of 0.01 % which increases as the wavelength increases (Fig 3).

**Efficiency of the Cell**

Solar conversion efficiency can be determined by the relation.

$$\eta = \frac{voc * jsc * ff * 100}{100} \quad (7)$$

Where

η is the solar conversion efficiency,

$V_{oc}$ is the voltage of the open circuit,

$J_{sc}$ is the short circuit current density of the cell, and

ff is the fill factor of the cell in percentage

Therefore

$$\eta = \frac{0.334 \times (-0.000236) \times (-44.4027) \times 100}{100} \quad (8)$$

$\eta = 0.0034999 \approx 0.35$ %

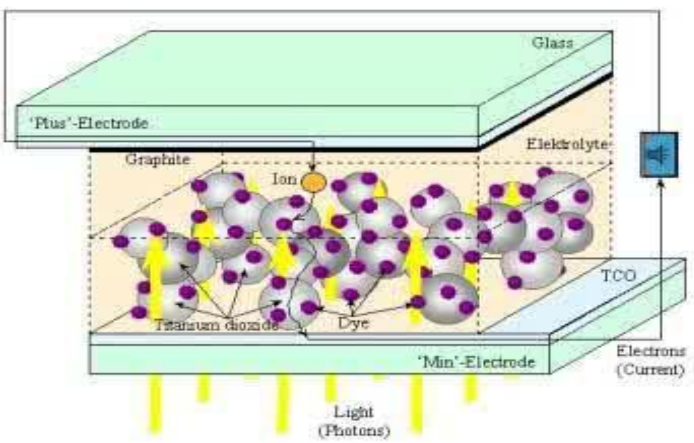


**Figure 1**Magnified image of a typical dye sensitized solar cell

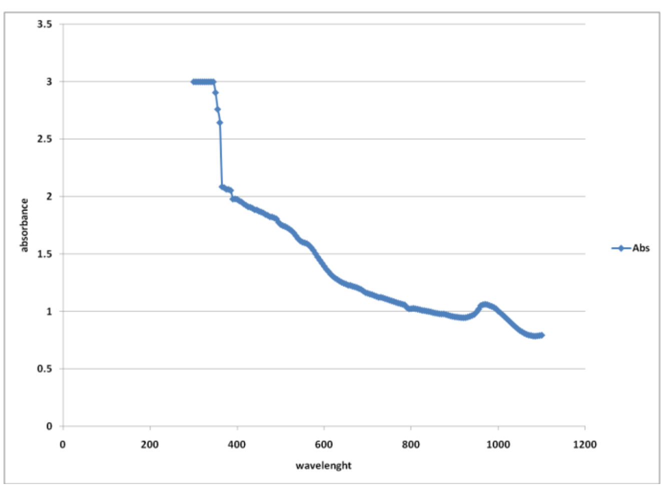


**Fig 2**Graph of liquid absorbance of tomatoes dye from tomatoes

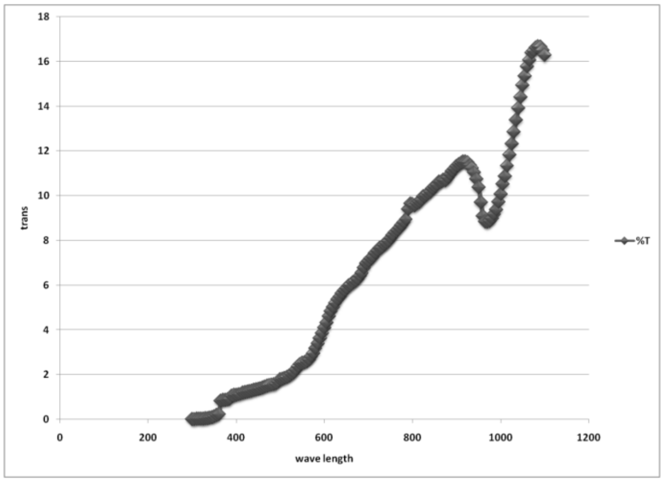


**Fig 3**Graph of liquid transmittance of tomatoes dye from tomato

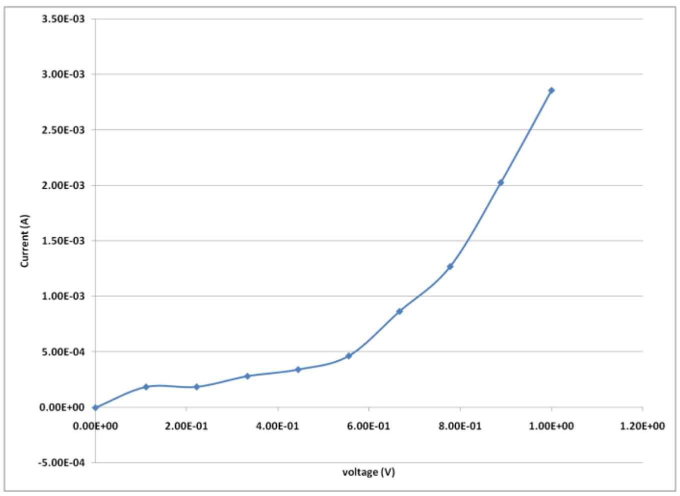


**Fig4:** I.V curve for the solar cell in dark

Fig 4 shows the current to voltage when there is no illumination, that is; when there is no light source (there is no reaction within the cell).

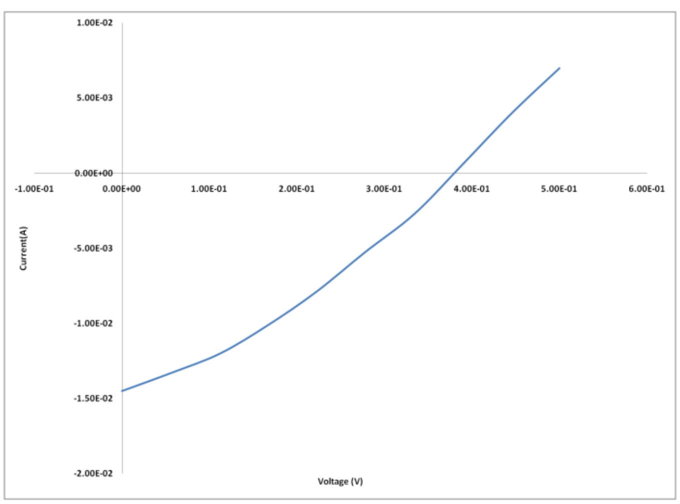


**Fig 5:** I.V curve for the solar cell in light.

This shows the current to voltage behaviour when illuminated using a solar simulator under constant laboratory condition. I.V curve shows the relationship between the current and the voltage as well as their behaviour under certain condition and also their conduction. From Figure5 above it shows that the cell is more active when there is illumination i.e. when there is sunlight, to enable the process to be more active.

## 5.0 Conclusion

In conclusion the stability factor of the cell tells more of its reactivity between the sensitizer dye and the redox electrolyte which does not reduce as a result of the reduction power of the electrolyte. It is advantageous because it is environmentally derived being that the dye was gotten from plant. It is easy to maintain and manage compared to silicon based cell. It is also easy to fabricate and design and it is a clean source of energy. To one cell connected in series of about 10 cells each can form a module and henceforth power light appliances. DSSC technology has an efficiency of above 11 % with a band gap for sensitizer of over 3.2 eV while this work achieved an efficiency of 35 %.

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