# FABRICATION OF DYE SENSITIZED SOLAR CELL USING ITO / $TiO_2$ / ZNO / LYCOPENE (TOMATO) 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 makes 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 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 and the efficiency calculated to be 0.035 ≈ 35 %.

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

## INTRODUCTION

The sun's energy is the primary source for most forms of energy found on the earth. Solar energy is clean, abundant, and renewable, reducing our dependence on fossil fuels, improving the quality of the air we breathe and stimulating our economy. Sunlight on earth drives the wind, fills hydroelectric reservoirs with rainwater, and produces heat, light, and biomass.

To date, many of the solar energy systems are significantly more expensive than the traditional options available to customers (e.g. engines, gas heaters, and grid electricity). The cost, performance and convenience of these systems must improve if solar energy is to compete in energy markets against more traditional alternatives.

The biggest problem with conventional approach is cost; solar cells also known as photovoltaic cells require comparatively thick layer of silicon in order to have reasonable photon capture rates, and silicon is an expensive commodity. There have been a number of different approaches to reduce this cost over the last decade, notably the thin-film approaches, but to date they have seen limited application due to a variety of pragmatic troubles. The dye-sensitized solar cell (DSSC) has been around for a long time, but obtained only low conversion efficiencies, by Professor Gratzel and his research group in the early 1990s, at the Swiss Federal Institution of Technology, Lausanne, dye sensitized solar cell became a subject of much research. It tends to offer some solution in terms of simplicity of fabrication, low cost of production and availability of materials needed.

Dye-sensitized solar cells also known as Gratzel cells are a rising interest for use as alternative energy sources. These miniature solar cells, typically made with titanium dioxide nanocrystalline mono layers, mimic the photochemical process of photosynthesis to convert light energy into electrical energy. The dye bound to the titanium dioxide plays the role of chlorophyll[1], which gives up an electron when excited by light Gratzel cells are essentially constructed by sandwiching the dyed $TiO_2$ between iodide/triodide electrolyte solutions. The basic idea of what a cell looks like at a magnified view is shown in figure 1 [2].

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

$$\text{Dye} + h\nu \rightarrow \text{Dye}^* \quad (1)$$

$$\text{Dye} + TiO_2/\text{ZNO} \rightarrow TiO_2 + \text{Dye}^* \quad (2)$$

$TiO_2 + CE \rightarrow TiO_2\ CE^* + Energy$ (3)

$Dye^* + I^- \rightarrow Dye + I_3^-$ (4)

$I_3^- + CE \rightarrow I^- + CE$ (5)

Overall $hv \rightarrow$ Energy (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 (1) [2]. When an electron reaches a certain excitation state, the dye will give up the electron to the $TiO_2$/ZNO (2). And travel through the load to the carbonized counter electrode, creating electrical energy (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 (4) [3] and picking another electron up from the counter electrode (5).

## 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.

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

### Deposition of Zinc Oxide

A solution with 0.1 molarity was prepared by mixing zinc acetate salt of 99.9995 % purity with distilled and de-ionized water in a capillary tube. The solution is mixed with the magnetic stirrer for 15 mins. The surface tension of the obtained solution is deduced by the height of the solution in the capillary tube.

### Spray Pyrolysis

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 droplet size was measured from the photography of the sprayed jet, the droplet velocity is determined from the measurement of the air pressure from the nozzle. The mean droplet size and velocity were 2.50 µm and 1 cm/s respectively.

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

### Titanium Deposition

First we stir well the Nano crystalline $TiO_2$ pastes before use, not shake unless bubbles could be formed. The $TiO_2$ paste is 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 use scotch magic tape from 3 m having a thickness of ~50 µm. This type 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 is a microscopic slide, preferably with polished edges. A glass rod could also the job. Let dry electrode or gently dry it 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 [2].

**Screen Printing**

Approximately 2.0 g of $TiO_2$ salt is 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 gather 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 titanim 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 is carried out by the carbolyte machine.

**Sensitizer Impregnation**

Lycopene extract from tomato is produced from a tomato variety with high lycopene content, within the range of 150 to 250 mg/kg. This particular variety is not generally marketed for direct consumption, but is used primarily in the production of this lycopene extract. The extract is produced by crushing tomatoes into crude tomato juice. 2 ml of ethanol is added to the tomato juice, and allowed to evaporate. With the aid of a chooser, 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 is brought out and then allowed to dry. When dried rinse the stained $TiO_2$ with ethanol, and allow 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 a 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.

The process is very fast, so don't overdo it. A homogeneous gray to black layer is enough.

Allow 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 Feeling**

The gap between the two electrodes can now be filled with electrolyte to complete the Dye Solar Cell. This is performed with either one of the three methods.

First, electrodes can be pressed together, and the electrolyte soaked in the resulting stack by capillary effect. Second, the two electrodes can be sealed together and the electrolyte injected via holes drilled through the cathode. Thirdly the $TiO_2$ thin film can be placed on the dye, to allow the dye be absorbed, and finally sealed with the carbonized counter electrode.

## 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.

## RESULTS

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

| Voltage_1 (1) | Current_1 (1) |
|---|---|
| +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 (1) | Current_1 (1) |
|---|---|
| -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 |

## DISCUSSION

From the graphs in fig 2 and 3 the liquid dye sensitizer (lycopene dye 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 below

$$\eta = \frac{voc * jsc * ff * 1000}{100}$$

Where

$\eta$ is the solar conversion efficiency

Voc is the voltage of the open circuit

Jsc is the short circuit current density of the cell

Ff is the fill factor of the cell in percentage

Therefore

$$\eta = \frac{0.334 \times (-0.000236) \times (-44.4027) \times 1000}{100}$$

$\eta = 0.034999 \approx 35$ %

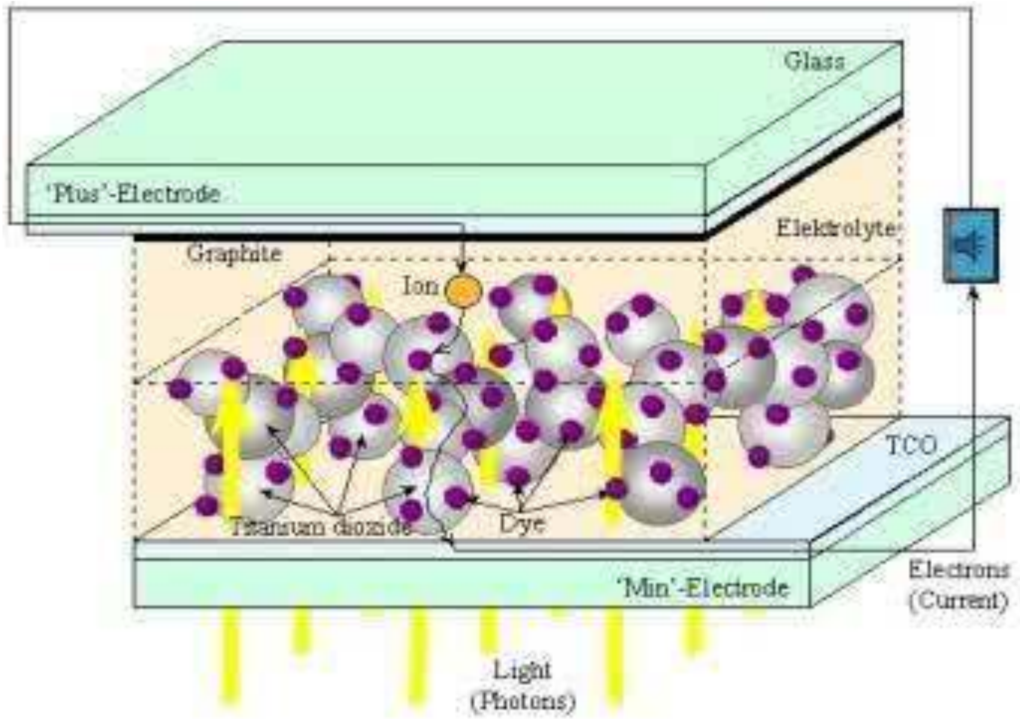


**Figure 1** Magnified image of a typical dye sensitized solar cell

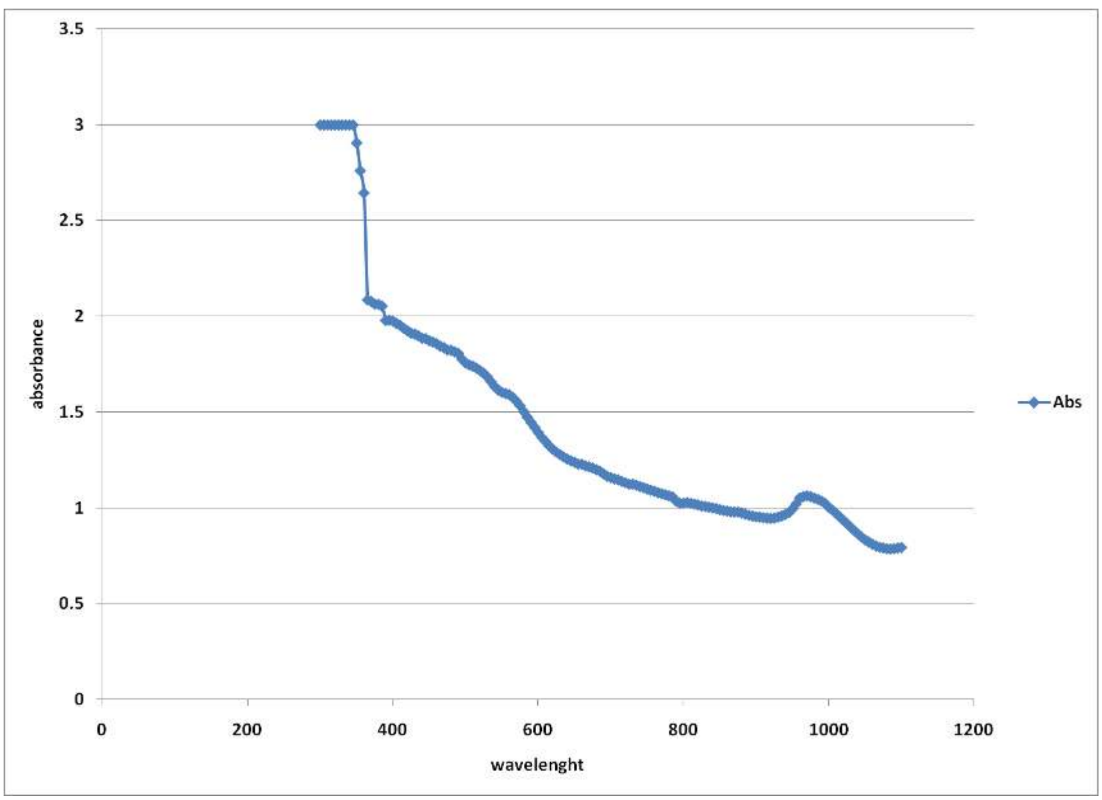

**Fig 2** Graph of liquid absorbance of lycopene dye from tomato

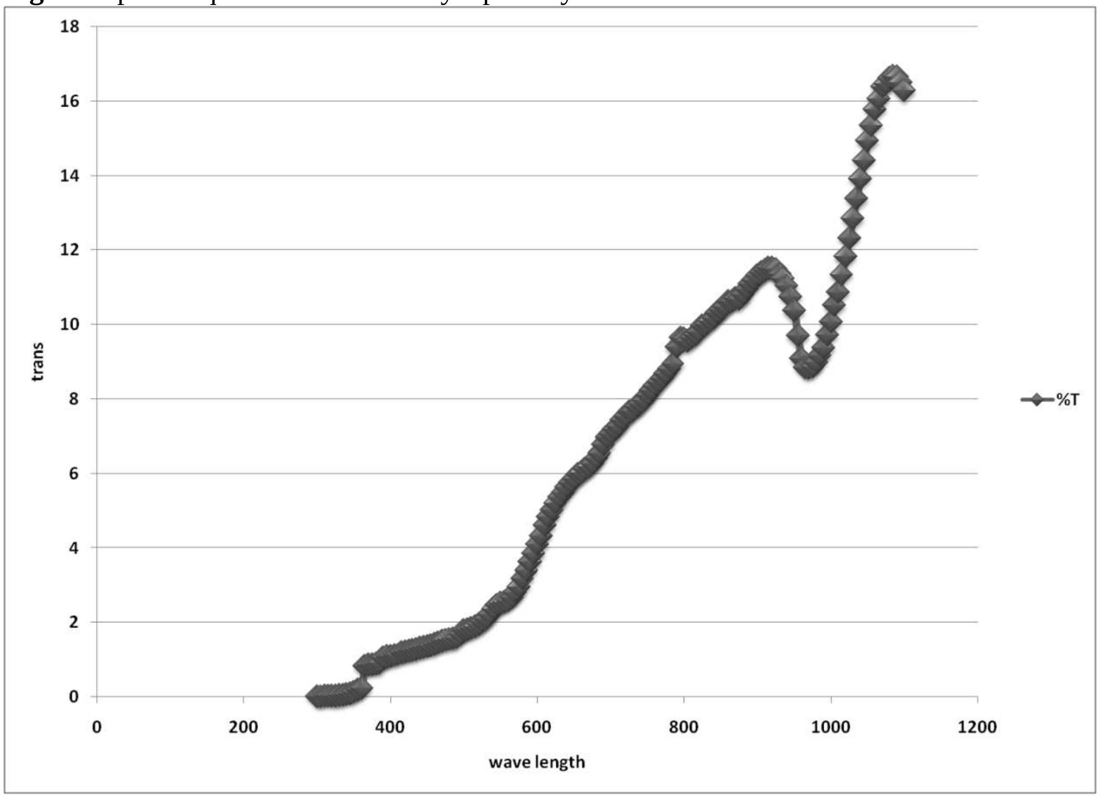


**Fig 3** Graph of liquid transmittance of lycopene dye from tomato

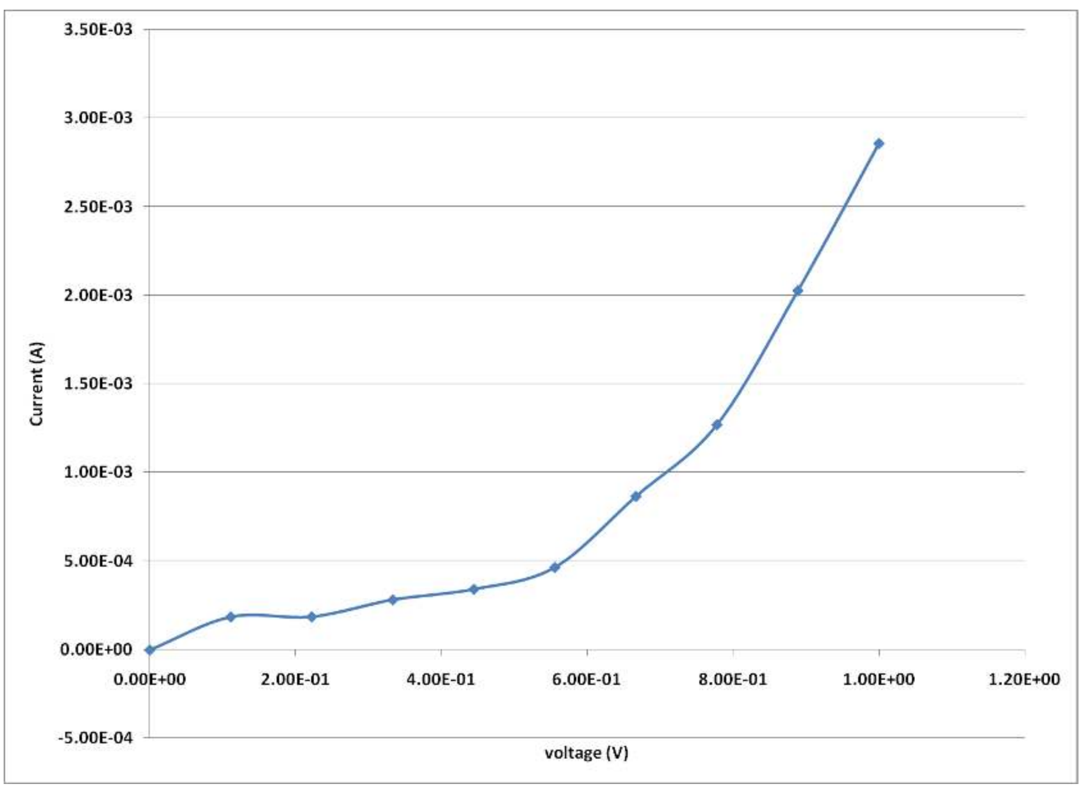

**Fig 4:** I.V curve for the solar cell in dark

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).

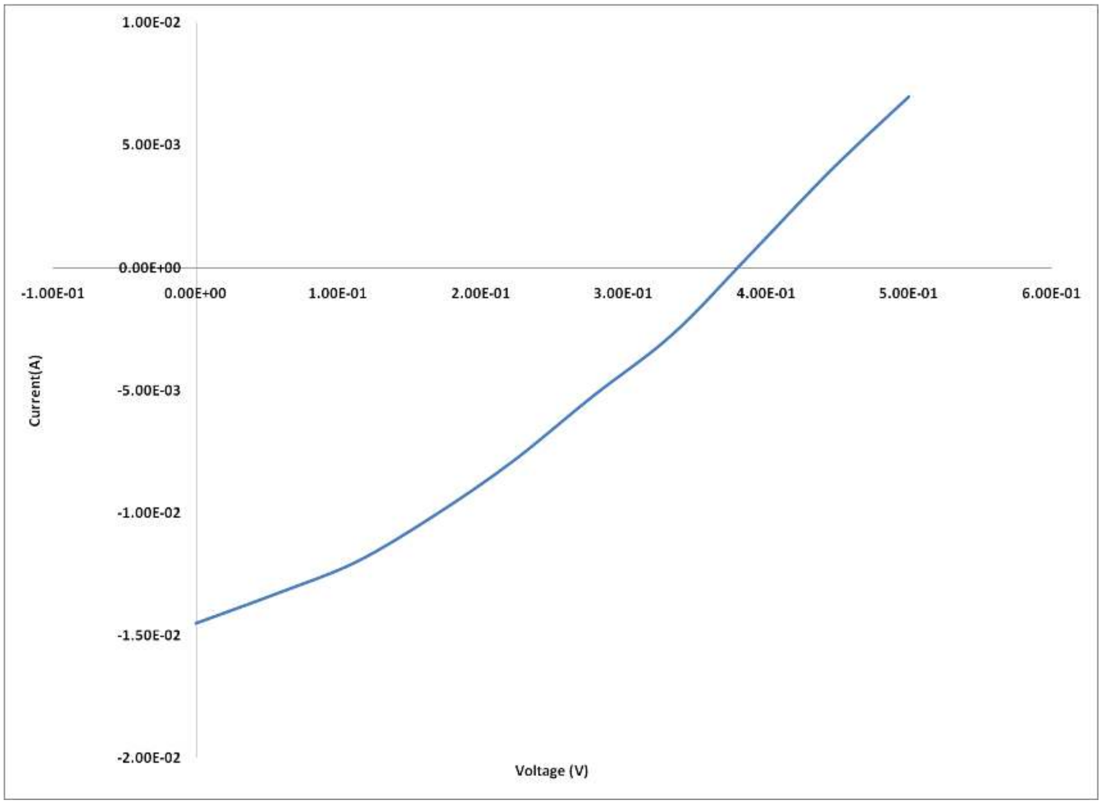


**Fig 5:** I.V curve for the solar cell in light.

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 the above graph 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.

## 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 s 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 compare 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 %.

## REFERENCE


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