Planar Electrophoretic Deposition (EPD) on Photo-electrode

Project report submitted in partial fulfillment
of the requirements for the degree of

Bachelor of Technology
in
Electronics and Communication Engineering

by

Ashish Kumar Singh (Y13UC054)
Dheeraj Balodia (Y13UC087)
Shubham Dangi (Y13UC274)
Shubham Sahu (Y13UC279)

Under Guidance of
Prof. Ganesh Dutt Sharma

LNMIIT
The LNM Institute of Information Technology

Department of Electronics and Communication Engineering
The LNM Institute of Information Technology, Jaipur

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The LNM Institute of Information Technology
Jaipur, India

CERTIFICATE

This is to certify that the project entitled Planar Electrophoretic Deposition (EPD) on Photo-electrode submitted by Ashish Kumar Singh - Y13UC054, Dheeraj Balodia -Y13UC087, Shubham Dangi - Y13UC274, Shubham Sahu -Y13UC279 in partial fulfillment of the requirement of degree in Bachelor of Technology (B. Tech), is a bonafide record of work carried out by him/her at the Department of Electronics and Electrical communication Engineering, The LNM Institute of Information Technology, Jaipur, (Rajasthan) India during the academic session 2016-2017 under my supervision and guidance and the same has not been submitted elsewhere for award of any other degree.

Date

Adviser: Prof. Ganesh Dutt Sharma

Acknowledgments

We would like to express our sincere gratitude to Prof. G.D Sharma for guiding and supporting us throughout the duration of this project. We would also like to thank our Project Guide Ms. Swati Bhardwaj for her valuable help in setting up the experiment as well as help with the equipment and problems encountered along the way.

Abstract

Dye Sensitized solar cells or popularly known as DSSC, are thin film solar cell. It is essentially a semiconductor formed between an Electrolyte and Photo sensitized anode. In modern terminology, it is also known as Gratzel cell. This new class of advanced solar cell can be likened to artificial photosynthesis due to the way in which it mimics natures absorption of light energy. Currently, its conversion efficiency is between 8 to and 11 percent(limited by the problems associated with both the electrolyte solution and the dye used), which is lower than most of other current solar technology. However, DSSC is a revolutionary technology that can be used to produce electricity in a wide variety of light conditions, indoors and outdoors, enabling the user to convert both artificial and natural light into energy to power a broad range of devices.

In this report, after getting an introduction to the device and its working properties we aim to study and demonstrate the broad range of industrial processes underlying the device. These processes are known as Electrophoretic planar deposition method and will be one of the important aspect of our work. There are variety of methods involved, and the aforementioned device will be made as per the given guidelines. Our remaining project will aim to synthesize multiple such prototype devices and measure and observe the various electrical and optical properties between them.

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Chapter *1*

Introduction

One of the most important source of regenerative energy and perhaps representing mankinds only inexhaustible energy source (and also the source of waterpower, wind and biomass) is Solar light. The annual energy input of solar irradiation on earth exceeds by thousand times the worlds yearly energy consumption (43

1.1 Energy

Energy has a large number of different forms, and there is a formula for each one. These are: gravitational energy, kinetic energy, heat energy, elastic energy, electrical energy, chemical energy, radiant energy, nuclear energy, mass energy. If we total up the formulas for each of these contributions, it will not change except for energy going in and out. It is important to realise that in physics today, we have no knowledge of what energy is. We do not have a picture that energy comes in little blobs of a definite amount. It is not that way. However, there are formulas for calculating some numerical quantity. [1]

Energy is usually measured in the unit of Joule (J), named after the English physicist James Prescott Joule (1818-1889), which it defined as the amount of energy required applying the force of 1 Newton through the distance of 1 m, 1 J = 1 Nm. 1 J is a very small amount of energy compared to the human energy consumption. Therefore, in the energy markets, such as the electricity market, often the unit Kilowatt hour (kWh) is used. On the other hand, the amounts of energy in solid state physics, the branch of physics that we will use to explain how solar cells work, are very small. Therefore we will use the unit of electron volt, which is the energy a body with a charge of one elementary charge (e = 1.602 1019 C) gains or losses when it is moved across a electric potential difference of 1 Volt (V), 1 eV = e 1 V = 1.602 1019 J.

1.2 Initiative to Meet Energy Crisis

Today's mix of energy use consists of 36 percent oil, 24 percent gas, 28 percent coal, six percent nuclear, six percent hydroelectric and one percent renewables, like wind and solar energy. Planet Earth is facing an energy crisis owing to an escalation in global energy demand, continued dependence on fossil-

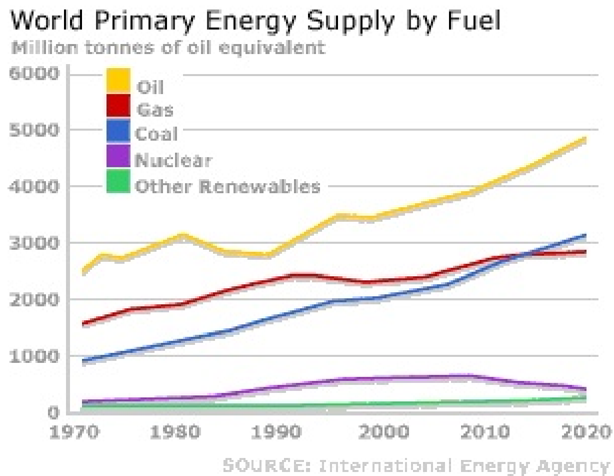


Figure 1.1 World Energy Supply

based fuels for energy generation and transportation, and an increase in world population, exceeding seven billion people and rising steadily. Excessive burning of fossil fuels is not only depleting natural resources, but is resulting in a steady increase of carbon dioxide emissions, which experts believe is responsible for increasing average global temperatures. While natural cyclical variations do occur in regional and global climates, there is now widespread agreement among scientific communities and governments that recent climate change is accelerating as a result of human intervention and that rapid and profound measures will be required to reduce harmful impacts.

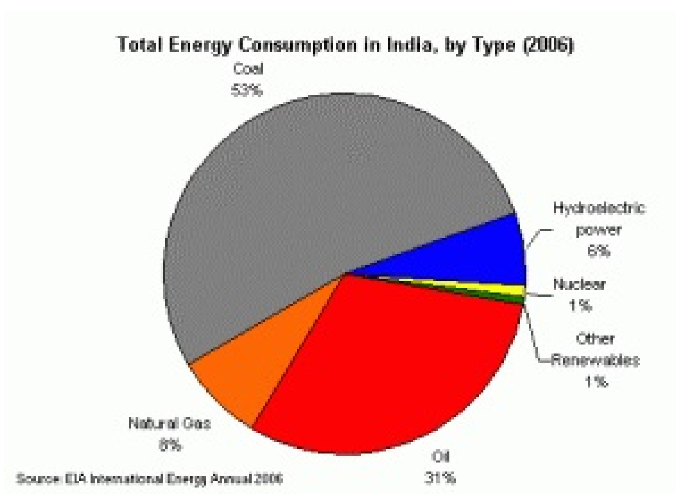


Figure 1.2 Total Energy Consumption

According to the International Energy Agency (IEA), India needs to in the next twenty years. Even though India possesses a rich heterogeneous mix of energy components, ambitious but unclear policies have created a difficult environment for potential investors. Thus, it will require extraordinary effort, innovative vision and viable solutions to meet the increasing demand for energy while maintaining an eco-friendly approach. [2] Gas, oil, coal and renewable energy are the main energy sources of India. However, certain pertinent questions still arise.[8]

1.3 Solutions and Cost Factor

Fortunately, there are two key ways we can maximize energy while offsetting the cost of it, and that is by 1) Using more alternative energy sources, 2) Making the things that use energy intelligent

The report aims to present the sun as the only energy source that can meet the oil depletion challenge. But solar energy ramp-up must be large-scale and immediate. Some of the factors that we can consider are

Cost Solar Power has always been viewed as an expensive technology but competition in the solar market in recent years has resulted in a drastic fall in installation prices. A solar PV system installed today costs less than half of what it did two years ago and it is likely that this cost could fall even further as we develop more affordable technologies for capturing energy from the sun.

Efficiency and space renewable energy critics will often complain of the low efficiency rates of solar PV panels, which are currently around 15, but when your fuel source is drawn from an infinite supply then this is only really an issue in terms of space. The great thing about solar Power is that systems are flexible and easily scalable.

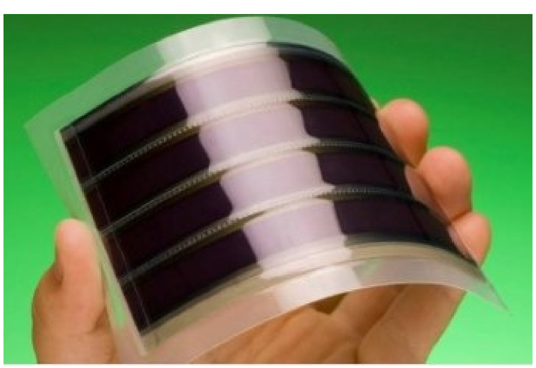
Intermittency and storage like most renewables, solar PVs biggest flaw is intermittency i.e. an irregular supply of electricity because the panels only produce a yield when the sun is shining. If we are to seriously invest in a solar electricity supply then we must first overcome this challenge with suitable storage technology.[7].

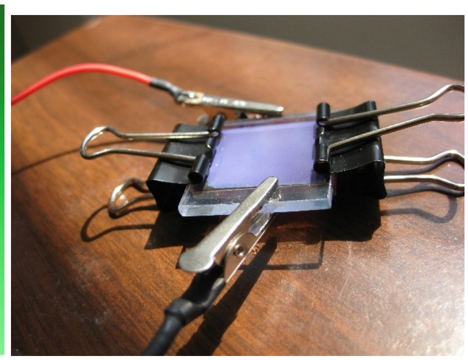
Chapter *2*

Dye-Sensitized Solar Cells

2.1 Introduction

A solar cell, or photovoltaic cell (previously termed ”solar battery”), is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. Most photo-voltaic solar panels are silicon based or a variation of. There are several different types of solar panel including tiles, film, and lightweight. Amorphous Solar Cells, Bio hybrid Solar Cell , Dye-Sensitized Solar Cell (DSSC) , Hybrid Solar Cell. Our main focus here will be Dye Sensitized Solar cell. Dye Sensitized solar cells (DSSC), also sometimes referred to as dye sensitized cells (DSC), are a third generation solar (photovoltaic) cell that is used to convert visible light into electrical energy. They were invented in 1991 by the researchers in cole Polytechnique Fdrale de Lausanne , Switzerland. One of the main advantages of this over traditional solar cell is its many features such as simple to make, semi-flexible, semi-transparent and low cost material. DSSCs are currently the most efficient third-generation and this makes DSSCs attractive as a replacement for existing technologies in ”low density” applications like rooftop solar collectors. . They have a good efficiency (about 10-14 percent) even under low flux of sunlight. However, a major drawback is the temperature sensitivity of the liquid electrolyte. Hence a lot of research is going on to improve the electrolytes performance and cell stability.





2.2 Structure and Principle

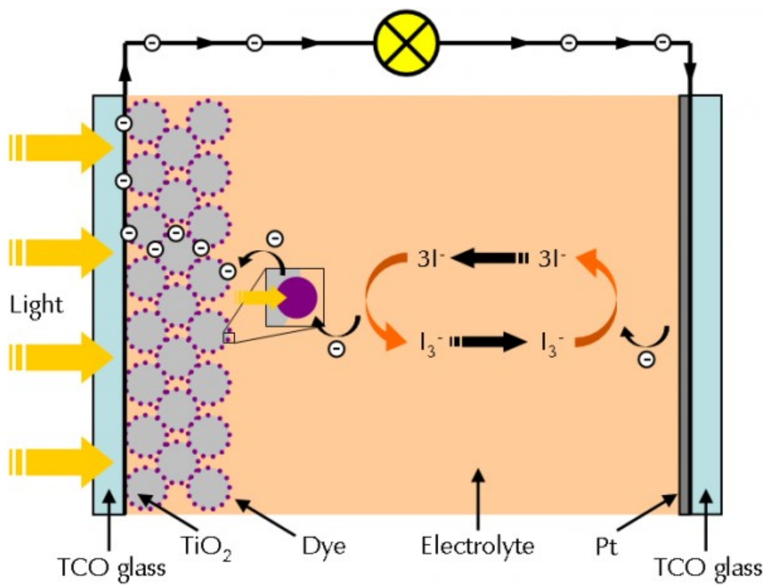


Figure 2.1 DSSC Structure

The anode of a DSC consists of a glass plate which is coated with a transparent conductive oxide (TCO) film. Indium tin oxide (ITO) or fluorine doped tin oxide are most widely used. A thin layer of titanium dioxide (TiO2) is applied on the film. The semiconductor exhibits a high surface area because of its high porosity.

The anode is soaked with a dye solution which bonds to the TiO2. The dye also called photosensitizers is mostly a ruthenium complex or various organic metal free compounds. For demonstration purposes, also plain fruit juice (such as from blackberries or pomegranates) can be used. They contain pigments which are also able to convert light energy into electrical energy.

The cathode of a DSC is a glass plate with a thin Pt film which serves as a catalyst. An iodide/triiodide solution is used as the electrolyte. Both electrodes are pressed together and sealed so that the cell does not leak. An external load can be powered when light shines on the anode of the dye solar cell. The dye is the photoactive material of DSSC, and can produce electricity once it is sensitized by light. [4]

STEP 1: The dye molecule is initially in its ground state (S). The semiconductor material of the anode is at this energy level (near the valence band) non conductive. When light shines on the cell, dye molecules get excited from their ground state to a higher energy state (S*),

STEP 2: The excited dye molecule (S*) is oxidized (see equation 2) and an electron is injected into the conduction band of the semiconductor. Electrons can now move freely as the semiconductor is conductive at this energy level.

STEP 3: The oxidized dye molecule (S+) is again regenerated by electron donation from the iodide in the electrolyte

STEP 4: In return, iodide is regenerated by reduction of triiodide on the cathode

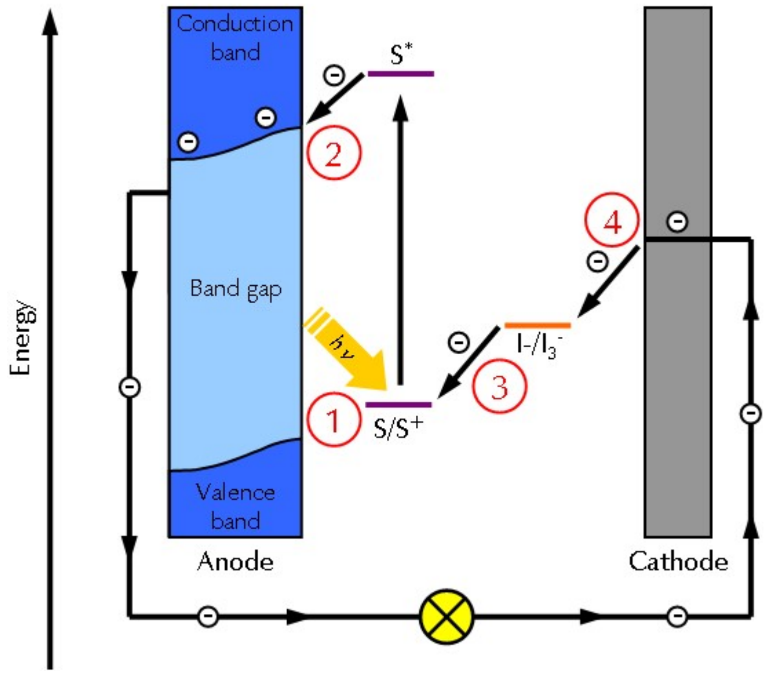


Figure 2.2 Principle of DSSC

It is the movement of these electrons that creates energy which can be harvested into a rechargeable battery, super capacitor or another electrical device.

2.3 Efficiency and Other Parameters

The efficiency is the ratio between maximum generated power Pmax and electrical input power Pin from the light source.

$$\eta = \frac{P_{\max}}{P_{in}} \cdot 100\%$$

Dye sensitized solar cell have a theoretical maximum energy conversion efficiency of 33 percent; however due to technical constraints, the actual energy conversion efficiency of DSSC is closer to 11 percent, which is less than half of the crystalline silicon based solar cells efficiency of 24.4 percent .Improving DSSC efficiency is critical to widespread adoption of this technology.

Schematic diagram of I-V curves with and without light

Current flux is nearly constant at lower potentials. It reaches its maximum when the potential is zero. The generated current decreases with increasing potential. It is zero at the open circuit potential. The cell can get damaged at excessively high values. The short circuit current ISC is the highest current that can be drawn from a solar cell. The short circuit current increases with increasing light intensity.

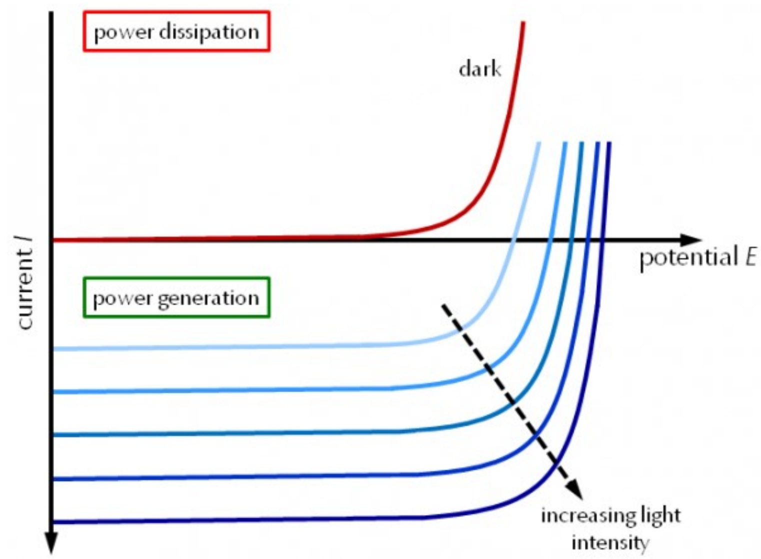


Figure 2.3 I-V characteristics

Meanwhile, The open circuit potential EOC is the highest voltage of a solar cell at a given light intensity. It is also the potential where current flow through a solar cell is zero. The Fill factor (FF) is an important parameter to specify the overall capabilities of a cell. It describes the quality and idealness of a solar cell.

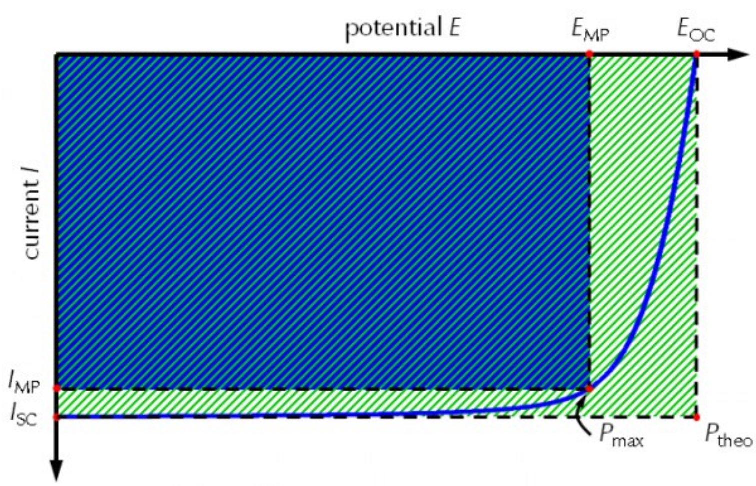


Figure 2.4 Fill Factor Representation

The Fill factor is the ratio of maximum generated power Pmax to theoretical power maximum Ptheo of a solar cell. The general formula for the Fill Factor is:

$$FF = \frac{P_{max}}{P_{theo}} = \frac{E_{MP} \cdot I_{MP}}{E_{OC} \cdot I_{SC}}$$

EMP and IMP are potential and current of the I-V curve where the generated power is at the maximum.

2.4 Electrophoretic Deposition

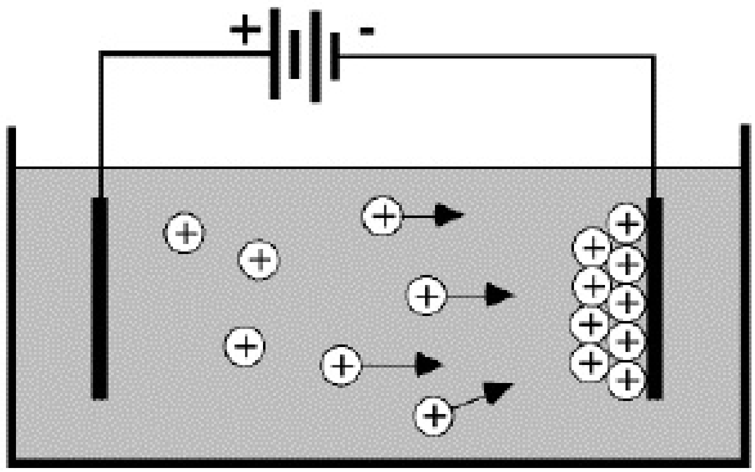


Figure 2.5 EPD Deposition

Electrophoretic deposition EPD is a method of coating a conductive part with particles suspended in a fluid dispersion under the influence of an electric field applied between the work part and the counter electrode. Similar to Electroplating coating electrophoretic deposition utilizes electrically charged particles moving between two electrodes (an anode and a cathode) immersed in a liquid media.However in contrast to conductive electrolytes used in electroplating, the fluids of electrophoretic dispersions are dielectric. It involves a broad range of industrial processes which includes electrocoating, cathodic electrodeposition, anodic electrodeposition, and electrophoretic coating, or electrophoretic painting. The process is useful for applying materials to any electrically conductive surface. The materials which are being deposited are the major determining factor in the actual processing conditions and equipment which may be used.

Implementation

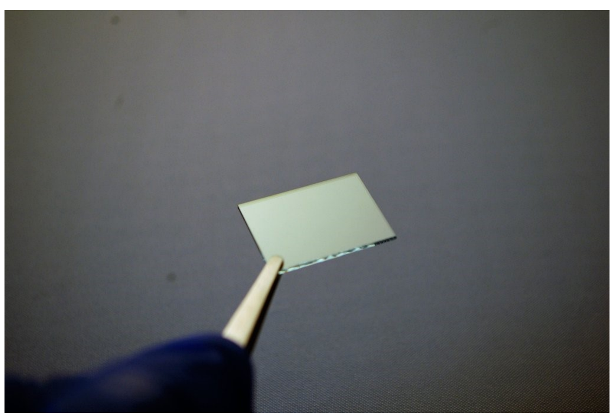
1. Place two electrodes into a mixture of solvent and particles.
2. Apply a voltage/current between the electrodes for a set period of time.
3. If after removal one of the electrodes has a coating of particles, then EPD has occurred.

Chapter *3*

Experimental Work

A demonstration and experiment was done initially to understand the basics of experimentation and the resulting effect it has on the values and calculation. The initial stage was cleaning of the glass substrate. The Whole experiment was done under the supervision of our project guide in the Material Synthesis laboratory and its adjoining Advanced Materials Laboratory.

3.1 Cleaning



Glass Substrate is a thin glass board on which a thin circuit is deposited with precision. It is a key material for LCD. They are the individual plies of glass used to fabricate glass units and may also be referred to as float glass, raw glass or glass lites. Glass substrate options include clear, tinted and low iron.

Sonication

Sonication is a process in which sound waves are used to agitate particles in solution. Such disruptions can be used to mix solutions, speed the dissolution of a solid into a liquid (like sugar into water), and remove dissolved gas from liquids. Sonicator Bath has been designed using MOSFET/IGBT and latest Microcontroller base technology. [6]

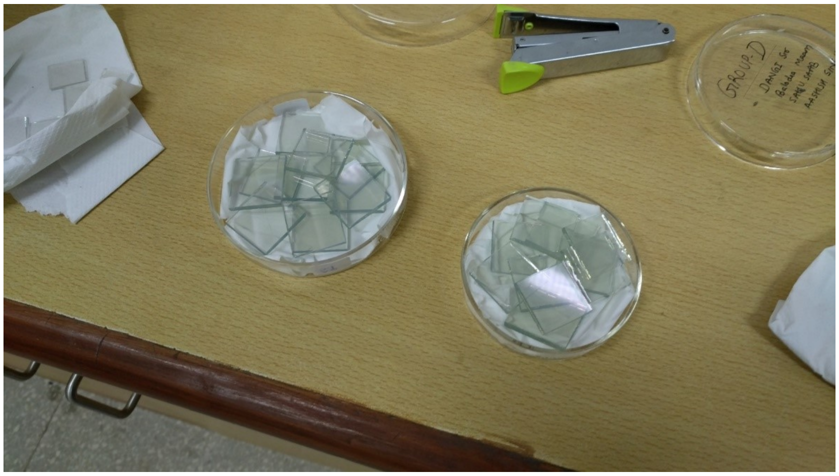
Components Involved and Steps followed

1) Ethanol
2) Isopropyl Alcohol
3) Distilled Water (Soap Solution)
4) Acetone

Firstly, clean the beakers with ethanol solution. The beaker was then dispersed in Soap solution and the glass slides to be cleaned were further put inside and then it was washed properly. Another beaker filled with distilled water was taken and the glass slides were put and then the resulting solution was cleaned and sonicated with digital ultrasonic cleaner for 2 minutes.

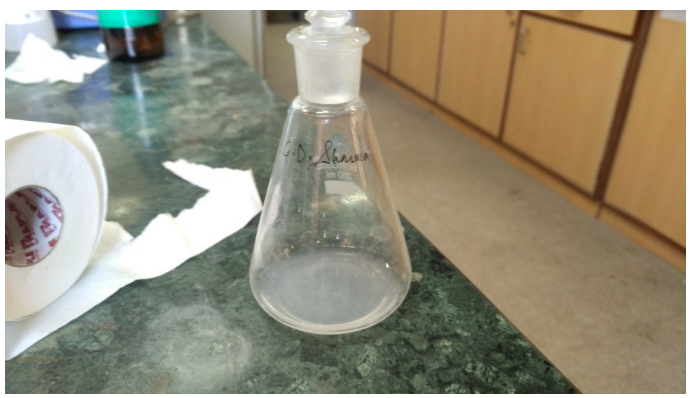
The slides were then put into **ethanol** for 2 minutes and then the same cleaning procedure was repeated. Isopropyl Alcohol was used in the next step and the glass slides were sonicated further along with the solution. The same glass slides were then washed and cleaned with acetone. The main reasons for cleaning in the specific order was that the **Acetone** will remove organic impurities from the chip substrates, and is particularly apt for dissolving oily or greasy contaminants. However, acetone evaporates rapidly and will redeposit the contaminants. Methanol works very well to dissolve the acetone with its contaminants, without rapidly evaporating. **Isopropanol** (a.k.a. isopropyl alcohol) is an excellent rinse agent for the methanol and contaminated acetone, and for lifting and removing particles.


The net cleaning effect was clearly visible with proper current values and no specks being present.



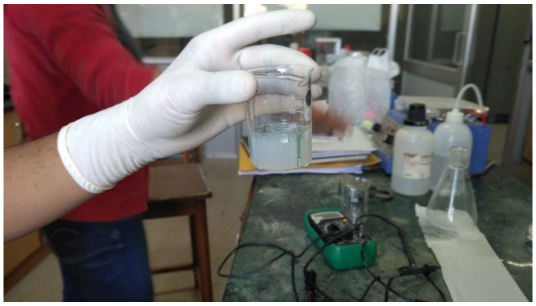
3.2 Layer Deposition

3.2.1 $TiCl_4$ treatment



Titanium tetrachloride is a titanium and chlorine compound and has the chemical formula $TiCl_4$, tetra coming from the four chlorine atoms. It is also known as Tetrachlorotitanium or Titanic chloride. It appears as a dense, colorless to pale yellow distillable liquid. It generally works as complement to the titanium dioxide deposition that is soon followed with it. $TiCl_4$ increases the electron conductance on the interface of the FTO glass. A suitable amount of $TiCl_4$ in the film could also provide a large surface area for dye adsorption

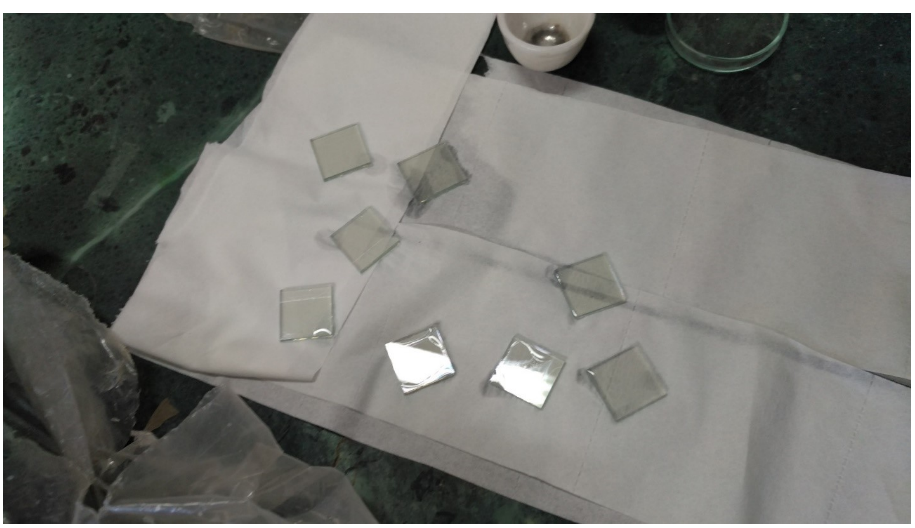
Titanium dioxide (TiO_2) electrodes are vital components for the fabrication of dye-sensitized solar cells. Titanium tetrachloride ($TiCl_4$) treatment is usually adopted as a pre- or post-treatment for the improvement of TiO_2 electrodes in DSSCs. Previous journals have associated these treatments with

the improvement of bonding strength between the fluorinated tin oxide (FTO) substrate and the porous TiO_2 layer. Recent studies and reports have also pointed in a healthy increase of the overall conversion efficiency using this deposition. [8]

Calcination is the process of subjecting a substance to the action of heat, but without fusion, for the purpose of causing some change in its physical or chemical constitution. A Hot air oven is used to condition the specimens to the specified temperature in the laboratory. The final samples are then ready for TiO2 treatment.



3.2.2 TiO_2 treatment

Titanium dioxide layers on glass substrates have been widely studied for optical and electronic applications because they have a

- High refractive index (up to 2.7),
- High Photo catalytical activity
- Good physical and chemical Stability
- Wide Band Gap (greater than 3 eV)
- High Dielectric Constant
- Good Optical Properties

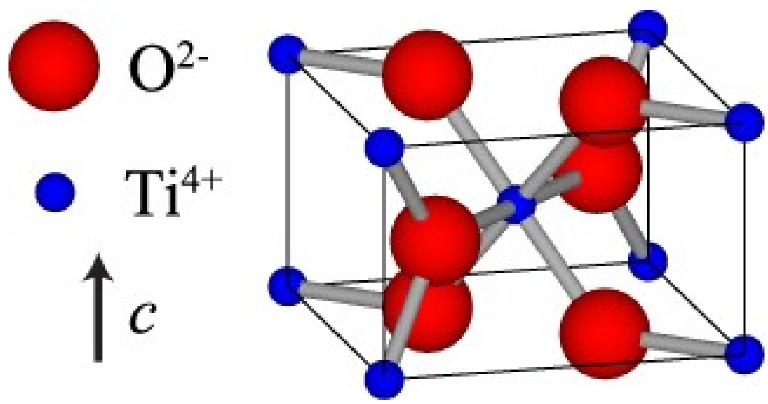


Figure 3.1 TiO_2 Structure

The metal oxide should provide mesoporous structure for dye adsorption and the bandgap edge levels should be adjusted with respect to the Dyes and electrolytes. Other metal oxides can also be used like ZnO and SnO2. Several research groups have tried and concluded that their efficiency is low compared to TiO2, because of less mesoporous structure in ZnO and SnO2 etc.Internal network structure is important to achieve high charge collection efficiency and more electron transportation. TiO2 is more stable compare to other metal oxides that is why it is the preferred choice.

Components Involved and steps followed

1) Acetyl Acetone (32 ml)
2) Titanium Dioxide (0.32 gm)
3) Iodine Powder (0.032 gm)

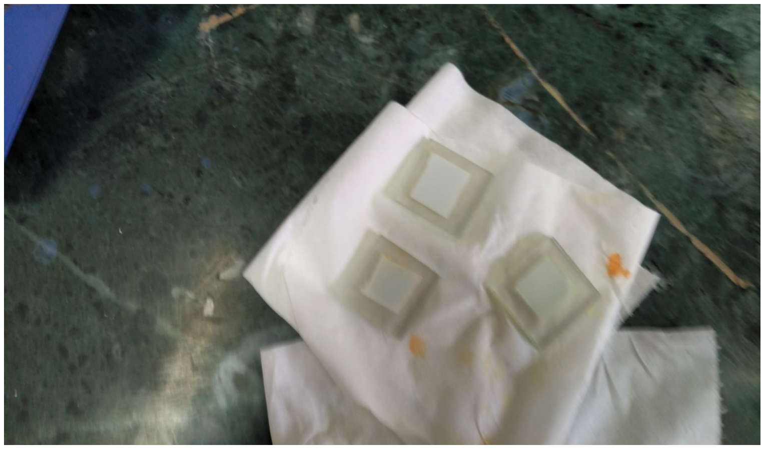
The ingredients are put together and the Resulting solution is mixed after carefully measuring the values. The Solution is further sonicated for 30 Minutes. It is then stirred for 20-30 Minutes at room temperature using Magnetic Stirrer

Connect the Power supply Clamp to our glass samples opposite to a reference counter electrode. Dip the Clamp with the Samples in the stirred solution. Turn on the power for the regulated supply and let it run for approx. 80-100 seconds. (Under the proper specification)

Power Supply: Voltage: 20 V
Current Amplitude: 100 mA

Magnetic Stirrer: Voltage- 220/230 VAC
Temperature Range-250 Degree Celsius

The experimental setup is as shown above.



Remove the Layer deposited chip carefully and lightly clean away the outer edges. The Results of the TiO2 film deposition are as given. We can notice a clear white thin deposition on the glass chips. These Substrates are then deposited in a Microwave furnace/Oven for Calcination.

3.2.3 Dye Solution

Composition

- Dye particles (0.0036 gm.)
- Ethanol Solution (10 ml)

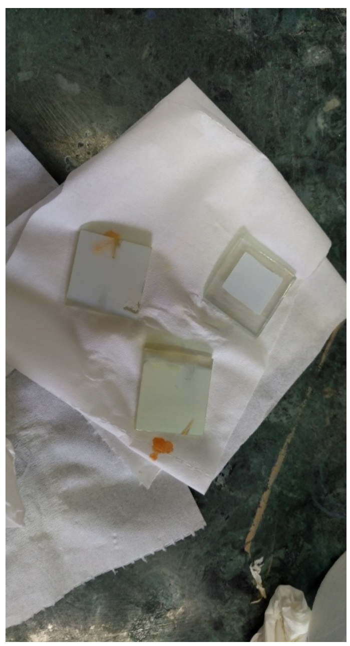
Example of dye molecule that is used in DSSC:

- Ttriscarboxy-rutheniumterpyridine [Ru(4,4,4"-(COOH)3-terpy)(NCS)3] (Black dye)
- 1-ethyl-3 methylimidazolium tetrocyanoborate [EMIB(CN)4]thanol Solution (10 ml)
- Copper-diselenium [Cu(In,GA)Se2]

MK Dye material was used however for this experiment.

After preparing the dye solution, we place the glass samples into Dye sol. for 24 hours under dark conditions. This is done due to the consideration of the samples being light sensitive under room conditions. After a period of 24 hours, the samples are removed and processed further. Some dye impurities are further removed by using ethanol with dropper on glass surface.

The final Samples are visible in the rightmost region. We can observe a clear coating of dark maroon color across the glass slides.




A before and after change is clearly seen in the samples.

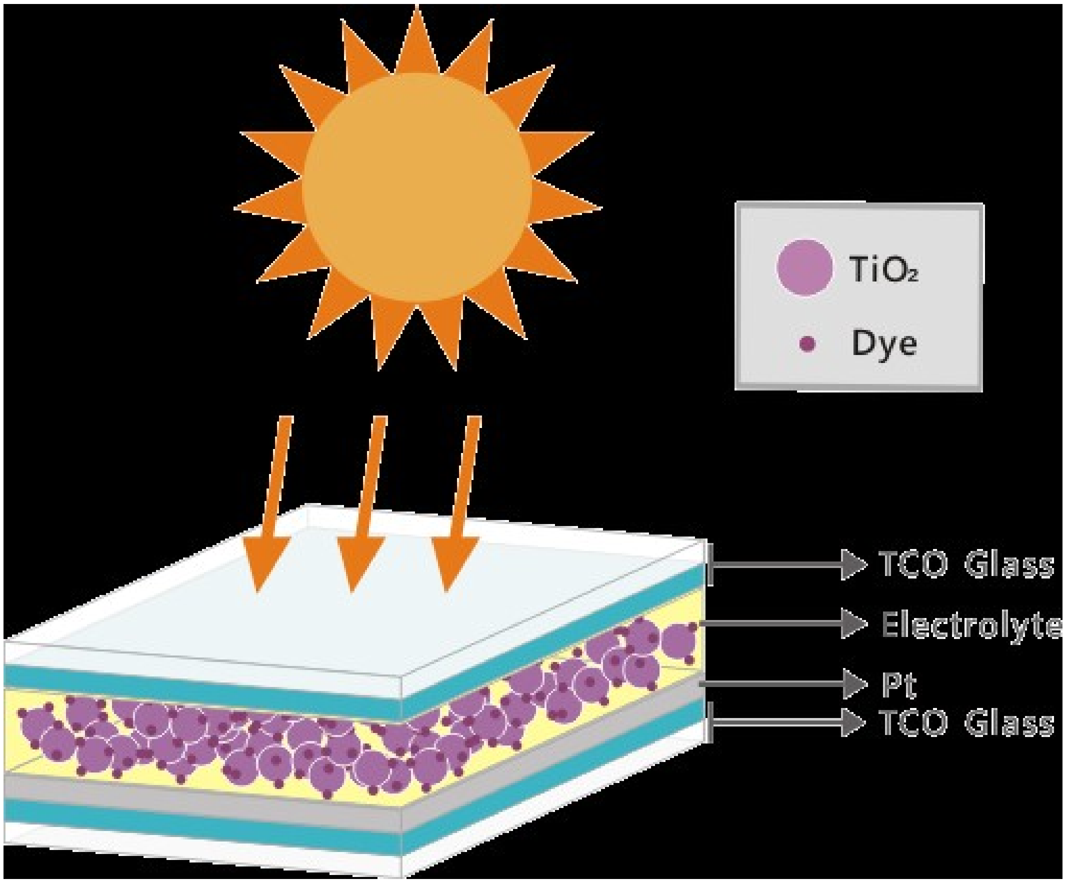
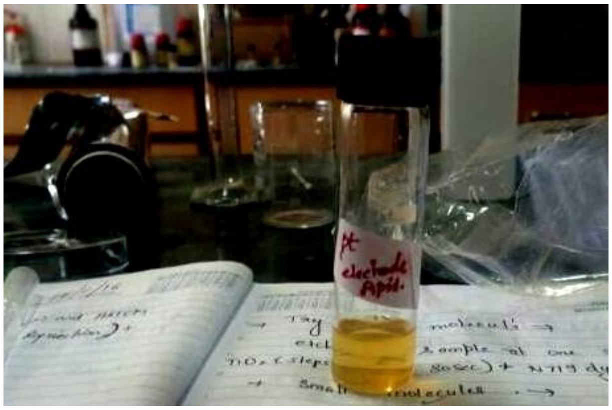


Figure 3.2 Plot : Dye Layer

Importance

The dye injects an electron into the conduction band of the TiO2 layer. The dyes in dye-sensitized solar cells (DSSCs) require one or more chemical substituents that can act as an anchor, enabling their adsorption onto a metal oxide substrate. This adsorption provides a means for electron injection, which is the process that initiates the electrical circuit in a DSSC. The dye molecules are quite small (nanometer sized), so in order to capture a reasonable amount of the incoming light the layer of dye molecules needs to be made fairly thick, much thicker than the molecules themselves.[7]

3.3 Negative Electrode and Electrolyte Solution




Cleaned FTO samples are treated with Platinum solution. Further Calcination at 450 degree Celsius is done. The Negative electrode (platinum based) is prepared using this method.

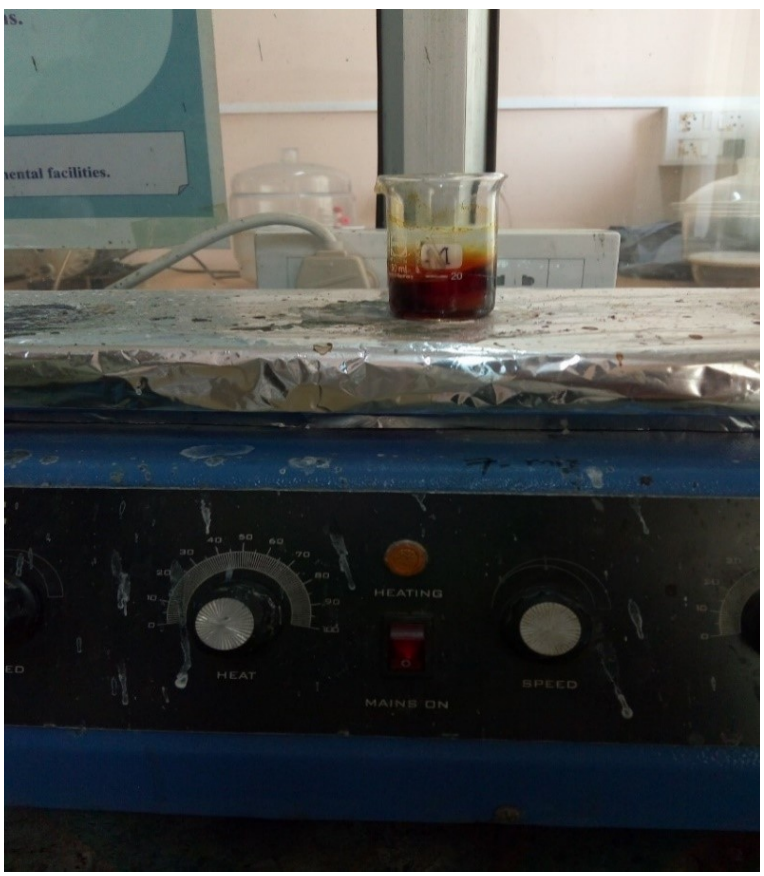
Electrolyte Solution

The components involved in Electrolyte solution was depicted above.

Solution	Quantity
LiI (Lithium Iodide)	0.0669 gm
I2 (Iodine)	0.0634 gm.
TBP (4-tert. Butylpyridine)	0.3380 gm
Acetonitrile	5 ml

Table 3.1 Electrolyte Composition

One of the basic component of the liquid electrolyte is the organic solvent. It helps us in giving an environment for the iodide and the triiodide ions and helps in the dissolution and diffusion. The physical characteristics of the electrolyte further include viscosity, donor number, dielectric constant etc., this affects the photovoltaic performance of the dye sensitized solar cell. This solution should further have long term stability along with chemical, thermal, electrochemical stability while maintaining the need to avoid degradation and desorption of the dye from the oxide layer. However we need to make sure that it does not exhibit a significant absorption in the visible light range.



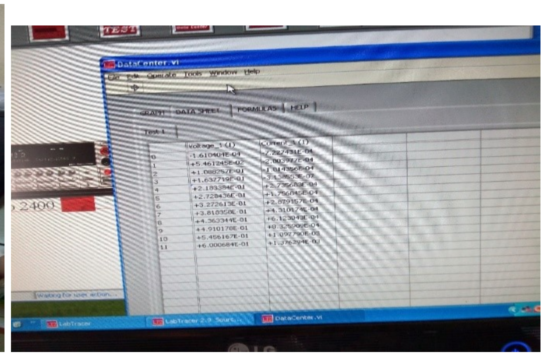
3.4 Assembly

Stirring the electrolyte using magnetic stirrer. Electrolyte is injected between the electrodes using syringe. Clips are used to assemble electrodes. Platinum electrode is connected with positive supply. Between the electrodes electrolyte is used carefully. Artificial sunlight at 100 mW/cm2 with 31 degree Celsius is used. Temperature needs to be maintained for proper result.

Chapter *4*

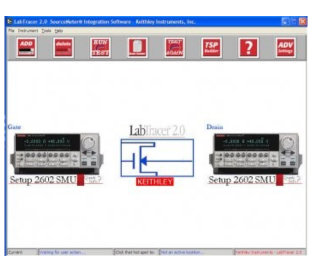
Results and Observation

4.1 Software Package



LabTracer is a program for characterizing components using SourceMeters and Series SourceMeters in a research environment. The program makes it easy to build tests for the Keithley Series 2600, Series 2400 and Model 6430 SourceMeters using a GUI interface.

Origin is a proprietary computer program for interactive scientific graphing and data analysis. It is produced by OriginLab Corporation, and runs on Microsoft Windows. Origin is an easy-to-use data analysis and graphing software and is used in statistics, signal processing, curve fitting and peak analysis. Version 8.0 was used for this experiment.



ORIGIN 8
The Data Analysis and Graphing Workspace

4.2 I-V Characterstics

The chief property of photovoltaic device (PV) is the Current-Voltage curve or the I-V characteristic which measures all the possible combinations of current and voltage output. As mentioned above, the maximum current occurs when there is no resistance (Short Circuit Current) while the maximum voltage occurs when there is a break in the circuit (Open Circuit Voltage). These curves are generally used to define basic parameters of the component. The I-V reading of the devices are as follows:

Voltage_1 (1)	Current_1 (1)
-9.313165E-05	-5.187858E-04
+4.222723E-02	-2.620974E-04
+8.421656E-02	-2.550352E-04
+1.262262E-01	-2.387589E-04
+1.683882E-01	-2.334772E-04
+2.105835E-01	-2.249533E-04
+2.527527E-01	-2.097648E-04
+2.948003E-01	-1.969491E-04
+3.369272E-01	-1.809303E-04
+3.789847E-01	-1.593372E-04
+4.210337E-01	-1.314456E-04
+4.632185E-01	-1.014296E-04
+5.052760E-01	-5.969828E-05
+5.475144E-01	+1.542825E-05
+5.895483E-01	+1.418910E-04
+6.317074E-01	+3.166909E-04
+6.737211E-01	+5.667654E-04
+7.158934E-01	+8.775443E-04
+7.579775E-01	+1.256742E-03
+8.001794E-01	+1.657123E-03

Figure 4.1 I-V Characterstics :Light

Voltage_1 (1)	Current_1 (1)
-1.610404E-04	-7.227431E-04
+5.461245E-02	+2.003977E-04
+1.088257E-01	+1.014356E-04
+1.637719E-01	+3.138553E-07
+2.183384E-01	+2.735683E-04
+2.728436E-01	+1.756845E-04
+3.272613E-01	+2.879157E-04
+3.818358E-01	+4.310174E-04
+4.363344E-01	+6.123043E-04
+4.910178E-01	+8.325909E-04
+5.456167E-01	+1.097790E-03
+6.000684E-01	+1.376294E-03

Figure 4.2 I-V Characterstics :Dark

]

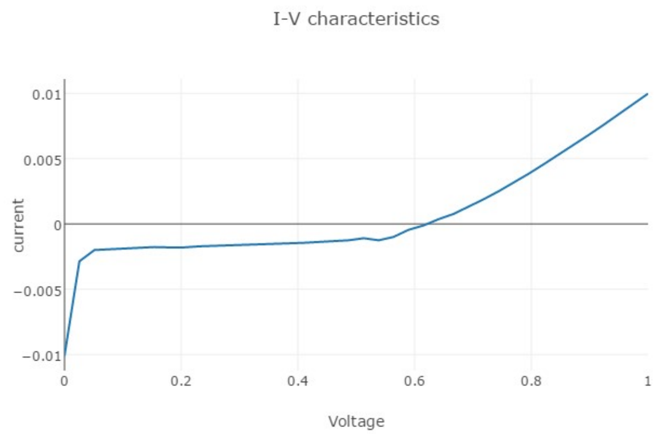


Figure 4.3 Plot : I-V Characterstics-Light

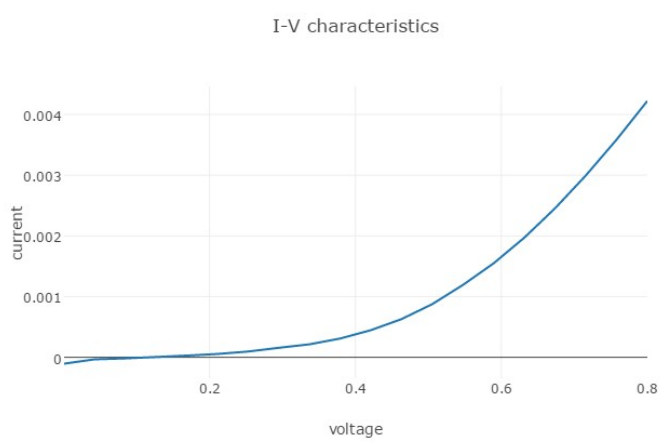


Figure 4.4 Plot : I-V Characterstics-Dark

Voltage_1 (1)	Current_1 (1)
+6.707829E-04	-1.049888E-04
+4.226995E-02	-3.396878E-05
+8.423185E-02	-1.841981E-05
+1.262925E-01	-5.139028E-08
+1.684266E-01	+2.785714E-05
+2.106047E-01	+5.437420E-05
+2.527918E-01	+9.476957E-05
+2.948547E-01	+1.560544E-04
+3.368649E-01	+2.134284E-04
+3.789685E-01	+3.087954E-04
+4.210422E-01	+4.462793E-04
+4.631922E-01	+6.289125E-04
+5.053337E-01	+8.755911E-04
+5.475107E-01	+1.192919E-03
+5.895966E-01	+1.549221E-03
+6.316438E-01	+1.971821E-03
+6.738219E-01	+2.456076E-03
+7.158740E-01	+2.995467E-03
+7.579606E-01	+3.584593E-03
+8.001856E-01	+4.222663E-03

Figure 4.5 I-V Characterstics :Device 2

Voltage_1 (1)	Current_1 (1)
-9.313371E-05	-1.011584E-02
+2.555780E-02	-2.862037E-03
+5.132826E-02	-1.998981E-03
+7.692116E-02	-1.953318E-03
+1.025141E-01	-1.890586E-03
+1.794913E-01	-1.798448E-03
+2.051497E-01	-1.794872E-03
+2.821511E-01	-1.658898E-03
+3.077856E-01	-1.615458E-03
+3.846897E-01	-1.484198E-03
+4.103131E-01	-1.443632E-03
+4.871727E-01	-1.252108E-03
+5.129732E-01	-1.095854E-03
+5.897929E-01	-4.469001E-04
+6.666933E-01	+7.644579E-04
+6.923389E-01	+1.291154E-03
+7.179873E-01	+1.882845E-03
+7.949651E-01	+3.830799E-03
+8.206782E-01	+4.554990E-03
+8.975656E-01	+6.792725E-03
+9.231237E-01	+7.567700E-03
+9.742661E-01	+9.167062E-03

Figure 4.6 I-V Characterstics :Device 3

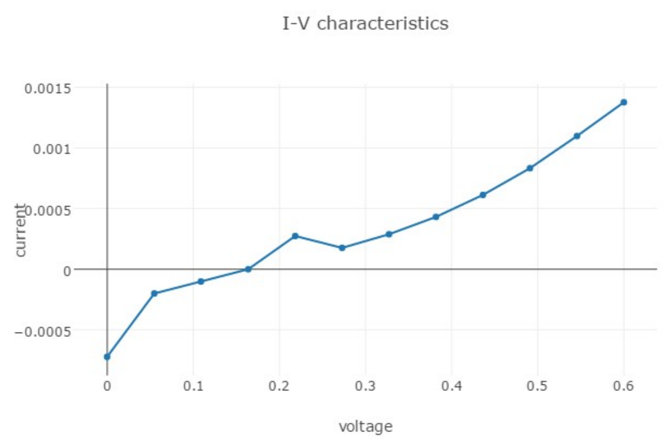


Figure 4.7 Plot : I-V Characterstics-Device 2

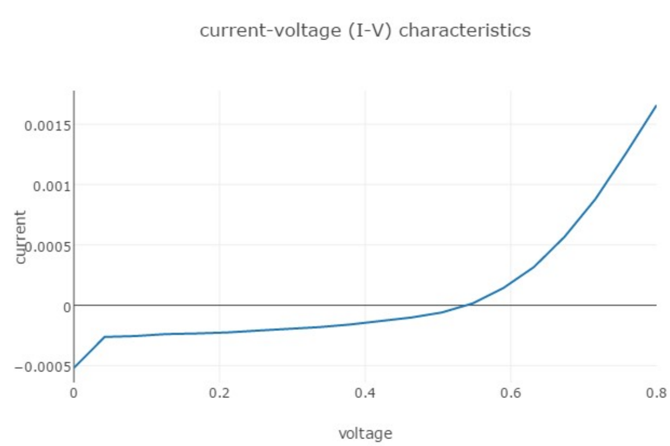


Figure 4.8 Plot : I-V Characterstics-Device 3

Device	Short Circuit Current	Open Circuit Voltage	Maximum voltage	Maximum Current	Fill Factor
A	0.6016	-0.001898	0.564	-0.0015	0.78
B	0.1638	-0.000232	0.113	-0.0001	0.337
C	0.5388	-0.0002621	0.465	-0.000196	0.648

Table 4.1 Experimental Results

4.3 Analysis

The result obtained are compiled as given above.The given parameters were calculated on the basis of theoretical standards and constants taken as per recommendation and various journals. The need for taking various parameters on the basis of light intensity was also considered and the devices are observed on the basis of different light conditions (Device A for Bright Light, Device B under dark conditions). The results observed were substandard and were however under the theoretical values. The current observed was in the lower range likely due to presence of impurities. The other parameters however were acceptable and as expected. There were a few discrepancies in the calculations and readings which was resolved by taking suitable adjustments in the final values. Overall the experiment to synthesize a prototype device was successful and worked under proper conditions. The values however recorded were substandard and this can be attributed to various factors such as proper deposition, impurities, electrolyte solution.

Chapter *5*

Conclusions and Future Work

The experiment started with an on hand study on solar devices and how technology has evolved into dye sensitized solar cell. Further study was done to learn about the structure and fabrication techniques used. Electrophoretic deposition was studied ahead and how the electrolytic process helps in the various parameters involved in solar devices. We then moved to laboratory work where various synthesization components were studied and worked under. All the various processes including cleaning, layer deposition, electrolyte preparation was done according to the proper procedure. A multitude of devices were made for observation and correct comparison. The reading observed after proper calculation however were substandard and below the normal expected values. This was attributed to various factors which are mentioned in the report. In the closing, it can said that the device produced was successful in implementation and can be termed satisfactory.

5.1 Scope of further work

A lot of study and research has been carried out on DSSC. Different aspects of Dye sensitized solar cell have been focused and investigations have been thus carried on. Many sensitizers including inorganic and organic dyes have been used. The major challenge in the fabrication and commercialization of DSSCs is the low conversion efficiency and stability of the cell. The degradation of the cell based on dye sensitization, undesirable electrolyte properties and poor contact with the electrodes are the main causes of the poor performance of DSSCs. To enhance the performance of the DSSCs, several research directions are suggested: improving the dye stability by finding the optimum parameters to slow the dye degradation; improving the dye structure to absorb more light at longer wavelengths, 780-2500 nm (the near infrared region, NIR); improving the morphology of semiconductors to attaining the best electronic conduction to reduce the dark current; Using dye and electrolyte additives to enhance the cell performance; and Improving the mechanical contact between the two electrode Thus, the choice of materials is very important in the fabrication and deployment of DSSCs because the conversion efficiency and stability of the cell do not depend on a single factor alone

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