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Study and Analysis of Dye Sensitized Solar Cells

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Abstract- *the need of energy is the basic need for any civilization. Through the years we have been using various kinds of energy sources to fulfill energy requirement. The search for a clean energy source, producing electricity at low production cost is always on. Solar energy is one of the best known energy options available to us. Even if we are able to convert a small fraction of solar energy falling on earth's surface into electricity, then the whole problem related to energy crisis would be resolved. But it has a disadvantage that initial cost for the equipment to harness the energy is very high. That is why it is not very popular in the market. But there is a technology which is making its cost cheaper.*

This technology is known as "DSSC". Which stands for, dye sensitized solar cell. DSSC is a new class of solar cell that belongs to the group of thin film solar cells. This solar cell partly by passes the photosynthesis reaction and makes a shortcut conversion of sunlight into electrical current. The inner part of this solar cell consists of semiconductor material. And in between semiconductor molecules, there are dye molecules, similar to chlorophyll in plants. Sunlight is absorbed by them. It makes dye electrons to move to a higher energy level. Then they become mobile and move through semiconductor circuit. This results in the flow of electricity. This cell was developed by Professor "Michael Gratzel".

Keywords: *Solar energy, Thin film solar cell, DSSC, TiO2, Dye, Pyranometer, Overall conversion efficiency, Semiconductor layer thickness and Silicon cell***.**

I. Introduction

Solar cells have gone through a number of years and they have gone through a number of phases. Their development can be described according to their construction principles. So we can call them solar cells of different generations.

In the first generation of solar cells silicon with a large area and in a single crystal of p-n junction diode was used. This is made from two doped crystals. One is doped with n type material having extra electrons. Other crystal is doped with p type impurities lacking some electrons. When both crystals are placed in contact with each other electrons from n type material starts flowing towards p type material. Eventually enough electrons will flow across the junction to equalize the Fermi level of the two regions. This result in a region at the interface called p-n junction. Where charge carriers are depleted or accumulated on each side of junction. In Silicon the transfer of electrons produces a potential barrier of 0.6 to 0.7V. Right now these solar cells accounts for approximately 86% of the total solar market.

In Silicon solar cells sunlight can provide enough energy to the electrons to move them from valence band to conduction band. This process is known as photo excitation. When an external load is applied these electrons lose their energy while flowing through external circuit. Then they again come back to the n side and recombine with the holes left by them. In this way sunlight creates electrical current. In any semiconductor band gap means the electron with that much energy or higher energy than band gap will contribute to produce electricity. In case of silicon semiconductor they can absorb most of the visible range light from red to violet. But the higher energy electrons at the blue, violet end have the more energy than required so it is wasted. Also there is one more issue that to absorb a good amount of photon energy we have to make n layer thick. This increases material cost and makes the construction complex. This creates one more problem that any electron which is on conduction band can recombine it with a hole on the n region before reaching the p-n junction. This puts an upper limit on the efficiency of Silicon solar cells. However the biggest problem with these cells has been the cost. Silicon processing is costly and the thick layer of Silicon increases its cost more. So we need a different form of solar energy utilization device which would convert solar energy into electricity but at economical price. By the years of observations and research we have got following graph which compares all kind of first generation solar cells efficiencies. We have seen three kinds of silicon solar cells. All of them have different characteristics. The three kinds of silicon cells manufactured during this time were as following:

1. Single crystal silicon cell
2. Multi crystalline silicon cell
3. Thick silicon film

***A.DSSC:* -** This name DSSC stands for "dye sensitized solar cells". A dye-sensitized solar cell (DSSC) is a solar cell that belongs to the group of thin film solar cells. A thin film solar cell works on the principle of photosynthesis in plants. This cell was developed by the scientist known as Michael Gratzel and Brian O Regan at the Ecole Polytechnique Federalede Lausanne in 1991. That's why the cell is known as GRATZEL'S solar cell also. He used mostly artificial dyes. But some organic dyes were also tried by him. The basic idea behind its development was, that every day we can see the most fascinating "solar cells", for example green spinach, algae, and green leaves on trees, converting sunlight by means of photosynthesis into energy containing nutrients like sugar, which are important for life. Why couldn't we use dyes either organic or synthetic dyes with a little bit of sunlight to generate electricity.

II. Manufacturing Steps Of Dssc

A. Negative Electrode*:* For the making of negative electrode we need to identify first the conducting side of the glass. This has been made conductive by the help of coating layer of Transparent Conductive Oxide (TCO). The coating is done only on one side of the glass so we use multimeter to find out the conducting side of the glass. Then we have to put a thin layer of titanium do oxide on the conducting side. For this we use pipette to put few drops of TIO2 on the glass surface. And then we use microscope slider glass to spread it through the whole glass surface. It need to be done very carefully then only the result will be good. Otherwise we would not get the required output. After this we dry the layer by the help of Hair Dryer operating in cool mode or we can dry it naturally in room condition.

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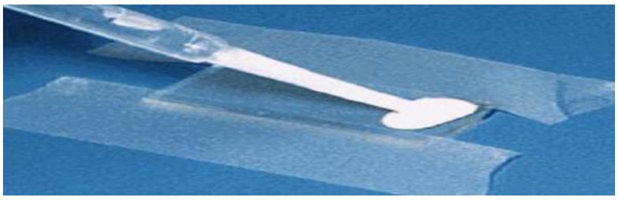

Fig.1: Putting TiO2 layer over conductive side of glass

B Dye Solution: The dye solution absorbs most of the sunlight falling on it. Thesemiconductor TIO2 layer absorbs only a small fraction of sunlight falling on it(mainly in the UV range).We make solution by the help of different dried fruits or leaves in water. For this we take any of the dye providers and dry them naturally then they become ready to use. We had "Butea frondosa(Palash)" leaves available with us. And we have tried the above given procedure to make dye with them. After putting them in the boiling water, we will observe that they will leave their color with leaving some chlorophyll in the water. Color of water will become same like the fruit or leaf. Then this dye solution will be ready to be use. But for some other natural fruits the procedure of dye making becomes different from the above given.

Fig.2: TiO2 coated glass in dye solution and Dried Plash Leaves

C Positive Electrodes: To prepare this we need to follow the same procedure first which have been followed in case of negative electrodes. First of all we need to determine the conducting side of the plate by the help of multimeter. After this we put a layer of graphite on the conducting side of the glass. For this we start scratching the Pencil against the conducting side of the electrode. Then a uniform layer of graphite is formed on the surface of conducting glass which works as a catalyst. And it provides the path for the electrons to flow.

Fig.3: Graphite coating over glass plate

The study about the counter electrode has shown if we use a composite plate made with graphite then that the bulk electrical resistance of the composite plate gradually 14 decreases from 6.7 mΩ cm to 1.7 mΩ cm as the graphite content increases in the counter electrode. It happens due to the formation of efficient electronic conducting networks. For DSSCs, the composite plates may be suitable substitutes for the conductive glass plates in the counter electrodes substrates of DSSCs. Experimental results revealed that composite plates at the optimum level (80 wt.% graphite loading) provide lower cell resistance, lower preparation cost and higher cell performance than common conductive glass plates. Therefore, in order to decrease the cost of the cells and to maintain good cell performance, this graphite-like composite plate prepared is a promising substitute for DSSCs.

D Electrolyte: Here we use Iodide type of electrolyte. This Electrolyte solution is kept in between positive electrode and TIO2 layer. Electrolyte performs a very important function in the whole electron flow circuit. After the dye molecule has lost one electron the dye molecule will decompose if a electron is not provided quickly. So dye molecule strip the electron by oxidizing iodide electrolyte into tri-iodide. This reaction takes very less time compare to what the lost electron from dye molecule takes to regain its original position. This reduces the chances of short circuit of solar cell. The above given steps make the Dye molecule again capable of providing electron for flowing in the external circuit.

Then this tri-iodide gets its electron by diffusing to the lower area of electrolyte, towards the positive electrode. There the lost electrons come after flowing through external circuit. These electrons combine with the iodide electrolyte. So electrolyte again regains its lost electron. So to close the circuit of electron flow the electrons flow through the negative electrode to the external load then they flow through positive electrode then by help of graphite they come to the electrolyte. This moves them to the negative electrode where dye molecules available in the porous space of TIO2 reabsorb them. In this manner they again become able to provide electrons for flowing in the external circuit.

Fig 4: Electrolyte Solution

III. Experimental Kit

We had the kit available, which contained all the articles to make a dye sensitized solar cell. It contained following articles.

Fig 5: Experimental kit components

1. Glass Plates: - All the glass plates have transparent conductive oxide (TCO) layer on one side, which make the glasses conductive. Transparent conductive oxide is made of SnO_2 or SnO_2:F.

2. TiO2 solution: - This solution is given in a certain quantity, to apply it over conductive side of glasses. The solution of TiO_2 powder was made with the acetic acid.

3. Dried Hibiscus leaves are given, which are used as a sensitizer. We need to add these leaves in boiling water to make dye.
4. Electrolyte: - As an electrolyte solution Iodine solution is there. This converts in to the tri-iodide after reacting with graphite which works as a catalyst.
5. Multimeter and wire mesh: - A multimeter is there which is used to measure short circuit current and open circuit voltage, if we connect it directly to the DSSC. It is
also used to find out conductive side of the glasses.
6. Pipette, Microscope slider glass, crocodile clips: **-** We need pipette at the time of coating TiO2 layer on conductive side.
7. Pencil and safety goggle: - Pencil is used to put a graphite layer on the positive electrode of DSSC and Safety goggle is given to perform furnace related operations safely.

IV. Working Principle

This transforms the energy present in light into electricity by means of following steps: DSSC kit absorbs the sunlight. Then the energy of sunlight is absorbed by the semiconductor material and then this energy is transferred to the dye molecules. It makes dye electrons to move to a higher energy level. Or we can say that electrons move from the valence band to the conduction band. Then it becomes mobile and moves through the titanium dioxide layer. Then it is collected on one side of conducting glass.

After electrons are collected on one side of conducting glass, we connect an external circuit between two electrodes. Electrons start moving through this external circuit connected with external load. Then electrons after moving through external circuit comes back to previous position after moving through counter electrode. This forms a close circuit helping lost electrons to re enter in the dye molecules. This is required for the continuous flow of electricity. Positive electrode collects these electrons from the external circuit and transfers those electrons to ions present in electrolyte. For this we need a catalyst for which graphite is used. This is deposited on the conducting TCO layer of counter electrode.

This catalyst provides help for the flow of electrons. Then the electrons through catalyst reach the electrolyte solution situated in between the positive and negative electrodes. And in the electrolyte solution there are a large number of charged ions. These ions get decomposed and provide electrons to the dye molecule whenever it is needed. The charged ions carry electrons to their original position through the porous areas of titanium dioxide network to the dye molecules where they regain their original positions. This step closes the circuit and recharged dye is capable of repeating process of transforming light into electricity. In this way electrical circuit is completed. Following figure completely depicts the working of these cells.

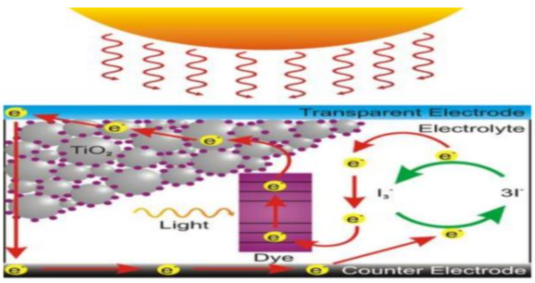

Figure 6: DSSC working principal

V. Experimental Work

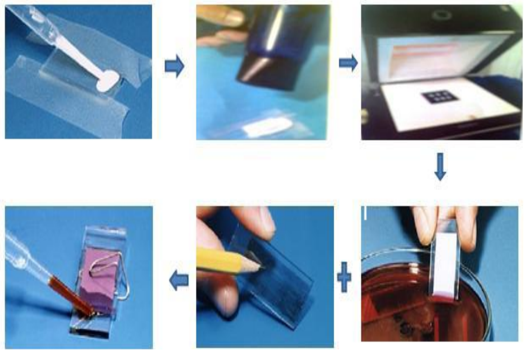

Fig 7: Line diagram for DSSC assembling

1. Putting and spreading TiO2 solution over conductive glass surface.
2. Drying this layer by help of hair dryer or naturally.
3. Sintering the dried semiconductor layer in the furnace.
4. Putting sintered semiconductor glass plate into dye solution.
5. Preparing positive electrode by adding graphite surface over conductive side of another glass.
6. Keeping both glasses together with the help of clips. Then we add electrolyte solution in- between positive and negative electrodes. After this we leave the cells for 15 to 20 minutes. In this time electrolyte solution spreads through whole semiconductor layer.

A. Formulas Used.

1. DSSC EFFICIENCY = (FF*Isc*Voc)/(SOLAR INPUT)
   WhereFF = Fill FactorIsc = Short circuit currentVoc = Open circuit voltage
2. FILL FACTOR = (Imax*Vmax)/(Isc*Voc)
3. DSSC EFFICIENCY = (Imax*Vmax)/ SOLAR INPUT
   B. Dyes Tried
   We have tried various alternatives to make dye sensitizer. For this we have made dyes from following natural fruits and leaves etc.

DYES: -
1. DRIED PALASH (Butea frondosa) FLOWERS
2. DRIED HIBISCUS FLOWERS
3. POMEGRANATE
4. RED WINE
5. BEET
6. MEHANDI
7. TURMERIC etc.

VI. RESULT & DISCUSSION

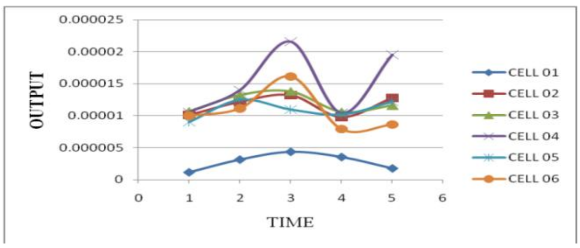

Fig.8: Variation in output of DSSCs with day time for Palash Flowers

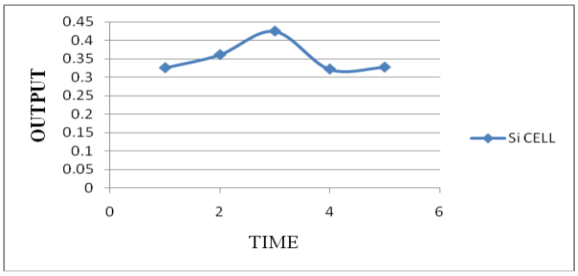

Fig.9: Variation in output of Silicon cell with day time

For the DSSC using dye solution made of Palash flowers, cell 4 has been most efficient in between all DSSCs. The thickness of cell 4 was 0.025 mm. For this dye all the cells have shown a common variation pattern in power output. Power output from the cells first increases with time, as the solar radiation input increases. Then it starts decreasing. And for the silicon cell this pattern is same as that of DSSCs.

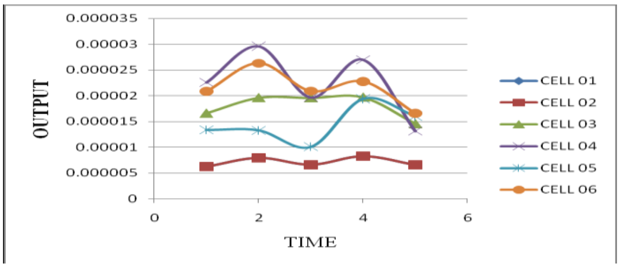

Fig.10: Variation in output of DSSCs with day time for Hibiscus Leaves

For the Hibiscus dye again cell 4, has shown maximum efficiency at each point of time. Here input increases from point 1 to 2, then decreases till point 5. Silicon cell has followed the same pattern as in case of Palash flowers, but DSSCs have shown some irregular pattern. For them output should start decreasing from point 3 to 5. But output did increase from point 3 to 4 then it decreased.

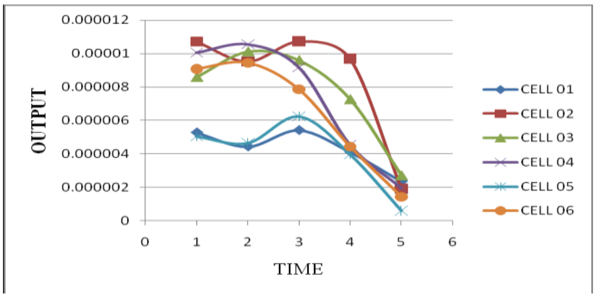

Fig. 11: Variation in output of DSSCs with day time for Pomegranate juice

For the Pomegranate juice all the DSSCs and Silicon cell have indicated the same pattern of output variation with input variation. And cell 2 was the best cell, which had thickness of 0.024mm.

VII. CONCLUSION

By observing all the work that we have done, we can draw following conclusions, regarding dye solutions:

1. DSSCs can work effectively with the natural dyes.
2. Efficiency of DSSC varies with the dye solutions used.
3. All the dye solutions have given different results with compare to other dyes.
4. Out of all eight dyes tried, dye made of DRIED HIBISCUS LEAVES, have given best result.
5. Output variation for all DSSCs with different dyes is showing fluctuating results with respect to time. But in general we can say that Power output of DSSC decreases with time. This is valid for Silicon cell also. With the increase of time the input light intensity first increases up to 12AM, after this intensity starts decreasing. Output from DSSC also first increases then decreases after 12.

VII. FUTURE WORK

We have drawn some conclusion from the project work. But still many areas are there, where we can improve DSSC efficiency.

1. In spite of trying manual coating of TiO2 layer, other methods like screen printing should be tried. Only by the help of machines, we can get a uniform layer of TiO2 throughout the area of semiconductor over conductive side of glass. This will help to improve the efficiency of DSSC.
2. At the time of experimentation the input light intensity should be constant. So artificial light source, should also be tried out. This will make us enable to accurately measure the variation of performance of DSSC with the variation of light input.
3. Some other seasonal fruits like Strawberries, Blackberries etc should be tried out.
4. At least one artificial dye should be used to compare their performance with natural dyes.
5. Comparison between all DSSC's performance and their variation will give us effective results, only if all the input parameters for cells are same. Also the construction of all DSSC should be similar to each other. Even all the cells should be facing towards direct sunlight.

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