

Integration of organic dye technology in the development of solar devices



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Report upon completion of the required tasks for pre-thesis work.

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ABSTRACT:

This project aims at designing an organic based solar cell that will be economically affordable and viable. A very common use of solar cell is the conventionally used silicon based solar. However due to its high cost, it remains immaterialized even though there is shortage of power supply.. Therefore, this project is set to find out the prospects of utilizing a much cheaper solar cell such as “**Dye Sensitized Solar Cell**” to fulfill the energy demand

OBJECTIVE:

Energy is a vital requirement for our daily lives which is created to make our lives easier by using technologically enhanced machines. As modern society developed, humans began consuming nonrenewable energy resources at a devastating rate. The sources of the energy produced by machines are mainly minerals and ores which are limited in quantity. Fossil fuels are slowly running out and their major combustion product CO₂ is starting to strongly affect our planets climate. In order to reduce fossil fuel consumption, reduce atmospheric pollution in the near future, countries around the world are looking to tap into renewable energy resources which will also be environment friendly.

Along with the major developments in the alternative sources of renewable energy, a major breakthrough was the “Solar Energy.” This energy is always in surplus. If we can only utilize this energy to its full potential, we will be able to solve the energy crisis. However, to do so, they need to be low-cost and efficient.

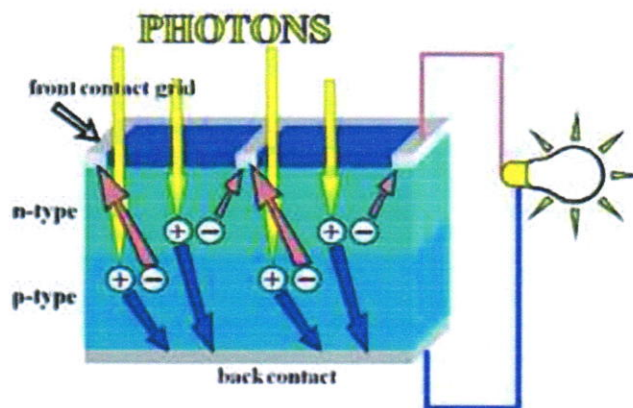
Photovoltaic cell, more generally known as “Solar cell” is used to collect this solar energy from sunlight and store it in a suitable medium like battery or transfer it directly to power grids for electricity. Most commonly used technology is the silicon based solar cell%. However the cost incurred by this technology is quite expensive. Integration of organic dye with solar devices was a major breakthrough in this field. It has, cost advantages and other features that are not found in other solar cells.

In this project, I would like to investigate the prospect of utilizing dye-sensitized solar cell which is cheap, environment friendly and easy to fabricate as potential means to generate power in Bangladesh. I have explained the process of the dye sensitized cells and outlined its special characteristics which make it more suitable to use for the society rather than other solar cell.

PROJECT OVERVIEW

The project mainly consists of the description of the way the dye sensitized solar system work and its advantages over other solar cells. To analyze the benefits and performance of the dye sensitized solar system, it is compared with the conventionally used silicon based solar cells.

Silicon Base Solar Cells



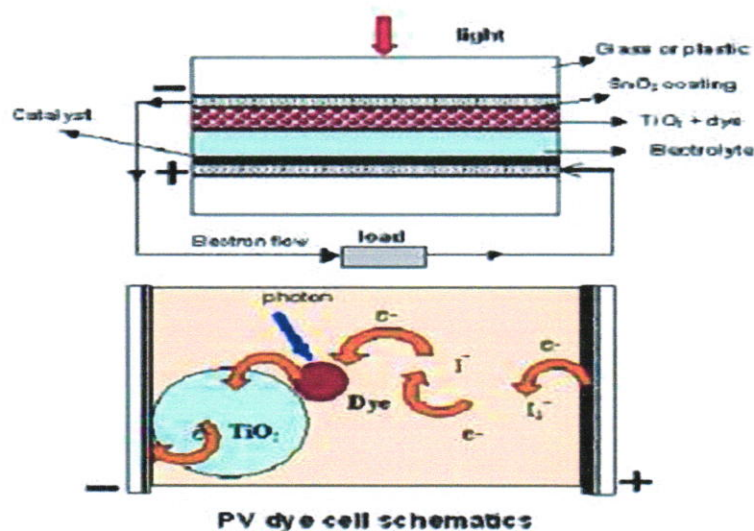
It consists of two thin layers of semi-conducting materials, silicon. They react to sunlight when it shines on the cell, creating an electric field across the layers and producing electricity. The greater the intensity of sunlight, the greater is the flow of electricity. This process is called the 'photovoltaic effect' and is explained in greater detail below.

1. The top semi-conducting layer is 'n' type layer, doped with phosphorus. This creates free moving negative charges called 'electrons'.
2. The base semi-conducting layer is 'p' type layer, doped with boron. This creates free moving positive charges called 'holes'.
3. When the 'n' and 'p' type layers are placed close together, as they are in a solar cell, the positively charged 'holes' and the negatively charged 'electrons' are attracted to each other. As they move into their respective neighboring layers they cross a boundary layer called the 'p-n junction'. This movement of negatively and positively charged particles generates a strong electrical field across the p-n junction. When sunlight strikes this field it causes the electron particles and the hole particles to separate, which in turn creates a voltage of around 0.5V.

- The voltage pushes the flow of electrons to the metal contacts at the front and back of the cell where it is conducted away along the wiring circuitry that connects the cells together.

As mentioned earlier this produces a good percentage of output. However it has a lot of drawbacks which will be discussed later in the project.

Dye Sensitized Solar Cell



Dye cells generate electricity from solar energy using nano-sized titanium dioxide particles impregnated with dye that absorbs a wide range of light waves from the sun. Here, again greater the intensity of light, greater the flow of electricity. The process is explained in details below.

- Nanoparticles of titanium dioxide are coated with a dye.
- They are applied to a conducting glass electrode immersed in an electrolyte solution containing iodine molecules and a second (platinum) electrode.
- When the light is incident on the transparent electrode, the energy is absorbed by the dye.
- The energy absorbed excites an electron in the dye molecule from ground state to the excited state and hence an electron (e^-) is formed.
- The electron is injected into a titanium dioxide particle and diffuses toward the glass electrode and from there a wire carries it to the external circuit.

6. The circuit closes when electrons return to the platinum electrode and diffuse across the electrolyte, returning to and regenerating the dye. At this point, $3I^-$ are oxidized into iodine ($I_3^- = I_2 + I^-$), and then again reduced to $3I^-$ by receiving e^- that is supplied from the cathode.

Unlike standard silicon-based solar cells, the TiO_2 cells are photo *electrochemical* in nature, making the manner by which they convert solar energy into electrical energy resemble photosynthesis. Like chlorophyll in plants, the light-absorbing dyes used in thin-film based solar cells absorb incoming sunlight and use that energy to perform chemical reactions

PROGRESS

Currently in the pre-thesis, the objective was to promote dye sensitized solar cell as the most suitable technology in the field of solar energy by comparing its characteristics with other solar cells. Through research experiments I have come up with following findings:

1. **Manufacturing Cost:** The dye-sensitized solar cells are made of low-cost materials and are cheaper to manufacture. These solar cells do not require any apparatus and can be printed on any flexible surface. Due to the reduced manufacturing costs, they are less expensive when compared to other semiconductor cells.
In case of silicon solar cells, not only the production line is large, complex and very expensive, but the raw materials (such as silicon) are costly and undersupplied.
2. **Cost per watt:** The total cost for silicon solar cell- \$2.25/watt, whereas for dye sensitized cell, it is - less than \$1.5/Watt
3. **Manufacturing process:** Silicon cells are pretty complex to build in contrast to DYI which is very easy to develop and requires simple equipment (screen printing, air ovens) and benign materials like Titania powder available at low cost.
4. **Price/performance ratio:** The overall peak power-production efficiency of dye-sensitized solar cells is about 11 percent, so they are best suited to low-density applications. Though the efficiency of DSSCs is less than many of the best thin-film cells, the price-to-performance ratio obtained through these solar cells is superior to others.

5. **Ability to Work at Wider Angles and in Low Light:** The dye used in dye-sensitized solar cells can absorb diffused sunlight and fluorescent light. Its also work in cloudy weather and low-light conditions without much impact on efficiency, while the other traditional cells would fail at illumination below a certain range. This makes them suitable for running small devices indoors. These solar cells also work at wider angles, a fact which makes the cells absorb most of the available sunlight.

Experiments on the silicon based solar cells tilted at an angle of 55 degree for cloudy and sunny weather shows the result shown in the table

TIME	Voc	Isc	WEATHER
12:00	16.78	0.016	Cloudy
12:00	18.76	0.23	Sunny

Another table is shown below which displays the result of a dye sensitized solar cell inside a room

V(mV)	WEATHER
260	Indoors

6. **Mechanical Robustness:** Dye sensitized solar cells are mechanically robust. They are made of lightweight materials and require no special protection from rains or trees or any other harsh objects. This makes them easy to use and maintain
7. **Ability to Operate at Lower Internal Temperatures:** As the temperature rises, some electrons in semiconductors are pushed to conduction band mechanically. Hence the silicon cells require protection by covering in a glass box. Such cells get heated easily and hence the efficiency is greatly reduced due to internal temperature. This situation is eliminated in the DSSCs. Because dye-sensitized solar cells are made of only a thin layer of plastic, heat radiates away easily to reduce the internal temperature. This lowering of temperature, in turn, helps in increasing the efficiency of the solar cells.

The Table below shows the types and characteristics of solar cell materials for comparison in terms of energy conversion efficiency and long-term reliability. The mainstream solar cells at present are silicon-based.

TYPE	MATERIAL	STRUCTURE	EFFICIENCY	ADVANTAGES	DISADVANTAGES
Si-base	Single-crystal	n-type silicon layer doped on single crystal p-type layer	25%	High efficiency, high reliability	Not suited for mass production; High cost, variable raw material price, little room for improvement in conversion efficiency
	Polycrystalline Si	n-type Si layer doped on polycrystalline p-type Si layer	20.4%	Relatively Lower cost, High efficiency, high reliability	Relatively Lower efficiency ; Variable raw material Price
	Amorphous Si	p-layer, i layer, and n layer deposited by CVD process 9.5%	9.5%	Relatively small use of Si material; Lower cost	Very Low efficiency; Light Degradation
Dye-sensitized	Dye, semiconductor, electrolyte	Place dye-absorbed TiO ₂ electrode in Electrolyte	10.4%	Capable of production by simple process in open air; Colorable, transparent; Maintain generation characteristics under room light	Ultraviolet Degradation

FUTURE WORK

For my thesis as a part of my investigation on the prospect of utilizing dye sensitized solar cell, I plan to fabricate it and practically implement its operations to turn the theories I have studied in pre-thesis in practice and practically show dye sensitized solar cell is more suitable for our use.

Though there are many advantages, there is some major disadvantages of the system which is the low efficiency and stability of the solutions used. So my major task for thesis will be to develop the cell to increase its efficiency and stability.

The procedure through which I have planned to fabricate the cell is shown below:

1. Preparing TiO_2 : Make a paste of TiO_2 using nanocrystalline grade TiO_2 powder, few drops of vinegar, a few drops of deionized water.

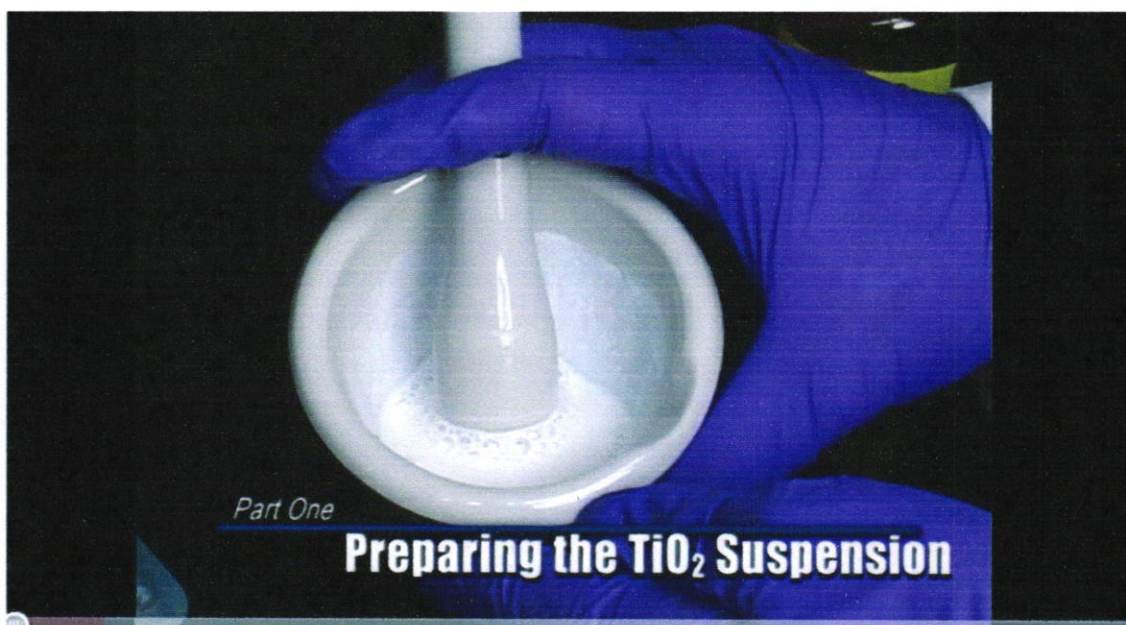


Fig. 1

2. The film: The paste of TiO_2 is applied as a thin film onto glass plates that have one side made electrically conductive by a thin film of indium tin oxide (ITO) which should be checked using a multimeter to make sure that the conducting side is facing up. Then TiO_2 paste is applied uniformly to conducting side of the ITO using a glass rod and quick downward sweeping motions. The thickness of the TiO_2 matrix is kept constant by covering the length of three edges of the plate with Scotch tape to a width of 2mm.

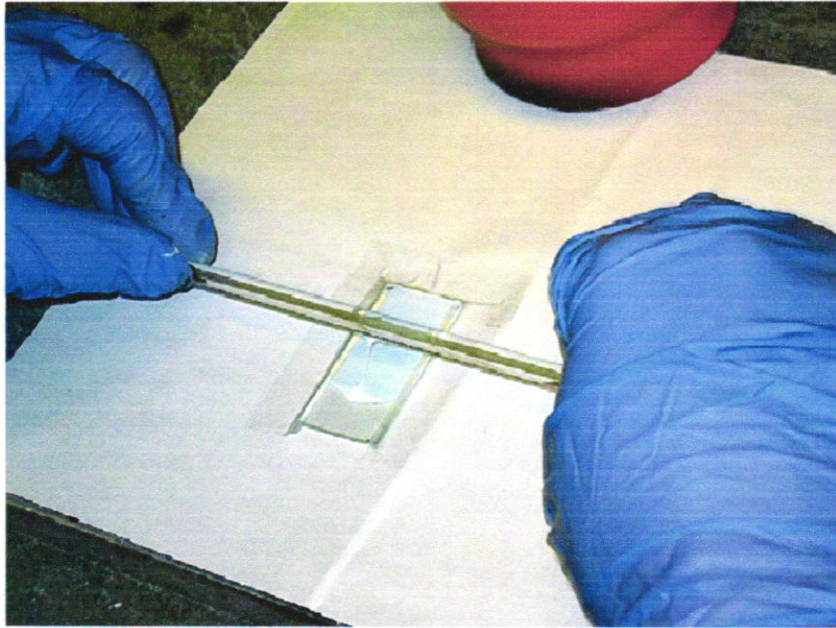


Fig. 2

3. Drying TiO_2 coat: The next step will be to heat the plates (sintered) over a Bunsen burner flame for 13-15 minutes, or until they have transitioned from white to a brownish color and back again in order to dry and strengthen the TiO_2 coat.

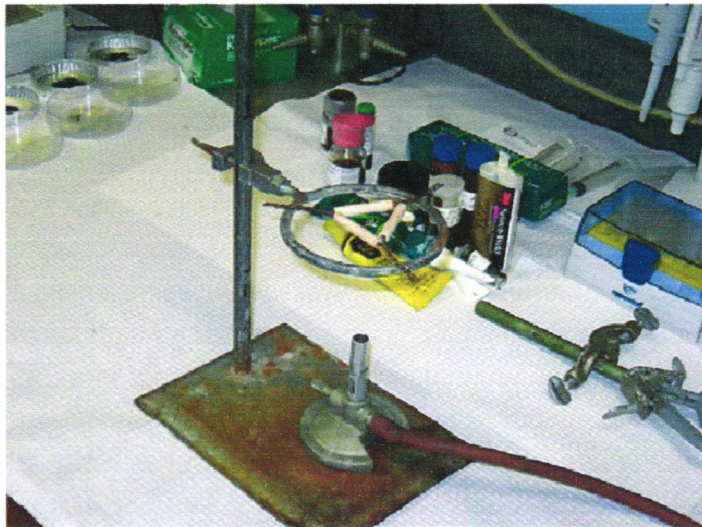


Fig. 3

4. Applying the dye: Once the TiO₂ plates are sintered completely and have been given time to cool, they are bathed in a bath of the appropriate dye, (raspberry juice) as shown in figure 4. The cells soak for about one hour until they are ready for extraction.

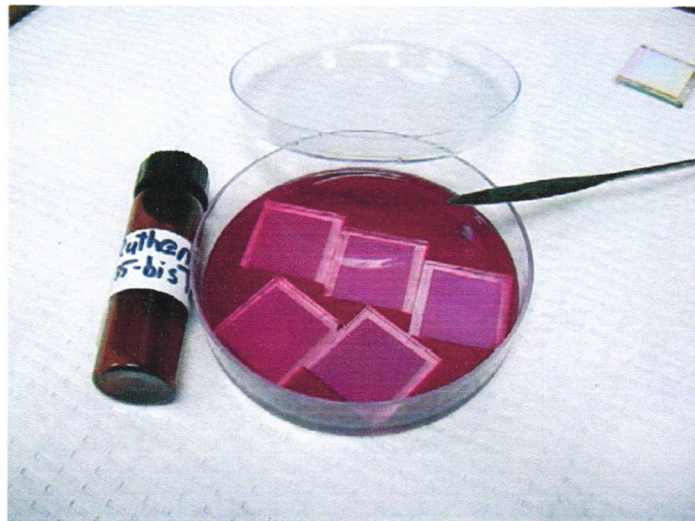


Fig.4

5. Preparing the counter electrode: The cathode is made by simply sketching one end of a glass slide with graphite pencil.

6. Adding the electrolyte: A few drops of a redox solution containing iodide ion is added on the counter electrode.
7. Putting up the apparatus together: The two glass slides are finally sandwiched. The sandwiching of the two plates is offset so that each one has a small portion exposed so that an alligator clamp can be attached. The negative clamp goes on the TiO₂/sensitizer plate and the positive clamp goes on the counter electrode plate. A multimeter is connected to check if it operates.



Fig. 5

PROBLEMS:

1. Understanding the process of the cell – Since the topic was totally new to me I had difficulties understanding its applications. Because the concept of dye sensitized solar cell is fresh, not much people know about it which is why I was not able to get much help.
2. Collecting the required materials: I wanted to show part of the cell or a demo of how it works. However I was not able to get the materials. Hopefully I will have all the necessary materials in my thesis.
3. Proving the theories: I have outlined the advantages theoretically but was am not able to prove it practically or with the appropriate data. I believe I will finish off this task in my thesis as well.

Conclusion:

From the research which I have shared in the report we may conclude that dye sensitized solar cell is more affordable than the conventionally used silicon based solar cell. As a part of my investigation I decided to design the cell to show the practical implementation and also work on the drawbacks to develop its efficiency and stability.

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