Effect of Ixora coccinea And Rosa indica Flower Dyes on the Efficiency of Dye sensitized Solar Cells

<u>National Science Fair Project Report</u>

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Category : Physical Science

<u>Submitted by</u>

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ARRAHMAAN INTERNATIONAL SCHOOL

(Creating the community of Excellence)

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ABSTRACT

The world is heavily dependent of fossil fuels, including coal, oil, and natural gas. Not only fossil fuels will be depleted one day, but also burning fossil fuels causes environmental damages to the world. We need clean, inexpensive, sustainable energy sources. Development of renewable energy resources in the near future is an urgent issue. Plants can use green chlorophyll and sunlight to produce nutrient which is termed as photosynthesis. Dye-sensitized solar cells use dyes or natural pigments like anthocyanin to capture light energy. Dye-sensitized solar cells are a class of thin-film solar cells, which can be made using low-cost materials and natural dyes. They can potentially achieve the same efficiency compared to bulky silicon photovoltaic cells, while providing many other advantages.

For my research, the independent variable is the type of flower dyes (Rosa indica and Ixora Coccinea). The dependent variable is the voltage and current output. This is measured using digital multimeter. The constants (control variables) are the dimensions of the cell, the amount of dyes used and the amount of sunlight and artificial light source. Anthocyanin dyes taken from Rosa indica and Ixora Coccinea flowers were used in titanium dioxide dye-sensitized solar cells. The unique ability of anthocyanin dyes to absorb light and convert it into electrons, makes them useful in dye-sensitized solar cell applications.

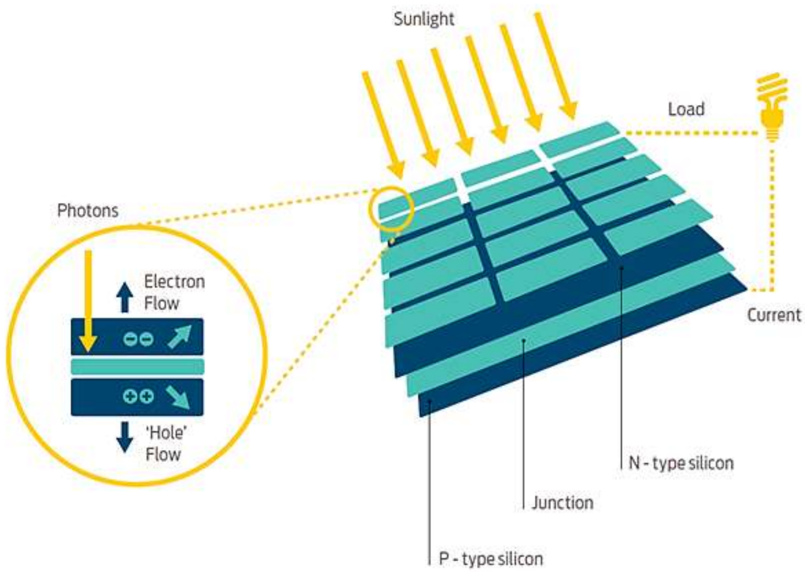
To construct the dye-sensitized solar cell, the tin oxide-coated piece of glass was cleaned with tissue wet with ethanol and the side of the glass that conducts was determined using the multimeter. Over the conducting side I spread the titanium dioxide (TiO_2) paste uniformly. Then, I dried and annealed the coated plate to form a thin film of TiO_2. Next, the TiO_2 coated conductive glass plate is soaked into the flower dyes to form the electrode. Many natural dyes possess a chemical group that can attach to the TiO_2 surface. A layer of dye is absorbed into each particle of TiO_2, which acts as an absorber of light. Next I placed a carbon-coated plate (counter electrode) on top of the electrode plate and binder clips secure the glass plates. This process is repeated 2 more times to make two different dye-sensitized cells using different flower dyes (Rosa indica and Ixora Coccinea). I exposed the solar cells with the TiO_2 side facing the

light and measured the voltage and current. I measured the voltage and current for the dye-sensitized cells in both sunlight and incandescent light.

Through my study I found that the DSSCs made from flower dyes extracted Ixora Coccinea gives the largest photovoltaic output than Rosa indica both under sunlight and incandescent light. The photovoltaic output made from Ixora Coccinea flower dye-based anthocyanin compares well than Rosa indica flower dye-based anthocyanin.

INTRODUCTION

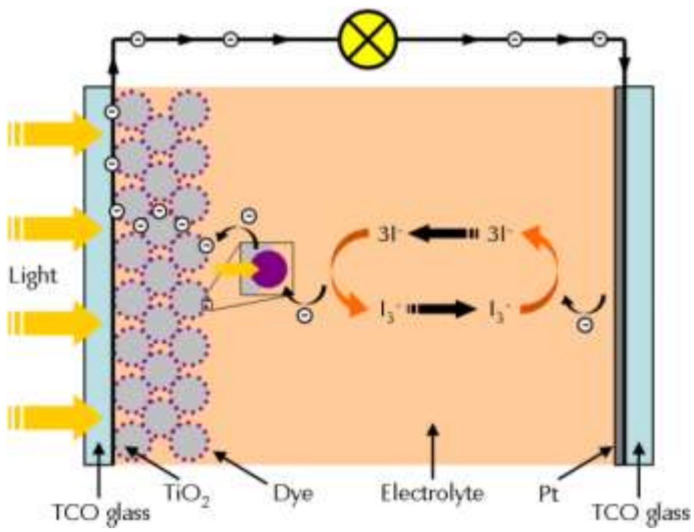
A solar cell is a device that converts photon energy into electrical current. Solar panels are made out of photovoltaic cells (which is why generating electricity with solar panels is also called solar PV) that convert the sun's energy into electricity. Photovoltaic cells are sandwiched between layers of semi-conducting materials such as silicone. Each layer has different electronic properties that energise when hit by photons from sunlight, creating an electric field. This is known as the photoelectric effect – and it's this that creates the current needed to produce electricity. Solar panels generate a direct current of electricity. This is then passed through an inverter to convert it into an alternating current, which can then be funneled into the National Grid or used by the home or business the solar panels are attached to.



In today's world, the mostly used solar cell is silicon based which is currently the most efficient one with approximately 25% of efficiency. Nevertheless, it also has weaknesses. The weakness of this type of solar cell is the high production cost which makes it more costly than the source of energy from fossil. Moreover, the fabrication of this type of solar cell itself is difficult due to the need of advanced clean room technology. With the development of nanotechnology, apparently a breakthrough in solar cell technology can be achieved. One of this is the dye-sensitized solar cell (DSSC) technology. This cell is extremely promising because it is made of low-cost materials and can be constructed without any advanced process technology, hence being accessible by researcher from developing countries.

Dye Sensitized solar cells (DSSC) are a third generation photovoltaic (solar) cell that converts any visible light into electrical energy. Dye-sensitized solar cells (DSSC) are an efficient type of thin-film photovoltaic cell. Modern dye-sensitized solar cells, or Gratzel cells, are based on a concept invented in 1988 by Brian O'Regan and Michael Gratzel, but the concept dates back to the 1960s and 70s. DSSC is a disruptive technology that can be used to produce electricity in a wide range of light conditions, indoors and outdoors, enabling the user to convert both artificial and natural light into energy to power a broad range of electronic devices.

Setup of a Dye Sensitized Solar Cell



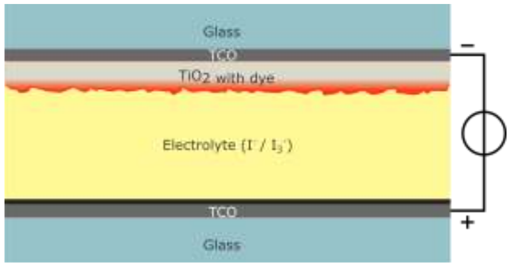
A modern DSSC is composed of a porous layer of titanium dioxide nanoparticles, covered with a molecular dye that absorbs sunlight, like the chlorophyll in green leaves. The titanium dioxide is immersed under an electrolyte solution, above which is a platinum-based catalyst. As in a conventional alkaline battery, an anode (the titanium dioxide) and a cathode (the platinum) are placed on either side of a liquid conductor (the electrolyte).

Sunlight passes through the transparent electrode into the dye layer where it can excite electrons that then flow into the titanium dioxide. The electrons flow toward the transparent electrode where they are collected for powering a load. After flowing through the external circuit, they are re-introduced into the cell on a metal electrode on the back, flowing into the electrolyte. The electrolyte then transports the electrons back to the dye molecules.

Dye-sensitized solar cells separate the two functions provided by silicon in a traditional cell design. Normally the silicon acts as both the source of photoelectrons, as well as providing the electric field to separate the charges and create a current. In the dye-sensitized solar cell, the bulk of the semiconductor is used solely for charge transport, the photoelectrons are provided from a separate photosensitive dye. Charge separation occurs at the surfaces between the dye, semiconductor and electrolyte.

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. To address this problem, a nanomaterial is used as a scaffold to hold large numbers of the dye molecules in a 3-D matrix, increasing the number of molecules for any given surface area of cell. In existing designs, this scaffolding is provided by the semiconductor material, which serves double-duty.

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 dyes are also called photosensitizers. 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.



Mechanism of DSSCs

The following steps convert in DSSC photons (light) to current:

1. The incident photon is absorbed by the photosensitizers adsorbed on the TiO_2 surface.
2. The photosensitizers are excited from the ground state (S) to the excited state (S^*). The excited electrons are injected into the conduction band of the TiO_2 electrode. This results in the oxidation of the photosensitizer (S^+).

$$S + h\nu \rightarrow S^*$$

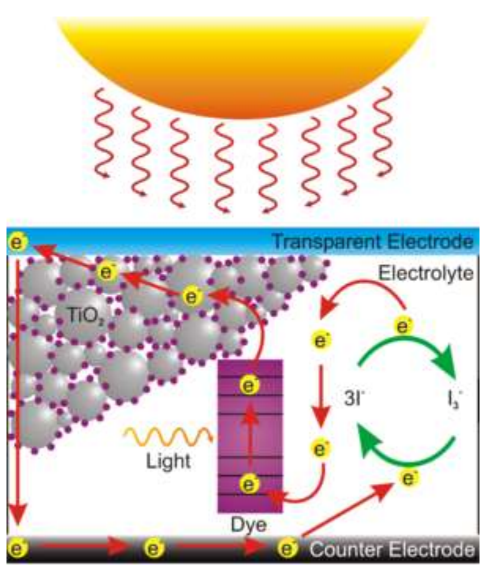
$$S^{\cdot} \xrightarrow{TiO_2} S^+ + e^-$$

3. The injected electrons in the conduction band of TiO2 are transported between TiO2 nanoparticles with diffusion toward the back contact (TCO). And the electrons finally reach the counter electrode through the circuit.
4. The oxidized photosensitizer (S^+) accepts electrons from the I^- ion redox mediator leading to regeneration of the ground state (S), and two I^--Ions are oxidized to elementary Iodine which reacts with I^- to the oxidized state, I_3^-.

$$S^+ + e^- \rightarrow S$$

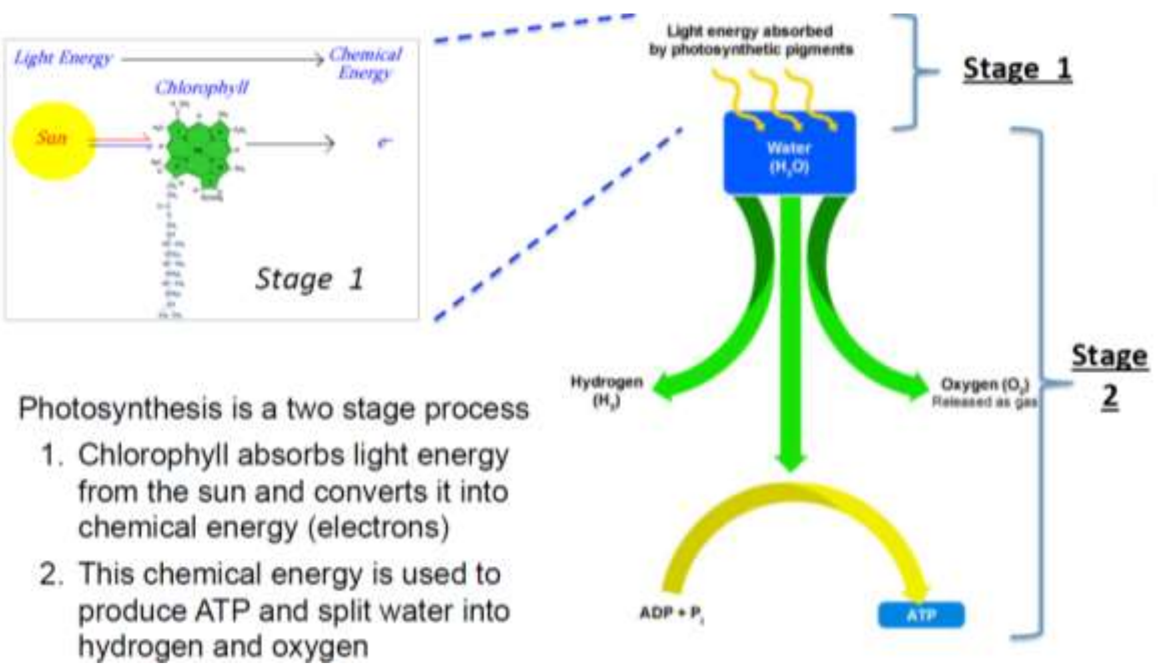
5. The oxidized redox mediator, I_3^-, diffuses toward the counter electrode and then it is reduced to I^- ions.

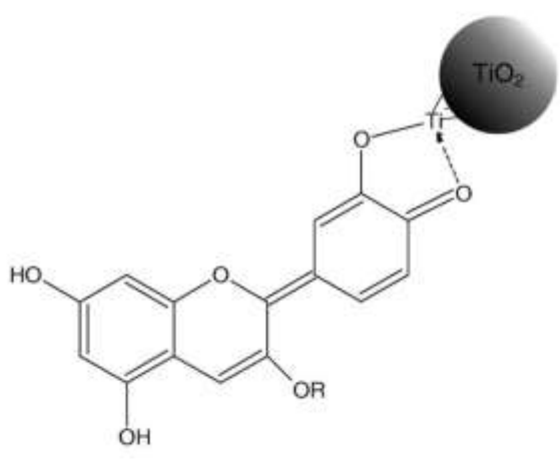
$$I_3^- + 2\,e^- \rightarrow 3\,I^-$$



Artificial photosynthesis using Anthocyanin pigments

Anthocyanin absorbance spectrum in the visible ranges (450-580 nm). Anthocyanin is a pigment that this is red, blue, and purple on the fruits, flowers, and leaves. Photosynthesis uses sunlight to convert water and carbon dioxide into oxygen and sugar. Photosynthesis is important for plants and also for animals that require oxygen to live. Chlorophyll pigments in the chloroplasts absorb sunlight, which is a critical part of photosynthesis. Dye-sensitized solar cells use dyes or natural pigments to capture light energy. This light energy excites electrons, which can then flow toward the electrode. Due to the nanometer sized particles of TiO2, the annealed surface is extremely rough at the nanoscale. The porous TiO2 is analogous to the chloroplast in leaves, in that it increases the amount of pigment molecules per volume, allowing more light to be absorbed. After a dye molecule transfers an electron to the TiO2, it is positively charged and needs an electron to become neutral. However most of the dye molecules are not in physical contact with the counter electrode. To solve this problem we use triiodide, which can "ferry" electrons between the counter electrode and the dye molecules. Scientists use synthetic dyes and natural pigments, like anthocyanins. Anthocyanins are a class of pigments found in many berries and other plants. Anthocyanins have higher efficiency than chlorophyll because of how anthocyanins bind to TiO2. The color of anthocyanin pigments depends on the pH and varies from red to blue to purple. In nature, anthocyanins are thought to have many roles, including attracting pollinators/animals and providing protection from excess sunlight.





Anthocyanin bound to TiO2

Cheap Dye-Sensitized Solar Cell Moves toward Commercialization

Solar to dye for: The colored windows at left in a government building in Seoul, South Korea, generate power using technology from Australian dye-based solar developer Dyesol.

STATEMENT OF THE PROBLEM

In times of fossil fuel shortage, increasing crude oil prices, as well as rejection of conventional energy sources (e.g. coal or nuclear power plants), sustainable energy forms become more and more the focus of attentions. Hydropower, wind power, geothermal power, or biomass processing are but a few of these sustainable resources. Another important source for renewable energy is solar power. Is it possible to harvest solar power using flower dyes to produce electricity?

Dye-sensitized solar cells use dyes to capture light energy. Manufacturing of Dye sensitized solar cell is simple, mostly low cost, and incorporate environmentally friendly materials. They have a good efficiency (about 10-14 %) 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 electrolyte's performance and cell stability. I planned to compare the effect of Rosa indica and Ixora Coccinea flower dyes (which have anthocyanin content) on the efficiency of Dye sensitized solar cell.

HYPOTHESIS

Ixora Coccinea flower is more effective on dye sensitized solar cells in producing high voltage compared to Rosa indica .


DESIGN OF STUDY

INDEPENDENT VARIABLES:

- Types of flowers (Rosa indica and Ixora Coccinea).

DEPENDENT VARIABLES:

- Current and Voltage

CONTROLLED VARIABLES

- Amount of TiO_2, Acetic acid, Ethanol and Triiodide Solution
- Quantity of Flower Extract
- Sunlight
- Temperature
- Intensity of Torch Light
- Dimension of Indium Tin Oxide Transparent conductive Glass Plate (20x20x1.1 mm)

MATERIALS:

- 2 types of flowers (Rosa indica and Ixora Coccinea)
- 4 Indium Tin Oxide Transparent conductive Glass Plate (20x20x1.1 mm)
- Nanocrystalline TiO_2
- Multimeter
- Ethanol
- Dilute Acetic acid
- Iodine solution
- Transparent tape
- Microscope Slide
- Watch Glass
- Tissue paper
- 2 jumper wires with alligator clips
- 2 binder clips
- Clamp or tongs to hold glass plate for carbon coating
- Cotton swabs
- Light source (Torch and Sun)
- Hot Plate

PROCEDURE:

1. Identify the conducting side of a tin oxide-coated piece of glass by using a multimeter to measure resistance. The conducting side will have a resistance of 20-30 ohms.
2. With the conducting side up, tape the glass on three sides to the center of a spill tray using one thickness of tape. Wipe off any fingerprints or oils using a tissue wet with ethanol.

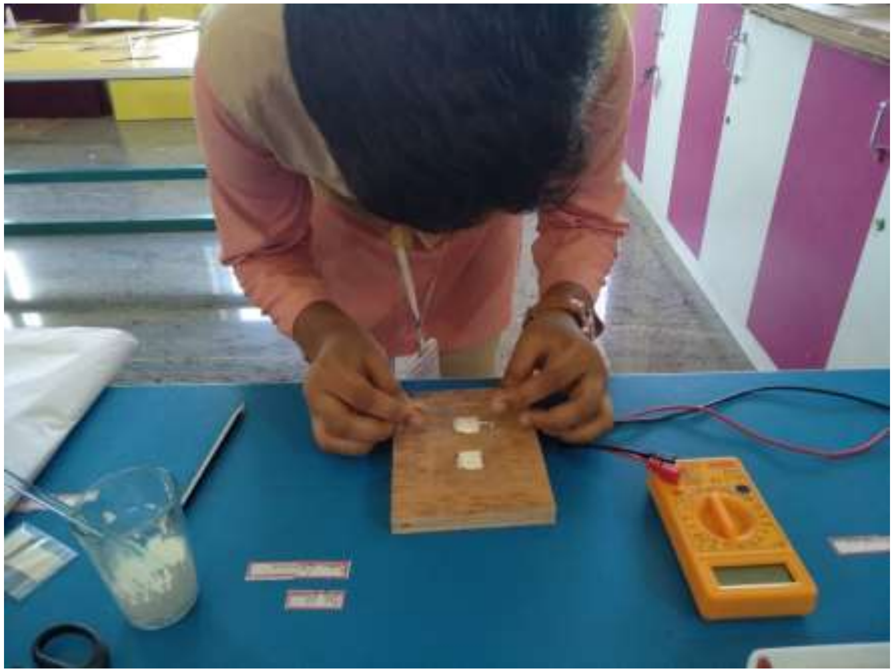
   Opposite sides of tape will serve as a spacer so the tape should be flat and not wrinkled. The third side of tape gives an uncoated portion where an alligator clip will be connected
3. *Preparation of TiO_2 paste*: -Grind about 0.5 gram of nanocrystalline titanium dioxide (TiO_2) with a few drops of very dilute acetic acid. Alternate grinding and addition of a few drops of very dilute acetic acid until a colloidal suspension with a smooth consistency is obtained, somewhat like latex paint.
4. For easier distribution, transfer the TiO_2 paste to a syringe. Wrap the end of the syringe with parafilm to keep the paste from drying out when not in use. Using the syringe significantly shortens the class working time, makes for easier clean-up, and gives paste of proper consistency that will last for more than a lab period.
5. Add a small amount of titanium dioxide paste and quickly spread by pushing down and across with a microscope slide before the paste dries. The tape serves as a 40-50 micrometer spacer to control the thickness of the titanium dioxide layer if you push down.
6. Carefully remove the tape without scratching the TiO2 coating. Leave the removed tape in a spill tray for disposal.
7. Heat the glass on a hotplate in a hood for 10-20 minutes. The surface turns brown as the organic solvent and surfactant dries and burns off to produce a white or green sintered titanium dioxide coating. Allow the glass to slowly cool by turning off the hotplate.
8. Immerse the coating in a source of anthocyanins, Rosa indica and Ixora Coccinea flower extract. The white TiO2 will change color as the dye is absorbed and complexed to the Ti(IV).
9. Rinse gently with water to remove any flower solids and then with ethanol to remove water from the porous TiO2. The ethanol should have evaporated before the cell is assembled.

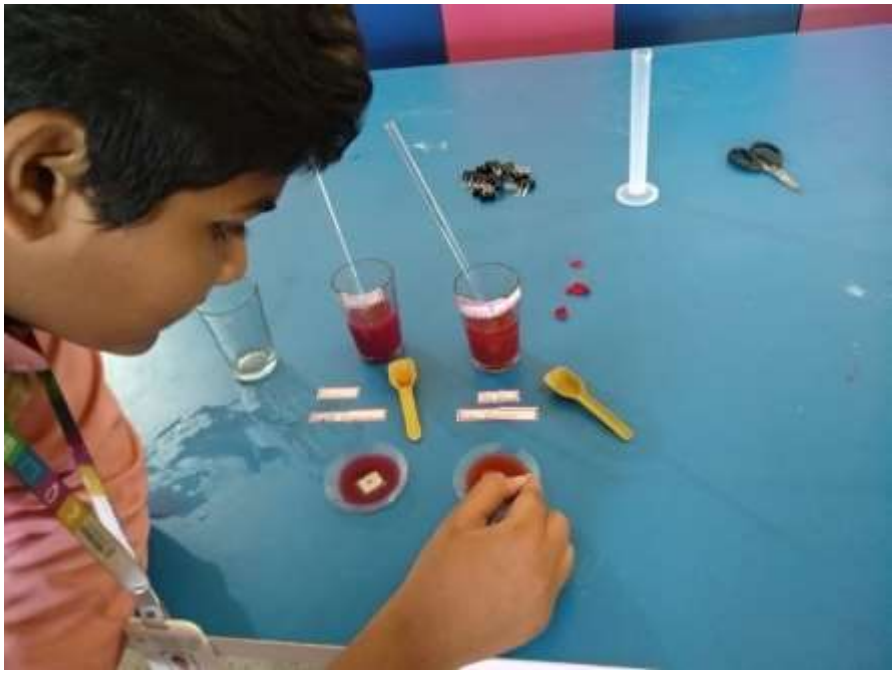
10. Pass a second piece of tin oxide glass, conducting side down, through a candle flame to coat the conducting side with carbon (soot). For best results, pass the glass piece quickly and repeatedly through the middle part of the flame.
11. Wipe off the carbon along the perimeter of three sides of the carbon-coated glass plate using a dry cotton swab.
12. Assemble the two glass plates with coated sides together, but offset so that *uncoated glass extends beyond the sandwich*. Do not rub or slide the plates. Clamp the plates together with binder clips.
13. Add a drop of a triiodide solution to opposite edges of the plate. Capillary action will cause the KI3 solution to travel between the two plates. (The KI3 electrolyte solution consists of 0.5 M KI and 0.05 M I2 in anhydrous ethylene glycol.) The solution can corrode the alligator clips in the next step so wipe off an excess.
14. Connect a multimeter using an alligator clip to each plate (the negative electrode is the TiO2 coated glass and the positive electrode is the carbon coated glass) and test the current and voltage produced by solar illumination (Sun) and illumination from a torch light.

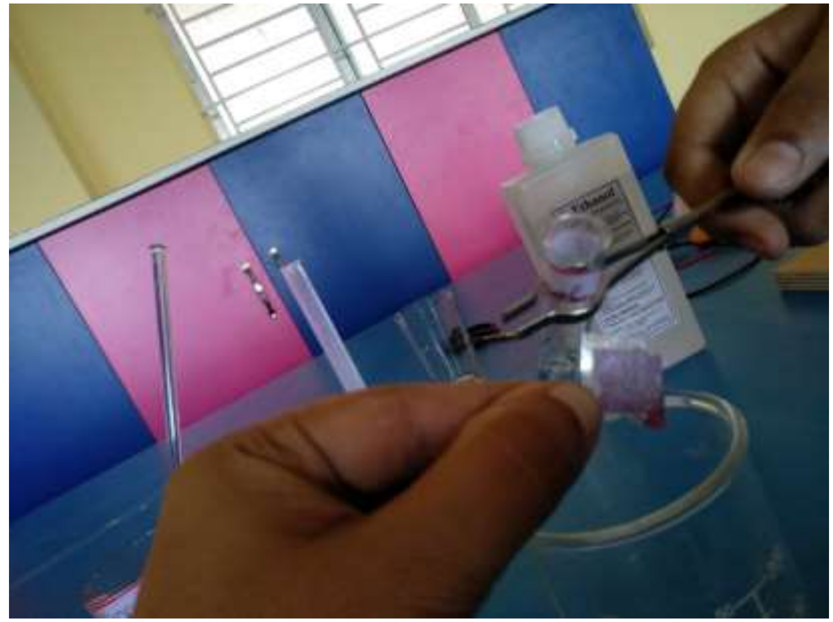
COLLECTION OF DATA

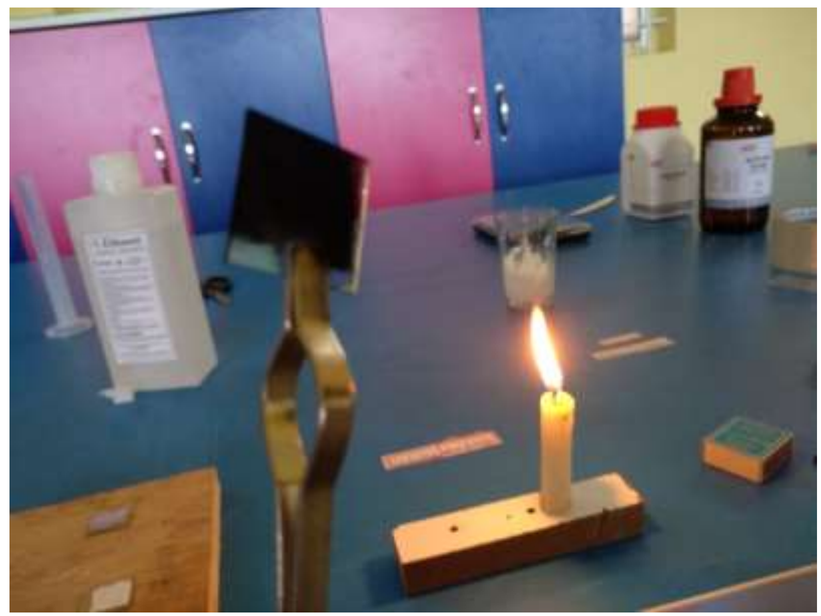
PHOTOGRAPHS

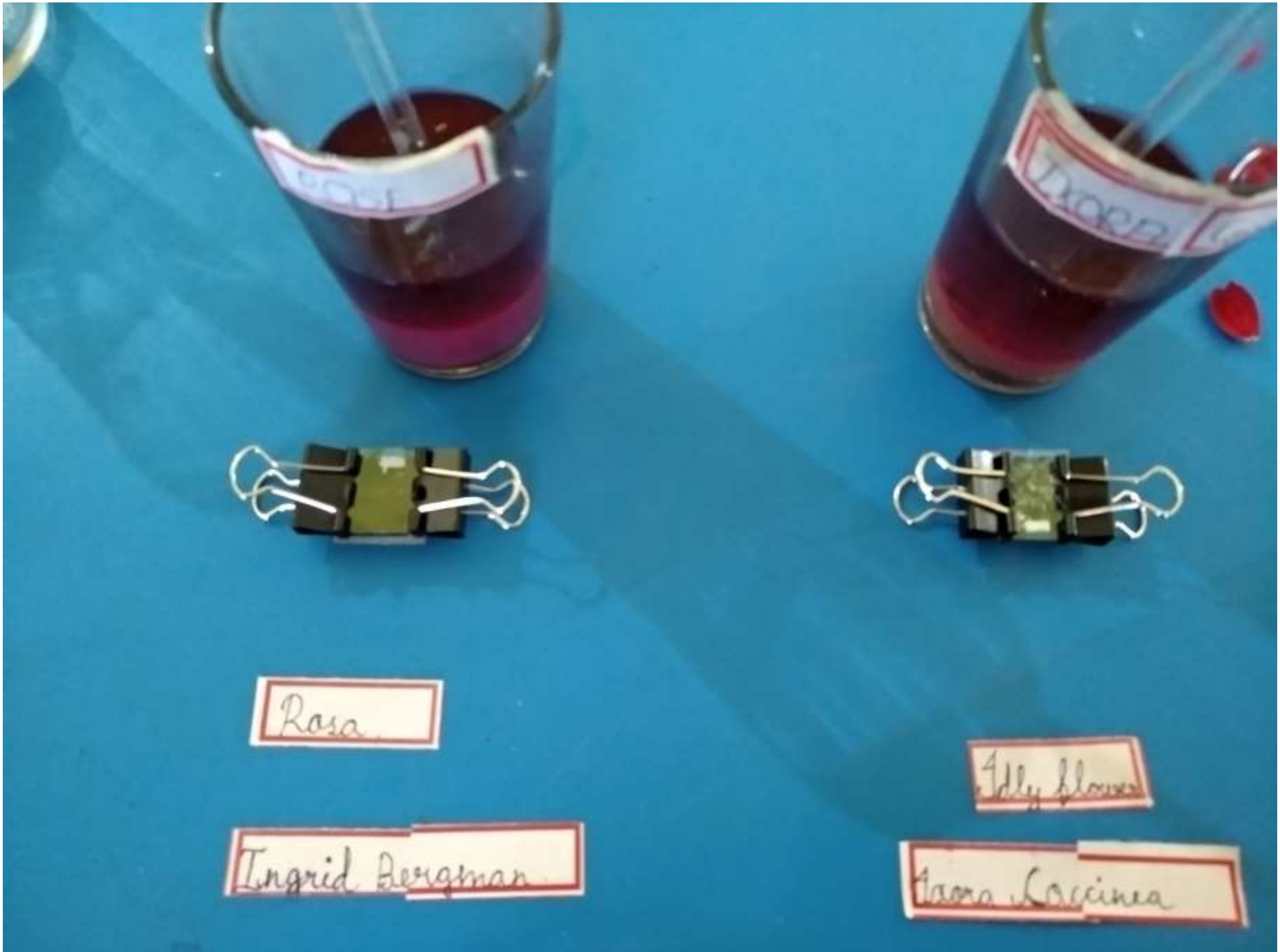

PCS
MODE








Rosa
Ingrid Bergman
Idly flower
Ixora Coccinea

TABULATION

***RESISTANCE OF THE* INDIUM TIN OXIDE TRANSPARENT CONDUCTIVE GLASS PLATES**

Glass Plates	Trial 1	Trial 2	Trail 3	Resistance (Ω)
Plate 1	23	25	22	23.33
Plate 2	26	29	24	26.33
Plate 3	21	23	21	21.67
Plate 4	26	24	25	25

EFFECT OF IXORA COCCINEA AND ROSA INDICA FLOWER DYES ON DYESENSITIZED SOLAR CELLS UNDER SUNLIGHT

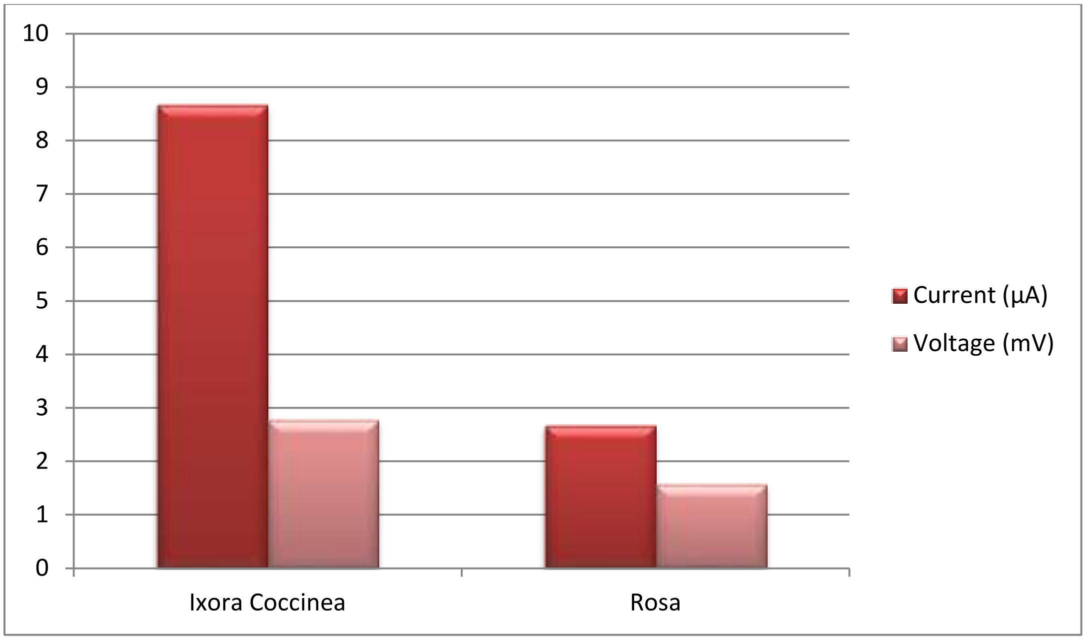
Flower Dye	Current (µA)				Voltage (mV)			
	Trial 1	Trial 2	Trail 3	AVG	Trial 1	Trial 2	Trail 3	AVG
Ixora Coccinea	9	8	9	8.67	2.8	2.8	2.7	2.77
Rosa indica	3	3	2	2.67	1.5	1.6	1.6	1.57

EFFECT OF IXORA COCCINEA AND ROSA INDICA FLOWER DYES ON DYESENSITIZED SOLAR CELLS UNDER TORCH LIGHT

Flower Dye	Current (µA)				Voltage (mV)			
	Trial 1	Trial 2	Trail 3	AVG	Trial 1	Trial 2	Trail 3	AVG
Ixora Coccinea	7	8	7	7.33	0.9	0.6	0.9	0.8
Rosa indica	1	2	2	1.67	0.7	0.6	0.6	0.63

GRAPHS

EFFECT OF IXORA COCCINEA AND ROSA INDICA FLOWER DYES ON DYESENSITIZED SOLAR CELLS UNDER SUNLIGHT



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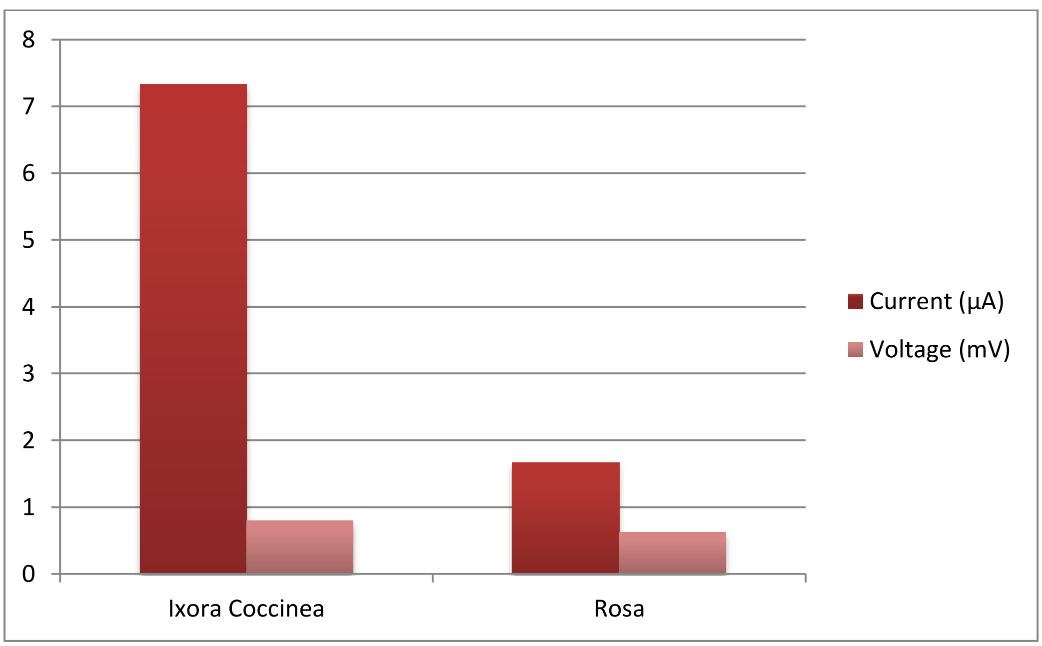

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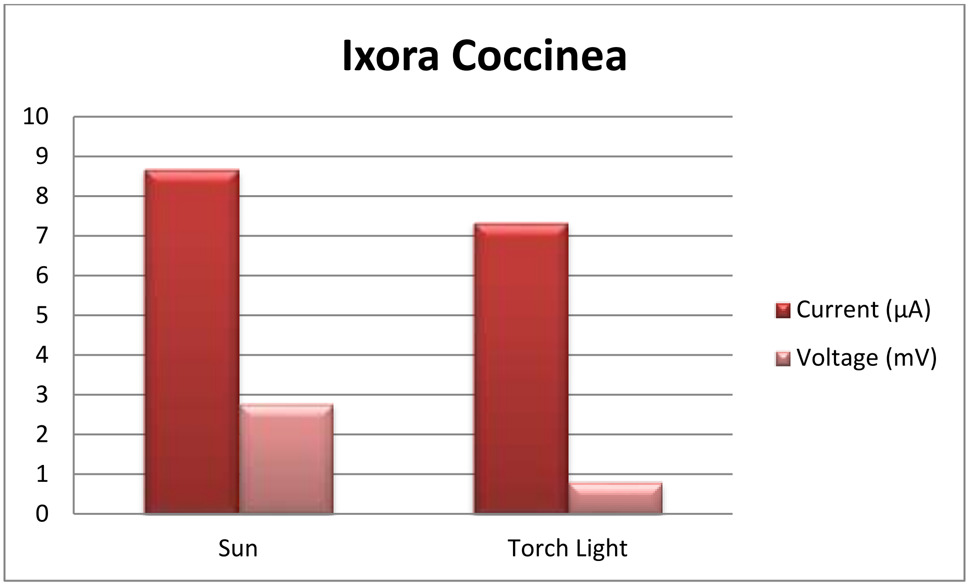
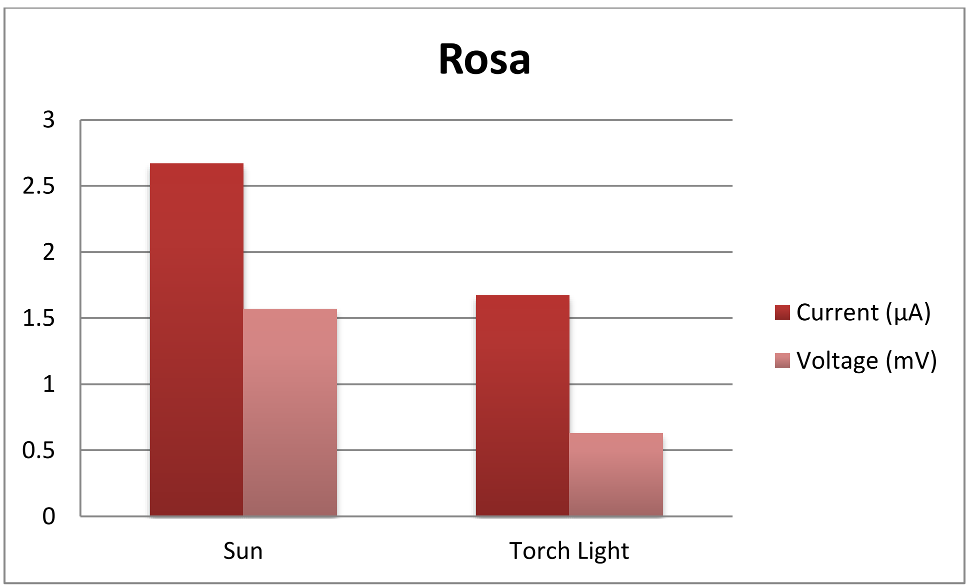




RESULTS AND DISCUSSION

- Through my research I found Ixora Coccinea flower dye is more effective on dye-sensitized solar cells in producing high voltage compared to Rosa indica .
- Ixora coccinea is one of the candidates of floral anthocyanins. It belongs to the Rubiaceae family, a large glabrous shrub growing throughout forest lands and also cultivated plant in the garden. It is a native to Asia and commonly known as Jungle of geranium or flame of the woods or vetchi in Ayurveda
- Natural anthocyanins act as photosensitizers for dye-sensitized solar devices. Anthocyanins responsible for the colours, red, purple, and blue, are in flowers fruits and vegetables. Berries, currants, grapes, and some tropical fruits have high anthocyanins content. Red to purplish blue-coloured leafy vegetables, grains, roots, and tubers are the edible vegetables that contain a high level of anthocyanins.
- So I selected Red coloured flowers for my investigation. Both Rosa indica and Ixora coccinea have anthocyanin pigments.
- I used fresh flowers for preparing the extract. To prepare the extracts in both flowers I mixed 75 ml of water with 75 g of flower petals and then extract the dye. But Ixora coccinea extract produces more efficiency.
- Two Light sources are used. Sun and Torch light. While I took reading at the terrace of my school it was very sunny (Time=12.30 pm). I used torch light inside my school science lab.
- The results shows that only under sunlight both flower dyes give maximum voltage compared to torch light.
- The dye sensitized cell produces atleast less voltage even under low light intensity (torch light) at room temperature. So I think it is more effective than solar panel especially for this reason.

APPLICATION

- **Dye-sensitized solar cells** (DSSCs) are **photovoltaic** devices that are **used to** convert light energy into electrical energy by the **use** of organic **dyes** (photosensitizers) and semiconductors.
- DSSC can be applied on architecture, interior applications, electronic products, and portable power systems. DSSC is a disruptive technology that can be used to produce electricity in a wide range of light conditions, indoors and outdoors, enabling the user to convert both artificial and natural light into energy to power a broad range of electronic devices.
- The organic dye solar cell is easier and less expensive to manufacture than the conventional semiconductor solar cell. The organic dye solar cell has the potential to be used to power buildings, portable electronic, remote controlled planes and vehicles, etc.
- DSSC needs to be sustainable for many years in building-integrated modules to avoid commotion of the building environment for repair or replacement and a lifespan of 5 years are sufficient for portable electronic chargers integrated into apparel and accessories.
- Dye sensitized solar cell makes large current densities and exceptional stability, as well as the low cost, makes practical applications feasible.

- ***Fully transparent solar cell could make every window and screen a power source***

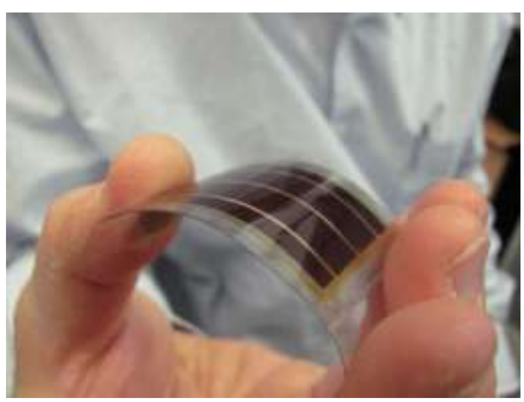
Back in August 2014, researchers at Michigan State University created a fully transparent solar concentrator, which could turn any window or sheet of glass (like your smartphone’s screen) into a photovoltaic solar cell. Unlike other “transparent” solar cells that we’ve reported on in the past, this one really *is* transparent, as you can see in the photos throughout this story. According to Richard Lunt, who led the research at the time, the team was confident the transparent solar panels can be efficiently deployed in a wide range of settings, from "tall buildings with lots of windows or any kind of mobile device that demands high aesthetic quality like a phone or e-reader."

- Now Ubiquitous Energy, an MIT startup we first reported on in 2013, is getting closer to bringing its transparent solar panels to market. Lunt cofounded the company and remains assistant professor of chemical engineering and materials science at Michigan State University. Essentially, what they're doing is instead of shrinking the components, they're changing the way the cell absorbs light. The cell selectively harvests the part of the solar spectrum we can't see with our eye, while letting regular visible light pass through.

ERIC WESOFF | FEBRUARY 18, 2014

Belectric Goes After Building-Integrated PV With Organic Solar Cells

Photo Credit: Picture courtesy of altPower



CONCLUSION

- My hypothesis, "Ixora Coccinea flower is more effective on dyesensitized solar cells in producing high voltage compared to Rosa indica " has been proved.
- Dye-sensitized solar cells (DSSCs) are a promising third-generation photovoltaic technology due to their ease in fabrication, low cost, ability to operate in diffused light, flexibility, and light weight.
- Ixora coccinea flowers have rich anthocyanin content (704.73 mg/100 g to 662.79 mg/100g) in fresh material. The crude anthocyanins extract from IC flower was stable at low pH $\leq$ 4 and sensitive to alkaline condition, high temperature and light. It can be considered as potential colorant in acidic foods or cosmetics.
- The performance of dye sensitized solar cells is mainly based on the dye as a sensitizer. Natural dyes have become a viable alternative to expensive and rare organic sensitizers because of its low cost, easy attainability, abundance in supply of raw materials and no environment threat. Various components of a plant such as the flower petals, leaves and bark have been tested as sensitizers. The nature of these pigments together with other parameters has resulted in varying performance. This review briefly discusses the emergence, operation and components of dye sensitized solar cells together with the work done on natural dye based dye sensitized solar cells over the years.

FUTURE ENHANCEMENT

- I want to continue my research in finding more efficient flower dye sensitized solar cell and test its application in various places especially how effectively this fully transparent solar cell could make every window and screen a power source.

ACKNOWLEDGEMENT

"Gratitude is the sign of Humanity". It is not fulfilled without praising the Almighty, for providing me this opportunity and strength to do my project.

I would like to express my deep thanks to my Correspondent Mr.A. Sathakkathullah for his constant support.

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