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Extraction of Betalain Dye from Beetroot and Preparation of Organic DSSC

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Abstract— this study is about the dye sensitizers extracted from organic and natural resources. This paper focuses on selection, extraction of natural dye and fabrication of betalain sensitized solar cell. The effect of the betalain dye and extraction method and parameters such as temperature, absorption rate, pH are analyzed. Also, light absorption by the dye and the effect of mixture or change in concentration of betalain extracts and acetic acid is investigated. . Results from betalain pigments presenting beetroot extracts are examined by using UV-Vis spectrometry, Dye sensitized solar cell(DSSC's) fallows same principle as the photosynthesis that occur In plants and trees. DSSC's are advantageous due to their non-toxic property, easy and less-cost Manufacturing process. Design and experimental process have major factors that increases the conversion efficiency. Hence, optimization of each component is necessary to attain best performance results, and thus the colour pigment in the dye plays major role. Cells are fabricated with simple procedure, sensitizer taken as a major component, the same consecutive procedure are followed by varying only the concentration of acitic acid and dye extract mixture.

Index Terms— Acetic acid, Betalain, Beetroot, dye sensitized solar cell (DSSC's), Efficiency, Natural dye, Organic.

1 INTRODUCTION

Nowadays globally energy consumption is increasing day by day. Due to increase in global energy consumption the demand is increasing on natural resources i.e., petroleum, coal, natural gas. Natural gas requires thousands of years to form. In this scenario the solar cells also called as photovoltaics come into picture. Where it is a form of clean renewable energy. This will consume solar light and convert into solar electrical energy.

So the solar cells have been invented which was inorganic. As the days goes the disposal in the environment was a very big issue because it was working under inorganic source which is harmful. Due to this the organic solar cells has got very good scope which is less harmful in the environment. The complete organic solar cell is not possible instead both organic and inorganic can make less polluted solar cell. There are 4 main classifications of solar cells are:1.Amorphous silicon solar cell 2.dye sensitized solar cell 3.perovskite solar cell 4.cadmium telluride solar cell.

This study deals with organic dye sensitized solar cell, since from a decade organic solar cell (OSC) are considered as promising photovoltaic technology. The dye sensitized solar cells (DSSC's) are the thin film layered cells, that emerged as less production cost of energy and manufacturing process is easier. This DSSC will absorb the sun light radiation to produce energy.

The principle of DSSC is same as the process of photosynthesis in plants that uses Sunlight to produce chemical energy that help in their growth.

This method is basically organic, where the natural dyes are extracted from beetroot. Titanium dioxide (Tio2) nano particles is an inorganic semiconductor, which plays a major role in this method, this is used as anode, act as an electron donor. Carbon coating on cathode, act as an electron acceptor. The dye between these two acts as a medium as shown in Fig.1.

Organic dyes used in the dye-sensitized solar cells often bear a resemblance to dyes found in plants, fruits, and other natural products, and several dye-sensitized solar cells with natural dyes have been reported by M. Thambidurai et al [3].

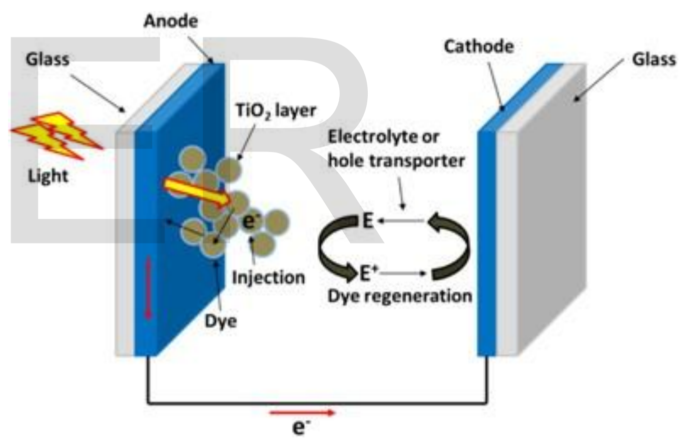

Fig. 1. Schematic Mechanism of DSSC

Fig.1 shows the DSSC working mechanism where photon from the sun strikes the anode and excites the betalain dye molecules and releases electron, which are injected into titanium (IV) oxide nanoparticle layer that act as semiconductor, increases the surface area that allows more light to be absorbed through a broad scale of visible spectrum. The electrons exits anode and flows through external circuit to the cathode and then into iodide electrolyte, the iodide ions becomes oxidized and transports the electrons back into the dye molecules which on receiving the electrons from electrolyte reduces back to its original form. The electrons are the form of charge carriers which transports the electrical energy for various applications.

2 EXPERIMENTAL

2.1 Preparation of FTO glass

Fluorine doped tin oxide (FTO) is a combination of NH4F and DBTDA. These 2 solutions are mixed up and the Fluorine is doped with the tin oxide. Then the solution is sprayed.

Pyrolysis is used to prepare the FTO glass. This process will produce maximum transparency material about 84% which let the sunlight absorption in the inner parts of the solar cells. The manufacture of the film with less sheet resistance is then for the enhancement of the conductivity. The simple anneal with different annealed temperature. Surface distribution of the particle and size of fluorine doped tin oxide is considered to be all the annealed temperature is used.

2.2 Preparation of Tio2 paste

Grind for 0.6 gram of titanium dioxide (TiO_2) nano sized crystals in a mortar and pestle with few drops of very minute acetic acid. Grinding and addition of a some drops of low dilute acetic acid until it obtain a colloidal suspension with smooth consistency as show in Fig.2 , A toothpaste-like consistency is very thick. And also mix a drop of dishwashing detergent as of surfactant. This quantity of TiO_2 is more enough for solar cells.

For distribution, put the TiO_2 paste to syringe. Close the end of the syringe with Para film because to keep out from drying when not in use. (If the paste get dries, the Tio2 need more water) Using the syringe which shortens the working time, makes it at ease to clean it up, and gives proper uniformity that reduces the preparation time.

Fig.2 Titanium dioxide paste

2.3 Extraction of betalain dye

Beetroot have been collected from shop and pulverizes into small pieces then dried in oven at 56˚C for 16-19 hrs and grinded to make a powder of 90 mesh size. Solvents are used for extraction of citric acid crystals and ethanol (99.8%). Extraction of concentrated of betalain. The grind dry beetroot peel powder (10gm) was mixed with water (50ml) and acetic acid, then made into paste. This was microwaved to extraction for 10 min. Then solution was centrifuged for 6 min at 2250 rpm in cooling centrifuge. The amount of betalain in each of the case as calculated as mg/g. The concentrated red solution has been diluted with distilled water and measured at wavelength 525nm. This quality was expressed in mg betalains/ 100gms powder.

2.4 preparation of anode

The conducting side of glass faced up, taping the glass of three sides to mid of a tray using single thickness of tape. Wipe it off any spills and fingerprints using a cloth wet in alcohol. Opposite side of the tape will be as a spacer. Another side of the glass will not be coated where the clip is connected.

Add a slight amount of Tio2 paste and then suddenly spread it by sliding down and with a slide before the paste get dries out as shown in Fig.3. The tape will serves as a 30-40 micrometer space to control the thickness of the Tio2 layer if you push it down.

Fig.3 Tio2 coated FTO glass

Carefully take off the tape without any scratches on the TiO_2 coating. Through the removed tape in to the spill bin for disposal. Heat the anode glass by placing it on hot plate Fig.4 for 10-15 minutes. The surface will turns to brown as the solvent and surfactant get dries and burns to produce a white sintered Tio2 coating. Leave let the glass get cool by switching off the hotplate. The sample may look similar before and after heating;

Immerse the coated glass in a betalain. The beetroot juice is obtained from beetroot. The white Titanium dioxide will change its color to reddish brown as the dye is absorbed.

Rinse it gently with water to take off any beetroot solids and with ethanol to dry water in the porous of TiO_2. The ethanol should be dried before the glass is assembled.

Fig.4 Tio2 coated glass placed on Hot plate

2.5 preparation of cathode

Pass the cathode of tin oxide glass, conducting side as down, by a candle flame, coat the conducting side with the carbon. Pass the glass very quickly and also repeatedly through the center part of the candle flame. Wipe off the soot on either edges of three sides of the soot-coated glass using a dry cotton tissue.

2.6 Assembly of electrodes

Assemble the glass plates of coated sides together, but offset so that only coated to come contact. Do not swab or slide the glass plates. Clamp the glass plates at same time with binder clips.

Add few drops of KI_3 solution on either sides of the plate. Capillary action will take place i.e., tri iodide solution to move between the two glass plates. The solution may corrode the binder clips. wipe off an excess solution.

3 RESULT AND DISCUSSION

3.1 UV-visible light absorption characteristics

Fig.5 shows that the UV-visible light absorption spectra of Betalain dye (Beta vulgaris). A Vast absorption band is observed at wavelength (ʎ) ~ 530-550 nm range as well as small hump at ʎ ~ 482 nm. Purple red betalain (ʎ~540 nm) and yellow betaxanthin (ʎ ~ 480 nm) pigments causes arise of two peaks .There is a good photon to electrical energy conversion efficiency in DSSC , because betalain dyes can absorb wider range of solar spectrum

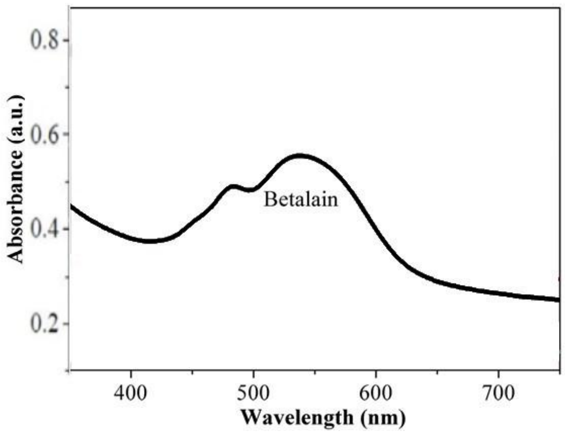

Fig.5 Visible light absorption spectra of betalain

Light absorption property of natural dyes are found to be losing Fig.6, when they are continuously projected heat. Temperature control circuit (TCC) is assembled with UV-visible spectrum and there is a rise in a temperature from 25 to 70°c and thereby we can study the light absorption behavior of the betalain at various temperature. Graph shows that the light absorption of the betalain dye at different temperature .when we heat the dye beyond the room temperature then light absorption capacity of the dye is gradually decreases stability of the dye with respect to dye is already been reported.

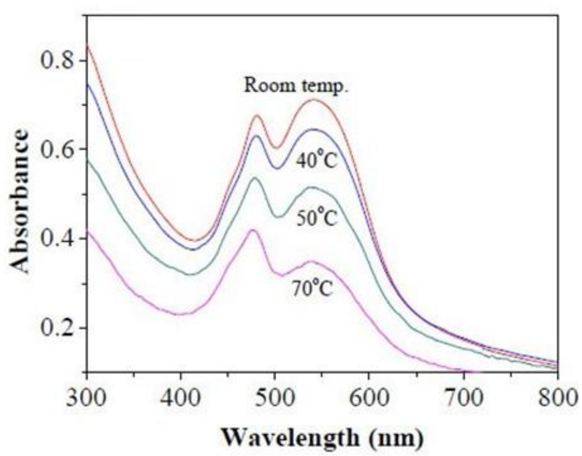

Fig.6 Temperature dependent UV-vis absorption spectra for betalain

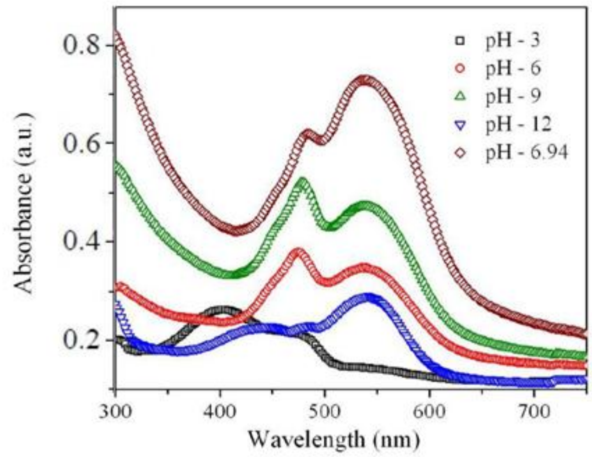

Fig.5 pH variation UV-vis absorption spectra for betalain

Table-1 encapsulates the info about the performance of betalain dye as sensitizer via the short circuit current, open circuit voltage, and fill factor and cell efficiency. The fill factor of the DSSCs is varied from 25% to 35%, The Voc and Isc vacillates from 0.27 to 0.31 V and 0.28 to 0.94 mA/cm2, respectively. The cell prepared by using betalain dye exhibited the penetrating light to electric energy conversion cell efficiency of 0.874%.

Table 1 Photo-voltaic parameters of DSSC sensitized by betalain dye

Sensitizer	Voc (V)	Isc (mA/cm2)	Fill factor (%)	Efficiency (%)
betalain and acetic acid	0.31	0.94	0.30	0.874

4 CONCLUSIONS

i. Organic dye sensitized solar cells are fabricated by using betalain extract from beetroot as sensitizer and Titanium dioxide (Tio2) as photo-anode material. The photo-voltaic characteristics such as open-circuit voltage (Voc), short-circuit current (Isc).fill factor (FF), efficiency (η) are measured with incident solar light (power of incident light (pin) 100 mW cm-2 from standard Air Mass of 1.5G). The solar to electric conversion efficiencies for betalain dye based solar cells (with active area of 4 cm2) are found to be 0.874%.

ii. The study on the pH and temperature dependent UV-vis absorption characteristics of the betalain dye is conducted.

5 SCOPE FOR FUTURE WORK

i. The experimentation can be continued by varying the acetic acid concentration mixture with betalain dye extracted from beetroot..

ii. The study can be made on mixture of natural dyes extracted from spinach, pomegranate and acetic acid.

iii. The study can conducted by coating organic dyes on different surfaces such as metallic and concrete structures.

iv. Study can be carried out on red, purple coloured flowers such as rose to prepare natural dyes and fabricate organic dye sensitized solar cell.

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