A STUDY ON DYE SENSITIZED SOLAR CELLS (DSSC'S) MADE FROM *COFFEE ARABICA* POWDER AND PULP WASTE GROWN IN CHIKKAMAGALURU WITH CARBON BLACK OBTAINED BY BURNING BIOPLASTIC AS COUNTER ELCTRODE AND SUNSCREEN CREAME WITH TiO_2 AS ANODE

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ABSTRACT:

Bio plastic sheets were prepared using starch. The anodes were smeared with Himalaya men natural bright cream (SPF 15[*]) that acted as TiO_2 semiconductor source. Counter electrodes were prepared using carbon obtained by anaerobically burning bio plastic which was synthesized in the laboratory. I^-/I_2 solution was used as the electrolyte. Coffee pulp and powder were used as sources for dye. Electrode – 4 prepared using coffee powder showed P_{max} 0.072 and Cell efficiency (η %) 0.222 it was equally efficient to Electrode – 3 prepared from coffee pulp with P_{max} 0.072 and Cell efficiency (η %) 0.211. DSSC' cells showed less stability for week long study. Further investigations can help these green DSSC's to improve performance.

KEY WORDS: DSSC's, Bio plastic, bio polymer, TiO_2.

1. INTRODUCTION:

Increase population demands have led to exponential requirements of energy. Environmental concerns have navigated mankind towards cleaner and abundant energy resource – the sun. Dye Sensitized Solar Cells (DSSC's) best known as Gratzel solar cells have come handy. Innumerable research papers available on such cells post its discovery in 1991, stands witness to its promising results and efficient utilization. Conventional solar cells require highly pure materials like silicon, whereas DSSC's work separately as charge carriers and light harvesting units, thereby reducing manufacturing cost. DSSC's have lower carbon foot print are ecofriendly and abundantly available. The only challenge for its wide production is efficiency level. Nano crystalline or mesoscopic TiO_2

based DSSC's are available as liquid junction cells, hole- conductor based solid-state cells and cells containing quasi-solid electrolytes with molten salts, polymers and gels. These modern DSSC's can be made flexible and wind able. Loss of electrolyte is a major shortcoming of such PV cells[1-8]. Keeping this in mind, we have fabricated DSSC's using bio plastic films and abundantly available natural dye sensitizer such as Coffee powder and coffee pulp waste. The counter electrode was taken as candle black (reported in our other paper) and carbon obtained from burning bio plastic.

2. EXPERIMENTAL:

Synthesis of bio plastic

2.5 g of pure starch was added into a beaker together with 25 cm^3 of distilled water. Then, 2 cm^3 of hydrochloric acid and 2 cm^3 of propan-1,2,3-triol were added to it. The mixture was boiled gently for 15 minutes, with a watch glass being put on top of the beaker, to prevent evaporation of water. Sodium hydroxide was added to neutralize the pH of the mixture. Finally, it was left in laminar air flow for 2 days to dry out. After two days, plasticized starch in sheet form was obtained[9].

Preparation of dye-Sensitizer Solutions

- Coffee pulp of *Coffee robusta* was obtained from local pulping agencies and the liquid was used as such.
- Coffee powder made from *robusta* variety free from all sorts of adulteration was boiled in hot water and filtered. The filtrate as such was used as dye source.

Preparation of Electrodes

The conductive glass plates (FTO glass, fluorine-doped SnO_2, sheet resistance 8-12 Ω/cm^2) were purchased from Aldrich. The above prepared bio plastic sheets were cut into square wafers. Few were uniformly smeared with Himalaya men natural bright cream (SPF 15*) as TiO_2 source to make them as photo anodes and others were smeared with candle black carbon to form the counter electrode. The bio plastic smeared with sunscreen was then dipped in coffee pulp, dried and excess was washed with alcohol.

Assembling

Solvents and chemicals were of reagent or spectrophotometric grade and were used as received.

An electrolyte solution was prepared as reported: 0.1 M of iodine (I_2) was mixed with 0.05 M of potassium iodide (KI) and 0.05 M of 3-methoxypropionitrile ($CH_3OCH_2CH_2CN$) in 50 mL of acetonitrile (C_2H_3N), stirred for 60 min. This electrolyte solution was poured in between mesoporous bioplastic film prepared above and assembled as electrodes. Both the electrodes were sandwiched between two conductive glass plates and clipped. No leaks (solvent evaporation) were detected[10,11]. The details of types of DSSC's prepared and the corresponding codes are provided in Table-1.

Table 1: List of sources of TiO_2 and dyes used for the experiment to prepare electrodes

ELECTRODE NUMBER	ANODE (Source of TiO_2)	DYE	CATHODE
3	A-2 (Himalaya men)	Coffee pulp	Anaerobically burnt bioplastic carbon
4	A-2 (Himalaya men)	Coffee powder	Anaerobically burnt bioplastic carbon

P-V Studies

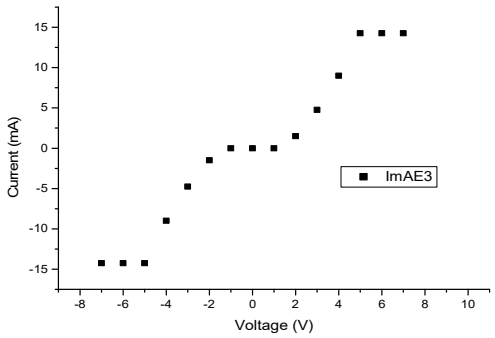
The ability of a solar panel to convert sunlight into usable energy, fit for human utilization is called as the efficiency of a photovoltaic solar panel. Choice of correct panels can be decided by knowing the efficiency of panel. Efficiency of a solar panel can be determined by P-V studies. The control and test DSSC's were subjected to P-V studies.

PV plots were obtained for the different DSSC's prepared using coffee pulp and coffee powder dyes. All slides were illuminated at a distance of 12 cm from source using tungsten filament as source. Control slides were done without dye and all control slides showed no conductivity.

An Additional test on the stability of coffee dye sensitized solar cells was carried out by monitoring some indicative parameter namely; current output under continuous sun illumination (100 mW/cm^2 and air mass 1.5) in a hermetically sealed solar cell with an electrolyte solution and without any cooling system throughout the study. Observations during the study are as reported and is discussed below.

3. RESULT AND DISCUSSION

The photovoltaic plots for electrode 3 and 4 are as shown in figures 1 and 2.



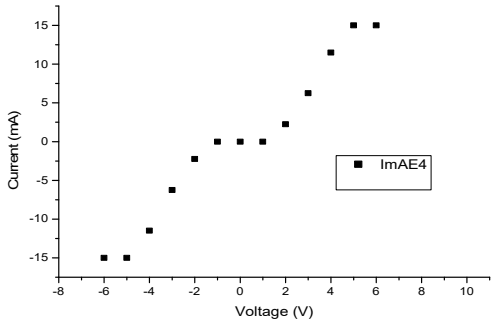


Fig-1: PV plots of DSSC for Electrode -3

Fig-2: PV plots of DSSC for Electrode- 4

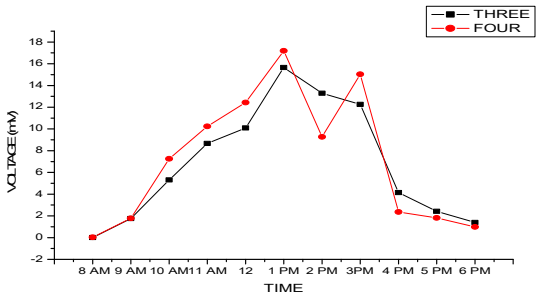
The solar efficiency of both the electrodes was calculated Table-2 summarizes the findings.

Table-2: Dye Sensitized Solar Cell efficiency for Electrodes 3 and 4

Code	P_{max}	Cell efficiency (η %)
Electrode- 3	0.072	0.211
Electrode- 4	0.075	0.222

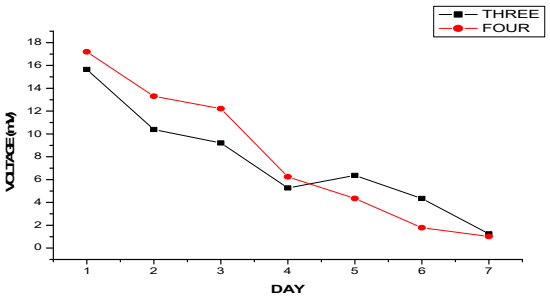
Both the electrodes 3 and 4 were prepared by using Himalaya men natural bright cream (SPF 15*) as TiO_2 source and black carbon obtained by burning the bioplastic anaerobically as the counter electrode. Electrode – 3 however had coffee pulp as the dye source and Electrode – 4 had coffee powder as the dye source. From Table – 2 it is clear that Electrode – 4 with P_{max} 0.072 and Cell efficiency (η %) 0.222 is equally efficient in comparison to the Electrode – 3 with P_{max} 0.072 and Cell efficiency (η %) 0.211. It can therefore be concluded that coffee powder from coffee beans had comparable dye characteristics to the dyes found in coffee pulp of the same variety.

Time dependent efficiency for DSSC of Electrodes 3 and 4 under sun illumination were carried out for one day (24 hours) and a week-long monitoring was performed each day at 1 PM. The results are as shown in Figure-3 and 4.



Electrodes 3 and 4

Fig-3: Time dependent efficiency for Electrodes 3 and 4 DSSC under sun illumination (100mW &air mass 1.5)



Electrodes 3 and 4

Fig-4: Time dependent efficiency for DSSC Electrodes 3 and 4 under sun illumination (100mW &air mass 1.5) for a week (voltage at 1PM taken)

Time dependent efficiency studies for DSSC's of Electrodes 3 and 4 under sun illumination show that the electrode was stable for a day, but the stability of the electrode decreased and fell down to 2 mV on the seventh day which was 18/16 mV on the first day. This destabilization could have occurred from the electrolyte solution that gets absorbed in the bioplastic. More electrolyte solution or conducting bioplastic could be used to eliminate this problem. Alternatively the cream used for the study as TiO_2 source may have degenerated. A separate study on stability of the cream for one week under sun illumination can throw light on the effectiveness of cream as an UV absorbent source and its utilization for energy production in DSSC's.

4. CONCLUSION

Use of bio plastic to prepare DSSC's can help in effectively managing the electrolyte drying problem that arises in such studies. These are environmental friendly and easy to handle. India in general and Chikkamagaluru in particular grows coffee to a large extent hence using its pulp waste can be a green method of waste management. However, the other parameters need to be set and efficiency of the cell should be kept constant for a long duration. From this paper we can further conclude that Electrode – 4 is slightly a better DSSC in comparison to Electrode – 3.

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