A study on environmental friendly Dye Sensitized Solar Cell for treatment of dyes using TiO_2

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ABSTRACT - Hydrothermal method for preparation of nanostructured TiO_2 was adopted and coated on to FTO coated glass as substrate. The TiO_2 coated plates were used as working electrodes. Dye Sensitized Solar Cells (DSSC) was prepared incorporating food dye and iodide solution as electrolyte. The crystallinity of prepared electrode was determined using X-ray diffraction technique. Effect of dye with variation in time on the efficiency of the solar cell was studied. Power output was determined both under simulated and natural conditions. The solar cells prepared were fairly stable for 24 hours but started deteriorating during seven days observatory study. With the help of the PV plots, FF, maximum power values were determined and efficiency of the cells were calculated. The controls showed no power output and conversion rates. The study could effectively suggest low cost effluent treatment containing food dyes with its simultaneous utilization in power generation.

Key words: TiO_2, Hydrothermal, Food colour, X-ray diffraction, DSSC.

1. INTRODUCTION AND REVIEW OF LITERATURE

Solar cells have gained momentum since past two decades. The third generation of solar cells i.e. Dye Sensitized Solar Cells (DSSC's) have come to the forefront recently. Dye-sensitized solar cells are cost efficient, versatile and electricity generators that have attracted the attention of academicians and industrialists. These DSSC's are alternative energy producers, they mimic natural photosynthesis. The light absorbing dye helps in promoting the electrons to the conduction band of the semiconductor substrate more effectively. Nano-porous semiconductor materials allow large number of dyes to adsorb on its surface, leading to widening of the band gap and large exciton binding energy, thereby improving the power efficiency of DSSC. TiO_2 based DSSC's have been reported to show higher efficiencies of nearly 11%. DSSC is a redox system, hence there is an intensive effort in optimizing the various parameters of the like the nature of electrolyte, thickness of the semiconductor layer, the type of dye and variation in functional groups of the dye. The dye should have intense absorption spectrum with anchoring groups such as carboxylic, carbonyl and hydroxyl to anchor to the semiconductor mesoporous layer. This strong absorption leads to efficient injection of electron into the conduction band of the semiconductor TiO_2[21-22]. Energy is produced in this process. After the electrolyte donates electron back to the dye, de excitation occurs. This process is reversible and reproducible. Dyes are used in our day to day life, removal of these from waste water before treatment poses a big challenge. Food colors are also washed into fresh waters contaminating the same few researchers have worked on removal of dyes from environment [1-19]. Useful utilization of such waste waters for energy production and their deterioration studies forms the basis of this study. Carbon coated counter electrodes and I^-/I_3 electrolyte solutions were adopted for the study as a preliminary investigation.

2. EXPERIMENTAL

2.1 Materials

The conductive glass plates (FTO glass, fluorine-doped SnO_2, sheet resistance 8-12 Ω/cm^2) and the Titanium di oxide (TiO_2) were purchased respectively from Aldrich and sd fine chemicals respectively. Solvents and chemicals were of reagent or spectrophotometric grade and were used as received. Food dyes containing carmoisine and tartrazine were purchased from the market and care was taken to sample one type of dye from products of different companies.

2.2 Preparation of electrodes and assembling

Photo anodes were prepared by depositing TiO_2 film on the FTO conducting glass: two edges of the FTO glass plate were covered with a layer of adhesive tape (3M Magic) to control the thickness of the film and to mask electric contact strips; successively the TiO_2 paste was spread uniformly on the substrate by sliding a glass rod along the tape spacer. FTO substrates were cleaned in an ethanol-water mixture for 30 min and then heated at 450 °C during 30 min prior to film deposition. The TiO_2 photo-anodes were then soaked in food dye solutions for ten minutes. Later, the photo-anodes were rinsed with distilled water and ethanol and dried. Carbon coated counter electrodes were prepared.

An electrolyte solution was prepared by mixing 0.1 M of I_2 with 0.05 M of KI and 0.05 M of 3-methoxypropionitrile in 50 mL of acetonitrile (C_2H_3N) and stirring for 60 min. This electrolyte solution was poured in the mesoporous TiO_2 film which was previously prepared using paraffin-film as framework to seal the cells to prevent evaporation of the liquids. The counter electrode was pressed against the impregnated anode and clamped firmly in a sandwich configuration. No leaks (solvent evaporation) were detected.

2.3 P-V studies

The prepared DSSC cells were illuminated with tungsten filament source (2370 Lux = 15 W) and maximum power was determined using Zener Diode. A PV plot was plotted and **η_{max} (maximum efficiency) %** was calculated. The stability of prepared cells was checked under one sun illumination and for one week duration (sun illumination between 12 noon to 3 PM).

3. P-V STUDIES RESULTS AND DISCUSSION

Orange red (BUSH) Carmoisine (14720) dye showed a cell efficiency of 10 %, this indicates that the compound has anchored to the semiconductor TiO_2 nano particle layer effectively and acted as a good dye. Apple green (Falcon) Tartazine (19140) showed cell efficiency of 10.2%. The current output was s fairly stable for nearly four days and stated deteriorating. The results are shown in Table 1 and (Fig 1-8).

Table 1: Dye sensitized solar cell efficiency.

Dye	**% Cell efficiency η**
ORANGE RED (BUSH) CARMOISINE (14720)	**10.0**
APPLE GREEN (FALCON) TARTAZINE (19140)	**10.2**

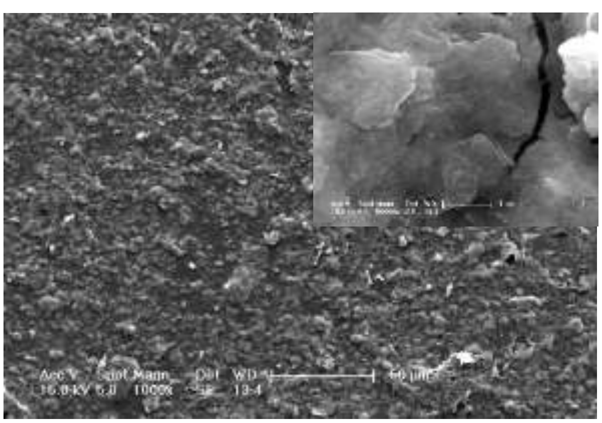


Fig – 1: ORANGE RED (BUSH) CARMOISINE (14720)

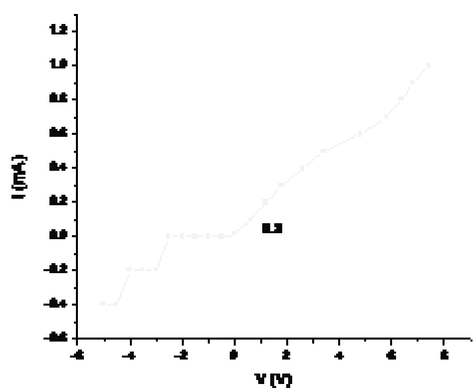
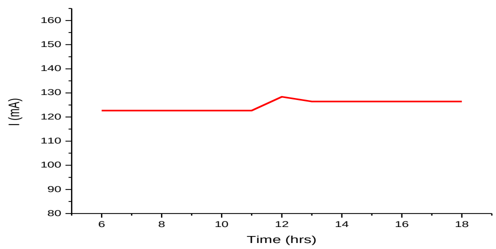
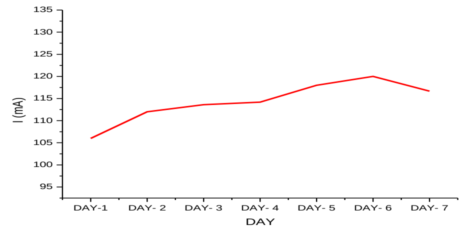


Fig 2: PV plots of DSSC for ORANGE RED (BUSH) CARMOISINE (14720)





3.1

Fig 3: Time dependent efficiency for ORANGE RED (BUSH) CARMOISINE (14720) DSSC under sun illumination (100mW &air mass 1.5)

Fig 4: Time dependent efficiency of DSSC under sun illumination (100mW &air mass 1.5) for a week

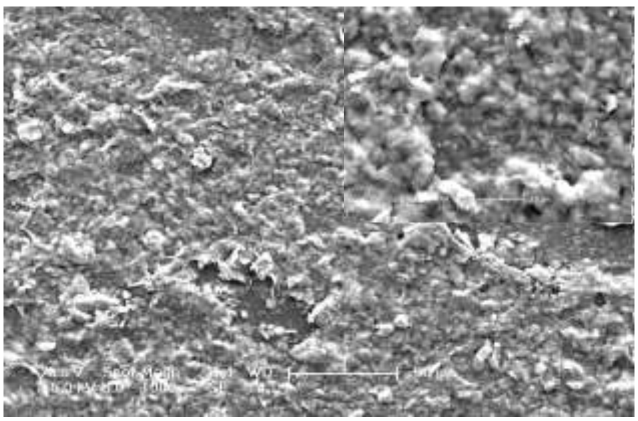


Fig 5: APPLE GREEN (FALCON) TARTAZINE (19140)

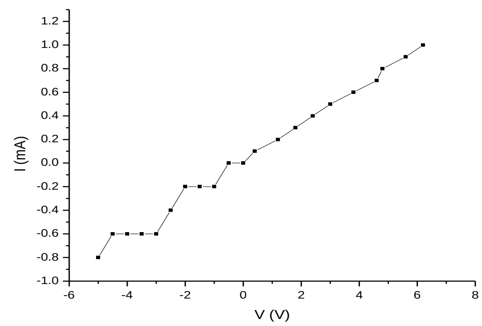
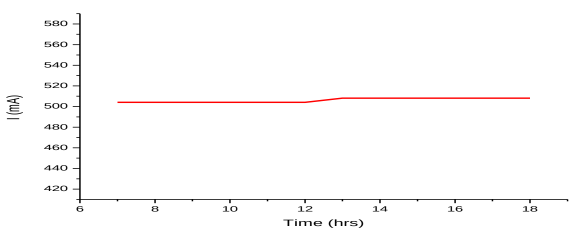


Fig 6: PV plots of DSSC for APPLE GREEN (FALCON) TARTAZINE (19140)



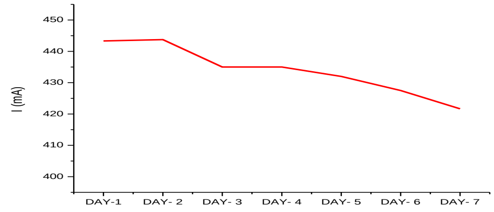


Fig 7: Time dependent efficiency for APPLE GREEN (FALCON) TARTAZINE (19140) DSSC under sun illumination (100mW &air mass 1.5)

Fig 8: Time dependent efficiency of DSSC under sun illumination (100mW &air mass 1.5) for a week

4. CONCLUSIONS

Both orange red dye (Carmoisine) and apple green dye (Tartazine) showed good efficiency until deterioration as indicated by the reduction in cell efficiency. These types of solar cells can therefore be useful in power production and dye decomposition. The variations in parameters like counter electrode and electrolyte solutions can add the voluminous work being carried out on such solar cells.

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