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Comparative Study of Surfactants in DSS Cell for Solar Energy Conversion and Storage

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Abstract: Studies of surfactant and their effect on photoelectric parameter of DSS cells containing Rhodamine-6G-EDTA-NaLS, Methylene Blue-EDTA-TX-100 and Azur B-EDTA-CTAB for solar energy conversion and storage. The observed cell performance in terms of maximum potential, maximum photocurrent, short-circuit current, power at power point, conversion efficiency and storage capacity are -1035.0 mV, 475.0 μA, 395.0 μA, 104.50 μW, 1.004 % and 140.0 minutes respectively. The proposed mechanism for the generation of photocurrent in DSS cells are reported here.

Index Terms**: Photochemicalc effect, electrical parameter, surfactant, solar energy, conversion efficiency, storage capacity.**

I. INTRODUCTION

Presently, world is facing energy crisis and it is a biggest challenge in front of all nations to meet the energy demand. The demand of energy, the consumption of fossil fuels and pollution level are increasing with an alarming rate worldwide. The solar energy is the most readily available non-conventional source of energy which is most abundantly and freely available renewable source of energy. The new approach for renewable energy sources has led to an increasing interest in DSS cells because of their reliable solar energy conversion and storage capacity. The DSS cells are those cells in which solar energy convert into electrical energy via formation of an energy rich species that exhibit the photochemical effect. DSS cell works on photochemical effect. The photochemical effect was first of all recognized by Rideal and Williams [1] and it was systematically studied by Rabinowitch [2-3], and then by other workers [4-9]. Some researchers [10-11] have studied on how to enhance the performance and optimum efficiency of dye sensitized solar cell for solar energy conversion. A detailed of literature survey reveals that PG cell consisting of various dyes with reductant, mixed dyes with reductant and dye with reductant and surfactant for solar energy conversion and storage reported time to time [12-26]. Recently some cells are developed by Meena and his co-workers [27-30] for generation of electrical energy from various photosensitiser and reductant. Present work is the effort to comparative study of surfactants in DSS cell for solar energy conversion and storage in the presence of Rhodamine-6G-EDTA-NaLS, Methylene Blue-EDTA-TX-100 and Azur B-EDTA-CTAB as a photosensitive compounds, reductant and surfactant respectively.

2. EXPERIMENTAL METHODS

Rhodamine-6G, Methylene Blue, Azur B (MERCK), NaLS, TX-100, CTAB (MERCK), EDTA (MERCK) and NaOH (MERCK) are used in the present research work. All the solutions are prepared in doubly distilled water and the stock solutions of all chemicals are prepared by direct weighing and are kept in colored container to protect them from the light. The entire cell is set systematically for photochemical studies, which consists of thin foil of electrochemically treated platinum as electrode and saturated calomel electrodes as a reference electrode. The distance between the illuminated and dark electrode is

45.0 mm. An ordinary tungsten lamp of 200 W is used as light source. Water filter is used to cut-off IR radiations. The photopotetial is obtained as the difference between the initial potential of the cell in dark and the equilibrium potential attained by the cell under constant illumination. The potential is first measured in dark and the change in potential on illumination is measured as a function of time. The solution is bubbled with prepurified nitrogen gas for nearly twenty minutes to remove dissolved oxygen. Solutions of photosensitizer, reductant, surfactant and sodium hydroxide are taken in an H-type glass tube. A platinum electrode (1.0 x 1.0 cm2) is immersed into one arm of H-tube and a saturated calomel electrode (SCE) is kept in the other. The whole cell is first placed in dark till a stable potential is obtained and then, the arm containing the SCE is kept in the dark and the platinum electrode is exposed to a 200 W tungsten lamp. A water-filter is used to cut off infrared radiations. The photochemical bleaching of Azur B is studied potentiometrically. A digital pH meter (Systronics Model-335) and a microammeter (Ruttonsha Simpson) are used to measure the potential and current generated by the cell, respectively. The current-voltage characteristics of DSS cell have been studied by applying an external load with the help of a carbon pot (log 470 K) connected in the circuit through a key to have close circuit and open circuit device. The experimental set-up of DSS cell is given in **Figure-1**. The effect of variation of different parameters has also been observed. The rate of change in potential after removing the source of illumination is 0.93 mV min^{-1}, 0.90 mV min^{-1} and 0.85mV min^{-1} in Rhodamine-6G-EDTA-NaLS, Methylene Blue-EDTA-TX-100 and Azur B-EDTA-CTAB DSS cells respectively.

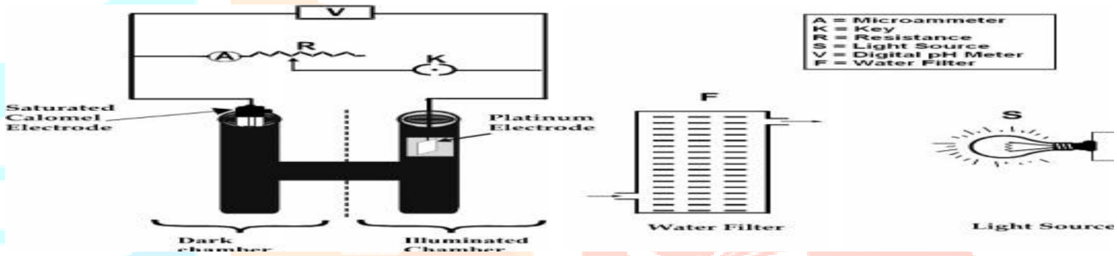

Figure-1: *Experimental Set-up of DSS Cell*

3. RESULTS AND DISCUSSION

3.1. Variation of photopotential with time in Rhodamine-6G-EDTA-NaLS, Methylene Blue-EDTA-TX-100 and Azur B-EDTA-CTAB DSS Cell:

The photopotential of Rhodamine-6G-EDTA-NaLS, Methylene Blue-EDTA-TX-100 and Azur B-EDTA-CTAB DSS cells are measured at different pH values and maximum photopotential is found at pH 12.40, 11.60 and 13.20. All the subsequent measurements are made at this pH value. The variation of photopotential with time for this DSS cells are shown in Table-2. As can be seen from the table that the photopotential increase upon illumination to a value of 1162.0, 1082.0 and 1035.0 mV in about 140.0, 130.0 and 150.0 minutes respectively and remains constant on further illumination. When the light is switched-off, the system does not regains its original potential; thereby, showing that the system is not perfectly reversible. The photo induced short circuit currents of -6G-EDTA-NaLS, Methylene Blue-EDTA-TX-100 and Azur B-EDTA-CTAB redox-couple in DSS cells are reported in Table-1. On illumination, maximum photocurrent 510.0, 490.0 and 475.0 µA in 140.0, 130.0 and 150.0 minutes in -6G-EDTA-NaLS, Methylene Blue-EDTA-TX-100 and Azur B-EDTA-CTAB DSS cells respectively.

DSS Cell	Dark Potential	Open Circuit Voltage	Photopotential (DV)	Illumination Time
Rh-6G-EDTA-NaLS	257.0 mV	1162.0 mV	905.0	140.0 min.
MB-EDTA-TX-100	237.0 mV	1082.0 mV	845.0	130.0 min.
AB-EDTA-CTAB	240.0 mV	1035.0 mV	795.0	150.0 min.

Table-1: *Variation of photopotential with time in DSS Cells*

3.2. Effect of Concentration of Dye, Reductant, Surfactant and pH on The DSS cell:

The effect of concentration of dye, reductant and surfactant concentration on photoelectric parameters is studied. It is observed that the photopotential and photocurrent are increasing with respect to the concentration of the photosensitizer, reductant and surfactant. A maximum is obtained for a particular value of photosensitizer (Azur B) concentration, reductant (EDTA) concentration and surfactant (CTAB) concentration. On further increase in concentration of photosensitizer (Azur B), reductant (EDTA) and surfactant (CTAB), a decrease in the electrical output of the cell is obtained.

Parameters	Photopotential (mV)	Photocurrent (µA)	Power (µW)
RH-6G-EDTA-NALS DSS Cell			
(Rhodamine-6G) × 10^{-5} M			
2.52	787.0	235.0	212.89
2.52	852.0	395.0	250.80
2.59	905.0	450.0	314.03
2.62	828.0	385.0	259.72
2.65	752.0	240.0	213.41
(EDTA) × 10^{-3} M			
1.35	762.0	322.0	245.36
1.40	846.0	392.0	331.63
1.44	905.0	450.0	407.25
1.49	828.0	385.0	318.78
1.54	735.0	302.0	221.97
(NaLS) × 10^{-3} M			
1.09	710.0	322.0	228.62
1.12	844.0	398.0	335.91
1.14	905.0	450.0	407.25
1.16	828.0	384.0	317.95
1.19	695.0	288.0	200.16
MB-EDTA-TX-100 DSS Cell			
(Methylene Blue) × 10^{-5} M			
1.98	732.0	322.0	235.70
2.01	796.0	388.0	308.85
2.04	845.0	420.0	354.90
2.08	785.0	376.0	295.16
2.11	712.0	312.0	222.14
(EDTA) × 10^{-3} M			
1.10	766.0	342.0	261.97
1.15	805.0	388.0	312.34
1.20	845.0	420.0	354.90
1.24	798.0	375.0	299.25
1.29	712.0	318.0	226.42
(TX-100) × 10^{-3} M			
0.79	756.0	315.0	238.14
0.81	812.0	376.0	305.31
0.84	845.0	420.0	354.90
0.86	788.0	368.0	289.98
0.88	712.0	302.0	215.02
A B-EDTA-CTAB DSS Cell			
(Azur B) × 10^{-5} M			
1.82	698.0	305.0	212.89
1.85	742.0	338.0	250.80
1.88	795.0	395.0	314.03
1.92	755.0	344.0	259.72
1.95	684.0	312.0	213.41
(EDTA) × 10^{-3} M			
1.06	713.0	313.0	223.77
1.11	752.0	346.0	260.19
1.16	795.0	395.0	314.03
1.20	747.0	352.0	262.94
1.25	688.0	309.0	212.59
(CTAB) × 10^{-3} M			
0.63	713.0	313.0	223.77
0.65	752.0	346.0	260.19
0.68	795.0	395.0	314.03
0.70	747.0	352.0	262.94
0.72	688.0	309.0	212.59

Table-1: Effect of Concentration of Dyes, Reductant, Surfactant and pH on the cell

The reason of the change in electrical output is that lower concentration of photosensitizer resulted into a fall in electrical output because fewer photosensitizer (Azur B) molecules are available for the excitation and consecutive donation of the electrons to the platinum electrode whereas the higher concentration of photosensitizer again resulted into a decrease into electrical output as the intensity of light reaching the dye molecules near the electrode decrease due to absorption of the major portion of the light by dye molecules present in the path. The reason of the change in electrical output is that the lower concentration of reducing agent resulted into a fall in electrical output because fewer reducing agent molecules are available for electron donation to photosensitizer (Azur B) molecule whereas the higher concentration of reducing agent again resulted into a decrease in electrical output, because the large number of reducing agent molecules hinders the dye molecules from reaching the electrode in the desired time limit. The reason of the change in electrical output is that the surfactants solubilize the dye molecules up to highest extent at or around their micelles concentration. The observed parameters of the DSS cells are presented in **Table-1.**

3.3. Current-Voltage (i-V) Characteristics of the DSS cell:

The short circuit current (i_{sc}) and open circuit voltage (V_{oc}) of the DSS cells are measured with the help of a multimeter (keeping the circuit closed) and with a digital pH meter (keeping the other circuit open), respectively. The current and potential values in between these two extreme values are recorded with the help of a carbon pot (log 470 K) connected in the circuit of Multimeter, through which an external load is applied. The current-voltage (i-V) characteristics of the DSS cells are containing Rhodamine-6G-EDTA-NaLS, Methylene Blue-EDTA-TX-100 and Azur B-EDTA-CTAB. Results of the DSS cells are reported in **Table-2.**

S.N.	**DSS Cell**	**Photopotential (mV)**	**Photocurrent (μA)**	**Fill Factor (η)**	**Power Point (μW)**
1.	**Rh-6G-EDTA-NaLS**	658.0	200.0	0.2516	131.60
2.	**MB-EDTA-TX-100**	514.0	220.0	0.2488	113.08
3.	**Azure B-EDTA-CTAB**	550.0	190.0	0.2556	104.50

Table-2: ***Current-Voltage (i-V) Characteristics of the DSS cell***

3.4. Storage Capacity and Conversion Efficiency of the DSS Cell:

The storage capacity of the DSS cells are observed by applying an external load (necessary to have current at power point) after terminating the illumination as soon as the potential reaches a constant value. The storage capacity is determined in terms of $t_{1/2}$, i.e., the time required in the fall of the output (power) to its half at power point in dark. It is observed that the cell can be used in dark for 170.0, 160.0 and 140.0 minutes on irradiation for 140.0, 130.0 and 150.0 minutes. So the observed storage capacity of the cell is 1.21%, 1.23% and 93%. The conversion of the efficiency of the DSS cells are determined as 1.26%, 1.08& and 1.004% with the help of photocurrent and photopotential values at the power point and the incident power of radiations by using the formula. The results are reported in **Table-3**.

$$\text{Fill factor } (\eta) = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}} \qquad \ldots\ldots\ (1)$$

$$\text{Conversion Efficiency} = \frac{V_{pp} \times i_{pp}}{10.4\ \text{mW}} \times 100\% \qquad \ldots\ldots\ (2)$$

3.5. Performance of the DSS Cells:

The overall performance of the DSS cells are observed and reached to remarkable level in the performance of DSS cells with respect to electrical output, initial generation of photocurrent, conversion efficiency and storage capacity of the DSS cell.

Table-4 shows the results are obtained in Rhodamine-6G-EDTA-NaLS, Methylene Blue-EDTA-TX-100 and Azur B-EDTA-CTAB DSS cells.

S.N.	**Parameter**	**Observed Value**		
		Rh-6G-EDTA-NaLS	**MB-EDTA-TX-100**	**Azur B-EDTA-CTAB**
1.	Dark potential	257.0 mV	237.0 mV	240.0 mV
2.	Open circuit voltage (V_{OC})	1162.0 mV	1082.0 mV	1035.0 mV
3.	Photopotential (DV)	905.0 mV	845.0 mV	795.0 mV
4.	Equilibrium photocurrent (i_{eq})	450.0 µA	420.0 µA	395.0 µA
5.	Maximum photocurrent (i_{max})	510.0 µA	490.0 µA	475.0 µA
6.	Initial generation of photocurrent	25.5 µA min^{-1}	24.5 µA min^{-1}	19.0 µA min^{-1}
7.	Time of illumination	140.0 min	130.0 min	150.0 min
8.	Storage capacity ($t_{1/2}$)	170.0 min	160.0 min	140.0 min
9.	% of storage capacity of cell	1.21	1.23	0.93
10.	Conversion efficiency	1.26%	1.08%	1.004%
11.	Fill factor (η)	0.2516	0.2488	0.2556

Table-4: Performance of Rh-6G-EDTA-NaLS, MB-EDTA-TX-100 and Azur B-EDTA-CTAB DSS Cell.

4. MECHANISM:

On the basis of results, a mechanism is for the generation of photocurrent in the DSS cell is represented in **Figure-2**.

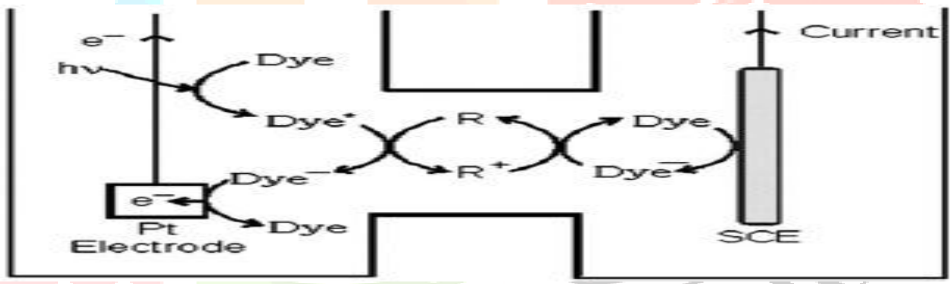

Figure-2: Mechanism for the Generation of Photocurrent in DSS Cell

5. CONCLUSION

On the basis of the results, it is concluded that NaLS, TX-100 and CTAB surfactant with EDTA reductant and Rhodamine 6G, Methylene Blue and Azur B can be used successfully as photosensitive compounds in a DSS cell. The conversion efficiency and storage capacity of the cells are 1.26%, 1.08% and 1.004% and 170.0, 160.0 and 140.0 minutes respectively, on irradiation for 140.0, 130.0 and 150.0 minutes developed DSS cell. It has been observed that the surfactants have not only enhanced the electrical parameters but also the conversion efficiency and storage capacity of DSS cell.

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