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Role of an Anionic Surfactant and Reductant in Photogalvanic Cell for Solar Energy Conversion and Storage

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Abstract- Photogalvanic cell is a type of solar cell in which solar energy converts into electrical energy via formation of energy rich species that exhibit the photogalvanic effect. Photogalvanic effect was studied in a photogalvanic cell containing Rhodamine 6G-EDTA-NaLS system. The observed cell performance in terms of maximum potential, maximum photocurrent, short-circuit current, power at power point, conversion efficiency and storage capacity in terms of half change time are -1162 mV, 510 µA, 450 µA, 131.60 µW, 1.26 % and 2.8 h, respectively . The mechanism was proposed for the generation of photocurrent in photogalvanic cell. It is also viewed that the Rhodamine 6G-EDTA-NaLS based photogalvanic cell, with the additional advantage of low cost and storage capacity, can give electrical output comparable to that for commercially used power property lacking photogalvanic cells.

Keywords- Photogalvanic effect1, maximum potential2, maximum photocurrent3, short-circuit current4, conversion efficiency5.

1. Introduction

Energy is the lifeline of the country's economy and development. The solar energy is the most readily available non-conventional source of energy which is most abundant and freely available renewable source of energy. The new approach for renewable energy sources has led to an increasing interest in photogalvanic cells because of their reliable solar energy conversion and storage capacity. The photogalvanic cells are based on some chemical reaction, which raises to high- energy products on excitation by photons. This cell works on photogalvanic effect and this effect was first observed by [1] and it was systematically studied by [2-12] Studies on how to enhance the performance and optimum efficiency of dye sensitized solar cells based on nanocrystals TiO2 films prepared with mixed template method for solar energy conversion [13-14]. Use of some reductant and photo sensitizer in photogalvanic cells for solar energy conversion and storage [15-17]. The studies of photogalvanic cell consisting various dyes with reductant, mixed dye with reductant and dye with reductant and surfactant [18-21]. Recently the photogalvanic effects in various interesting system were observed by [22-27]. The photochemical conversion of solar energy into electrical energy was observed by [28-32]. Role of photosensitizer for generation of electrical energy in photogalvanic cells were studied by [33-37]. The present work is the effort to observe the role of surfactant (NaLS) and reductant (EDTA) in presence of Rhodamine-6G as photosensitizer in photogalvanic cell for solar energy conversion and storage.

2. Experimental Methods

Rhodamine 6G (MERCK), NaLS (LOBA), EDTA (MERCK) and NaOH (MERCK) were used in the present work. All the solutions were prepared in doubly distilled water and the stock solutions of all chemicals were prepared by direct weighing and were kept in a colored container to protect them from the light. The whole system was set systematically for photogalvanic studies, which consists of thin foil of electrochemically treated platinum as the electrode and saturated calomel electrodes as a reference electrode. The distance between the illuminated and dark electrode is 45 mm. An ordinary tungsten lamp of 200 W was used as light source. Water filter was used to cut off IR radiations. The photopotetial was obtained as the difference between the initial potential of the system in dark and the equilibrium potential attained by the system under constant illumination. The potential was first measured in the dark and the change in potential on illumination was measured as a function of time. The solution was bubbled with prepurified nitrogen gas for nearly twenty minutes to remove dissolved oxygen. Solutions of dye, reductant, surfactant and sodium hydroxide were taken in an H-type glass tube. A platinum electrode (1.0 x 1.0 cm2) was immersed into one arm of the H - tube and a saturated calomel electrode (SCE) was kept in the other. The whole system was first placed in dark till a stable potential was obtained and then, the arm containing the SCE was kept in the dark and the platinum electrode was exposed to a 200 W tungsten lamp. A water-filter was used to cut off infrared radiations. The photochemical bleaching of Rhodamine 6G was studied potentiometrically. A digital pH meter (Systronics Model-335) and a microammeter (Ruttonsha Simpson) were used to measure the potential and current generated by the system, respectively. The current-voltage characteristics of photogalvanic 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 photogalvanic 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 was 0.93mV min-1 in Rhodamine 6G-EDTA-NaLS.

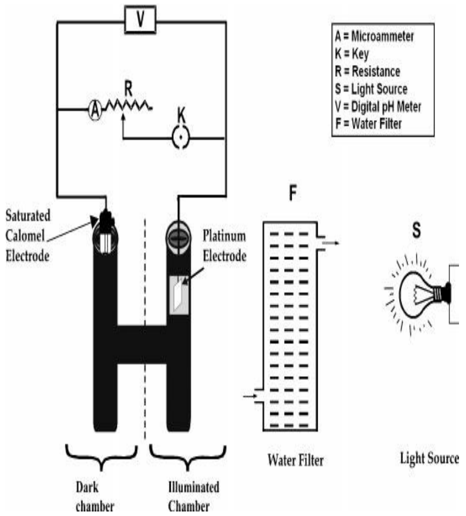

Fig.1. Experimental set-up of photogalvanic cell.

3. Results and Discussion

3.1. *Effect of Variation of Dye (Rhodamine 6G) Concentration on The System*

It was observed that the photopotential and photocurrent were increased with the increase in concentration of the dye. A maximum was obtained for a particular value of Rhodamine 6G concentrations, above which a decrease in the electrical output of the cell was obtained. The effect of variation of Rhodamine 6G concentration on photopotential and photocurrent are reported in Figure 2.

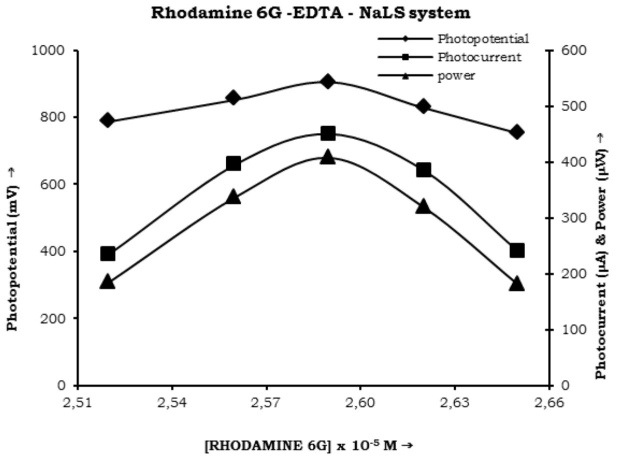

Fig. 2. Variation of photopotential, photocurrent and power with (Rhodamine 6G) concentration

3.2. *Effect of Variation of EDTA Concentration on the System*

The photopotential and photocurrent were found to increase with the increase in concentration of the reductant [EDTA], till it reaches a maximum. On further increase in concentration of EDTA, a decrease in the electrical output of the cell was observed. The effect of variation of the EDTA concentration on the photopotential and photocurrent of Rhodamine 6G-EDTA-NaLS system is given in Figure 3.

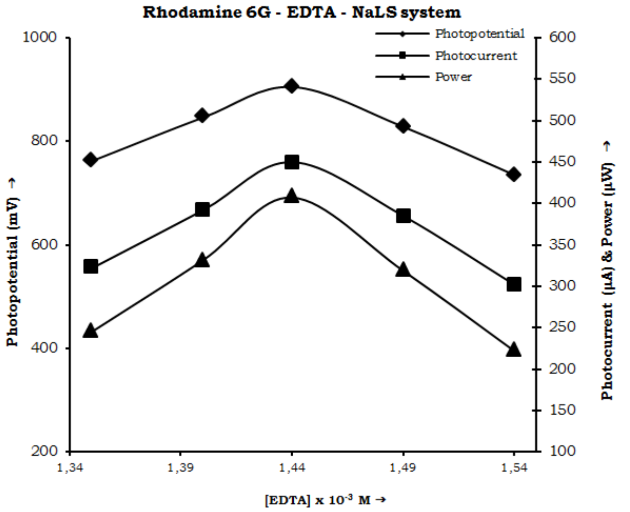

Fig. 3. Variation of photopotential, photocurrent and power with EDTA concentration

3.3. Effect of Variation of Nals Concentration on the System

The effect of variation of [NaLS] was investigated in Rhodamine 6G-EDTA-NaLS system. It was observed that the electrical output of the cell was found to increase with increasing the concentration of surfactant reaching a maximum value. On further increase in their concentrations, a fall in photopotential, photocurrent and power of the photogalvanic cell was observed. The results are reported in Figure 4.

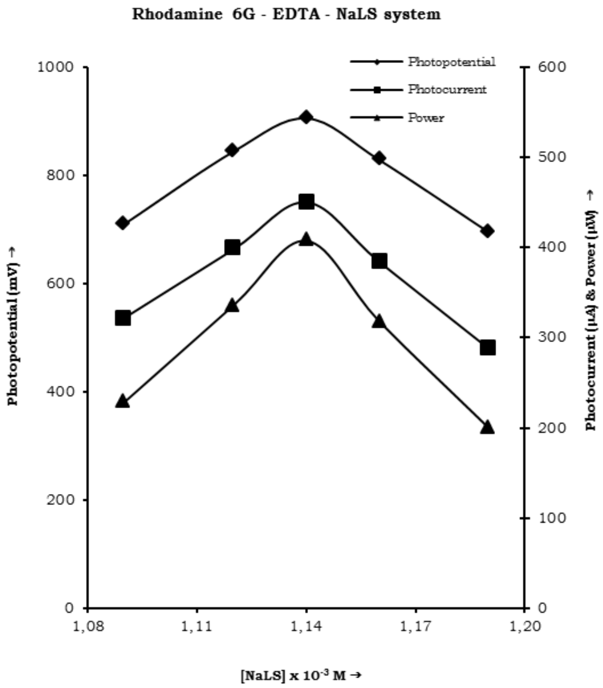

Fig. 4. Variation of photopotential, photocurrent and power with NaLS concentration

3.4. Effect of Variation of pH on the system

Photogalvanic cell containing Rhodamine 6G - EDTA - NaLS system was found to be quite sensitive to the pH of the solution. It was observed that there is an increase in the photopotential and photocurrent of this system with the increase in pH value (In the alkaline range). At pH 12.40 a maxima was obtained. On further increase in pH, there was a decrease in photopotential and photocurrent. The effect of variation of pH on photopotential and photocurrent are given in Figure 5.

3.5. Effect of Diffusion Length on the System

The effect of variation of diffusion length (distance between the two electrodes) on the current parameters of the cell (i_{max}, i_{eq} and initial rate of generation of photocurrent) was studied using H-shaped cells of different dimensions. It was observed that with an increase in diffusion length, i_{max} and rate (μA min.$^{-1}$) both showed an increase but the i_{eq} showed a negligibly small decreasing behaviour with the increase in diffusion length. So virtually, it may be considered as unaffected by the change in diffusion length. The results are graphically represented in Figure 6.

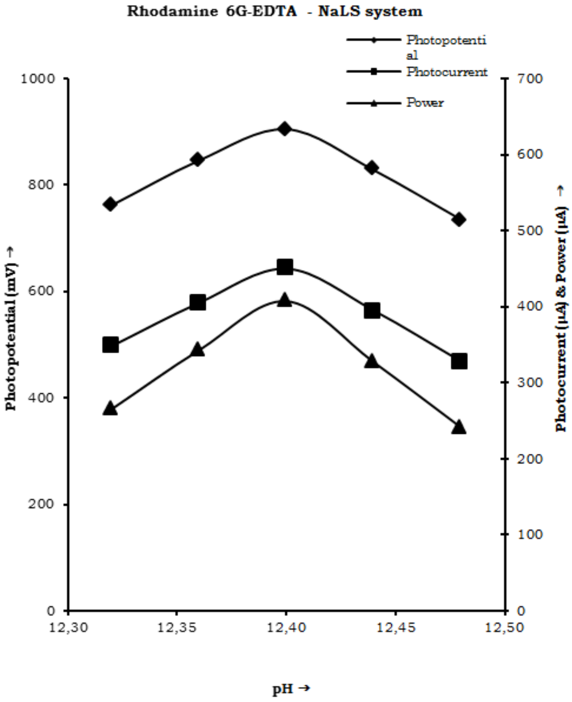

Fig. 5. Variation of photopotential, photocurrent and power with pH

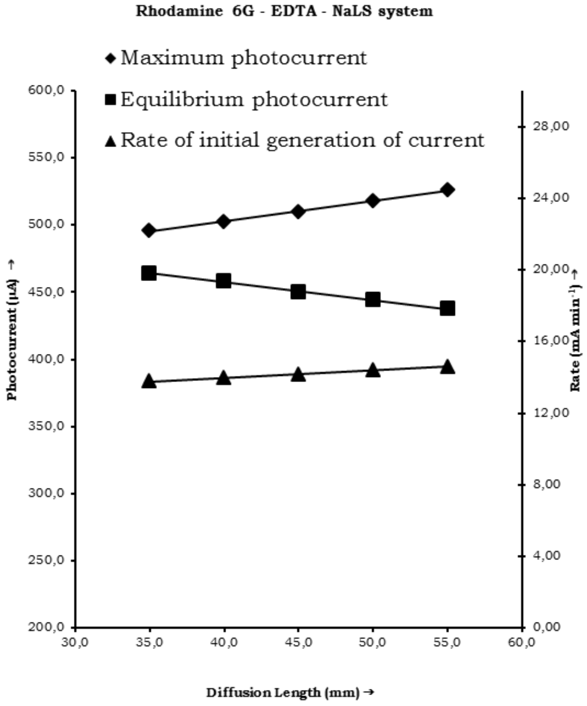

Fig. 6. Variation of current parameter with diffusion length

3.6. Effect of electrode area on the system

The effect of electrode area on the current parameters of the cell was also studied. It was observed that with the increase in the electrode area, the value of maximum photocurrent (i_{max}) was found to increase, whereas the equilibrium photocurrent (i_{eq}) was affected slightly, rather it was decreased slightly. The effect of variation of electrode area on maximum photocurrent (i_{max}) and photocurrent at equilibrium (i_{eq}) is graphically represented in Figure 7.

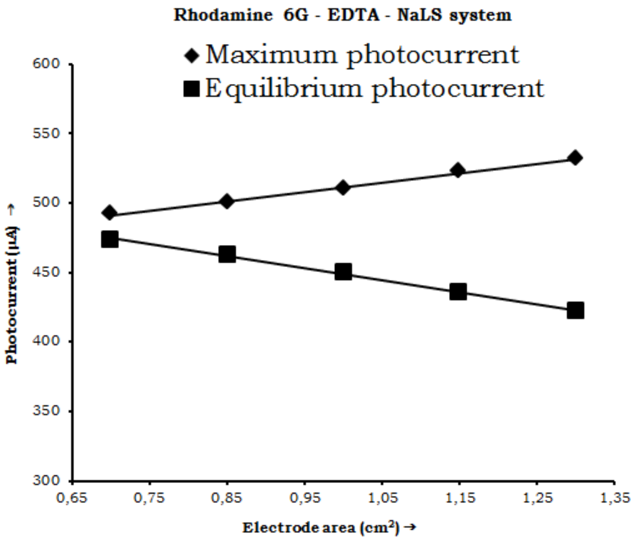

Fig. 7. Variation of current parameter with electrode area

3.7. Effect of Temperature on the System

The effect of temperature on the current parameters of the cell was also studied. It was observed that the photocurrent of the photogalvanic cell was found to increase with an increase in the temperature whereas the photopotential was found to decrease. The effect of temperature on total possible power output in the Rhodamine 6G-EDTA-NaLS System was also studied and it was observed that there was a linear relation between the electrical output of the cell and temperature. The results are graphically represented in Figure 8.

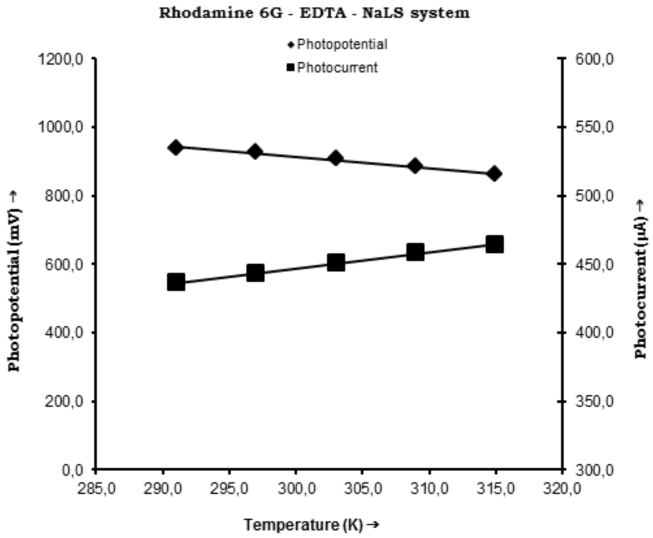

Fig. 8. Variation of photopotential and photocurrent with temperature

3.8. Effect of Light Intensity on the System

It was found that the photocurrent showed a linear increasing behaviour with the increase in light intensity whereas photopotential increases in a logarithmic manner and the light intensity was measured in term of mWcm-2 with the help of solarimeter (CEL Model SM 203). The results of the effect of variation of light intensity on the photo potential and photocurrent are graphically represented in Figure 9.

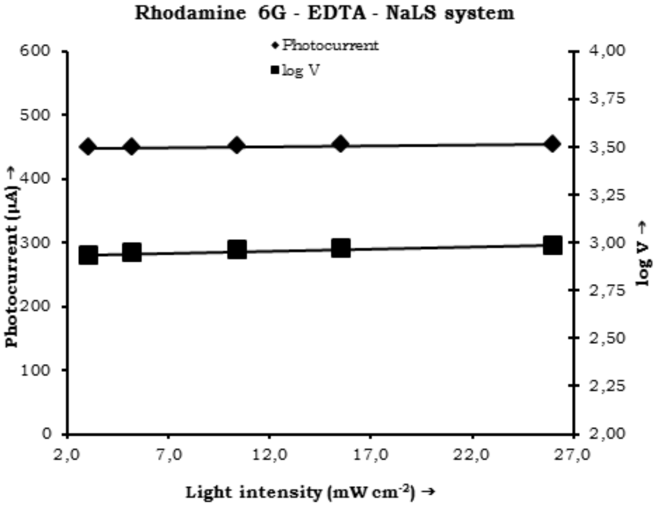

Fig. 9. Variation of photopotential and log V with light intensity

3.9. Current-Voltage Characteristics of the Cells

The short circuit current (i_{sc}) and open circuit voltage (V_{oc}) of the photogalvanic cells were 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 were recorded with the help of a carbon pot (log 470 K) connected in the circuit of multimeter, through which an external load was applied. The current-voltage (i-V) characteristics of the photogalvanic cells containing Rhodamine 6G –EDTA –NaLS system is graphically shown in Figure 10.

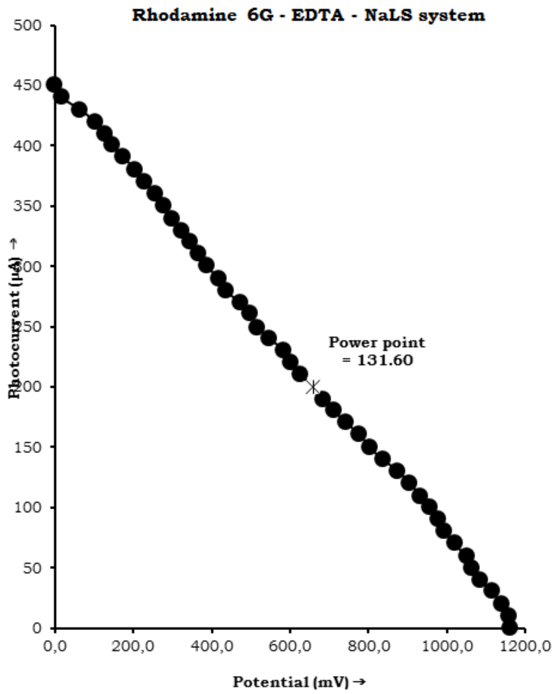

Fig. 10. Current-Voltage curve of the cell

3.10. *Storage Capacity of the Cell (in dark)*

The storage capacity of the photogalvanic cell was observed by applying an external load (necessary to have current at power point) after termination the illumination as soon as the potential reaches a constant value. The storage capacity was determined in terms of t1/2, i.e., the time required in the fall of the output (power) to its half at the power point in the dark. It was observed that the cell can be used in dark for 170.0 minutes, whereas photovoltaic cell cannot be used in the dark even for a second. A photogalvanic system has the advantage of being used in the dark but at lower conversion efficiency. The results are graphically represented in Figure 11.

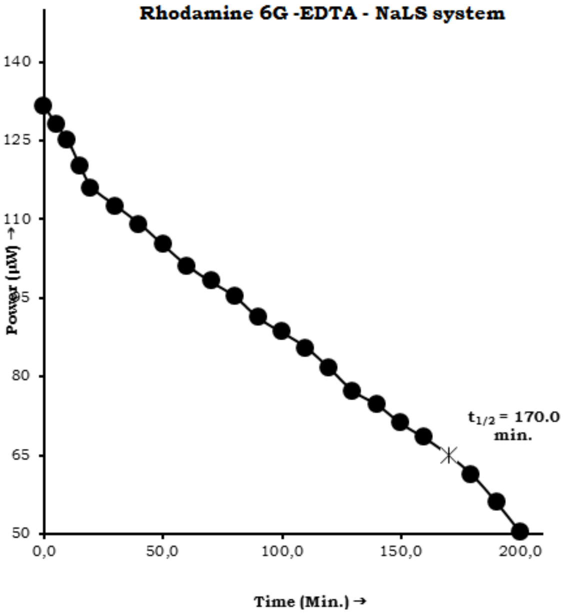

Fig. 11. Performance of the cell

3.11. *Conversion Efficiency of the Cell*

With the help of photocurrent and photopotential values at power point and the incident power of radiations, the conversion efficiency of the cell was determined as 1.2653% using the formula.

$$\text{Fill factor } (\eta) = \frac{V_{pp} \text{ x } i_{pp}}{V_{oc} \text{ x } i_{sc}} \tag{3.1}$$

$$\text{Conversion Efficiency} = \frac{V_{pp} \text{ x } i_{pp}}{10.4 \text{ mW}} \text{x} 100\% \tag{3.2}$$

10.4 mW

Mechanism

On the basis of these observations, a mechanism is suggested for the generation of photocurrent in the photogalvanic cell as:

Illuminated Chamber

On irradiation, dye molecules get excited.

$$\text{Dye} \xrightarrow{h\nu} \text{Dye}^* \tag{3.3}$$

The excited dye molecules accept an electron from reductant and converted into semi or leuco form of dye, and the reductant into its excited form

$$\text{Dye}^* + \text{R} \longrightarrow \text{Dye}^- \text{(Semi or leuco)} + \text{R} \tag{3.4}$$

At Platinum Electrode:

The semi or leuco form of dye loses an electron and gets converted into the original dye molecule

$$\text{Dye}^- \longrightarrow \text{Dye} + e^- \tag{3.5}$$

Dark Chamber

At Calomel Electrode

Dye molecules accept an electron from electrode and get converted into semi or leuco form

$$\text{Dye} + e^- \longrightarrow \text{Dye}^- \text{ (Semi or leuco)} \tag{3.6}$$

Finally leuco/semi form of dye and oxidized form of reductant combine to give the original dye and reductant molecule. This cycle of mechanism is repeated again and again leading production of current continuity.

$$\text{Dye}^- + \text{R}^+ \longrightarrow \text{Dye} + \text{R} \tag{3.7}$$

Where Dye, Dye*, Dye-, R and R+ are the dye, excited form of dye, semi or leuco form of dye, reductant and oxidized form of the reductant, respectively. The process of mechanism in photogalvanic cell is represented in Figure 12.

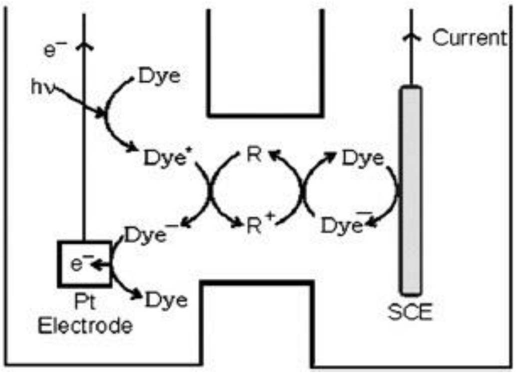

Fig. 12. Processes of mechanism in photogalvanic cell.

4. Conclusion

On the basis of the results, it is concluded that sodium lauryl sulphate and ethylene diamine tetra acetic acid can be used successfully as anionic surfactant and reductant respectively in a photogalvanic cell. The conversion efficiency of the cell is 1.26% and the storage capacity of the cell is 170 minutes. It has been observed that the anionic surfactants and reductants have not only enhanced the conversion efficiency but also the storage capacity of the cell. Photogalvanic cells have the advantages of having in-built storage capacity. Thus, photogalvanic cells showed good prospects of becoming commercially viable.

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Nomenclature

i_{eq} = photocurrent at equilibrium
i_{max} = maximum photocurrent
i_{pp} = photocurrent at power point
i_{sc} = short circuit current
ml = milliliter
mV = millivolt
M = molarity
pp = power point
$t_{1/2}$ = storage capacity of cell
DV = observed photopotential
V_{oc} = open circuit voltage
V_{pp} = photo potential at the power point
η = fill factor
mA = microampere
mW = microwatt

S.N.	Parameter	Observed Value
1	Dark potential	257.0mV
2	Open circuit voltage	1162.0mV
3	Photopotential (DV)	905.0mV
4	Equilibrium photocurrent	450.0 mA
5	Maximum photocurrent	510.0 mA
6	*IGP	25.5 mA min^{-1}
7	Times of illumination	140.0 min
8	Storage capacity ($t_{1/2}$)	170.0 min
9	% of storage capacity	1.2142%
10	Conversion efficiency	1.2653%
11	Fill factor (η)	0.2516

*IGP=Initial generation of photocurrent

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