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Study of Photogalvanic effect in Photogalvanic cell containing mixed Surfactant (NaLS+Tween-80), Methylene blue as a Photosensitizer and Xylose as Reductant

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Abstract

Photogalvanic effect was studied in a photogalvanic cell containing methylene blue-xylose-NaLS+Tween-80 system. The photo potential and photocurrent were observed 645.0 mV and 210.0 μA respectively. The conversion efficiency of the system was observed 0.5313 % and fill factor was determined as 0.3024. The cell performance was observed100.0 minutes in dark. The effects of different parameters on the electrical output of the cell were observed and current-voltage (i-V) characteristics of the cell were also studied.

Keywords: Photopotenial, photocurrent, methylene blue, xylose, Tween-80, fill factor, conversion efficiency.

Introduction

Energy is an integral part of Nation. The world needs all form of energy to perform different tasks. The quality of human life depends to large degree of availability of energy.

First of all the photogalvanic effect was observed by Rideal and Williams[1] and then was systematically investigated by Rabinowitch[2-3] and later by various other workers time to time.[4–8] Studies in photogalvanic cells for solar energy conversion and storage reported by Ameta et al[9–11]. Effect of dyes along with surfactant was studied by Gangotri et al[12–13]. Genwa and Gangotri have reported a comparative studies in anionic cationic and nonionic surfactant and Azur B –NTA–CPC system in photogalvanic cell[14]. Studies of surfactants in Photogalvanic cell–NaLS–EDTA–Azur–B system studied by Meena et al[15]. Gangotri and Gangotri studied micellar effect of photogalvanics for solar energy conversion and storage using Safranine O-EDTA-CTAB-80 system.[16] Gangotri and Bhimwal carried out a comparative study on the performance of photogalvanic cell with different photosensitizer for solar energy conversion and storage[17]. A detailed Literature survey reveals that different photo sensitizers and reductants have been used in photo galvanic cell for development of photo galvanic system[18-26].

Material and Methods

Methylene blue as photosensitizer, xylose as reductant and mixed surfactant (NaLS+Tween-80) were used in this system. All solutions were prepared in doubly distilled water and were kept in amber coloured containers to protect them from sun light. A mixture of solutions of dye, reluctant, mixed surfactant and sodium hydroxide were taken in an H-type glass tube which is blackened by black carbon paper and white. A shiny platinum foil electrode was immersed in one limb of the H-tube and a saturated calomel electrode (SCE) was immersed in the other limb. The whole system was first placed in the dark till a stable potential was attained, then the limb containing the platinum electrode was exposed to a 200 W tungsten lamp (Philips). A water filter was used to cut off thermal radiation.

A digital pH meter and micro ammeter were used to measure the photo potential and photocurrent generated by the system respectively. The current voltage characteristics were studied by applying an external load with the help of a carbon pot (log 470 K) connected in the circuit. Over all experimental set up is given in figure 1.

Results and Discussion

Effect of variation of photosensitizer (methylene blue) concentration on the system: Dependence of photo potential and photocurrent on the concentration of photosensitizer (Methylene blue) was studied. It was observed that lower concentration of photosensitizer resulted into a fall in photopotential and photocurrent because fewer photosensitizer (methylene blue) molecules are available for the excitation and consecutive donation of the electrons to the platinum electrode. A greater concentration of dye 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 observed results are summarized in table-1.

Effect of variation of reductant (xylose) concentration on the system: The electrical output of the photogalvanic cell was affected by the variation of reductant (xylose) concentration on the system.

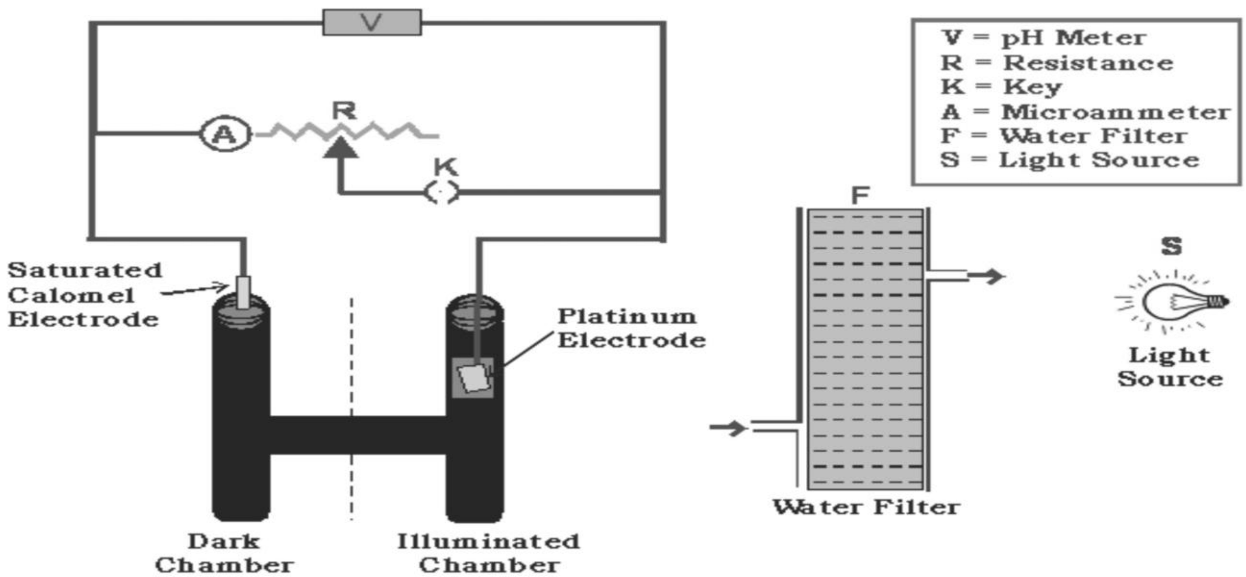

Figure-1
Experimental set up

Lower concentration of reducing agent resulted into a fall in electrical output because fewer reducing agent molecules were available for electron donation to photosensitizer (methylene blue) molecule.

Large 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 observed results are summarized in table-1.

Effect of variation of mixed surfactant (NaLS+Tween-80) concentration on the system: For photo galvanic cell having methylene blue–xylose-NaLS+Tween-80 system, the photo potential and photocurrent varied with variation in concentration of mixed surfactants i.e. NaLS and Tween-80. In one case concentration of NaLS was kept constant and concentration of Tween-80 was varied. In other case the concentration of Tween-80 was kept constant and concentration of NaLS was varied. In both cases a maxima was found for a particular value of NaLS and Tween-80 concentration above which decrease in electrical output of photogalvanic cell was obtained. The observed results are summarized in table 1.

Effect of variation of pH on the system: The electrical output of the photogalvanic cell was affected by the variation of pH on the system. It can be observed from the table 1 that there is an increase in electrical output of the cell with the increase in pH values. At pH 12.84 a maxima was obtained. On further increase in pH, there was a decrease in photo potential and photocurrent. Thus, photogalvanic cells containing the methylene blue-xylose-NaLS+Tween-80 system were found to be quite sensitive to the pH of the solutions.

Table-1
Effect of Variation of Methylene blue, Xylose, NaLS, Tween-80 and pH

Parameters	Photopotential (mV)	Photocurrent (μA)
[Methylene blue] $\times 10^{-5}$ M		
3.60	548.0	142.0
3.80	597.0	181.0
4.00	645.0	210.0
4.20	604.0	177.0
4.40	562.0	136.0
[Xylose] $\times 10^{-3}$ M		
1.96	543.0	138.0
1.98	598.0	185.0
2.00	645.0	210.0
2.02	602.0	177.0
2.04	554.0	143.0
[NaLS] $\times 10^{-3}$ M		
6.36	536.0	144.0
6.38	599.0	185.0
6.40	645.0	210.0
6.42	592.0	182.0
6.44	512.0	138.0
[Tween-80] $\times 10^{-4}$ M		
5.60	562.0	157.0
5.90	603.0	185.0
6.20	645.0	210.0
6.50	597.0	177.0
6.80	555.0	148.0
pH		
12.78	538.0	145.0
12.81	587.0	178.0
12.84	645.0	210.0
12.87	592.0	181.0
12.90	542.0	152.0

Light Intensity = 10.4 $mWcm^{-2}$ Temp. = 303 K

It was observed that the pH for the optimum condition has a relation with pKa of the reductant and the desired pH is higher than in pKa value (pH>pKa). The reason may be the availability of the reductant in its anionic form, which is a better donor form. The observed results are summarized in table 1.

Effect of diffusion length: Effect of variation of diffusion length (distance between the two electrodes) on the current parameter of the cell (i_{max}) has been studied using H-shaped cells of different dimensions. It is observed that in the first few minutes of illuminations there is sharp increase in the photocurrent. As a consequence, the maximum photocurrent (i_{max}) of photocurrent increase with increase in diffusion length, but this is not observed experimentally. Therefore, it may be concluded that the main electroactive species are the leuco or semi-leuco form of dye (photosensitizer) and the dye in illuminated and dark chamber respectively. The reductant and its oxidation product act only as electron carriers in the path. The results are summarized in table 2.

Effect of electrode area: The effect of electrode area on the current parameters of the cell has also been studied. It was observed that with the increase in the electrode area the value of maximum potential (i_{max}) is found to increase. The results are summarized in table 3.

Current–voltage (i-V) characteristics of the photogalvanic cell: The photogalvanic cell containing methylene blue-xylose-NaLS+Tween-80 system, the short circuit current (i_{sc}) and open circuit voltage (V_{oc}) of the photogalvanic cells were measured with the help of a microammeter (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 microammeter, through which an external load was applied. The Current–Voltage (i-V) characteristics of the photogalvanic cell containing Methylene blue-Xylose-NaLS+Tween-80 system is reported in figure 2.

It was observed that current–voltage (i-V) curve deviated from their regular rectangular shapes. A point in i-V curve, called power point (pp) was determined where the product of current and potential was maximum and the fill-factor was calculated using the following formula:

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

Where V_{pp} and i_{pp} represent the value of potential and current at power point, respectively and V_{oc}, i_{sc} represent open circuit voltage and short circuit current, respectively. The value of fill factor (η) = 0.3024 was obtained and the power point of cell (pp) = 55.25μW was determined on the system.

Cell performance and conversion efficiency: The performance 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 performance was determined in terms of $t_{1/2}$, (figure-3) i.e., the time required in fall of the output (power) to its half at power point in dark. It was observed that the cell can be used in dark for 100 minutes. The conversion efficiency of the cell was determined as 0.5313 % using the following formula:

$$\text{Conversion efficiency} = \frac{V_{pp} \times i_{pp}}{A\ 10.4 mWcm^{-2}} \times 100\% \quad (2)$$

Where $V_{pp,}$ i_{pp} and A are photopotential at power point, Photocurrent at power point and electrode area respectively.

Table– 2
Effect of diffusion length

Diffusion length (mm)	Maximum photocurrent i_{max} (μA)	Equilibrium photocurrent i_{eq} (μA)	Rate of initial generation of photocurrent (μA min^{-1})
35.0	232.0	218.0	7.25
40.0	236.0	214.0	7.38
45.0	240.0	210.0	7.50
50.0	244.0	206.0	7.63
55.0	249.0	202.0	7.78

[Methylene blue] = 4.0×10^{-5} M
[Xylose] = 2.0×10^{-3}M
[NaLS] = 6.40×10^{-3} M
[Tween-80] = 6.2×10^{-4} M
Light Intensity = 10.4 mW cm^{-2}
Temperature = 303 K
pH = 13.20

Table-3
Effect of electrode area

Methylene blue-Xylose-NaLS+Tween-80 System	Electrode Area (cm^2)				
	0.70	0.85	1.00	1.15	1.30
Maximum photocurrent i_{max} (μA)	232.0	236.0	240.0	244.0	248.0
Equilibrium photocurrent i_{eq} (μA)	222.0	218.0	210.0	203.0	196.0

[Methylene blue] = 4.0×10^{-5} M
[Xylose] = 2.0×10^{-3}M
[NaLS] = 6.40×10^{-3} M
[Tween-80] = 6.2×10^{-4} M
Light Intensity = 10.4 mW cm^{-2}
Temperature = 303 K
pH = 13.20

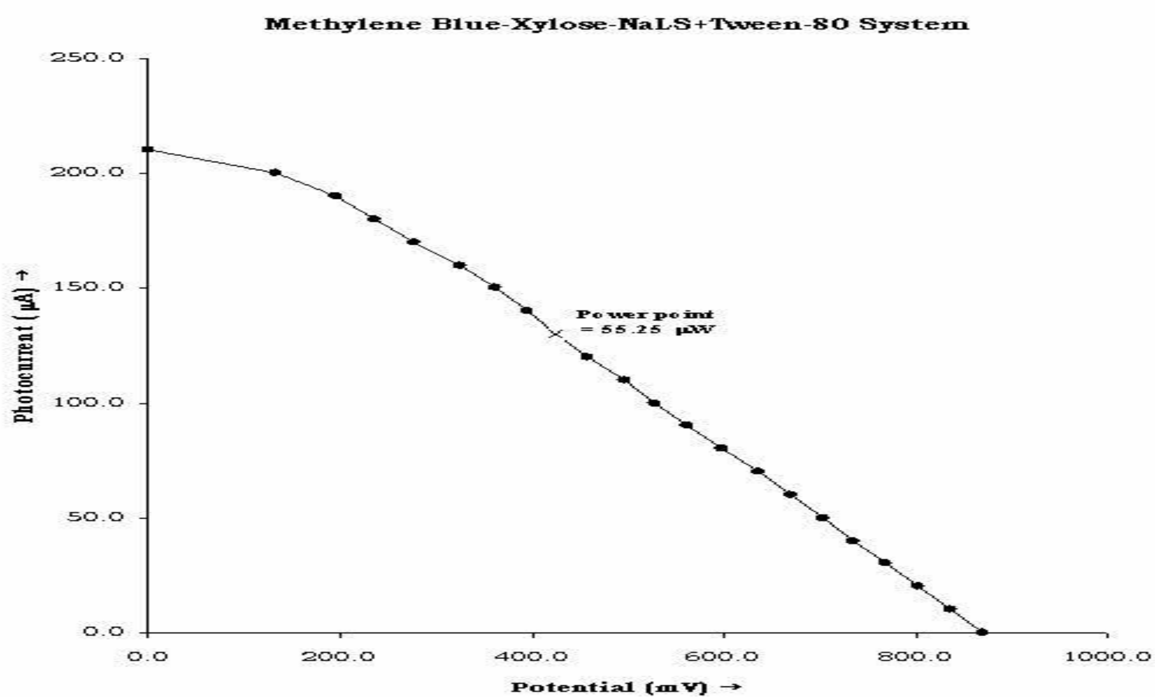

Figure-2
Current-Voltage (i-V) curve of the cell

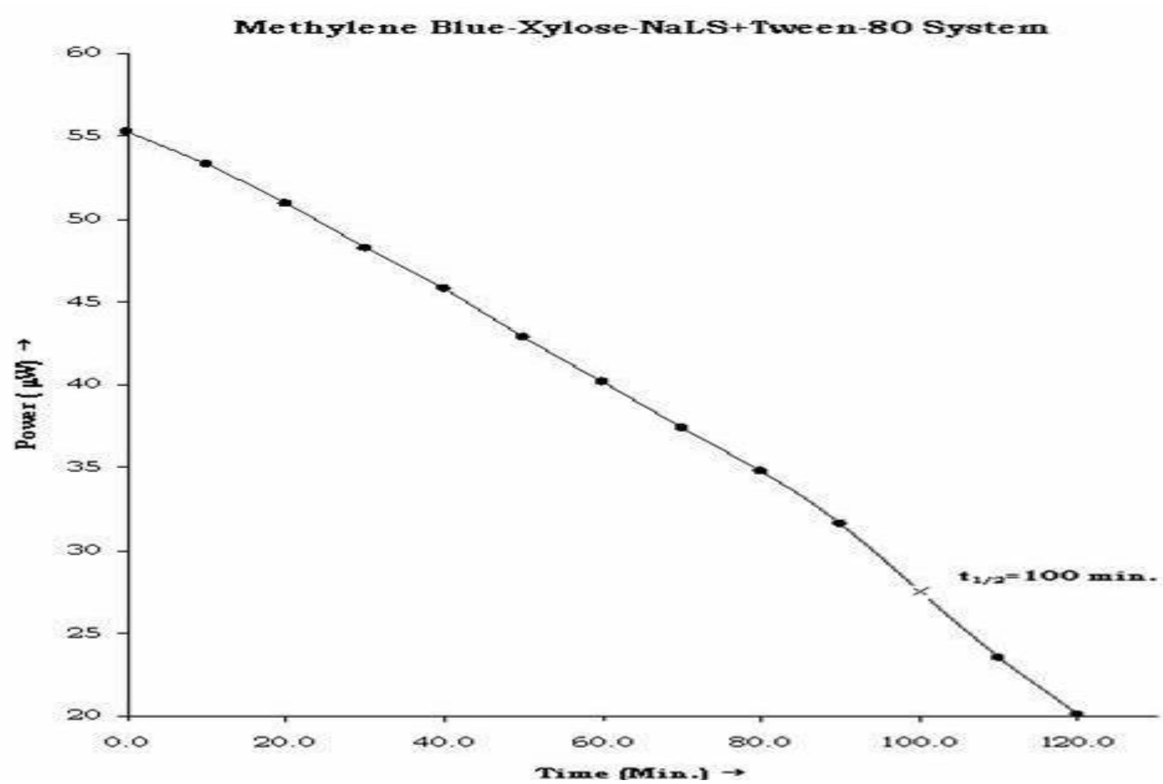

Figure-3
Performance of the Cell

Mechasnism: On the basis of above investigations the mechanism of the photocurrent generation in the photogalvanic cell may be proposed as follows:

Illuminate Chamber

$$\text{Dye} \xrightarrow{h\nu} \text{Dye}^* \quad \text{(i)}$$

$$\text{Dye}^* + \text{R} \longrightarrow \text{Dye}^- \text{ (semi or leuco)} + \text{R}^+ \quad \text{(ii)}$$

At platinum electrode:

$$\text{Dye}^- \longrightarrow \text{Dye} + e^- \quad \text{(iii)}$$

Dark Chember

At counter electrode:

$$\text{Dye} + e^- \longrightarrow \text{Dye (semi or leuco)} \quad \text{(iv)}$$

$$\text{Dye}^- + \text{R}^+ \longrightarrow \text{Dye} + \text{R} \quad \text{(v)}$$

Here Dye, Dye $^-$, R and R^+ are the dye (methylene blue), its leuco form, reductant (xylose) and its oxidized form, respectively.

Conclusion

On the basis of observed results, conclusively mixed surfactant affected photogalvanic to a large extent. The mixed surfactant have not only enhance the conversion efficiency but storage capacity of photo galvanic cells also and exhaustive efforts still have the scope to enhance electrical output as well as storage capacity of photo galvanic cells along with reduction in there cost to get commercial viability. The conversion efficiency, $t_{1/2}$ and fill factor are recorded as 0.5313%, 100.0 min. and 0.3024 respectively in methylene blue-xylose-NaLS+Tween-80 system.

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