USE OF TOLUIDINE BLUE-EDTA-TWEEN-80 SYSTEM IN PHOTOGALVANIC CELL FOR SOLAR ENERGY CONVERSION AND STORAGE

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Abstract**:** Solar energy conversion and storage was studied through Photogalvanic effect using photogalvanic cells containing Tween -80 as non-ionic surfactant with Toluidine Blue (TB) as photosensitizer and Ethylene diaminetetraacetic acid (EDTA) as reductant. The photopotential and photocurrent and storage capacity for Toluidine blue-EDTA-Tween-80 system were 430mV, 50 µA and 60 minutes. respectively. Conversion efficiency, fill factor, were also determine. The current voltage characteristics of the cell have also been studied. The effect of different parameters on the electrical output of the cell was investigated and a mechanism for the generation of photocurrent in this photogalvanic cell has also been proposed.
Keywords: Photopotential, photocurrent, conversion efficiency, fill factor, storage capacity.

I INTRODUCTION

The role played by energy in social and economic development of any nation is important. Renewable and non-renewable sources are two type of sources in whole world. Solar energy is a renewable source of energy and certainly there is ample supply of solar radiation at the earth surface to meet any conceivable energy need of man in the foreseeable future. It is only continuously reliable and renewable source of energy, and its use, at least now does not present significant pollution and waste disposable problems. The novel approach for renewable sources of energy has led to an increasing interest in photogalvanic cells because of their reliable solar energy conversion and storage capacity. Photogalvanic cell works on photogalvanic effect. The photogalvanic effect was reported by Rideal and Williams [1] but it was systematically studied by Rabinowitch [2] and Clark and Echert [3]. Electron transfer via organic dye for solar energy conversion were reported by Alfred et al. [4]. Conversion of sunlight into electricity by dye sensitized solar cell have also been studied by Quing et al [5] and Hao et al [6]. Study of Solar energy conversion and storage has also been done by Gratzel [7] and Miyasaka[8]. Ameta et al. [9]. Gangotri and Reger [10] Pramila and Gangotri [11], Gangotri and Gangotri [12] Gangotri and Meena [13] have used micelles with different photosensitizer and reductant in developing photogalvanic cells for solar energy conversion and storage. Gangotri and Lal [14]-[15] Lal and Gangotri [16] have studied on mixed dye. Role of surfactant in photogalvanic cell for solar energy conversion and storage studied by Gangotri and Meena [17]. Genwa et.al.[18], Saini et al [19], Gangotri and Solanki [20], Meena and Gangotri[21] Gangotri and Lal [22], koli [23], Meena and Gangotri [24], have been used some more dye in photogalvanic cell containing micelles, reductant and photosensitizers and reported the good amount of electrical output in photogalvanic cell. Toluidine blue is stable and low-cost dye among the dyes, therefore Toluidine blue dye with nonionic surfactant has been selected in the present investigation. The variation of different parameters on electrical output of photogalvanic cell was studied in detail.

II. MATERIALS AND METHODS

Toluidine blue, EDTA, surfactants and Sodium Hydroxide were used in present works. All the solutions were prepared in double distilled water and kept in colored containers to protect from light. H–Shaped glass cell was used containing known amount of photosensitizer toluidine blue, reductant EDTA, surfactant Tween-80 and NaOH.The total volume of mixture solution always kept 25.0 ml. A platinum electrode was dipped into one limb of the cell having window and saturated calomel electrode (SCE) was kept in another limb of the H- Shape tube. The terminal of the electrodes was connected to digital P^H meter. The whole system was first placed in dark and measured the potential till a stable potential was obtained, then the platinum electrode containing limb was exposed to a 200 W tungsten lamp as a light source and the limb containing the SCE was kept in dark. A water filter was placed between the exposed limb and the light source to cut-off infrared radiations.

The photochemical bleaching of Toluidine blue was studied potentiometrically. Potential and current generated by system were measured by the digital pH meter and microammeter respectively. The current voltage characteristics of the cells were studied using an external load with the help of carbon pot (log 470 k) connected in the circuit through a key to have close circuit and open circuit device.

III. RESULT AND DISCUSSION

EFFECT OF VARIATION OF EDTA CONCENTRATION

With the increase in concentration of the reductant EDTA the photopotential is found to be increase till it researches a maximum. on further increase in concentration of EDTA, a decrease in the electrical output of the cell is observed. A maximum photopotential and photocurrent was observed at an optimum value of dye ($2.40x10^3$M). The lesser number of molecule available for electron donation from dye on decreasing the concentration of reductant. the other hand, the movement of dye molecules may be hindered by the higher concentration of reductant to reach the electrode in the desired time limit and it may be the reason for a decrease in electric output.

The effect of variation of the EDTA concentration on the photopotential and photocurrent of EDTA- TB- Tween -80 system is given in **Table-1**

EFFECT OF VARIATION OF TOLUIDINE BLUE CONCENTRATION

It is observed that the photocurrent, photopotential and power are increased with increase in concentration of the photosensitizer. When concentration of dye is increased, excited dye molecule increased near platinum electrode and consecutive electron transfer therefor increase the photopotential, photocurrent and power. On further increase in the concentration of Toluidine blue a decrease in the electrical output of the cell was obtained. A maximum photopotential (430mV) and photocurrent (50µA) and power (21.50 (µW) obtained for a particular value of Toluidine Blue concentration ($4x10^5$M).

The effect of variation of the Toluidine Blue concentration on the photopotential and photocurrent and power of EDTA- TB- Tween-80 system is given in **Table –1**

EFFECT OF VARIATION OF TWEEN-80 CONCENTRATION

In Toluidine blue-EDTA-Tween-80 system it was observed that electrical output of the cell is found to increase on increasing the concentration of tween-80, reaching a maximum value at optimum value of concentration ($2.00x10^3$M). On further increase in their concentration, a fall in photopotential and photocurrent of photogalvanic cell is obtained. The effect of variation of the Tween-80 concentration on the photopotential and photocurrent of EDTA- TB- Tween-80 system is given in **Table – 1**

EFFECT OF VARIATION OF P^H

Photogalvanic cell containing Toluidine Blue-EDTA-Tween-80 system is found to be quite sensitive to the P^H of the solution. It was observed that there is an increase in the photopotential and photocurrent of this system with the increase in P^H value. At P^H 11.80 maximum photopotential is observed. Further increase in P^H there is decrease in photopotential and photocurrent of the system. The effect of variation of P^H on photopotential and photocurrent given in the **Table-1**

Table-1 Effect of variation of the variation of Toluidine blue-EDTA, Tween-80 and P^H

Parameters	Photopotential(mV)	Photocurrent (µA)	Power (µW)
[EDTA] X 10^3M			
1.0	310.0	15.0	4.65
1.6	390.0	32.0	12.48
2.4	430.0	50.0	21.50
3.2	290.0	40.0	11.60
4.0	180.0	26.0	4.68
[Toluidine blue] x 10^5M]			
3.0	280.0	18.0	5.04
3.5	330.0	26.0	8.58
4.0	430.0	50.0	21.50
4.5	380.0	40.0	15.20
5.0	240.0	20.0	4.80
[Tween-80] x 10^3M			
1.2	345.0	32.0	11.04
1.6	380.0	43.0	16.34
2.0	430.0	50.0	21.50
2.5	310.0	30.0	9.30
3.0	280.0	22.0	6.16
P^H			
10.6	215.0	15.0	3.22
11.2	325.0	22.0	7.15
11.8	430.0	50.0	21.50
12.4	345.0	30.0	10.35
13.0	270.0	18.0	4.86

[TB] = 4.00 x 10^{-5}M, [EDTA] = 2.40 x10^{-3}M, [Tween -80] = 2.00 x 10^{-3}M, Light Intensity = 10.4mW cm^{-2}, p^H = 11.80, Temp. 303K

EFFECT OF VARIATION OF ELECTRODE AREA

The effect of electrode area on the current parameters has also been studied. It is observed that the increase in the electrode area, the value of maximum potential (i_{max}) is found to increase. The effect of variation of electrode area on the maximum potential (imax) and Equilibrium Photocurrent (i_{eq}) is graphically represented in fig.1

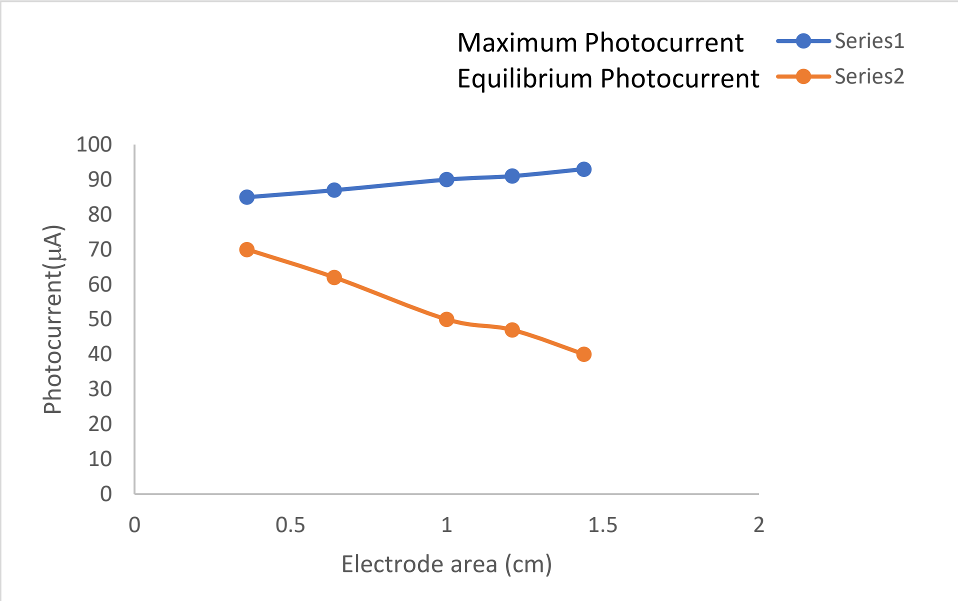

Fig.1 Variation of current parameters with electrode area

EFFECT OF VARIATION OF TEMPRATURE

The photopotential and photocurrent of the photogalvanic cell found to increase with increase temperature with corresponding rapid fall in the photopotential. The effect of temperature on total possible power output in the system is also studied and observed that with increase in temperature the power output of the cell increases slowly irrespective of the rapid fall in photopotential. Observed data is given in **Table-2**

Table-2Effect of temperature

Temperature(K)	Photopotential (mV)	Photocurrent (µA)	Power (µW)
298	450.0	47.0	21.15
303	430.0	50.0	21.50
308	410.0	53.0	21.73
313	390.0	56.0	21.84
318	370.0	59.0	21.83

EFFECT OF LIGHT INTENSITY

The effect of light intensity on the electrical output was studied by using light sources of different intensities (different watts). It was observed that photocurrent showed a linear increasing behavior with the increase in light intensity where as photopotential increases in a logarithmic manner. This increasing behavior of electrical output due to increase in number of photons with increase in light intensity. The effect of variation of light intensity on the photopotential and photocurrent are summarized in **Table -3.**

Table – 3 Effect of light intensity

Light Intensity (mW cm $^{-2}$)	Photopotential (mV)	Photocurrent (µA)	Log V
3.1	360.0	38.0	2.55
5.2	400.0	45.0	2.60
10.4	430.0	50.0	2.63
15.6	480.0	59.0	2.68
26.0	610.0	76.0	2.78

[TB] = 4.00 x10^{-5}M, [EDTA] = 2.40 x10^{-3}M, [Tween-80] = 2.00 x10^{-3}M, P^{H} = 11.80, Temp. 303K

i-V CHARACTERISTICS OF THE CELL

The short circuit current (i_{sc}) and open circuit voltage(V_{oc}) of the photogalvanic cells are measured with the help of a multimeter (keeping the circuit close) and with digital P^H meter (keeping the other circuit open)respectively .The current and potential values in between these two extreme values (i_{sc} and V_{oc}) 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 .It is observed that i-V curve deviated from their regular rectangular shapes. Power Points (where the product of current and potential is maximum) are determine and the fill-factors is calculated by using the formula:

$$\text{Fill factor} = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{oc}}$$

Where V_{pp} and i_{pp} represent the value of potential and current at power point, respectively. V_{oc}, i_{sc} represent open circuit voltage and short circuit current, respectively. The i-V Characteristics for Toluidine blue- EDTA-Tween-80 system is graphically shown in **Fig.2** and observed data of fill factor for this system are reported in **Table-4**

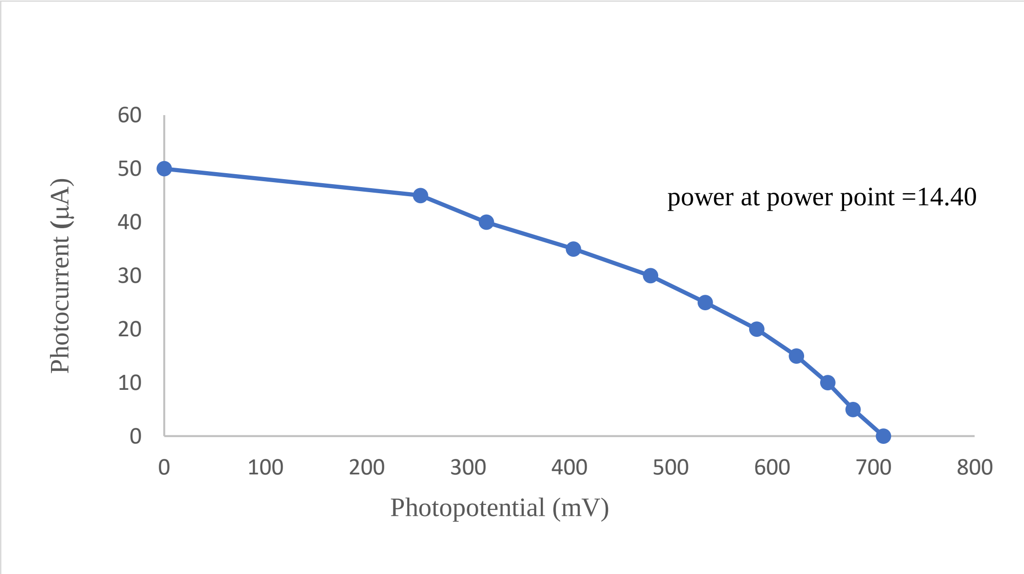

fig-2 current -voltage (i-v) curve for tb-edta-tween-80 system

PERFORMANCE OF THE CELL

The performance is determined in terms of $t_{½}$ i.e., the time required in fall of the output (power) to its half at power point in dark. It is observed that the cell containing with Toluidine blue- EDTA -Tween-80 cell can be used in dark for 60.0 minutes. On the basis of observed results cell than TB TB-EDTA-tween -80 system is more efficient photogalvanic cell from the power generation and performance point of view. The performance of cell is graphically shown in Fig.2

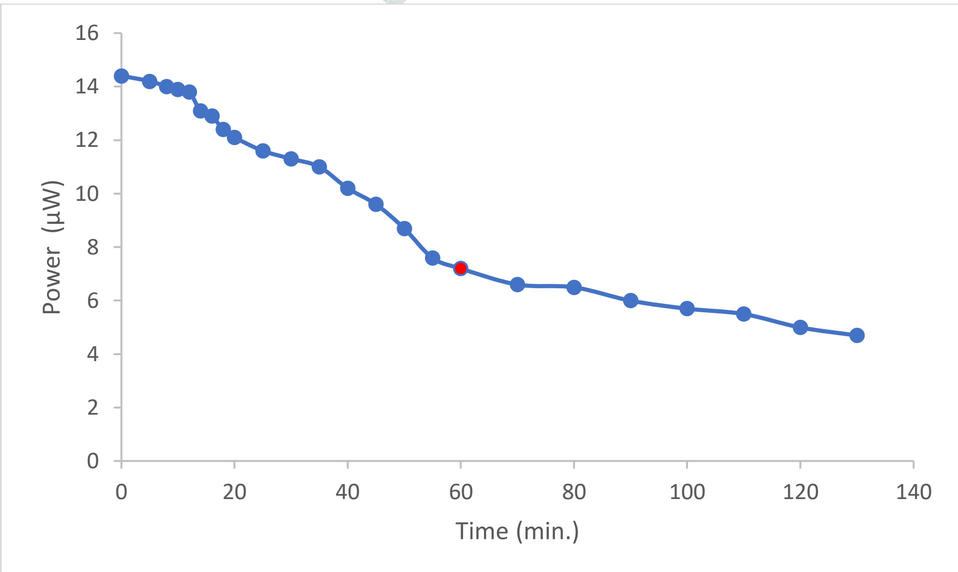

Fig-3 Performance of the cell

CONVERSION EFFICIENCY OF THE CELL

With the help of current and potential values at Power Point (pp) and the incident power of radiations, the conversion efficiency of the cell is determined as 0.1384 % in presence of TB-EDTA-Tween-80 system by using the formula:

$$\text{Conversion Efficiency} = \frac{V_{pp} \times i_{pp}}{10.4\ \text{mW/cm}^2} \text{x}100\%$$

The conversion efficiency and sunlight conversion data for this system reported in **Table-4**

Table-4 electrical parameters of Toluidine blue-EDTA-Tween-80 system

S.no.	Parameter	Observed values in TB-EDTA-Tween-80 system
1	Dark potential	280
2	Open circuit voltage (V_{oc})	710.0Mv
3	Photopotential (ΔV)	430.0mV
4	Short circuit current (i_{sc})	50.0μA
5	Current at power point (i_{pp})	30.0 μA
6	Potential at power point (V_{pp})	480.0mV
7	Equilibrium photocurrent (i_{eq})	50.0μA
8	Maximum photocurrent (i_{max})	90.0μA
9	Charging time	95min.
10	Storage capacity ($t_{1/2}$)	60min.
11	Conversion efficiency	0.1384%
12	Fill factor (η)	0.405
13.	Power at power point	14.40 (μW)

IV MECHANISM

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

$$TB \xrightarrow{h\nu} TB^*$$

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

At platinum electrode

$$TB^- \longrightarrow TB + e^-$$

Dark chamber

$$TB + e^- \longrightarrow TB^- \text{ (semi or leuco)}$$

$$TB^- + R^+ \longrightarrow TB + R$$

Were TB, TB*, TB⁻, R and R⁺ are the Toluidine blue, excited Toluidine blue, semi-or leuco- Toluidine blue, reductant and oxidized form of the reductant, respectively.

V CONCLUSIONS

Photogalvanic cell are cheap due easily availability of dye, reductant and surfactant. Photogalvanic cell works in dark and it is very useful for solar energy conversion and storage.it is concluded on the basis of result that the nonionic surfactant can be used with dye and reductant in photogalvanic cell. Storage capacity point of view TB-EDTA-Tween 80 system is more efficient. Finally, it may be concluded on the above observation that nonionic surfactant with toluidine blue and EDTA used successfully in photogalvanic cell. Cell can be used in dark at its power point for 60 mi. Due to inbuilt storage capacity photogalvanic cell show good prospects of becoming commercially viable. Effort will be made in future to make it more efficient.

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