ASIAN JOURNAL OF PHARMACY & LIFE SCIENCE

MICELLIZATION OF MIX DYE, CELESTINE AND METHYLENE BLUE-EDTA-SODIUM LAURYL SULPHATE SYSTEM FOR THE GENERATION OF ELECTRICITY IN A PHOTOGALVANIC CELL

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ABSTRACT

Celestine and Methylene blue has been used as a photosensitized in photogalvanic cell for solar energy conversion. EDTA was used as an electronic donor (reductant) and sodium lauryl sulphate (surfactant) was used as an anionic micelle for greater photoejection of electrons. The photopotential and photocurrent without surfactant was found to be 692 mV and 71 mV respectively whereas with surfactant their values were found to be 744 mV and 104 µA respectively. The effect of various parameters on the electrical output of the cell has been studied. The current voltage (i-V) characteristics of the cell have also been observed. Performance of the cell was determined in dark at its power point.

KEYWORDS: Celestine and Methylene blue dye, Sodium lauryl sulphate, Photogalvanic cell

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Received: 22/02/2011 Accepted: 23/03/2011

INTRODUCTION

As natural resources are being exhausted at ever-increasing pace and when all natural resources of energy will be completely exhausted then man will have no other alternative then to utilize solar energy. It is not only new, harmless and low cost source of energy but also this alternative source of energy will let us all to overcome energy crisis.

During last decade photochemical production of compounds with high energy had been a fascinating field of research. Davis *et al.*[1] investigated the photoredox reaction of metal ions for photochemical solar energy conversion. An expanded conjugation photosensitizers with two different adsorbing group of cell was investigated by Yao *et al.*[2] Matsumura *et al.*[3] studied sensitization of zinc oxide and TiO_2 electrodes by xanthene dyes and tetraphenyl porphyrins. Zinc and magnesium prophyrins and their polymers as sensitizers had been reported by Minami *et al.*[4] Pichat *et al.*[5] investigated photovoltage determining mechanism in dye sensitized solar cells. Ameta et al.[6] studied use of micelles in photochemical conversion of solar energy using Azur A - Glucose system. Hara et al.[7] design new coumarin dyes having thiophene moities for highly efficient organic dye sensitized solar cells. Dye sensitized photoelectrochemical and solid solar cells, charge seperation transport and recombination was observed by Tennakone *et al.*[8] Alkaitis *et al.*[9] have explained tunneling of photoelectrons from micelles to aqueous phase. Use of toluidine blue-mannitol system in a photogalvanic cell for solar energy conversion was observed by Ameta *et al.*[10]. Efficient dye-sensitized photoelectrochemical cells for the direct conversion of sunlight to electricity has been reported by Kalyansundram et al.[11] Enhancement in power out put of solar cell consisting of mixed dyes was observed by Jana et al.[12] Fruit extracts and ruthenium polypyridine dyes for sensitization of TiO_2 in photoelectrochemical solar cell was reported by Gracia et al.[13] Quaternary self organisation of porphyrine and fullerene units by clusterization with gold nanoparticles on SnO_2 electrode for organic solar cell was studied by Hasobe *et al.*[14]. In the present work we have extended our studies to Celestine and methylene blue dye.

EXPERIMENTAL

Celestine and Methylene blue (Reidel), EDTA (Merck), sodium hydroxide (Qualigens) and sodium lauryl sulphate (Hi media) were used. All the solutions were prepared in double distilled water and kept in amber coloured containers to protect them from light. A mixture of solutions of dye (1.33×10^{-5} M),

EDTA (5.33×10^{-3} M), NaOH water was filled in the H-shaped glass cell. Platinum electrode (1.0×1.0 cm^2) was dipped in one limb of the cell and saturated calomel electrode (SCE) in the other. The platinum electrode was exposed to a 200 W tungsten lamp (Philips) and the limb containing SCE was kept in the dark. A water filter was used to avoid thermal effects. The intensity of the light was measured with the help of a solarimeter (Solarimeter Model 501 CEL) in the units of $mWcm^{-2}$. In another experiment under same conditions NaLS was also added.

The photopotential and photocurrent generated by the system methylene Blue/EDTA/NaLS/OH/hν were measured by a digital conductance multimeter (SYSTRONICS 435) and micro ammeter (Kew) respectively. The current voltage (i-V) characteristics of the cell were studied by using an external load (linear 470) in the circuit. Although a lot of work has been done on use of dye-reductant system in photogalvanic cell but the performance (output) of the cell is low. It was observed that use of surfactant will drastically increase the output of cell. This was the motive behind present work. Anionic, cationic and neutral micelles were used but it was observed that when methylene dye was incorporated into anionic surfactant it will drastically increase the probability of photoejection of electrons. The anionic micelle was found to give better output than the cell without micelles.

Variation of Potential with Time

The potential of cell was determined in dark and then platinum electrode was exposed to light. Change in potential was noted with the period of illumination until it attains a stable value. The variation of potential in the celestine methylene blue-EDTA system with time is given in Table 1.

When light source was removed, the direction of change in potential was slightly reversed and again a stable value was obtained after some time.

Variation of Current with Time

It was observed that current increases with the time of illumination and in few minutes of illumination, it reaches to its maximum. When the source of illumination was removed, a decrease in current was observed. The variation of current with respect to time is given in Table 2

Effect of pH

It was observed that photopotential and photocurrent changes with change in pH. As the pH was increased, there is an increase in photopotential and photocurrent till is reaches a maximum. On further increase in pH, decrease in photopotential and photocurrent is noted. The results of the effect of variation of pH on photopotential and photocurrent are summarized in Table 3.

EFFECT OF DYE AND REDUCTANT CONCENTRATION:

Dependence of photopotential and photocurrent on the concentration of the dye and reductant was studied and the results are summarized in the Table 4 and 5 respectively.

As evident from Table 4 that when concentration of dye is lower the photopotential and photocurrent have lower values because fewer dye molecules are available for excitation and consecutive donation of the electrons to the platinum electrode. When the concentration of dye is increased, photopotential and photocurrent increases due to an increase in the number of dye molecules undergoing excitation and electron donation to electrode.On the other hand, if concentration of dye is further increased, a decrease in photopotential and photocurrent is observed. It is due to fact that only a small fraction of light reaches the dye molecules present near the electrode. Dye molecules present in the bulk of the solution absorb a major portion of the light. Therefore, electron transfer from dye molecules to electrode is retarded, when results in decrease in power output. A maximum photocurrent (71.0 μA) and photopotential (692.0 mV) is generated at an optimum value of dye concentration (1.33×10^{-5} M).

TABLE – 1 VARIATION OF PHOTOPOTENTIAL WITH TIME

[Mix Dye] = 4.00×10^{-5}M Temperature = 303 K

[EDTA] = 5.73×10^{-3}M Intensity = 35.0 mWcm^{-2}

pH:10.6

Time (min.)	**Potential (mV)**
0.0	-221.0 (Dark potential)
5.0	-244.0
10.0	-264.0
15.0	-356.0
20.0	-575.0
25.0	-702.0
30.0	-743.0
35.0	-770.0
40.0	-820.0
45.0	-850.0
50.0	-885.0
55.0	-910.0
60.0	-910.0
65.0 (Light off)	-910.0
70.0	-908.0
75.0	-894.0
80.0	-876.0
85.0	-850.0
90.0	-845.0
95.0	-840.0
100.0	-840.0
105.0	-840.0
110.0	-839.0

TABLE – 2 VARIATION OF PHOTOCURRENT WITH TIME

[Mix Dye] = 4.00 x 10^{-5}M
[EDTA] = 5.73 x 10^{-3}M
pH = 10.6

Temperature = 303 K
Intensity = 35.0 mWcm^{-2}

Time (min.)	Potential (mV)
0.0	0.0
5.0	55.0
10.0	70.0
15.0	93.0
20.0	102.0
25.0	106.0
30.0	109.0
35.0	111.0
40.0	114.0
45.0	117.0
50.0	118.0
55.0	120.0
60.0	120.0
65.0 (Light off)	120.0
70.0	117.0
75.0	113.0
80.0	108.0
85.0	106.0
90.0	105.0
95.0	105.0
100.0	104.0
105.0	104.0
110.0	103.0

TABLE –3 EFFECT OF pH

[Mix Dye] = 4.00×10^{-5}M Temperature = 303 K
[EDTA] = 5.73×10^{-3}M Intensity = 35.0 mWcm^{-2}

pH	Photopotential (mV)	Photocurrent (µA)
10.1	400.0	87.0
10.2	522.0	95.0
10.5	602.0	114.0
10.6	689.0	120.0
10.7	650.0	110.0
10.8	600.0	103.0
10.9	450.0	90.0

EFFECT OF DYE AND REDUCTANT CONCENTRATION:

Dependence of photopotential and photocurrent on the concentration of the dye and reductant was studied and the results are summarized in the Table 4 and 5 respectively.

As evident from Table 4 that when concentration of dye is lower the photopotential and photocurrent have lower values because fewer dye molecules are available for excitation and consecutive donation of the electrons to the platinum electrode. When the concentration of dye is increased, photopotential and photocurrent increases due to an increase in the number of dye molecules undergoing excitation and electron donation to electrode.

On the other hand, if concentration of dye is further increased, a decrease in photopotential and photocurrent is observed. It is due to fact that only a small fraction of light reaches the dye molecules present near the electrode. Dye molecules present in the bulk of the solution absorb a major portion of the light. Therefore, electron transfer from dye molecules to electrode is retarded, when results in decrease in power output. A maximum photocurrent (71.0 µA) and photopotential (692.0 mV) is generated at an optimum value of dye concentration (1.33×10^{-5} M). Similarly an optimum value for reductant concentration (5.33×10^{-3} M) was observed at which maximum power was generated. If concentration of reductant is lower than optimum value, fall in power output has been observed; as very few reductant molecules are available for electron donation to the dye molecules. On the other hand, higher concentration of reductant causes hindrance to dye molecules to approach the electrode in the desired time limit. Thus higher concentration of reductant also results in decrease in power output of cell.

TABLE – 4 EFFECT OF EDTA CONCENTRATION

[Mix Dye] = 4.00 x 10^{-5}M Temperature = 303 K
pH = 10.6 Intensity = 35.0 mWcm^{-2}

[EDTA] x 10^{3} M	Photopotential (mV)	Photocurrent (µA)
4.73	551.0	54.0
4.86	630.0	60.0
5.06	666.0	65.0
5.33	692.0	71.0
5.52	558.0	67.0
5.78	484.0	63.0

TABLE – 5 EFFECT OF MIX DYE CONCENTRATION

[EDTA] = 5.73 x 10^{-3}M Temperature = 303 K
pH= 10.6 Intensity = 35.0 mWcm^{-2}

[Mix Dye]x10^{5} M	Photopotential (mV)	Photocurrent (µA)
0.66	575.0	60.0
1.33	692.0	71.0
2.66	640.0	68.0
4.10	594.0	66.0
5.33	542.0	63.0
6.00	489.0	57.0

EFFECT OF LIGHT INTENSITY

It was observed that the photocurrent shows a linear relationship with an increase in the intensity of light whereas photopotential increases with increasing light intensity in a logarithmic manner. The results are given in Table 6

TABLE – 6 EFFECT OF LIGHT INTENSITY

[Mix Dye] = 4.00 x 10^{-5}M Temperature = 303 K
[EDTA] = 5.73 x 10^{-3}M pH = 10.6

Light intensity (mWcm^{-2})	Photopotential (mV)	log V	Photocurrent (µA)
15.0	573.0	2.7581	55.0
20.0	604.0	2.7810	59.0
25.0	630.0	2.7993	63.0
30.0	661.0	2.8202	66.0
35.0	692.0	2.8401	71.0

TABLE – 7 EFFECT OF DIFFUSION LENGTH

[Mix Dye] = 4.00 x 10^{-5}M Temperature = 303 K
[EDTA] = 5.73 x 10^{-3}M Intensity = 35.0 mWcm^{-2}
pH = 10.6

Diffusion length D_L (cm)	Maximum photocurrent i_{max} (µA)	Equilibrium photocurrent i_{eq} (µA)
1.0	66.0	65.0
1.5	67.0	64.0
2.0	68.0	63.0
2.5	69.0	63.0
3.0	71.0	62.0

The number of photons per unit area (incident power), striking the dye molecules around the platinum electrode, increase with an increase in the light intensity and there is a rise in photopotential and photocurrent. However, an increase in light intensity will also raise the temperature of the cell. Therefore, intensity of medium order (35.0 mW cm^{-2}) was used for all investigation.

EFFECT OF DIFFUSION LENGTH

The effect of variation of diffusion length on current parameters (i_{max}, i_{eq}) was also studied. i_{max} was found to increase as diffusion length was increased but i_{eq} showed negligible small decreasing behaviour with an increase in diffusion length. The results are summarized in Table 7

CURRENT VOLTAGE CHARACTERISTICS OF THE CELL

The open circuit voltage (V_{oc}) and short circuit current (i_{sc}) of this cell was measured from digital pH meter (keeping the circuit open) and from multimeter (keeping the circuit closed), respectively. The electrical parameters in between two extremes were determined with the help of a carbon pot (Linear 470 K) connected in the circuit of the multimeter, through which an external load was applied. The i-V characteristics of the all containing mix dye-EDTA system is shown graphically in Figure 1.The value of potential and current at power point is presented as V_{pp} and i_{pp} respectively. With the help of the i-V curve, the fill factor and conversion efficiency of the cell were determined using the formula,

$$\text{Fill Factor} = \frac{V_{pp} \text{ X } i_{pp}}{V_{oc} \text{ X } i_{sc}}$$

$$\text{Conversion efficiency} = \frac{V_{pp} \text{ x } i_{pp}}{\text{Intensity (m W cm}^{-2}\text{)}} \text{ x } 100\ \%$$

The fill factor and conversion efficiency of the cell was 0.28 and 0.5974 % respectively. The same experiment was performed in the presence of surfactant (NaLS) and the results are graphically represented in Figure 2. Further, the fill factor and conversion efficiency of the cell in this case was calculated as 0.40 and 0.9874%, respectively.

The performance of the cell was studied by applying the external load necessary to have current and potential at power point after removing the course of light. It was observed that the cell can be used without surfactant in the dark at its power point for 25 minutes, and with surfactant it can be used for 32 minutes. The photovoltaic cell cannot be used in the dark even for a second whereas the photogalvanic system has an additional advantage of being used in the dark of course with lower conversion efficiency.

EFFECT OF SURFACTANT CONCENTRATION:

The effect of sodium lauryl sulphate concentration on photopotential and photocurrent in the photogalvanic cell was also studied. The results obtained are shown in Table 10 It was observed that as the concentration of sodium lauryl sulphate was increased that was corresponding increase in photopotential and photocurrent. Further increase in concentration of this surfactant resulted into decrease in the output. The charge of micelle will also play an important role to decide the efficiency of photo ionization process. The negative potential inside the anionic micelle aggregate will favor the process of photo ionization and therefore, it will increase the efficiency of the cell.

TABLE – 10 EFFECT OF NaLS CONCENTRATION

[Mix Dye] = 2.66×10^{-5}M	Temperature = 303 K
[EDTA]= 5.73×10^{-3}M	Intensity = 35.0 mWcm^{-2}
pH = 10.0	

[NaLS] x 10^4 M	Photopotential (mV)	Photocurrent (µA)
-	692.0	71.0
3.33	415.0	101.0
4.00	590.0	102.0
4.66	744.0	104.0
5.33	677.0	103.0
6.00	614.0	101.0

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