THE USE OF SURFACTANT IN PHOTO GALVANIC CELLS FOR SOLAR ENERGY CONVERSION AND STORAGE: A TERGITOL 7 -MANNITOL – METHYLENE BLUE SYSTEM

Dr. (Mrs.) PramilaTanwar

Assistant Professor, DESM National Council of Educational Research and Training
Sri Aurobindo Marg, New Delhi (India)

ABSTRACT

The photo galvanic cell containing Tergitol 7 as micellar species, mannitol as an electron donor and methylene blue as photo sensitizer has been used for solar energy conversion and storage. The electrical output of the cell was 999.0 mV, 85.0, A and 849.15, W respectively as photo potential, as photocurrent and as power at power point of the cell. The current voltage characteristics of the cell has been studied, and observed conversion efficiency was 0.2664 %, determine fill factor was 0.32. The performance of the cell in dark was 45.0 minutes.

***Keywords:* Conversion Efficiency, Mannitol, Methylene Blue, Photocurrent, Photogalvanic Cells, Photopotential, Power Point, Sodium Hydroxide**

I. INTRODUCTION

Fujishima and Honda (1972) were the first to report the photo electrolysis of water using Titanium Oxide; however the evolution of oxygen at illuminated TiO_2- electrolyte interface was observed earlier by Boddy (1968). Derwent and Porter (1981) and Amouyal et al (1980) used CdS and RuO_2 catalyzed hydrogen generation from water. Benemann et al (1973) demonstrated that spinach chloroplasts mixed with ferredoxin and clostridium kluyverihydrogenase evolved hydrogen in the light. Chatterjee et al (1993) have used colloidal Fe_2O_3 particles and studied theirsize effect in the photochemical generation of hydrogen from water, whereas Laurent Jakob et al(1993) have reported vacuum-ultraviolet photolysis of water as means of organic degradation of organic pollutants in aqueous system. Bamwenda et al (1994) used an aqueous solution of ethylene glycol over ultrafine gold supported on TiO_2 for hydrogen production. Tanwar and Gangotri (2007) studied the effect of photogalvanic cell containing Sodium lauryl Sulphate as Micellar Species, Mannitol as reductant and Safranine as photosensitizer were used to study the effect of anionic micelles for solar energy and storage. Genwa, K. R., Kumar, A., and Sonel, A (2009) studied the photogalvanic cells solar energy conversion and storage.

II. EXPERIMENTAL

Stock solutions of Tergitol 7, mannitol, and methylene blue were prepared in doubly distilled water. A mixture of solutions of Tergitol -7(Aldrich),.mannitol (Ases),. methylene blue (Loba. and sodium hydroxide was taken in a glass tube H –shaped cell. The total volume of the mixture should always be 25.0 ml. A platinum electrode (1.0 x 1.0 cm $^{2)}$ was immersed in one arm and saturated calomel electrode (SCE) was kept in other arm. The whole apparatus was placed in dark till stable potential was obtained, then the arm containing the SCE was kept in dark and electrode was exposed to a 200 W tungsten lamp. A water filter was placed to cut off infra–red radiations and to neutralize the thermal effect. A digital pH meter (systronics model 335), and micro ammeter (OSAW, India), were used to measure the potential and current generated by the system respectively.

III. RESULTS AND DISCUSSION

The performance of the photo galvanic cell was observed by applying an external load (necessary to have current at power point) after terminating illumination as soon as the photo potential reaches a constant value. The performance was determined in terms of $t_{1/2}$ i.e. the time required to fall of the power output to its half at power point in dark.

3.1 Characteristics of the Cell

The short circuit current I_{sc} and open circuit voltage V_{oc} of the photo galvanic cell measured with the help of a multimeter (keeping the other circuit closed), and with a digital pH meter (keeping the other circuit open) respectively. The current and potential values between these two extreme values recorded with the help of carbon pot (log 470K) connected in the circuit of multimeter, through which an external load was applied. The current - voltage characteristics of the cell have been studied and with the help of i-v curve, the fill factor of the photo galvanic cell was determined as 0.32 using formula

$$\text{Fill-Factor (n)} = \frac{Vpp \times Ipp}{Voc \times Isc}$$

V_{pp} = potential at power point, I_{pp}, = current at power point, V_{oc} = open circuit voltage, I_{sc} = short circuit current.

3.2 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 was determined as 0.2644 % in the presence of T 7 by using the formula.

$$\text{Conversion efficiency} = \frac{V_{pp} \times I_{pp} \times 100\%}{10.4(\text{mW/cm}^2)}$$

Where V_{pp} = potential at power point and I_{pp}= current at power point.

3.3 Effect of variation of Tergitol T7 concentration

The critical micelle concentration of is 6.0 mM. It was observed that it was necessary to keep the concentration of the surfactant slightly higher or around their critical micelle concentration to obtain the optimum output from the cell. The anionic surfactant shows its maximum electrical output at its critical micelle concentration because at this concentration dye solubilization power is highest, and it provides stability to the system. The observations are reported in Table 1.

Table 1

Effect of Variation of Anionic Micelles, tergitol 7 concentration

[T -7] x 10^3 M	4.6	5.8	6.0	7.2	8.0
Photo potential (mV)	755.0	875.0	999.0	885.0	765.0
Photocurrent (,A)	40.0	72.0	85.0	70.0	35.0
Power(,W)	30.2	63.0	849.15	61.9	26.7

[Mannitol] = 2.0 x 10^{-3}M, [Methylene blue] = 4.0 x 10^{-6}M, pH = 12.8 Light Intensity = 10.4 Wcm^{-2}, Temperature = 303 K

3.4 Effect of Variation of pH

The variation of pH greatly effects the T7-mannitol-metheylene blue system. It is found that maximum value occurs at pH 12.8. it is observed that the pH for the optimum condition has a relation with pKa of the reductant and the desired pH is higher than its pKa value (pH>pKa).

The reason is the availability of reductant in its anionic form, which is a better donor form. At lower or higher pH values, the electrical output decreases. The results are given in Table no. 2.

Table 2

Effect of pH

pH	12.4	12.6	12.8	13.0	13.2
Photo potential (mV)	285.0	590.0	999.0	610.0	300.0
Photocurrent (,A)	60.0	82.0	85.0	75.0	50.0
Power(,W)	17.1	48.3	849.15	45.7	15.0

[Mannitol] = 2.0 x 10^{-3}M, [methylene blue] = 4.0 x 10^{-6} M, [T7] = 6.0 x 10^{-3} M, Light Intensity = 10.4 m Wcm^{-2}, Temperature = 303 K

3.5 Effect of variation of Mannitol concentration

The electrical output of the cell increases with the increase in the concentration of reducing agent till it reaches an optimum value, and then there is a decrease in photo potential and photocurrent while increasing the concentration of the mannitol (reductant). The fall in the concentration of reductant also resulted into a fall in power output. It was found that mannitol (reductant) showed its maximum electrical output at 2.0 x 10^{-3} M concentration due to the availability of fewer reducing agent molecules for electron donation to dye molecules and higher concentration hinder the dye molecules movement towards electrode in desired time limit.The results are summarized in Table 3.

Table 3

Effect of Mannitol concentration

[Mannitol] x 10^3 M	2.0	2.4	2.8	3.2	3.6
Photo potential (mV)	660.0	865.0	999.0	835.0	600.0
Photocurrent (,A)	59.0	78.0	85.0	75.0	52.0
Power(,W)	38.9	67.4	849.15	62.6	31.2

[Methylene blue] = 4.0 x 10^{-6} M, [T 7] = 6.0 x 10^{-3} M, Light Intensity = 10.4 m Wcm^{-2},

Temperature = 303 K, pH =12

3.6 Effect of variation of methylene blue (Dye) concentration

Photo sensitizer (Dye)) shows its maximum electrical output at 4.0 x10^{-6} M concentration. Lower Concentration of dye resulted into a fall in electrical output due to fewer dye molecules are available for the excitation and consecutive donation of the electrons to the platinum electrode. Higher concentration of dye resulted into a fall in electrical output because the intensity of light reaching the dye molecules near the electrode decreases due to absorption of the major portion of the light by dye molecules present in path.

The results are reported in Table 4.

Table 4

Effect of dye concentration

Methylene blue] x 10^6 M	1.6	2.8	4.0	5.2	6.4
Photo potential (mV)	500.0	760.0	999.0	825.0	450.0
Photocurrent (,A)	40.0	66.0	85.0	72.0	30.0
Power(,W)	20.0	50.1	849.15	59.4	13.5

[Mannitol] =2.0 x 10^{-3} M, Light Intensity = 10.4 m Wcm^{-2} , [T 7] = 6.0 x 10^{-3} M

Temperature = 303 K, pH =12.8

A comparision of photogalvanic cells T 7 -mannitol-methylene blue system with mannitol-methylene system is reported in Table No. 5.

Table 5

Performance of the photo galvanic cells in Dark

Anionic Micelle	Power (,W)	$T_{1/2}$ (min.)
T 7-Mannitol-Methylene blue system	32.0	45.0
Mannitol-Methylene blue system (without micelles)	25.0	30.0

3.7 Mechanism

On the basis of the above investigations, the mechanism of photocurrent generation in the photo galvanic cell can be proposed as follows:

Illuminated Chamber

Bulk Solution

Methylene blue Methylene blue* (1)

Methylene blue* + R Methylene blue$^-$ + R$^+$ (2)

At Platinum electrode

Methylene blue$^-$ Methylene blue + e^- (3)

Dark Chamber at counter electrode

Methylene blue + e^- $\longrightarrow$ Methylene blue$^-$ (4)

Methylene blue$^-$ + R$^+$ $\longrightarrow$ Methylene blue + R (5)

Where Methylene blue, Methylene blue*, Methylene blue, R and R$^+$ are dye Methylene blue, its excited forms leuco or semileuco forms, reductant and its oxidized forms, respectively. It may be concluded that the leuco- or semi-reduced forms of dye and dye itself are the main electro active species at the dark chamber. The reductant and its oxidized form behave as an electron carrier in the cell diffusion through the path.

IV. CONCLUSION

The Tergitol 7 -mannitol- methylene blue system was studied by applying the desired external load to have the potential and current corresponding to power point, after removing the source of illumination. It was observed that the performance of the cell in dark is45.0mins. The anionic micelles not only enhances the electrical output of the cell but it also increases the half life and conversion efficiency of the cell.

REFERENCES

[1] Amouyal et al (1980) used CdS and RuO_2 catalyzed hydrogen generation from water. Amouyal, E., Keller, P., and Moradpour,1980.A.J.Chem.Soc.Chem. Comm1019.

[2] Bamwenda et al (1994) used an aqueous solution of ethylene glycol over ultrafine gold supported on TiO_2 for hydrogen production. Bamwenda, G.R.,Tsubota, S.,Kobayashi, T.,and Haruta, M.1994.J. Photochem. Photobiol. A: Chem.77:59.

[3] Benemann et al (1973) demonstrated that spinach chloroplasts mixed with ferredoxin and clostridium kluyveri hydrogen as evolved hydrogen in the light.
Benemann, J.R., Berenson, J.A., Kaplan, N.O. , and Procnatn, M.D. 1973.Acad.Sci.U.S.A. 70: 2319

[4] Chatterjee et al (1993) have used colloidal Fe_2O_3 particles and studied their size effect in the photochemical generation of hydrogen from water.Chatterjee,S.,Sarkar,S.,andBhattacharyya,S.N.1993.J.Photochem.Photobiol. A: Chem.72:183.

[5] The evolution of oxygen at illuminated TiO_2- electrolyte interface was observed earlier by Boddy.
Boddy, P.J., 1968. J. Electrochem.Soc. 115:199.

[6] Derwent and Porter used CdS and RuO_2 catalyzed hydrogen generation from water. Derwent J.R., and Porter, G. 1981. J.Chem.Soc.Chem.Comm. 145.

[7] Fujishima and Honda (1972) were the first to report the photo electrolysis of water using Titanium Oxide; however the evolution of oxygen at illuminated TiO_2- electrolyte interface was observed. Fujishima, I., and Honda, K.1972. Nature. 238: 37

[8] Laurent Jakob et al (1993) have reported vacuum-ultraviolet photolysis of water as means of organic degradation of organic pollutants in aqueous system.

[9] Laurent,J., Hashem, T.M., Burki,S., Nabila,M.,Guindy and Andre, Braun, J. Photochem. Photobiol. A: Chem.75: 97. (1993)

[10] Tanwar and Gangotri have studied the effect ofphotogalvanic cell containing Sodium lauryl Sulphate as Micellar Species, Mannitol as reductant and Safranine as photosensitizer were used to study the effect of anionic micelles for solar energy conversion and storage Tanwar,P., and Gangotri, K.M.,2007. Energy Sources. 1253: 1257.

[11] Genwa, K. R., Kumar, A., and Sonel, A. 2009.Photo galvanic solar energy conversion. Appl. Energy 1431-1436, 86.