Research Journal of Recent Sciences ISSN 2277 - 2502
Vol. **1(ISC-2011),** 117-121 **(2012)** *Res.J.Recent.Sci.*

Optimum efficiency of photogalvanic cell for solar energy conversion and storage containing Brilliant Black PN-Ammonium lauryl Sulphate – EDTA system

Genwa K.R. and Chouhan Anju
Department of Chemistry, Jai Narain Vyas University, Jodhpur, Raj, INDIA

Available online at, www.isca.in
(Received 30th December 2011, revised 5th January 2012, accepted 28th January 2012)

Abstract

Photogalvanic effect was studied in a photogalvanic cell containing Brilliant Black PN as photosensitizer in Ammonium Lauryl Sulphate-EDTA system. A sintered filter was used in H-cell between the diffusion length. In Brilliant Black PN- Ammonium Lauryl Sulphate–EDTA system the photopotential and photocurrent were observed 972.0 mV and 1125.0 μA respectively. The conversion efficiency of the system was observed 3.0490% and fill factor was determined as 0.25. The cell performance (storage capacity) was observed 130.0 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. The mechanism was proposed for the generation of photocurrent in photogalvanic cell.

Keywords, Photogalvanic effect, Brilliant Black PN, ammonium lauryl sulphate, fill factor and conversion efficiency.

Introduction

Energy is accepted as intrinsically linked with environmental, social and economic dimensions of sustainable development. The demand of energy, the consumption of fossil fuels and pollution level are increasing with an alarming rate worldwide. Looking into the seriousness of problem, various stakeholders have now become aware of the urgent need for management of resources and energy conversion activities. The energy consumed in the household sector is perhaps the single largest consumer of energy in the nation's economy.

Our vision is to conversion of solar energy into electrical energy in photogalvanic cell through redox reaction because solar energy is currently high on absolute costs compared to other sources of power such as non –renewable sources. The photogalvanic cell was used as a converter device which converts solar energy (photon) in to electrical energy. It is based on photogalvanic effect. The photogalvanic effect was first observed by Rideal and Williams[1] and it was systematically investigated by Rabinowitch[2-3] and then by other workers[4-9]. Later on studies in photogalvanic cell systems with various sensitizers for solar energy conversion and storage reported time to time[10-15]. Genwa and Coworkers reported some new photogalvanic cells in view of electrical parameters and solar energy conversion and storage[16-20]. Recently, 3G sintered filter between diffusion lengths of H-cell was used and study of Photogalvanic effect and energy efficiency in Photogalvanic cell Composed of Erythrosine as a Photosensitizer in Ammonium Lauryl Sulphate –EDTA system and Study of Electrical parameters and Energy Efficiency in Photogalvanic cell Containing Erythrosine as a Photosensitizer in Benzethonium Chloride –EDTA System investigated[21-22].

Material and Methods

Solutions of EDTA (1.28 x 10^{-3}M), Brilliant Black PN (1.44 x10^{-5}M), Ammonium Lauryl Sulphate (1.56 x 10^{-3} M) and sodium hydroxide were prepared in doubly distilled water and were kept in amber colored containers to protect them from sun light. A mixture of solutions of dye (Brilliant Black PN), reluctant (EDTA ,surfactant (Ammonium Lauryl Sulphate) and sodium hydroxide was taken in an H-type glass tube which is blackened by black carbon paper to unaffected from sun radiation. A shiny platinum foil electrode (1.0 x 1.0 cm^2) was immersed in one limb of the H-tube and a saturated calomel electrode (SCE) was immersed in the other limb. A sintered filter Silica Gel Disc 3 Grade (3 G = 15-40 μ porous sizes of silica granules) was placed in H-tube between diffusion lengths. This filter is used for analytical work with medium precipitates and filtration precipitate can permit selected solution only.

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. Photochemical bleaching of the dye was studied potentiometrically. A digital multimeter (Aplab 41/2 Model no.1087.) was used to measure the potential and current 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 shown in figure-1.

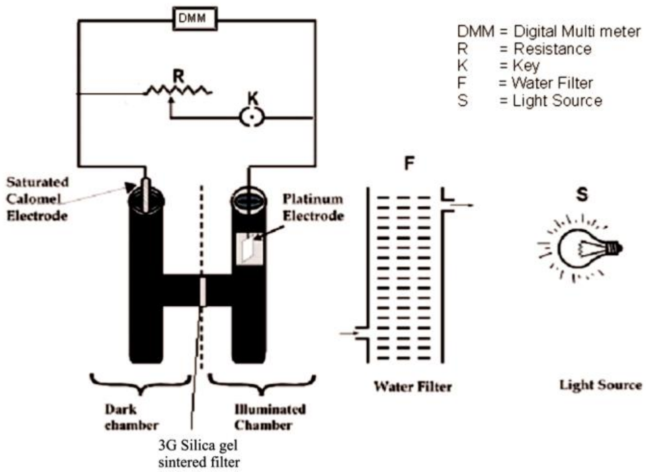

Figure-1
Experimental Set-up

Results and Discusson

Presentation and analysis of Absorption spectra of Photo sensitizer (Black PN): The spectral properties of photosensitizer (Brilliant Black PN) studied with the help of Double Beam UV-VIS Spectrophotometer (Systronics Model no. 106). It was observed that the photosensitize shows absorption peak (λ max) in visible region with maximum at 570 nm. Absorption spectrum of photosensitizes after adding known Concentration of surfactant solution spectra of absorption shift toward longer wavelength is called Red Shift due to Change of concentration of ALS. The concentration of Brilliant Black PN and Ammonium Lauryl Sulphate solution for the experiment were kept at 1.44 x 10^{-5} M and 1.56 x 10^{-3} M respectively .The changes in the spectra can Shown in figure-2.

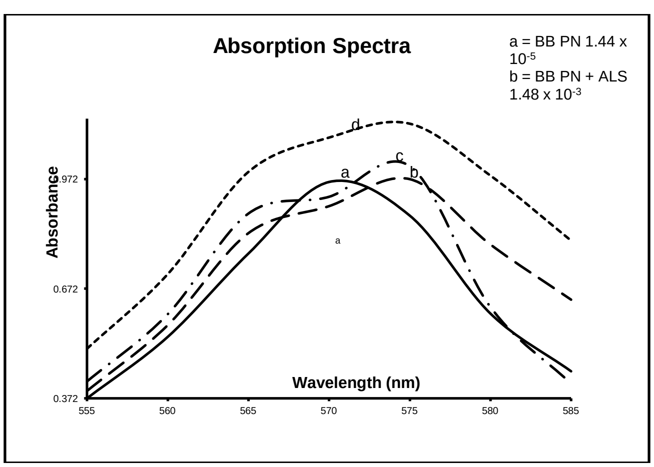

Figure-2
Absorption Spectra of Brilliant Black PN

Effect of variation of Brilliant Black PN Ammonium Lauryl Sulphate, **EDTA concentration and pH:** It was observed that the photopotential and photocurrent increased with increase in concentration of the dye [Brilliant Black PN]. A maxima was obtained for a particular value of dye concentration (1.44 x 10^{-5} M) above which a decrease in electrical output of the cell was observed. On the lower concentration range of dye, there are a limited number of dye molecules to absorb the major portion of the light in the path and, therefore, there is low electrical output, whereas higher concentration of the dye does not permit the desired light intensity to reach the molecules near the electrodes because on further increase the concentration of dye and it act as a filter for the incident light. Preventing sufficient intensity of Light from reaching the dye molecules in the solution Hence the photo bleaching of dye decrease so the result are decreasing there is corresponding fall in the power of the cell.

The electrical output of the cell was increased on increasing the concentration of surfactant [Ammonium lauryl Sulphate]. A maxima was obtained at a certain value of surfactant concentration (1.56x10^{-3}M). On further increasing the concentration of surfactant it react as a barrier and major portion of the surfactant photo bleach the less number of dye molecules so that a down fall in electrical output was observed.

With the increase in concentration of the reductant [EDTA], the Photo potential was found to increase till it reaches a maximum value of EDTA concentration (1.28x 10^{-3}M). On further increase in concentration of EDTA, a decrease in the electrical output of the cell was observed.

The fall in power output was also resulted with decrease in concentration of reductant due to less number of molecules available for electron donation to the cationic form of dye on 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 will also result in to a decrease in electrical output. The results showing the effect of variation of Brilliant Black PN, Ammonium lauryl Sulphate EDTA and pH Photogalvanic cell containing Black PN, Ammonium lauryl Sulphate – EDTA system was found to be quite sensitive to pH of the solution.

The system shows an increase in the photopotential and photocurrent of the cell with increase in pH value (in alkaline range). At pH 11.33 a maxima was achieved. On further increase in pH, there was a decrease in photopotential and photocurrent.

It is quite interesting to observe that pH at the optimum condition for reductant has a relation with its pK_a value, i.e. the desired pH should be slightly higher than their pKa value ($pH = pK_a + 1$ to 3). The results are summarized in table-1.

Table-1
Effect of Variation of Brilliant Black PN, Ammonium lauryl Sulphate EDTA and pH
[EDTA] = 1.28 x 10^{-3} M Temp. = 303 K

Parameters	Photopotential (mV)	Photocurrent (μA)
[Brilliant Black PN] x 10^{-5} M		
1.20	698.0	825.0
1.28	750.0	910.0
1.36	874.0	1015.0
1.44	972.0	1125.0
1.52	855.0	1012.0
1.60	758.0	915.0
1.68	689.0	824.0
[ALS] x 10^{-3} M		
1.44	690.0	830.0
1.48	749.0	918.0
1.52	870.0	1021.0
1.56	972.0	1125.0
1.60	858.0	1019.0
1.64	750.0	913.0
1.68	688.0	822.0
[EDTA] x 10^{-3} M		
1.16	696.0	823.0
1.20	752.0	911.0
1.24	876.0	1022.0
1.28	972.0	1125.0
1.32	853.0	1018.0
1.36	760.0	916.0
1.40	690.0	820.0
pH		
11.27	692.0	827.0
11.29	754.0	912.0
11.31	878.0	1024.0
11.33	972.0	1125.0
11.35	855.0	1020.0
11.37	756.0	918.0
11.39	682.0	825.0

I-V Characteristics of the Cell: The i- V Characteristics of the cell containing Brilliant Black PN, Ammonium lauryl Sulphate, EDTA observed with the help of digital multimeter. The short circuit current (i_{sc}) and open circuit voltage (V_{oc}) of the cells were measured with the help of a multimeter keeping the circuit closed and 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 micrometer, through which an external load was applied. I-V curve is shown in figure-3. It was observed that i-V curve deviated from their regular rectangular shapes. A point in i-V curve, called power point was determined where the product of current and potential was maximum and the fill factor was calculated as 0.25 using formula.

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

Figure-3

Current-voltage (i-v) curve of cell: 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 $t_{1/2}$, 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 130.0 minutes. The Results are represented graphically in Figure-4. Conversion efficiency of the cell was determined as 3.0490% using the formula,

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

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

ILLUMINATED CHAMBER

Dye $\xrightarrow{h\upsilon}$ Dye * ..... (i)

Dye * + R $\longrightarrow$ Dye^- (semi or leuco) + R^+ ..... (ii)

At platinum electrode,

Dye^- $\longrightarrow$ Dye + e^- ...... (iii)

Dark Chamber

At counter electrode,

Dye + e^- $\longrightarrow$ Dye^- (semi or leuco) ...... (iv)

Dye^- + R^+ $\longrightarrow$ Dye + R ...... (v)

Here Dye, Dye*, Dye^-, R and R^+ are the dye (Erythrosine), its excited form , leuco form, reductant (EDTA) and its oxidized form, respectively.

Conclusions

In the system of Brilliant Black PN- Ammonium lauryl Sulphate –EDTA the observation were also taken with simple H-cell (without filter) conversion efficiency was recorded as 1.9939, t1/2 (working period of cell in dark) 110 min., and fill factor 0.24 respectively. In the system of Black PN- Ammonium lauryl Sulphate -EDTA the use of a 3G Silica gel sintered

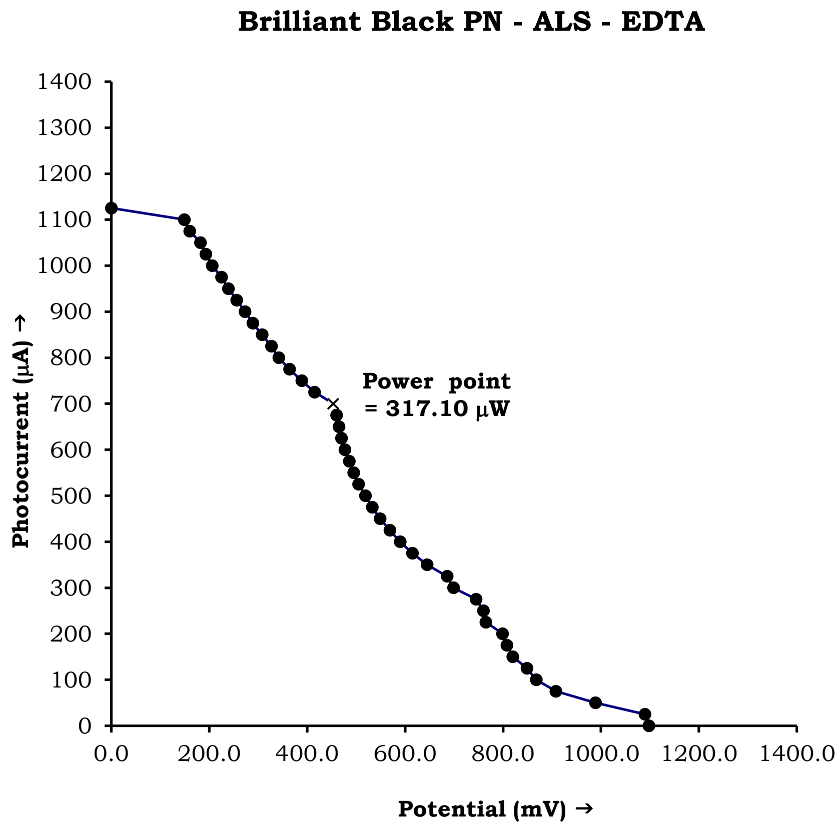

Figure-3 Current-voltage (i-v) curve of cell

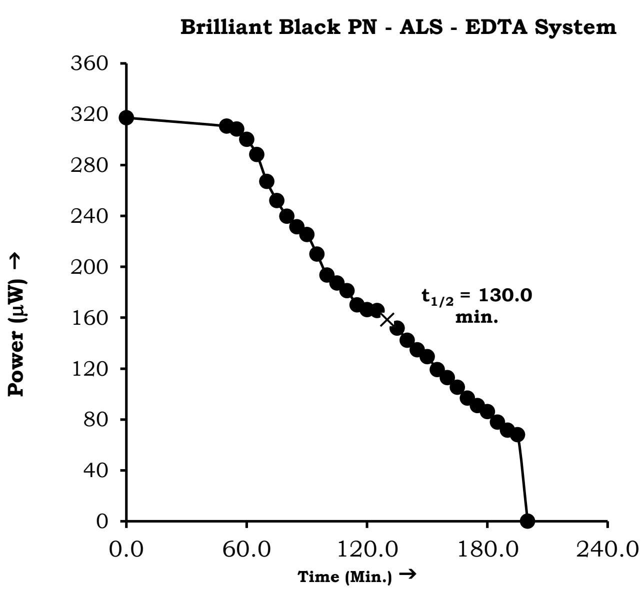

Figure-4
Performance of the cell

(3G 15-40 μ Porous Size of Silica Granules) was placed in H –tube, between diffusion lengths the filter is used for analytical work with medium precipitates and Filtration of fine Grain Precipitates not only enhances the electrical output of the cell but also increases the conversion efficiency and storage capacity.

Acknowledgement

University grant commission New Delhi for financial assistance under the P.D.F –U.G.C. Scheme of (No. F. 31-15) (sc) 2008 / (SA-III) dated 11-9-2009.

References

1. Rideal E.K. and Williams D.C., The action of light on the ferrous iodine iodide equilibrium, *J. of Chem. Soc.*,127, 258-269 **(1925)**

2. Rabinowitch E., The photogalvanic effect I, the photochemical properties of the thionine iron system, *J. Chem. Phy.*, **8,** 551-559 **(1940)**

3. Rabinowitch E., The photogalvanic effect II, the photogalvanic properties of the thionine-iron system, *J. Chem. Phy.*, **8,** 560-566 **(1940)**

4. Potter A.C. and Thaller L.H., Efficiency of some iron-thionine photogalvanic cell, *Solar Energy*, **3,** 1-7**(1959)**

5. Albery W.J. and Archer M. D., The potential of zero current, *Eletrochimica Acta,* **211,**155-1163 **(1976)**

6. Peter D., David R. Hobart N., Litchin N., Hall A. and John E., Sensitization of an iron-thiazine photogalvanic cell to the blue, An improved match to the insolation spectrum, *Solar Energy*, **19,** 567-570 **(1977)**

7. Hall D.E., Wildes P.D. and Lichtin N.N., Electrodic phenomena at the anode of the totally illuminated thin layer iron –thionine photogalvanic cell, *J. Electrochem. Soc*, **125**, 1365-1371**(1978)**

8. Gomer R., Photogalvanic cells, *Electrochimica Acta*, **20,** 13- 20 **(1975)**

9. Nasielsk J., Mesmaeker A. and, Leempoel P.,The photoelectrochmistry of the Rhodamine B-hydroquinone system at optically transparent bubbling gas electrodes, *Electrochimica Acta*, **23,** 605-611 **(1978)**

10. Ameta S.C., Khamesra S., Chittora A.K. and Gangotri K.M., Used of Sodium Lauryl Sulphate in a photogalvanic cell for solar energy conversion and storage, methylene blue –EDTA system, *Int. J. Energy Res.*, **13,** 643-647 **(1989)**

11. Ameta S. C., Khamesra S., lodha S. and Ameta R., Use of thionine- EDTA system in Photogalvanic cell for solar energy conversion, *J. Photochem. Photobiol. A, Chem.*, **48,** 81-86 **(1989)**

12. Dube S., Lodha A., Sharma S.L. and Ameta S.C., Use of an Azur-A-NTA system in a photogalvanic cell for solar energy conversion, *Int. J. Energy Res.*, **17,** 359-363 **(1993)**

13. Gangotri K.M., Meena R.C. and Meena R., Use of miscelles in photogalvanic cells for solar energy conversion and storage, cetyl trimethyl ammonium bromide glucose-toluidine blue system, *J. Photochem. Photobiol. A, Chem*., **123,** 93-97 **(1999)**

14. Gangotri K.M. and Lal C., Use of mixed dyes in photogalvanic cell for solar energy conversion and storage, EDTA methylene Blue and Azur-B system, *Energy Sources part A*, 23**,** 267-273 **(2001)**

15. Gangotri K.M., Gunsaria R.K., Meena R.C., Use of surfactant in photogalvanic cell for solar energy conversion and storage, NaLS-Glycerol- Azur A, Afinidad, **60** 563-567 **(2003)**

16. Genwa K.R. and Chouhan A., Studies of effect of heterocyclic dye in photogalvanic cell for solar energy conversion and storage NaLS -ascorbic System, *J. Chem. Sci.*, **116,** 339-345**(2004)**

17. Genwa K.R. and Chouhan A., Role of heterocyclic dye (Azur A) as a photosensitizer in photogalvanic cell for solar energy conversion and storage, NaLS-ascorbic acid system, *Solar Energy*, **80,** 1213-1219 **(2006)**

18. Genwa, K.R. and Sonel A., An Approach to Solar energy conversion and storage with Malachite Green-Aribnose-NaLS system, *J. Ind. Council Chem*., **24,** 78-81**(2007)**

19. Genwa K.R. and Kumar A., Studies in Nile blue-NaLS System for solar energy conversion and Management, photogalvanic performance and Conversion Efficiency, *J. Ind. Council.Chem.*, **26,** 181-186**(2009)**

20. Genwa K.R., Kumar A. and Sonel A., Photogalvanic solar cell conversion, study with Photosensitizers Toludine Blue and Malachite Green in Presence of NaLS, Appl.Energy, **86,** 1431-1436**(2009)**

21. Genwa K.R., and Chouhan A., Study of Photogalvanic effect and energy efficiency in Photogalvanic cell Composed of Erythrosine as a Photosensitizer in Ammonium Lauryl Sulphate –EDTA system, *J. Ind. Council Chemists*, **28,** 60-64 **(2011)**

22. Genwa K.R. and Chouhan A., Study of Electrical parameters and Energy Efficiency in Photogalvanic cell Containing Erythrosine as a Photosensitizer in Benzethonium Chloride EDTA System, *Energy Sci. and Technol.*, **2,** 18-24**(2011)**