CSCanada
Energy Science and Technology
Vol. 2, No. 1, 2011, pp. 18-24
DOI:10.3968/j.est.1923847920110201.651

ISSN 1923-8460[PRINT]
ISSN 1923-8479[ONLINE]
www.cscanada.net
www.cscanada.org

Study of Electrical Parameters and Energy Efficiency in Photogalvanic Cell Containing Erythrosine as a Photosensitizer in Benzethonium Chloride – EDTA System

Anju Chouhan[1]; K.R. Genwa[1,*]

[1]Department of Chemistry, Jai Narain Vyas University, India
[*]Corresponding author. E-mail: krg2004@rediffmail.com

Brief Introduction of the authors

Dr. K.R.GENWA, Born in 1st August 1969 and received his M. Sc. degree in Chemistry in 1992 and Ph. D. degree in Chemistry in 1994 from Jai Narain Vyas University, Jodhpur, Rajasthan (India). Dr. Genwa has worked as Assistant Professor in Department of Chemistry, Jai Narain Vyas University Jodhpur. He taught Physical Chemistry and presently Dr. Genwa is working as Associate Professor , Jai Narain Vyas University. Jodhpur. He is working in the field of Photochemistry especially in solar energy conversion and storage by use of photogalvanic cells. He has published 30 scientific papers in National and International Journals. He has Completed one Major Research Project on Solar energy conversion funded by UGC, New Delhi.

Dr. ANJU CHOUHAN born in 5th AUGUST 1975 Jodhpur (India) and received her M.Sc. degree in Chemistry in 2000 and Ph. D. degree in Chemistry in 2002 from Jai Narain Vays University, Jodhpur, Rajasthan (India) Dr. Anju Chouhan is PDF- UGC in Department of Chemistry Jai Narain Vyas University. She is working in the field of photochemistry especially in solar energy conversion and storage by use of photogalvanic cell she has published 5 Research papers in national and International Journals she has one project which is PDF- UGC financial support by UGC, New Delhi.

Received 27 March, 2011; accepted 18 April, 2011

Abstracts

Photogalvanic effect was studied in a photogalvanic cell containing Erythrosine as photosensitizer in Benzethonium Chloride EDTA system . A sintered filter was used in H-cell between the diffusion length. In Erythrosine - Benzethonium Chloride - EDTA system the photopotential and photocurrent were observed 890.0 mV and 250.0 μA respectively. The conversion efficiency of the system was observed 0.8282 % and fill factor was determined as 0.33. The cell performance was observed 95.0 minutes in dark. The effects of different parameters on the electrical output of the cell and current-voltage (i-V) characteristics of the cell were studied. A mechanism was also proposed for the generation of photocurrent in photogalvanic cell.

Key words: Photogalvanic effect; Erythrosine; Benzethonium Chloride; Fill factor; Conversion efficiency

Chouhan, Anju, & Genwa, K.R. (2011). Study of electrical parameters and energy efficiency in photogalvanic cell containing erythrosine as a photosensitizer in benzethonium chloride – EDTA system. *Energy Science and Technology, 2*(1), 18-24. Available from: URL: http://www.cscanada.net/index.php/est/article/view/ j.est.1923847920110201.651
DOI: http://dx.doi.org/10.3968/j.est.1923847920110201.651

INTRODUCTION

The production and use of energy is vital to the economics of all countries. The social economics and scientific development are directly linked to the development of energy sources.

These energy sources may be classified as non renewable sources like wood, coal, oil. Non convectional (renewable) sources like solar energy, geothermal energy, wind energy and biomass.

At world level, about 98% power is supplied by non- renewable sources and about 2% is supplied by renewable sources. The photogalvanic cell is a device which converts solar energy into electricity. 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 later by various other workers[4-10]. Hoffman and Litchtin[11] have discussed various problems encountered in the development of this field. A detail literature reveals that different photosensitizers have been used in photogalvanic cell along with reductant and surfactant. Ameta et al.[12-14] used surfactant in photogalvanic cell for solar energy conversion and storage in NaLS –Glycerol – Azur A system and discussed the micellar effect in different photogalvanic cell systems .Dye along with surfactant was studied by Gangotri et al.[15-19]. Comparative Studies in anionic cationic and nonionic Surfactant and Azur B-NTA

–CPC System in photogalvanic cell system were reported by Genwa and Gangotri[20-21] The effect of heterocyclic dyes and photogalvanic effect in photogalvanic cells for solar energy conversion and storage was investigated by Genwa and Chouhan[22-24]. Recently Genwa and Coworkers reported some new photogalvanic cells in view of electrical parameters and solar energy conversion and storage[25-33].

1. EXPERIMENTAL

EDTA (Ases), Benzethonium Chloride (Loba), Erythrosine (Ases) and sodium hydroxide (s.d. fine) were used in the present work. 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, surfactant and sodium hydroxide was taken in an blackened H-type glass tube. 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 4 Grade (4 G = 5-15 μ porous sizes of silica granules) was placed in H-tube between diffusion length. This filter is used for analytical work with fine and very fine precipitates particles are filtered and filter 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 multi meter [Aplab 4 $^{1/2}$ Model 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.

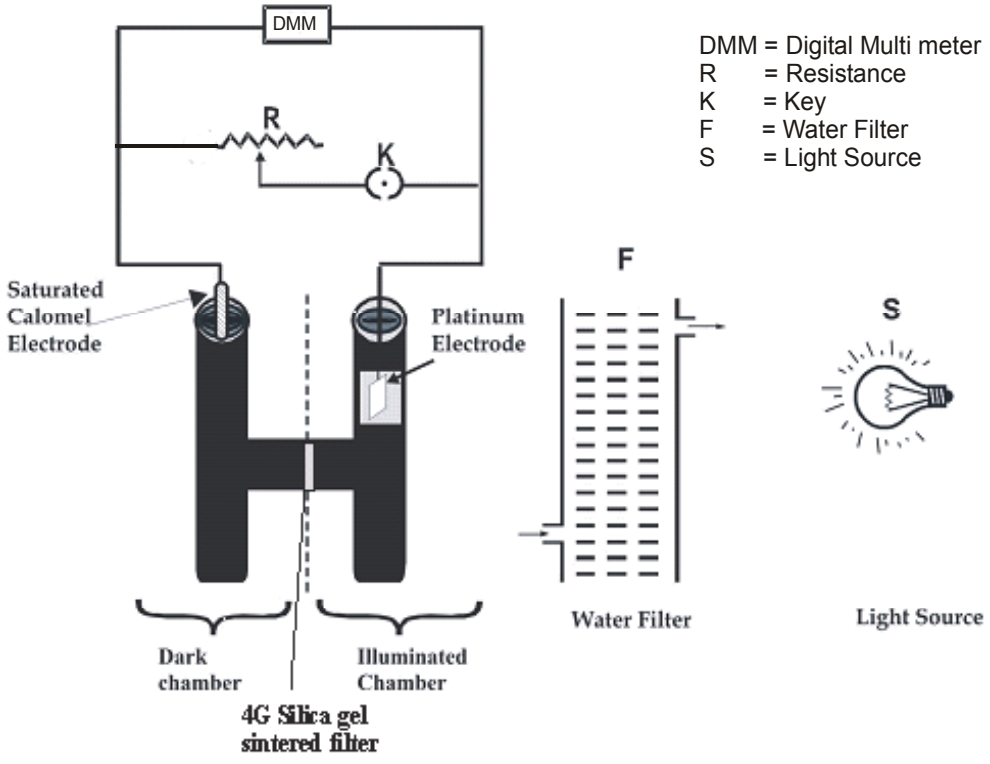
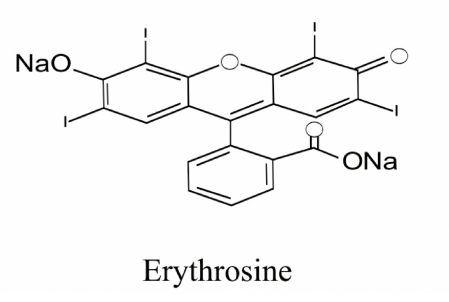
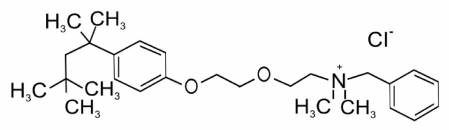


Figure 1
Experimental Set Up

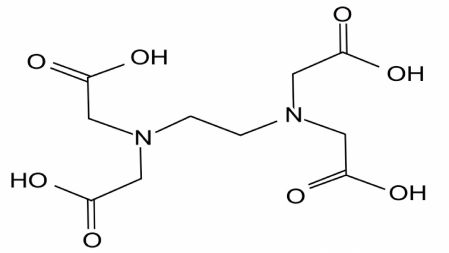
Structure of photosensitzer, surfactant and reductant used :



Erythrosine



Benzethonium Chloride



EDTA

2. RESULTS AND DISCUSSION

2.1 Absorption Properties of photosensitizer surfactant

The spectral properties of photosensitizer (Erythrosine) studied with the help of spectrophotometer (systronics Model 106). It was observed that the photosensitizer shows absorption peak (λmax) in visible region with maximum at 505 nm. Absorption spectrum of photosensitizer surfactant solution was also taken. The concentration of Erythrosine and Benzethonium Chloride solution for the experiment were kept at 1.68 x 10^{-5} M and 1.24 x 10^{-3} M respectively. The changes in the spectra can seen in figure 2 .

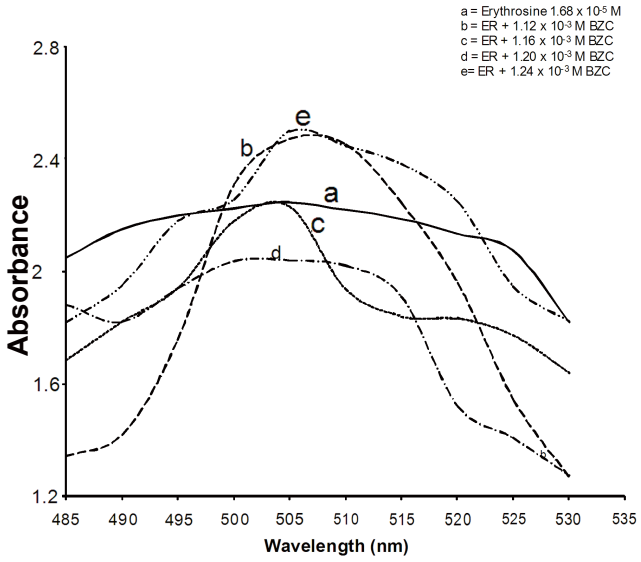


Figure 2
Absorption Spectra of Erythrosine

2.2 Effect of Variation of Erythrosine, Benzethonium Chloride, EDTA Concentration and pH.

It was observed that the photopotential and photocurrent increased with increase in concentration of the dye [Erythrosine]. A maxima was obtained for a particular value of Erythrosine concentration 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 and hence, there is corresponding fall in the power of the cell.

The electrical output of the cell was increased on increasing the concentration of surfactant [Benzethonium Chloride]. A maxima was obtained at a certain value. On further increasing the concentration, a down fall in electrical output was observed.

With the increase in concentration of the reductant [EDTA], the Photopotential was found to increase till it reaches a maximum value. 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.

Photogalvanic cell containing Erythrosine Benzethonium Chloride – 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 13.3 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 pK_a values (pH = pK_a + 1 to 3). The results showing the effect of variation of Erythrosine Benzethonium Chloride, EDTA concentration and pH are summarize in table 1.

Table 1
Effect of Variation of Erythrosine, Benzethonium Chloride, EDTA and pH

Parameters	Photopotential (mV)	Photocurrent (μA)
[Erythrosine] x 10^{-5} M		
1.44	575.0	82.0
1.52	680.0	93.0
1.60	787.0	142.0
1.68	890.0	250.0
1.76	735.0	140.0
1.84	648.0	93.0
1.92	565.0	85.0
[BZC] x 10^{-3} M		
1.12	574.0	82.0
1.16	682.0	91.0
1.20	786.0	113.0
1.24	890.0	250.0
1.28	734.0	142.0
1.32	642.0	96.0
1.36	564.0	87.0
[EDTA] x 10^{-3} M		
1.52	576.0	84.0
1.56	683.0	93.0
1.60	782.0	114.0
1.64	890.0	250.0
1.68	736.0	113.0
1.72	641.0	97.0
1.76	561.0	86.0
pH		
12.4	573.0	83.0
12.7	682.0	94.0
13.0	785.0	145.0
13.3	890.0	250.0
13.6	730.0	140.0
13.9	643.0	94.0
14.2	563.0	88.0

Light Intensity = 10.4 mWcm-2 Temp. = 303 K

2.3 Effect of Diffusion Length and Electrode Area

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. A sintered 4G silica filter was placed between diffusion lengths. 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 summarised in table 2.

Table 2
Effect of Diffusion Length

Diffusion length DL (mm)	Maximum photocurrent i_{max} (μA)	Equilibrium photocurrent i_{eq} (μA)	Rate of Initial generation (μA) min^{-1}
35.0	328.0	255.0	16.4
38.0	334.0	253.0	16.7
40.0	346.0	252.0	17.3
45.0	350.0	250.0	17.5
50.0	355.0	248.0	17.7
52.0	360.0	245.0	18.0
54.0	366.0	244.0	18.3

[Erythrosine] = 1.68 x 10^{-5} M Light Intensity = 10.4 $mWcm^{-2}$
[BZC] = 1.24 x 10^{-3} pH = 13.3
[EDTA] = 1.64 x 10^{-3} M Temp. = 303 K

2.4 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 summarised in table 3.

Table 3
Effect of Electrode Area

Erythrosine – BZC –EDTA system	Electrode Area (cm^2)				
	0.36	0.64	1.00	1.44	1.69
Maximum Photocurrent i_{max} (μA)	338.0	345.0	350.0	355.0	362.0
Equilibrium Photocurrent i_{eq} (μA)	255.0	252.0	250.0	248.0.0	246.0

[Erythrosine] = 1.68 x 10^{-5} M Light Intensity = 10.4 $mWcm^{-2}$
[BZC] = 1.24 x 10^{-3} M pH = 13.3
[EDTA] = 1.64 x 10^{-3} M Temp. = 303 K

2.5 i-V Characteristics of the Cell

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 Multimeter, through which an external load was applied. The i-V characteristics of the cell containing Erythrosine –Benzethonium Chloride – EDTA is given in figure 3.

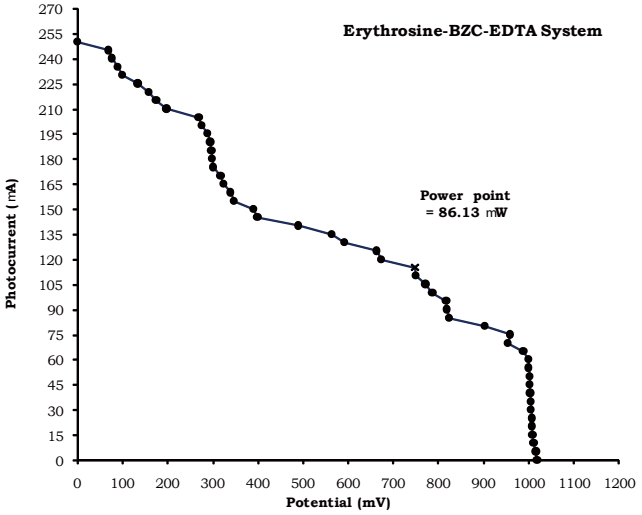


Figure 3
Current-voltage (i-V) Curve of the Cell

It was observed that i-V curve deviated from their regular rectangular shapes (figure. 3). 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 0.33 using 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} are the value of potential and current at power point respectively and V_{oc}, i_{sc} are open circuit voltage and short circuit current respectively.

2.6 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. 4) 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 95 minutes. The conversion efficiency of the cell was determined as 0.8282 % using the following formula:

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

Where is A is electrode area of platinum electrode.

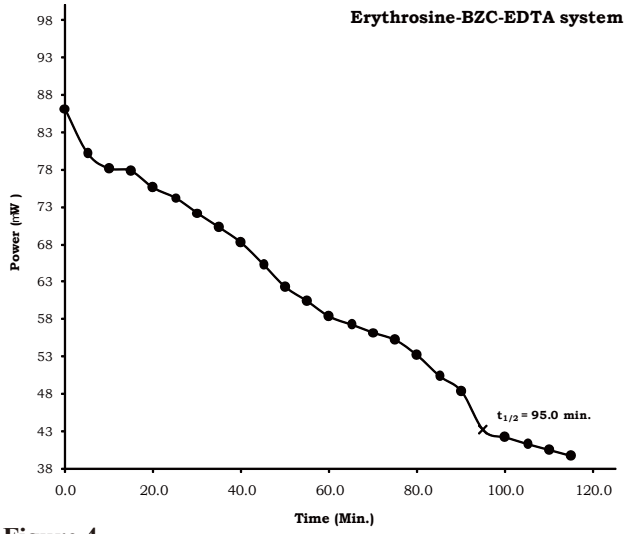


Figure 4
Performance of the Cell

3. MECHANISM

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

ILLUMINATED CHAMBER

$$Dye \longrightarrow Dye^{*} \quad (i)$$

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

At platinum electrode :

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

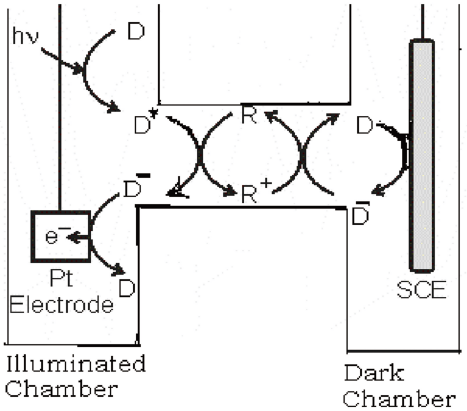
DARK CHAMBER

At counter electrode :

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

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

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



SCE =Saturated Calomel Electrode
D =Dye(Photosensitizer]
R =Reductant
e^{-} =Electron

CONCLUSION

Various forms of solar cells like photoelectrochemical, photovoltaic and photogalvanic cells are studied for harvesting solar energy. Photovoltaic cells are widely used in most countries for conversion and storage of solar energy but owing to their low storage capacity, photogalvanic cells are preferred because they have the added advantage of inherent storage capacity. The use of a 4G Silica gel filter between the diffusion lengths in H-tube not only enhances the electrical output of the cell but also increases the conversion efficiency and storage capacity.

ACKNOWLEDGEMENTS

Authors are thankful to Prof. Mrs. (Dr.) Sunita Kumbhat, Head, Department of Chemistry, J.N.V. University, Jodhpur for providing necessary facilities and one of the author (Anju Chouhan) is grateful to UGC, New Delhi for providing financial assistance under U.G.C. - P.D.F. scheme. (No. F. 31-15(sc) 2008/(SA-III) dated 11-9-2009

REFERENCES

[1] Rideal , E.K. & Williams, D.C. (1925).The Action of Light on the Ferrous Iodine Iodide Equilibrium. *J. Chem Soc, 127,* 258-269.

[2] Rabinowitch, E. (1940). The photogalvanic Effect I: the Photochemical Properties of the Thionine-iron System. *J. Chem Phy, 8*, 551-559.

[3] Rabinowitch, E. (1940).The Photogalvanic Effect II: the Photogalvanic Properties of the Thionine-iron System. *J. Chem Phy, 8,* 560-566.

[4] Potter , A. C. & Thaller, L.H. (1959). Effeciancy of Some iron-thionine Photogalvanic Cell. *Solar Energy, 3*, 1-7.

[5] Goomer, R. (1975). Photogalvanic Cell. *Electrochimica Acta, 20*, 13-20.

[6] Albery, W.J. & Archer, M.D. (1976). The Potential of Zero Current. *Electrochimica Acta, 21*, 1155-1163.

[7] Peter, D., Wildes, David, R., Hobart, Norman, N., Litchin, dale, E., Hall, John, A. & Eckert. (1977). Sensitization of an Iron-thazina Photogalvanic Cell to the Blue: An Improved Match to the Insolation Spectrum. *Solar Energy, 19,* 567-570.

[8] Wildes, P.D & Lichtin, N.N. (1978). Indirect Measurement of Thionine-leucothionine Synproportionation Rate Constant by a Photochemical Perturbation Technique. *J. Phy. Chem, 82,* 981-984.

[9] Murthy, A.S.N., Dak, H.C. & Ready, K.S. (1980). The Photogalvanic Effect in a Riboflavin-ethylenediamin Tetra Acitic acid System. *Int. J. Energy Res, 4*, 339.

[10] Hall, D.E., Wildes, P.D. & Litchin, N.N. (1978). Electrodic Phenomina at the Anode of Totally Illuminated, thin Layer Iron Thionine Photogalvanic Cell. *J. Electrochem. Soc, 125,* 1365-1371.

[11] Hoffman, M.Z. & Lichtin, N.N. (1979). *Solar Energy, 21*, 153.

[12] Ameta, S.C., Gangotari, K.M. Ameta, R., & Dubey, G.C. (1990). Use of Methylene Blue – Mannitol System in Photogalvanic Cell for Solar Energy Conversion. *Acta Ciencia Indica, XIV C,* 35.

[13] Ameta, S.C., Khamesra, Lodha, A. & Gangotari, K.M. (1991). Use of Brij-35 in Photogalvanic Cell for Solar Energy Conversion and Storage: methylene blue-EDTA System. *Chimka Chronicka new series A, 20,* 169.

[14] Ameta, S.C., Gangotri, K.M., & Dubey,T.D. (1990). Use of Tuluidine Blue- Maleic Hyderazide System in photogalvanic cell For Solar Energy Conversion. *Asian J. of Chemistry, 2,* 19.

[15] Gangotri, K.M., Meena,R.C. & Meena Rajni, (1999). 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.

[16] Gangotri, K.M. & Lal, C. (2001). Use of Mixed Dyes in Photogalvanic Cell for Solar Energy Conversion and Storage: EDTA Methylene Blue and Azur-B System. *Energy Sources part A: recovery. Utilization and environmental effects, 23,* 267-273.

[17] Gangotri K.M. and Meena. R.C. 2001. Use of Reducatnt and Photositizer in Photogalvanic Cell for Solar Energy Conversion and Storage: Oxalic acid – Methyline blue system. *J. Photochem. Photobiol. A : Chem., 141,* 175-177.

Gangotri, K.M., Gunsaria, R.K. and Meena, R.C. (2003).

[18] Use of Surfactant in Photogalvanic Cell for Solar Energy Conversion and Storage: NaLS-Glycerol-Azur A. *AFINIDAD, 60,* 563-567.

Gangotri, K.M. & Gangotri, P. (2009). Studies of Micellar

[19] Effect on Photogalvanic: Solar Energy Conversion and Storage in EDTA Safranine O-Tween-80 System. *Energy & Fuels, 23,* 2767-2772.

[20] Genwa, K.R. & Gangotri, K.M. (2004). Comparative Studies in Anionic Cationic and non Ionic Surfactant in Photogalvanic Cells for Solar Energy Conversion and Storage. Point of View: Nitrilotriacidic – Azur B System. *J. Ind. Chem. Soc., 81,* 592-594.

[21] Genwa, K.R. & Gangotri, K.M. (2004). Studies on Photogalvanic Cell Containing Azur B-NTA-CPC System. *J. Ind. Council. Chem., 21,* 21-25.

[22] Genwa , K.R. & Chouhan, A. (2004). Study of Photogalvanic Effect in Azur C NaLS Ascorbic Acid System. *Res. J. Chem. Environ, 8,* 55-58.

[23] Genwa, K.R. & Chouhan, A. (2006). 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.

[24] Genwa , K.R. & Chouhan, A. (2004). Studies of Effect of Heterocyclic Dye in Photogalvanic Cell for Solar Energy Conversion and Storage NaLS -ascorbic System *J. Chem. Sci., 116,* 339-345.

[25] Genwa, K.R., Chouhan, A., Mahaveer, and Prakash, I. (2006).Study of Photogalvanic Cell Containing AZUR

B-NaLS-Ascobic acid System. *J. Indian Chem. Soc., 83,* 799-802.

[26] Genwa, K.R., Mahaveer, and Prakash, I. (2006). Photogalvanic Effect: Comparative Studies in Three Dyes Rhodamine B, methylene Blue and Safranin. *J. Indian Chem. Soc., 83,* 165-167.

[27] Genwa, K.R. & Khatri, N.C. (2006). Role of Azine Dyes as Photosensitizer in Photogalvanic cell: for Solar Energy Conversion and Storage : Brij 35-Safranine-DTPA system *Int. J. Chem. Sci., 4,* 703-712.

[28] Genwa, K.R. & Khatri, N.C. (2007). Brij-35-Bismark Brown – DTPA System In Photogalvanic Cell. *J. Indian Chem. Soc., 84,* 269-272.

[29] Genwa, K.R. & Mahaveer (2008). Photogalvanic Cell: a New Approach for Green and Sustainable Chemistry. *Solar Energy Mat. & Solar Cell., 92,* 522-529.

[30] Genwa, K.R. & Kumar, A. (2009).Studies in Nile blue-NaLS System for Solar Energy Conversion and Management: Phtogalvanic Performance and Conversion Efficiency. *J. Ind. Council Chemist, 26,* 181-186.

[31] Genwa, K.R., Kumar, A. and Sonel, A. (2009). Photogalvanic Solar Cell Conversion: Study with Photosensitizers Toludine Blue and Melachite Green in Presence of NaLS. *Applied Energy, 86,* 1431-1436.

[32] Genwa, K.R. & Sonel, A. (2007). Photogalvanic Cell: Study of Toluidine Blue-Arabinose-CPC System in View of Electrical Parameters. *Bull. Electrochemistry, 23*, 243-246.

[33] Genwa ,K.R. & Khatri, N.C. (2009). Comparative Study of Photosentizing Dyes in Photogalvanic Cells of Solar Energy and Storage: Brij-35-DTPA System. *Energy & Fuels, 23,* 1024-1031.

