STUDY FOR SOLAR ENERGY CONVERSION & STORAGE IN SOLAR CELL: YELLOW 5GN-EDTA SYSTEM

Kanta Meena, Shiv Ram Saini and R.C. Meena

Department of Chemistry, Jai Narain Vyas University,
(Rajasthan Jodhpur), India

ABSTRACT

The photovoltages and photocurrent in photogalvanic cell were studied for conversion and storage of solar energy by using yellow 5GN as a photo sensitizer and EDTA as a reductant. The observed cell performance in terms of photopotential, photocurrent, conversion efficiency, fill factor and storage capacity in terms of half change time are 905.0mV, 450.0μA, 1.45%, 0.5 and 170.0 minutes on irradiation for 140 minutes, respectively. The effects of different parameters on electrical output of the cell were observed and a mechanism has been proposed for generation of the photopotential and photocurrent in photo galvanic cell.

Keywords: Yellow 5 GN, EDTA, photopotential, photocurrent & fill factor

1. INTRODUCTION

Energy is necessary for the survival of life. The solar cells convert sunlight directly in to electricity with acceptable conversion efficiency. The photo galvanic cells are based on some chemical reaction, which rise to high energy products on excitation by photons. This cell works on photogalvanic effect. The photo effects in electrochemical systems were first reported by Becquerel [1]. It has been reported that only negative photo potential should be obtained with carbonyl compounds. The photo galvanic effect was first observed by Rideal and Williams [2], but it was systematically investigated by Rabinowitch [3-4] and later on Suda et al. [5]. K.Jana reported enhancement in the power output of a solar cell consisting of mixed dye [6]. Ameta et al. [7] reported use of toluidine blue nitroloacetic acid (TB-NTA) system in photo galvanic cell for solar energy conversion. They also reported the use of micelles in photo galvanic cell for

solar energy conversion and storage in Azur A Glucose system, Bromophenol-EDTA system and Fluoroscein-EDTA system [8]. Gangotri et al studied the photo galvanic effect in mixed reductants system for solar energy conversion and storage [9]-[11]. Photo galvanic cells containing reductants, surfactants and photosensitizes were reported by Meena et al. [12]- [19]. Present work is the effort to observe the photochemical study of photo galvanic cell containing Orange-G- EDTA system for solar energy conversion and storage.

2. EXPERIMENTAL

The system contains Yellow 5GN, EDTA, NaOH and water, used in the reported system is distilled twice in the laboratory only. All the solutions were prepared in distilled water and the stock solutions of the chemical were prepared by the direct weighting and were kept in a coloured container to protect them from the light. The system was systematically set for photo galvanic studies, which consists of electrochemically treated platinum as electrode and saturated calomel electrode as a reference electrode. The distance between the illuminated and dark electrode is 45 mm. The photosensitive solutions i.e. mixture of solution dye, reductant and sodium hydroxide is filled into an H- shaped glass tube. The cell is either painted black or is covered with a black glaze paper leaving a window in one arm. A Pt electrode of (1.0 * 1.0 cm^2) is dipped into one arm and in another arm saturated calomel electrode (SCE) was placed. Terminal of the electrode are connected to a digital pH meter (systronics) to measure the photopotential and the current is measured by the micrometer (OSAW INDIA). The system is then exposed to source of light (tungsten lamp 200W). A water filter is used to avoid thermal effect of light.

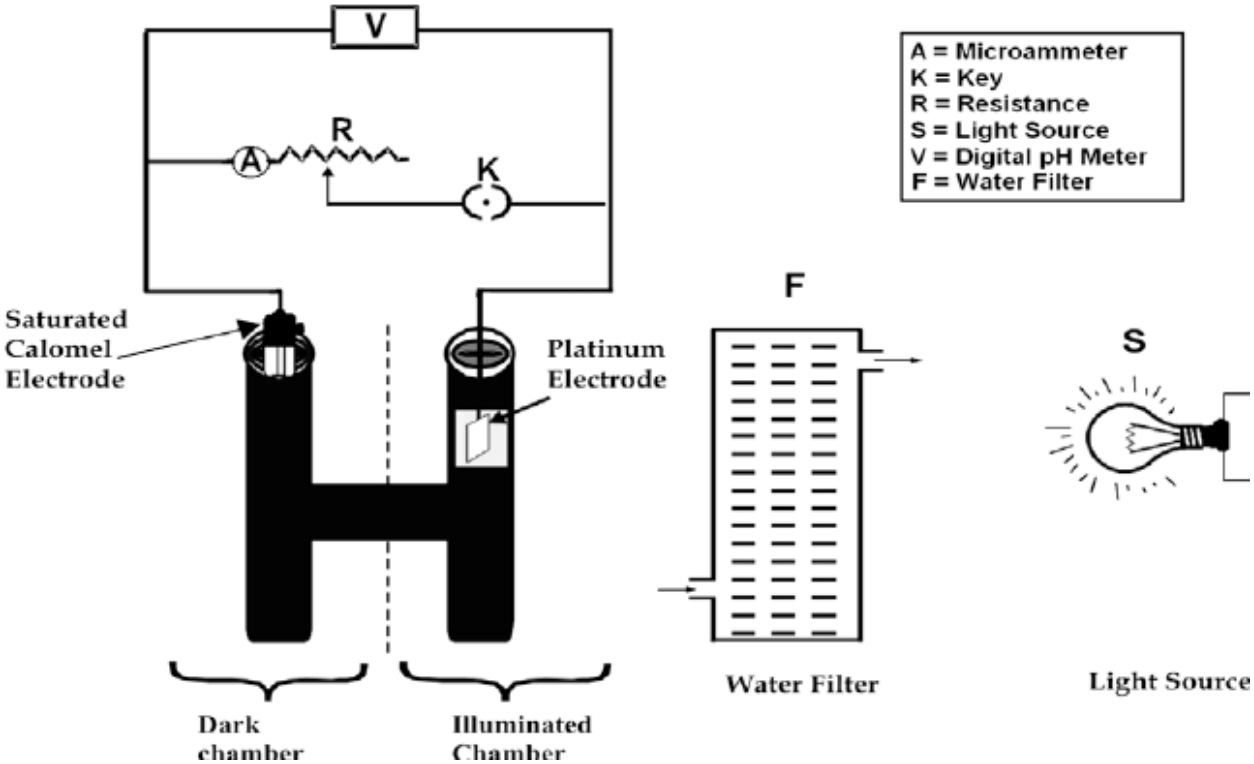

Figure - 1 Experimental Set up

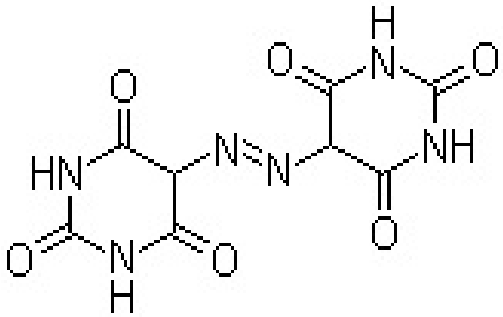

Figure - 2 Yellow 5GN

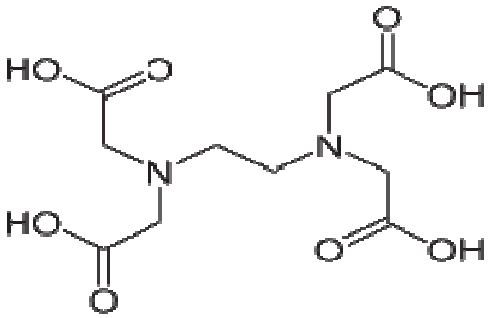

Figure - 3 EDTA

3. RESULT & DISCUSSION

3.1 STUDY OF VARIATION IN YELLOW 5 GN DYE

Study of variation of dye concentration is founded that the photopotential and photocurrent were increase with the increase in concentration of the dye (Yellow 5GN). A maximum was obtained for a particular value of yellow 5 GN concentrations, above which decrease in the electrical output of the cell was obtained. The results are shown as below in table-1

Table – 1 Study of Variation Yellow 5GN

pH=12. Light intensity=10.4mW cm^{-2} Temp. =303K

Concentration(M)	$1.2*10^{-5}$	$1.6*10^{-5}$	$2.4*10^{-5}$	$2.8*10^{-5}$	$3.2*10^{-5}$
Photopotential(mV)	842	909	941	901	843
Photocurrent (μA)	228	250	275	248	213
Power(μW)	191.9	227.2	258.7	223.4	179.4

3.2 STUDY OF VARIATION IN (EDTA) REDUCTANT

On increasing the concentration of reductant (EDTA), keeping constant the concentration of photosensitizer the cell output was found to increase and reached to a maximum value and then decreased on further increased the concentration. The fall in electrical output at lower concentration of reductant is due to less no. of molecules available for electron donation and the higher concentration may hinder the movement of dye molecules towards electrode in a desired time limit. The results are shown as below in Table-2

Table – 2 Study of Variation (EDTA) Reductant

pH=12 Light intensity=10.4mW cm^{-2} Temp. = 303K

EDTA ($2.80*10^{-5}$)	2.22	2.54	2.82	3.12	3.42
Photopotential(mV)	834	889	941	901	827
Photocurrent(uA)	219	244	274	247	217
Power (μW)	182.6	216.9	557.8	222.5	179.4

3.3 STUDY OF VARIATION IN PH

Study of variation in pH on photoelectric parameters of cell is observed that the cell containing Yellow 5GN to be quite sensitive to the pH of the solution. It was observed that the system works effectively in strong alkaline range. The working range was (pH 10.0 – 12.0). Photopotential of the system was found to increase as the pH increased, and after reaching the maximum pH value, it decreases on further increasing the pH. The results are shown as below in Table-3

Table – 3 Study of Variation pH

pH=12. Light intensity=10.4mW cm^{-2} Temp. = 303K

PH	11.6	12.0	12.4	12.8	13.2
Photopotential(mV)	824	905	941	898	836
Photocurrent(uA)	217	251	274	259	222
Power (μW)	178.8	227.1	257.8	232.5	185.5

3.4 STUDY OF VARIATION IN DIFFUSION LENGTH

The effect of variation of diffusion length (distance between the two electrodes) on the current parameters of the cell (i_{max}, i_{eq} and initial rate of generation of photocurrent) was studied using H-shaped cells of different dimensions. It was observed that with an increase in diffusion length, i_{max} and rate (μA $min,^{-1}$) both showed an increase but the i_{eq} showed a negligibly length. So virtually, it may be considered as unaffected by the change in diffusion length. The results are shown as below in Table-4

Table – 4 Study of Variation Diffusion length

S.No	Variation in diffusion length (mm)	Maximum photocurrent (i_{max}) μ A	Equilibrium photocurrent (i_{eq}) μA	Rate of generation of current uA (min^{-1})
1.	35.0	90.5	106.5	38.04
2.	40.0	102.0	104.2	40.05
3.	45.0	109.3	104.3	41.25
4.	50.0	114.9	104.2	45.33
5.	55.0	119.3	104.3	47.85

3.5 STUDY OF VARIATION IN TEMPERATURE

It was observed that the photocurrent of the photo galvanic cell is found to be increased with the temperature whereas the photo potential decreased. This is because the internal resistance of the cell decreases at higher temperature, which results in rise in photocurrent, and also there will be a fall in photo potential. The results are shown as below in Table-5

Table – 5 Study of Variation Temperature

S. No	Temperature	Photopotential (mV)	Photocurrent(μA)
1.	293	940	90
2.	298	932	92
3.	303	850	96
4.	308	905	110
5.	313	810	130

4. PERFORMANCE OF THE CELL:

Performance of the cell was determined at its power point. It was determined from the rate of fall in power of the cell after the illumination is stopped. An external load was applied to have current and potential values equivalent to the value at power point. Then the time taken to reach the half of the value at power point was noted down. This is termed as $T_{1/2}$ and is actually the measure of the performance of the cell in dark (the storage capacity of the cell).

Fill factor of the cell was determined by using the following formulae –

$$\text{Fill Factor} = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}} \quad \text{.....[E1]}$$

= 0.50

Where i_{pp} and V_{pp} are the photo current and photo potential at power point. V_{oc} and i_{sc} are the Photopotential of open circuit and photocurrent at short circuit.

5. CONVERSION EFFICIENCY OF THE CELL:

Conversion efficiency of the cell was calculated with the help of current and potential values at the power point and the intensity of light. It is defined as the efficiency of the cell to convert light energy in to electrical energy.

The following formula was used.

$$\text{Conversion Efficiency} = \frac{V_{pp} \times i_{pp}}{} \quad \text{.....[E2]} \quad \times 100\%$$

10.4 Mw/Cm^2

1.4488

Table – 6 Observation table of Yellow 5GN

SNo. Observations	Values
1. Dark potential	322 mV
2. Open circuit voltage (VOC)	1422 mV
3. Photopotential (V)	1100 mV
4. Equilibrium Photocurrent(i_{eq})	270 mA
5. Maximum photocurrent (i_{max})	300 μA
6. Initial generation of photocurrent	25.45 min
7. Time of illumination	210 min
8. Storage capacity	80 min
9. % Storage Capacity ($t_{1/2}$)	57.14 %
10. Conversion efficiency	1.4488 %
11. Fill factor (η)	0.50

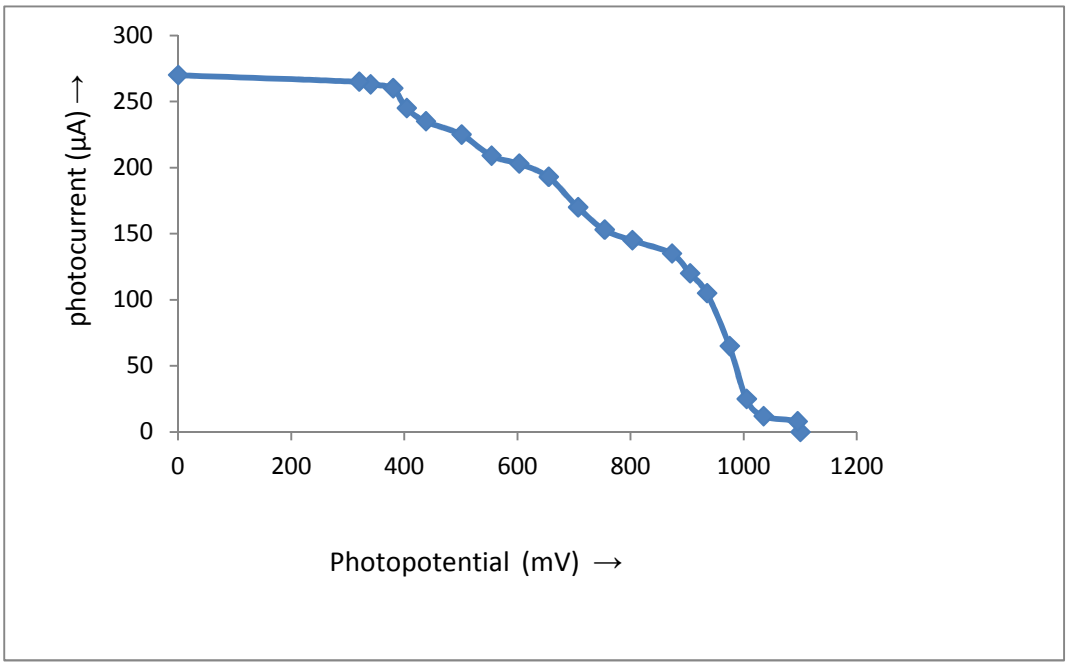

Figure – 4; -* Current-*Voltage (i-v) curve of the cell

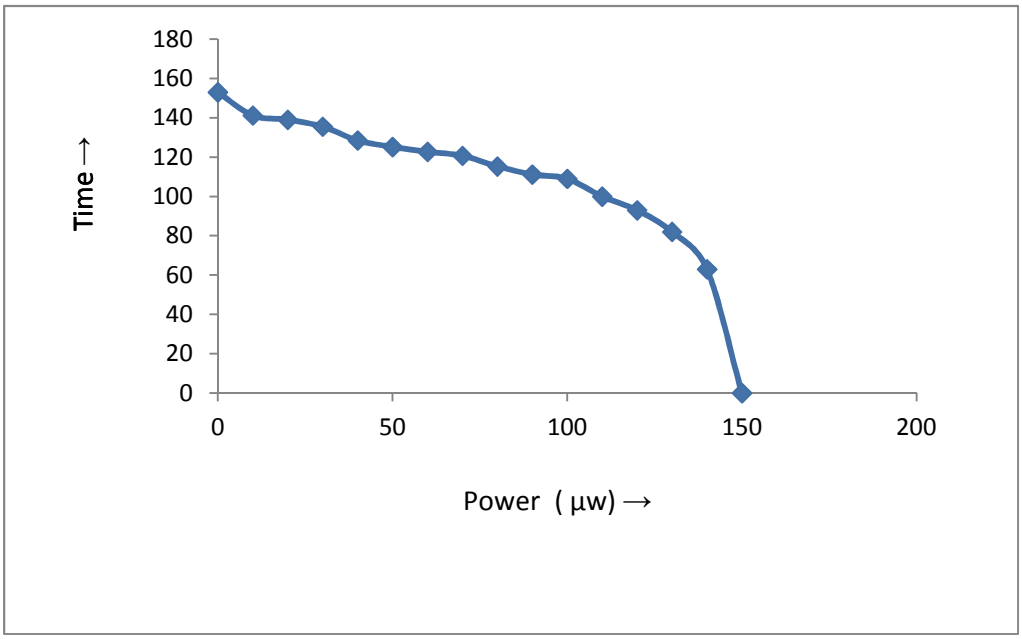

Figure – 5; - The performance of photo galvanic cell

6. MECHANISM

On the basis of these observations the suggested mechanism for generation of photocurrent in photogalvanic cells is:-

Dye → Dye*

Dye* + R → dye^- (semi or leuco) + R*

At Pt electrode

Dye^- → Dye + e^-

Dark chamber

Dye + e^- → Dye^- (semi or leuco)

Dye + R → Dye + R

Where Dye, Dye*,dye^-,R and R^+ are the dye, excited form of dye, semi or leuco dye, reductant and oxidized form of the reductant respectively.

7. CONCLUSION

On the basis of the results, it is concluded that Yellow 5GN and EDTA can be used successfully in a photogalvanic cell. The conversion efficiency and storage capacity of the cell is 1.4488 % and 150 minutes respectively, on irradiation for 210 minutes developed photogalvanic cell. It has been observed that the reductant has not only enhanced the electrical parameters (i.e. photopotential, photocurrent and power) but also enhanced the conversion efficiency and storage capacity of photogalvanic cell. The efforts are also successful because of the photogalvanic cells showed good prospects of becoming commercially viable.

8. ACKNOWLEDGEMENT

The authors are thankful to the Head Department of Chemistry Jai Narain Vyas University Jodhpur Rajasthan (342005) for providing the necessary laboratory facilities to conduct this research work and also thankful to UGC New Delhi India for providing RGNF for financial support to this research work.

9. NOMENCLATURE

I_{eq} = photocurrent at equilibrium

I_{max} = maximum photocurrent

I_{pp} = photocurrent at power point

I_{sc} = short circuit current

mv = millivolt

m = molarity

pp = power point

$t_{1/2}$ = storage capacity of cell

Dv = observed photopotential

Voc = open circuit voltage

Vpp = photo potential at the power point

n = fill factor

µA = microampere

µW = microwatt

REFERENCE

1. E. Becquerel, "on electron effects under the influence of solar radiation" C.R. Acad. Sci. Paris, 9,561, (1839)

2. E.K Rideal and E.G Williams, "The action of light on the ferrous iodine equilibrium" J. Chem. Soc. Trans., 127, 258-269, (1925)

3. E. Rabinowitch, "The photogalvanic effect 1: the photochemical properties of the thionine- iron system" J. Phys. Chem., 8, 551-559, (1940)

4. E. Rabinowitch, "The photogalvanic effect II: the photogalvanic properties of the thionine-iron system" J. Phys. Chem., 8, 560-566, (1940)

5. Y. Suda, Y.Shimoura, T. Sakata and H. Tsubomura, "Photogalvanic effect in the thionin iron system at semiconductor electrodes" J. Phys. Chem., 82,268-271, (1978)

6. A.K. Jana, "solar cells based on dyes. J. Photochem. Photobiol", 132, 1-17, (2000)

7. S.C.Ameta, S. Khamesra, A.K.Chittora and K.M.Gangotri, "Uses of sodium lauryl sulphate in a photogalvanic cell for solar energy conversion and storage methylene blue – EDTA system'' Int. J. Energy 13(6), 643- 647, (1989)

8. S.C. Ameta, S. Khamesra, Lodhas and Ameta, “Use of thionin-EDTA system in photo galvanic cell for solar energy conversion’’ Res. J. Chem. Sci.,” 48(1), 81-86, (1989)

9. K.M. Gangotri, R.C. Meena, “Use of reductant and photo sensitizer in photogalvanic cells for solar energy conversion and storage: oxalic acid–methylene blue system” J. Photochem. Photobiol. A. Chem., 141, 175-177, (2001)

10. K.R. Genwa and M. Genwa, “Photogalvanic cell: A new approach for green and sustainable chemistry” Sol. Energy Mater. Sol. Cells,” 92(5),522-529, (2008)

11. K.M. Gangotri and V. Indora, “Studies in the photogalvanic effect in mixed reductants system for solar energy conversion and storage: Dextrose and Ethylenediamine tetra acetic acid– Azur A system” Sol. Energy, 84, 271-276, (2010)

12. M. Chandra and R.C Meena, “Role of Photo sensitizer for generation of Electrical Energy in Photo Galvanic Cell” Int. J. Chem. Sci., 8(3), 1447-1456, (2010)

13. M. Chandra and R.C Meena, “Solar Cell consisting of photosensitizer- reductant for generation of electrical Energy” J. Chem. & Pharm. Res., 3(3), 264-270, (2011)

14. M. Chandra A. Singh, and R.C. Meena, “Role of Rose-Bengal- Mannitol System for generation of energy in photogalvanic cell” Int. J. Phys. Sci., 7(42), 5642-5647, (2012)

15. P. Koli, U. Sharma, K.M. Gangotri, “Solar energy conversion and storage, Rhodamine B-Fructose photogalvanic cell” Renew. Energ., 37(1), 250-258, (2012)

16. A.S. Meena, P.L. Meena, M Chandra, R. Meena, Shribai and R.C. Meena, “Electrochemical studies of anionic and cationic surfactants in photogalvanic cell for solar energy conversion and storage’’ Int. J. Electr. Eng. Technol., 4(4), 180-187, (2013)

17. A.S Meena, Rishikesh, Shribai and R.C. Meena, “Photochemical studies of micelles in photogalvanic cell for solar energy conversion and storage’’ Int. J. Adv. Res. Eng. Technol., 4(6), 17- 26, (2013)

18. A.S Meena, Rishikesh, Shribai and R.C. Meena, “Electrochemical studies of anionic and cationic surfactants in photogalvanic cell for solar energy conversion and storage” Int. J. Electr. Electron. Telecomm. Eng., 4(2),180-187, (2013)

19. R.C. Meena, Neelakshi and Manju, “Studies on conversion and storage of solar energy in photogalvanic cells: Congo red and Glycerol system, Int. Chem. Pharm. Sci., 2(2), 612-616, (2014)

20. S.Meena, S.R. Saini and R.C. Meena, “Role of photosensitizer (orange - G) in photo galvanic cell for generation of solar energy” Int. J. Eng. Sci. res. Technol., 4(2),135-141, (2015)

21. S.Meena, S.R. Saini and R.C. Meena, “Studies of surfactant and photosensitizer in photo cell for solar energy conversion and storage: methyl violet nals and EDTA system” Int. J. Adv. Eng. Res. Technol., 3(1),11-20, (2015)