ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

ROLE OF PHOTOSENSITIZER (ORANGE-G) IN PHOTOGALVANIC CELL FOR GENERATION OF SOLAR ENERGY

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ABSTRACT

The Orange-G is used as photo sensitizer with EDTA as reductant for the enhancement of the conversion efficiency and storage capacity of photo galvanic cell for its commercial viability. The observed value of the photo generation of photo potential was 932.0mV and photocurrent was 265.0 µA. The observed power at power point was 156.40 mW and the conversion efficiency was 1.50 %. The fill factor 0.5035 was observed experimentally observed at the power of the cell. The photo galvanic cell that developed can work for 140 min in dark. The storage capacity of the cell is 60.8%. The effect of different parameters on electrical output of the cell was observed. A mechanism has also been proposed for the generation of the photocurrent and photo potential in photo galvanic cell.

KEYWORDS: Orange-G, Photo potential, Photocurrent, EDTA and Fill Factor.

INTRODUCTION

Energy is the soul of life. All forms of life require energy to grow and survive. Solar energy is an abundant energy resource. The direct use of solar energy produces no green house gases, and it has the potential to displace large quantities of fossil fuels. So the use of solar energy as a renewable alternative has been gaining serious attention as future energy resources. The photo effects in electrochemical systems were first reported by Becquerel [1]. It has been reported that only negative pphotopotential 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 photosensitizers were reported by Meena et al. [12]-[17].Persent work is the effort to observe the photochemical study of photo galvanic cell containing Orange-G- EDTA system for solar energy conversion and storage.

EXPERIMENTAL

Orange-G (MERCK), EDTA (MERCK) and NaOH (MERCK) were used in the present work. The stock solutions of all chemicals were prepared by direct weighing, in doubly distilled water and were kept in colored container to protect them from light. The system was systematically set for photo galvanic studies, which consists of electrochemically treated platinum as electrode and saturated calomel electrodes as a reference electrode. The distance between the illuminated and dark electrode is 45 mm. A tungsten lamp of 200 W was used as light source. Water filter was used to cut-off IR radiations. The photo potential was obtained as the difference between the initial potential of the system in dark and the equilibrium potential attained by the system under constant illumination. First of the potential measured in dark and the change in potential on illumination was measured as a function of time. Solutions of dye, reductant, and sodium hydroxide were taken in an H-type glass tube. A platinum electrode (1.0 x 1.0 cm2) was immersed into one arm of H-tube and a saturated calomel electrode (SCE) was kept in the other. The whole system was first placed in dark till a stable potential was obtained and then, the arm containing the SCE was kept in the dark and the platinum electrode was exposed to a 200 W tungsten lamp. A water-filter was used to cut off infrared radiations. A digital pH meter (Systronics Model-111) and a microammeter (Ruttonsha Simpson) were used to measure the potential and current generated by the system, respectively. The experimental set-up of

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

photogalvanic cell is given in Figure 1. The effect of variation of different parameters has also been observed.

RESULT AND DICUSSION

EFFECT OF VARIATION OF DYE (ORANGE-G) CONCENTRATION ON THE CELL:

It is founed that when concentration of dye increased, the photopotential and photocurrent were increased with it. A maximum was obtained for a particular value of Orange-G concentrations, above which a decrease in the electrical output of the cell was obtained. The reasonof the change in electrical output is that lower concentration of photosensitizer resulted into a fall inelectrical output because fewer photosensitizer (Orange-G) molecules are available for theexcitation and consecutive donation of the electrons to the platinum electrode whereas the higherconcentration of photosensitizer (Orange-G) again resulted into a decrease into electrical outputas the intensity of light reaching the dye molecules near the electrode decrease due to absorption ofthe major portion of the light by dye molecules present in the path. The results are given in Table 1.

EFFECT OF VARIATION OF REDUCTANT (EDTA) CONCENTRATION ON THE CELL:

Effect of variation of reductant concentration is that the photopotential and photocurrent were found to increase with the increase in concentration of the reductant [EDTA], till it reaches a maximum. On further increase in concentration of EDTA, a decrease in the electrical output of the cell was observed. The reason ofthe change in electrical output is that the lower concentration of reducing agent resulted into a fall inelectrical output because fewer reducing agent molecules are available for electron donation photophotosensitizer (Orange-G) molecule whereas the higher concentration of reducing agent againresulted into a decrease in electrical output, because the large number of reducing agent molecules hinders the dye molecules from reaching the electrode in the desired time limit. The results are givenin Table 2.

EFFECT OF VARIATION OF PH ON THE CELL:

The effect of variation in pH on photoelectric parameters of cell is observed and found that the cell containing Orange-G-EDTA to be quite sensitive to the pH of the solution. It is observed that there is an increase in the photoelectric parameters of this cell with the pH value (In the alkaline range). At pH 12.2 a maxima is obtained. On further increase in pH, there is a decrease in photoelectric parameters. 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 in pKa value (pH>pKa). The reason of the change in electrical output is that the availability of the reductant in its anionic form, which is a better donor form. The above same is reported in Table 3.

EFFECT OF DIFFUSION LENGTH AND ELECTRODE AREA ON THE CELL:

The effect of variation in diffusion length (distance between the two electrodes i.e. SCE and Pt electrode) on the photoelectric parameters of the cell (Imax, ieq and initial rate of generation of photocurrent) is studied using H-shaped cells of different dimensions. It is observed that both imax and rate of change in initial generation of photocurrent (μA min-1) increase with respect to the diffusion length whenever the equilibrium photocurrent (ieq) shows a small decrease with respect to the diffusion length. The effect of electrode area on the photoelectric parameters of the cell is also reported here. The rate of change in photoelectric parameters with respect to the diffusion length is presented in Table 4.Similarly, Table 5 shows rate of change in photoelectric parameter with respect to electrode area.

EFFECT OF TEMPERATURE AND LIGHT INTENSITY ON THE CELL:

The effect of temperature and light intensity on the photoelectric parameters of the cell is studied. It is observed that the photocurrent of the photo galvanic cell is found to be increased with the temperature whereas the photo potential is decreased. The reason of the change in electrical output is that internal resistant of the cell decreases at higher temperature resulting into a rise in photocurrent and correspondingly, there will be a fall in photo potential. The observation is presented in Table 6. Similarly, Table 7, shows rate of change in photoelectric parameter with respect to light intensity. The light intensity is measured in terms of mWcm-2 with the help of solarimeter (CEL Model SM 111). It is found that the photocurrent show linear increasing fashion with light intensity whereas the photo potential show an increment in a logarithmic fashion.

CURRENT-VOLTAGE (I-V) CHARACTERISTICS OF THE CELL:

The short circuit current (isc) and open circuit voltage (Voc) of the photogalvanic cells are measured with the help of a multimeter (keeping the circuit closed) and with a digital pH meter (keeping the other circuit open), respectively. The current and potential values in between these two extreme values are recorded with the help of a carbon pot (log 470 K) connected in the circuit of Multimeter, through

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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which an external load is applied. The current-voltage (i-V) characteristics of the photogalvanic cells containing Orange-G-EDTA cell is graphically shown in Figure 2.

A point in i-V curve, called power point (pp) was determined where the product of current and potential was maximum and fill factor was calculated by using the following formula.

$$\text{Fillfactor}(\eta) = \frac{\text{Vpp x ipp}}{\text{Voc x isc}} \quad (1)$$

STORAGE CAPACITY AND CONVERSION EFFICIENCY OF THE CELL

The storage capacity (performance) of the photogalvanic cell is observed by applying an external load (necessary to have current at power point) after terminating the illumination as soon as the potential reaches a constant value. The storage capacity is determined in terms of $t_{1/2,}$ i.e., the time required in the fall of the output (power) to its half at power point in dark. It is observed that the cell can be used in dark for 140 minutes on irradiation for 230 minutes. So the observed storage capacity of the cell is 60.8 % the results are graphically presented in Figure 3. The conversion of the efficiency of the cell is determined as 1.5038 with the help of photocurrent and photo potential values at the power point and the incident power of radiations by using the formula

$$\text{ConversionEfficiency} = \frac{\text{Vpp x ipp}}{10.4\ \text{mW}} \text{ x100\%} \quad (2)$$

PERFORMANCE OF THE CELL

The overall performance of the photogalvanic cell is observed and reached to remarkable level with respect to electrical output, initial generation of photocurrent, conversion efficiency and storage capacity of the photogalvanic cell.

Table-8:- Performance of the cell

s. no.	parameters	observed value
1.	Dark potential	240.0 mV
2.	Open circuit voltage (VOC)	1175.0 mV
3.	Photopotential (DV)	932.0 mV
4.	Equilibrium photocurrent (I eq)	265.0 mA
5.	Maximum photocurrent (I max)	280.0 mA
6.	Initial generation of photocurrent	28.45
7.	Time of illumination	230.0 min
8.	Storage capacity (t1/2)	140.0 min
9.	% of storage capacity of cell	60.8%
10.	Conversion efficiency	1.5038 %
11.	Fill factor (□)	0.50

MECHANISM

On the basis of these observations, a mechanism is suggested for the generation of photocurrent in the photogalvanic cell as:

$$\text{Dye} \longrightarrow \text{Dye}^* \quad (3)$$

$$\text{Dye}^* + \text{R} \longrightarrow \text{Dye}^- \text{(Semi or leuco)} + \text{R} \quad (4)$$

$$\text{Dye}^- \longrightarrow \text{Dye} + e^- \quad (5)$$

$$\text{Dye} + e^- \longrightarrow \text{Dye–} \text{ (Semi or leuco)} \quad (6)$$

$$\text{Dye}^- + \text{R}^+ \longrightarrow \text{Dye} + \text{R} \quad (7)$$

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

CONCLUSION

Conclusively the reductant (EDTA) and dye (Orange-G) can be used successfully in a photogalvanic cell. The conversion efficiency and storage capacity of the cell is 1.5038 and 140 minutes respectively, on irradiation for 230 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.

NOMENCLATURE

Ieq = photocurrent at equilibrium
Imax = maximum photocurrent
Ipp = photocurrent at power point
Isc = short circuit current
Ml = milliliter
mV = millivolt
M = molarity
Pp = power point
$t_{1/2}$ = storage capacity of cell

ISSN: 2277-9655
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DV = observed photopotential
Voc = open circuit voltage
Vpp = photopotential at power point
η= fill factor
mA = microampere
mW = microwatt

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.

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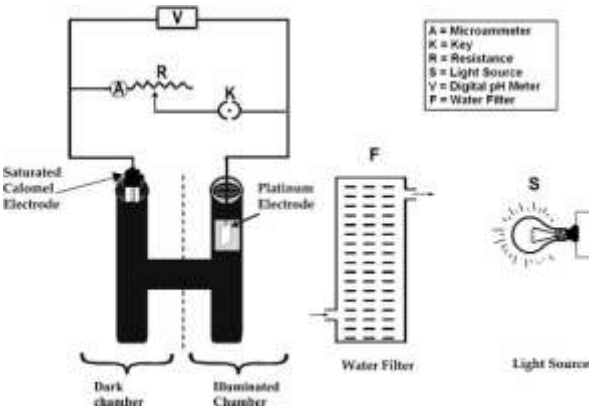

figure :1 experimental set up of photogalvanic cell

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

Table- 1:- Effect of variation of dye concentration

EDTA = 2.80×10^{-3}M Light intensity = 10.4mWcm^{-2} pH = 12.2 Temp. 303K					
Orange-G × 10^{-5}	1.2	1.6	2.0	2.40	2.80
Photopotential (mV)	880	905	932	892	878
Photocurrent	248	252	265	255	242

Table-2:-Effect of variation of reductant concentration

Orange-G = 2.0×10^{-5} M Light intensity = 10.4mWcm^{-2} pH = 12.2 Temp. 303K					
EDTA 2.80 × 10^{-5}	2.20	2.50	2.80	3.10	3.40
Photopotential (mV)	875	900	932	910	887
Photocurrent	242	248	265	250	245

Table-3:- Effect of variation of pH

Orange-G = 2.0×10^{-5} M EDTA = 2.80×10^{-3} M Temp. = 303K Light intensity = 10.4mW cm^{-2}					
P^H	11.4	11.8	12.2	12.6	13.0
Photopotential (mV)	865	896	932	889	867
Photocurrent	240	252	265	259	243

Table -4:-Effect of diffusion length

Orange-G = 2.0×10^{-5} M EDTA = 2.80×10^{-3} M Temp. = 303K Light intensity = 10.4mW cm^{-2} pH = 12.2			
Diffusion path length D_L (mm)	Maximum photocurrent I_{max} (µA)	Equivalent photo current Ieq(µA)	Rate of initial generation of current
35.0	250	286	27.37
40.0	272	272	27.87
45.0	280	265	28.45
50.0	285	252	28.76
55.0	292	240	28.99

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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Table-5:- Effect of electrode area

range-G = 2.0×10^{-5} M EDTA = 2.80×10^{-3} M Temp. = 303K Light intensity = 10.4mW cm^{-2} pH = 12.2					
Electrode Area (cm^2)	0.36	0.64	1.00	1.44	1.69
Maximum photocurrent $I_{max.}$	245	252	265	270	278
Equilirium photocurrent I_{eq}	255	248	242	235	230

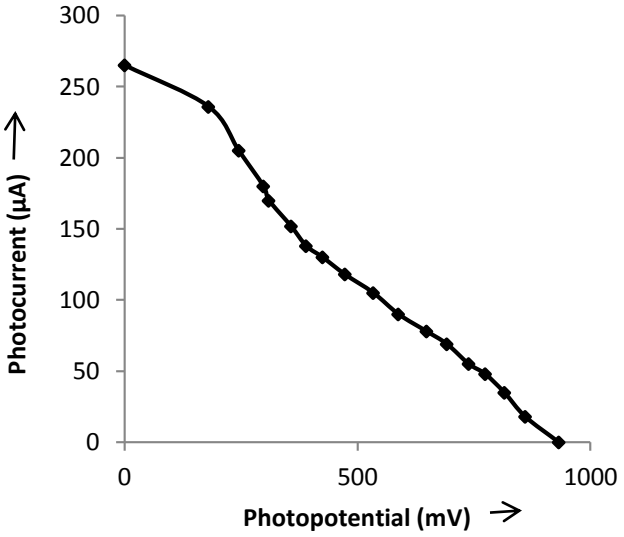
Table-6:- Effect of temperature

Orange-G = 2.0×10^{-5} M EDTA = 2.80×10^{-3} M Light intensity = 10.4mW cm^{-2} pH = 12.2					
Temperature	293	298	303	308	313
Photopotential (mV)	1042	986	932	912	868
Photocurrent (µA)	248	254	265	268	273

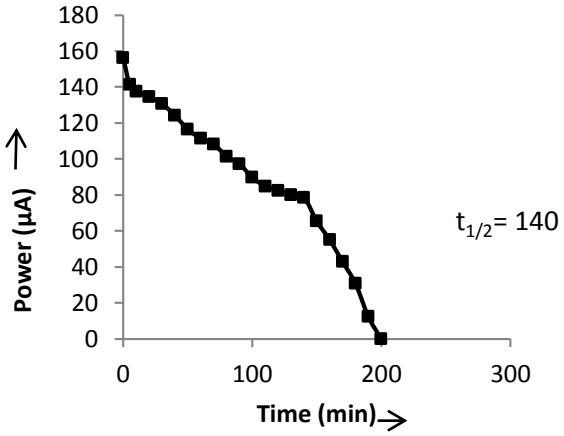
Table-7:-Effect of light intensity

Orange-G = 2.0×10^{-5} M EDTA = 2.80×10^{-3} M Temp. = 303K pH = 12.2					
Light intensity =10.4mWcm^{-2}	3.1	5.2	10.4	15.6	26.0
Photopotential (mV)	882	910	932	955	973
Photocurrent (µA)	244	252	265	272	276
Log V	5.332	5.360	5.392	5.414	5.428

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114



Figure;-2 Current-Voltage(i-V) characteristics of the photo galvanic cell



Figure;-3 The performance of photo galvanic cell