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Studies on conversion and storage of Solar Energy in Photogalvanic Cells: Congo red and Glycerol system

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Abstract

Photogalvanic effect was studied in photogalvanic cell containing Glycerol as reductant and Congo red as photosensitizer. The photopotential and photocurrent generated were 587.0mV and 110.0μA respectively. The power of the cell was 45.0μW at its power point. The observed conversion efficiency was 0.66% and fill factor was determined as 0.74. The photogalvanic cell can be used in dark for 40 min. showing the storage capacity of the cell against charging time was 180 min. The effects of different parameters on electrical output of the cell were observed.

Keywords: Photogalvanic cell, photosensitizer, cell efficiency, Congo red.

Contents

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1. Introduction

Becquerel [1] first observed the flow of current between two unsymmetrical eliminated metal electrode in sunlight. Although Rideal and Williams [2] first reported the photogalvanic effect but it was systematically studied by Rabinnowitch [3, 4]. Later on it was investigated by many workers [5-15]. The physical properties and constitution of photovoltaic cell that convert light into electrical energy directly was studied by Trivich [16]. Dyes have also been used in photovoltaic cells [17, 18] but due to their high cost and poor storage capacity they are not a commercial and viable sources of energy for domestic and industries. The photogalvanic cell employs use of dye as a photosensitizer. A number of dyes electrodes and surfactants have been studied [19-22]. Many reducing agents have been tried in photogalvanic cells [23-35]. The present work includes the study of photogalvanic cell using Congo red and Glycerol system.

2. Materials and Methods

Present work is carried out using Congo red dye (LOBA), Glycerol (ASSESS) and NaOH (S.D.fine). The stock solutions of chemicals were prepared in doubly distilled water and were kept away from the sun or in amber colored bottles. The photosensitive solution i.e. mixture of solution of glycerol, Congo red and sodium hydroxide is filled into the cell consisting of 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. Terminals of the electrode are connected to a digital pH meter (Systronics) to measure the photopotential and the current is measured by the microammeter (OSAW INDIA). The system is then exposed to source of light (tungsten lamp 200W). A water filter is used to avoid the thermal effect of light.
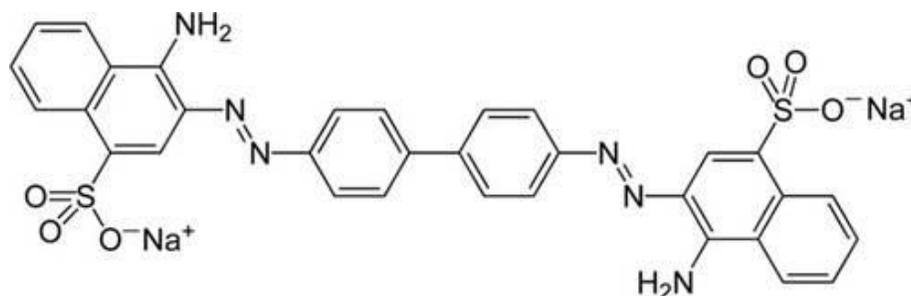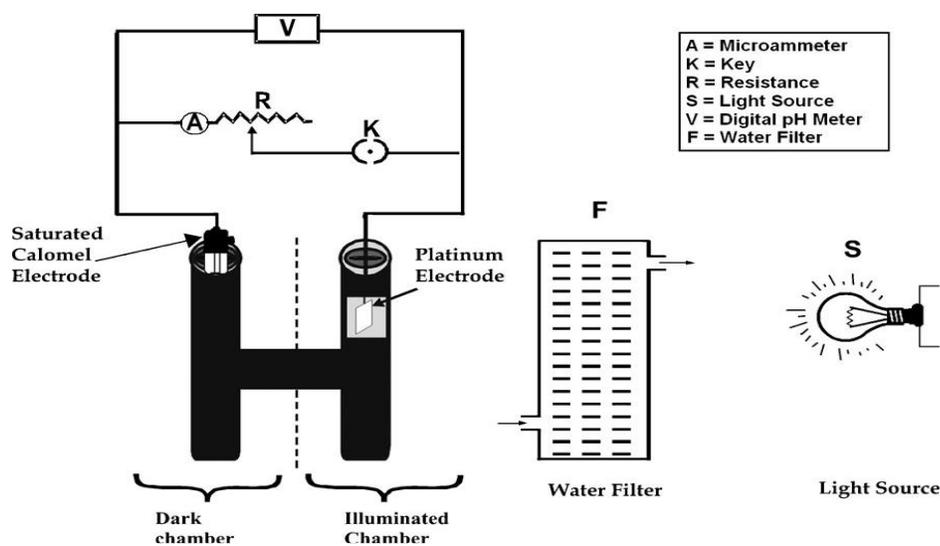

Fig.1. Congo red

Fig.2. Experimental Set up

The photochemical decolorisation of Congo red was studied potentiometrically. The study of current voltage characteristics and determination of power point was accomplished by making use of carbon (log 470K).

3. Results and Discussion

An effort is made to make the comparative cost of solar cell easily available and low cost and hence suitable reductant and photosensitizer have been used for the present work. The important observations of the system are given in table 1, which are reflecting the overall outcome.

Table 1. Observations for Congo red - Glycerol System

S.no.	Observations	Values
1.	Open ciruit voltage	840.0mV
2.	Photo potential	587.0mV
3.	Equilibrium photocurrent	105.0mV
4.	Maximum photocurrent	110.0μA
5.	Current at power point	88.0μA
6.	Potential at power point	782.0μA
7.	Power at power point	45.0μA/min
8.	Rate of generation	38.02μA/min
9.	Conversion efficiency	0.66%
10.	Charging time	180 min
11.	$t_{1/2}$	40 min
12.	Fill factor	0.74

3.1. Effect of variation in concentration of Glycerol (reductant)

On increasing the concentration of Glycerol, keeping constant the concentration of Congo red, the cell output was found to increase and reached to a maximum value and then decreased on further increasing 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.

Table 2. Effect of variation in concentration of Glycerol

Concentration(M)	Photopotential	Photocurrent
4.40×10^{-4}	802.0	101.0
4.60×10^{-4}	822.0	107.0
4.80×10^{-4}	840.0	110.0
5.00×10^{-4}	820.0	105.0
5.20×10^{-4}	800.0	102.0

3.2. Effect of variation in concentration of Congo red (photosensitizer):

On increasing the concentration of Congo red there was an increase in photopotential and photocurrent because at lower concentration there will be limited no. of photosensitizer molecules to absorb light in cell, whereas the higher concentration will not permit the desired light intensity to reach the photosensitizer molecules near electrodes and hence there will be a corresponding fall in power of cell.

Table 3. Effect of variation in concentration of Photosensitizer

Concentration(M)	Photopotential	Photocurrent
1.2×10^{-6}	775.0	30.0
1.4×10^{-6}	805.0	95.0
1.6×10^{-6}	840.0	110.0
1.8×10^{-6}	810.0	90.0
2.0×10^{-6}	780.0	75.0

3.3. Effect of variation in pH:

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.

Table 4. Effect of variation in pH

pH	Photopotential	Photocurrent
10.0	820.0	90.0
11.0	832.0	100.0
12.0	840.0	110.0
13.0	830.0	98.0
14.0	818.0	85.0

3.4. Effect of diffusion length:

The maximum photocurrent (i_{max}) and rate of generation of photocurrent decreased with an increase in diffusion length. The value of equilibrium photocurrent (i_{eq}) was also observed to be independent with respect to change in diffusion length (rather it slightly decreases). If the oxidized form of reductant is formed only in illuminated chamber and it is considered to be the electroactive species in dark chamber, then it must diffuse from the illuminated to dark chamber to accept electron from the electrode. Therefore it may be concluded that the main electroactive species are the leuco or semi dyes (photosensitizer) and the dye in the illuminated and dark chamber respectively.

Table 5. Effect of diffusion length

Variation in diffusion length (mm)	Maximum photocurrent i_{max} (µA)	Equilibrium photocurrent i_{eq} (µA)	Rate of generation of current (µA/min)
35.0	90.0	106.0	38.02
40.0	100.0	105.0	40.05
45.0	110.0	105.0	42.25
50.0	115.0	105.0	45.36
55.0	118.0	104.0	48.75

3.6. Effect of temperature:
A linear relationship is obtained between the output of the cell and temperature. On increasing temperature the photocurrent was increased. This is because the internal resistance of the cell decreases at higher temperature, which results in a rise in photocurrent, and also there will be a fall in photopotential.

Table6. Effect of temperature

Temperature	Photopotential	Photocurrent
293	922	75
298	800	92
303	840	110
308	895	118
313	750	126

3.7. i-V characteristics and Conversion Efficiency:
The current voltage (i-V) characteristics of the photogalvanic cell containing Congo red- Glycerol system is represented graphically in fig.3.
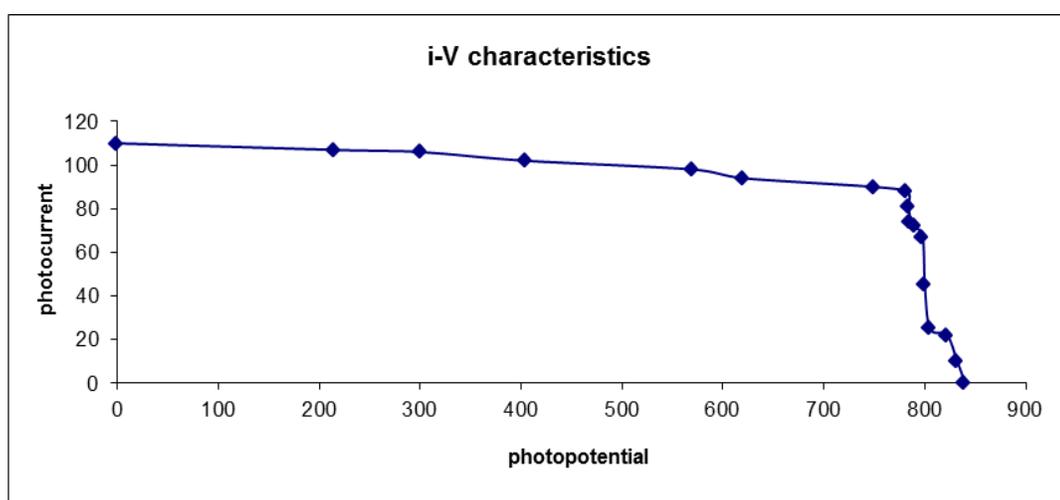

Fig.3 i-V characteristics of the cell

The power point is also determined on the i-V curve, which is a point where the product of photocurrent and photopotential is maximum. Using the formulae given below the conversion efficiency and fill factor was obtained as 0.6616% and 0.74 respectively.

$$\text{Conversion efficiency} = V_{pp} \times i_{pp}/10.4 \text{mVcm}^{-2}$$
$$\text{Fill factor (n)} = V_{pp} \times i_{pp}/ V_{oc} \times i_{sc}$$

Where V_{pp}, i_{pp}, V_{oc} and V_{sc} are the photopotential at power point and current at power point, potential in open circuit and current in short circuit respectively.
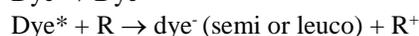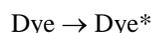
3.8. Performance of the cell:
The cell performance was studied by making use of external load necessary to have current at power point after stopping the illumination. It is expressed in terms of $t_{1/2}$ i.e. the time required to fall in the power to the half value of power point. It was observed that the cell could be used for 40.0 minutes in dark.
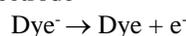
3.9. Mechanism:
On the basis of these observations the suggested mechanism for generation of photocurrent in photogalvanic cells is: -
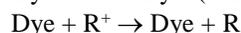
Illuminated chamber

$\text{Dye} \rightarrow \text{Dye}^*$

$\text{Dye}^* + \text{R} \rightarrow \text{dye}^- \text{ (semi or leuco)} + \text{R}^+$

At Pt electrode

$\text{Dye}^- \rightarrow \text{Dye} + \text{e}^-$

Dark chamber

$\text{Dye} + \text{e}^- \rightarrow \text{Dye}^- \text{ (semi or leuco)}$

$\text{Dye} + \text{R}^+ \rightarrow \text{Dye} + \text{R}$
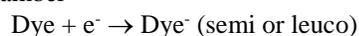
Where Dye, Dye*, Dye⁻, R and R⁺ are the dye, excited form of dye, semi or leuco dye, reductant and oxidized form of the reductant respectively.,

4. Conclusion

The energy consumption is growing tremendously due to rapid industrialization. In that case the solar energy is the greatest asset for all over the world. For direct conversion of solar energy into electrical energy technologies are needed. Photogalvanic cells are one of them. They are low cost due to the use of dyes, which are cheap and used in minute quantities. Reductants like glycerol are also not very expensive. So the conclusion is that the photogalvanic cells are better option for solar energy conversion and storage and also has a lot of scope for its development.

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