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ROLE OF PHOTOSENSITIZER FOR GENERATION OF ELECTRICAL ENERGY IN PHOTOGALVANIC CELL

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ABSTRACT

The photovoltages and photocurrents in photogalvanic cell containing a dye rose bengal and oxalic acid as reducing agent have been determined. The photo-outputs with oxalic acid are higher than rose bengal and glucose system. The efficiency of the rose bengal-oxalic acid photogalvanic cell has been estimated to be 0.981 %. The photopotentials and photocurrent generated, conversion efficiency, power of the cell and cell performance of the photogalvanic cells were determined. The effects of different parameters on electrical output of the cell were observed .A mechanism has also been proposed for the generation of the photocurrent in photogalvanic cell.

Key words: Photogalvanic cell, Rose bengal, Oxalic acid, Glucose, Power point, Conversion efficiency.

INTRODUCTION

Today, global warming and the rapid decrease in energy resources caused by the large-scale consumption of fossil fuels have become serious. Accordingly, renewable energy resources are attracting a great deal of attention, and solar energy is one of the most promising future energy resources. The photoeffects in electrochemical systems were first reported by Becquerel[1,2] in his investigation on the solar illumination of metal electrodes long back. Surash and Hercules[3] proved that only negative photopotential should be obtained with carbonyl compounds. Alonso *et al.*[4] reported the use of electrodeposited $CdSe_{0.5}$ $Te_{0.5}$ electrode for solar energy conversion. Jana and Bhowmik[5] reported enhancement in the power output of a solar cell consisting of mixed dyes. Hara *et al.*[6] investigated design of new coumarin dyes having thiophene moieties for highly efficient organic dye-sensitized solar cells. Ameta *et al.*[7] reported use of toluidine blue-nitrolotriacetic acid (TB-NTA) system in

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photogalvanic cell for solar energy conversion. They also reported the use of micelles in photogalvanic cell for solar energy conversion and storage in azur A-glucose system[8], bromophenol blue-EDTA system[9] and fluoroscein-EDTA system[10]. Bohrmann-Linde and Tausch[11] reported photogalvanic cells for classroom investigation, and Monat and McCusker[12] reported femto-second excited state dynamics of an iron (II) polypyridyl solar cell. Schwarzhurg and Willig[13] explored the origin of photovoltage and photocurrent in nanoporous, dye-sensitized, photoelectrochemical solar cell. The sensitization of nanoporous films of TiO_2 with santaline (red sandal wood pigment) and the construction of a dye–sensitized solid-state photovoltaic cell was attempted by Tennakone and Kumara[14]. Yadav *et al.*[15] reported use of bismarck brown-ascorbic acid (BB-AA) system in photogalvanic cell for solar energy conversion. Various other photogalvanic cells containing reductants and photosensitizers were reported[17-34].

The research in the field of photogalvanic cells is still in its infancy with respect to its viability and practical applicability and, therefore, requires thorough exploration to increase the conversion efficiency and storage capacity by selecting a suitable redox couple and photosensitizer. A detailed survey of literature reveals that no attention has been paid to electrochemical behaviour of rose bengal-oxalic acid and therefore, the present work has been undertaken.

EXPERIMENTAL

Rose bengal (LOBA), oxalic acid (LOBA), glucose (LOBA) and sodium hydroxide (s.d. fine) were used without further purification in present work. All the solutions were prepared in doubly distilled water and were kept in amber colored containers to protect them from sunlight. The whole system was set systematically for photogalvanic studies, which consists of thin foil 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. An ordinary tungsten lamp of 200 W was used as light source. Water filter was used to cut-off IR radiations. The photopotetial 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. The potential was first measured in dark and the change in potential on illumination was measured as a function of time.

The solution was bubbled with prepurified nitrogen gas for nearly twenty minutes to remove dissolved oxygen. Solutions of dye, reductant and sodium hydroxide were taken in a

H-type glass tube. A platinum electrode (1.0 x 1.0 cm^2) 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. The photochemical bleaching of rose bengal was studied potentiometrically. A digital pH meter (Systronics) and a micro-ammeter (OSAW, India) were used to measure the potential and current generated by the system, respectively. The i-V characteristics of the cells were studied using an external load (log 470 k) in the circuit. The effect of variation of different parameters has also been observed

The rate of change in potential after removing the source of illumination was 1.20 min in rose bengal-oxalic acid; therefore, the system may be used in photogalvanic cell more successfully than the rose bengal and glucose system.

RESULTS AND DISCUSSION

Rose bengal-oxalic acid system

The photopotential of rose bengal-oxalic acid system was measured at different pH values and maximum photopotential was found at pH 12.6. All the subsequent measurements were made at this pH value. The variation of photopotential with time for this system is shown in Fig. 1. As can be seen from the figure that the photopotential increases upon illumination to a value of 1239.0 mV in about 260.0 min. and remains constant on further illumination. When the light is switched-off, the system does not regains its original potential; thereby, showing that the system is not perfectly reversible.

Rose bengal-glucose system

The photopotential of rose bengal-glucose system was measured at different pH values and maximum photopotential was found at pH 11.0. All the subsequent measurements were made at this pH value. The variation of photopotential with time for this system is shown in Fig. 2. As can be seen from the figure that the photopotential increases upon illumination to a value of 1080.0 mV in about 315.0 min. and remains constant on further illumination. When the light is switched-off, the system does not regains its original potential; thereby, showing that the system is not perfectly reversible. We have also examined the photocurrent of rose bengal in presence of glucose. The observed

photopotentials and currents are comparable less than that of rose bengal-oxalic acid system (Table 1).

The photoionduced short circuit currents of rose bengal-oxalic acid and rose bengal-glucose in photogalvanic cells are shown in Fig. 3. On illumination, maximum photocurrents 190.0 μA is obtained in 315.0 min in rose bengal-oxalic acid system and 180.0 μA in 260.0 min in rose bengal-glucose system. The rose bengal-glucose system takes much smaller time than rose bengal-oxalic acid system. The trend in short circuit photocurrents of rose bengal-oxalic acid is much better than rose bengal-glucose system (Table 1).

Table 1: Electrical output of photogalvanic cells

Parameter	Rose bengal-oxalic acid system	Rose bengal-glucose system
Open circuit voltage (V_{oc})	1239.0 mV	1080.0 mV
Photopotential (V)	1137.0 mV	968.0 mV
Equilibrium photocurrent (i_{eq})	160.0 μA	160.0 μA
Maximum photocurrent (i_{max})	190.0 μA	180.0 μA
Short circuit current (i_{sc})	175.0 μA	160.0 μA
Current at power point (i_{pp})	110.0 μA	100.0 μA
Potential at power point (V_{pp})	1022.0 μA	704.0 μA
Power at power point	64.0 μA/min	62.8 μA/min
Rate of generation	56.8 μA/min	56.0 μA/min
Conversion efficiency	0.981%	0.744%
Charging time	180.0 min	260.0 min
$t_{1/2}$	90.0 min	60.0 min
Fill factor (n)	0.51	0.44

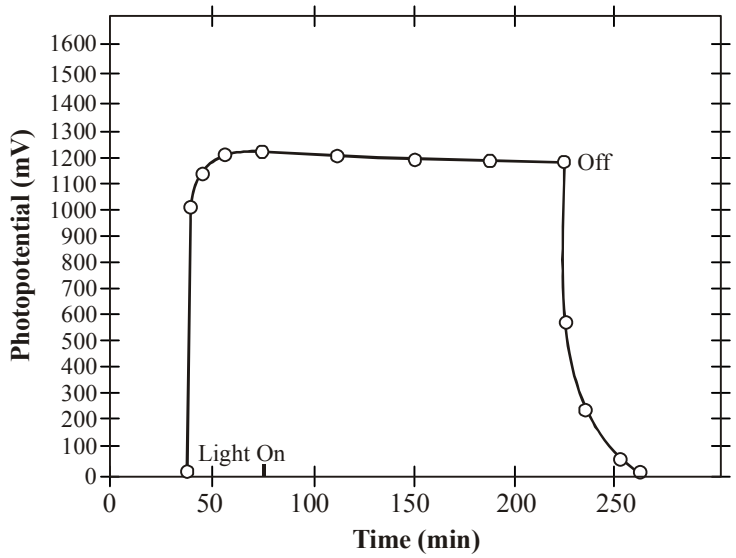

Fig. 1: Variation of photopotential with time in rose bengal-oxalic acid in photogalvanic cell

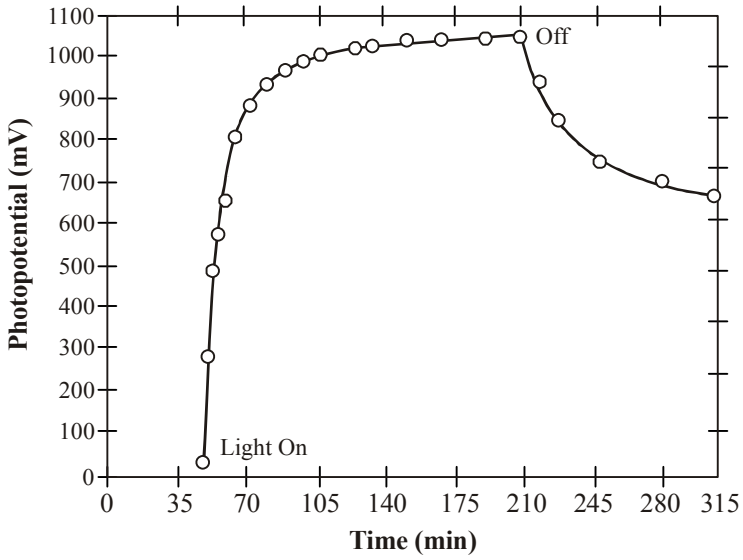

Fig. 2: Variation of photopotential with time in rose bengal-glucose in photogalvanic cell

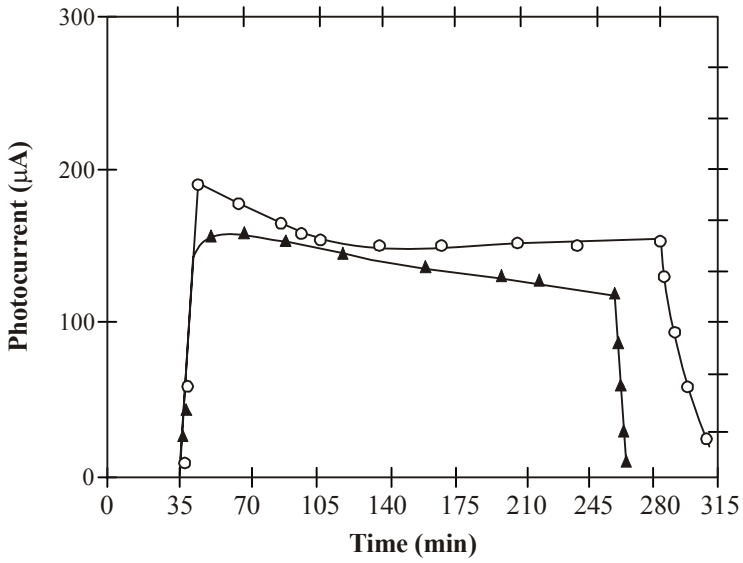

Fig. 3: Variation of photocurrent with time in Rose bengal-oxalic acid (▲▲) and Rose bengal-glucose (○○) photogalvanic cell

Power conversion efficiency of photogalvanic cell

One of the important characteristics of any electrochemical cell is its power conversion efficiency. The i-V characteristics of rose bengal-oxalic acid and rose bengal-glucose photogalvanic cells have been investigated to estimate the power conversion efficiency of the cell. The maximum possible power output from the cell can be obtained from the rectangle of maximum area, which can be drawn under i-V curve

The power points (a point on the curve, where the product of potential and current was maximum) in i-V curves were determined and their fill factors were also calculated. These are summarized in Table 2. The efficiency of the rose bengal-oxalic acid photogalvanic cell has been calculated to be 0.981 percent and that of rose bengal-glucose photogalvanic cell has been calculated to be 0.744 percent

Table 2: i-V Characteristics of the photogalvanic cells

Systems	V_{oc} (mV)	i_{sc} (μA)	V_{pp} (mV)	i_{pp} (μA)	n
Rose bengal-oxalic acid	1239	175.0	1022.0	110.0	0.51
Rose bengal-glucose	1080	160.0	704.0	100.0	0.44

The conversion efficiency and sunlight conversion data for these two systems are reported in Table 3.

Table 3: Conversion efficiency and sunlight conversion data

System	Fill factor (n)	Conversion efficiency (%)	Sunlight conversion data	
			Photopotential (mV)	Photocurrent (µA)
Rose bengal-oxalic acid	0.51	0.98	1239	190
Rose bengal-glucose	0.44	0.74	1080	180

On the basis of these observations, the higher conversion efficiency was found in rose bengal-oxalic acid system.

Performance of the cell

Performance of both the systems were studied by applying the desired external load to have the potential and current corresponding to power point. The time $t_{1/2}$ was determined after removing the source of light. It is the time taken in reaching half the value of power of the cell. The performance of cells and $t_{1/2}$ are summarized in the Table 4.

Table 4: Performance of the photogalvanic cells in dark

System	Power (µW)	$t_{1/2}$ (min)
Rose bengal-oxalic acid	64.0	90.0
Rose bengal-glucose	62.8	60.0

On the basis of the observed data, the rose bengal-oxalic acid is the more efficient cell from power point of view.

MECHANISM

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

Illuminated chamber

$$Dye \longrightarrow Dye^{*} \quad ...(1)$$

$$Dye^{*} + R \longrightarrow Dye^{-} \text{ (semi or leuco)} + R^{+} \quad ...(2)$$

At Platinum electrode

$$Dye^{-} \longrightarrow Dye + e^{-} \quad ...(3)$$

Dark chamber

$$Dye + e^{-} \longrightarrow Dy^{-} \text{ (semi or leuco)} \quad ...(4)$$

$$Dye^{-} + R^{+} \longrightarrow Dye + R \quad ...(5)$$

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

CONCLUSION

Photogalvanic cells are low cost due to the use of a dye, which are low cost and used in minute quantities. The reductant like oxalic acid and glucose are also not very expensive. So working with a photogalvanic cell has a lot of scope for its development.

On the basis of observation in the present study, it is concluded that photogalvanic cells are better option for solar energy conversion and storage. Also this system with better electrical output good performance and storage capacity may be used in near future. According to observation of photogalvanic effect in these two systems, rose bengal-oxalic acid system is the more efficient than rose bengal-glucose system.

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