Role of Ponceau-S-Glucose for Generation of Electrical Energy in Photo galvanic Cell

Mahesh Chandra

Department of Chemistry, Deshbandhu College, New Delhi-110019, E-mail: drmahesh100@gmail.com

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ABSTRACT

Photo galvanic effect was studied in photo galvanic cells containing Ponceau-S as dyes and Glucose as reductants. The photo galvanic cells were determined the photo potential, photocurrent, conversion efficiency, power of cell and performance of cell. The effects of various parameters like pH, light intensity, diffusion length, reductant concentration and dye concentration on the electrical output of the cell is studied. The current voltage (I–V) characteristic of the cell is also studied and a mechanism for the generation of photocurrent is proposed.

Keywords: Photo galvanic cell, Photo potential, Ponceau-S, Glucose, Photocurrent.

1. INTRODUCTION

The global warming and the rapid decrease in energy resources caused by the large-scale consumption of fossil fuels have become a serious problem. Accordingly, renewable energy resources are attracting a great deal of attention and solar energy will be one of the most promising future energy resources. In the present investigation, Ponceau-S has been used as photo sensitizer and Glucose as reductant for generation of electrical energy in photo galvanic cell. The photo effects in electrochemical systems were first reported by Becquerel\(^1\). Alonso et al. reported the use of electrodeposited CdSeO\(_2\) studied in photo galvanic cells containing Ponceau\(^1,2\), Volume 4, 2012. The current voltage (I–V) was plotted.

2. EXPERIMENTAL METHODS

All the solutions were prepared in doubly-distilled water and stored in amber-colored containers to protect them from light. A mixture of the solution of the dye, Glucose, sodium hydroxide and water were filled into a H-shaped glass cell. A platinum electrode (1 × 1 cm\(^2\)) was placed in one compartment of the cell and a reference saturated calomel electrode (SCE) in the other compartment. The platinum electrode was exposed to a 200 W tungsten lamp while the SCE was kept in the dark. The temperature of the system was maintained at 303 K (±0.1). A water filter was used to cut-off infrared radiations. A digital pH meter and a microampermeter were used to measure the potential and current, respectively. The current–voltage characteristics were determined by applying extra load with the help of carbon pot (log 500 K) connected in the circuit. With this variable resistor (carbon pot), current-voltage curve was plotted.

3. RESULTS AND DISCUSSION

3.1. Effect of pH

The effect of pH on the electrical output of the cell is shown in Figure 1. Photo potential and photocurrent are increased with increasing pH until at pH 13. Further increase in pH results in a decrease in the electrical output of the cell. The dependence of the photo potential and photocurrent on the concentration of the dye was studied and the results are shown in Figure 2. On increasing the concentration of Ponceau-S, both the photo potential and the photocurrent increase till a maximum is achieved at 4.8 × 10\(^{-3}\) M, after which both characteristics are decreased. A small output is obtained at a low concentration of Ponceau-S because a smaller number of dye molecules are available for excitation and consecutive donation of electrons to the platinum electrode. A large concentration of dye results in a decrease in photo potential because the intensity of light reaching the dye molecules (near the electrode) decreases due to the major portion of the light being absorbed by the dyes available in its path.

3.2. Effect of Glucose concentration

The dependence of photopotential and photocurrent on the concentration of the reductant (that is, Glucose) was studied and the results are shown in Figure 3. Both the photopotential and the photocurrent achieve maximum values at the concentration of 2 × 10\(^{-3}\) M of Glucose. At low concentrations, the power output is small due to the fewer number of reductant molecules available for electron donation to the dye molecules, whereas a large concentration of reductant hinders the movement of dye...
Mahesh Chandra,
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molecules reaching the electrode in the desired time limit. The variation of two electric parameters with light intensity is shown in Figure 4. The photocurrent is linearly increased with increasing in the intensity of the light, whereas the photopotential is increased in a logarithmic manner. The number of photons per unit area (incident power) that strike the dye molecules around the platinum electrode increases with the increase in the light intensity. Hence, the photocurrent and the photopotential of the photo galvanic cell are favorably increased.

3.3. Effect of diffusion length
H-cells of different dimensions were used to study the effect of the variation of diffusion length on the current parameters of the cell (I_{max}, I_{oc} and initial rate of current generation). The results are shown in Figure 5. There was a sharp increase in photocurrent (I_{max}) initially. This behavior indicates an initial rapid reaction, followed by a slow rate-determining step at a later stage.

3.4. Current voltage (i–V) characteristics, conversion efficiency and performance of the cell
The open-circuit voltage (V_{oc}) and short-circuit current (I_{sc}) of the photogalvanic cell were measured by means of a digital multi-meter (keeping the circuit open) and a micro-ammeter (keeping the circuit closed), respectively. The current and potential between two extreme values (V_{oc} and I_{sc}) were recorded with the assistance of a carbon pot (linear 470 K) that was connected in the circuit of the multi-meter and through which an external load was applied. The i–V characteristic of the cell containing a Ponceau-S Glucose system is shown in Figure 6. With the help of the i–V curve, the fill factor and conversion efficiency of the cell are found to be 0.55 and 0.8560 %, respectively, using the formulas:

\[
\text{Fill Factor} = \frac{V_{pp} \times I_{pp}}{V_{oc} \times I_{sc}}
\]

\[
\text{Conversion Efficiency} = \frac{V_{pp} \times I_{pp}}{10.4 mWcm} \times 100 \%
\]

The potential and the current at the power point [A point in the i–V curve is called the power point (pp) and was determined where the product of photocurrent and photo potential is maximum] are represented by V_{pp} and I_{pp}, respectively. The performance of the cell was studied by applying the external load that was necessary to have the current and the potential at the power point after removing the source of light. The cell can be used in the dark at its power point for 46 min, whereas photovoltaic cell cannot be used in the dark even for a second, a photogalvanic system has the advantage of being used in the dark but at lower conversion efficiency.

3.5. Mechanism
As no reaction is observed between the Ponceau-S and Glucose in the dark, it may be concluded that the redox potential of Glucose is much higher than that of Ponceau-S. A rapid fall in potential is observed when the platinum electrode is illuminated. The potential reaches a steady value after certain period of exposure. Although the direction of the change of potential is reversed on removing the source of light, the potential does not returns to its initial value. This means that the main reversible photochemical reaction is also accompanied by some side irreversible reactions. The electro active species in this photo galvanic system is thus different from that of the well-studied thionine–iron (II) system. In the present case, the leuco- or semi reduced dye is considered to be the active species in the illuminated chamber and the dye itself in dark chamber. On the basis of the information gained previously, the mechanism of photocurrent generation in the photo galvanic cell can be represented as follows:

3.5.1. Illuminated Chamber
Bulk solution

\[ \text{PS} \xrightarrow{hv} \text{PS}^* \]

At electrode

\[ \text{PS}^* + R \rightarrow \text{PS} + R^* \]

(Platinum electrode)

3.5.2. Dark chamber
At electrode

\[ \text{PS} + e^- \rightarrow \text{PS}^- \]

Bulk solution

\[ \text{PS}^- + R^* \rightarrow \text{PS} + R \] (SCE electrode)

Where, R, R+, PS, PS- are the reductant Glucose, its oxidized form, Ponceau-S and its leuco or semileuco forms, respectively.

4. CONCLUSION
On the basis of the results, it is concluded that Ponceau-S can be used successfully as a photo sensitizer in a photo galvanic cell. The conversion efficiency of the cell is 0.8560% and the cell can be used in dark at its power point for 46 min. Photo galvanic cells have the advantages of having in-built storage capacity. Thus, photo galvanic cells show good prospects of becoming commercially viable.

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RESEARCH


52