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KEY WORDS: Punica granatum, Glucose, Brij 35, maximum photocurrent, Photogalvanic effect (PGE), fill factor, power point, and conversion efficiency.

STUDY OF PHOTOGALVANIC EFFECT IN NATURAL DYE (PUNICA GRANATUM EXTRACT)-GLUCOSE- BRIJ 35 SYSTEM FOR SOLAR POWER GENERATION AND STORAGE

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ABSTRACT

The world's ever-increasing population, combined with economic and technological growth and a new, modern way of life, has led to high energy demand and consumption.The aim of this study is to harness and store solar energy through Punica granatum natural dye–Glucose-Brij 35 photogalvanic cell. This photogalvanic cell in alkaline medium has shown encouraging and very impressive improvement in solar power generation and storage. This combination of chemicals has shown harnessing of 120.34 μW maximum power with the storage capacity of 150 minutes as half change time from the 10.4 $mWcm^{-2}$ artificial and low intensity of light. In this study, the observed optimum cell performance in terms of the maximum photopotential, maximum photocurrent, and short-circuit current is 1063 mV, 914 μA, and 869 μA, respectively.

INTRODUCTION

The majority of the machinery that is employed in factories and homes wastes a remarkable amount of energy. Therefore, they have a greater energy consumption, which results in a higher demand for energy. In addition, a significant amount of energy, namely in the form of electricity, is wasted during transmission and distribution, which results in a pressure on the supply of energy. The energy situation is made even more precarious by the needless and wasteful use of various energy sources. Accordingly, renewable energy resources are attracting a great deal of attention, and solar energy is one of the most promising future energy resources [1]. Developed and developing countries of the world are focussing on environmental damage observed due to conventional energy powers. Non conventional energy sources occur in nature which is regenerative or inexhaustible like solar energy, wind energy, hydropower, geothermal, biomass, tidal and wave energy. The photogalvanic (PG) cells are photo-electro-chemical system based on the "photogalvanic effect". The PG cell is a device producing energy through the photochemical processes occurring inside the electrolyte solution on absorption of light and which give rise to high energy products on excitation by a photon. These energy products loose photo-energy electrochemically to generation the electricity. These cells are quite different from the other solar cells. Different kinds of dyes as light absorbing materials, organic/inorganic chemicals as reductant, and anionic/ cationic/ neutral surfactants as micelles have been exploited for the solar energy conversion and storage through the PG cell technology. Becquerel[2] was the first toobserve the flow of current between the unsymmetrical illuminated metal electrodes in sunlight, and the photogalvanics were first reported by Rideal andWilliams[3], but it was systematically investigated byRabinowitch[4-5]. Later on Kaneko and Yamada[6], Murthyet al.[7], Rohatgi Mukherjee et al.[8], Folcher and Paris[9],Alfredo et al.[10], Dube et al.[11], Bayer et al.[12], Matsumotoet al.[13] and Shiroishi et al.[14] have studied someinteresting photogalvanic systems. Bisquert et al.[15] havereviewed the physical–chemical principles of dyesensitized solar cells, whereas Mayer[16] has presented the molecular approaches to solar energy conversion. Theproblems encountered in the development of photogalvaniccells have been discussed from time to time.Krasnoholovets et al.[17], Madhwani et al.[18], Gangotri andBhimwal[19], Genwa and Chauhan[20], Genwa andSingh[21], Rathode et al. [22-23]. have recently developed some photogalvanicsystems for solar energy conversion and storage. Theresearch team led by Yadav et al. [125-126] has published findings on thesatisfactory electrical output achieved using various dyes asphotosensitizers in photogalvanic cells. They also investigated the impactof surfactants on these cells and explored novel photogalvanic celldesigns with a focus on electrical parameters and the conversion andstorage of solar energy.Thescientific community has successfully converted solarenergy in electrical energy up to desired extent throughvarious processes but storage capacity of solar energy is still not up to the mark to use it as and when required.Many of them have used different photo-sensitizers, surfactants, reductants in photogalvanic cells, but noattention has been paid to the use of this system containing naturaldye extract Punica granatum as energy material to enhance the electrical output andperformance of the photogalvanic cell. Therefore, thepresent work was undertaken to achieve better performanceand commercial viability of the photogalvanic cell.

RESULT AND DISCUSSION

(a) Variation of Photopotential and Photocurrent with Time:

The photogalvanic cell was placed in dark till it attained a stable potential and then the platinum electrode was exposed to light. It was observed that potential changes on illumination and it reached a constant value after a certain period. When the light source was removed, the direction of change in potential was reversed and a stable potential are again obtained after sometime. Figure 1 is a graphical representation of the variation of potential in the Punica granatum–Glucose-Brij 35 system with respect to time. It was observed that there was a rapid rise in photocurrent ofPunica granatum dye–Glucose-Brij 35 system on illumination and it reaches a maximum value(914 μA) within a few minutes. This value is denoted by i_{max}. Then the current was found to be decrease gradually with the period of illumination finally reached ata constant value. This value is represented as i_{eq} (869 μA). The variation of photocurrent in system with respect to time is represented in figure 2.

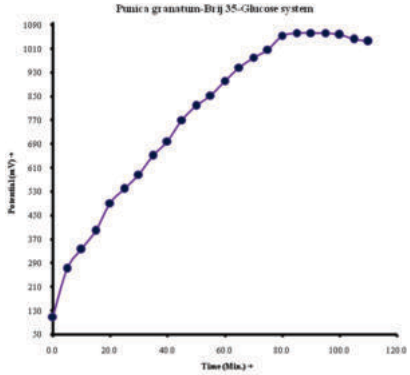

Fig.1 VARIATION OF POTENTIAL WITH TIME

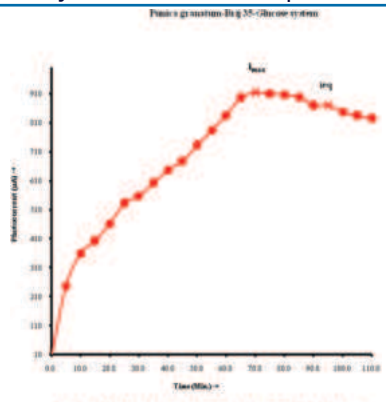

Fig. 2 VARIATION OF PHOTOCURRENT WITH TIME

(b) Effect of Variation of Reductant Glucose and Surfactant Brij 35 Concentration:

The impact of variation of Glucose and Brij 35concentration are given in table 1. With increasing the concentration of the Glucose, photopotential, current and power were found to be increase till it reaches a maximum value at 2.7 x 10^{-3} M. These values are 954.0 mV, 869.0 µA and 829.03W respectively. On further increase in concentration of Glucose, a decrease in the electrical output of the cell was observed. The fall in power output was also resulted with decrease in concentration of Glucose due to less number of molecules available for electron donation to the Punica granatum dye. On the other hand, the movement of dye molecules hindered by the higher concentration of the Glucose to reach the electrode in the desirable time limit and it will also result into a decrease in electrical output. The electrical output of the cell was increased on increasing the concentration of Brij 35. A maximum result was obtained at a certain value (2.9 x 10^{-3}M) of concentration of Brij 35. On further increasing the surfactant concentration it react as a barrier and major portion of the surfactant photobleach the less number of dye molecules so that a down fall in electrical output was observed.

Table -1. Effect of variation of Glucose and Brij 35 concentrations
Light Intensity = 10.4 mW cm-2 , Temperature = 303 K , pH = 12.57

Concentrations	Photopotential (mV)	Photocurrent (µA)	Power (W)
[Glucose] x 10-3 M			
2.3	761.0	642.0	488.56
2.5	867.0	741.0	642.45
2.7	954.0	869.0	829.03
2.9	858.0	752.0	645.22
3.1	754.0	548.0	413.19
[Brij 35] x 10-3 M			
2.5	737.0	636.0	468.73
2.7	876.0	762.0	667.51
2.9	954.0	869.0	829.03
3.1	835.0	751.0	627.09
3.3	711.0	624.0	443.66

(c) Effect of Diffusion Length:

The impact of variation of diffusion length (it is 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 glass cells of different dimensions. It was observed that in the first few minutes of illuminations there is sharp increase in the photocurrent. As a consequence, the maximum photocurrent (i_{max}) increased with increasing diffusion length because the path for photochemical reaction was increased, whereas equilibrium photocurrent (i_{eq}) decreased linearly. Therefore, it may be concluded that the main electroactive species are the leuco or semi form of dye (photosensitizer) in the illuminated and dark chamber respectively. The Glucose and its oxidation product act only as electron carriers in the path. The results are given in figure 3.

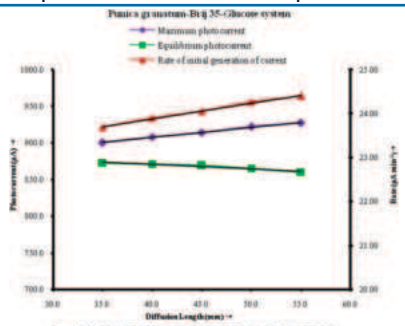

Fig. 3 VARIATION OF CURRENT PARAMETERS WITH DIFFUSION LENGTH

(d) Effect of Temperature:

With an increase in the temperature, the photocurrent of the PG cell was found to increase with a corresponding rapid fall in potential. The effect of temperature on total possible power output in the Punica granatum natural dye–Glucose-Brij 35 system was also studied and it was observed that with the increase in temperature (temperature range under observation) the power output of the cell increase slowly irrespective of the rapid fall in photopotential. The results are reported in table 2.

Table- 2 Variation of Photopotential and Photocurrent with Temperature

Punica Granatum–Glucose –Brij-35 system	Temperature (K)				
	298.0	300.0	303.0	310.0	317.0
Photopotential (mV)	958.0	957.0	954.0	951.0	948.0
Photocurrent (A)	865.0	866.0	869.0	871.0	874.0

(e) Current-Voltage (i-V) Properties of the Cell:

The short circuit current (i_{sc}) 869 µA and open circuit voltage (V_{oc}) 954 mV of the PG cell were measured with the help of a microammeter (keeping the circuit closed) and with a digital pH meter (keeping the circuit open), respectively. The photo current and potential values in between these two extreme values were recorded with the help of a carbon pot (log 470 K) connected in the circuit of multimeter, through which an external load was applied. The i-V properties of the PG cell containing Punica Granatum extract, Glucose and Brij 35 chemicals are graphically shown in figure 4. It was observed that i-V curve deviated from its regular rectangular shape. A point in the i-V curve, called power at point (pp), was determined where the product of photo current (i_{pp}) 220 µA and potential (v_{pp}) 547 mV was maximum. With the help of i-V curve, the fill-factor was reported 0.1302 by using the formula:

$$\text{Fill factor}(\eta) = \frac{V_{pp} \times I_{pp}}{V_{oc} \times I_{sc}}$$

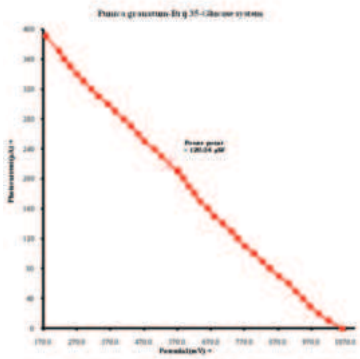

Fig. 4 CURRENT VOLTAGE (i-V) CURVE OF THE CELL

(f) Cell Performance and Conversion Efficiency

The performance of the PG cell was observed by applying an external load (necessary to have current at power point) after terminating the light source as soon as the potential reaches at a constant value. The performance was determined in terms of $t_{1/2}$, i.e., the time required in fall of the power output to its half

at power point in dark. It was observed that the cell containing Punica granatum–Glucose-Brij 35 systemcan be used in dark for 150 minutes. With the help of photo current and potential values at power point and the incident power of radiations, the conversion efficiency of the cell was determined as 1.1571 % using the formula. The results are graphically represented in time-power curve (figure 5).

$$\text{Conversion efficiency} = \frac{V_{PP} \times I_{PP}}{A \times 10.4 mWcm^{-2}} \times 100\%$$

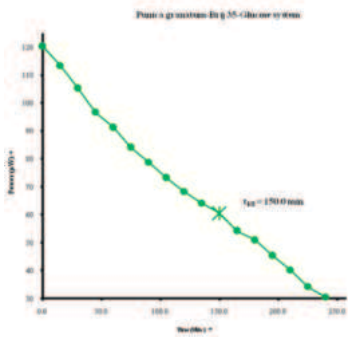

Fig. 5 TIME-POWER CURVE OF THE CELL

Mechanism

When the dye molecule is excited by the light in the presence of electron donating substance (Glucose), the dye rapidly changed into colorless form. The dye now acts as a powerful reducing agent and can donate electron to other substance and reconverted to its oxidized state. On the basis of earlier studies a tentative mechanism in PG cell shown in figure 6.

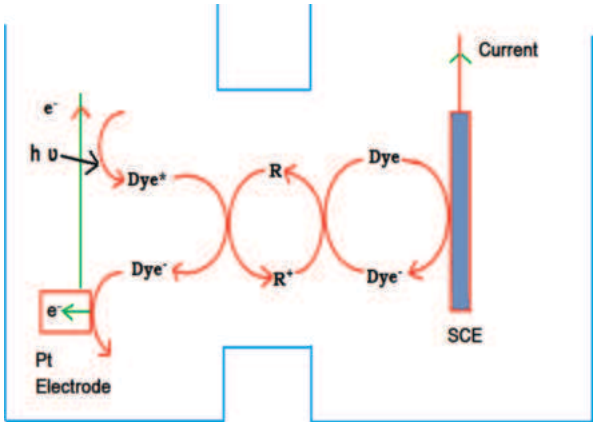

Fig. 6 Scheme of Mechanism

SCE = Saturated calomel electrode D = Dye (Photosensitizer)
R = Reductant D* = Semi & Leuco form

MATERIALS AND METHODS

Glucose, Brij 35 and NaOH of Loba Chemie were used in the present work. Solutions of Glucose, Punica granatum extract, Brij-35 and NaOH (1N) were prepared in double distilled water (conductivity 3.5×10^{-5} Sm^{-1}) and kept in amber coloured containers to protect them from sun light. 25 ml solution of these chemicals was taken in an H–type glass tube which was blackened by black carbon paper to protect from sun light. A shiny Pt foil electrode (1.0 x 1.0 cm^2) was immersed in one limb of the H–tube and a saturated calomel electrode (SCE) was immersed in the other limb. Pt-electrode acts as a working electrode and SCE as a counter electrode. The whole system was first placed in the dark till a stable potential was attained, then the limb containing the Pt-electrode was exposed to a 200 W tungsten lamp (Philips). A water filter was used to cut off thermal radiation. A digital multimeter (HAOYUE DT830D Digital Multimeter) was used to measure the photo potential and current generated by the system respectively. The i-V characteristics were studied by applying an external load with the help of Carbon pot (log 470 K) connected in the circuit the PG cell set-up is shown in figure 7.

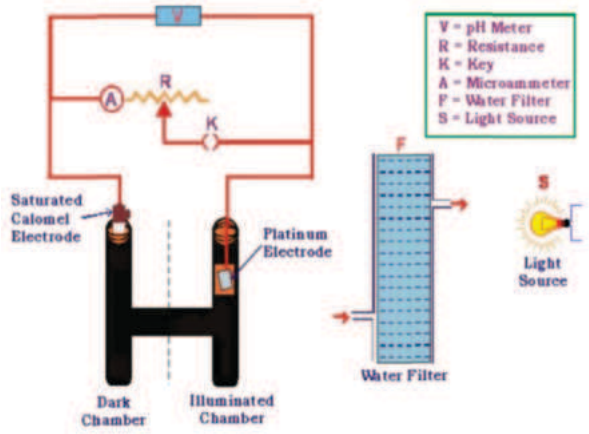

Fig.7 Photogalvanic Cell Set-up

CONCLUSIONS

The Punica granatumextract having good photo-sensitizer property. These characteristics of the dye make it a good light absorbing materials for the use in dye sensitized PG cells. In present study, this dye has responded favorably to the use of good reductant Glucose in the presence of small Pt working electrode, combination electrode as counter electrode and Brij 35 assurfactant at high pH to show abruptly enhanced photogalvanics (current 869 μA, power 120.34 μW). This study revalidates efficacies of the small Pt working electrode, combination electrode, surfactant, and high pH for having the increased solar power generation and storage from any dye sensitizer through the PG cells. Therefore, the Punica granatum–Glucose-Brij 35 system with small Pt electrode will be an option for construction of highly efficient PG solar cells.

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