



Enhanced Electrical Results of Mixed Dyes System (MG and TB + D-Arabinose + Brij-35) System in Photogalvanic Cell for Conversion and Storage

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ABSTRACT

A study plan has been proposed for systematic research in the field of photogalvanic (PG) cells for solar energy conversion and storage. Research on PG cells is essential and recommended for development of society. Our goal is to enhance the conversion of solar energy into electrical energy and its storage in PG cells. The MG and TB + D-Arabinose + Brij-35 PG cell system was used to analyze electrical results of PG cell characteristics. In this investigation, the open circuit voltage (Voc), photopotential (PP), and photocurrent (PC) were measured at 18.00 mV, 31.00 μ A, and 538.00 mV, respectively. Several PG cell characteristics have been varied in order to examine the effects of solar energy. The main goal of PG cell research is to use methodical scientific techniques to examine dyes for better electrical results. Based on obtained results research, surfactants (Brij-35) with mixed dye have shown promise in studies and require further investigation, particularly to improve outcomes.

Keywords: D-Arabinose, Electrical output, Mixed dyes, Photopotential, Conversion efficiency.

INTRODUCTION

Solar energy can be stored and transformed into electrical power using photogalvanic (PG) cells. PG cells are based on a photochemical reaction that produces good electrical effects when activated by a photon. Once the electrochemical energy is lost from these energy-dense cells, electricity is produced. Becquerel¹, (1839) reported on photo effects are photophysical nature that rely on the radiations. Rideal and Williams² (1925)

mentioned on electrochemical system for excitation of radiations. Rabinowitch³ (1940) studied on photoelectrochemical properties (PEP) and reported on electrochemical nature. Subsequently, other researchers (Ameta *et al.*,⁴, 1989) examined some outcomes for relevant PG (PG) cell. Later, aspects related to PG were investigated by Gangotri and Regar⁵ (1997); Gangotri and Lal⁶, (2000); Genwa and Sonel⁷, (2010); Gangotri and Lal⁸, (2013); Genwa and Singh⁹, (2013); Gangotri and Lal¹⁰, (2013); and Bhimwal *et al.*,¹¹, (2013), respectively. For a scientific



approach to PG systems was examined by Koli and Sharma¹² (2016). For more equitable outcomes, DSS, tartrazine, and EDTA were investigated by Rathore and Lal¹³ (2018) and their conversion efficiency (CE), $t_{0.5}$, and fill factor (FF) of EDTA-DSS-DYE system in PG cells were investigated; the corresponding findings were 0.280%, 100.0 min, and 0.3024. According to Lal and Gangotri¹⁴ (2022), the CE was 0.2812% as well as storage capacity (for the mixed surfactant system) was recorded for 120.00 minutes. For a scientific approach to regulating the dye reductant process, the most relevant research on the sunlight^{15,16}. The PG cell performance on mixed surfactant PGs was in the dark for 110.00 minutes by Lal and Gangotri¹⁷ (2022). The most current and relevant work on electromagnetic radiation nature that are renewable as well as eco-friendly environment has been reported by Lal and Gangotri¹⁸ (2023). After conducting a comprehensive literature review¹⁹⁻²¹, numerous dye-based PG systems have been examined in PG cells, but no one has focused on employing a system of mixed dyes. Due to this reason, research planned to better made up of TB and MG with Brij-35 surfactants for solar conversion as well as storage in PG cells. We choose this particular piece for this reason in particular. The main goal of PG cell research is to use methodical scientific techniques to photochemically examine dyes. PG cell research objectives describe the precise accomplishments a researcher hopes to accomplish, such as creating new knowledge, investigating a condition, or testing an electrical result. This helps to provide direction, define the scope, and focus the electrical outcomes. Research on PG cells is important because it studies into a sustainable and affordable method of converting solar energy into electricity and storing it at the same time. By eschewing complicated semiconductors, PG cells may provide a cleaner, more affordable option to traditional solar cells. By identifying the best chemical combinations and materials, the research seeks to increase efficiency and create devices that are more affordable, effective, and naturally storage-capable for future broad use.

MATERIAL AND METHODS

Preparation of solutions and Experimental set

All solutions of dyes Malachite green (MG), Toluidine blue (TB), reductant (D-Arabinose) and the surfactants (Brij-35) were prepared

(Table 1). The solutions were prepared in double distilled water by weighing with the help of precision balance. Different solution like dyes (MG, TB) were prepared by keeping the concentration of 2.0×10^{-5} M, 8.0×10^{-6} M, Reductant (D-Arabinose) at 2.0×10^{-3} M, surfactant (Brij-35) at 6.0×10^{-3} M and 1N NaOH solution.

Table 1: Required chemicals for PG cell experiments

Sr. No	Chemicals	Specifications
1	Malachite green	E. Merck
2	Toluidine blue	E. Merck
3	Sodium hydroxide	SISCO
4	Sodium lauryl sulphate	E. Merck
5	D(-) Arabinose system	S. D. Fine
6	Digital pH meter (Model - 335)	Systronics
7	Microammeter (Model - 65)	Systronics

An H shaped PG cell (Fig.1), methodology setup²², was used for study. For the experiment, H shaped glass tube was filled with surfactants, dyes, reductants, NaOH and double distilled water. The total volume of solution was made 25 mL. Platinum electrode (1.0×1.0 cm²) dipped in one arm of this H-shaped glass tube, while a calomel electrode was dipped in another arm. A 200 W tungsten light source is used to expose the cell containing the platinum electrode.

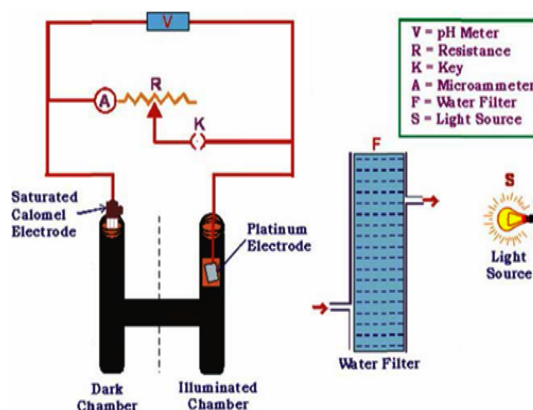


Fig. 1. Methodology setup of PG cell

RESULTS

Effect of variation of dyes concentration

Through the practical analysis, the obtained results of PG cell were increased by increasing the concentration of MG & TB mixed dyes system with surfactant (Brij-35) and reductant D-(Arabinose). The concentration of dyes affects the PG outcomes because the photochemical reaction which depends on absorption of light by the dye's molecules. Because

there were fewer dye molecules absorbing sunlight, the cell's electrical output was likewise low when the chemical concentration was low (Table 3 and 4). Better findings obtained at this concentration of Malachite green 2×10^{-5} M & Toluidine blue 8×10^{-6} M. On increasing the concentration of dyes, the efficiency of the cell decreases because the part of light is absorbed by the dye's molecules situated away from the platinum electrode and the dyes molecules situated near the platinum electrode cannot get desired light and the output of cell becomes low.

Table 2: Effect of variations of TB dyes concentration

Mixed dye+D-Arabinose +Brij-35 system	[TB] $\times 10^{-6}$ M				
	7.0	7.5	8.0	8.5	9.0
PP(mV)	211	249	330.0	263	187
PC(μ A)	16	22	31.0	29	20
Power(μ W)	3.376	5.478	10.230	7.627	3.740

Brij-35 = 6×10^{-3} M, Light Intensity = 10.4 mWcm^{-2} , D-Arabinose = 2×10^{-3} pH = 12.90, Temp = 303 K, MG = constant

Table 3: Effect of variations of MG dyes concentration

Mixed dye + D-Arabinose + Brij-35 system	[MG] $\times 10^{-5}$ M				
	1.0	1.5	2.0	2.5	3.0
PP(mV)	201	236	330.0	257	179
PC(μ A)	14	20	31.0	27	17
Power(μ W)	2.814	4.720	10.230	6.939	3.043

Brij-35 = 6×10^{-3} M, Light Intensity = 10.4 mWcm^{-2} , D-Arabinose = 2×10^{-3} pH = 12.90, Temp = 303 K, TB = constant

Effect of reductant concentration

By the practical analysis we measured that if change the strength (to increase) of reductants (D-Arabinose) then the results of PG cell also increase because the cell electrical output depends on movements of dyes molecules. When increase the concentration of reductants the movement of dyes molecules is hindered due to which the dyes molecules cannot reach the electrode with in their prescribed time limit and hence the power generation decreases. The maximum output of cell obtained on at 2.0×10^{-3} M concentration of reductant. During experimental process, measured photocurrent were $31.0 \mu\text{A}$ and PP 330.0 , respectively.

Effect of surfactant concentration

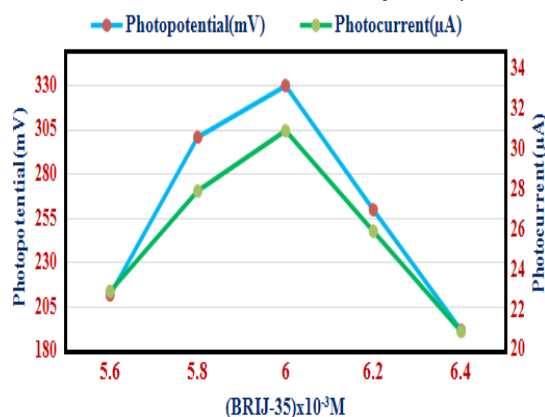
When the mixed dyes system with reductant D-Arabinose analysis with the variation of surfactants (Brij-35) concentration. We found that if we increase the concentration of surfactants the electrical out (PP & PC) of cell also increase. the maximum electrical production capacity of PG cell was obtained at

6.0×10^{-3} M concentration of the surfactants (Brij-35). On further increasing this concentration of surfactants we observed a decrease in the value of PC and PP of the cells, Fig. 2. Apart from this surfactant combines with dyes and forms a protective layer due to which the dyes do not get damaged in light. if the concentration of surfactants adds more than require concentration this process doesn't proceed properly. The effect of surfactants concentration on PG cell output is presented in Table 4.

Table 4: Variations of Brij-35

Mixed dye + D-Arabinose + Brij-35 system	[Brij-35] $\times 10^{-3}$ M				
	5.6	5.8	6.0	6.2	6.4
PP(mV)	212.0	301.0	330.0	260.0	192.0
PC(μ A)	23.0	28.0	31.0	26.0	21.0
Power(μ W)	4.876	8.428	10.230	6.760	4.032

MG = 2.0×10^{-5} M TB = 8.0×10^{-6} M D-Arabinose = 2×10^{-3} pH = 12.90

**Fig. 2. Observations of photopotential & photocurrent with (BRIJ-35) Concentration**

Impact of pH fluctuation on the system

Variation of pH on PG cell with mixed dyes system (MG and TB) by different concentration of NaOH. we found that with increasing the pH value photocurrents and photo potential of the cell decrease (Table 5, Fig. 3). The maximum output of cell was obtained at 12.90 pH value. The high electricity production of the cell at this pH value 12.90 indicates that the reductant behaves as a good donor at this pH medium.

Table 5: Study on variations of pH of the system

Mixed dye + D-Arabinose + Brij-35 system	pH of the System				
	12.5	12.7	12.9	13.1	13.3
PP(mV)	227.0	278.0	330.0	292.0	244.0
PC(μ A)	11.0	17.0	31.0	21.0	14.0
Power(μ W)	2.497	4.726	10.230	6.132	3.416

Brij-35 = 6×10^{-3} M MG = 2.0×10^{-5} M TB = 8.0×10^{-6} M D-Arabinose = 2×10^{-3}

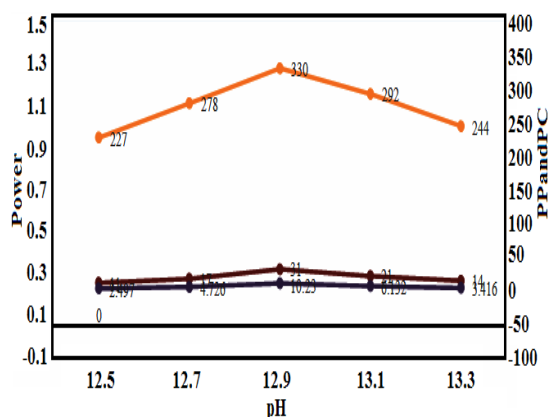


Fig. 3. Study on variations of pH of the system

Current-voltage characteristics of the PG cell

Electrical outcomes were measured using micrometer and digital pH metre, respectively. The *i-v* calculations for MG and TB mixed dyes system are shown in the graph. There is a point on these *i-v* curve Power point, as shown in Fig. 4. On the basis of study, result of fill factor of MG & TB mixed dyes system is 0.1325.

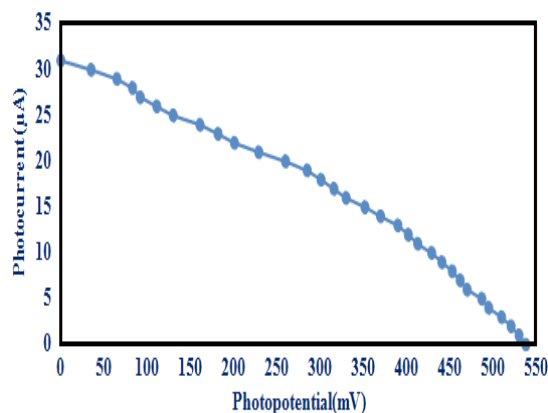


Fig. 4. Current Voltage (*i-v*) Curve of the Cell

CE, FF and Performance of the cell

For MG and TB mixed dyes with surfactants (Brij-35) system, obtained T_{1/2} was 122 minutes. This electrical value of a PG cell was reported for this system during experiment. By maintaining fractional timing that how long it took for the power output to decrease to half its value, we were able to determine T_{1/2}. By using platinum foil electrode (1.0 × 1.0 cm²) with MG and TB mixed dyes system, we obtained FF and CE 0.1325 and 0.05209%, respectively.

$$FF = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}} \times 100\% \quad (1)$$

$$CE = \frac{A \times 10.4 \text{ MW cm}^{-2}}{A \times 10.4 \text{ MW cm}^{-2}} \quad (2)$$

Where V_{pp} = potential, i_{pp} = current at power point, V_{oc} = open circuit voltage, i_{sc} = short circuit current.

Effect of variation of diffusion length

H shape cells have been used whose diffusion length (DL) is from 35mm to 55mm. The electrical output of these cells has been determined with malachite green and toluidine blue mixed dyes system with surfactants (Brij-35). The photocurrent of the cell also increase that is the value of i_{max} increase and the value of i_{eq} decrease. This increase and decrease are due to the increase in photochemical reaction path and we can also say that this change occurred due to the flow of electrode active species produced in the cell reaction. The particles that carry the main electron are dyes. The work of these two forms is just that they carry the electron from one place to another. The maximum output of the cell comes with a diffusion length of 45 mm. The lower and higher diffusion length is not good for best result. All obtained results are shown in Tables 6.

Table 6: Variations of DL

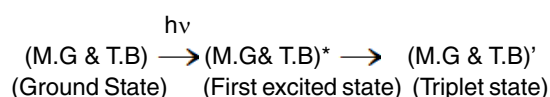
D _L (mm)	PC i_{max} (µA)	PC i_{eq} (µA)	Initial Rate of generation of current (µA min ⁻¹)
35	61.0	43.0	0.92
40	69.0	37.0	1.03
45	76.0	31.0	1.26
50	85.0	27.0	1.28
55	92.0	23.0	1.30

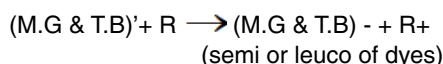
[Brij-35] = 6 × 10⁻³M, [MG] = 2.0 × 10⁻⁵M, [TB] = 8.0 × 10⁻⁶M, [D-Arabinose] = 2 × 10⁻³ pH = 12.90

Mechanism

Based on data from experiments, the following reaction mechanism is proposed. Through a multi-step process incorporating semiconductor-based substances like dye or photosensitizer, a PG solar cell transforms chemical energy into electrical energy. First, electrons are excited by photons, or light particles, forming electron-hole pairs. Electrons are then pushed to the photophysical and photochemical processes by the semi- or leuco form of dye's internal electric field, which separates these charges. Ultimately, an external circuit allows these separated charges to flow, producing an electric current that may charge electronic devices.

Illuminated chamber

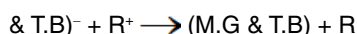
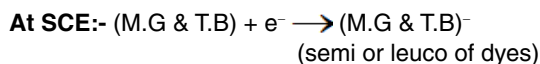




At Platinum electrode



Dark chamber



Where (M.G & T.B), (M.G & T.B)⁻ show dyes and their reduced form of dyes. R and R⁺ denoted as reductant and oxidized form of reductant.

Table 7: Measured electrical results of current study

Sr. No	Electrical results	Mixed dye+D-Arabinose +Brij-35 system
1	Open Circuit Voltage (V_{oc}) mV	538.0
2	Short Circuit current i_{sc} (μA)	31.0
3	Photopotential ΔV (mV)	330.0
4	Current at power point i_{pp} (μA)	18.0
5	Fill factor (η)	0.1325
6	Conversion efficiency (%)	0.05209
7	$t_{1/2}$ (min)	122.00

CONCLUSION

Based on obtained results (Table 7), MG and TB mixed dyes, along with the surfactant

Brij-35 and reductant D-(Arabinose), have good electrical output. The cell's storage capacity was 122 min; its conversion efficiency was 0.0529% and FF is approximately 0.1325. This PG cell is very cost-effective since it uses inexpensive surfactants, reductants, and photosensitizers. We can conclude from the aforementioned findings that mixed dyes system with surfactants (Brij-35) and reductants D-Arabinose is good as recommended PG cell. Its quality can be further enhanced by employing additional reductant surfactants and dyes in the PG cell.

Nomenclature: SE is Solar energy, RE is Renewable energy, PG is photogalvanic, $t_{1/2}$ = cell storage capacity, CT is charging time, i_{max} is the maximal photocurrent, PGS is the photogalvanic system, DL is Diffusion length, and MG is Merigold, FF = fill factor, CE = conversion efficiency, CP = cell performance.

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Conflict of Interest

There are no conflicting interests among the researchers.

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