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RESEARCH ARTICLE

Innovative Study of Prospective Energy Source Through C DEA+ACG+EDTA System for Photogalvanic Cell

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Abstract

Objective: Enhancing the process of transformation of solar energy into electricity and storing it using photogalvanic (PG) cells for greater electrical output is the goal of the study endeavor. **Methods:** Two electrodes, a digital pH metre, a resistance key, a carbon pot, and a micro-ammeter make up the PG cell setup. For superior electrical results, the specifically created H-shaped PG cell was investigated. In a PG cell with C DEA+ACG+EDTA system, the various solar parameters (concentration, diffusion length, electrode area, pH etc.) were investigated. By changing the various parameters of the PG cell, the major impact of solar energy was investigated. For the PG cell, a 25 ml solution of surfactant (08 ml), reductant (05 ml), and dye (12 ml) was combined with distilled water and alkali. In terms of improved electrical results from renewable energy, the PG cell has experimentally demonstrated the effective system that was the intended target of the research. The comparison was made with the existing methods by relevant literature survey. **Findings:** The observed highest photopotential and maximum photocurrent for the C DEA+ACG+EDTA PG cell were 1038 mV and 612.00 μA, respectively. Performance and conversion efficiency of the PG cell were discovered to be 189.00 minutes and 1.2315%, respectively. **Novelty:** The photogalvanic is emerging field of research and manuscript contains substantial electrical output, conversion efficiency and storage capacity of developed photogalvanic cell with special attention to better performance and reduces the cost of the photogalvanic cell for its commercial viability. The main objective of the research was to increase considerable electrical production. The goal has been accomplished by using the C DEA+ACG+EDTA PG cell setup to get good electrical results.

Keywords: Solar Energy; Photopotential; Electrical Production; EDTA; Photocurrent

1 Introduction

The solar energy contents, such as water photolysis and photosynthesis, are based on these exciting photochemical processes. Non-renewable energy sources have their own drawbacks in addition to risky operations and a polluting environment. The use of fossil

fuels like wood, coal, kerosene, etc. is quickly moving them closer to being completely depleted. As a result, developing alternate sources is necessary. Solar energy cells are the most practical alternative energy source. Solar storage principles are the foundation of photogalvanic (PG) cells. The research community has not been interested in a thorough investigation of the electrical output of PG cells. In order to achieve this goal of feeding the world with pollution-free nature for sustainable development, the current study reports superior results PG cell. Photogalvanic (PG) cells are the solar cells that have been most thoroughly researched. As a result, photogalvanics have better dye-based storage capacity than photovoltaic cells, and as a result, the D-RS (Dye-Reductant-Surfactant) system is comparatively effective in the field of photogalvanics [(1)]. The first-order kinetic model was used to follow the reaction kinetics of dye photodegradation, and a photodegradation mechanism for dyes was presented [(2)]. On sudan-fructose based PG cells, Koli (2021) was investigated for solar energy conversion and storage at low and artificial sun intensity [(3)]. Dye Sensitized Solar Cell (DSSC) is an easy to manufacture photovoltaic technique but lacks its stability and higher conversion efficiency factors [(4)]. Bromocresol green (BCB) dye with various electrodes and cell diameters were examined by Koli et al. on improved and simplified PG cells for solar energy harvesting in 2021 [(5)]. It was suggested to do research using solar parameters. Different electrical outputs, including photocurrent, photopotential, conversion efficiency, fill factor, and cell performance, were used to study the PG cells [(6)]. Observations of the cell's electrical output for the tartrazine, D-Fructose, and lauryl glucoside systems have also been made. The power point potential (PPP), open circuit potential (OCP), power point of cell (pp), and short circuit current (SCC) were measured [(7)]. For solar cell transformation and storage, various parameters in a photogalvanic using a D-Xylose+MB+Brij-35+NaLS PG cell were investigated [(8)]. With particular reference to improved electrical output and solar energy storage, the mixed surfactants (Brij-35+NaLS) in PGS have experimentally demonstrated the efficient system as the desired target of the research [(9)]. For methylene blue-xylose-NaLS+CTAB system, photopotential and photocurrent were observed as better results [(10)]. Further extensive study of photogalvanic effect in photogalvanic cell was performed by using of mixed surfactant [(11)]. In the solar system, many surfactant-dye- reductants (SDR) have been employed, however none of the aforementioned parties have paid attention to the usage of Alizarin cyanine green (ACG) to increase the electrical output. The current work (C DEA+ACG+EDTA system) PG cell was therefore started.

2 Methodology

2.1 Solution preparations

To achieve meaningful results, all solutions for the experiment (sodium hydroxide, oxalic acid, Ethylenediamine tetraacetic acid (EDTA), Alizarin cyanine green (ACG), and Cocamide DEA) were prepared using distilled water (DW). Oxalic acid was used to standardize with NaOH solution in each set of experiments. To protect solutions from sunlight, all of these are stored in amber-colored flasks.

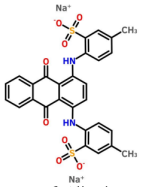
S.No.	**Dye: Alizarin cyanine green (ACG)**	
1	Molecular Formula: $C_{28}H_{20}N_2Na_2O_8S_2$	 Structure of Alizarin cyanine green
2	Molecular Weight: 622.57	
3	Visible Colour: Bluish green powder	
4	Melting point/ Freezing point [°C]: 235 - 238 °C	
5	Solubility in water [% weight]: Soluble in water	
6	Absorption maxima: 608 - 642 nm	
7	Dye content : Min 75%	

Fig 1. Description of Dye ACG

2.2 Methodology for set –up for C DEA+ACG+EDTA

PG cells have been developed using specially constructed H-shaped glass tubes. For the oxidation of dye degradation and Bacteriostatic efficacy of myco synthesized copper nanoparticles was evaluated [(12)]. Except for the one window designed to block electromagnetic radiation, the H tube was entirely darkened. The H tube was filled with sodium hydroxide (01 ml), surfactants (C DEA, 08 ml), reductant (EDTA, 05 ml), and photosensitizer (ACG, 12 ml) solutions (Figure 2). In order to

complete the solar circuit during the experiment, both ends of the electrodes were connected through the cell circuit, resistance key, micro-ammeter, 200 W electric lamp (which included a W filament). The water filter was employed for the configuration of the experiment's light sources and to block radiation. Maximum photopotential (PPmax), maximum photocurrent (PCmax), photocurrent (PC), and maximum power (Pmax) were all measured in the presence of formic acid [13]. For PG cells, the electrical findings were assessed in terms of the PP_{max} (1038.00 mV), PC_{max} (612.00 μA), PP (480.00 μA), and Pmax (354.24 μW). The uncertainty of metres (such as microammeters and pH metres) was related to the handling (errors) and calibration factors of scientific instruments. The experiment's cell arrangement required the use of a very diluted solution of the dye (ACG = 3.20 X 10^{-5} M), reductant (EDTA = 3.20 X10^{-4} M), and surfactant (C DEA = 10.82 X 10^{-4} M). The temperature in the environment was 303 K, and the cell illumination time was 90.00 minutes. Figure 2 shows the experimental results for EDTA+ACG+C DEA system.

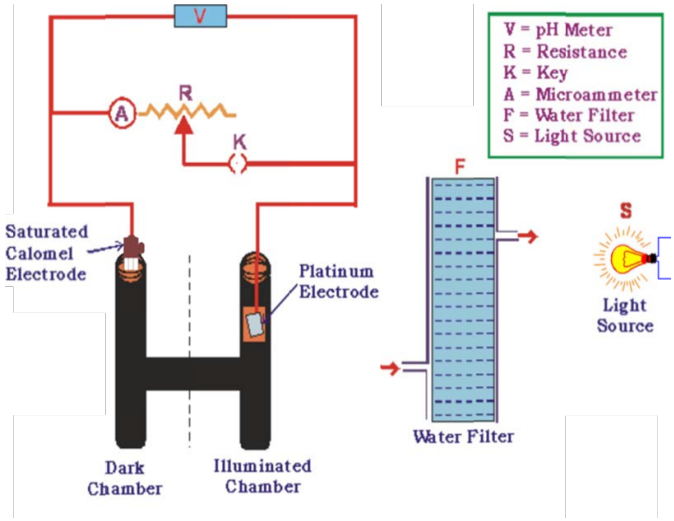


Fig 2. Methodology set up for PG cell

3 Results and Discussion

3.1 Variation of Alizarin cyanine green on the PG system

The change of dye concentration for EDTA+ACG+C DEA has been investigated in the current study. The electrical results in the EDTA+ACG+C DEA system increase with an increase in ACG concentration, peaking at 4.00 x10^{-5} M, and then begin to decline. Due to the hydrophobic character of ACG, which results in a lower nature of ACG for the absorption of light, the electrical output is comparably low (ACG= 3.16 X 10^{-5} M). When ACG molecules are present in higher concentrations (ACG > 3.16 X 10^{-5} M), a substantial number of them crowd the surface of the absorbent. The best molecules are present when the ACG concentration is in the middle (ACG = 3.16 X 10^{-5} M), allowing the best light source to reach the molecule closest to the electrode and trigger photochemical reactions. In Tables 1, 2 and 3 and Figures 3 and 4, all outcomes that were observed are provided.

3.2 Variation of EDTA on the PG system

The change of EDTA concentration for EDTA+ACG+C DEA has been investigated in the current study. The observed results rise as EDTA concentration increases. When EDTA concentration is increased, the electrical output also progressively rises to a maximum value at 3.20 X 10^{-4} M before falling off in the EDTA+ACG+C DEA system. Comparatively less amounts of reductant EDTA are available for electron donation to ACG to produce the ionic nature at lower concentrations of EDTA. The quantity of EDTA molecules accessible for photophysical conversion to ACG to create the cationic form, which inhibits the ACG molecules, is larger at much higher concentrations of ethylene dimethyl tetraacetic acid (EDTA > 3.20 X 10^{-4} M). The reductant concentration is an intermediate range where satisfactory results are obtained [14]. The explanation for this is that there are the ideal numbers of reductant molecules that create beneficial pathways for semi- or leuco-forms of dye ACG molecules present. The findings revealed that the deep sleep mode's current consumption was just 10 mA, which is generally significantly less

Table 1. Variation of ACG, EDTA, C DEA, and $_P$H

	Light Intensity = 10.4 mWcm^{-2} Temperature = 303 K		
Parameters	**Photopotential (mV)**	**Photocurrent (μA)**	**Power (μW)**
[ACG] $\times 10^{-5}$ M			
3.15	550.00	240.00	132.00
3.16	738.00	480.00	354.24
3.17	523.00	214.00	111.92
[EDTA] $\times$ 10^{-4} M			
3.10	553.00	240.00	132.72
3.20	738.00	480.00	354.24
3.30	634.00	236.00	149.62
[C DEA] $\times$ 10^{-4} M			
10.80	591.00	250.00	147.75
10.82	738.00	480.00	354.24
10.84	693.00	288.00	199.58
pH			
13.06	550.00	240.00	132.00
13.09	738.00	480.00	354.24
13.13	523.00	214.00	111.92

Table 2. Effect of Diffusion Length on the System

Diffusion length (mm)	Maximum photocurrent i_{max} (μA)	Equilibrium photocurrent i_{eq} (μA)	Rate of initial generation of photocurrent (μA min^{-1})
35.00	413.00	580.00	8.26
40.00	445.00	498.00	8.90
45.00	612.00	480.00	12.24
50.00	522.00	383.00	10.44
55.00	602.00	109.00	12.04

Table 3. Effect of Electrode Area on the System

EDTA+TB+NaLS	Electrode Area (cm^2)				
	0.40	0.80	1.20	1.60	2.00
Maximum photocurrent i_{max} (mA)	459.0	550.0	612.0	610.0	739.0
Equilibrium photocurrent i_{eq} (mA)	630.0	516.0	480.0	380.0	250.0

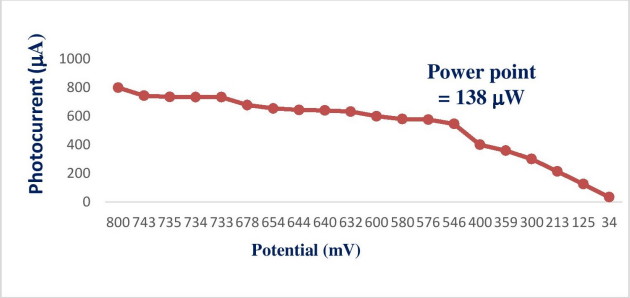


Fig 3. Current voltage (i-V) curve of PG cell

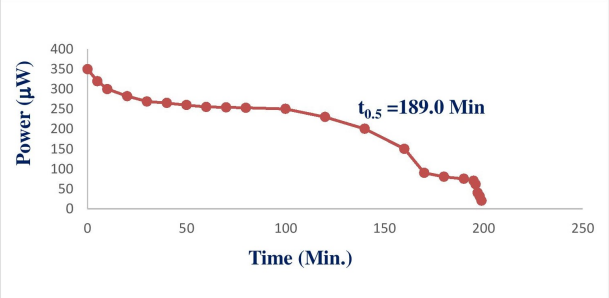


Fig 4. Performance of the PG cell

than the system's current consumption . For ACG variation on the PG system, the photopotential, photocurrent, and power are measured; the resulting values are 738 mV, 480.00 μA, and 354.24 μW, respectively. By changing the various parameters of the PG cell, the effect of solar energy was investigated. In Tables 1, 2 and 3 and Figures 3 and 4 , all outcomes that were observed are provided.

3.3 Variation of C DEA on the PG system

The PG cell with the EDTA+ACG+C DEA system tested the photo reactivity of NaLS with electrical power. It was observed that if the concentration of C DEA was raised, the outcome would increase up to a certain point before declining thereafter. Lower C DEA concentrations (surfactants 6.00 X10^{-5} M) resulted in reduced solubilization of the molecules for photophysical processes on the surface. While there are many more surfactant molecules available for photophysical processes in hydrophobic interaction at higher surfactant concentrations (C DEA > 6.00 10^{-5} M), which may diminish electron carrier. The considerable electrical output was recorded at a surfactant concentration of 6.00X 10^{-5} M C DEA, which is an intermediate range. In PG cells, the surfactant combination may lead to better precipitation than the individual precipitate of a single surfactant . Surfactant interaction at the micelles' interface is to blame for this. The obtained values for the photopotential, photocurrent, and power for the change of C DEA on the PG system are 738 mV, 480.00 μA, and 354.24 μW, respectively. The effects will be used to create a PG cell with a larger electrical output than the results that have already been published. Tables 1, 2 and 3 and Figures 3 and 4 present all of the outcomes that were observed for system.

3.4 Variation of pH on the PG system

In the current investigation, the concentration of hydrogen ions was recorded. As the alkaline nature (pH) increased, the current parameters were also gradually increased and reached a maximum value of a certain range (pH=13.09 at max.), after which the EDTA+ACG+C DEA system decreased. Poor results are observed on a pH range between 13.03 and higher (pH > 13.15). In contrast, excellent outcomes are observed at the intermediate range (pH = 13.09). This is because dye molecules (ACG) have a nature that makes them superior for photochemical processes. This is due to micelle interaction with dye molecules. On the PG system, every output is recorded for C DEA fluctuation, and the results are Open circuit voltage, photocurrent and power are 1038.00 mV, 480.00 μA, and 354.24 μW, respectively. The pH variation in the EDTA+ACG+C DEA system is shown in Tables 1, 2 and 3 . If the efficient systems are developed to the appropriate level, they may replace the solar cells currently available on the market and be able to meet the electrical demand required for sustainable development.

3.5 Variation of diffusion length on the PG system

The cell was utilised for experiments with diffusion lengths ranging from 35 mm to 55 mm. In the EDTA+ACG+C DEA system, the current parameters of the PG cell were investigated. The rate of photocurrent's initial generation is accelerated by increasing diffusion length. At 45.00 mm, very positive results are attained, with values of photocurrent (612.00 μA), equilibrium photocurrent (480.00 μA), and beginning photocurrent generation (12.24 mA/min), respectively. The photocurrent is acquired

in a corresponding way because dye molecules cannot absorb the light source at lower and higher diffusion lengths (35 mm and 55 mm), respectively. At intermediate range of diffusion length, 413.00 mA of maximum photocurrent, 580.00 mA of equilibrium photocurrent, and 8.26 mA/min. of starting photocurrent generation were measured. The difference in diffusion length for the EDTA+ACG+C DEA system is seen in Table 2 .

3.6 Variation of electrode area of the cell

The current characteristics of the PG cell were calculated using electrode areas ranging from 0.40 cm^2 to 2.00 cm^2 (0.8 X 0.5 to 2.0 X 1.0 cm). Study was conducted on the maximum photocurrent (i_{max} in mA) and equilibrium photocurrent (i_{eq} in mA). Maximum photocurrent of 459.00 mA and equilibrium photocurrent of 630.00 mA were obtained on 0.40 cm^2 of electrode area, and maximum photocurrent of 739.00 mA and equilibrium photocurrent of 250.00 mA were obtained on 2.00 cm^2 of electrode area. Maximum photocurrent (612.00 μA) and equilibrium photocurrent (580.00 mA) were recorded at 1.20 cm^2 of electrode area, which are comparatively greater electrical outputs in the EDTA+ACG+C DEA system. Table 4 displays the observed results for the change in electrode area on the EDTA+ACG+C DEA system. Koli et al. reported on congo red dye-formaldehyde as a new sensitizer-reductant couple for enhanced simultaneous solar energy conversion and storage by photogalvanic cells at the low and artificial sun intensity and Low-power early forest fire detection and warning system [15]. They have reported the electrical cell performance of the PG cell as Ppp 782 μW, i_{sc} 3200 μA, Voc 1074 mV, and CE 11.02% at artificial and low illumination intensity.

3.7 (i-V) characteristics of the PG cell

The fill-factor (FF) and power point (PP) were calculated (equ. 1):

$$\text{Fill factor } (\eta) = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}} \tag{1}$$

$$\text{Power Point } (pp) = Vpp \times i_{pp} \tag{2}$$

Where

V_{pp} is value of potential, i_{pp} is current at power point, V_{oc} is open circuit voltage, i_{sc} is short circuit current

The value of FF of the cell circuit was calculated as 0.3082 and the pp was obtained as 138.0 μW for the PG cell. Figure 3 shows the power point of a cell in EDTA+ACG+C DEA System.

3.8 Cell performance and conversion efficiency of the PG system

The determined performance is (Figure 4) in terms of $t_{1/2}$ and the observed value was 189.00 minutes in dark. PG cell conversion efficiency (CE) was determined as 1.2315 % (by using of the equ. 3). The conversion efficiency of the methylene blue-xylose-mixed surfactant system was 0.6769% [16]. Use of Congo red dye-formaldehyde as a new sensitizer-reductant couple for enhanced simultaneous solar energy conversion and storage by photogalvanic cells at the low and artificial sun intensity [17]. The PG cell performance and efficacy were found 24.00 minutes and 0.2630%, respectively [18].

$$\text{Conversion efficiency } = \frac{V_{pp} \times i_{pp}}{A10.4mW_{cm^{-2}}} \times 100\% \tag{3}$$

Where $V_{pp,}$ is photopotential at power point of cell, i_{pp} is photocurrent at power point of cell, A is electrode area of cell

3.9 Mechanisms

Experimentally, the following chemical reaction occurs, showing the movement of electrons within the cell circuit.

3.9.1 Illuminate Chamber

The ACG molecules (photosensitizer) absorb quantum radiation in the photophysical and photochemical process (equation 4) and become excited as follows. Excited ACG takes electrons from reductants and transmits its energy to other molecules for a chain reaction in the secondary phase (equation 5).

$$\mathrm{ACG} \xrightarrow{h\nu} \mathrm{ACG}^* \tag{4}$$

$$\mathrm{ACG}^* + \mathrm{R} \longrightarrow \mathrm{ACG} + \mathrm{R}^+ \tag{5}$$

3.9.2 Photochemical reaction at Pt electrode

In the secondary reaction, the semi- or leuco-form of ACG (equation-6) loses an electron to an electrode and changes into the original ACG molecule

$$ACG^{-} \longrightarrow ACG + e^{-} \tag{6}$$

3.9.3 Photochemical reaction at dark Chamber

At the counter electrode, the photosensitizer (ACG molecules) gains an electron from the counter electrode and changes into a semi- or leuco-form of ACG as a fellow (equation 7). Finally, the ACG (leuco/semi-form) and the reductant (oxidized form) combine to produce the original ACG dye and EDTA reductant (R) molecules (equation 8), and the photochemical cycle is completed

$$ACG + e^{-} \longrightarrow ACG^{-} \tag{7}$$

$$ACG^{-} + R^{+} \longrightarrow ACG + R \tag{8}$$

Where: ACG is alizarin cyanine green (dye), ACG* is excited form of alizarin cyanine green. ACG^{-} is semi or leuco form of alizarin cyanine green, R is Reductant, R^{+} is oxidized form.

Table 4. Effect of EDTA+ACG+C DEA

S. No.	Parameters	Single surfactant
1.	Open Circuit Voltage (V_{OC})	**1038.0 mV**
2.	Photopotential (DV)	**738.0 mV**
3.	Maximum Photocurrent (i_{max})	**612.0 μ A**
4.	Short Circuit Current (i_{sc})	**480.0 μ A**
6.	Current at Power Point (i_{pp})	**212.0 μ A**
7.	Potential at Power Point (V_{pp})	**725.0 mV**
8.	Power at Power Point (PP)	**138 μ W**
9.	Fill factor (h)	**0.3082**
10.	Conversion Efficiency (%)	**1.2315 %**
11.	$t_{1/2}$	**189.0 min**
12	Charging Time (min.)	**90.0 min**

4 Conclusion

The primary goals of the project were to lower the cost of PG cells while also improving electrical outcomes. By noting the good amount of storage capacity of the EDTA+ACG+C DEA system, the goal has been accomplished. The obtained results are better than previously published results . If the cost and overall efficiency of the efficient systems are decreased to the appropriate level, they may replace the current PG cells on the market and be able to meet all of humanity's electrical needs. In conclusion, the findings of the observed PG cell are higher than those of the PG system published by Lal and Gangotri in 2022. Rathore et al. 2022 and Koli et al., 2021. For ACG variation on the PG system, the photopotential, photocurrent, and power are measured; the resulting values are 738 mV, 480.00 μA, and 354.24 μW, respectively. The EDTA+ACG+C DEA PG cell's open circuit voltage is 1038.00 mV, compared to an earlier reported value of 895.00 mV (published work by Lal and Gangotri, 2022). In contrast to previously reported fill factors of 0.211, 0.200, 0.240, and 0.207 (published work by Koli et al., 2021) the EDTA+ACG+C DEA PG cell fill factor is 0.3082. While the greatest photocurrent in the EDTA+TB+NaLS PGS was recorded at 150.00 uA, the study published in the journal "Indian Journal of Science and Technology" in 2022 already had values of 190 uA. Based on the PG cell's observed results, we have found that the EDTA+ACG+C DEA surfactants have improved the cell's electrical output as well as its ability to convert energy into PGS. In terms of current specifications, the PG cells might be the finest fuel cell in the area of solar radiation transformation and potential.

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