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Innovative Study on Photogalvanic cell for Solar Energy Conversion and Storage Through Brilliant Cresyl Blue+ Ascorbic acid + Sodium Lauryl Sulphate

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ABSTRACT

The current study reports better findings photogalvanic (PG) cell in order to accomplish this objective of providing the globe with pollution-free nature for sustainable development. The goal of the research is to increase electrical output by the use of PG cells, which will result in increased electrical output. Better PG cell output has been the desired goal of the research, and this has effectively proved the efficient system in an experimental way. The Open circuit voltage (Voc), and photocurrent found for the Brilliant Cresyl Blue (BCB) + Ascorbic acid (AA) + Sodium Lauryl Sulphate (SLS) combination was 1124.0 mV and 240.00 µA, respectively. A proposed photochemical method for the conversion of solar radiation energy was offered for the current generation of PG cells. The BCB+AA+SLS system, PG cell configuration was used to get the desired electrical results.

Keywords: Brilliant cresyl blue, Ascorbic acid, Sodium lauryl sulphate, Photogalvanic cell.

INTRODUCTION

The photochemical reactions are important content for the solar energy, such as water photolysis and photosynthesis. In addition to unsafe operations and a polluted environment, non-renewable energy sources have their own disadvantages. The Fossil fuels (kerosene, coal, wood, etc.) are getting closer to being entirely exhausted as a result of human consumption. Therefore, creating alternative sources is required. The most practical alternative energy source is solar energy cells. The solar cells that have undergone the most in-depth investigation are PG cells. The PG cells are relevant to the photochemical nature. The studied-on PG cell in use of different surfactant in PG cell[1] for NaLS-Azur A-Glycerol (Gangotri, *et al.,* 2003), Use about surfactant in PG cell[2] for Tx-100-Azur C-Glycerol (Gunsaria and Hussain, 2004) and the role of EDTA-Azure A-SLS scientific path[3] about energy was studied (Gunsaria and Hussain, 2004).

Role of oxalic acid reductant and brilliant cresyl photosensitizers[4] for good results (Gunsaria *et al.,* 2005) and same way about cationic micelles effect on PG cells[5] for cetyl pyridinium chloride (CPC) with congo red dye+Xylose system (Gunsaria *et al.,* 2012) also in favour to better finding. The research on mixed photosensitizer with MB system[6] for glycol-NALS system for solar power conversion

and storage (Gangotri and Mohan, 2022). The ionic micelles effect (positive ions) on PG cell[7] for CPC system (Gunsaria & Meena 2012) and CMC studies of different surfactant, CTAB, Tween etc.[8] by scientific method to explore its potential in PG cell (Tiwari, *et al.,* 2020).

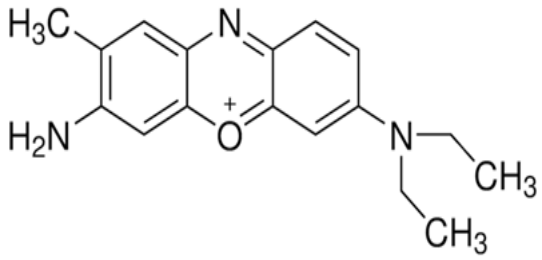
PG cells as better cell in spinach extract[9] of different artificial dye and natural dye (Koli, 2014), The better results consultable development[10] for generation of current (Stevenson K., 1981), Enhanced electrical output by mixed surfactant for solar cells: EDTA+NaLS+CPC+Tween-80 system[11] for TB photosensitizer (Meen *et al.,* 2024), Use of oxalic acid as reductant and MB[12] as photosensitizer (Gangotri and Meena 2001), Sustainable and green chemistry approach[13] for PG cells (Genwa and Genwa 2008), Studied on PG cell with DSS, Tartrazine and EDTA[14] for conversion solar energy and storage (Jayshree and Mohan 2018), followed by study of PG cell for electrical output[15] as same way by lauryl glucoside surfactant, Tartrazine photosensitizer and D-fructose reductant (Jayshree *et al.,* 2022).

A progressive study for a potential energy source using the photo-galvanic system (Jayshree *et al.,* 2022) was conducted in light of recent innovative way for better results[16] in PG cells. The results of mixed surfactant about Brij-35 and NaLS with MB dye (Lal and gangotri, 2022) were published in the "International journal of energy research" journal[17]. EDTA-Alizarin cyanine green (ACG)-sodium stearate (SS) PG cell as an inventive study[18] in for better findings (Genwa and Prasad, 2023). A novel method for doing cutting-edge research on sustainable energy sources using a mixed surfactant system for PG cell (Lal and Gangotri, 2023) and reported results are published in "Environment science and pollution research" journal[19]. Many surfactant-dye-reducing agents (SDR) have been used across the solar system, but none of those mentioned parties have given BCB+AA+SLS combination to any thought as an alternative way of enhancing electrical production. As a result, work on the current PG cell (BCB +AA+ SLS system) began.

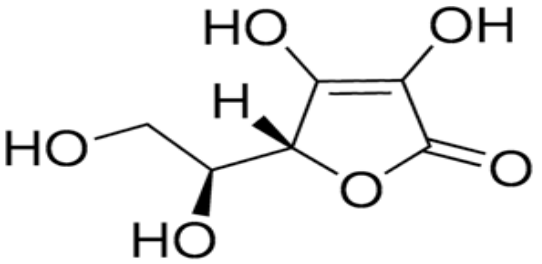
Methodology

Solution preparations

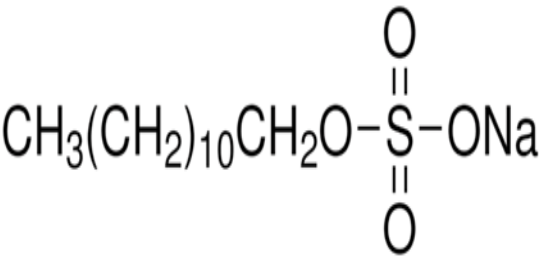
All of the experiment's approaches, including sodium hydroxide, BCB, and AA, were made with distilled water (DW) in order to produce results that were relevant. In each series of tests, oxalic acid was employed to standardize the solution containing sodium hydroxide. All of these solutions were stored in brown-colored bottles for non-reactive form from radiation.



Structure of BCB



Structure of Ascorbic Acid (AA)



Structure of SLS

Methodology for set–up for BCB+AA+ SLS system

Experiment: The PG cell set-up consists of two electrodes, a digital pH metre, key of resistance, a carbon pot, and an ammeter. For improved electrical results, studies into the specially created H-shaped PG cell were conducted. During the experiment, the resistance key, micro-ammeter, 200 W electric lamp (which had a W filament), and both ends of the electrodes were connected to complete the solar circuit. The experiment's light sources and radiation protection were set up using the water filter. The various solar parameters in a PG cell with a BCB+SLS+AA system was examined. The main effects of solar energy were examined by adjusting the PG cell's various parameters. For the PG cell, distilled water, alkali, and a mixture of surfactant, reductant, and dye were combined in solution. The temperature in the system was 303 K, and the cell

illumination time was 40.00 min during experimental process. The experimental setup Fig.1 for BCB +AA+ SLS system is reported for better findings.

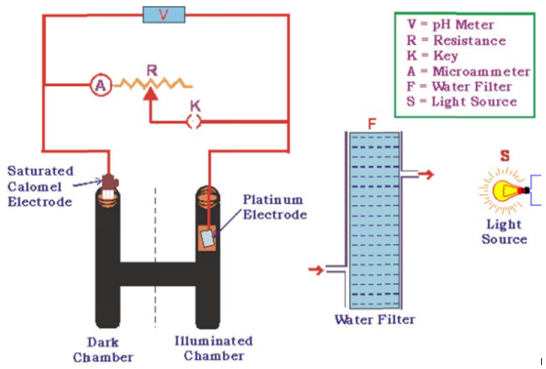


Fig. 1. Methodology for PG cell

RESULTS AND DISCUSSION

Variation about BCB concentration

The change of dye concentration for BCB+AA+SLS has been investigated in the current study. The electrical results in the BCB+AA+SLS system increase with an increase in BCB concentration, peaking at BCB X 10^{-4} M, and then begin to decline. Due to the hydrophobic character of cresyl blue, which results in a lower nature of BCB for the absorption of light, the electrical output is comparably low (BCB X 10^{-4} M). When BCB molecules are present in higher concentrations (BCB>10^{-4} M), a substantial number of them crowd the surface of the absorbent. The best molecules are present when the BCB concentration is in the middle (BCB X 10^{-4} M), allowing the electromagnetic source to collision to molecules closest to the electrode and trigger photochemical reactions. For BCB variation on the PG system, the Open circuit voltage (Voc), Isc, I_{max}, V_{pp}, i_{pp}, and P_{pp} are measured; the resulting values are 1124 mV, 220.0 μA, 240.0 μA, 624 mV, 100.0 μA, and 62.4 μW, respectively. In Table 1, 6 and Fig. 2-4, all outcomes that were observed are reported.

Table 1: Variation of BCB Concentration

Parameters	BCB Dye X 10^{-4} M concentration				
	1.0	1.2	1.4	1.6	1.8
V_{dark} (mV)	723	714	887	703	682
V_{max} (mV)	1142	1160	1176	1136	1113
Voc (mV)	1116	1108	1124	1096	1087
i_{max} (μA)	210.0	220.0	240.0	220.0	200.0
i_{sc} or i_{eq} (μA)	190.0	200.0	220.0	200.0	180.0
V_{pp} (mV)	585.0	570.0	624.0	574.0	596.0
i_{pp} (μA)	80.2	98.0	100.0	90.0	80.4
P_{pp} (μW)	52.65	57.00	62.40	57.40	47.68

Table 2: Variation of SLS Concentration

Parameters	SLS X 10^{-3} M concentration				
	0.4	0.6	0.8	1.0	1.2
V_{dark} (mV)	704	731a	887	725	682
V_{max} (mV)	1132	1151	1176	1155	1124
Voc (mV)	1078	1112	1124	1131	1066
i_{max} (μA)	180.0	220.0	240.0	200.0	170.0
i_{sc} or i_{eq} (μA)	160.0	200.0	220.0	180.0	150.0
V_{pp} (mV)	585.0	561.0	624.0	496.0	564.0
i_{pp} (μA)	80.0	98.0	100.0	90.0	80.0
P_{pp} (μW)	46.80	56.10	62.40	49.60	45.10

Table 3: Variation of Reductant Concentration (Ascorbic acid)

Parameters	Ascorbic acid X 10^{-3} M concentration				
	0.2	0.4	0.6	0.8	1.0
Vdark (mV)	703	729	887	713	698
Vmax (mV)	1151	1169	1176	1160	1146
Voc (mV)	1101	1109	1124	1118	1088
imax (μA)	200.0	220.0	240.0	220.0	210.0
isc or ieq (μA)	180.0	200.0	220.0	200.0	190.0
Vpp (mV)	616.0	532.0	624.0	515.0	628.0
ipp (μA)	80.0	98.0	100.0	90.0	80.0
Ppp (μW)	49.28	53.20	62.40	51.50	50.24

Table 4: Variation of NaOH Concentration (pH)

Parameters	pH of Solution				
	13.24	13.27	13.30	13.33	13.26
V_{dark} (mV)	729	706	887	717	732
V_{max} (mV)	1132	1162	1176	1148	1143
Voc (mV)	1078	1114	1124	1109	1097
i_{max} (μA)	140.0	200.0	240.0	220.0	200.0
i_{sc} or i_{eq} (μA)	120.0	170.0	220.0	200.0	190.0
V_{pp} (mV)	575.0	593.0	624.0	535.0	520.0
i_{pp} (μA)	60.0	80.0	100.0	90.0	80.90
P_{pp} (μW)	34.50	47.44	62.40	53.50	52.00

Table 5: Pt electrode size (Length X Width) in cm and Area

Parameters	pH of Solution				
	0.3x0.2 (0.06 cm^2)	0.4x0.2 (0.08 cm^2)	0.4x0.3 (0.12 cm^2)	0.5x0.3 (0.15 cm^2)	1.0x1.0 (1.00 cm^2)
V_{dark} (mV)	718	731	887	720	887
V_{max} (mV)	1148	1115	1176	1136	1176
Voc (mV)	1101	1078	1124	1091	1124
i_{max} (μA)	150.0	200.0	240.0	200.0	240.0
i_{sc} or i_{eq} (μA)	14.50	185.0	220.0	195.0	220.0
V_{pp} (mV)	595.0	500.0	624.0	531.0	624.0
i_{pp} (μA)	80.0	90.0	100.0	90.0	80.0
P_{pp} (μW)	47.60	50.00	62.40	53.10	62.40

Table 6: Analysis of the Variation in the Chemical Composition of the BCB Photosensitizer

S. No	The amount of chemical solution utilised					Resultant Concentration			
	0.001 MBCB (mL)	0.01ML AA (mL)	0.01 SLS (mL)	1 M NaOH (mL)	DDW (mL)	BCB X 10^{-4} M	AA X 10^{-3} M	SLS X 10^{-3} M	NaOH pH
1	2.5	1.5	2.0	4.0	15.0	1.0	0.6	0.8	13.30
2	3.0	1.5	2.0	4.0	14.5	1.2	0.6	0.8	13.30
3	3.5	1.5	2.0	4.0	14.0	1.4	0.6	0.8	13.30
4	4.0	1.5	2.0	4.0	13.5	1.6	0.6	0.8	13.30
5	4.5	1.5	2.0	4.0	13.0	1.8	0.6	0.8	13.30

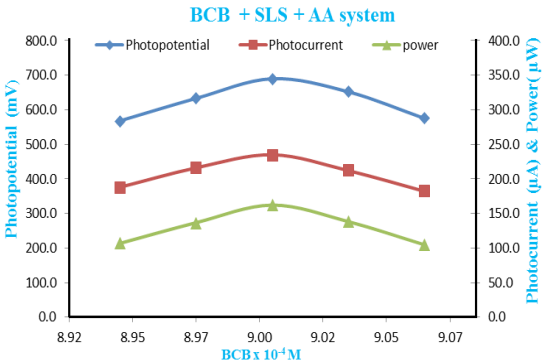


Fig. 2. Variation of photopotential(PP), photocurrent(PC) and power

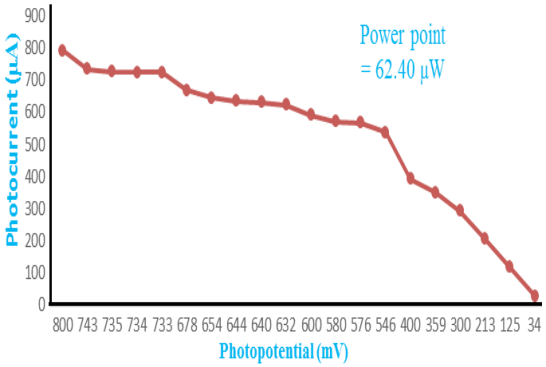


Fig. 3 Photocurrent power (i-v) of modified PG cell

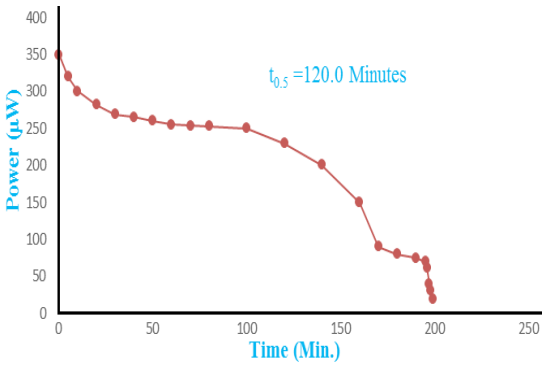


Fig. 4 Performance of the PG cell

Variation of SLS concentration

The PG cell with the BCB+AA+SLS system tested the photo reactivity of SLS with electrical power. It was found that if the concentration of SLS was increased, the result would rise until a particular point before falling after that. For photophysical processes on the surface, the solubilization of the molecules was reduced at lower SLS concentrations (surfactants X 10^{-3} M). Higher surfactant concentrations (SLS>10^{-3} M) may reduce the electron carrier because there are significantly more surfactant molecules available for photophysical reactions in hydrophobic contact. The considerable electrical output was recorded at a surfactant concentration of M X10^{-3} M SLS, which is an intermediate range. The mixture of surfactants may produce better precipitation in PG cells than the precipitate from a single surfactant alone. Surfactant interaction at the micelles' interface is to blame for this. For SLS variation on the PG system, the Open circuit voltage (Voc), I_{sc}, I_{max}, V_{pp}, i_{pp}, and P_{pp} are measured; the resulting values are 1124 mV, 220.0 μA, 240.0 μA, 624 mV, 100.0 μA, and 62.4 μW, respectively. Table 2, 8 and Fig. 2-4 present all of the outcomes that were observed for system.

Variation of AA concentration

The change of AA concentration for BCB+AA+SLS system has been investigated in the current study. The observed results rise as AA concentration increases. When AA concentration is increased, the electrical output also progressively rises to a maximum value at AA X 10^{-3} M before falling off in the BCB+SLS+AA system. Comparatively less amounts of reductant EDTA are available for electron donation to BCB to produce the ionic nature at lower concentrations of AA. The quantity of AA molecules accessible for photophysical conversion to AA to create the cationic form, which inhibits the AA molecules, is larger at much higher concentrations of ethylene dimethyl tetraacetic acid (AA>10^{-3} M). The reductant concentration is an intermediate range where satisfactory results are obtained. This can be explained by the presence of the ideal number of reductant molecules, which open up

advantageous paths for semi- or leuco-forms of dye BCB molecules. The results showed that the deep sleep mode consumed only 10 mA of current, which is often far less than the system's current usage. For AA variation on the PG system, the Open circuit voltage (Voc), I_{sc}, I_{max}, V_{pp}, i_{pp}, and P_{pp} are measured; the resulting values are 1124 mV, 220.0 μA, 240.0 μA, 624 mV, 100.0 μA, and 62.4 μW, respectively. In Table 3,7 and Fig. 2-4, all outcomes that were observed are provided.

Table 7: Analysis of the Variation in the Chemical Composition of the L AA Reductant

S. No	Volume of Chemical Solution used					Resultant Concentration			
	0.00 MBCB (mL)	0.01 M AA (mL)	0.01 SLS (mL)	1 M NaOH (mL)	DDW (ml)	BCBX10^{-4} M	AA X10^{-3} M	SLS X10^{-3} M	NaOH pH
1	3.5	1.5	2.0	4.0	15.0	1.4	0.2	0.8	13.30
2	3.5	1.0	2.0	4.0	14.5	1.4	0.4	0.8	13.30
3	3.5	1.5	2.0	4.0	14.0	1.4	0.6	0.8	13.30
4	3.5	2.0	2.0	4.0	13.5	1.4	0.8	0.8	13.30
5	3.5	2.5	2.0	4.0	13.0	1.4	1.0	0.8	13.30

Table 8: Examination of Modifications in the Chemical Make-Up of the Variation SLS Surfactant

S. No	Volume of Chemical Solution					Resultant Concentration			
	0.001 M BCB (mL)	0.01 M AA (mL)	0.01 SLS (mL)	1 M NaOH (mL)	DDW (mL)	BCB X 10^{-4} M	AA X 10^{-3} M	SLS X 10^{-3} M	NaOH pH
1	3.5	1.5	1.0	4.0	15.0	1.4	0.6	0.4	13.30
2	3.5	1.5	1.5	4.0	14.5	1.4	0.6	0.6	13.30
3	3.5	1.5	2.0	4.0	14.0	1.4	0.6	0.8	13.30
4	3.5	1.5	2.5	4.0	13.5	1.4	0.6	1.0	13.30
5	3.5	1.5	3.0	4.0	13.0	1.4	0.6	1.2	13.30

Variation of pH range

In the current investigation, the concentration of hydrogen ions was recorded. As the basic nature (pH) increased, the current parameters were also gradually increased and reached an optimum value of a certain pH scale (pH=13.30), after which the BCB+AA+SLS system decreased. Poor results are observed on a pH range between 13.24 and higher (pH>13.30). In contrast, better outcomes are observed at the intermediate range (pH=13.30). This is because dye molecules (BCB) have a nature that makes them superior for photochemical processes. For pH variation on the PG system, the Open circuit voltage (Voc), I_{sc}, I_{max}, V_{pp}, i_{pp}, and P_{pp} are measured; the resulting values are 1124 mV, 220.0 μA, 240.0 μA, 624 mV, 100.0 μA, and 62.4 μW, respectively. The pH variation in the BCB+SLS+AA system is shown in Table 4 and 9.

Table 9: Examination of alterations in the Chemical Make-Up of the Variation Cell: Sodium hydroxide (NaOH)

S. No	Volume of Chemical Solution used					Resultant Concentration			
	0.001 MBCB (mL)	0.0 M AA (mL)	0.01 SLS (mL)	1M NaOH (mL)	DDW (mL)	BCB X 10^{-4} M	AA X 10^{-3} M	SLS X 10^{-3} M	NaoH PH
1	3.5	1.5	2.0	3.0	15.0	1.4	0.6	0.8	13.24
2	3.5	1.5	2.0	3.5	14.5	1.4	0.6	0.8	13.27
3	3.5	1.5	2.0	4.0	14.0	1.4	0.6	0.8	13.30
4	3.5	1.5	2.0	4.5	13.5	1.4	0.6	0.8	13.33
5	3.5	1.5	2.0	5.0	13.0	1.4	0.6	0.8	13.36

Variation of DL on the PG system

The cell was utilised for experiments with diffusion lengths (DL) ranging from particular PG cell path. In the BCB+SLS+AA system, the electrical output of the PG cell was observed. 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 (220.0 A) and equilibrium photocurrent (220.0 A), respectively. The photocurrent is acquired in a corresponding way because dye molecules cannot absorb the light source at lower and higher diffusion lengths, respectively. For diffusion length variation on the PG system, the Open circuit voltage (Voc), I_{sc}, I_{max}, V_{pp}, i_{pp}, and P_{pp} are measured; the resulting values are 1124 mV, 220.0 μA, 240.0 μA, 624 mV, 100.0 μA, and 62.4 μW, respectively.

Variation of EA of the cell

The current characteristics of the PG cell were calculated using electrode areas (EA) ranging from 0.06 cm^2 to 1.00 cm^2. The study was conducted on the photocurrent and photocurrent for better results. For electrode area variation on the PG system, the Open circuit voltage (Voc), I_{sc}, I_{max}, V_{pp}, i_{pp}, and P_{pp} are measured; the resulting values are 1124 mV, 220.0 μA, 240.0 μA, 624 mV, 100.0 μA, and 62.4 μW, respectively and recorded at 1.20 cm^2 of electrode area.

(i-V) characteristics of the PG cell

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

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

Power Point (pp) = V_{pp} x i_{pp} (2)

Where: V_{pp} is value of potential, i_{pp} is current at power point, Voc is open circuit voltage, i_{sc} is short circuit current.

The FF of the circuit was calculated and the P_{pp} was obtained as 62.40 μW for the PG cell. Table 10 displays the observed results for the (i-V) characteristics of the PG cell for BCB+NaLS+AA system. All observations of PG cell Fig. 4 for BCB+AA+SLS system is reported.

Table 10: Photocurrent power (i-v) of modified PG cell

S. No	Photocurrent (uA)	Photopotential (mV)	Power (uW)
1	200.0	65	13.00
2	180.0	173	31.14
3	160.0	292	46.72
4	140.0	393	55.02
5	120.0	510	61.20
6	100.0	624	62.40
7	80.0	726	58.00
8	60.0	847	50.82
9	40.0	958	38.32
10	20.0	1053	21.06

Cell performance and conversion efficiency (CE) of the PG system

In terms of t1/2, the calculated performance is shown in Fig. 5, and the experimental value was 120.00 min in the dark. The CE of PG cells was found to be 1.236 percent (equ 3).

$$\text{Conversion efficiency} = \frac{V_{pp} \times i_{pp}}{A\ 10.4 mWcm^{-2}} \times 100\% \quad (3)$$

Where A is the cell's electrode area, V_{pp} is the photopotential at the cell's power point, and i_{pp} is the photocurrent at the same point.

Effect of variation of light intensity

The light intensity about the PG cell was studied for electrode areas for solar energy. The study was conducted on the maximum photocurrent (i_{max} in mA) and equilibrium photocurrent (i_{eq} in μA). At 10.4 $mWcm^{-2}$, very positive results are obtained, displays the observed results for the change in electrode area on the PG cell system.

Mechanisms

The following chemical process manifests in a laboratory environment, showing the electrons movement of within circuit of the PG cell.

Illuminate chamber

In the photophysical and photochemical reactions process (equation 4) the BCB molecules (Dye) capture quantum photons and are stimulated as follows. Excited BCB takes up electrons from reductants in the second stage (equation 5) and transmits its energy to a variety of other molecules.

$$BCB \xrightarrow{h\nu} BCB^* \quad (4)$$

$$BCB^* + AA \longrightarrow BCB + AA^+ \quad (5)$$

PG cell reaction at Pt electrode

On the other hand, in the secondary reaction, semi- or leuco-form (equation 6) returns to its original form by giving the electron to an electrode.

$$BCB^- \longrightarrow BCB + e^- \quad (6)$$

PG cell reaction at dark Chamber

Equation 7 describes how the dye (BCB molecules) at the counter electrode absorbs the electrons from the counter electrode and transforms into a semi- or leuco-form of BCB as a result. Equation 8 shows that the photochemical cycle is ultimately finished when the BCB (leuco/semi-form) and the reducing agent unite to provide the original BCB and AA molecules.

$BCB + e^- \longrightarrow BCB^-$ (7)

$BCB^- + AA^+ \longrightarrow BCB + AA$ (8)

Where: AA is ascorbic acid; AA^+ is the oxidized form of reductant (ascorbic acid); BCB is brilliant cresy blue dye; BCB* is excited form of BCB; and BCB^- is semi or leuco form of brilliant cresy blue.

CONCLUSION

Novelty and Prospectus and Recommendation

The project's main objectives were to reduce the price of PG cells while simultaneously enhancing electrical performance. The objective has been attained by taking into account the BCB+SLS+AA system's good amount of storage capacity. The existing PG cells on the market may be replaced, and these efficient systems may be able to supply all of humanity's electrical demands if the price and general efficiency are reduced to the necessary level.

Importance of work

We have discovered that the BCB+AA+SLS system have enhanced the PG cell's electrical output as well as its capacity to convert energy based on the findings of the observed experiments. The PG cells would be the best cell in terms of current specifications for solar energy conversion and power. The BCB+AA+SLS cell's open circuit voltage is 1124 mV, compared to an earlier reported value of 690.00 mV (published work). The reported fill factors of BCB+AA+SLS system is 0.2523. While the good photocurrent in the EDTA+TB+NaLS PGS was recorded at 150.00 μA, the study published in 2022 already had particular values. In conclusion, the findings of the observed PG cell are higher than those of the PG system published in 2022. The BCB+AA+SLS PG system, the Open circuit voltage (Voc), I_{sc}, I_{max}, V_{pp}, i_{pp}, and P_{pp} are measured; the resulting values are 1124 mV, 220.0 μA, 240.0 μA, 624.0 mV, 100.0 μA, and 62.40 μW, respectively. Maximum photocurrent of 240.00 μA and equilibrium photocurrent of 220.00 μA were obtained were recorded at 1.20 cm^2 of electrode area, which are comparatively better electrical outputs in the BCB+AA+SLS system. The effects will be used to create a PG cell with a larger electrical output than the results that have already been published (see references 6, 17, and 19). If efficient systems are sufficiently advanced, they might take the place of the solar cells that are currently available on the market and have the ability to supply the necessary electricity for environmentally friendly growth.

Abbreviation

BCB = Brilliant Cresy Blue
AA = Ascorbic Acid
SLS = Sodium lauryl sulphate
PGS = photogalvanic system
PG cell = photogalvanic cell
i_{eq} = photocurrent at equilibrium
i_{sc} = short circuit current
i_{pp} = photocurrent at power point
mV = millivolt in cell circuit
ml = milliliter for PG cell
Voc = open circuit voltage
$t_{1/2}$ = storage capacity of cell
pp = power point of cell
M = molarity of solution used
V_{pp} = photopotential at power point
μA = microampere in cell circuit
μ= fill factor for PG cell
i_{max} = maximum photocurrent
μW = microwatt in cell circuit

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Conflicts of interest

Authors have no any conflict of interest.

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