Study on photogalvanics for sunlight power conversion and storage using the combination of bromocresol purple, sodium lauryl sulphate and ascorbic acid

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Abstract
Conducting an extensive study of the current outcomes of PG system appears to be of good interest to the scientific community. In an effort to meet the global goal of creating a pollution-free environment for sustainable development, this study reports better PG cell results. A present cell with a Bromocresol Purple (BCP)+NaLS+AA system was used to analyse the different solar properties. By changing a number of the PG cell's characteristics, BCP investigated the primary impacts of solar energy. Better electrical results from renewable energy have been the goal of the research and the PG cell has effectively shown the system's efficiency in an experimental process.

For BCP+NaLS+AA system, Photopotential, photocurrent, maximum photocurrent and equ. photocurrent was measured 918.00 mV, 564 µA, 618.00 µA and 564 µA, respectively. The PG cell's fill factor, conversion efficiency and performance were 160.00 minutes, 0.3937 and 2.3446% respectively, according to the data. The results showed that the PG system had undergone a more comprehensive and innovative study.

Keywords: NaLS, Bromocresol Purple, Photogalvanics, Photocurrent, Ascorbic Acid.

Introduction
Because of human usage, fossil fuels such as wood, coal, kerosene and others are rapidly running out. Finding additional sources is therefore essential. Solar energy cells are the most advantageous alternative energy source. Utilizing the PG effect, the PG cell allows solar energy to be converted and stored. Solar energy is based on photochemical processes such as water photolysis and photosynthesis. Dye based photochemistry has significantly improved as a result of research into the mechanisms underlying reactions that involve electron transfer in photoelectrochemical devices.

PG cells are based on cetrimonium bromide surfactant, ascorbic acid reductant, sunset yellow FCF coloring photosensitiser and NaOH alkali[6]. The molecular relationship with sodium dodecyl sulphate and BCP spectral analysis are compared as photosensitizers for usage in PG cells[12]. Alizarin cyanine green[2], Brilliant Yellow[16] and Sudan[5] were used in the PG cell for energy conversion and storage. Research work on PG Cell for the electrical system output i.e. Lauryl glucoside[17], Tartrazine system[18], Innovation for prospective energy source through solar cell[8], Role of reductant and photosensitizers in solar energy conversion and storage: Oxalic acid-brilliant cresyl system[4] and Innovation in progressive study for prospective energy source through photo-galvanic-system: D-Xylose+MB+Brij-35+NaLS work[9] reported for improved outcomes. Correction between spectrophotometric and photoelectrochemical analysis of the dye-surfactant combination in PG cells[13], prospective energy source research as using EDTA+TB+NaLS for PG cell[1], innovative study in renewable energy source through mixed surfactant system for eco-friendly environment[10], isopropyl alcohol[19], ascorbic Acid[15] and C DEA[3] were all reported.

Comparative study on sunlight ensuing PG results in the conversion of energy for sustainable development[11]. The study explores the role of different solvents in the efficiency of solar cells manufactured from natural dyes and evaluates their optical and electrical performance[14]. To reduce costs, a low-cost thin-film solar cell technique known as the dye sensitized solar cell (DSSC)/Gratzel Cell emerged[20]. The current voltage (i-V) characteristic of the cell has been observed and a tentative mechanism for the generation of photocurrent has been proposed[7]. Throughout the solar system, a variety of surfactant-dye-reducing agents (SDR) are being employed. However, none of those parties have investigated bromocresol purple (BCP) as a potential substitute for increasing electrical generation. As a result, the present PG cell (BCP+NaLS+AA scheme) was developed. PG cells are the solar cells that have been studied the most. Fossil fuel sources have drawbacks of their own in addition to the potential to contribute to pollution and risky behaviour.

Material and Methods
Solution preparations: Distilled water (DW), ascorbic acid, sodium hydroxide, sodium lauryl sulphate (NaLS) and bromocresol purple were all used in the experiment to ensure that the results were applicable. For every test series, the alkaline medium was standardized using oxalic acid. All of these materials are kept in amber-colored vials to shield them from radiation.

Methodology: The BCP was investigated using a specially made H-shaped photogalvanic system (PGS), carbon pot, micro-ampere, resistance key and digital pH meter. Solutions of alkali (4.5 ml), surfactants (NaLS, 04 ml), reducing agents (AA, 3.5 ml), distilled water (07 ml) and dye (BCP, 06 ml) were placed in a 25 ml H tube (Fig. 1). To complete the solar circuit in the experiment, a resistance key, micro-ampere, 200 W electricity bulb (with a W filament) and each of the ends of the electrodes were jointed. The water filter was used to build the experiment's light sources and radiation barrier. In the presence of light, measurements were made of power, photopotential and photocurrent.

Measured photopotential, photocurrent (PC), maximum photocurrent and equ. photocurrent for the BCP+NaLS+AA were 918.00 mV, 564 µA, 618.00 µA and 564 µA respectively. The results showed that the PG cell's performance, fill factor (FF) and conversion efficiency (CE) were 160.00 minutes, 0.3937 and 2.3446% respectively. Figure 1 depicts the BCP+NaLS+AA system's experimental configuration.

Results and Discussion

Variation of BCP concentration: The dye concentration change for BCP+NaLS+AA has been investigated in the current work. When a particular surfactant is present, the electrical output rises because it makes dye molecules more soluble and stabilizes them in water. As the BCP concentration rises, the BCP+NaLS+AA system's electrical output rises as well, peaking at 4.6×10^{-5} M before starting to fall. The dye's hydrophobic nature results in a decreased BCP for light absorption, which has the effect of producing an electrical output that is comparatively low (BCP = 2.0×10^{-5} M). When the concentration is higher (BCP > 6.0×10^{-5} M), a large number of BCP molecules swarm the surface of the absorbent.

The best molecules are present at the optimal concentration (BCP = 4.6×10^{-5} M), allowing the ideal light source to reach the molecule closest to the electrode and start photochemical reactions. Regarding the BCP+NaLS+AA, the measured PP, PC, maximum PC and equ. PC were, in the order, 918.00 mV, 564 µA, 618.00 µA and 564 µA.

During lab analysis, 160.00 minutes, 0.3937 and 2.3446% respectively, were determined to represent the PG cell's performance, FF and CE. Figures 2-4 and table 1 present all the observed data.

Variation of AA concentration: The current study has looked into the change in AA concentration for BCP+NaLS+AA. The observed effects increase in tandem with the AA concentration. At significantly reduced reductant concentrations, there are accessible reductant molecules for donating electrons to dye the to generate the ionic nature, whereas at significantly greater reductant concentrations, there are more reducing agents' particles that can undergo photophysical shift to dye to form the ionic form, thus hampers the dye molecules. Similarly, as the AA level is increased, the BCP+NaLS+AA system's electrical output decreases and progressively rises to its maximum value at 2.24×10^{-3} M.

A relatively smaller quantity of reductant EDTA is available to supply radicals to BCP in order to achieve the ionic character at a lesser concentration of AA (2.16×10^{-3} M). More AA molecules are accessible for photophysical conversion to AA at significantly greater concentrations (2.32×10^{-3} M) of ethylene dimethyl tetraacetic acid (AA > 2.32×10^{-3} M) which results in the cationic form that inhibits the AA molecules. A reasonable result can be achieved within a threshold region of the reducing agent's concentration (2.24×10^{-3} M).

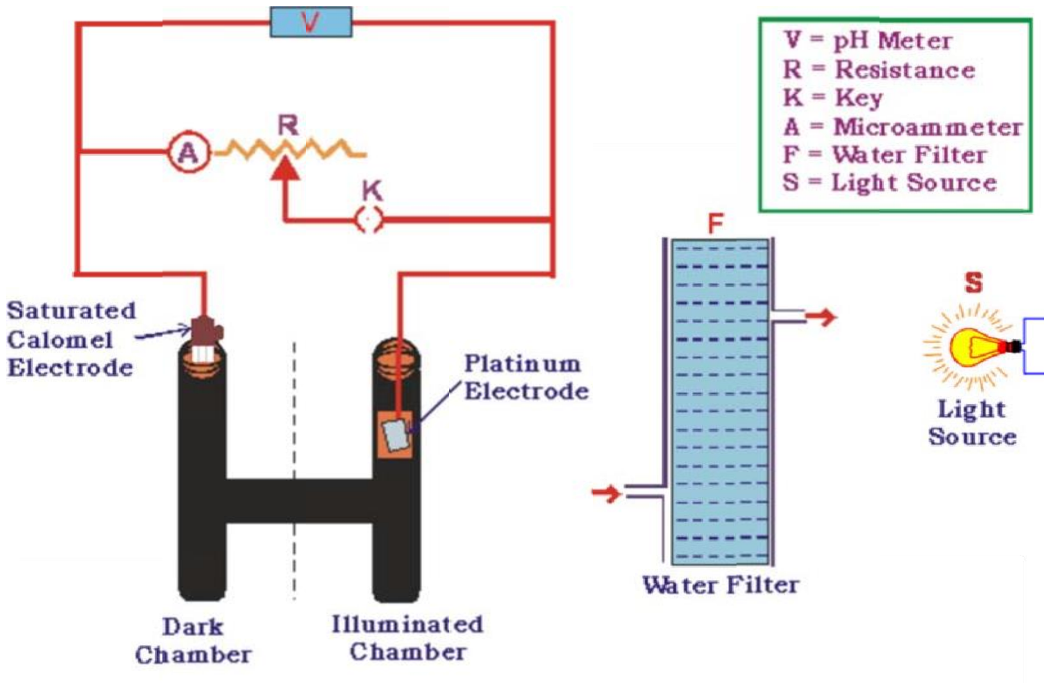

Fig. 1: Methodology for PG cell

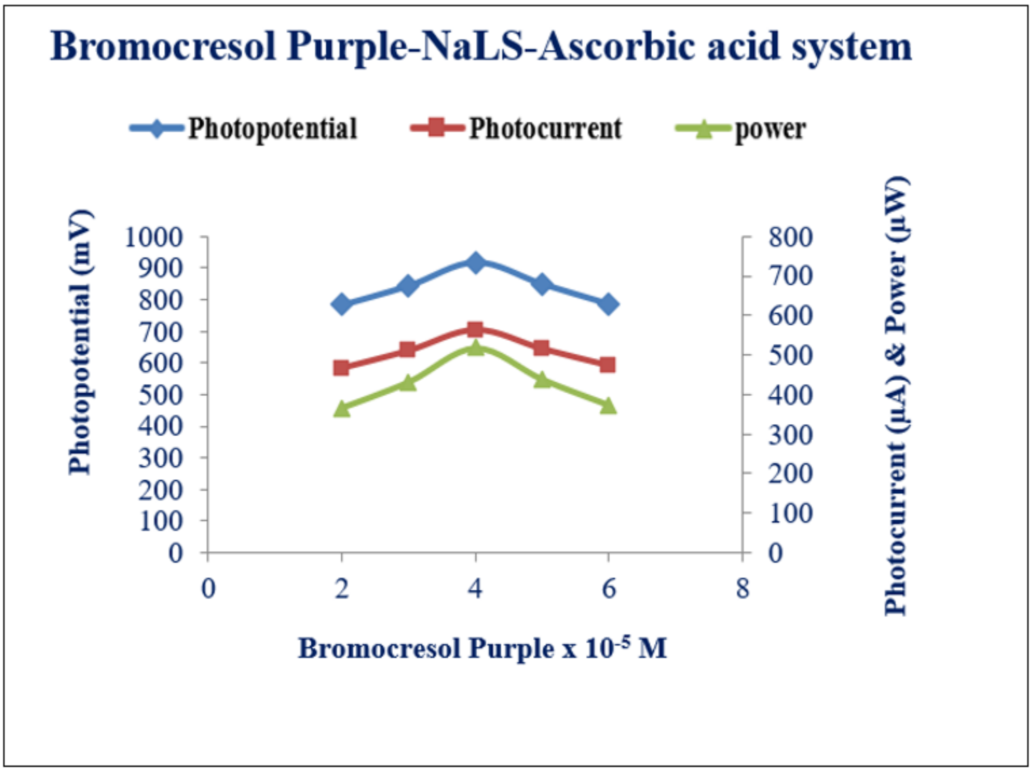

Fig. 2: PG cell variation outcomes

Table 1
Variation of BCP, AA, NaLS and pH

	Light Intensity = 10.4 mWcm^{-2} Temperature = 303 K		
Parameters	**Photopotential (mV)**	**Photocurrent (µA)**	**Power (µW)**
[BCP] ×10^{-5} M			
2.0	783.0	466.0	364.87
3.0	844.0	511.0	431.28
4.6	918.0	564.0	517.75
5.0	849.0	515.0	437.23
6.0	786.0	472.0	370.99
[AA] × 10^{-3} M			
2.16	785.0	458.0	359.53
2.20	840.0	507.0	425.88
2.24	918.0	564.0	517.75
2.28	836.0	511.0	427.20
2.32	781.0	455.0	355.35
[NaLS] × 10^{-3} M			
2.4	778.0	467.0	363.32
2.8	840.0	507.0	425.88
3.2	918.0	564.0	517.75
3.6	846.0	510.0	431.46
4.0	782.0	471.0	368.32
pH			
12.50	766	472	361.55
12.54	831	508	422.14
12.58	918	564	517.75
12.62	836	512	428.03
12.66	772	476	367.47

The optimal concentration of reductant molecules which provide dye BCP molecules in their semi- or leuco-forms with favorable pathways, can be used to explain this. In contrast to the machine's current usage, the restful sleep mode only used 10 µA of current, according to the data. 918.00 mV, 564 µA, 618.00 µA and 564 µA were the measured PP, PC, maximum PC and equ. PC for the BCP+NaLS+AA respectively. 160.00 minutes, 0.3937 and 2.3446% respectively were determined to represent the PG cell's performance, FF and CE. Figures 2-4 and table 1 present all the collected data.

Variation of NaLS concentration: The surfactant combination rather than the single surfactant precipitate may have the best precipitation in PG cells for individual surfactants. PG cell with BCP+NaLS+AA system was used to study the photo reactivity of NaLS with electrical power. It was discovered that increasing the quantity of NaLS would cause the result to rise to a specific point before falling. At lower NaLS quantities (surfactants 2.4×10^{-3} M), the solubilization of the molecules was reduced for photophysical actions on the surface. Although greater amounts of surfactant particles are accessible for photophysical effects during hydrophobic contact, greater surfactant quantities (NaLS > 4.00×10^{-3} M) may cause the electron carrier to decrease.

A significant electrical output was seen at 3.2×10^{-3} M NaLS, an intermediate surfactant concentration. Regarding the BCP+NaLS+AA, the measured PP, PC, maximum PC and equ. PC were, in the order: 918.00 mV, 564 µA, 618.00 µA and 564 µA. The results showed that the PG cell's performance, FF and CE were 160.00 minutes, 0.3937 and 2.3446% respectively. The system's reported results are shown in table 1 and figures 2-4.

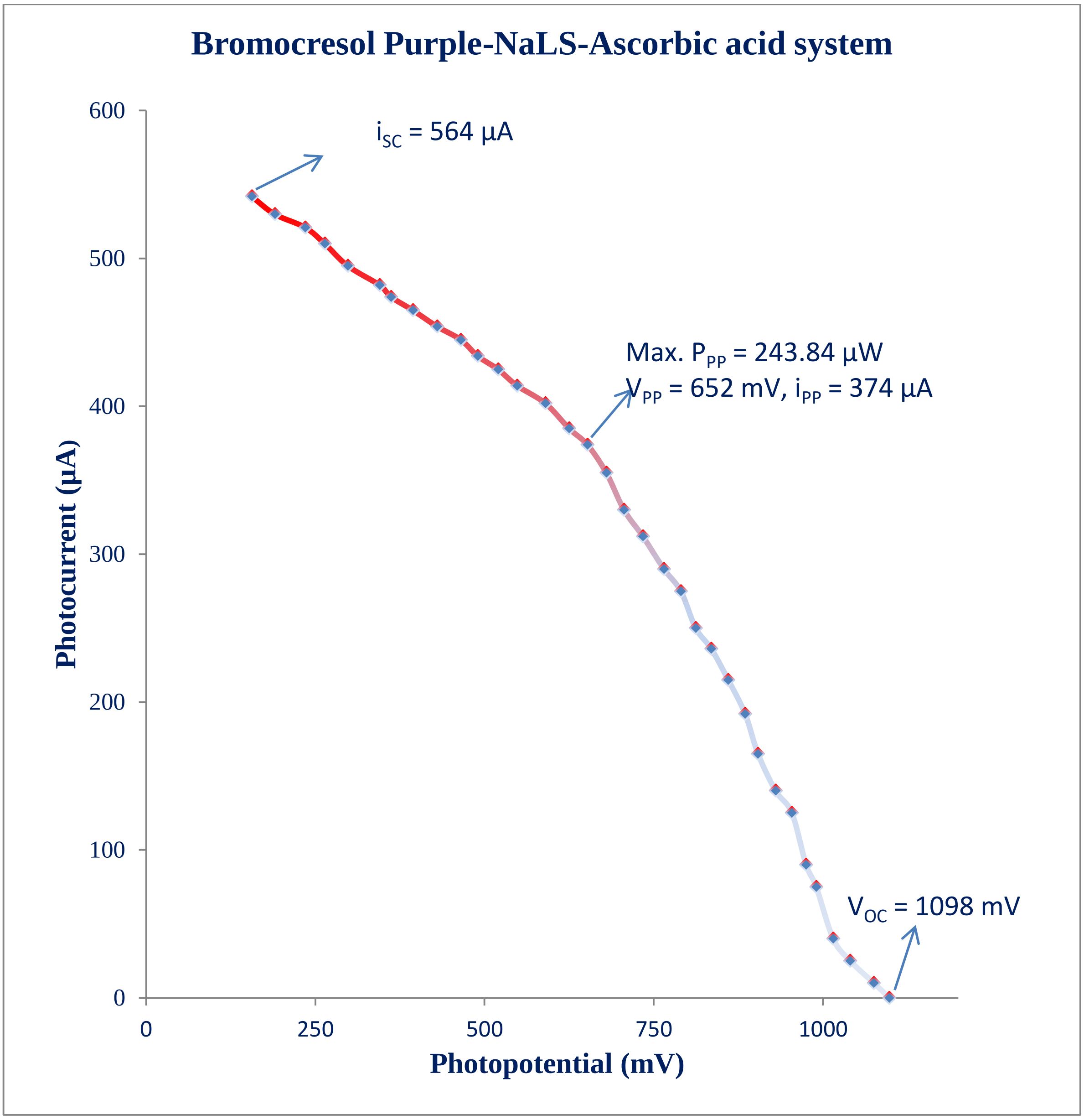

Fig. 3: Current voltage (i-V) curve of cell

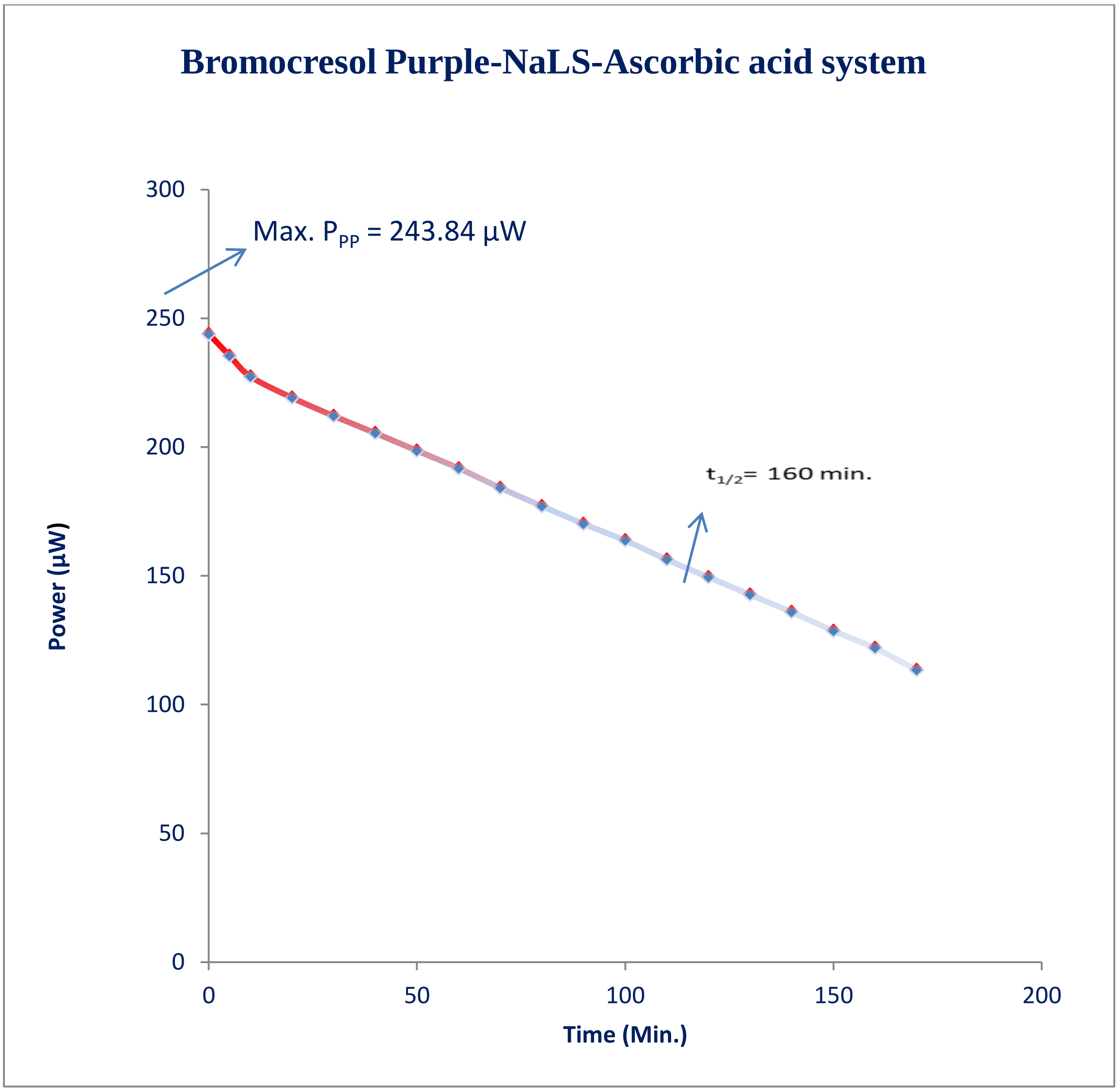

Fig. 4: Performance of the PG cell

Table 2
Current voltage (i-V) characteristics of the PG cell

Photopotential (mV)	Photocurrent (µA)	Fill Factor (η)
1098	0	
1040	25	
990	75	
954	125	
904	165	
860	215	
812	250	
765	290	
706	330	
652	**374**	**0.3937**
590	402	
520	425	
465	454	
394	465	
345	482	
264	510	
190	530	

Table 3
Performance of the pg cell

Time (Min.)	Power (µW)
0	243.84
10	227.36
20	219.11
30	212.04
40	205.39
50	198.56
60	191.75
70	184.12
80	177.05
90	170.16
100	163.72
110	156.31
120	149.44
130	135.90
140	112.08
150	128.61
160	**121.92**
170	113.41

Table 4
Effect of variation of light intensity

BCP-NaLS-AA System	Light Intensity ($mWcm^{-2}$)				
	3.1	5.2	10.4	15.6	26.0
Photopotential (mV	901.0	910.0	918.0	925.0	931.0
Photocurrent (µA)	551.0	557.0	564.0	569.0	575.0
Log V	2.9547	2.9590	2.9628	2.9661	2.9689

Variation of pH range: The quantity of hydrogen ions has been investigated for this study. As the basic composition (pH) rose, the BCP+NaLS+AA system decreased and the present set of parameters likewise gradually climbed, reaching a maximum value within certain limits (pH=12.58 at max). Poor outcomes are observed on a pH range of 12.50 to 12.66 and higher (pH > 12.66). However, the intermediate range (pH = 12.58) yields better results. This is because dye molecules (BCP) are more suited for photochemical processes. Regarding the BCP+NaLS+AA, the measured PP, PC, maximum PC and equ. PC was, in the order 918.00 mV, 564 µA, 618.00 µA and 564 µA. The performance, FF and CE of the PG cell were found to be 160.00 minutes, 0.3937 and 2.3446% respectively. Table 1 displays the BCP+NaLS+AA system's pH variation.

Diffusion length variation on the PG system: The cell's testing used diffusion lengths ranging from 40 mm to 60 mm. In the BCP+NaLS+AA system, the current properties of the project were investigated. BCP causes the diffusion length to rise during photocurrent production at a faster rate. Excellent results are attained at 50.00 mm where 618 µA and 564.00 µA respectively are recorded for the photocurrent and equilibrium photocurrent.

Ram et al[16] discovered a decrease in electricity generated in the PG cell's uniform route. The values obtained for the PP, PC, maximum PC and equivalent PC for the BCP+NaLS+AA were 918.00 mV, 564 µA, 618.00 µA and 564 µA respectively. The results showed that the PG cell's performance, FF and CE were 160.00 minutes, 0.3937 and 2.3446% respectively.

Variation of electrode area: The electrode thicknesses that varied from 0.36 cm^2 to 1.96 cm^2, were used to calculate the current PG cell characteristics. An enhanced combined solar power generation and storage system, as well as a low-power early warning of forest fires and alerting system in artificial and low-illuminated BCP photogalvanic cells adopting a sensitizer-reductant combination were reported by Genwa and Prasad[2,3]. The photocurrent was the focus of the study in order to achieve better results. Regarding the BCP+NaLS+AA, the measured PP, PC, maximum PC and equ. PC were in the order 918.00 mV, 564 µA, 618.00 µA and 564 µA. The PG cell's performance, FF and CE were in order: 160.00 minutes, 0.3937 and 2.3446%.

(i-V) characteristics of the PG cell: The power point (PP) and FF were computed using equation 1:

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

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

where potential by Vpp, power point current by ipp, open circuit voltage by Voc and short circuit current by i_{sc} are presented. The pp of the PG cell was determined to be 243.84 µW, while the cell circuit's FF value was 0.3937. The observed outcomes for the (i-V) PG cell characteristics for the BCP+NaLS+AA system are shown in table 2. A cell's power point in the BCP+NaLS+AA system is displayed in fig. 4.

The PG system's CE and cell performance: Regarding $t_{1/2}$, the value that was observed was 160.00 minutes in the dark, whereas the computed performance is displayed in (fig. 4). It was discovered that the PG cells' conversion efficiency (CE) was 2.3446 % (eq. 3)

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

where Vpp is the photopotential at the cell's voltage point, ipp is the photocurrent at the same place and A is the electrode area of the cell. Table 3 displays the observed outcomes for the BCP+NaLS+AA system's PG cell performance.

Effect of variation of light intensity: 3.1 $mWcm^{-2}$ to 26.0 $mWcm^{-2}$ electrode areas were utilised to compute the photovoltaic cell's light intensity. The maximum (imax) and equilibrium (ieq) photocurrents in µA were the main subjects of the inquiry. Table 4 shows the observed outcomes for the BCP+NaLS+AA system's change in electrode area. At 10.4 $mWcm^{-2}$, very good results are obtained.

Mechanisms: The motion of electrons within the cell circuit is demonstrated by the following chemical reaction which takes place in a laboratory.

Illuminate Chamber: The following is how the BCP molecules (Dye) are stimulated in the process of photophysical and photochemical reactions (eq. 4) after they absorb quantum photons. Excitable BCP transmits its energy to different molecules by absorbing electrons from reductants in the secondary phase (eq. 5).

$$BCP \xrightarrow{h\nu} BCP^{*} \quad (4)$$
$$BCP^{*} + AA \longrightarrow BCP + AA^{+} \quad (5)$$

Photochemical process at the Pt electrode: On the other hand, during the secondary reaction, the semi- or leuco form of BCP (eq. 6) returns to the initial BCP molecules after donating an electron to an electrode.

$$BCP^{-} \longrightarrow BCP + e^{-} \quad (6)$$

Photochemical reaction at dark Chamber: Equation 7 explains why the dye (BCP molecule) at the counter ion changes into a semi- or leuco-form of BCP after absorbing an electron from the opposite electrode. Equation 8 demonstrates that the photochemical processes cycle is finally completed when the reductant (oxidized form) and BCP (leuco/semi-form) combine to produce the initially generated BCP dye and AA particles.

$$BCP + e^{-} \longrightarrow BCP^{-} \quad (7)$$
$$BCP^{-} + AA^{+} \longrightarrow BCP + AA \quad (8)$$

where BCP stands for bromocresol purple dye, BCP* for the excited form of bromocresol purple, BCP^{-} for the semi-or leuco form of bromocresol purple and AA^{+} for the oxidized form of reductant (ascorbic acid).

Conclusion

The primary goals of the study were to improve electrical performance and to lower the cost of PG cells. With the BCP+NaLS+AA system's enormous storage capacity, the goal has been achieved. If the cost and overall effectiveness of such devices are brought down to the required level, they might potentially replace the current PG cells on market today and meet all of humanity's energy needs. We achieved better PG cell outcomes based on the observed studies, demonstrating that the BCP+NaLS+AA surfactants have improved the electrical output and energy conversion capability of the PG cell.

The open circuit voltage of the BCP+NaLS+AA cell is now 1098.00 mV. For the BCP+NaLS+AA excellent photocurrent, a previously reported value of 150.00 µA was changed to 564.00 µA. In conclusion, the observed PG cell yields higher results than the published and reported PG systems.

Regarding the BCP+NaLS+AA, the measured photopotential, photocurrent, maximum photocurrent and equ. photocurrent were in the order: 918.00 mV, 564 µA, 618.00 µA and 564 µA. 160.00 minutes, 0.3937 and 2.3446% were the results of the PG cell's performance FF and CE respectively. The effects will be employed to produce a PG cell with a higher electrical output than previously published results[5,8,13]. The development of efficient systems could eventually replace the current wave of solar cells on the market and provide the electricity required for sustained, long-term growth.

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