INNOVATIVE STUDY OF PHOTOGALVANIC CELL FOR SOLAR ENERGY CONVERSION AND STORAGE

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ABSTRACT:

The scientific community is compelled so is search out the renewable source of energy to feed the whole world with non-polluting nature and commercially viability. Thus, the solar energy is the best option to fulfill the energy demand. World will have to significantly reduce its coal and oil use to accelerate climate action. A huge proportion of world electricity generation comes from thermal power, most of which is coal based. The non – renewable sources of energy have their own limitations along with hazardous processes involved and pollution creating. The consumption of fossil fuels like wood coal kerosene etc. is so rapid is reaching towards their complete depletion. Solar energy is already becoming cost competitive with solar power and better storage capacity, the day is not far when renewable energy will compete with coal-based power. However, over the next few decades. Currently, about more than half of world energy demand is met by two fossil fuels -coal and oil. Actual plan of research work was proposed for systematic investigating in the field of photo galvanic cell for solar energy transformation. It was necessary and proposed to carry out experimental work under the solar parameters. Detailed literature survey about different photo galvanic cells have been used in solar transformation for best results. Methods: A detailed reaction mechanism for the proposed solar cell for generating of photocurrent and photocurrent has been studied. PG Cells were studied for solar energy transformation system. Findings: PG Cells were studied using different parameters via photocurrent, Photo potential, conversion efficiency, fill factor and cell performance. The above values are as following 245.0 μA, 1267.0 mV, 0.6875%, 0.4972 and 129.0 minutes. Electrical output of the cell has also been observed for Dye based photo galvanic cell. Novelty: The photo galvanic is emerging field of research and manuscript contains substantial electrical output, conversion efficiency and storage capacity of developed photo galvanic cell with special attention to better performance and reduces the cost of the photo galvanic cell for its commercial viability.

KEYWORDS:

RENEWABLE ENERGY, INNOVATION, PHOTOCURRENT, PHOTOPOTENTIAL, FILL FACTOR, CONVERSION EFFICIENCY.

INTRODUCTION

The promising photochemical reactions like photosynthesis and photolysis of water are the basis of solar energy contents. The non-renewable energy sources have their own limitations along with hazardous processes involved and pollution creating environment. Global scientific community is compelled to search out the renewable source of energy to feed the whole world with non-polluting nature and commercially viability. Thus, the solar energy is the best option to fulfil the energy demand. The promising photochemical reactions like photosynthesis and photolysis of water are the basis for solar energy contents. Rideal and Williams [1] were pioneers to observed photogalvanics. Whereas, Rabinowitch [2,3] has systematically investigated the endergonic photochemical reaction between iron this online system and have observed this photochemical reaction thoroughly and its suitability for trapping solar energy as source renewable energy. It was also supported by the research work of Suda et al. [4], Murthy et al [5] and Bayer et al. [6]. Hallet [7], has developed some photo galvanic cell with semiconductor. The optimum results have been mentioned by Wildes et al. [8], Dixit and Mackay

[9] Albery and Archer [10]. photo electrochemical process have been observed by Memming [11] and Hamdi and Aliwi [12] whethron some effiecnet photo galvanic systems have been reported by Ameta et al. [13, 14], Gangotri et al. [15], Lal [16], Gangotri and Meena [17], Madhwani et al.[18]using different reductant and photo sensitizers in PG cells.In orderto enhance the electrical output PG cell Genwa and Genwa [19], Genwa et al.[20]and Gangotri and Gangotri[21] have also reported some efficient systems using surfactants. Gangotir and lal and Lal and gangotri have determined the photo galvanic effect in PG cell using mixed surfactants and reactants and photo sensitizer whereas chnadr et al have observed the role of photo sensitizers and a reductant for generation of electrical energy in pg cell and bhimwal et al. have compare the research output of various sugar cell as reducing agents. Mao S, et al. [26], Thareja Pet al.[27],Molina-Bolivar JA, et al [28], Lee NM and Lee BH[29] have also observed mixed micellization in PG cells to observed the electrical output as well as storage capacity. The group of scientists are paying their attention enhance the results by selecting the cheaper compounds in PGS for their commercial viability. They have used different dye, surfactant and reductant in the solar system but no attention paid to use of mixed surfactant dye reductant combination to enhance the electrical output, therefore, the present work was undertaken.

EXPERIMENTAL METHOD

Laboratory work for solutions Preparation: During the experiment stage, the solutions of D-xylose (reductant), dye-methylene blue (photo sensitizer), Brij-35+NaLS (mixed surfactants), and sodium hydroxide, were prepared by using double distilled water. The total volume for the experimental set was 25.00 ml during experiments. The prepared solution of NaOH was standardized by oxalic acid in each PGS. All the solutions are kept in an amber color flask to protect them from sunlight.

Methodology for set –up of the PGS: First of all, we designed a photo galvanic system (figure 1) having fabricated H-shape glass tubes. The designed photo galvanic system was two arms. During the experiment, both ends of electrodes were connected through the resistance key, carbon pot, micro-ammeter and Digital pH meter for complete electrical circuit for measurement of the potential and current of the PGS. Saturated calomel electrode was dipped in one arm and Platinum electrode was dipped in another arm. One arm of the H tube was completely blackened except for the window to absorb light. Another arm of the H tube was totally blackened. The known solutions of two different surfactants Brij-35+NaLS (mixed surfactants), D-xylose (reductant), methylene blue (photo sensitizer), sodium hydroxide and double distilled water were filled in H tube. During experiments, 200 W electric bulb (W Filament containing) and water filter were used for light sources and to cut off IR radiations for experiment setup, respectively. Total volume was 25.00 ml for each set during the experiment method. The methodology figure for the PGS is given in figure 1.

RESULTS AND DISCUSSION

Variation of Dye-Methylene blue (phot osensitizer) concentration on the PGS: It was observed that when we increase the concentration of dye MB, the electrical output also increases and attains maximum value on particular concentration value and then decreases in D-Xylose+MB+Brij-35+NaLS system. On a lower concentration range of methylene blue, the low number of Dye-Methylene blue limits the absorption of the light source, so the electrical output is low. In contrast, at a higher concentration range of methylene blue, there are so many molecules present that the desired light source does not reach the molecule near the electrode. At intermediate range of methylene blue concentration, there are optimum molecules present that the optimum light source does reach the molecule near the electrode and maximum photo potential (1267.00 mV), maximum photocurrent (245.00 mA) and maximum power (152.14 μW) were obtained. Table 1 and graphical figure 2 shows the variation of photo sensitizer concentration in the D-Xylose+MB +Brij-35+NaLS system.

Variation of D-xylose (Reductant) concentration on the PGS: It was observed that when we increase the concentration of reductant (D-xylose), the electrical output also increases and attains maximum value on particular concentration value and then decreases in D-Xylose+MB+Brij-35+NaLS system. On a lower concentration range of Reductant, a smaller number of reductant molecules being available for electron donation to methylene blue to form the cationic form. In contrast, at a higher concentration range of Reductant, there are a larger number of reductant molecules being available for electron donation to methylene blue to form the cationic form which hinders the methylene blue. At intermediate range of Reductant concentration, there are optimum number of reductant molecule present that form favorable condition for semi or leuco form of dye molecules and maximum photo potential (1278 mV), maximum photocurrent (265 mA) and maximum power (173.60 μW) were obtained. Table 1 and graphical figure 2 shows the variation of xylose concentration on the D-Xylose+MB + Brij-35+NaLS system.

Variation of (NaLS+Brij-35) concentration on the PGS: The electric power of the PG cell havingD-Xylose+MB+Brij-35+NaLSsystem was increased on increasing the concentration of Brij-35 keeping NaLS concentration constant (around its CMC value) and reached at optimum position and decreased on further increase the concentration of Brij-35. Then the concentration of NaLS was increased keeping Brij-35 concentration constant till it reached at optimum position and decreased on further change in concentration of NaLS. On a lower concentration range of both surfactants, and less ability to solubilize the molecules for electron transfer process in hydrophilic hydrophobic interaction. In contrast, at a higher concentration range of both surfactants, and there are a larger number of surfactant molecules being available for electron transfer

process in hydrophilic hydrophobic interaction which may reduce electron transfer. At the intermediate range of surfactant concentration, and, there are significant effects on electrical output for the photo galvanic system. This is because surfactant can help to separate photoproducts through hydrophilic–hydrophobic interaction of the micelles interface. The Table 1 and graphical figure 3 show the variation of mixed surfactant in D-Xylose+MB+Brij-35+NaLS system.

Variation of pH on the PGS: It was observed that when we increase the pH, the electrical output also increases and attains a maximum value of particular value (pH=13.00 at max.) and then decreases in D-Xylose+MB+Brij-35+NaLS system. Table I shows the variation of pH on D-Xylose+MB+Brij-35+NaLS system.

Variation of diffusion length on the PGS: The current parameter of the cell (i_{max}, i_{eq}) and initial rate of generation of photocurrent of PG cell having D-Xylose+MB+ Brij-35+NaLS system was observed with change in diffusion lengths (distance between two electrodes). It was found that with an increase in diffusion length maximum photocurrent (i_{max}) and rate ($\mu A\ min^{-1}$) go on increasing but the equilibrium photocurrent (i_{eq}) shows negligible small decreasing trends. So, virtually it may be considered unaffected by the change in diffusion length. On a lowest diffusion length (35mm), the lowest number of dye molecules limits the absorption of the light source, so the photocurrent is obtained as minimum value (262.00 mA).

Variation of electrode area of the cell on the PGS: The current parameter – maximum photocurrent (i_{max}), equilibrium photocurrent (i_{eq}) of PG cell having D-Xylose+MB+Brij-35+NaLSsystem was observed that these were regular increase in maximum photocurrent but equilibrium photocurrent was almost independent on increase in electrode area rather affected in reverse direction. Table 3 shows the variation of electrode area on D-Xylose+MB+Brij-35+NaLSsystem.

Variation of Mixed Surfactant (NaLS+Brij-35) for solar radiation transformation and potential: The electric power of the PG cell having D-Xylose +MB + Brij-35+NaLS system was changed on changing the concentration of Brij-35 keeping NaLS concentration constant (around its CMC value) and reached a maximum value and decreased on further increase the concentration of Brij-35. Then the concentration of NaLS was increased keeping Brij-35 concentration constant till it reached a maximum value and decreased on further increase in concentration of NaLS. The Table 4 and graphical Figure 4 and 5 show the variation of mixed surfactant in D-Xylose +MB +Brij-35+NaLS system.

i-V characteristics (current–voltage) of the PGS: In the PG cell having D-Xylose+MB+Brij-35+NaLS system, the short circuit current ^{i}sc is measured by micro ammeter keeping the circuit closed and open circuit voltage V_{oc} by digital pH meter keeping other circuit open. it is observed that the highest value of photo potential Vpp and photocurrent were measured by applying an eternal load with the help of carbon pot (log 470 K) connected in the circuit. The highest value of potential obeyed in the circuit is known as potential at power point corresponding to highest value of short circuit current is known as current at power point i_{pp}. These four vales (^{i}sc , V_{oc} $V_{pp\ and}$ $i_{pp,}$) were used in formula in one the determine the fill factor of PGS and formula to determine the power point of pgs. The fill-factor was calculated using the following formula:

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

Where

V_{pp} is value of potential

i_{pp} is current at power point

V_{oc} is represent open circuit voltage

i_{sc} is short circuit current

The value of fill factor of cell (η) = 0.4972 was observed and the power point of cell (pp) = 60.16μW was obtained for the PGS. Graphical Figure 4 shows the power point of cell in D-Xylose+MB+ Brij-35+NaLS System.

Cell performance and conversion efficiency on the PGS: The D-Xylose+MB+Brij-35+NaLSsystem was terminated the light source at the value of photocurrent so observed at power point of the PG cell by applying electric load from light source. The time was recorded at which the photogalvanic cell has reached to a half the value of the power in off light mode. The performance of the cell was determined in term of $t_{1/2}$. The determined value was 120.00 min. The Table IV and graphical Figure 3 show the performance of the PG cell in D-Xylose+MB+ Brij-35+NaLS System.

Determination of PG cell performance is shown by figure-5 in term of $t_{1/2}$ and its observed value was 120.00 minutes in dark. PG cell conversion efficiency was determined as 0.5688 % using the following formula:

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

Where $V_{pp,}$ is photopotential at power point of cell,

i_{pp} is Photocurrent at power point of cell,

A is used electrode area of cell.

MECHANISM: Experimentally the following chemical

transformation takes place, indicate the flow of electron in current.

$$MB \xrightarrow{h\nu} MB^{*} \quad \text{(excited form)} \ldots\ldots\ldots\ldots \textbf{(i)}$$

$$MB^{*} + R \longrightarrow MB^{-} \quad \textbf{(semi or leuco)} + R^{+} \ldots\ldots\ldots\ldots \textbf{(ii)}$$

Photochemical reaction at platinum electrode: The semi or leuco form of MB (dye) loses an electron to electrode and converts into original dye molecule.

$$MB^{-} \longrightarrow MB + e^{-} \quad \ldots\ldots\ldots\ldots \text{(iii)}$$

Photochemical reaction at dark Chamber: The following chemical transformation takes place.

At counter electrode: Methylene Blue molecules (photo sensitizer) gain an electron from electrode and converts into semi or leuco form of dye molecule.

$$MB + e^{-} \longrightarrow MB^{-} \text{ (semi form or leuco form)} \quad \ldots\ldots\ldots\ldots \text{(iv)}$$

And finally, methylene blue (leuco/semi form) and the reductant (oxidized form), combine to give original methylene blue (MB) dye and Xylose reductant(R) molecules and the whole photochemical cyclic process continues.

$$MB^{-} + R^{+} \longrightarrow MB + R \quad \ldots\ldots\ldots\ldots \text{(v)}$$

Where

MB is Methylene blue (dye)

MB* is excited form of methylene blue

MB^{-} is semi or leuco form of methylene blue,

R is Reductant (xylose)

R^{+} is oxidized form of the reductant

CONCLUSION

On the basis of the observed results of the PGS havingD-Xylose+MB+Brij-35+NaLS system, we have observed that the mixed surfactants have not only enhanced the electrical output of cell but also enhance the energy conversion of the cell for PGS. These PGS played main role in reduction in their cost to make commercial viability by selecting the proper redox couple, with respect to photo-storage and mixture of surfactants. PG Cells were studied using different parameters via photocurrent, Photopotential, conversion efficiency, fill factor and cell performance. The above values are as following 245.0 μA, 1267.0 mV, 0.6875%, 0.4972 and 129.0 minutes. Electrical output of the cell has also been observed for Dye based photogalvanic cell. 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 photo galvanic cell for its commercial viability.

Illuminate Chamber: MB molecules (photosensitizer) were getting excited and excite MB accept electron and transfer to xylose

NOMENCLATURE

i_{eq}= photocurrent at equilibrium

i_{sc}=short circuit current

i_{pp}=photocurrent at power point

mV=millivolt

ml=milliliter

M =molarity

$t_{1/2}$=storage capacity of cell

pp=power point

V_{pp}=photopotential at power point

V_{oc}=open circuit voltage

mA=microampere

η=fill factor

mW=microwatt

PGS = photogalvanic system

PG=photogalvanic cell

i_{max}=maximum photocurrent

MB= Methylene blue

NaLS =Sodium lauryl sulphate

TABLE– 1. PHOTOGALVANIC OUTPUTS

Parameters	Photo potential (mV)	Photocurrent (μA)	Power (μW)
[Methylene blue] $\times 10^{-5}$ M			
6.00	1267.00	245.00	152.14
[D-Xylose] $\times 10^{-3}$ M			

5.11	1267.00	245.00	152.14
[NaLS] × 10^{-3} M			
8.45	1267.00	245.00	152.14
[Brij-35] × 10^{-4} M			
9.10	1267.00	245.00	152.14
P^H			
11.790	1267.00	245.00	152.14

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	1250.00	235.00	6.28
40.00	1256.00	250.00	6.39
45.00	1278.00	265.00	6.70
50.00	1265.00	200.00	5.64
55.00	1250.00	195.00	5.78

TABLE- 3. EFFECT OF ELECTRODE AREA ON THE SYSTEM

Methylene blue-D-Xylose-NaLS+Brij-35 System	Electrode Area (cm^2)				
	0.80	0.95	1.10	1.15	1.20
Maximum photocurrent i_{max} (μA)	261	263	265	271	281
Equilibrium photocurrent i_{eq} (μA)	242	231	235	230	226

TABLE 4. EFFECT OF MIXED SURFACTANTS [NALS+BRIJ-35] FOR PGS

S. No.	Parameters	Single surfactant NaLS	Mixed surfactant NaLS+Brij-35
1.	Open Circuit Voltage (V_{OC})	870.0 mV	**1278.0 mV**
2.	Photopotential (ΔV)	635.0 mV	**1267.0 mV**
3.	Maximum Photocurrent (i_{max})	175.0μA	**265.0μA**
4.	Short Circuit Current (i_{sc})	90.0μA	**230.0μA**
5.	Equilibrium Photocurrent (i_{eq})	90.0μA	**245.0μA**
6.	Current at Power Point (i_{pp})	55.0μA	**126.0μA**
7.	Potential at Power Point (V_{pp})	595.0 mV	455.0 mV
8.	Power at Power Point (PP)	32.72mW	**60.16 mW**
9.	Fill factor (η)	0.3630	0.4972
10.	Conversion Efficiency (%)	0.3100%	**0.6875%**
11.	$t_{1/2}$	55.0 min	**129.0min**
12	Charging Time (min.)	55.0 min	104.0 min

As per the results so observed, shown in table 4, the efficiency of the pg cell mixed surfactant has tremendously increased with special reference to current parameters, power, conversion efficiency and $t_{1/2}$ value (the storage

capacity) almost the doubled of the charging time of the cell.

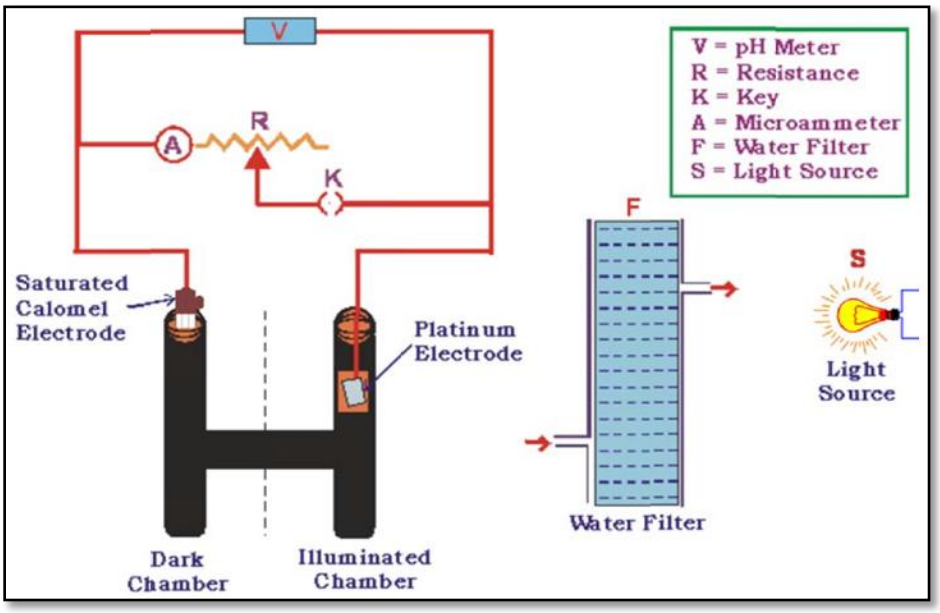

FIGURE 1. METHODOLOGY SET UP OF P

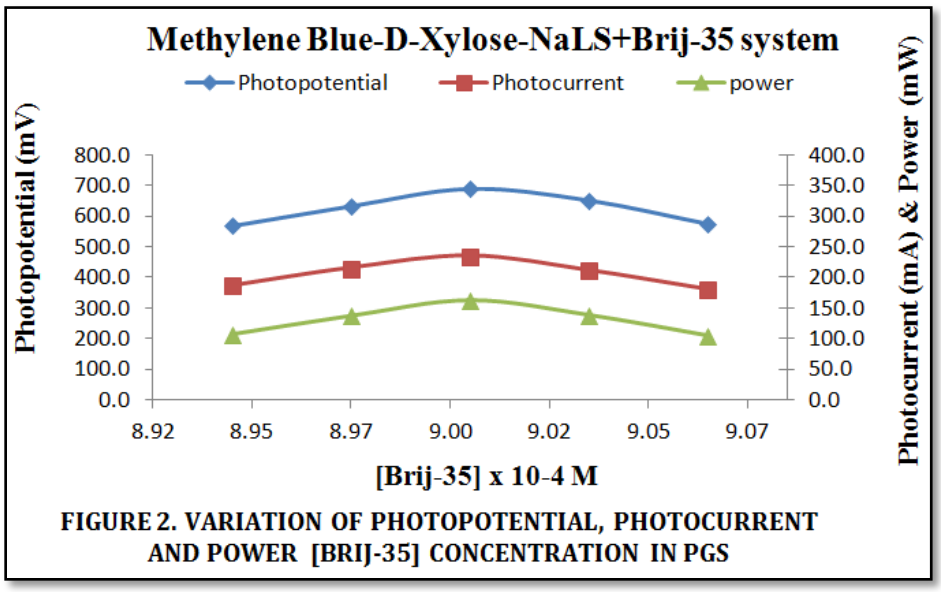

FIGURE 2. VARIATION OF PHOTOPOTENTIAL, PHOTOCURRENT AND POWER [BRIJ-35] CONCENTRATION IN PGS

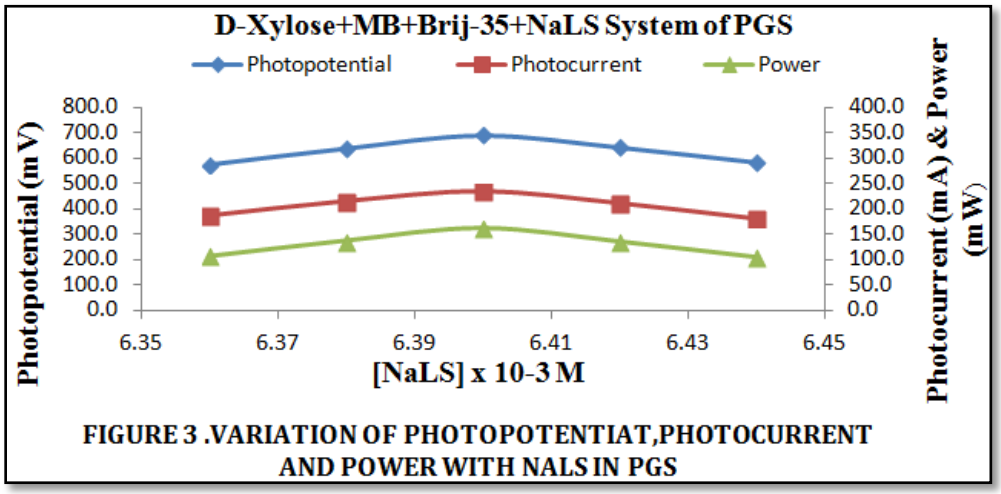

FIGURE 3 .VARIATION OF PHOTOPOTENTIAT,PHOTOCURRENT AND POWER WITH NALS IN PGS

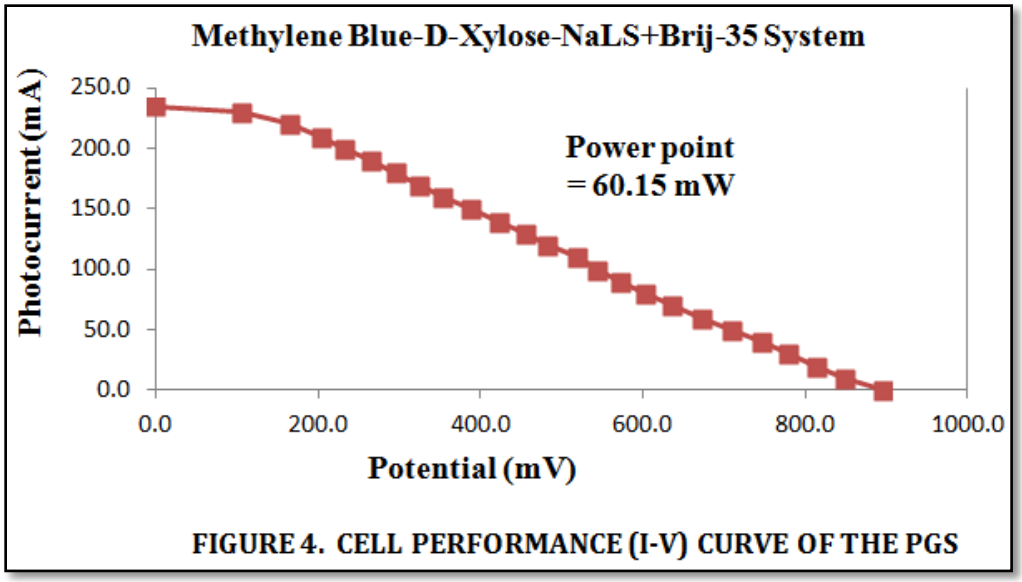

FIGURE 4. CELL PERFORMANCE (I-V) CURVE OF THE PGS

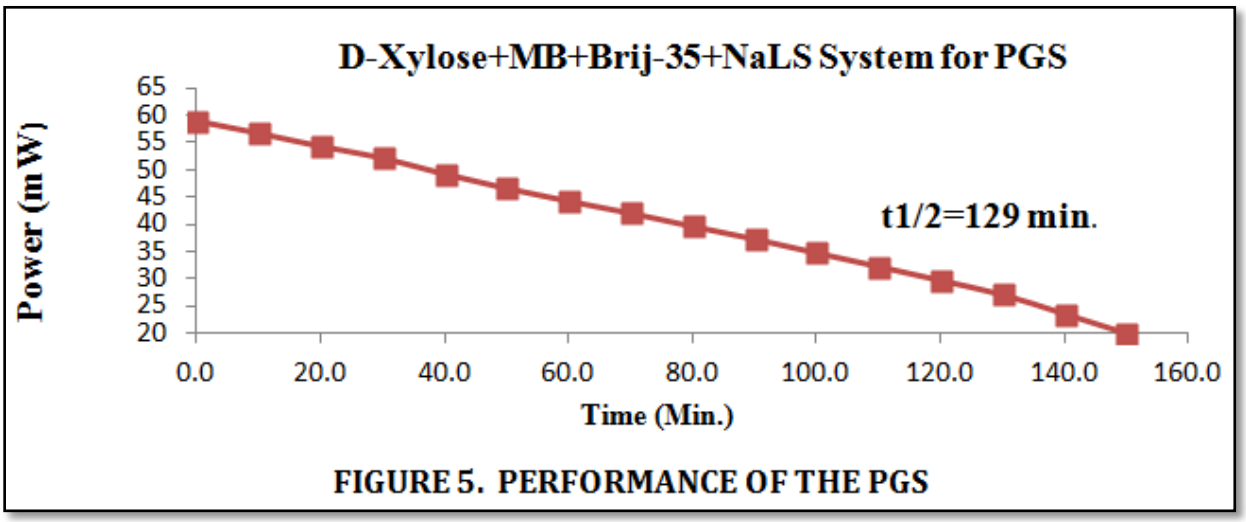

FIGURE 5. PERFORMANCE OF THE PGS

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