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Use of Lissamine Green as Photosensitizer in Ascorbic Acid-Tween-80 System for Solar Power Generation

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Abstract

The object of the research work is to study photogalvanic effect in lissamine green–tween-80 surfactant combination for enhancement of electrical output in photogalvanic cell. The photogalvanic effect studied in lissamine green-tween-80-ascorbic acid system. Electrical parameter like photopotential and photocurrent is generated 846 mV and 859 µA respectively. The power generated from the system is 124.56 µW at its power point. The conversion efficiency of system is 1.19 % and fill factor is 0.1384. The cell works one hour 130 minutes in dark. A mechanism is also purposed for photo generation of electricity. i-V characteristic of the cell also studied.

Key words: Photopotential, photocurrent, i-V characteristics, photogalvanic effect (PGE), fill factor, conversion efficiency.

1. Introduction

The world energy demand is increasing tremendously, these results in higher consumption of fossil fuels, which severely damaged our environment. Energy and environment issues are closely linked with each other. Today we need renewable, cost effective, environment benign energy resources. Solar energy is most promising solution of all these, it is cheap, easily available and pollution free. Solar energy can be converted into electrical energy using solar cells like photo voltaic and photogalvanic cell. Photogalvanic cell has potential to replace existing solar cell due to its low cost and inbuilt storage capacity.

Photogalvanic cell are based on photo galvanic effect or Bequeral effect in which the effect of light results in photo chemical process in the solution of electrolyte. These are galvanic cell induced by light, absorption of light results in generation of higher energy products which subsequently undergoes redox reaction to produce current. The photogalvanic cell is firstly reported by Rideal and William[1]. It was systematically investigated by Rabinowitch[2-3] using thionine iron system. Photogalvanic effect in Iron (II) poly (N-acrylaminomethyl-thionine) studied by Tamilarasan and Natrajan[4]. Murthy A.S.N. and Reddy K.S.[5] Studies on photogalvanic effect in system containing Toluidine blue. Rohatgi-Mukherji K.K et al.[6] have studied on Photovoltage Generation of the Phenosafranine Dye-EDTA Sandwich Cell. Ameta S.C. et al.[7-8] have also developed some interesting photogalvanic cells. Gangotri K.M. et al[9-10] have increased the electrical output as well as storage capacity up to reasonable mark by using various photosensitizer with micelles in photogalvanic cell. Meena R.C. and Singh G.[11] have reported the use of dyes and reductants in photogalvanic cell for solar energy conversion and storage. The effect of heterocyclic dyes and photogalvanic effect in photogalvanic cells for solar energy conversion and storage was studied by Genwa K.R. and Chouhan A.[12] Genwa K.R. and Sonel A.[13] studied an approach to solar energy conversion and stoage with Toluidine Blue- Arabinose-CPC system. Genwa K.R. and Kumar A.[14] studied an approach to solar energy conversion and storage with Nile blue-NaLS system and Thiazine dye-anionic surfactant system. Genwa et al.[15] have reported the Ascorbic acid-Crystal violet-Dioctyl sulphosuccinate system in photogalvanic cell for study energy efficiency of the cell. Genwa K. R. and Singh K.[16-18] have reported reasonable values of electrical output with different dyes i.e. Brilliant Blue-FCF, Lissamine green-B and Bromocresol green as photosensitizers in photogalvanic cells for solar energy conversion and storage. Genwa K. R. and Sagar C. P.[19]

invented photogalvanic behaviour of Xylidine ponceau dye in Xylidine ponceau – Tween 60 – Ascorbic acid system. The research team led by Yadav et al. [20-23] has published findings on the satisfactory electrical output achieved using various dyes as photosensitizers in photogalvanic cells. They also investigated the impact of surfactants on these cells and explored novel photogalvanic cell designs with a focus on electrical parameters and the conversion and storage of solar energy.

The scientific society has used different photosensitizers, surfactants, reductants in photogalvanic cells for conversion of solar energy into electrical energy but no attention has been paid to the use of this system containing lissamine green dye as energy material to increase the electrical output and performance of the photogalvanic cell. Therefore, the present work was undertaken to obtain better performance and commercial viability of the photogalvanic cell.

2. Materials and method

Loba chemie of lissamine green, ascorbic acid, tween-80 and NaOH were used in the present work. Stock solutions of all chemicals were prepared in double distilled water. During preparation of the dye solution the precaution was taken to protect the solution from light and to store it in a dark coloured container. 25 ml of a mixture having a known volume of dye, reductant, surfactant and NaOH solution of different concentrations was taken into a blackened H-shaped glass tube. A platinum foil electrode (1.0 cm^2) was immersed in one arm of the cell. The counter electrode standard calomel electrode was placed in another limb of H-shaped glass tube. The pH of the solution was adjusted and measured by a pH meter. When the cell attained a stable potential in dark the Pt foil electrode was exposed to light source (tungsten lamp). A water filter was placed between the light source and the cell to cut-off thermal radiation. Electrical outputs of the cell like potential and current were measured with a digital multimeter (HAOYUE DT830D). The photogalvanic cell set-up is shown in Figure 1.

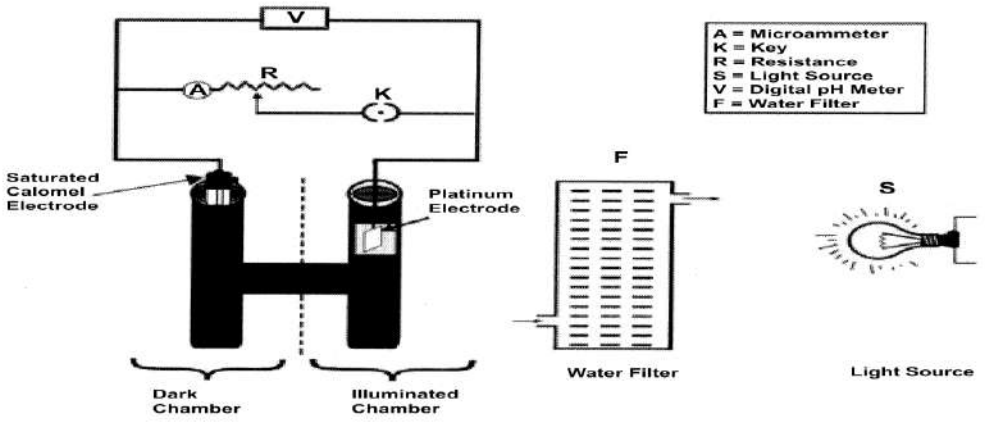

Fig-1: Experimental set up of photogalvanic cell

3. Mechanism of photovoltage and photocurrent generation in a cell

When dye is excited by the light in the presence of electron donating substance (reductant), the dye is rapidly changed into colourless form. The dye now acts as a powerful reducing agent and can donate electron to other substance and reconverted to its oxidized state. On the basis of earlier studies a tentative mechanism in the photogalvanic cell may be proposed as follows:

Illuminated chamber: On irradiation, dye molecules get excited.

$$\text{Dye} \xrightarrow{h\upsilon} \text{Dye}^* \qquad \text{(i)}$$

The excited dye molecules accept an electron from reductant and converted into semi or leuco form of dye, and the reductant into its excited form.

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$Dye^* + R \longrightarrow Dye^- (semi\ or\ leuco) + R^+$ (ii)

At Pt-electrode:

The semi or leuco form of dye loses an electron and converted into original dye molecule.

$Dye^- \longrightarrow Dye + e^-$ (iii)

Dark Chamber:

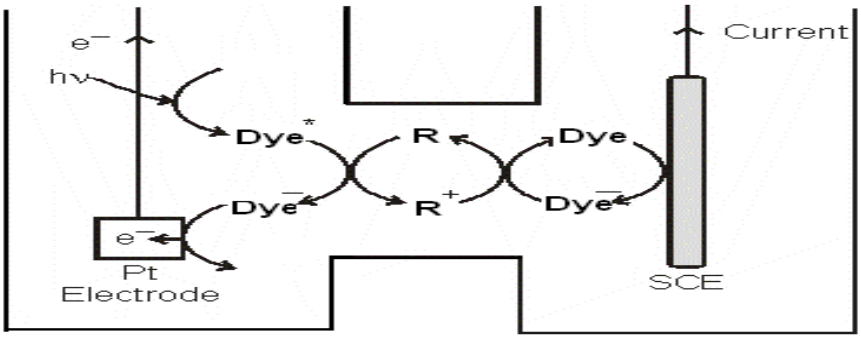
At counter electrode:

$Dye + e^- \longrightarrow Dye^- (Semi\ or\ leuco)$ (iv)

Finally leuco/semi form of dye and oxidized form of reductant combine to give original dye and reductant molecule. This cycle of mechanism is repeated again and again leading production of current continuously.

$Dye^- + R^+ \longrightarrow Dye + R$ (v)

Here Dye, Dye*, Dye^-, R and R^+ are the dye, its excited form, leuco form, reductant and its oxidized form, respectively. The scheme of mechanism is shown in Fig.2



SCE = Saturated calomel electrode D = Dye (Photosensitizer)
R = Reductant D^- = Semi & Leuco form

Fig. 2 Scheme of mechanism

4. Result and Discussion

(a) Variation of photovoltage and current with time

Initially the whole system was placed in the dark, potential generated in the photogalvanic cell was found to change with time, after some time it attained a stable potential and then the Pt-electrode was exposed to the tungsten lamp. It was observed that the potential increased on increasing illumination, which was due to the increase in number of excited dye molecule and their conversion into semi or leuco form after accepting the electron from reductant, and it reached a maximum constant value after a certain period of illumination. This maximum potential is termed V_{max}**.** When the light source was removed, the direction of potential was reversed and a stable potential was again obtained after some time. There was a rapid rise in the photocurrent of the photogalvanic cell on illumination and it reached a maximum value within few minutes. This maximum value current was denoted by I_{max}. The current was found to decrease gradually with the period of illumination and finally reached a constant value at equilibrium. This value is represented as I_{eq} shown in figure 3 and 4.

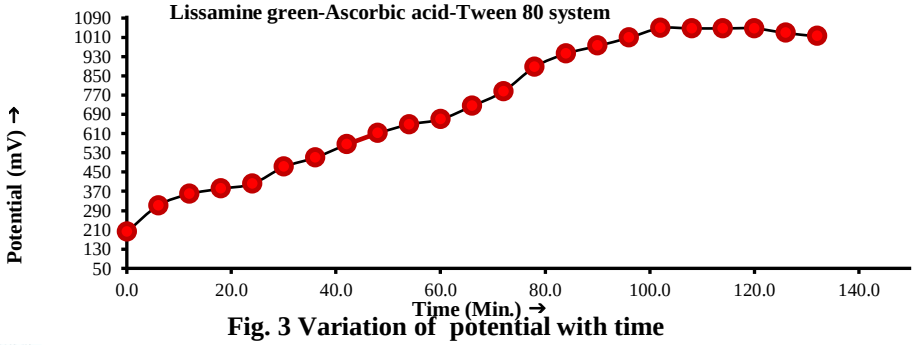


Fig. 3 Variation of potential with time

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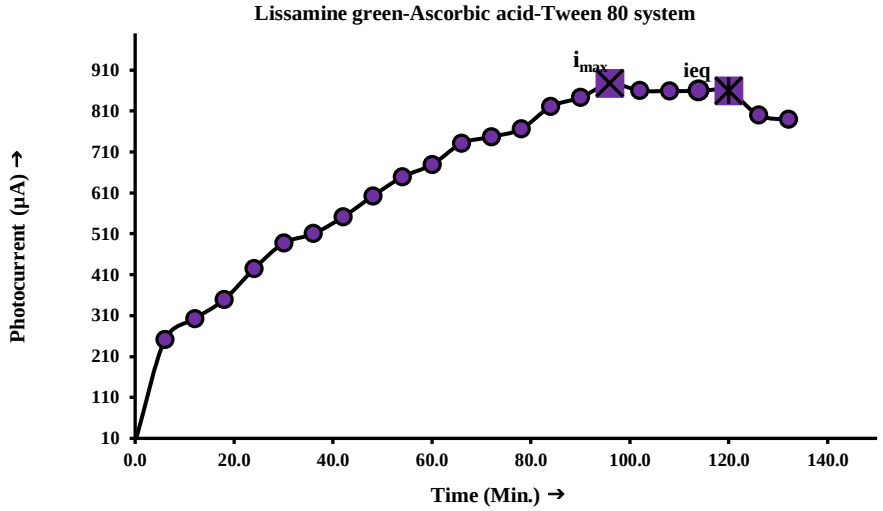

Fig. 4 Variation of photocurrent with time

(b) Effects of lissamine green, ascorbic acid and tween-80 concentration on electrical output of photogalvanic cell

The effect of variation of dye lissamine green, reductant ascorbic acid and surfactant tween-80 concentration are given in table 1, 2 and 3. Lissamine green - ascorbic acid – tween-80 system showed the best efficiency at the dye concentration of 2.9×10^{-5} M. It was observed that as the dye concentration was increased, the photopotential and photocurrent increased to a maximum value at this concentration and decreased on further increase in dye concentration. Low electrical output observed at the minimum concentration range of dye due to limited number of lissamine green molecules to absorb the major part of the light in the path, while higher concentration of lissamine green again resulted in a decrease in electrical output because intensity of light reaching to those dye molecules which are near to the electrode decreases due to absorption of the major portion of the light by the lissamine green molecules present in the path. Therefore corresponding fall in the electrical output. With an increase in reductant concentration the electrical output increased and reached a maximum value at a particular concentration (2.1×10^{-3} M) of reductant. On further increase in reductant concentration the electrical output decreased. At lower concentration of reductant less number of molecules were available for electron donation to excited dye molecule so electron output is low and at higher concentration of reductant large number of reductant molecules hinders the dye molecule to reach the electrode within a required time period. It has been studied that pKa values of the reductant must be lower than the pH of the system. The cell output increased with an increase in tween-80 concentration but after achieving a particular value, the electrical output of the cell started decreasing. The maximum electrical parameter was obtained at concentration of tween-80 2.9×10^{-3} M. On further increasing the concentration of surfactant a fall in electrical output was observed. Tween-80 not only assists in solubilisation of dye molecule but also stabilize the system with respect to electrical output.

Table-1 Variation of photopotential, photocurrent and power with lissamine green concentration

Lissamine green - Ascorbic acid - Tween 80 System	[lissamine green] x 10^{-5} M				
	2.5	2.7	2.9	3.1	3.3
Photopotential in mV	669.0	770.0	846.0	766.0	658.0
Photocurrent in μA	620.0	733.0	859.0	696.0	586.0
Power in μW	414.78	564.41	726.71	533.13	385.58

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Table- 2 Effects of ascorbic acid concentration on electrical output of photogalvanic cell

Lissamine green - Ascorbic acid - Tween 80 System	[Ascorbic acid] x 10^{-3} M				
	1.7	1.9	2.1	2.3	2.5
Photopotential in mV	681.0	785.0	846.0	790.0	680.0
Photocurrent in µA	561.0	670.0	859.0	698.0	588.0
Power in µW	382.04	525.95	726.71	551.42	399.84

Table- 3 Effects of tween-80 concentration on electrical output of photogalvanic cell

Lissamine green - Ascorbic acid - Tween 80 System	[Tween-80] x 10^{-3} M				
	2.5	2.7	2.9	3.1	3.3
Photopotential (mV)	657.0	810.0	846.0	783.0	634.0
Photocurrent (µA)	655.0	791.0	859.0	771.0	678.0
Power (µW)	430.34	640.71	726.71	603.69	429.85

(c) Effect of pH variation

It was observed that the photopotential and photocurrent of the lissamine green - ascorbic acid – tween-80 system increased and reached the maximum at pH 12.21 and then decreased with an increase of pH value. It was found that the optimum electrical output obtained at a particular pH value might be caused by better availability of reductant donors formed at that pH value. It was also observed that in an acidic medium the efficiency of the cell was poor. It might be due to proton attachment to the dye and reductant molecules, which resulted in poor electron donating power of the dye and reductant molecules to the platinum electrode. Effect of pH on electrical parameters depicted in figure 5.

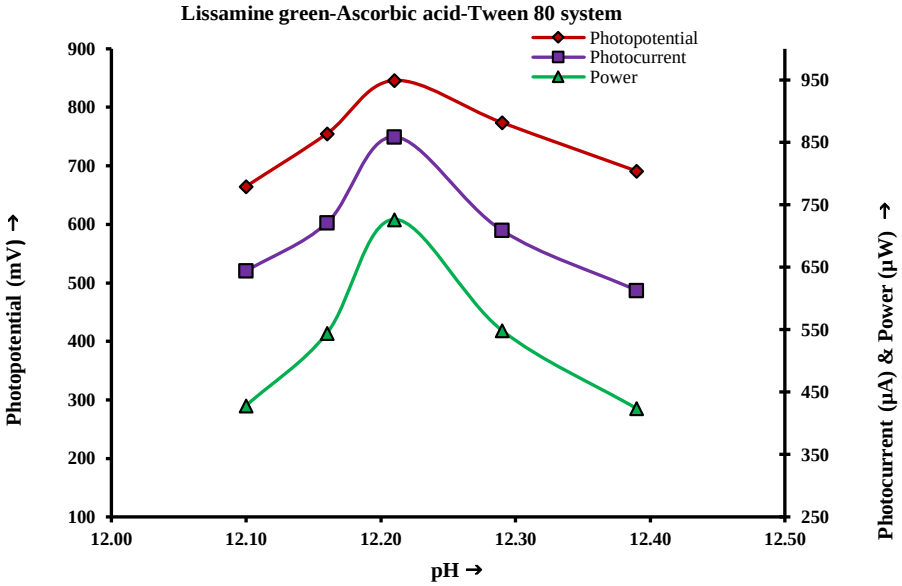

Fig. 5 Variation of photopotential, photocurrent and power with pH

(d) Effect of diffusion length

The current parameters of the cell i_{max}, i_{eq} and initial rate of generation of photocurrent of photogalvanic cell containing lissamine green - ascorbic acid – tween-80 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 of generation of current (µA min^{-1}) go on increasing but the equilibrium photocurrent (i_{eq}) shows negligible small decreasing trends. So, virtually it may considered as unaffected by the change in diffusion length. Effect of diffusion length on electrical parameters depicted in figure 6.

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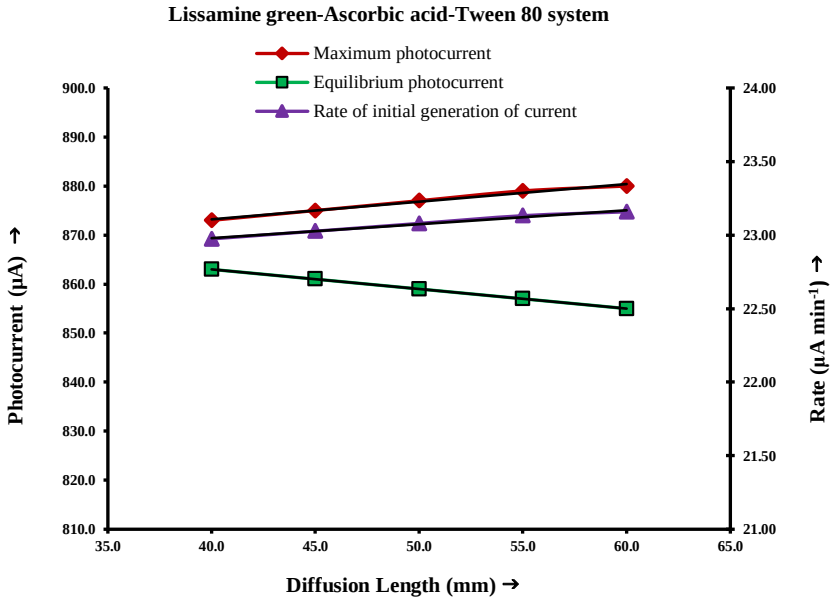

Fig. 6 Variation of current parameters with diffusion length

(f) Effect of electrode area

Using Pt-electrode with different surface areas allowed for more research into the influence of electrode area on the cell parameters. It was observed that the value of maximum photocurrent (i_{max}) increased with increasing the size of electrode area. This was one of the things that were noticed (rather it is affected in reverse manner). The impact that changing the electrode area has on Maximum Photocurrent (i_{max}) and equilibrium Photocurrent (i_{eq}) is provided in table 4

Table-4 Variation of current parameters with electrode areas

Lissamine green - ascorbic acid - tween 80 system	Electrode area (cm^2)				
	0.80	0.90	1.0	1.3	1.5
Max^m Photocurrent in μA	874.0	875.0	877.0	879.0	881.0
Equilibrium Photocurrent in μA	862.0	861.0	859.0	857.0	855.0

(g) Current voltage (i-V) characteristics of the cell

The Current–Voltage (i-V) characteristics of the photogalvanic cells containing lissamine green - ascorbic acid – tween-80 system is graphically represented in Figure 7. Photogalvanic cell containing lissamine green - ascorbic acid – tween-80 system, the short circuit current (i_{sc}) and open circuit voltage (V_{oc}) were measured with the help of a microammeter (keeping the circuit closed) and with a digital pH meter (keeping the other circuit open), respectively. The highest value of photopotential and photocurrent were observed with the help of a carbon pot (log 470 K) connected in the circuit of microammeter, through which an external load was applied. It was observed that current voltage curve deviated from their regular rectangular shape. A point in i-V curve called power point was determined where the product of current and potential was maximum and fill factor was calculated using the formula

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

The value the fill-factor was calculated as 0.1384 using the formula and the power point of cell 124.56 μW was obtained on the system. Where V_{pp} and i_{pp} represent the value of potential and current at power point, respectively. It was noticed that i-V curve was deviated from regular rectangular shape.

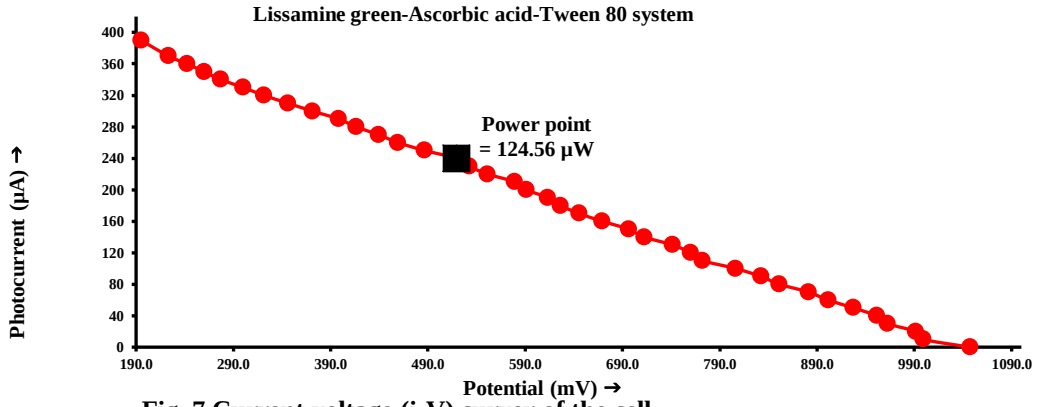

Fig. 7 Current voltage (i-V) curver of the cell

(h) Cell performance and conversion efficiency

The conversion efficiency of the cell was determined by using the formula given bellow.

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

The performances of the photogalvanic cell determined in terms of $t_{1/2}$ time required to fall the power to its half at its power point in dark .cell can works 130 minutes in the dark. The results are graphically represented in time-power curve (figure 8).

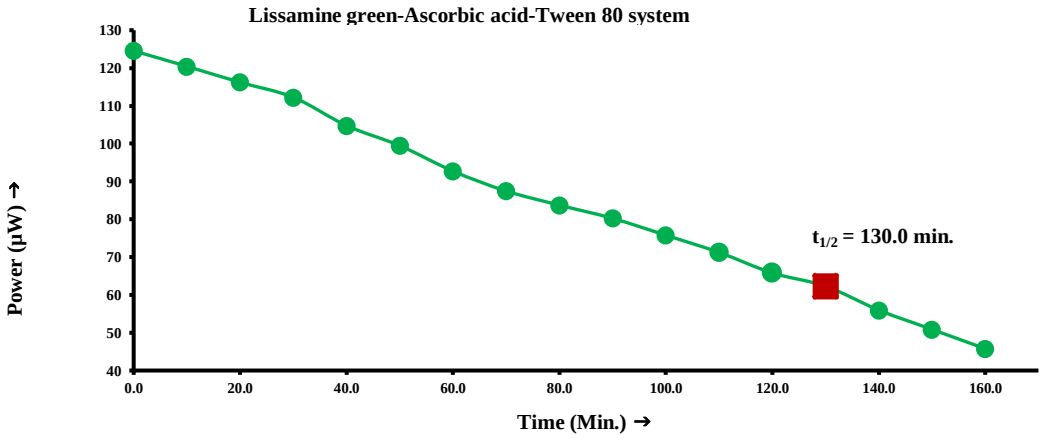

Fig. 8 Time-power curve of the photogalvanic cell

Conclusion

A photogalvanic cell has low conversion efficiency but has additional advantage of inbuilt storage capacity. Research should be focused on making these cell commercial viable by enhancing their conversion efficiency using appropriate combination of Dye surfactant, as these are low cost and easy to fabricate. The highest value of V_{oc} (1047 mV), i_{sc} (859 µA), power (124.56 µW), fill factor (0.1384), conversion efficiency (1.19%) and storage capacity (130.0 min.) was obtained in lissamine green–ascorbic acid–tween-80 system. Therefore, it may be concluded that efficient photogalvanic cell can be fabricated with the use of lissamine green–ascorbic acid–tween-80 system in cell for energy conversion and performance point of view.

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