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Photo galvanics: Studies of Green Photo Sensitizer (*Prosopis cenaria* Leaf Extract) for Solar Energy Conversion and Storage with Triton X-100-EDTA- System

Naresh Kumar, Shanker Lal Meena* and Pramod Kumar Meena

Department of Chemistry, J.N.V. University, Jodhpur, Rajasthan, **INDIA**

Email:slmeenajnvu.chemistry@gmail.com

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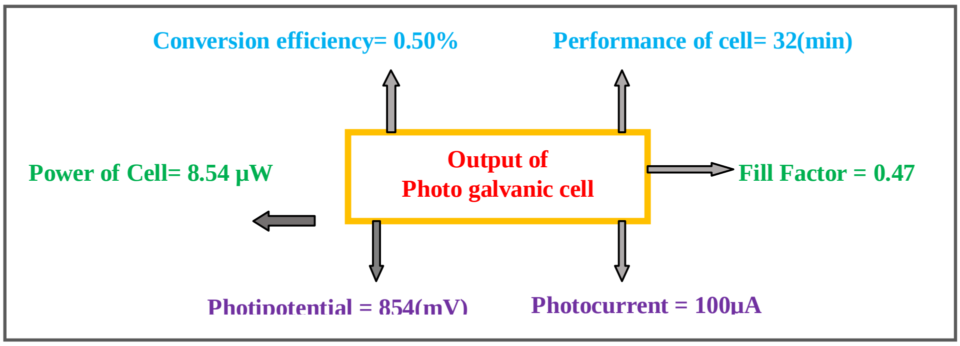
ABSTRACT

The Photo galvanic effect was studied in Photo galvanic cell comprises with Prosopis cinneria leaf extract as green photo sensitizer with Triton X-100-EDTA systems. EDTA used as a reductant and Triton X-100 as a surfactant. Natural photo sensitizer (Prosopis cinneria leaf extract) has been studied to applicable some insight with intent of finding relatively cheaper, cost effective and eco friendly photo sensitizer for further improvement of the efficiency of the photo galvanic cell. The observed cell performance in terms of photo potential, photocurrent, fill factor and storage capacity are 854.0 mV, 100.0 μA, 0.47 and 32 min, respectively. The effects of different parameters on electrical output of the cell were observed and a mechanism has been proposed for the renewable energy production system is discussed in this work, together with the future outlook on the impact of green photo sensitizer for applied alternative green energy source for the Sustainable development in present scenario.

Graphical Abstract



Keywords: *Proscopis cineria* Extract, Trition X-100, EDTA, Photo potential, Photocurrent.

INTRODUCTION

Worldwide energy production is based irresistibly on fossil fuels that include coal, oil, and gas. This will remain so at least for the next two or three decades because of the large supply and reasonable availability. However, burning fossil fuels produces carbon dioxide (CO_2), which is one of the major issues in global warming. So presently need for alternative energy production sources without CO_2 release into the atmosphere such as solar, wind, water, and geothermal energy. These all technologies applied in energy production from alternate sources. Renewable and efficiency are the key mechanisms to drive forward the low-carbon transition and reduce pollutant emissions. Renewable and efficiency that are defined in the Sustainable development agenda are met or exceeded in present scenario. In the new Policies Scenario, global energy needs rise more slowly than in the past but still expand by 30% between today and 2040. A global economy growing at an average rate of 3.4% per year and population that expands from 7.4 billion today to more than 9 billion in 2040. Renewable sources of energy meet 40% of the increase in primary demand and their explosive growth in the power sector marks the end of the boom years for coal. The largest contribution to demand growth almost 30% comes from India, whose share of global energy use rises to 11% by 2040 and still well below its 18% share in the anticipated global population. The way that the world meets its growing energy needs changes dramatically in the new Scenario, with the lead now taken by natural gas, by the rapid rise of renewable and by energy efficiency [**1**].In present the solar energy industry is one of the growing forces in renewable energy system, because of the increasing demand in clean energy, solar energy is clean and renewable .The device in which solar energy is convert into electrical energy are called solar cells. Photo galvanic cells are under preliminary research stage these have high conversion efficiency but low storage capacity and the latter are found to have good storage capacity but low conversion efficiency. Nowadays there are several major directions for solar technology development for photo galvanic cell that system directly converts the solar energy into electrical energy. Becquerel [**2**] first observed in 1839 the flow of current between two unsymmetrical illuminated metal electrodes in sunlight. Later, it was observed by Rabinowitch [**3**] and potter [**4**] .A dye sensitized solar cell which is based on a semiconductor formed between a photosensitized anode and on electrolyte systematic investigation was done [**5**]. And a metal based photo galvanic solar panel is the most commonly used solar technology to generate electrical energy was studied [**6**]. The effect of reductant and photo sensitizer in photo galvanic cells for solar energy conversion and storage has been reported in numerous studies,[**7-9**]. The photo chemical conversion of solar energy into electrical energy was studied [**10, 11**]. Gangotri *et al*, also studied use of some reductant and photo sensitizer in photo galvanic cell for solar energy conversion and storage [**12**].The photochemical conversion of solar energy in to electric energy was also reported by Meena *et.al* [**13**]. Recently the photo galvanic effect in various interesting system were observed [**14, 15**]. A detailed literature [**16-20**] survey reveals that different photosensitize and EDTA have been used in photo galvanic cells, but no attention has been lucrative to apply as green and eco friendly photo sensitizer in photo galvanic cell. Present works is the endeavor to observe the photochemical study of green photo sanitizer in photo galvanic cell containing *Prosopis cinneria* leaf extract -Triton X-100-EDTA System for solar energy conversion and storage.

MATERIALS AND METHODS

Chemicals: The natural photo sensitizer (*Prosopis cinneria* leaf extract), has been used as green photo sensitizer, Triton X-100, EDTA and NaOH (>98%Assay-purity) surfactant, reductant, and as alkaline medium, respectively. All the solutions except *Prosopis cinneria* leaf extract were prepared in single distill water and kept in amber colored containers to protect them from sunlight. The solution of natural photo sensitizer (*Prosopis cinneria* leaf extract) has been dissolved in minimum amount of methanol then prepared in distilled water and centrifuge the filtered solution by centrifuged machine.

Experimental Methods: The Photo galvanic cell is made of H–shaped glass tube. A mixture of solution of *Prosopis cinneria* leaf extract, EDTA-Triton X-100 and sodium hydroxide was taken in an H-shaped glass tube. All the Solutions except *Prosopis cinneria* leaf extract were prepared in single distilled water and kept in amber colored containers to protect them from sunlight. A platinum electrode (as negative terminal) ($1.0\times1.0 cm^2$) is immersed in illuminated chamber against window and a saturated calomel electrode (SCE) is kept in the dark chamber. The terminals of electrodes are connected to a digital pH meter. The whole system was first placed in dark till a stable potential was obtained. A water filter was used to cut off infrared radiations. A digital pH meter (modal-III) and a microameter were used to measure the potential and current generated by the system, respectively.

RESULTS AND DISCUSSION

Study of Variation of photo Potential with Time, cell charging: The Photo galvanic cell was placed in dark till it attained a stable potential and then the platinum electrode was exposed to light. It was observed that potential changed on illumination increase and reached at maximum value after a certain period. When the light source was removed, the potential of the cell was decreased and stable potential was again obtained after some time. The results are summarized in table 1 and are graphically reported in figure 1.

Table 1 Variation of Potential with Time

Time (min)	Potential(mV)	Time(min)	Potential(mV)
0	246	110	800
10	363	120	820
20	307	130	855
30	358	140	957
40	390	150	983
50	435	160	995
60	476	170	1105
70	552	180	110
80	672	190	1100
90	675	200	1100
100	711	-	-

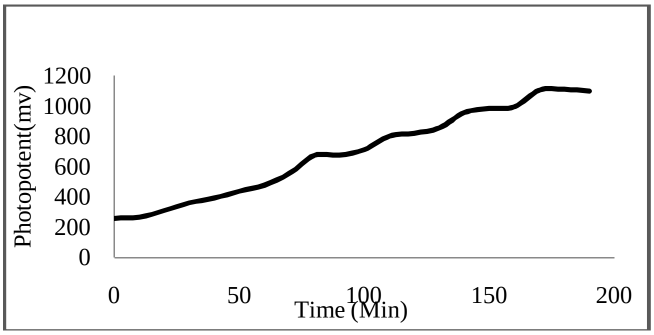


Figure 1. Variation of potential with time during charging of cell.

Effect of variation of Green Photo sensitizer [*Prosopis cinneria* leaf extract] concentration: It was observed that the photo potential and photocurrent were increased with the increase in concentration of the *Prosopis cinneria* leaf extract. A maximum value of electrical parameter were obtained in photo galvanic cell for a particular concentration of *Prosopis cinneria* leaf extract, above which a decrease in the electrical output of the cell was obtained due to intensity of light and natural dye molecule near platinum electrode decrease. All observed results are reported in figure 2 and summarized in table 2.

Table 2. variation of photo potential, photocurrent and power with green photo sensitizer [(*Prosopis cineria* Extract] concentration

Green photosensitize (mL)	Photo potential (mV)	Photo current (µA)	Power (µW)
1	785.0	75.0	58.8
2	810.0	85.0	68.8
4	854.0	100.0	85.4
6	805.0	90.0	72.4
8	765.0	78.0	59.6

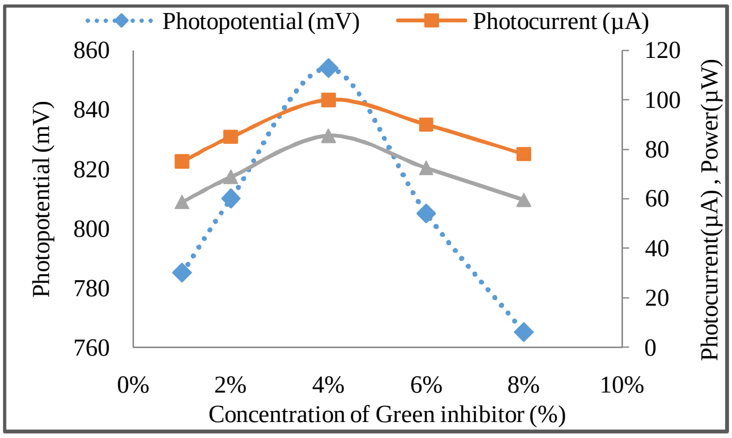


Figure 2. Variation of photo potential and photocurrent with green photo sensitizer (*Prosopis cineria* Extract) concentration.

Effect of Variation of [EDTA] Concentration: With the increase in concentration of the reductant [EDTA], the photopotential was found to increase till it reaches maximum value. On further increase in concentration of EDTA, a decrease in the value of photopotential and photocurrent of the cell was observed. The effect of the variation of the EDTA concentration on the photopotential and photocurrent *Prosopis cinneria* Tx-100 EDTA System are given in table 3 and graphically represented in figure 3.

Table 3. Effect of variation of [EDTA] concentration

[EDTA] X 10^{-3} M	Photopotential (mV)	Photocurrent (µA)	Power (µW)
1.35	705.0	69.0	48.6
1.40	770.0	80.0	61.6
1.44	854.0	100.0	85.4
1.49	770.0	85.0	64.5
1.51	742.0	75.0	55.6

[*Prosopis cinneria*] = 4mL Light intensity=10.4mWcm^{-2}
pH=1108 Temp=303K

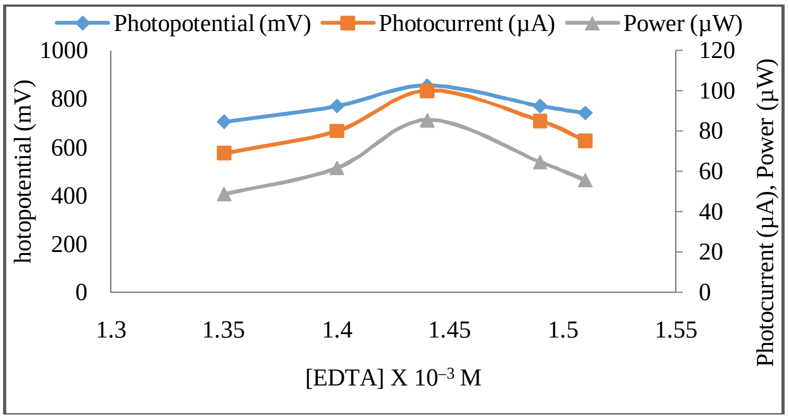


Figure 3. Variation of Photopotential and Photocurrent with [EDTA] Concentration.

Study of variation of pH: Photo galvanic cell containing *Prosopis cinneria* leaf extract and Triton X-100-EDTA System was observed that it is very much sensitive to the pH of the solution. It was observed that there was an increase in the photo potential of this system with the increase in the pH value (in the alkaline medium). At pH 11.8 a maximum value of photo potential and photocurrent were obtained. On further increase in pH, there was a decrease in photo potential and photocurrent. When pH is very than the number of OH^- ions combine with oxidized form of EDTA therefore photo potential and photocurrent both are decrease at higher value of pH. The effect of pH on photo potential and photocurrent are given in table 4 and graphically represented in figure 4.

Table 4. Effect of variation of pH

pH	Photopotential (mV)	Photocurrent (μA)	Power (μW)
10.5	692.0	70.0	48.4
11.2	759.0	85.0	64.5
11.8	854.0	100.0	85.4
12.2	771.0	88.0	67.8
12.8	713.0	68.0	48.4

[*Prosopis cinneria*]=4mL [Triton X- 100]=4.7×10^{-3}M

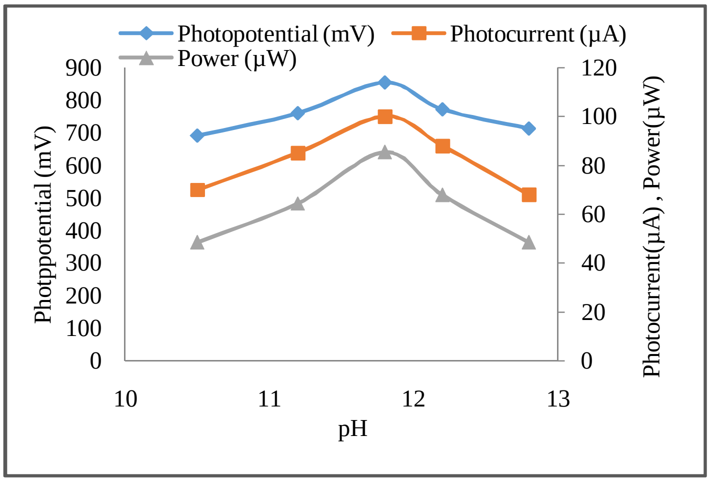


Figure 4. Variation of Photopotential and Photocurrent with pH.

Performance of the Cell and Conversion Efficiency: The open-circuit voltage (V_{oc}) and short-circuit current (i_{sc}) of the photo galvanic cell were measured by means of a digital multimeter (keeping the circuit closed). The current and potential between two extreme values (V_{oc}) and (i_{sc}) were recorded with the assistance of a carbon pot (linear 470 K) that was connected in the circuit of the multimeter and through which an external load was applied. The i-V characteristics of the cell containing a-Triton X-100-EDTA System are shown graphically in figure 5 and cell performance in figure 6. A point in the i-V curve, called the power at power point (pp), was determined where the product of photocurrent and photo potential is maximum. All observed results are reported in a table 4. The potential and the current at the power point are represented by (V_{pp}) and (i_{pp}) respectively. With the help of the (i-V) curve, the Fill Factor and Conversion Efficiency of the cell are found to be 0.47 and 0.50 % respectively, using the formulae.

$$\text{Fill Factor} = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}}$$

$$\text{Conversion Efficiency} = \frac{V_{pp} \times i_{pp}}{10.4 mWcm^{-2}} \times 100 \quad \%$$

Where V_{pp} and i_{pp} are the potential and current at power point and 10.4 mw/cm^2 is intensity of incident radiation.

The performance of the photo galvanic cell was observed by applying an external load necessary to have current at power point after terminating the illumination as soon as the potential reaches a constant value. The performance and storage capacity of cell was determined in terms of $t_{1/2}$ i.e. the time required in fall of maximum power (power at power point)) to its half in dark. It was observed that the cell can be used in dark for 32.0 min Thus, whereas photovoltaic cell cannot be used in the dark even for a second, a photo galvanic system has the advantage of being used in the dark, but at lower conversion efficiency. It is observed that the cell consisting 4 mL of *Prosopis cinneria* extract 2 mL of M/100 EDTA, 4 mL NaOH and reaming doubly distilled water to make total volume of solution equal to 25 mL.

I–V characteristics of the Cell: The short circuit current (i_{sc}) and open circuit voltage (V_{oc}) of the photo galvanic cells were observed with the help of a multimeter (keeping the circuit closed) and with digital pH meter (keeping the other circuit open), respectively. The current and potential values in between these two extreme values were recorded with the help of a carbon pot (log 470K) connected in the circuit of multimeter, through which an external load was applied. The i-V characteristics of the photo galvanic cells containing *Prosopis cinneria* Tx-100 EDTA System are given in table 5 and graphically shown in figure 5 and 6.

Table 5. Current-Voltage (i-V) characteristics of the cell

Photocurrent (μA)	Photopotential (mV)	Fill Factor (η)
100	0	
95	90	
90	180	
85	325	
80	505	
75	654	
70	732	
60	870	0.47
50	890	
45	902	
40	920	
30	930	
25	950	
20	960	
15	980	
0	1100	

[*Prosopis cinneria*]= 4mL, [TX-100]=4.7×10^{-3}M
pH=11.8, Temp.=303K, Light intensity=10.4mW cm^{-2}

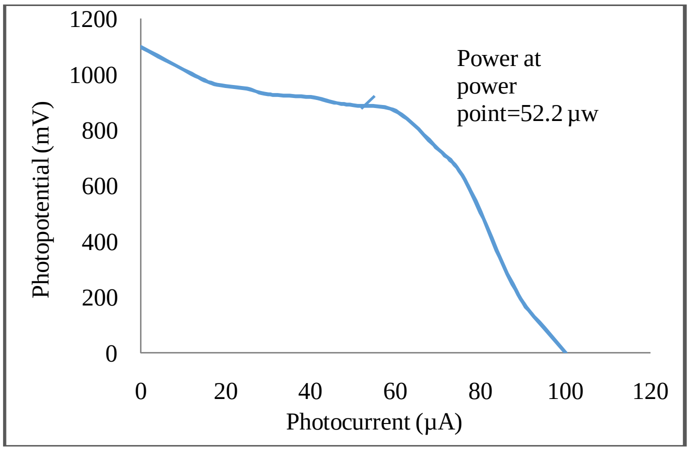


Figure 5. Current-Voltage (i-v) curve of the cell.

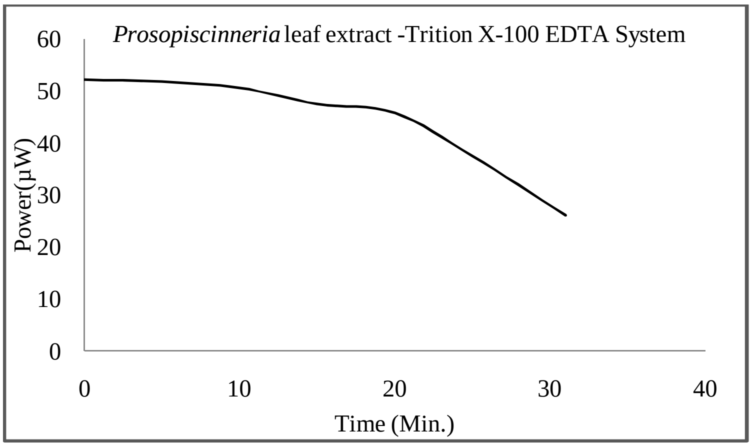


Figure 6. Performance of the cell.

Mechanism: In the dark chamber no reaction was observed between the green photo sensitizer and EDTA, it may be concluded that the redox potential of EDTA is much higher than that of green photo sensitizer. A rapid fall in potential is observed when the platinum electrode is illuminated. The potential reaches a steady value after certain period of exposure. Although the direction the change of potential does not returns to its initial value. This means that the main reversible photochemical reaction is also accompanied by some side irreversible reactions. The electro active species in this photo galvanic system is thus different from that of the well-studied natural photo sensitizer -EDTA system. In the present case, the lecuo-or semi reduced natural photo sensitizer is considered to be the electrode active species in the illuminated chamber, and the natural photo sensitizer itself in dark chamber. The following reaction steps have been proposed for the generation of photocurrent at the anode in the photo galvanic cell.

Illuminated chamber: The green dye molecules (GPS) get excited to its singlet state and inter system crossed to its triplet state on illumination

$$\text{GPS} \xrightarrow{h\nu} \text{GPS * (Excited)} \qquad (1)$$

The excited dye molecules (GPS *) accept an electron from reductant and get converted into semi or leuco form of green dye, and the reductant gets converted to its oxidized form

$$\underset{\text{(Reductant)}}{\text{GPS* + R}} \longrightarrow \text{GPS}^{-}\text{(Semi or leuco)} + \underset{\text{(Oxidized reductant)}}{R^{+}} \qquad (2)$$

At platinum electrode: The semi or leuco form of dye loses an electron and converted into original dye molecule (GPS).

$$\text{GPS}^{-} \longrightarrow \text{GPS} + e^{-} \qquad (3)$$

Dark Chamber

At counter electrode: GPS accepts an electron from electrode and converted in semi or leuco form

$$\text{GPS} + e^{-} \longrightarrow \text{GPS}^{-} \qquad (4)$$

Finally leuco/semi form of green dye and oxidized reductant combine to produce original dye and reductant molecule and the cycle will go on

$$\text{GPS}^{-} + R^{+} \longrightarrow \text{GPS} + R \qquad (5)$$

Where GPS , GPS *, GPS $^{-}$, R and R^{+} are the GPS, excited form of GPS , semi or leuco form of GPS , reductant and oxidized form of the reductant, respectively. Here GPS is denoted as Green photo sensitizer.

APPLICATION

This work is investigating the photochemical activity in photogalvanic cell of natural photosensitizer extracted from *Prosopis cenaria* leaf useful for solar energy conversion and storage. Inherent storage capacity is the extreme advantage of this device.

CONCLUSION

On the basis of observation, it can be concluded that the field has still a scope to give viability in the direction of solar energy conversion and storage. *Prosopis cineria* leaf Extract used as photo sensitizer with Triton X-100 and EDTA in alkaline media and was found increasing and decrease in pH value of solution. The observed cell performance in terms of photo potential, photocurrent, fill factor and storage capacity are 854.0 mV, 100.0 μA, 0.47 and 32.0 min, respectively. The green photo sensitizers used in the present work have given this indication very clearly that the cost as well as eco friendly and viability in all the respect may be achieved if the work is handled with full attention and photo galvanic cell may have their superiority in the field of solar energy conversion and storage.

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