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Role of Green Photo-Sensitizer in Photo-Galvanic Cell for Generation of Solar Energy

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Abstract: The Magnolia Champaca flower extract was used as green photo sensitizer with CTAB-EDTA systems for the enhancement of the conversion efficiency and storage capacity of photo galvanic cell for its commercial viability. Natural photo sensitizer (Magnolia Champaca extract) has been studied to obtain some insight with aim of finding relatively cheaper, cost effective and eco friendly photo sensitizer for further improvement in the electrical performance of galvanic cell. The observed cell performance in terms of photo potential, photocurrent, fill factor and storage capacity are 1080.0mV, 90.0μA, 0.40 and 40.0 minutes, respectively. The effects of different parameters on electrical output of the cell were observed and a mechanism has been proposed for generation of the photo potential and photocurrent in photo galvanic cell.
Keywords: Magnolia Champaca Extract, CTAB, EDTA, photo potential, photocurrent

I. INTRODUCTION

Energy is one of the most fundamental and essential for development of nations. Energy is the lifeline of the country's economy and development. Because of the increasing demand in clean energy, solar energy is clean and renewable. In present the solar energy industry is one of the growing forces in renewable energy system .The device, in which convert solar energy into electrical energy are called solar cells. As long ago as in 1839 Becquerel observed that light can cause changes in the current and voltage characteristics of certain electrochemical cells After four year this concept of dye sensitization was carried out by Meyer from photography to photo electrochemical cells .Photo galvanic cells are under preliminary research stage these have high conversion efficiency but lacks storage capacity and the latter are found to have good storage capacity but low conversion efficiency. The success of any solar cell depends upon its power conversion efficiency. However, the worldwide demand for energy is expected to keep increasing at 5 percent each year [1]. Nowadays there are several major directions for solar technology development for photo galvanic 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 Rideal [3] and Rabinowitch[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]. Use of some reductant and photo sensitizer in photo galvanic cells for solar energy conversion and storage was investigated [7]. The studies of photo galvanic cell consisting various dyes with reductant and surfactant were done [8]-[9]. Recently the photo galvanic effect in various interesting system were observed [10]-[11]. The photo chemical conversion of solar energy into electrical energy was studied [12]-[13]. Gangotri at al. also studied use of some reductant and photosensitizer in photogalvanic cell for solar energy conversion and storage[14].The photochemical conversion of solar energy in to electric energy was also reported by Meena et.al.[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 paid to use of green photo sensitizer in photo galvanic cell containing Magnoliya Champaca CTAB- EDTA System in the photo galvanic cell for solar energy conversion and storage. Present works is the effort to observe the photochemical study of green photo sanitizer in photo galvanic cell containing Magnoliya Champaca -CTAB- EDTA System.

II. MATERIALS AND EXPERIMENTAL METHOD

A. Chemicals

The natural photo sensitizer (Magnolia Champaca flower extract), CTAB (N-cetyl- N,N,N-trimethlyl ammonium bromide, EDTA and NaOH (98%Assay) have been used as green photo sensitizer, surfactant ,reductant, and alkaline medium, respectively. All the solutions except Magnolia Champaca extract have been prepared in doubly distilled water and kept in amber colored containers. The solution of natural photo sensitizer (Magnolia Champaca flower extract) has been prepared in methanol.

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B. Experimental Methods

The Photo galvanic cell is made of H –shaped glass tube . A mixture of solution of Magnoliya Champaca, EDTA -CTAB-(N-cetyl- N,N,N-trimethlyl ammonium bromide and sodium hydroxide was taken in an n H-shaped glass tube. All the Solutions were prepared in doubly distilled water and kept in amber colored containers to protect them from sunlight .A platinum electrode (as negative terminal)(1.0x1.0cm^2) is immersed in illuminated chamber against window o and a saturated calomel electrode (SCE) is kept in the dark chamber. The terminal 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. The experimental set-up of photo galvanic cell is given in Figure-1

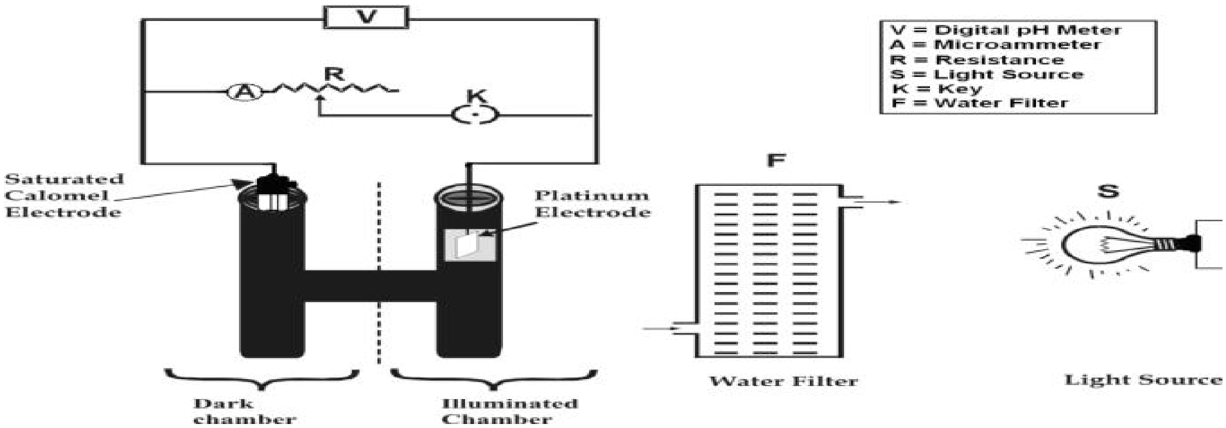

Fig. 1 Experimental set-up of Photo galvanic cell

III. RESULT AND DISCUSSION

A. Study of Variation of Potential with Time

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)	0	5	10	15	20	25	30	40
Potential(mV)	620	710	810	980	1080	920	790	680

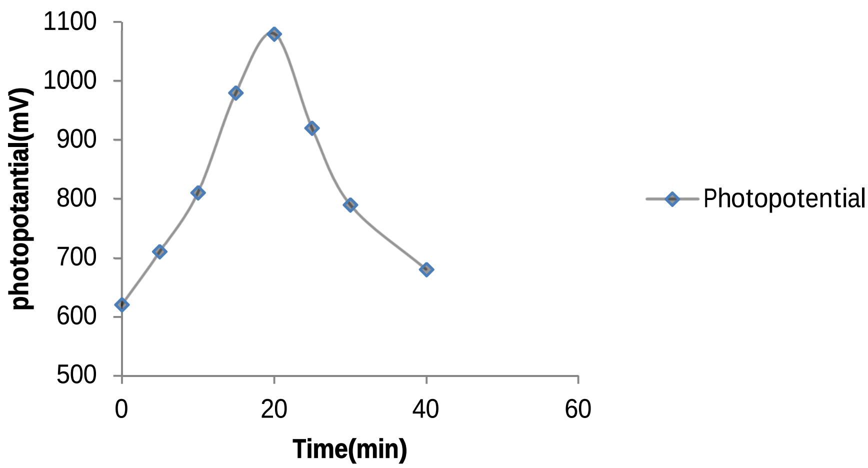

Figure 1 : Variation of potential with time during charging of cell

Variation of Current with Time It was observed that there was a rapid increase in the photocurrent of Magnoliya Champaca CTAB-EDTA System on illumination and it reached a maximum value of photocurrent within few minutes. This value is denoted by i_{max}. Then the current was found to decrease gradually with the period of illumination, finally it was reached a constant value at equilibrium. This value is represented as i_{eq}. On removing the source of illumination, the current was decreased.

B. *Study of Variation of pH*

Photo galvanic cell containing Magnoliya Champaca -CTAB-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 11.7 a maximum value of photo potential and photocurrent were obtained. On further increase in pH, there was a decrease in photo potential and photocurrent.

C. *Effect of Variation of Green Photo Sensitizer [Magionila Champaca] Concentration*

It was observed that the photo potential and photocurrent were increased with the increase in concentration of the Magionila Champaca. A maximum value was obtained for a particular concentration of Magionila Champaca, above which a decrease in the electrical output of the cell was obtained. All observed results are reported in Figure-2 and summarized in able 2.

Table -2 variation of photo potential, photocurrent and power with Green Photo sensitizer [Magionila Champaca Extract] concentration

Concentration %	Photo potential (mV)	Photo current (μA)	Power μ W
4	620	90	55.8
6	710	100	71
8	810	120	97.2
10	980	130	124.4
12	1080	125	135
14	920	110	101.2
15	790	90	71.1
16	680	70	47.6

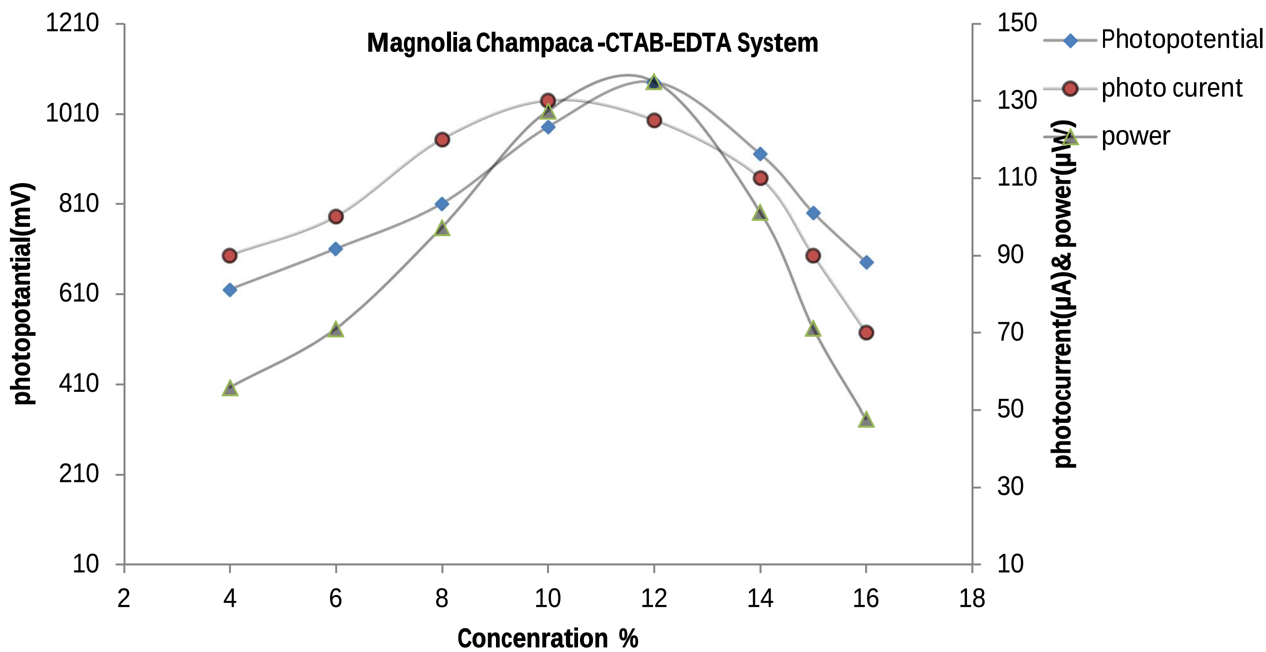

Fig 2 Variation of photo potential and photocurrent with green photo sensitizer (Magnolia champaca) concentration

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D. Effect of Variation of Surfactant [CTAB] Concentration

The photo galvanic cell having Magnolia Champaca -EDTA-CTAB system, the photo potential and photocurrent were increased with the increase in concentration of the surfactant. A maximum was found for a particular value of CTAB concentration, above which decrease in electrical output of photo galvanic cell was obtained. All observed results are reported in Figure-3 and table 3. The reason of the change in electrical output is that micelles solublize the dye molecules up to highest extend at or around their micelles concentration upon increase in CTAB concentration to a value higher than CMC a charge transfer complex between dye and surfactant which is hyrophobic in nature so a fall in electrical output was observed.

Table: 3 variation of of photo potential, photocurrent and power with with CTAB concentration.

Concentration %	Photo potential (mV)	Photo current (μA)	Power
2	540	90	48.6
4	582	95	55.29
6	668	100	66.8
8	626	80	49.92
10	590	70	41.3

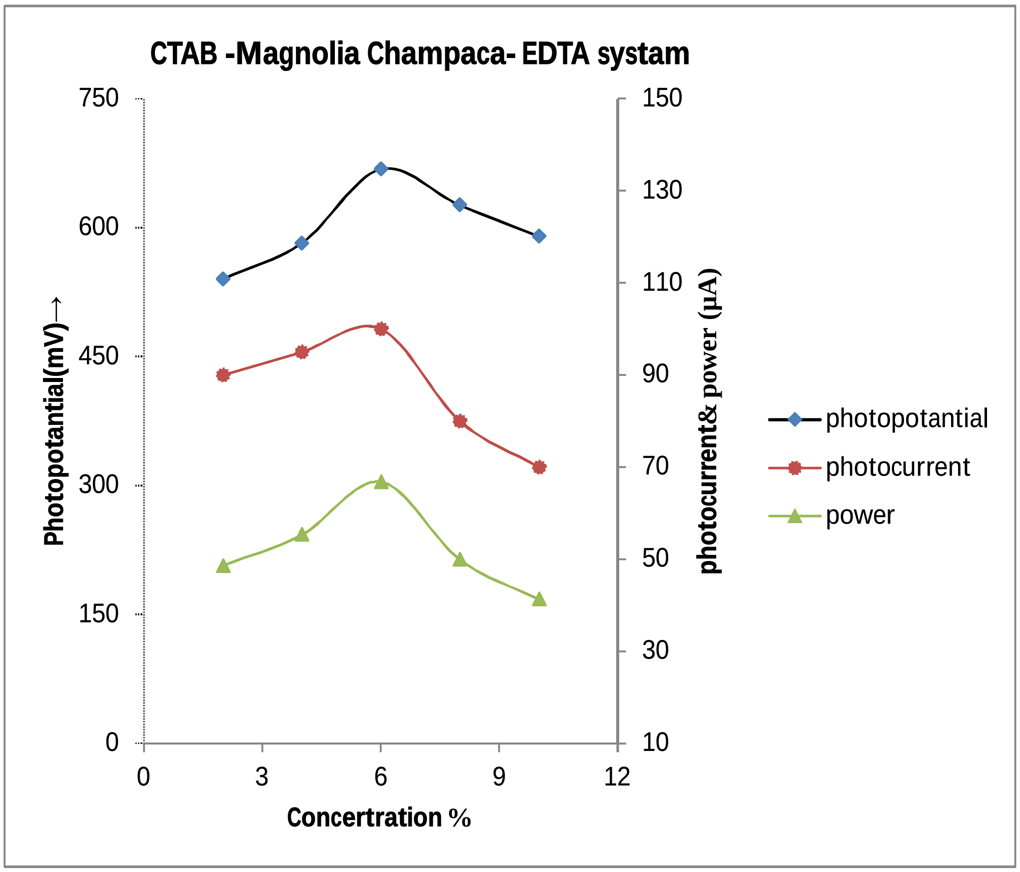

Figure: 3 Variation of photo potential, photocurrent and power with CTAB concentration

IV. 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 Magnoliya Champaca -CTAB-EDTA System are shown graphically in Figure -4 and cell performance in Fig.-5 . A point in the i-V curve, called the power point (pp), was determined where the product of photocurrent and photo potential is maximum. All observed results are reported in a table number 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 0.2 and 1.42 % respectively, using the formulae.

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

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

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 the output (power) to its half at power point in dark. It was observed that the cell can be used in dark for 40.0 minutes 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.

Table-4:- parameter the cell

S.No.	Parameter	Observed value
1.	Dark potential	239.0 mV
2.	Open circuit voltage (VOC)	1319.0 mV
3.	Photopotential (DV)	1080.0 mV
4.	Equilibrium photocurrent (I eq)	130.0 mA
5.	Maximum photocurrent (I max)	140.0 mA
6. 2	Initial generation of photocurrent	25.5
7.	Time of illumination	100.0 min
8	Storage capacity (t1/2)	40.0 min
9.	% of storage capacity of cell	40
10.	Conversion efficiency	1.4 %
11.	Fill factor (□)	0.2

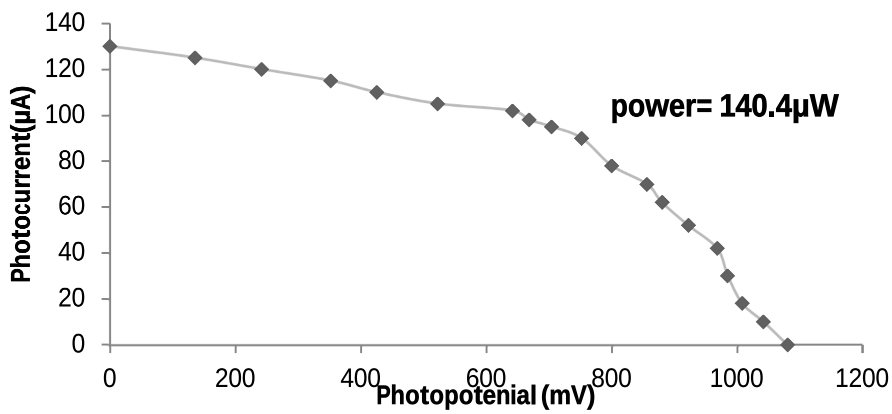

Fig.-4 Current-Voltage (i-v) curve of the cell

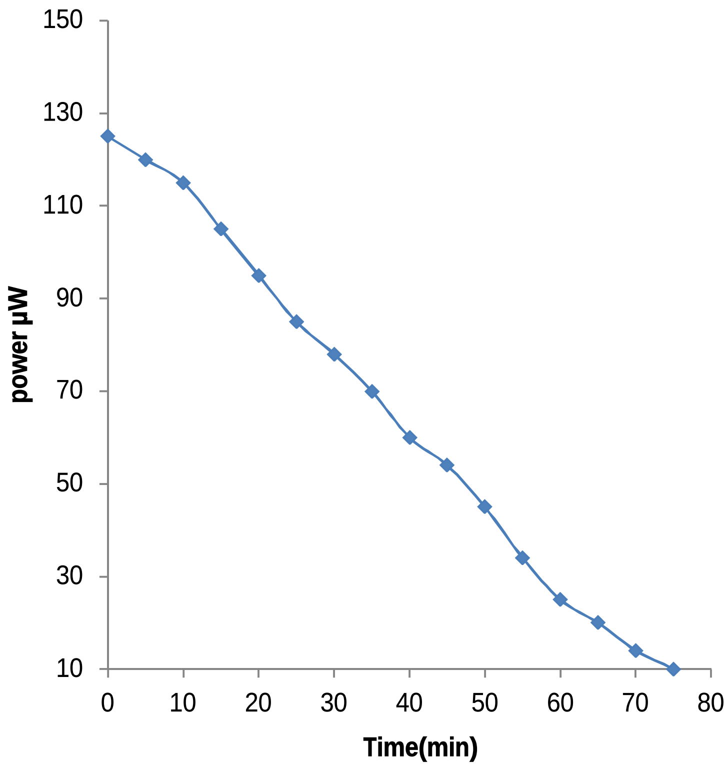

Figure-5 Performance of the Cell

A. 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 photosensitizer -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.

On the basis of these observations, a mechanism is suggested for the generation of photocurrent in the photogalvanic cell as:

Illuminated Chamber:

$$\text{GPS} \xrightarrow{hv} \text{GPS*}$$

$$\text{GPS * + R} \longrightarrow \text{GPS}^{-} \text{ (Semi or leuco) + R}$$

At Platinum Electrode:

$$\text{GPS}^{-} \longrightarrow \text{GPS} + e^{-}$$

Dark Chamber

At Calomel Electrode:

$$GPS + e^- \longrightarrow GPS^- \text{ (Semi or leuco)}$$

$$GPS^- + R^+ \longrightarrow GPS + R$$

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.

VI. 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. The more systems may be found out with better electrical output, good performance and storage capacity. . The observed cell performance in terms of photo potential, photocurrent, fill factor and storage capacity are 1080.0mV, 90.0µA, 0.20 and 40.0 minutes, 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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