Studies of Green Photosensitizer in Photo-electrochemical Cell for Solar Energy conversion and storage

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Abstract:

In our work, the wheatgrass extract was used as green photo sensitizer with oxalic acid as reductant for the enhancement of the conversion efficiency and storage capacity of photo electrochemical cell for its commercial viability. Natural photo sensitizer (wheatgrass 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 cell. The photo potential and photocurrent generated were 1130mV and 210μA respectively. The observed value of the photo potential at PowerPoint was 512 mV and photocurrent was 90μA whereas maximum power of the cell was46.08 μW and conversion efficiency 0.44 %and fill factor 0.19 were experimentally determined at power point of cell. The effects of variation 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 electrochemical cell.

Keywords: wheatgrass leaf extract, oxalic acid, photo potential, photocurrent

1. Introduction:

Mankind faces a great energy challenge due to the depletion of fossil fuels at an alarming rate with exponential increase in population and growing demand for the modern lifestyle. Energy is one of the most fundamental and essential for development of nations. Energy is the lifeline of the country's economy and development and also maintains the quality of our environment. Using fossil fuels as the primary way to generate electricity causes a significant effect on the environment. Oil and gas industries have high carbon dioxide (CO_2) emission which is a great environment concern. To overcome this situation, utilization of omnipresent and abundant solar energy has become the most promising one.

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. The device, in which convert solar energy into electrical energy are called solar 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 photoelectron chemical solar cell that system directly converts the solar energy into electrical energy. The photo electrochemical cell is based on photo galvanic effect. This term was first time used by Rabinwitch and Rideal [2-3] in which the influence of light on the electrode potential is due to a photo electrochemical process in the body of electrolyte. Therefore, photo galvanic cells are quite different from other cells like galvanic or voltaic cells. A dye sensitized solar cell which is based on a semiconductor formed between a photosensitized anode and on electrolyte systematic investigation was done. And a metal based photo galvanic solar panel is the most commonly used solar technology to generate electrical energy was studied [5-6]. Use of some reductant and photo sensitizer in photo galvanic cells for solar energy conversion and storage was investigated. The studies of photo galvanic cell consisting various dyes with reductant and surfactant were done [7-9]. 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[16-22]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 Wheatgrass extract-oxalic acid System in the photo electro chemical solar cell for solar energy conversion and storage. Present works is the effort to observe the photo electrochemical study of green photo sanitizer in photo electrochemical cell containing Wheatgrass extract-Oxalic acid System.

2. Materials and Experimental method

2.1 Chemicals:

The natural photo sensitizer (wheatgrass leaf extract), oxalic acid and Mohave been used as green photo sensitizer, reductant, and alkaline medium, respectively. All the solutions have been prepared in doubly distilled water and kept in amber colored containers. The solution of natural photo sensitizer (wheatgrass leaf extract 10%) has been dissolved in minimum amount of ethanol then prepared in distilled water.

2.2 Experimental Methods

The Photo galvanic cell is made of H –shaped glass tube. A mixture of solution of wheat grass extract oxalic acid 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 and a saturated calomel electrode (SCE) is kept in the dark chamber. The terminal of electrode is 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 micrometer were used to measure the potential and current generated by the system, respectively. The experimental set-up of photo electrochemical cell is given in Figure-1

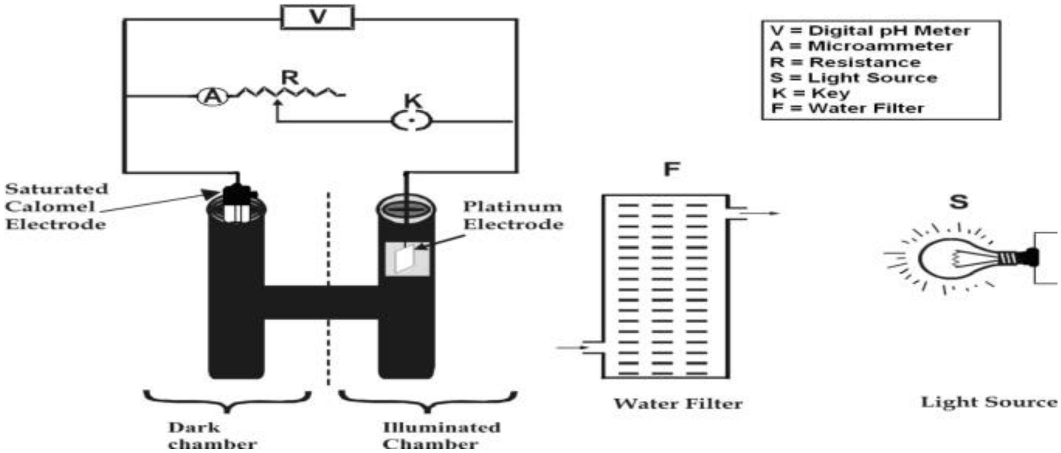

Fig. 1 Experimental set-up of Photo electrochemical cell

3. Result and Discussion

3.1 Study of Variation of Potential with Time:

The Photo electrochemical 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 increase on illumination 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 2.

Table 1 Variation of Potential with Time:

Time(min)	0	5	10	15	20	25	30	40
Potential(mV)	180(V_{Dark})	262	295	350	385	425	496	540
Time(min)	50	60	70	80	100	110	120	130
Potential(mV)	620	680	710	780	885	910	1120	1130

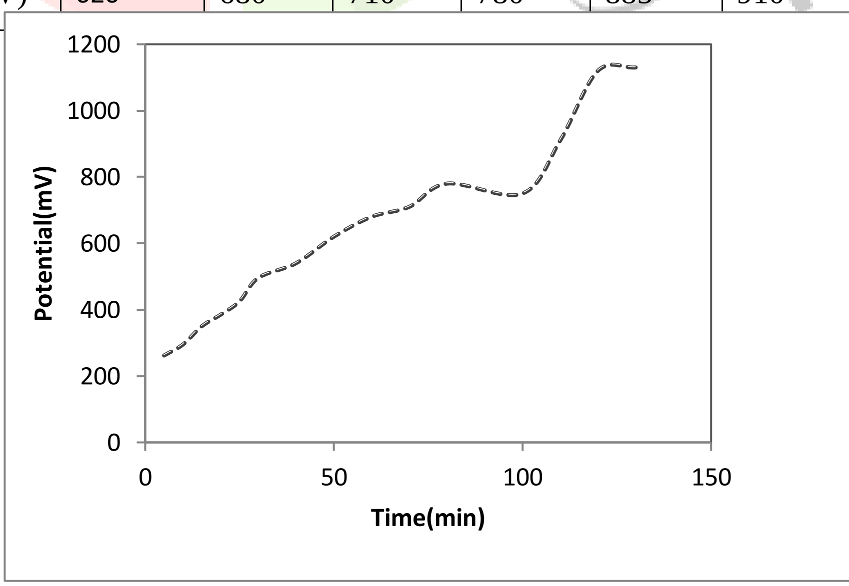

Figure 2: study of potential with time during charging of cell

3.2: Effect of variation of Green Photo sensitizer [10 %wheat grass extract] quantity on cell parameters

In photo electrochemical solar cell, to study the effect of wheatgrass extract concentration on the electrical output of cell, different concentration of green photosensitizer was used while the concentration of different component of the cell kept constant. Table 2 shows that with the increase in concentration of the wheatgrass extract the photo potential and photocurrent were found to increase until it reaches a maximum value, above which a decrease in the electrical output of the cell was obtained. All observed results are reported in Figure-3 and summarized in able 2.

Table.2-Effect of Variation of Green Photo sensitizer [10% wheat grass extract] quantity on cell parameters[a]

Quantity of 10% Wheatgrass extract (ml)	Photopotential(mV)	Photocurrent(μA)	Power(μW)
1	540	80	43.2
2	645	110	70.95
3	756	138	104.32
4	890	180	160.2
5	1010	196	197.96
7	1040	210	218.4
8	805	98	78.89
10	780	84	65.52

[a] At [oxalic acid]= $1.4x\ 10^{-3}$M ,Tem.=300 k Light intensity = 10.4mWcm^{-2} ,electrode area=1 cm^2 , Diffusion length=5.3 cm

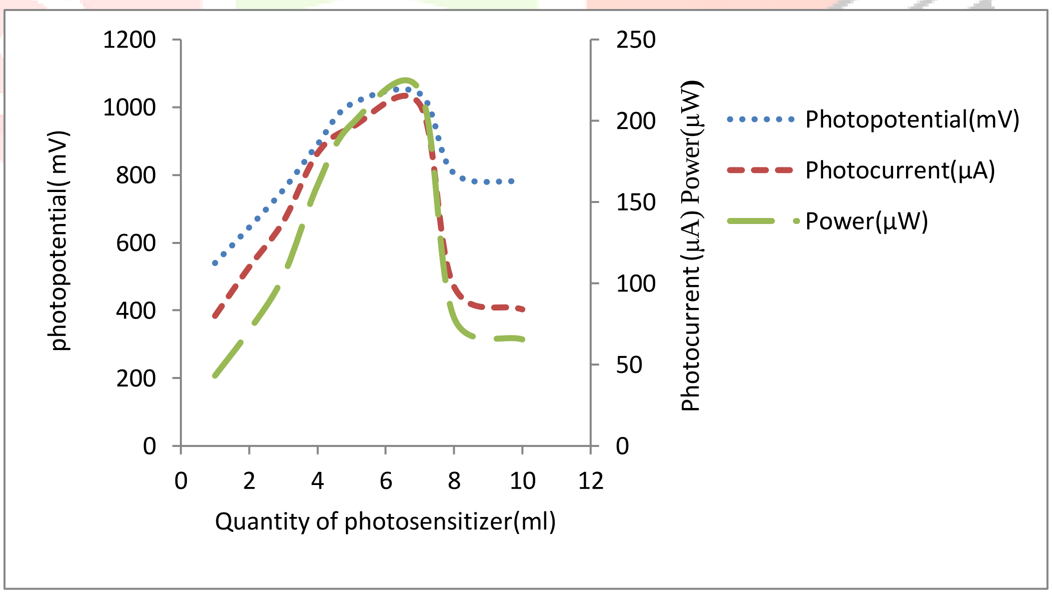

Fig 3 Effect of Variation of Green Photo sensitizer **[**wheatgrass extract**]** concentration on electrical output

3.3 Effect of variation of reductant [Oxalic acid] concentration

Figure 4 shows the effect of oxalic acid electrolyte on electrical output of the system. It is observed that with increase in concentration of the reductant in wheatgrass leaf extract-oxalic acid system, the photo potential was found to increase till it reaches a maximum value. On further increase in concentration of the reductant, a decrease in electrical output of cell was observed. At very low concentration of electrolyte, the fall in power output was resulted with decrease in concentration of reductant due to less number of molecules available for electron donation to the green dye. On other hand, the movement of dye molecules may be hindered by the higher concentration of reductant to reach the electrode in the desired time limit and it will also result in to decrease in electrical output of the cell. All observed results are reported in Figure-4 and summarised in table 3.

Table: 3 Effect of Variation of reductant [oxalic acid] ×10⁻3 M concentration.[b]

[Oxalic acid]×10^{-3}M	Photopotential(mV)	Photocurrent(μA)	Power(μW)
1.2	580	85	49.3
1.3	650	92	59.8
1.35	712	105	74.76
1.4	780	110	85.8
1.48	810	84	68.04

[b] At [Quantity of 10% Wheatgrass extract]= 7 ml ,Tem.=300 k , Light intensity = 10.4mWcm^{-2}, electrode area=1 cm^2 , Diffusion length=5.3 cm

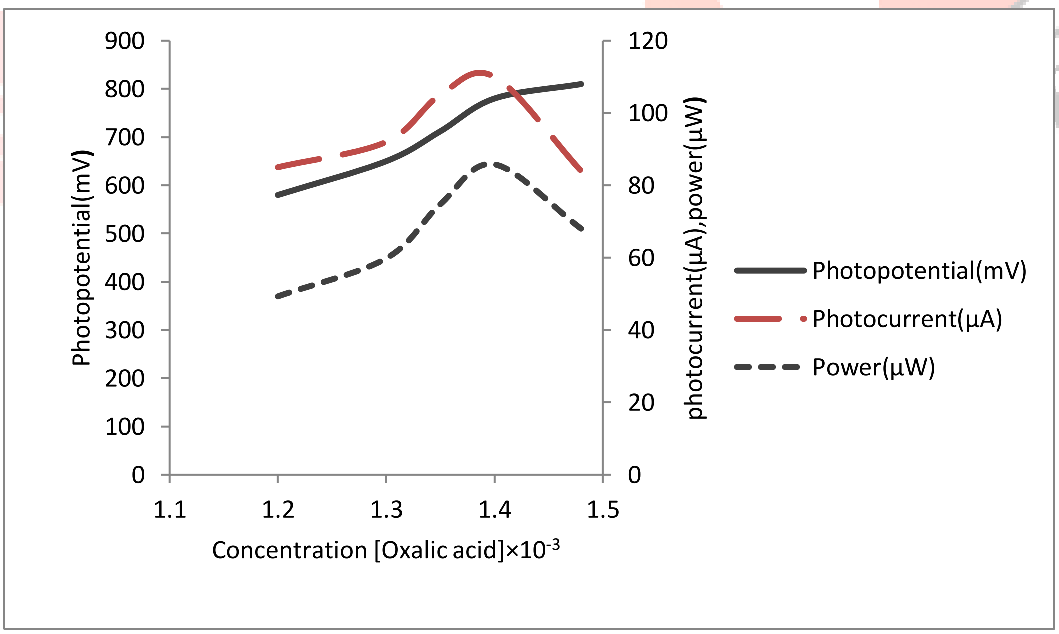

Figure: 4 Effect of Variation of oxalic acid concentration on photo potential, photocurrent and power

3.4 Current -voltage (i-v) characteristics of the photo electrochemical cell

The current –voltage (i-V) characteristics of the cell containing wheatgrass extract-oxalic acid System are shown graphically in Figure -5. A point in the i-V curve, called power point (pp) is determined where the product of photocurrent and photo potential was maximum. The potential and the current at the power point are represented by (V_{pp}) and (i_{pp}) respectively. 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 through which an external load was applied. All observed results of i-V characteristic and storage capacity are reported in a table number 4.

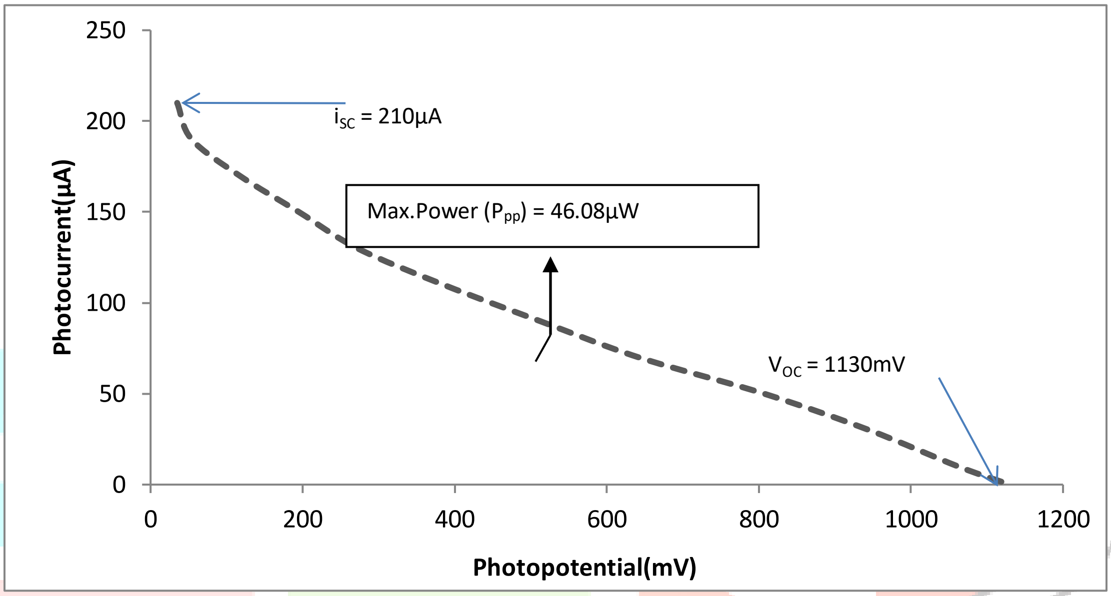

Fig.5- Photocurrent and photopotential (i-v) characteristics curve for the cell

3.5. Performance of the cell and conversion efficiency

The performance of the 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 220.0 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. Fig.-6 show the cell performance and all observed results of performance and storage capacity are reported in a table number 4. To the overall performance of the cell was observed with respect to electrical output, initial generation of photocurrent, photo potential, conversion efficiency and storage capacity of the photo electrochemical cell. The results so obtained in wheatgrass extract-oxalic acid System are summarized in Table 4.With the help of the (i-V) curve Fig- 5, the Fill Factor and Conversion Efficiency of the cell are found to be 0.19 and 0.44 % respectively, using the formulae. Fill Factor $= \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}}$ and

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

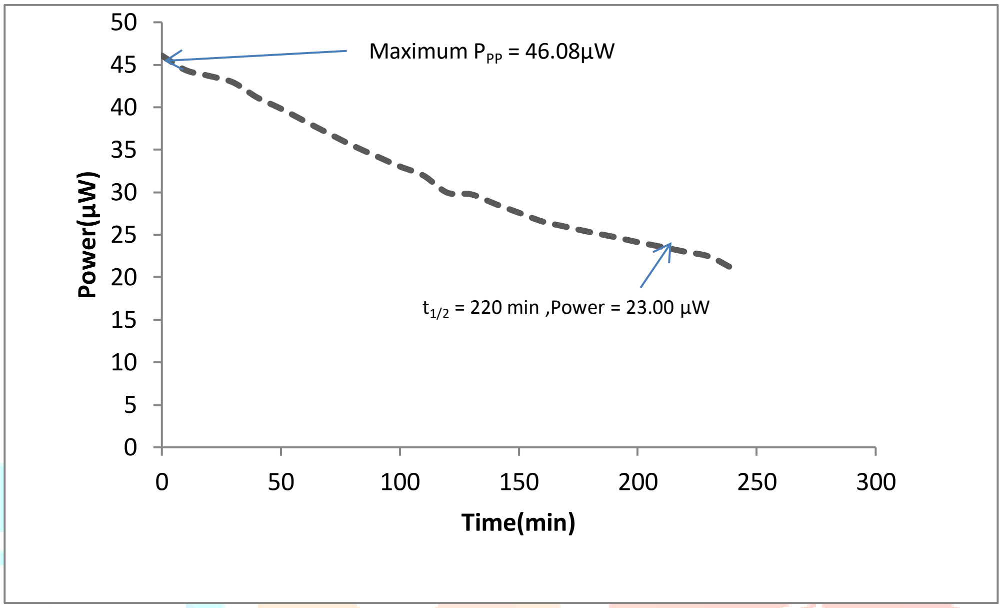

Fig.6-Storage capacity (performance) of the cell

Table-4:- performance of Photo electrochemicalcell[c]

Parameter	Observed result
Open circuit voltage (V_{OC})	1130 mv
Short circuit current (i_{SC})	210 µA
Storage capacity($t_{1/2}$)	220 min
Conversion efficiency(Ƞ)	0.44%
Fill factor(F_r)	0.19
Photo potential at power point (V_{PP})	512 mV
Current at power point(i_{PP})	90 µA
Maximum Power at power point (p_{pp})	46.08 µW
Photopotential(ΔV)	950 mV

[C]At [Quantity of 10% Wheatgrass extract] = 7 ml, [oxalic acid]= 1.4x 10^{-3}M ,Tem.=300 k , Light intensity = 10.4mWcm^{-2}, electrode area=1 cm^2 , Diffusion length=5.3 cm

4. Mechanism of current generation

The photo excited dye (GPS) accepts an electron from reductant to form leuco or semi form of green photosensitizer. The green photo sensitizer and leuco or semi green photosensitizer form is the electro active species in the dark and illuminated chambers, respectively. The reductant and its oxidized form act only as electron carriers in the path. The leuco or semi green dye gives electron to Pt electrode connected through external circuit with SCE at which green dye accepts an electron. Finally, luco/ semi form of dye and oxidized form of reductant may combine to give original dye and reductant molecule in the dark chamber. The leuco or semi forms are the two reduced forms of the dye. The semi is the one electron reduced state of dye and leuco is the two electron reduced state of the dye. The energy stored in the charge separated from semi or leuco can be converted into the electrical energy. Also, the formation of charge transfer complex between dye and ionic liquid is very important in production of energy. 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 mechanism of photocurrent generation in the photo electrochemical cell can be schematically represented as follows.

Illuminated Chamber

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

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

At Platinum Electrode:

$$GPS^- \longrightarrow GPS + e^-$$

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.

5**. Conclusion**

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 electrochemical cell may have their superiority in the field of solar energy conversion and storage. Because of the simple preparation technique, widely available and low cheap cost natural dye as an alternative sensitizer for dye-sensitized solar cell is promising. 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 1130.0 mV, 210.0μA, 0.19 and 220.0 minutes, respectively. On the basis of studies and obtained results in developed

Solar cell it can be concluded that wheatgrass extract- oxalic acid system is an efficient system and can be use in photo electrochemical solar cell for solar energy conversion and storage.

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