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Simultaneous Conversion and Storage of Solar Power in Photogalvanic Solar Cell by Using Pomegranate Juice as Natural Photosensitizer in Alkali Medium

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Abstract: ***With the increasing demand of energy, the solar power as a supplement and potential substitute to the fossils' fuels. the need of solar power conversion and storage techniques have much importance. The photo-galvanic solar cells are capable of solar energy conversion and storage simultaneously. In previous work various synthetic photo sensitizers have been used by researchers, to develop eco friendly Galvanic solar cell, natural photosensitizer (Pomegranate juice) is used with reductant (fructose), and Surfactant (NaLS) in alkali solution. The obtain cell performance in terms conversion efficiency, fill factor, storage capacity, photocurrent, photopotential and maximum power of the cell are 10.3%, 0.38, 220 minutes,0.984 mA, 510 mV and 268 µW respectively.***

Keywords: Natural Photosensitizer, Galvanic Solar Cell, Photopotential, Photocurrent, Conversion efficiency

1. Introduction

We cannot think existence of life on our planet without energy. Energy is an elementary input for all our activities and also required for essential necessities of human being, energy's production and utilization both are the indicators of economical and scientific progress. The solar energy can be harvested indirectly or directly by various solar power techniques [1-3]. The photogalvanic cells are also one of the promising solar cell technologies which are capable of converting solar energy directly in electricity with extra advantage of power storage [4-9]. Photogalvanic solar cells are solution-based dye sensitized solar cells which involve non-spontaneous photo-electro chemical reactions, in which a molecule is excited by the absorption of photon and gives high energetic species. These species can lose their energy electrochemically and come back to ground state [10-12]. In Photogalvanic solar cells two electrodes immerged in alkaline solution of photosensitizer and reductant, surfactant may beadded in this solution to increase the stability of electrolyte in solution, electrolyte and one electrode is illuminated then the potential difference arises between the electrodes. The previous work on photogalvanic cells have focused exclusively on the enhancement of the cell performance by manipulating one or more cell fabrication variables (like concentrations and nature of the photosensitizers, area of the electrodes, diffusion lengths, illumination intensity, etc.)[11-13]. Author has also used natural sensitizer to develop eco friendly photogalvanic solar cell [14]. Recently, the impressive electrical output has been reported cells fabricated of modified electrodes (Pt of miniaturized size with combination electrode) and modified sensitizers -Fructose reductant electrolyte by adding Sodium lauryl sulphate surfactant [15].Therefore photogalvanic cell has to be capable of being used for over long time period in a sustainable manner. Therefore, from this view point, having PG cell with good electrical output only would not be sufficient for realizing durable solar cell devices, but these cells have to show good storage capacity. Therefore, to develop ecofriendly photogalvanic solar cell and increase the storage capacity of photogalvanic solar cell, cell is fabricated with natural photosensitizer- pomegranate juice, Fructose as reductant, sodium lauryl sulfate as reductant and NaOH is used for alkaline medium.

2. Materials Used

Pure pomegranate juice as photosensitizer, Fructose (IUPAC name-1,3,4,5,6 – pentahydroxy-2-hexanone) as reductant, Sodium lauryl sulfate (IUPAC name-Sodium dodecyl sulfate) has been used as a surfactant material, 1 M NaOH is used during experimental work and NaOH is standardized with1/2 M Oxalic acid. All solutions have been prepared in distilled water.

3. Experimental Setup of the Photogalvanic Cell

The experimental setup consists of H-shape glass tube, which is covered by black carbon paper, only 1.5 cm^2area of one arm is transparent for illumination. A homogeneous mixture of photosensitizer, reductant, surfactant and NaOHispreparedin distilled water and distilled water is also added to make25 ml total volume of the solution. This solution and both electrodes (platinum electrode and saturated calomel electrode (SCE) combination with p^H electrode) are put in H – shape tube. Platinum electrode is dipped in one limb of the H-shape tube having a window which act as illuminated chamber and another limb act as dark chamber. The terminals of the electrodes are connected to outer circuit (digital multimeter (KROSS-S DT830D) and digital p^H meter (111 E) is connected to p^H electrode which is in combination with saturated calomel electrode). Initially photopotential is measured in dark this potential is called dark potential (V_{Dark}). After measuring stable dark potential, the limb containing transparent window is exposed to a light source (tungsten lamp). A water beakeris placed between the illuminated chamber and the light source to filter infrared-radiations and maintain constant temperature. The photopotential generated by the system is measured by the digital multimeter and photocurrent is measured by microammeter (osaw) after getting maximum potential. The current voltage study of photogalvanic cell has been studied by applying an external load with the help of carbon pot(log 407 K) connected in the circuit through a key to have close circuit and open circuit device.

4. Mechanism of Current Generation

The cyclic mechanism is followed by photogalvaniccellto generate electricity and photogalvanic behavior has been found reversible for several cycles[16]. Ionic species such as reducing agents and their oxidized products are electron carriers in the cell. The electrons are migrate from one electrode to another electrode by exchange between photosensitizer and reductant can be represented in figure 1.

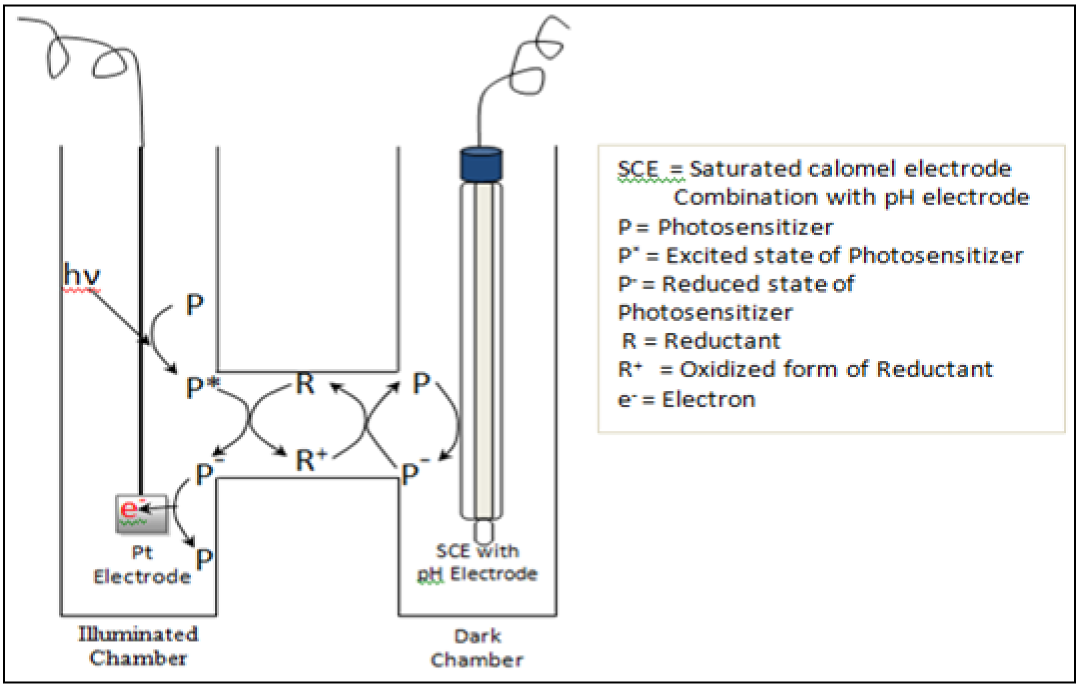

Figure 1: Scheme of mechanism of current generation

5. Method and Calculation

When stable potential is obtained in dark (V_{dark}) while circuit is open, then pt electrode is illuminated, rise in potential is observed. The highest potential observed is termed as maximum potential (V_{max}) and after some time potential goes down marginally to a relative stable value called as open-circuit potential (V_{oc}). Then, circuit is closed by circuit key to observe maximum current (i_{max}) at zero resistance. After some time, current goes down marginally to a relative stable value called as equilibrium current (i_{eq}) or short circuit current, the potential at this point (i_{eq}) is nearly zero. To study the i-V characteristics of the cell the resistance of circuit is slowly raised with the help of carbon pot log 470 K device to note increasing potential values corresponding to decreasing current, till current is zero and potential is nearly equal to V_{oc}. The product of current with corresponding potential is called power. The power is calculated for each current value at which potential has been noted. In this way, the highest power obtained is called power at power point (P_{pp}). The current and corresponding potential at P_{pp} is termed asi_{pp} and V_{pp} respectively. The characteristic resistance (R_{pp}) at P_{pp} is calculated by Ohms Law, $R_{pp}= V_{pp}/i_{pp}$. The storage capacity/ half life (time taken for fall in the power of the cell to its half value of P_{pp}) of cell in dark are studied at characteristic external resistance (R_{pp}).The fill factor (FF) and conversion efficiency (CE) of the cell are calculated by using following formula.

$$\text{Fill Factor (FF)} = \frac{V_{pp} \text{ x } i_{pp}}{V_{cc} \text{ x } i_{sc}}$$

$$\text{Conversion Efficiency (CE)} = \frac{V_{pp} \text{ x } i_{pp} \text{ x } 100\%}{\text{P x A}}$$

$$\text{Photopoteniial } (\Delta V) = V_{OC} - V_{Dark}$$

Where,
V_{pp} = Potential at Power point.
I_{pp} = Current at Power point
V_{oc} = Open circuit voltage
I_{sc} = Short circuit current
P = Power of incident light (mW/cm^2)
A = Electrode area (cm^2)
V_{Dark} = Dark potential

6. Result and Discussions

The overall performance of the Photogalvanic cells consisting of the pomegranate juice as photosensitizer, fructose as reductant and SLS as a surfactant in the alkaline medium was observed.

6.1 Performance of the cell

The performance of the photogalvanic cell was determined with respect to the electrical outputsuch as (i) generation of photopotential (ii) initial generation of photocurrent and i-V Characteristics of cell (iii) storage capacity (iv) conversion efficiency and Fill factor of the cell system.

6.1.1. Generation of photopotential

When transparent window/ pt electrode is exposed to light then potential of the cell increases regularly and get maximum value, this value is called Vmax, after few minutes potential attend constant value, this value is called V_{OC}. Results of change in potential are shown in table-1.

Table 1: Potential variation with the illumination time

Time (Min)	10	20	30	40	50	60	70	80	90	100
Potential (mV)	190	200	250	310	400	490	580	660	700	700

6.1.2 Initial generation of photocurrent and i-V Characteristics of Photogalvanic Solar Cell

When circuit is closed then current reaches maximum (i_{max}) it is the initial generation of current. By the help of external resistance current- potential values are observed, observed results have been tabulated in table -2.

Table 2.1: V Characteristics of Photogalvanic Solar Cell

Photo current (mA)	Photo potential (mV)	Power (μW)
0.984	50	49.2
0.972	100	97.2
0.960	150	144
0.890	200	178
0.820	250	205
0.770	300	231
0.730	350	255.5
0.670 (I_{PP})	**400 (V_{PP})**	**268 (P_{PP})**
0.580	450	261
0.470	500	235
0.330	550	181.5
0.200	600	120
0.100	650	65
0	700	0

6.1.3 Storage capacity of the cell

Storage capacity / half life of the cell is studied at power point and absence of external light source. In the absence of external light, power of the cell decreases continuously. Results have been shown in figure 2.

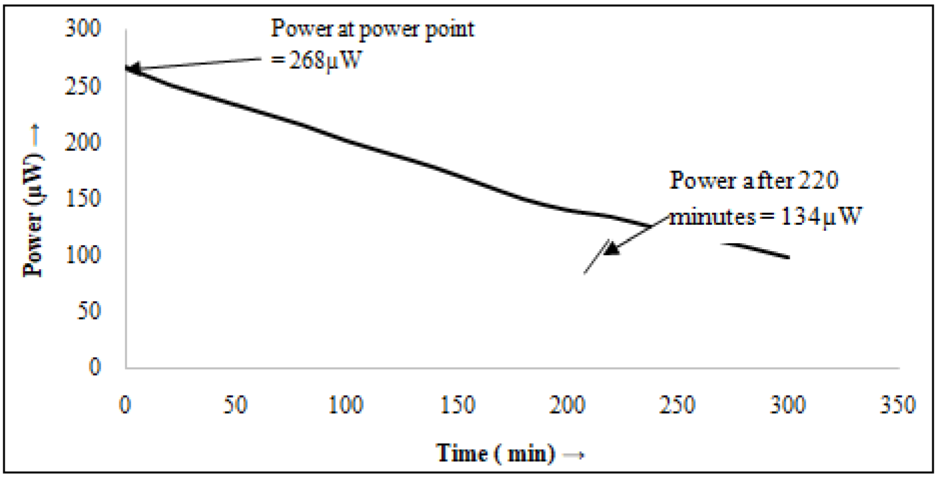

Figure 2: Storage capacity of cell

6.1.4 Fill factor and conversion efficiency

$$\text{Fill Factor (FF)} = \frac{400\text{mV x } 0.670\text{mA}}{700\text{mV x } 0.98\text{mA}}$$

Fill Factor (FF) = 0.38

$$\text{Conversion Efficiency (CE)} = \frac{400\text{mV x } 0.670\text{mA x } 100\%}{0.25\text{cm}^2\text{x } 10.4\text{mWcm}^{-2}}$$

Conversion Efficiency (CE) = 10.30 %

6.2 Effect on cell performance by variation in concentration of different components of solution of galvanic solar cell

The effect of variation in concentration of different components on cell performance have been studied having one component is variable and other are fixed. Each cell having total 25 ml of solution including all components, doubly distilled water is taken as much as to make total volume of solution equal to 25 ml. Results have been tabulated as follows.

6.2.1 Variation in photosensitizer concentration[b]

Quantity of Pure pomegranate juice (ml)	Potential V_{OC} (mV)	Current I_{SC} (mA)	Power at power point (µW)	Fill factor	Conversion efficiency (%)
0.40	668	0.970	222	0.34	8.5
0.45	688	0.978	248	0.36	9.5
0.50	700	0.984	268	0.38	10.30
0.55	689	0.980	253	0.37	9.7
0.60	669	0.972	232	0.35	8.9

[b]At[SLS] = 1.4 × 10^{-2}M, [Fructose] = 6×10^{-4}M, pH = 11.88, Temp = 303K , Light intensity = 10.4 mW $cm^{-2,}$ electrode area = 0.25 cm^2, Diffusion length = 5.3 cm

6.2.2 Variation in Reductant concentration[c]

[Fructose]×10^{-4}M	Potential V_{OC} (mV)	Current I_{SC} (µA)	Power at power point (µW)	Fill factor	Conversion efficiency (%)
2	663	0.962	215	0.33	8.2
4	687	0.976	238.7	0.35	9.1
6	700	0.984	268	0.38	10.3
8	690	0.981	244.4	0.36	9.4
10	670	0.978	222	0.33	8.5

[c]At[SLS] = 1.4 × 10^{-2}M, pomegranate juice = 0.50ml, pH = 11.88 , Temp = 303 K , Light intensity = 10.4 mW $cm^{-2,}$ electrode area = 0.25 cm^2, Diffusion length = 5.3 cm

6.2.3 Variation in Surfactant concentration[d]

[SLS]×10^{-2}M	Photopotential V_{OC} (mV)	Photocurrent I_{SC} (mA)	Power at power point (µW)	Fill factor	Conversion efficiency (%)
1.0	660	0.960	212.2	0.33	8.1
1.2	680	0.972	230.4	0.34	8.8
1.4	700	0.984	268	0.38	10.3
1.6	685	0.980	239.3	0.35	9.2
1.8	665	0.970	217.7	0.34	8.4

[d]At[Fructose] = 6 × 10^{-4}M, pomegranate juice = 0.50ml, pH = 11.88 , Temp = 303 K , Light intensity = 10.4 mW $cm^{-2,}$ electrode area = 0.25 cm^2, Diffusion length = 5.3 cm

6.2.4 Variation in pH[d]

pH	Photopotential V_{OC} (mV)	Photocurrent I_{SC} (µA)	Power at power point (µW)	Fill factor	Conversion efficiency (%)
11.88	690	0.960	228	0.34	8.7
11.93	693	0.972	249.6	0.37	9.6
11.98	700	0.984	268	0.38	10.3
12.03	695	0.980	254.8	0.37	9.8
12.08	692	0.970	233	0.35	9.0

[d]At[Fructose] = 6 × 10^{-4}M, pomegranate juice = 0.50ml, [SLS] = 1.4 × 10^{-2}M, Temp = 303 K , Light intensity = 10.4 mW $cm^{-2,}$ electrode area = 0.25 cm^2, Diffusion length = 5.3 cm

7. Conclusion

Previous researchers used synthetic dyes as photosensitizer in photogalvanic solar cell. In this research work pomegranate juice is used as photosensitizer with fructose as reductant and sodium lauryl sulphate as surfactant to develop ecofriendly photoglavanic solar cell. The storage capacity is the advance feature of photogalvanic solar cell, in this work the observed storage capacity is very high (220 minutes) in comparison to earlier reported photogalvanic system.

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