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SOLAR ENERGY CONVERSION AND STORAGE POTENTIAL OF PHOTOSENSITIZING DYE IN PHOTO GALVANIC CELL

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ABSTRACT

Photogalvanic cell are electrochemical cells based on photogalvanic effect, which are used for converting solar energy into electrical energy and its storage. In the present study Nephthol Green B – Ascorbic acid –NaLS, Victoria Blue R – Ascorbic acid – NaLS, Metanil Yellow – Ascorbic acid –NaLS, were used for experimentation. Nepthol Green B, Victoria Blue R and Metanil Yellow were used as photosensitizers, ascorbic acid was used as reductant and Sodium lauryl sulphate was used as surfactant. Maximum conversion efficiency of 1.0614%was evident in case of VBR-Ascorbic acidNaLS system, followed by 1.0288% in case of NGB-Ascorbic acid-NaLS system and 1.0069% in MY-Ascorbic acid-NaLS system.Photopotential of 818 mV, 815 mV and 810 mV and power of 107.0 µW, 110.39 µW and 104.72 µW was reported in the three types of photogalvanic cells respectively.

Keywords- photogalvanic cell, photogalvanic effect, Nepthol Green B, Victoria Blue R and Metanil Yellow, Conversion efficiency, storage.

INTRODUCTION

Renewable and Non-renewable sources are the two basic categories of energy sources which are available for extracting energy required for completing various tasks and activities. Nonrenewable energy resources include coal, natural gas, oil, and nuclear energy. These are the resources which once used cannot be replaced. It is a major problem for human race as they are highly dependent on them for the supply of most of the energy and the problem of pollution associated with their usage. Renewable energy is the energy which is extracted from renewable resources i.e. the sources which can be naturally replenished. Renewable resources include carbon neutral sources like sunlight, wind, rain, tides, waves, and geothermal heat. Among these solar energy is a significant source as Sun is the most powerful source of energy.

The solar energy can be efficiently utilized through photogalvanic effect i.e. the generation of electric current in a material upon exposure to light. It is a physical and chemical phenomenon. The photogalvanic effect, involves the production of high energy components which serve as reservoir of energy, by stimulation of molecules by photons. This is then converted into electrical energy. This conversion of solar energy into electrical energy in a solar device has been a subject of interest of scientists and researchers throughout the world. It has been considered as the way out of the problem of power crisis. Thus, the photogalvanic cells are sensible devices of source of energy and have future applications and uses.

In 1839, Becquerel while experimenting first observed the flow of current between metal electrodes in sunlight (Becquerel, 1839). The photogalvanic effect was first systematically experimented and reported by Rideal and Williams (Rideal and Williams,

1925). However it was Rabinowitch in 1940, who designed the first photogalvanic cell using the iron-thionine system (Rabinowitch, 1940). The Photogalvanic cell may be defined as the "dye sensitized photoelectrochemical cell chargeable in light for solar power generation and storage".A photogalvanic cell consists of H-shaped glass tube containing two electrodes dipped in solution of dye, reductant, NaOHand surfactant, if used (Koli, 2014).

EXPERIMENTAL METHOD

The present research study was designed to assess the solar energy conversion and storage potential of certain photosensitizing dye in photogalvanic cell. Combination of Nephthol Green B – Ascorbic acid –NaLS, Victoria Blue R – Ascorbic acid –NaLS, Metanil Yellow – Ascorbic acid –NaLS, were used for experimentation.

Various scientists and researchers have been working on this concept. Some significant work which has contributed in this field are summarized here:

Dube et al., 1997 studiedthe photogalvanic effect for azur B-NTA (Nitrilo-tri-acetic acid) system. They usedazur B as a sensitizer and NTA was used as a reductant. The effect of various factors on the electrical parameters and current voltage characteristics of the cell were studied.

Gangotri and Lal, 2005 assessed the photogalvanic effect in a photogalvanic cell consisting of Ethylenediaminetetra-acetic acid as reductant. They used methylene blue and thionine as photosensitizers. They reported a conversion efficiency of 0.43 per cent and the maximum output of cell of 67.68 mW. They also stated that the cell could be used for thirty minutes in the dark.

Habeb et al., 2007 carried out their study on photogalvanic cell using rhodamine B as photosensitizer, EDTA as reductant, and sodium lauryl sulphate as surfactant. They reported a an electrical outputs of 210 mV and 70μA and storage capacity 20 min in dark after 55 min of illumination of the cell. Various aspects for example pH, temperature, light intensity, concentration of dye, concentration of EDTA, and concentration of NaLS were also considered.

Meena et al., 2008 performed their experiments on thymole blue as photosensitizer andascorbic acid as reducing agent. The photopotential and photocurrent observed were 810.00mV and 150.0 μA, respectively and reported a conversion efficiency of 0.8038%. Maximum power of cell was 82.06 μW. They also observed the storage capacity of 54.00 minutes in dark for the experimental cell.

Nenival and Gangotri, 2011 used ascorbic acid as reducing agent and bismark brown dye as photosensitizer to assess the solar energy conversion and storage of the photogalvanic cell. They observed 810.0 mV, 175.0μA and 70.0 of photopotential, photocurrent and power. They also reported a conversion efficiency of 0.6646%.

For the present study, in the photogalvanic cell systems Victoria Blue R, Nephthol Green B, Metanil Yellow (LobaChemie, Mumbai), ascorbic acid (Ases Chemical, Jodhpur), NaLS (Sisco Research Laboratories, Mumbai) and NaOH (RFCL, New Delhi) were used. The stock solutions of ascorbic acid (1.4 x 10-3 M), Victoria Blue R (2.8 x 10-5 M), NaLS (1.6 x 10-3 M) and sodium hydroxide (1M) were prepared in doubly distilled water and kept in amber coloured containers to protect them from sun light. A mixture of solutions of dye (Victoria Blue R), reductant (Ascorbic acid), surfactant (NaLS) and sodium hydroxide taken in a blackened H-Shaped glass container to keep the total volume of reaction mixture always 25.0 ml. A platinum foil electrode (1.0 x 1.0 cm2) was immersed in to one limb of H-shaped glass container and Saturated calomel electrode (SCE) was immersed in another limb. The whole system was first placed in dark. When stable potential (mV) was obtained in dark, it was measured. Then limb containing

platinum foil electrode was exposed to a tungsten lamp of different wattage. A water filter was placed between the light source and cell to cutoff infra-red radiations. The pH of the system was adjusted by adding the desired volume of standard NaOH solution. pH of the reactive system was measured by a digital pH meter (Systronics model 335). Similarly experiments were set up for Nephthol Green B – Ascorbic acid –NaLS and Metanil Yellow – Ascorbic acid – NaLSsystems.Photopotential and photocurrent generated by this system were measured by a digital pH meter and micro ammeter (Nucon) respectively. Current-voltage (i-V) characteristics of the cell were studied using an external load resistance (log 470 K) in micro ammeter circuit

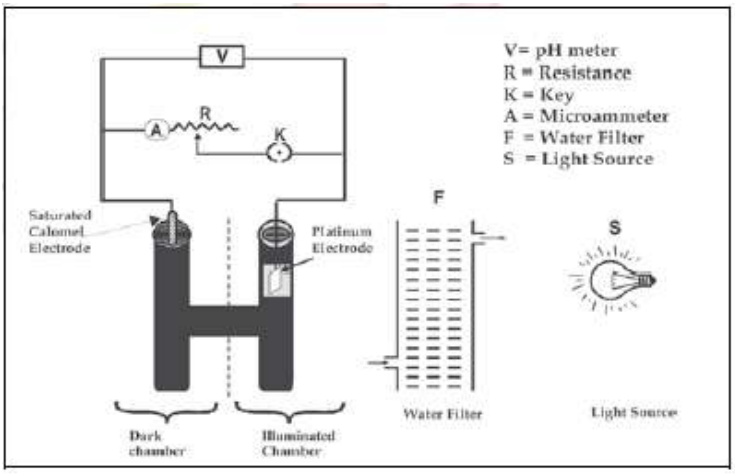


Fig: Experimental Set up of a Photogalvanic cell (Source: Gangotri and Lal, 2005)

Observation Table

S.No.	Electrical Parametrs	Observed Values		
		NGB Ascorbic acid- NaLS System	VBR-Ascorbic acid- NaLS System	MY- Ascorbic acid- NALS System
1	Open Circuit Voltage, VOC (mV)	1050.0	1045.0	1020.0
2	Photopotential, ΔV (mV)	818.0	815.0	810.0
3	Maximum Photocurrent, i_{max}(μA)	446.0	445.0	390.0
4	Short Circuit current, isc (μA)	365.0	360.0	335.0
5	Equilibrium Photo current, i_{eq}(μA)	365.0	360.0	335.0
6	Current at power point, i_{pp}(μA)	200.0	190.0	220.0
7	Potential at Power point, V_{pp}(mV)	535.0	581.0	476.0
8	Power at Power Point (μW)	107.00	110.39	104.72
9	Rate of generation of current (A min^{-1})	16.07	15.89	12.19
10	Charging Time (min.)	120.0	130.0	140.0
11	Fill factor (η)	0.2791	0.2934	0.3889
12	Conversion Efficiency (%)	1.0288	1.0614	1.0069
13	$t_{1/2}$(minutes)	160.0	140.0	110.0

ANALYSIS OF THE RESULT

In the present research investigation, a photopotential of 818 mV, 815 mV and 810 mV was observed for NGB -Ascorbic acid-NaLS System, VBR-Ascorbic acid-NaLS system and MY-Ascorbic acid-NaLS system respectively. Power of 107.0 µW, 110.39µW and 104.72µW was observed in the three experimental systems. Maximum photocurrent was 446 µA, 445 µA and 390 µA. Maximum conversion efficiency was evident in case of VBR-Ascorbic acid-NaLS system i.e. 1.0614%. It was followed by 1.0288% in case of NGB-Ascorbic acid-NaLS system and 1.0069% in MY-Ascorbic acid-NaLS system.

Mechanism- Both singlet and triplet excited states of dye are involved here, but triplet state being relatively more stable than singlet state has role in storage capacity. The main electroactive species are the leuco or semi dye and the dye in the illuminated and the dark chamber, respectively. However, the reductant and its oxidized product act only as electron carriers in the path.Light energy is converted in to chemical energy by driving a suitable redox reaction against the potential gradient. The thionine-Fe (II) aqueous photogalvanic system is shown as:

$$TH^{+} \xrightarrow{h\upsilon} {}^{1}TH^{+} + {}^{3}TH^{+}$$

$${}^{3}TH^{+} + H^{+} \longrightarrow 3TH^{2+}$$

$${}^{3}TH_2^{2+} \longrightarrow TH^{+} \ (I_{SC} \text{ to ground state})$$

$${}^{3}TH_2^{2+} + Fe^{2+} \longrightarrow {}^{*}TH^{2+} + Fe^{3+}$$

(Semi – thionine radical formation)

$${}^{*}TH^{2+} + Fe^{3+} \longrightarrow TH^{+} + Fe^{2+} + H^{+}$$

(Back thermal reaction)

$${}^{*}TH^{2+} \longrightarrow TH^{+} + H^{+} + e^{-}$$

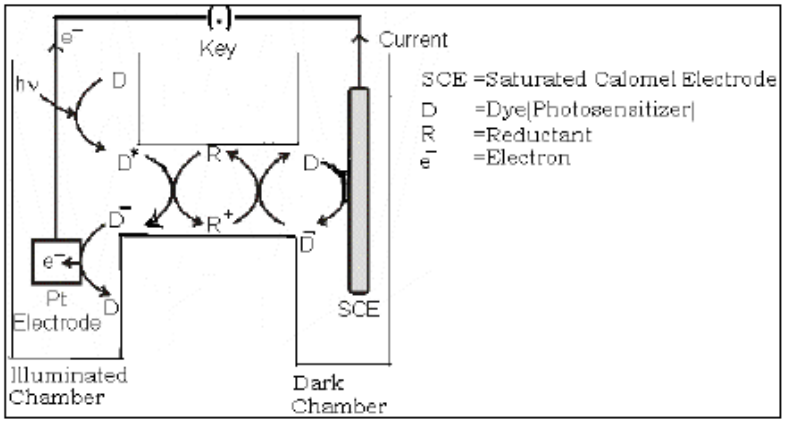
(Anode Reaction at illuminated electrode)

$$Fe^{3+} + e^{-} \longrightarrow Fe^{2+}$$

(Dark electrode)

Where TH^{+} was dark thione oxidized form. Illuminated chamber: On irradiation, dye molecules get excited. 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. At platinum electrode the semi or leuco form of dye loses an electron and gets converted into original dye molecule.

Dark Chamber:At calomel electrode dye molecule accepts an electron from electrode and gets converted into semi or leuco form. 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. The scheme of mechanism is shown in Figure



Inside the cell, there is only diffusion controlled motion of ions in solution. Therefore, photogalvanic cell requires that incident light be absorbed close to the light electrode in order to enable the electron-rich species to reach the electrode by diffusion within its lifetime. It is intended to be achieved by blackening H-cell externally and keeping a small window for illumination of platinum electrode.Further, the higher diffusion retards energy wasting reverse reaction (electron transfer from Pt electrode to dye, and from dye to reductant in illuminated chamber) and increases isc leading to improvement in overall performance of the cell (Gomer, 1975; Shiroishiet al., 2002).

World is facing energy crisis in present time and to meet the increasing energy demand is a challenging task. There is an urgent need to search a renewable device which can be used for energy conversion and storage for maximum time. An effort has been made through this work by experimenting with three dyes (Nephthol Green B, Victoria Blue R and Metanil Yellow) in photogalvanic cell systems and appreciable resultshave been obtained. The electrical parameters of three systems were observed using reducing agent (Ascorbic acid). The effect of pH and concentration of reductant, surfactant, dye and effect of diffusion length, temperature, light intensity on electrical parameter were studied in detail. On the basis of results obtained it may be concluded that efficient photogalvanic cell can be fabricated with the use of VBR–Ascorbic acid–NaLS system in view of conversion efficiency.

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