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Studies of Photoelectrochemical Effect in Dye Sensitized Solar Cell: Sodium Lauryl Sulphate –Bromothymol Blue– Oxalic Acid System

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ABSTRACT:
Solar cells are devices that can convert solar energy into electrical energy. The aim of solar cell research is to increase the solar energy conversion efficiency at low cost to provide a cost-effective sustainable energy source. For this purpose the photogalvanic effect in photoelectrochemical cells, using Sodium Lauryl Sulphate as surfactant, Bromothymol blue as photosensitizer, and Oxalic acid as electron donor, was experimentally investigated. Five different standard H-cell configurations were set-up by varying the electrolyte. Long-term open-circuit voltage measurements were conducted in order to check the constancy of the cells. Light on-off reproducibility investigates were also carried out throughout prolonged cell operations. The photopotential and photocurrent generated by this cell were 880.0 mV and 215.0 µA, respectively. The effect of various parameters likes reductant concentration, dye concentration, pH etc. on the electrical output of the cell has been studied. Performance of the cell was determined in dark at its power point.

KEYWORDS: Bromothymol blue, Sodium Lauryl Sulphate, Photopotential, Photocurrent, Diffusion Length.

INTRODUCTION:

In the developing countries rapid industrialization is very often hampered by inadequate energy availability. Communications, health, shelter and other basic needs of the society are also very much restrained by inadequate availability of energy at several phases, sometimes to such an extent that it even brings the whole process of planning in that sector to a standstill position.

We have a challenge to meet the increasing global energy consumption without sacrificing our future environment. Solar energy provides clean abundant energy and is therefore best option for an environmentally friendly energy source in future. Solar cells are devices that are able to convert solar energy into electrical energy. The aim of solar cell research is to increase the solar energy conversion efficiency at low cost to provide a cost-effective sustainable energy source [1].

Silver chloride electrode immersed in an electrolyte and connected to a counter electrode was illuminated with sunlight a voltage and electric current was produced. It was observed by Becquerel in 1839 [2-3], this phenomenon is known as the Becquerel effect. It was the beginning of the present era of photochemistry and photoelctrochemical cells based on photoelectrochemical effect. Photoelectrochemical effect is defined as a change in the electrode potential (in open circuit) or in the current flowing (in close circuit) in an electrode/electrolyte system on irradiation [4]. Photogalvanic cell is a Photoelectrochemical device in which light is absorbed by a highly absorbing electrolyte solution to provide energy for a reaction [5]. Electrical energy is generated by subsequent transfer of charge to electrode by a photoreduced or photooxidized molecule diffusing from the bulk of the electrolyte. This device is in principle, perhaps closest of the PEC devices for photosynthesis.

Researchers have recently reported some better photogalvanic systems for solar energy conversion and storage by using different combinations of nPhotosensitizers-Reductants-Surfactants in Photoelectrochemical cells

From the literature survey [6-20], it was observed that no attention has been paid to intensification of efficiency and commercial viability of the photoelectrochemical solar cells / photogalvanic cells. Therefore this work is undertaken.

EXPERIMENTAL WORK:

Double distilled water is used for preparation of solutions and all the stock solutions prepared by direct weighing and kept in dark coloured vessels to protect them from direct light.

H-shaped glass tube is used as cell vessel. A total 25.0 ml volume of the mixture of known concentration of the solutions of photosensitizer (Bromothymol Blue), Sodium hydroxide, surfactant, oxalic acid as reductant, and double distilled filled in H-cell. 1.0 x 1.0 cm^2 dimension platinum electrode is dipped in one arm and a Saturated Calomel Electrode (SCE) is immeresed in the other arm of the H tube. The electrodes are then connected to a digital pH meter- Systronics Model – 335 and the entire setup was first placed in dark till a constant potential was obtained, then the platinum electrode was exposed to a 200 W tungsten lamp (Surya). A water filter was used to cut off infrared radiations. The photochemical bleaching of Bromothymol blue was studied potentiometrically. A microammeter (INCO Model No. 65) was used to measure the potential and current generated by the cell.

OBSERVATIONS, RESULTS AND DISCUSSIONS:

STUDY THE EFFECT OF VARIATIONS OF PH OF THE SYSTEM:

The effect of variations of pH on photopotential and photocurrent are reported in table-1. Cell containing Sodium lauryl sulphate – Bromothymol Blue – Oxalic Acid System is found to be very sensitive to the pH of the solutions. An increase in the electrical output with the increase in pH value (in the alkaline range) is observed. At pH 12.4 a maximum output is obtained and on further increase in pH, there is a decrease in electrical output.

Table 1: Effect of Variations of pH of the system

[NaLS]= 6.0 x 10^{-3}M Intensity of Light = 10.4 mW cm^{-2}

[BTB] = 4.00 x 10^{-5} M Temp. = 303 K

[Oxalic Acid] = 3.00 x 10^{-3} M

NaLS–Bromothymol Blue–Oxalic Acid System	pH				
	12.0	12.2	12.4	12.6	12.8
Photopotential (mV)	563.0	690.0	**880.0**	720.0	554.0
Photocurrent (μA)	92.0	158.0	**215.0**	160.0	86.0
Power (μW)	51.79	109.02	**189.2**	115.20	47.64

STUDY THE EFFECT OF VARIATIONS OF SODIUM LAURYL SULPHATE CONCENTRATION:

In the study of variations of concentration of surfactant (sodium lauryl sulphate) it is observed that electrical output of the cell increases on increasing the concentration of surfactant (sodium lauryl sulphate) reaching a maximum value and on further increase in their concentration; a fall in photopotential, photocurrent and power of photogalvanic cell is observed and the results are reported in Table-2

Table 2: Effect of Variations of NaLs Concentration

[BTB] = 4.00 x 10^{-5} M Temp. = 303 K

[Oxalic Acid] = 3.00 x 10^{-3} M pH of system = 12.4
Intensity of Light = 10.4 mW cm^{-2}

NaLS–Bromothymol Blue–Oxalic Acid System	[NaLs] x 10^{3} M				
	5.0	5.5	6.0	6.5	7.0
Photopotential (mV)	553.0	680.0	**880.0**	710.0	550.0
Photocurrent (μA)	95.0	150.0	**215.0**	155.0	84.0
Power (μW)	52.54	102.00	**189.2**	110.05	46.20

STUDY THE EFFECT OF VARIATIONS OF CONCENTRATION OF OXALIC ACID:

The effect of variations of the Oxalic Acid concentration on the electrical productivity of Sodium lauryl sulphate–Bromothymol Blue–Oxalic Acid System is reported in table 3. It is observed that with the increase in concentration of the reductant i.e. Oxalic Acid, the photopotential is found to be increase till it touches a maximum and on additional rise in concentration of Oxalic Acid a decline in the electrical productivity of the cell is observed.

Table 3: Effect of Variations of OXALIC ACID Concentration

[NaLS]= 6.0 x 10^{-3}M Intensity of Light = 10.4 mW cm^{-2}
[BTB] = 4.00 x 10^{-5} M Temp. = 303 K
pH = 12.4

NaLS–Bromothymol Blue–Oxalic Acid System	[OXALIC ACID] x 10^{3} M				
	2.0	2.5	3.0	3.5	4.0
Photopotential (mV)	533.0	666.0	**880.0**	722.0	540.0
Photocurrent (μA)	90.0	140.0	**215.0**	165.0	82.0
Power (μW)	47.97	93.24	**189.20**	119.13	44.28

STUDY THE EFFECT OF VARIATIONS OF CONCENTRATION OF BROMOTHYMOL BLUE:

An increase in electrical productivity (photopotential and photocurrent) is observed with the increase in concentration of the dye (BTB). In these variations a maximum is attained for a specific value of Bromothymol Blue concentration, beyond which a decline in the electrical productivity (photopotential and photocurrent) of the cell is obtained and the results are reported in table 4.

Table 4: Effect of Variations of [Bromothymol Blue]

[NaLS]= 6.0 x 10^{-3}M Intensity of Light =10.4 mW cm^{-2}
[Oxalic Acid] = 3.00 x 10^{-3} M pH of system = 12.4

NaLS–Bromothymol Blue–Oxalic Acid System	[Bromothymol Blue] x 10^{5} M				
	3.6	3.8	4.0	4.4	4.6
Photopotential (mV)	553.0	698.0	**880.0**	762.0	640.0

Photocurrent (μA)	99.0	160.0	**215.0**	175.0	122.0
Power (μW)	54.7	111.7	**189.2**	133.3	780.8

STUDY OF CURRENT-POTENTIAL (i-V) CHARACTERISTICS OF THE SYSTEM:

The current-potential (i-V) characteristics of the photogalvanic cells containing NaLS–Bromothymol Blue–Oxalic Acid System is given in figure 1.

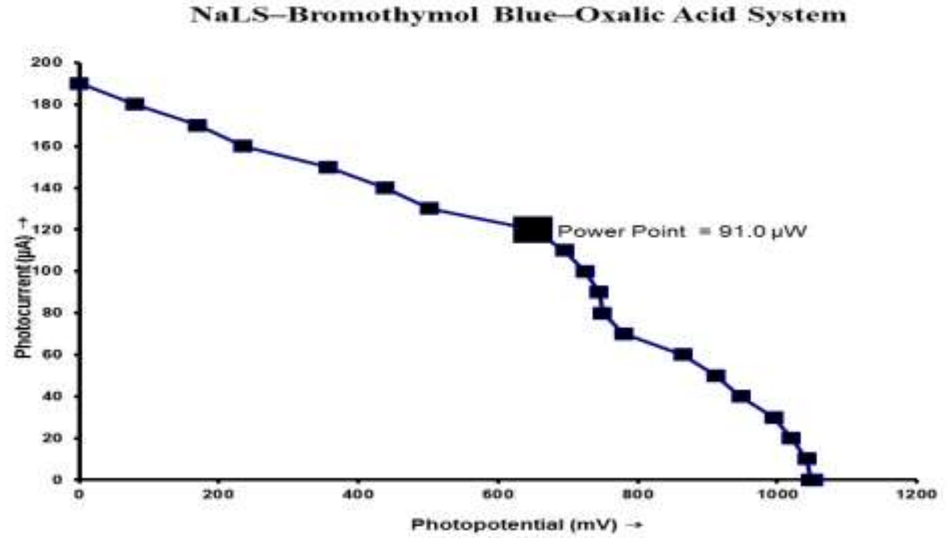

FIG 1. CURRENT - POTENTIAL (i - V) CURRVE OF THE CELL

In this i-V curve we found that it deviates from regular rectangular shape. A point in i-V curve where the product of current and potential is maximum, called Power Point (PP) and the fill-factor is calculated at power point by using the formula :

$$\text{Fill factor } (\eta) = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}} \qquad \ldots\ldots\ldots(1)$$

Where V_{pp} is potential and i_{pp} is current at power point.
V_{oc} is open circuit voltage, i_{sc} is short circuit current.

STORAGE CAPACITY (PERFORMANCE) OF THE CELL:

The storage capacity or performance of the system is perceived by applying an exterior load (required to have current at power point) after swiching off the illumination as soon as the potential ranges a constant value. The storage capacity or performance of the system is determined in terms of $t_{½}$ (it is the time taken in fall of the power output to its half at power point in dark). It is detected that the NaLS–Bromothymol Blue–Oxalic Acid system can be used in dark for **138.0 minutes.** The graphical representation of outcomes is given in figure 2.

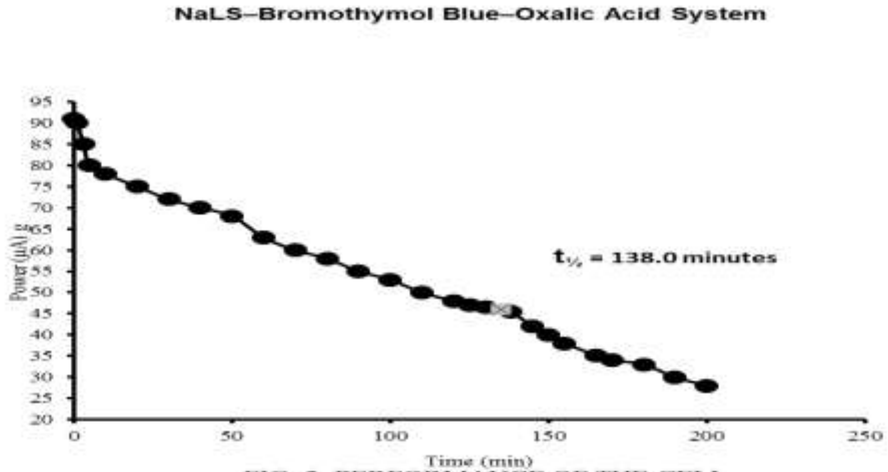

FIG.-2 PERFORMANCE OF THE CELL

CONVERSION EFFICIENCY OF THE CELL:

By using current and potential values at Power Point (pp) and the incident power of radiations, the conversion efficiency of the cell is calculated by usinf following formula. The conversion efficiency of the system is 0.88%.

$$\text{Conversion Efficiency} = \frac{V_{pp} \times i_{pp}}{10.4\ \text{mW/cm}^{-2}} \quad 100\% \qquad \ldots(2)$$

CONCLUSION:

Traditional fossil fuels meet most of our energy demand than solar alternatives. The high cost, low conversion efficiency and low capacity are limitation of solar alternatives. In present study of photoelectrochemical cell of various system combinations we have reached upto a good output and by using surfactant-reductant-photosensitizer conversion efficiency, storage capacity and other electrical parameters were improved and stability of system also enriched.

The commercially viable systems are still likely to be discovered. The appropriate selection of different types of surfactants; reductant and photosensitizer give rise to an efficient system which can be used in creation of photogalvanic system and can be used for society to overcome the energy problem to some extent. This kind of solar cell will be economical viable and pollution free and can be handle easy. The efforts must made to rise electrical out-put by picking appropriate material to reach the preferred results for commercial sustainability of the photogalvanic cells to decrease the energy crisis in some extent.

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