

USE OF COOMASSIE BRILLIANT BLUE- EDTA SYSTEM IN PHOTO-ELECTROCHEMICAL SOLAR CELL FOR STUDY OF ELECTRICAL CHARACTERISTICS AND ENERGY EFFICIENCY

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ABSTRACT

In a photoelectrochemical cell using Coomassie Brilliant Blue R-250 dye acting as a photo-sensitizer in an EDTA system, the photo-sensitizer generated photo potential and photocurrent with an EDTA reductant of 940.0 mV and 380.0 μ A were measured to learn more about the photo galvanic effect. For the Coomassie Brilliant Blue R-250-EDTA system, the fill factor (FF), conversion efficiency (CE), and the maximum power at the Power Point were calculated. The findings were 0.27 and 1.86%, 97.0 μ W respectively. Half the cell's power reaches 48.06 (μ W) in 190 minutes on turning off the light source. The results of different specifications on the cell's electrical output and its current-voltage (i-v) properties were studied.

Keywords: Photosensitizer, Conversion Efficiency, Potential, Fill Factor, Current, Coomassie Brilliant Blue.

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INTRODUCTION

In modern society, energy is a fundamental human need, and as farming, industrial and developmental activities advance, so does the need for energy. Predictable properties similar to diesel, oil, fuel, natural gas, coal, wood, and petrol continue to be depleted due to their high rate of usage. Due to the quick depletion of current sources and the ensuing urgent need for energy in the future, the scientific community concentrated on discovering renewable energy sources. One of the most common types of renewable energy is significant as well as indefinite. It is common knowledge that solutions for effective solar energy exchange and storage should be developed and put into use. Solar electromagnetic energy can be transformed into electricity using photovoltaic technology or other methods, and it can also be stored as chemical energy in induction devices, capacitors, and electric batteries. Solar-generated electrical energy can be used practically to electrolyze water, and the resulting hydrogen can be stored as fuel for later use. In terms of hydraulic potential energy, solar energy can also be stored. Additionally, solar energy can be stored in the band energy of chemical compounds, and through reversible chemical processes, the same materials can continuously store and release solar energy. K.M.Gangotri *et al.*¹ detail the photogalvanic study on the Methylene Blue-EDTA-NaLS system. C.Lal *et al.*² describe the photogalvanic cell study of methylene blue and Thionine as a photosensitizer and reductants in an EDTA system. R.C.Meena *et al.*³ reported that the Photoelectrochemical study used Methylene Blue (MB) and EDTA as a reductant and Azure B as a dye. K.M.Gangotri *et al.*⁴ represent the Photoelectrochemical effect that was investigated in a Photoelectrochemical cell containing methylene blue as a sensitivity agent and oxalic acid as are reductor. C.Lal *et al.*⁵ reported that the photogalvanic cell transforms solar energy into electricity. In this study, a reductant acts as a mannose, methylene blue as a dye, mannose as a reductant, and NaLS as a surfactant. S.Yadav *et al.*⁶ describes the photo galvanic study on the New MB Blue-EDTA-Safranine-o system. P. Bandyopadhyay *et al.*⁷ studied the new MB as a sensitizer and EDTA as a reductant. K.M.Gangotri *et al.*⁸ describe the Photoelectrochemical study on the Azure A-Rose Bengal-Zno triturated system. K.M. Gangotri *et al.*⁹ reports the photo galvanic study on safranine-o as a photosensitizer, EDTA as a reductant, and Tween-80 as a surfactant. P.Gangotri *et al.*¹⁰ describes the photo galvanic study on the Safranine-o-EDTA-NaLS system. According to a thorough literature review¹¹⁻³³ different photo-sensitizers and EDTA have been used in Photoelectrochemical Cells; but no attention has been paid to the Coomasie Brilliant Blue R-250- EDTA system for converting and storing

solar energy. Therefore, in this present study, a Photoelectrochemical Cell was set up utilizing an organic dye-EDTA system with different concentrations of the dye and reductant.

EXPERIMENTAL

Material

The material used as per the specifications given below:

S. No.	Chemical	Specifications
1.	Coomassie Brilliant Blue R-250	Loba Chemical
2.	Ethylenediamine tetra-acetic acid	ASES Chemical
3.	Sodium Hydroxide	Loba Chemical
4.	Phenolphthalein	ASES Chemical

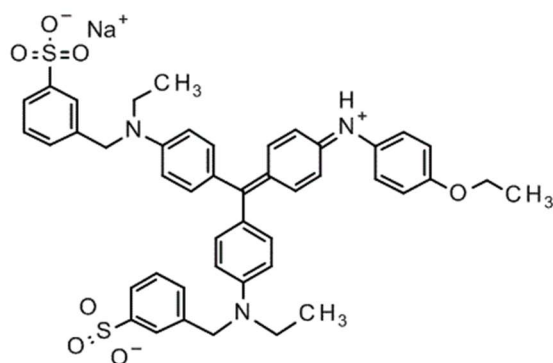
Structures of the Compounds

(a) Dye- Coomassie Brilliant Blue R-250

Appearance – Brownish purple powder,

Molecular weight– 825.99 gm/mol, Absorption maxima-554-563 nm,

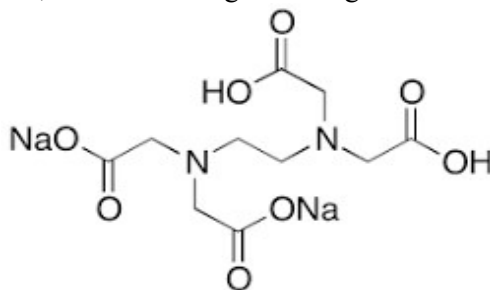
Molecular formula– $C_{45}H_{44}N_3NaO_7S_2$



Structure of Coomassie Brilliant Blue R-250

(b) Ethylene di amine Tetraacetic Acid (EDTA)

Molecular formula- $C_{10}H_{14}N_2Na_2O_8$, Molecular weight- 336.1gm/mol



Structure of EDTA Disodium Salt

Preparation of Solution

Every solution is made using twice-distilled water. Direct measuring is used to create all chemical stock solutions, and then they are stored in colored containers to protect them from light. In the current experiment, we used a variety of solutions, including EDTA (M/100), NaOH (1N) solution, and Coomassie Brilliant Blue R-250 (M/100).

Procedure

To maintain the total volume of the mixture measured in 30 ml, an H-shaped glass tube is filled with sodium hydroxide, double-distilled water, and sensitivity reduction solution. Placed on one leg of the H tube is a saturated calomel electrode (SCE), while the other is a platinum electrode. The size of the platinum electrode is 0.5 cm^2 . The electrode terminals are connected to the digital multimeter and the

entire Placed in complete darkness. The photoelectric power is measured in the dark after the cells stabilize its power. The platinum electrode-containing member is then cooled with a 200-watt tungsten lamp. When the lamps with different watts were used then different light intensities can be obtained.

The Current Generation Mechanism

The mechanisms of photoelectric charge and spontaneous discharge are employed in a photoelectrical system to transform light energy into electrical energy. When light power is converted to chemical power, the appropriate redox process is initiated in response to a voltage gradient. The reduced and oxidized forms of the acceptor-donor complex are represented by the letters A and D. By spontaneous inverting in the dark, this process allows electrons to be transported over external circuits. The cells discharge as a result of the process, which converts chemical energy to electricity. Oxidized form of dye A1, A2, and the reduced form of dye D1, D2 are used to generate electricity. The photocurrent generation process in a Photoelectrochemical cell is shown in the following diagram in Fig.-1.

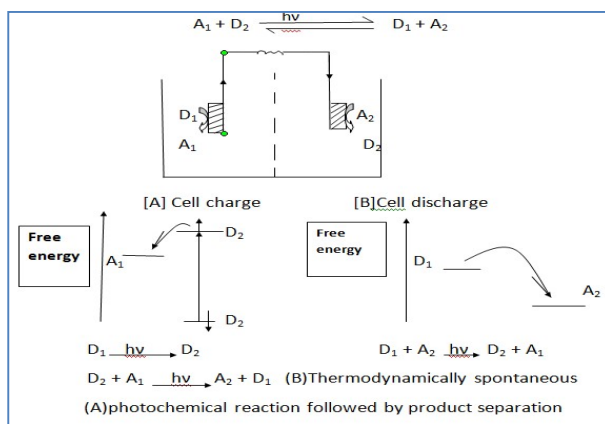


Fig.-1: Diagram of the Current Generating Mechanism in a Photoelectrochemical Cell: (a) Photochemically Charged System; (b) Spontaneous Discharge System

RESULTS AND DISCUSSION

Absorption Study in UV Visible Spectrophotometer

Absorption a study of dye solution with time was carried out by using a UV spectrophotometer shown in Fig.-2, and this study helped to find that the initial absorbance of dye solution is 1.87 cm⁻¹ but when the absorbance is measured after the reaction of dye solution, it comes to 1.23 cm⁻¹. The absorbance diminishes with increasing time, as seen by the absorbance spectra.

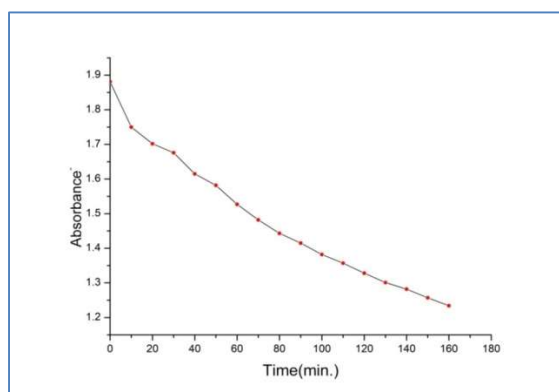


Fig.-2: Time-Dependent Changes in Absorbance

Studying the absorption of the dye solution of Coomassie Brilliant Blue, this dye gave the highest absorption peak (λ_{max} 595nm) at a 2.38cm⁻¹ absorbance of the dye solution. Graphically represented in Fig.-3

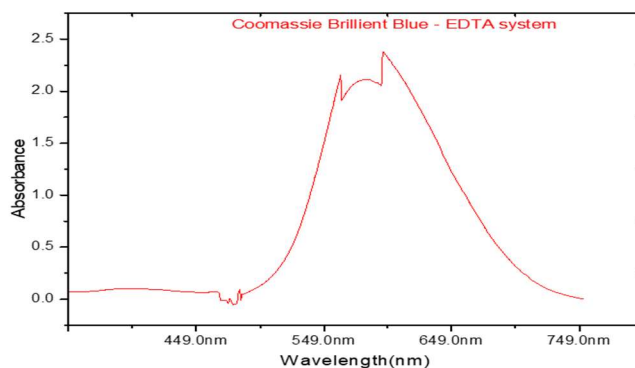


Fig.-3: UV-Visible spectra of Coomassie Brilliant Blue Dye

Degradation Efficiency (%)

The dye solution's absorption spectra were recorded, and the rate of degradation was determined by the change in dye maximum intensity. In the ultraviolet (UV) area, the primary absorption peak is evident at 554 nm. The degradation efficiency³⁴ was then measured to be 34.22 %.

$$\text{Degradation efficiency (\%)} = \frac{C_0 - C}{C_0} \times 100$$

Where C_0 is the dye's initial concentration and C is the concentration after photodegradation.

Variation of Potential with Time

The platinum electrodes of photogalvanic cells are first exposed to light and then placed in darkness to analyze potential variations. It was discovered that the potential value changes with light before becoming constant. When the light eventually stopped, the potential shift was reversed and a stable potential was again reached. Fig.-4 provides a visual representation of this study.

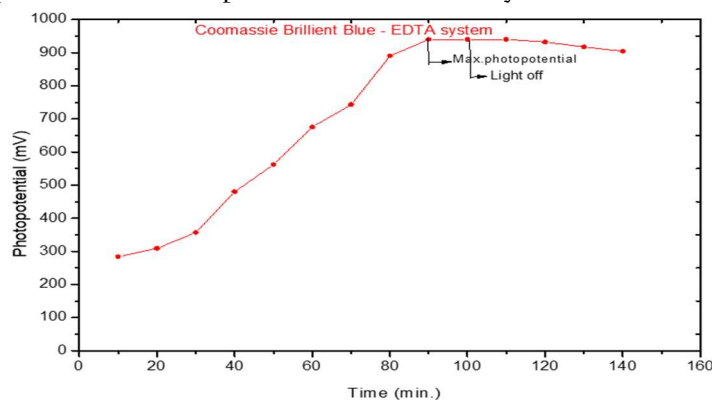


Fig.-4: Variation of Photopotential with Time

Effect of Current Gradually During Cell Charging

On lighting, it was seen that the current of the Coomassie Brilliant Blue R-250-EDTA system rose quickly and reached its maximum within a short period, which is indicated by the symbol $I_{\max}$. Following that, the current progressively decreased throughout the course of the illumination duration before finally stabilizing at a constant value. I_{eq} is used to represent this value. When the lighting source was removed, it was discovered that the current had decreased. The variation of current in this system is graphically represented in Fig.-5.

Investigation of (i-v) Properties During Cell Charging

When the cell is put under direct light sources, electrical parameter characteristics including voltage in an open circuit (V_{oc}) and current in a short circuit (i_{sc}) may be seen. In addition to measuring photo potential and photocurrent, a digital multimeter is utilized to measure short circuit current ($i_{sc} = 380 \mu A$) and open circuit voltage ($V_{oc} = 920 \text{ mV}$).

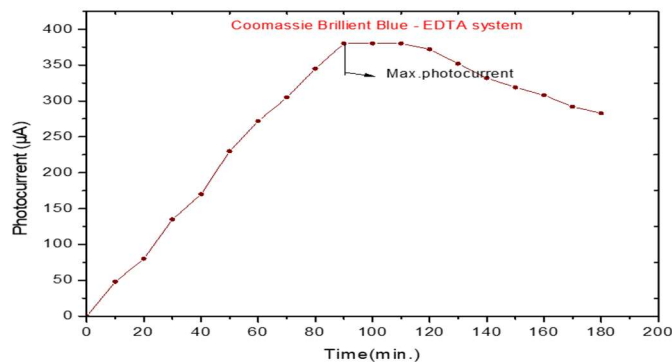


Fig.-5: Variations in Current over Time When the Cell is being charged

The photo potential and photocurrent values were measured using carbon links that were put between these two extreme levels in the circuit of a digital multimeter via which an external load was applied. The photo galvanic cell at Power Point with the highest power ($P_{PP} = 97 \mu W$) Coomassie Brilliant Blue in the R-250-EDTA system, according to Fig.-6 current-voltage (i-v) characterizes.

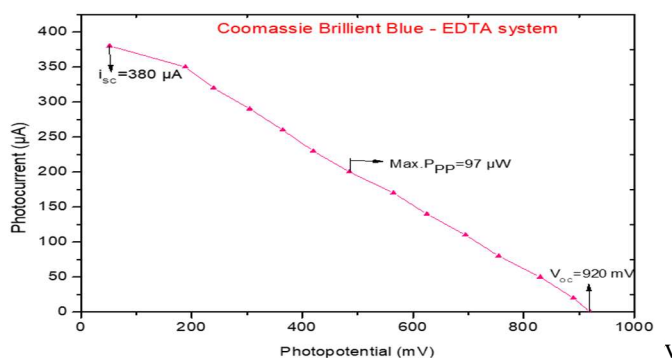


Fig.-6: Curve Describing the Relationship between a Cell's (i-v) Properties and the Effects of Potential and Current

Fill Factor

The fill factor was found to be 0.27 using the (i-v) curve, which produces the maximum values of open circuit voltage (V_{OC}) and short circuit current (i_{SC}). This formula:

$$\text{Fill Factor} = \frac{V_{PP} \times i_{PP}}{V_{OC} \times i_{SC}}$$

In this equation the open circuit voltage is indicated by V_{OC} , the short circuit current is denoted by i_{SC} , and the power point at current and potential is given by i_{PP} and V_{PP} .

Storage Capacity of the Cell

Applying a load from the outside allows one to see the storage capacity of the cell after the light has been switched off and the potential has stabilized. Storage capacity is determined by the time it takes for maximum power at Power Point (P_{PP}) to diminish to half in the dark, or $t_{1/2}$. A cell's half-life has been measured to be 190 minutes. The storage capacity of the cell is shown in Fig.-7.

Conversion Efficiency

The conversion efficiency of a solar cell is based on the energy incident, which is then converted into electrical energy.

$$\text{Conversion efficiency} = \frac{V_{PP} \times i_{PP}}{A \times P} \times 100\%$$

Where A is the platinum electrode's surface area (in cm^2) and P is the power of incident light and V_{PP} and i_{PP} are the power points at potential and power point at current, respectively. This Coomassie Brilliant Blue-EDTA system has a solar efficiency of 1.86 percent.

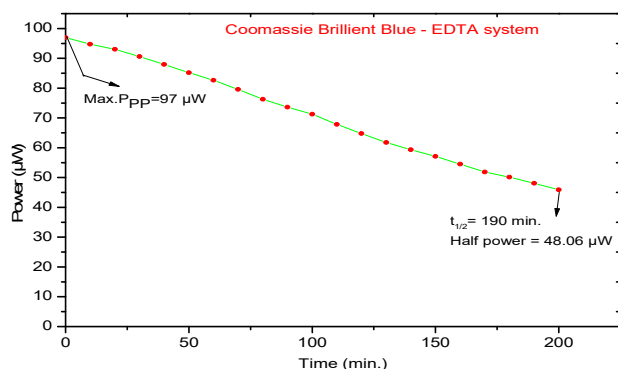


Fig.-7: Cell Performance (capacity) Curve for the Time of Cell Discharge

Study of the Cell's Photocurrent, Photopotential and Photo Power

The photocurrent shunt is set to $30\ \mu\text{A}$, and the gap between photocurrent and photopotential is gradually expanding. The cell can produce up to $97\ \mu\text{W}$ at a maximum potential of $485\ \text{mV}$ and a maximum current of $200\ \mu\text{A}$. Fig.-8 provides a graphic illustration of the investigation into photo potential and power in conjunction with the cell's photocurrent.

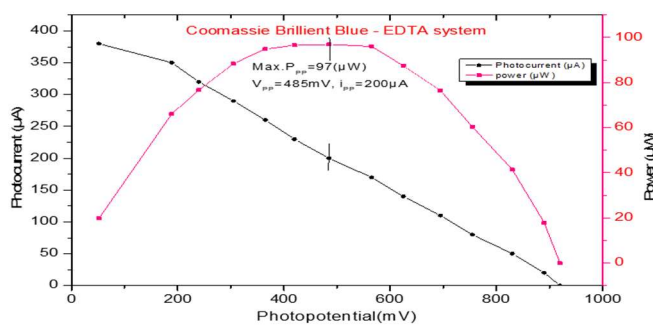


Fig.-8: Potential and Current Variations with Power

Variation with a Concentration of [Coomassie Brilliant Blue] dye

The effects of every variable on the cell performance side from dye concentration were examined. It was shown that when dye concentration increased, the electrical output of the cell peaked at a specific dye concentration before beginning to decrease. It was discovered that the potential and current of the system increased as the dye content rose. A maximum value was attained for a particular dye concentration of $[1.92 \times 10^{-4}\text{M}]$, which is graphically shown in Fig.-9.

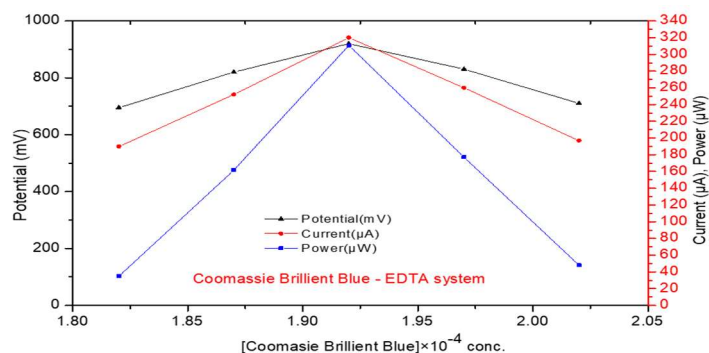


Fig.-9: Variation of Dye Concentration with Photopotential, Photocurrent, and Power

Variation with Concentration of [EDTA] Reductant

As the concentration of the reductant (EDTA) increased throughout the experiment until it reached a maximum value, it was observed that the photo potential increased as well. As the EDTA concentration

was raised, it was seen that the cell's electrical output was decreasing. It was discovered that when EDTA concentration climbed, so did the photocurrent and photopotential of the system. A maximum value was attained for a particular value of EDTA concentration [$1.64 \times 10^{-4} \text{M}$], which is graphically represented in Fig.-10.

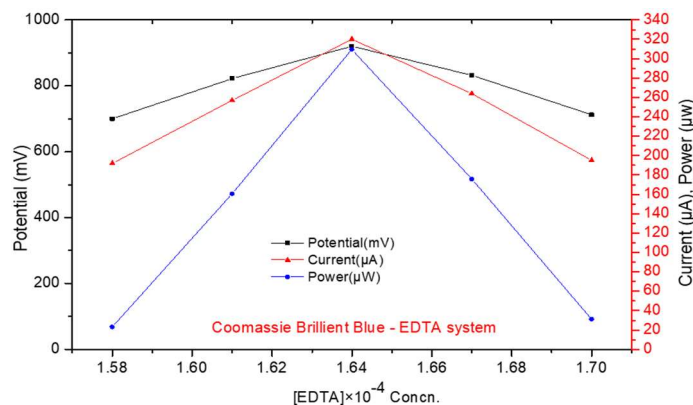


Fig.-10: Effects of [EDTA] Concentration on Potential and Current

The Effectiveness of the Cell

Table-1: Shows the Results of all Observed Parameters for Cell Performance.

Parameters	Observed result
Open circuit voltage (V_{oc})	940 mV
Short circuit current (i_{sc})	380 μA
Storage capacity ($t_{1/2}$)	190 min.
Conversion efficiency	1.86 %
Fill factor	0.27
Potential at PowerPoint(V_{pp})	485 mV
Current at Power Point(i_{pp})	200 μA
Maximum power at Power Point(P_{pp})	97 μW
Photopotential (Δv)	708 mV

CONCLUSION

According to the aforementioned research, Coomassie Brilliant Blue R 250 functions well in a solar cell as a photosensitizer. The fill factor of the solar cell was 0.27, and its efficiency was 1.86 percent. Though they lack an internal storage space, photovoltaic cells are more efficient at converting energy than photogalvanic cells. Photogalvanic cells have the potential to be commercially successful due to storage capability. The need for sustainable energy has increased interest in Photoelectrochemical cells due to their capacity to convert solar energy to electrical energy.

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CONFLICT OF INTERESTS

No conflicts of interest exist, according to the authors, with the publishing of this work.

AUTHOR CONTRIBUTIONS

All of the authors made important contributions to this study, including the conception and design of the manuscript, the collection and contribution of data, the development of the analytic tools, the formatting and editing of the paper, and the approval of the final draft for publishing.

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