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Comparatively Study of Three Dyes Sensitized Solar Cell and Their Characterizations

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ABSTRACT

Due to the large scale consumption of energy, the demand of renewable energy sources is increasing day by day. Solar energy is a most popular source for renewable energy now in this era. My research paper is regarding to the synthesis of Dye Sensitized Solar cells (photogalvanic cells) and their use in solar energy conversion and storage. This paper emphasis on the DSS cells and their comparatively characterizations. The result are showing their comparatively storage capacity and conversion efficiency.

Keywords: Solar energy, Renewable energy, Dyes sensitized solar cell and conversion efficiency.

INTRODUCTION

Renewable energy

Energy from nature which is possible to replenish in less than a human lifetime without diminishing resources of the planet, such as waves, wind, sunlight, biomass, and thermal energy that are stored in earth crust and can be used in a variety of ways, is known as renewable energy[1]. In addition to being inexhaustible and renewable, these energy sources also emit fewer greenhouse gases and reduce environmental crises.

The shift to non renewble to renewable energy by multiple issues as skyrocketing fossil fuel prices, worsening climate changes, macroeconomic instability, health consequence and pressure of energy crisis.

Since 2011, renewable energy has surpassed traditional energy sources in terms of development, affordability, and growth.536GW of renewable energy were produced in 2023[2], it is 13% of total energy uses[3]. The uses of renewable energy are in agriculture, building, industry and transport has also enabled greater integration of renewable as 30% of our electricity currently comes from renewable resources.

Solar energy

Solar energy[4] is promising technique in renewable resources of energy and it has capacity to resolve the crises and demand of future of energy. Solar power is most promising renewable energy source for the planet in the future. The sun's radiation reaches a peak of 3.8×10^{23} kW, with Earth absorbing around 1.8×10^{14} kW of it[5,12]. Solar energy is abundant, free, and readily accessible in nature, therefore it can meet the world's energy needs, according to literature reviews[6,13].

DSS cells

Solar cells are cells or modules that directly convert sunlight into electricity by using semiconductors.

DSScells[7] is a photogalvanic cell which convert solar energy to electricity and store also. in DSS solar cell organic (natural or synthetic) and inorganic dyes are use a as a sensitizer[8]. Natural dyes are easy to available and cheaper no environmental threat.

Methodology

The present work makes use of the following chemicals:

Table 1: Chemicals used

Sr. No	Chemicals	Specifications
1	Rhodamine B	Loba Chemie, Mumbai
2	Acid Black 1	Loba Chemie, Mumbai
3	Erythromycin B	Ases Chemical, Jodhpur
4	EDTA	Ases Chemical, Jodhpur
5	TiO_2	Sisco Research Laboratories, Mumbai
6	Oxalic Acid	Ranbaxy, Mumbai
7	Sodium hydroxide	RFCL, New Delhi
8	Phenolphthalein	Sisco Chem, Mumbai

These are followings dyes which are used for synthesis of dye sensitized solar cells as-

Rhodamine B

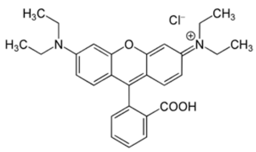
Chemical formula : $C_{28}H_{31}ClN_2O_3$

IUPAC Name : 9-(2-Carboxyphenyl)-6-(diethylamino)-N,N-diethyl-3H-xanthen-3-iminium chloride

Molecular mass : 479.02 g mol^{-1}

λ_{max} : 554 nm

Structural formula :



Acid Black 1

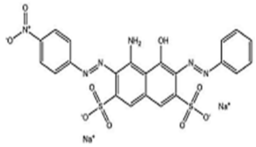
Chemical formula : $C_{22}H_{14}N_6Na_2O_9S_2$

IUPAC Name : 4-amino-5-hydroxy-3-[(4-nitrophenyl)azo]-6-(phenylazo)-2,7-Naphthalene disulfonic acid, disodium salt

Molecular mass : 616.49 g mol^{-1}

λ_{max} : 618 nm

Structural formula :



Erythromycin B

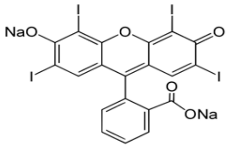
Chemical formula : $C_{20}H_6I_4Na_2O_5$

IUPAC Name: 2-(6-Hydroxy-2,4,5,7-tetraiodo-3-oxo-xanthen- 9-yl)benzoic acid

Molecular mass: 879.86 g mol^{-1}

λ_{max}: 530 nm

Structural formula:



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Preparation of Solutions

All solutions, including dye solutions, M/100 EDTA, 1M NaOH, and 0.5M oxalic acid, were made with double-distilled water. Direct weighing was used to make synthetic dye stock solutions (M/100), which were then stored in colored containers to keep light out.

Experimental Photo Galvanic Cell Set-Up

A glass tube of H-type was filled with mixture of dye, reluctant, surfactant, and NaOH solutions, and it was blackened with black charcoal paper to shield it from sunlight. At one end of H-tube, saturated calomel electrode was situated, while a lustrous Pt foil electrode (1.0x1.0 cm^2) was situated at the other. The SCE functions as a counter electrode, while the platinum electrode serves as the active electrode. The system was initially maintained in a state of darkness until a stable potential was achieved. Subsequently, a Philips 200 W tungsten lamp was employed to illuminate the limb that contained the platinum electrode. The thermal radiation was eliminated by employing a water filter. The photochemical bleaching of the dye was examined using the potentiometric technique.

A Systronics 335 digital pH meter was used to detect potential, and Nucon micrometer was used to measure current produced by system. By adding a carbon pot and an external load to circuit of cell arrangement, the i-v characteristics were investigated.

RESULT AND DISCUSSIONS

Table 2: Comparison of photoelectric parameters of three systems

Sr. No	Electrical Parameters	Observed values Rhodamine B–TiO_2-EDTA System	Acid Black 1–TiO_2-EDTA System	Erythromycin B–TiO_2-EDTA System
1	Open Circuit Voltage, V_{OC} (mV)	1220	1290	1330
2	Dark potential (mV)	1007	1290	1330
3	Photopotential, ΔV (mV)	1220	1290	1330
4	Maximum photo potential ($V_{max.}$) (mV)	1220	1290	1330
5	Maximum Photocurrent, imax (μA)	138	990	587
6	Short Circuit current, i_{sc}	230	690	590
7	Current at power point, i_{pp}	140	420	320
8	Potential at Power point, V_{pp}	580	650	640
9	Power at Power Point	118.23	103.05	112.16
10	Fill factor (η)	0.289	0.307	0.261
11	Conversion Efficiency (%)	0.781	2.625	1.969
12	$t_{1/2}$ (minutes)	58.20	47.24	52.22

Note: data obtained by observation during research work in lab

Potential variation with time

Figures 1, 2, and 3 show the outcomes of the potential fluctuation over time for each of the three systems in photogalvanic cells. It was noted that the potential increased with lighting, and that the direction of the potential shift reversed when the light source was removed. Additionally, it was noted that in all three systems, distinct time periods were required to get a stable potential following lighting as well as to create a stable dark potential. The erythromycin B-TiO_2-EDTA system had the greatest open circuit voltage (V_{oc}) value, whereas the rhodamine B-TiO_2-EDTA system had the lowest. The Acid Black 1-TiO_2-EDTA system produced the greatest voltage at power point (V_{pp}) values, followed by Erythromycin B–TiO_2-EDTA system and lowest in Rhodamine B –TiO_2-EDTA system i.e. 650.0 mV, 640.0 and 580.0 mV respectively.

According to these observations, the most effective photo galvanic cell is the cell containing Erythromycin B–TiO_2-EDTA system followed by the cell containing Acid Black 1–TiO_2-EDTA system and Rhodamine B –TiO_2-EDTA system from generation of potential point of view.

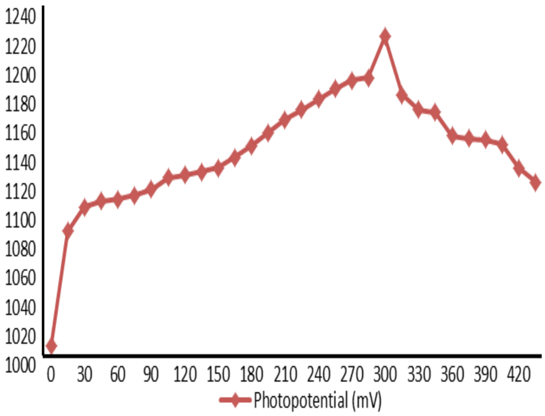

Fig. 1. Variation of Potential with Time for Rhodamine B–TiO_2-EDTA system

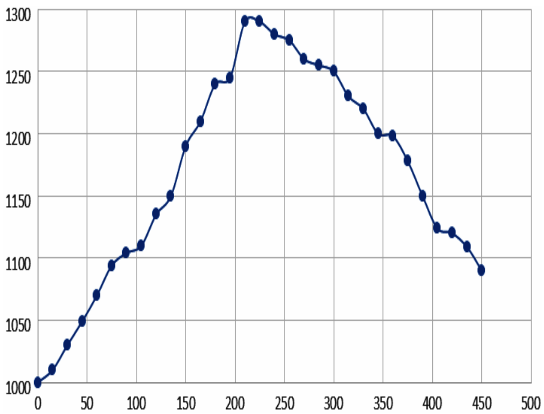

Fig. 2. Variation of Photocurrent with Time for Acid black-1–TiO_2-EDTA system

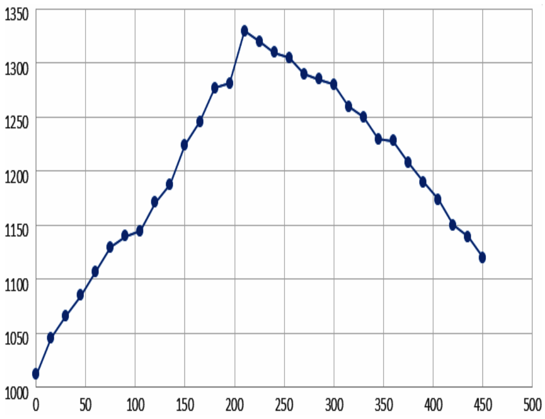

Fig. 3. Variation of Photocurrent with Time for Erythromycin B–TiO_2-EDTA system

Variation of current with time

Based on the findings, it was found that all three systems' currents rapidly grew to their maximum levels within a few minutes of illumination (imax) at 990 A, 587 A, 138 A in Acid Black 1–TiO_2-EDTA system followed by the cell containing Erythromycin B–TiO_2-EDTA system and Rhodamine B–TiO_2-EDTA system, respectively and Short circuit current (i_{sc}) was also observed and the values are 690 A, 590 A, and 230 A respectively.

According to these observations, the most effective system is Acid Black 1–TiO_2-EDTA system followed by the cell containing Erythromycin B–TiO_2 -EDTA system and Rhodamine B–TiO_2-EDTA system, respectively from generation of current point of view.

Effect of variation of dyes concentration

Figures 4, 5, and 6 have previously provided a graphic illustration of the effects of varying dye concentrations. In all three systems—the Rhodamine B–TiO_2-EDTA system, the Acid Black 1-TiO_2-EDTA system, and the Erythromycin B–TiO_2-EDTA system—the dye concentration was maintained at 1.0×10^{-3} M. As the dye concentration increased, it was found that both photocurrent and photopotential increased. For successful electrical output, it was thought that the dye concentration should be maintained at 10^{-3} M.

Higher dye concentrations will stop desired light intensity from getting molecules close to electrodes, bring about in a corresponding drop in the cell's power. At lower end of range of dye concentration, there is fewer dye molecules to absorb the majority of light in the path, leading to low electrical output.

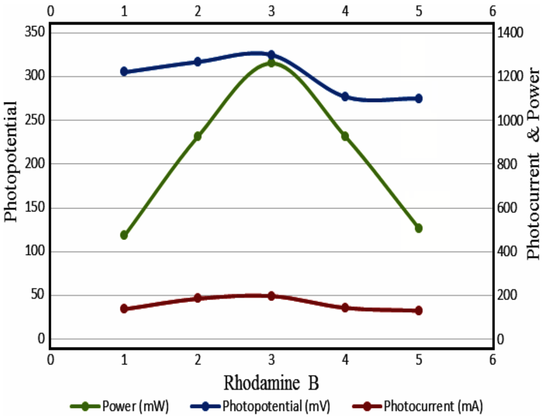

Fig. 4. Photopotential, Photocurrent and Power Variation with Dye Concentration

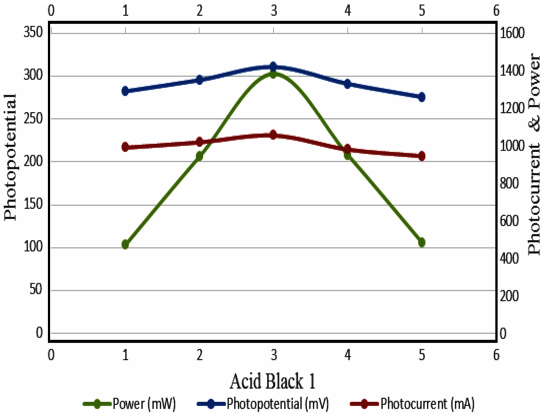

Fig. 5. Photopotential, Photocurrent and Power Variation with Dye Concentration

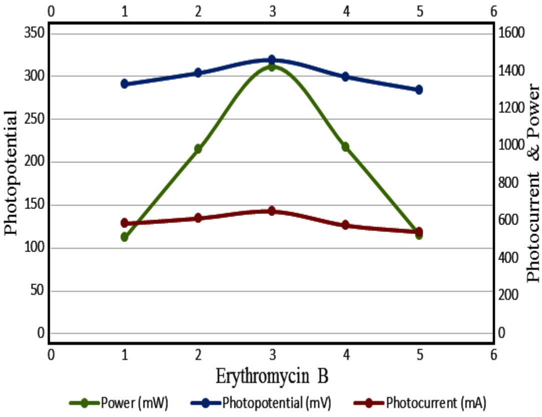

Fig. 6. Photopotential, Photocurrent and Power Variation with Dye Concentration

Effect of reductant concentration variation

EDTA was used as reductant in photo galvanic cell. Variation of reductant concentration effects all 3 systems have been given graphically and represented in Fig. 7, 8 and 9, respectively. The concentration of reductant was kept $5.0x10^{-4}$ M in all three system, i.e. Rhodamine B–TiO_2-EDTA system, Acid Black 1–TiO_2-EDTA system and Erythromycin B–TiO_2-EDTA system.

The photogalvanic cell's electric output was seen to grow as concentration of reductant increased until it reached to its maximum value, at which point both photocurrent and photopotential decreased as reductant concentration increased further.

Because there were less molecules available to donate electrons to dye molecule, the reduction in power output also led to decrease in reductant concentration. However, the high reductant concentration once more led to a reduction in electrical output as the dye molecules were unable to reach the electrode within the allotted time due to the enormous quantity of reductant molecules.

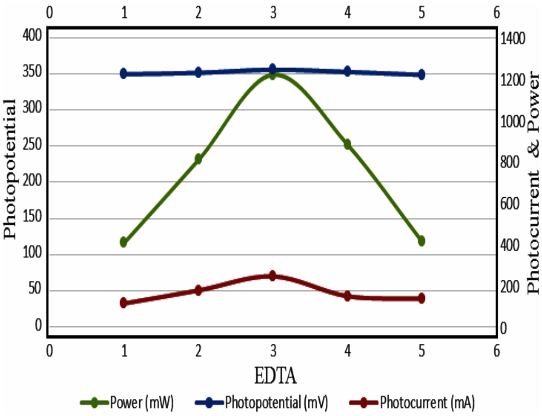

Fig. 7. Variation of Photocurrent, Photopotential and Power with EDTA Concentration for. Rhodamine B–TiO_2-EDTA system

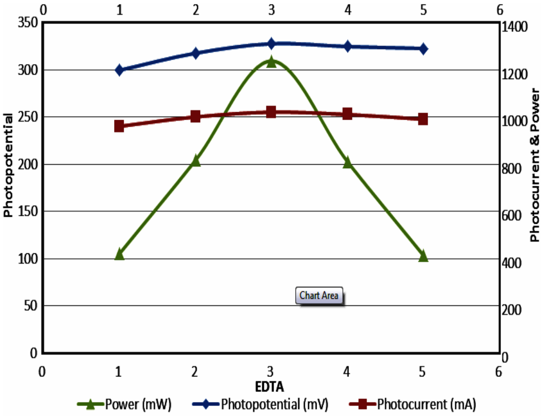

Fig. 8. Variation of Photocurrent, Photopotential and Power with EDTA Concentration for Acid Black 1–TiO_2-EDTA system

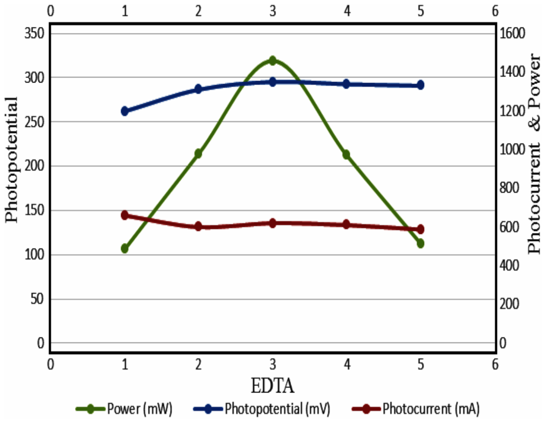

Fig. 9. Variation of Photocurrent, Photopotential and Power with EDTA Concentration for and Erythromycin B–TiO_2-EDTA system

Current-voltage characteristics of cell

While short circuit current was measured with a microammeter by keeping other circuit closed, and open circuit voltage (V_{oc}) was measured with digital pH meter by keeping other circuit open. By connecting carbon pot (log 470K) to microammeter's circuit and applying an external load, electrical parameters were ascertained between these two extreme values i.e. V_{oc} and i_{sc}. i-V curves in each of the three systems were found to depart from their typical rectangular forms. These i-V curves' power point—a location on curve where product of potential and current was at its maximum—was identified, and their fill factor (η) was computed. Table 3 provides a summary of these statistics.

Table 3: Current–voltage characteristics of cell

System	V_{oc}(mV)	i_{sc}(A)	V_{pp}(mV)	i_{pp}(A)	η
Rhodamine B–TiO_2-EDTA system	1220	230.0	580.0	140.0	0.289
Acid Black 1–TiO_2-EDTA system	1290	690.0	650.0	420.0	0.307
Erythromycin B–TiO_2-EDTA system	1330	590.0	640.0	320.0	0.261

Note: data obtained by observation during research work in lab.

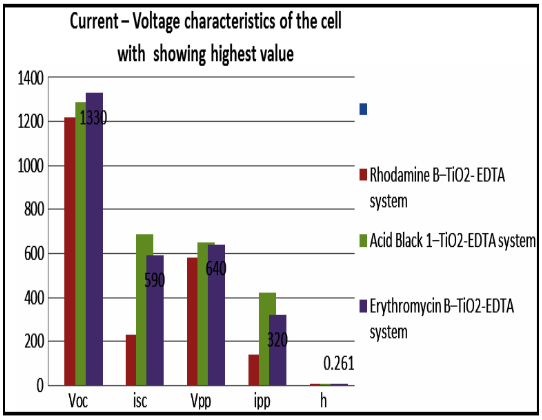

Fig. 10. Current–Voltage characteristics of cell with showing highest value

According to η calculations, the most effective system is Acid Black 1–TiO_2-EDTA system followed by the cell containing Rhodamine B–TiO_2- EDTA system and Erythromycin B–TiO_2-EDTA system.

Performance of cell

By supplying the appropriate external load to produce current and potential correspond to power point after remove illumination source, photogalvanic cell's performance was evaluated as $t_{1/2}$.

After light source was removed, the $t_{1/2}$ was calculated. Time it takes to attain half of power value is $t_{1/2}$. Table 4 presents the results that were achieved. Cell performance was examined, and Table 4 summarizes the power and performance ($t_{1/2}$) comparisons for the three systems.

Table 4: Storage capacity of cell

System	Power (μW)	$t_{1/2}$ (min)
Rhodamine B–TiO_2-EDTA system	118.23	58.20
Acid Black 1–TiO_2-EDTA system	103.05	47.24
Erythromycin B–TiO_2-EDTA system	112.16	52.22

Note: data obtained by observation during research work in lab.

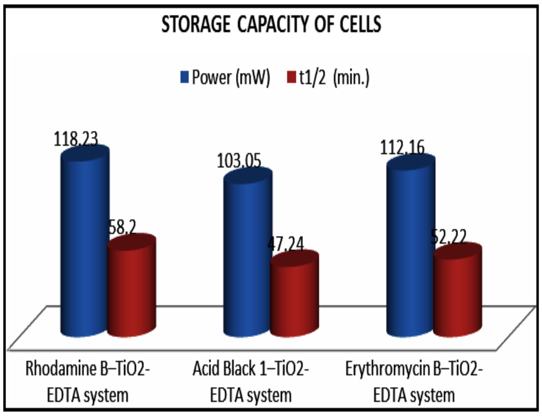

Fig. 11. Storage capacity of cells

From the perspective of power generation and performance, the Rhodamine B–TiO_2-EDTA system is the most effective system, followed by the cell containing the Erythromycin B–TiO_2-EDTA system and the Acid Black 1-TiO_2-EDTA system, respectively, according to the data that has been observed.

Cell conversion efficiency

Power of incident radiations and electrical output at power point were used to determine the conversion efficiency of each of the three systems. Additionally, all three systems were exposed to sunlight (under ideal circumstances). Table 5 reports the solar conversion statistics and conversion efficiency for these three systems.

Table 5: Cell conversion efficiency

System	Fill Factor(η)	Conversion Efficiency (%)
Rhodamine B–TiO_2-EDTA system	0.289	0.781
Acid Black 1–TiO_2-EDTA system	0.307	2.625
Erythromycin B–TiO_2-EDTA system	0.261	1.969

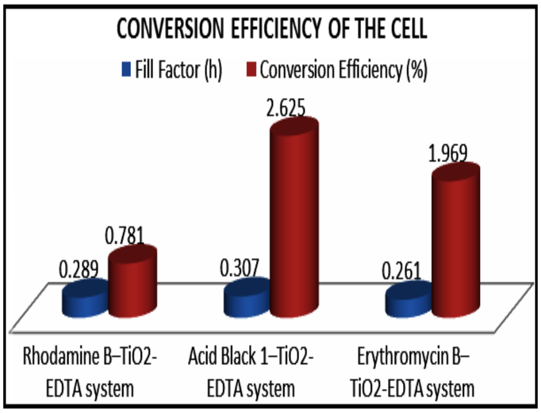

Fig. 12. Cell conversion efficiency

According to above observations, highest conversion efficiency was observed in Acid Black 1–TiO_2-EDTA system followed by the cell containing Erythromycin B –TiO_2- EDTA system and Rhodamine B–TiO_2-EDTA system, respectively.

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Conflict of interest

In my research work, there is no conflict of interest by authors.

REFERENCES

1. Panwar, N.; Kaushik, S.; Kothari. S.; Role of renewable energy sources in environmental protection: A Review, *Renew Sus Energy Rev.*, **2011**, *15*(3), 1513-1524.
2. Energy Department of Rajasthan Gov., **2023**.
3. Renewble energy Department, Rajasthan government., **2024**.
4. Lewis.N.S., Toward cost-effective solar energy use., *Science.*, **2007**, *315*(5813), 798-801.
5. Armaroli, Balzani, V., The future of energy supply: challenges and opportunities., *Angew Chem Int Edition.*, **2007**, *46*, 1-252-66.
6. Tang, W.; Chen, X.; Xia, J.; Gong, J., and Zeng, X. Preparation of an Fe-doped visible-light-response TiO_2 film electrode and its photoelectrocatalytic activity., *Mater. Sci. Eng.*, B., **2014**, *187*, 39–45. 271.
7. Gangotri, K.M.; Genwa, K.R.; Kalla, P. Regar, O.P.; Lal, C., and Meena,R., “Photogalvanic Cells as a Device for Solar Energy Conversion and Storage.” *Asian J. Chem. Reviews.*, **1994**, *5*, 69.
8. Genwa, K.R., and Chauhan,A., “Study of photogalvanic effect and energy efficiency in photogalvanic cell composed of erythrosine as a photosensitizer in Ammonium lauryl sulphate-EDTA system.” *J. Indian. Council Chem.*, **2011**, *28*(1), 60-64.