Use of Photosensitizer in a Photoelectrochemical Cell for Solar Energy Conversion and Storage

S. L. Meena[1], R. K. Bhupesh[2]*, K. Meena[3], V. Saini[4], C. Pal[5]

Department of Chemistry, Jai Narain Vyas University, Jodhpur, 342011, (India)

***Corresponding author :** ravikumarbhupesh1955@gmail.com

ABSTRACT

Aniline blue as a Photosensitizer and EDTA as a reductant were used to study the photo electrochemical cell. The photocurrent and photo potential produced were respectively 1100.0 mV and 350 µA. The maximum power of the cell was 102.85 µW, and the recorded conversion efficiency was 3.95%. The cell had a 0.26 fill factor. In terms of storage (performance), the photo electrochemical cell can operate at this power level for 140.0 minutes. Different parameters effects on the cell electrical output were seen. Here, a mechanism for photocurrent generation in photo electrochemical cells is proposed.

Keywords: Potential, current, fill factor, conversion efficiency, storage capacity of cell.

1. INTRODUCTION

Photo electrochemical cells are dye-based sensitive solar cells that can convert and store solar energy. The only solar cells that can generate and store solar energy are photo electrochemical ones photon stimulates a molecule in a non-spontaneous photo electrochemical reaction, which results in the production of highly energy species. After the species lose their energy, they return to their ground state. A.E. Becequeral made the first discovery of the photo galvanic effect in 1839.

Humanity's economic progress and quality of living are intimately linked to and entirely dependent on our use of energy. The most important component of human civilization that enters into progressive processes is energy. Any nation's only means of survival in terms of growth and security is through its access to energy. People use the energy sources, whether they live in the country's rural or metropolitan areas. Wood, coal, kerosene, and other fossil fuels were used frequently in ancient times, and the rate of consumption of these fuels was so high that it eventually led to their total depletion. Fossil fuel sources have their own limitations in addition to being expensive and having a negative environmental impact.

Life depends on photosynthesis, which also serves as the planet's most efficient sun energy converter. Numerous bacterial species, cyan bacteria, and plants all exhibit it. All life on our world depends on it for energy, and it is the source of the fossil fuels that power our technologies. Using the energy from sunshine, the process of photosynthesis transforms carbon dioxide into organic compounds, particularly sugars. All of the carbon found in organic substances within an organism's body comes from photosynthesis. Photosynthetic organisms transform tonnes of carbon each year into biomass. The majority of the energy that powers modern society has been generated through photosynthetic solar energy conversion.

In the field of photo galvanic cell, Genwa et al.[1-6], Gangatori et al.[7-10] and Meena et al.[11-23], reported effect of concentration of photosensitizes, reductant, surfactant, diffusion length, electrode area and temperature on electrical output of the cell. Although several photosensitizers and EDTA have been employed in photogalavanic cells, a thorough discussion and literature study acknowledge that the employment of Aniline blue dye system in the photogalavanic cell for solar energy conversion and storage has not been taken into account.

2. EXPERIMENTAL SETUP

The H-shaped glass tube used in the photo electrochemical cell experimental setup has a clear window in one arm for light. The photo sensitizer, EDTA, reductant, and NaOH were all present in known concentrations in the solution that was put into the H-glass tube. The H-shaped tube was filled with 30ml of the solution. One leg of the H-shaped tube with the window serving as the light chamber has a platinum electrode dipped into it. A digital multimeterwas connected to the electrode terminal. The photogalavanic cell stable potential was measured while it was dark; this potential is known as the dark potential. Then a tungsten lamp was used as a light source and a limb with a transport window was introduced. The digital multimeter measures the photocurrent and photo potential that are produced.Fig.1. Show the experimental setup for photoelectrochemical cell

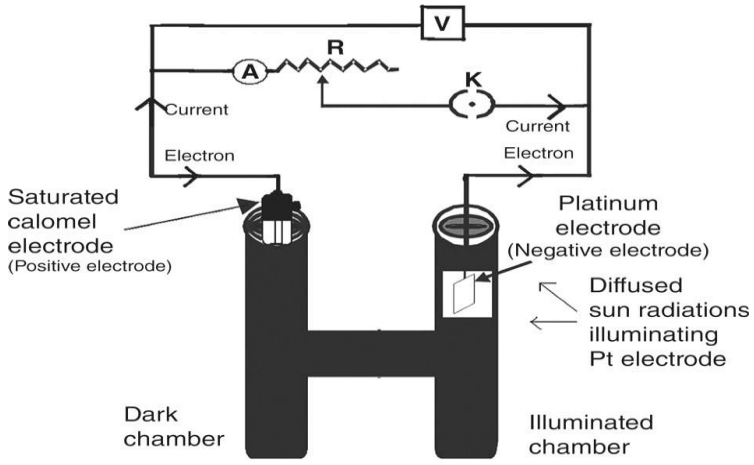


Fig.1. Experimental setup for Photoelectrochemical cell

Material used

S.No.	Chemical names	Specification
1.	Aniline blue dye	Loba chemical
2.	EDTA disodium salt	ASES Chemical
3.	Sodium hydroxide	Loba chemical

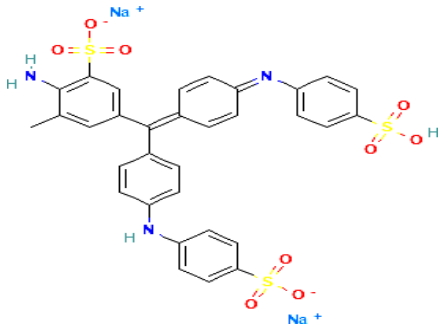
Aniline blue dye (M/100) solution, EDTA (M/100) solution, 1M NaOH solution, electrode area ($0.25cm^2$).

Structures of the compound used

(A) Aniline blue dye-

Chemical formula - $C_3H_{25}N_3O_9S_3Na_2$, Molecular weight-737.74

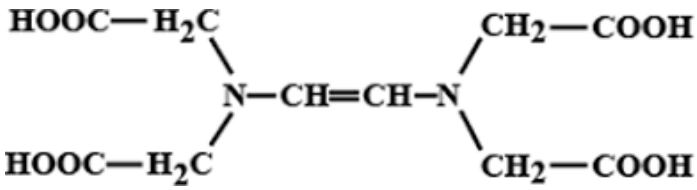
Absorption- 591-595nm



Structure of Aniline blue dye

(B) EDTA disodium salt

Molecular formula-$C_{10}H_{14}N_2Na_2O_8$ Molecular weight- 336.1

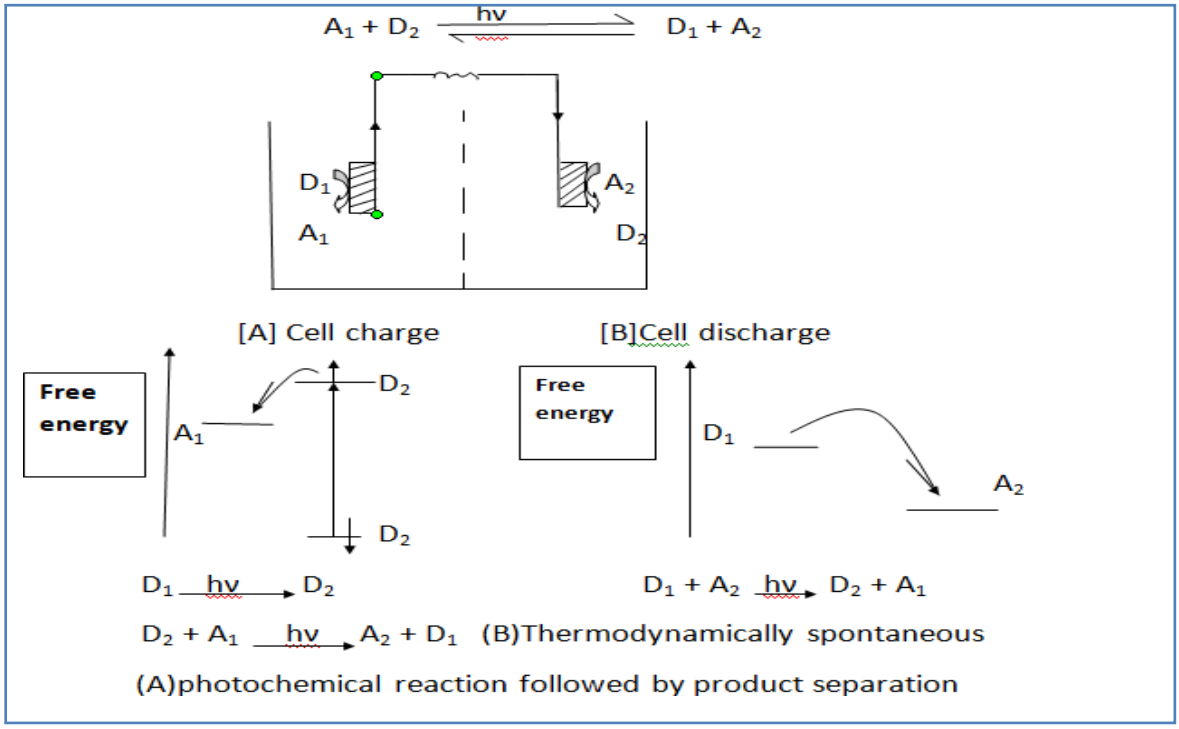


Ethylenediaminetetra acetic acid

Mechanism of current generation

A photo electrochemical system that converts light energy into electrical energy through photochemical charging and spontaneous discharging procedures. The cells are charged when they are illuminated. The transformation of light power into chemical power, in response to a voltage gradient,the proper redox process is set off.

Where A and D stand for the reduced, oxidized, and reduced versions of the acceptor-donner complexes, respectively. In the dark, the reaction spontaneously reverses, allowing electron transport across an external circuit. Chemical power is transformed into electrical power during the process, and the cell is discharge.



Producing electrical power: A_1, A_2 are oxidized, and D_1, D_2 reduced forms of dyes.

Fig.1 Scheme of mechanism for current generation in Photo electrochemical cell: (a) photo chemically charged; (b) spontaneously discharged

3. RESULT AND DISCUSSION

Study of photo potential with time

When the relationship between potential and time is examined with various dye solutions, the maximum potential of 6.2ml of dye solution is higher; this voltage is known as the open circuit voltage (V_{OC}=1100mV), while the potential of the remaining dye solutions is lower and the voltage rises over time. In order to analyze potential variation, the platinum electrode of the photo electrochemical cell was first exposed to light before being placed in the dark until it reached a stable potential. It was found that the potential value fluctuates with illumination and eventually achieves a constant value. After some time, when the light ended, the potential change's direction was reversed, and a stable potential was once more attained. Graphically represented in Fig.3.1

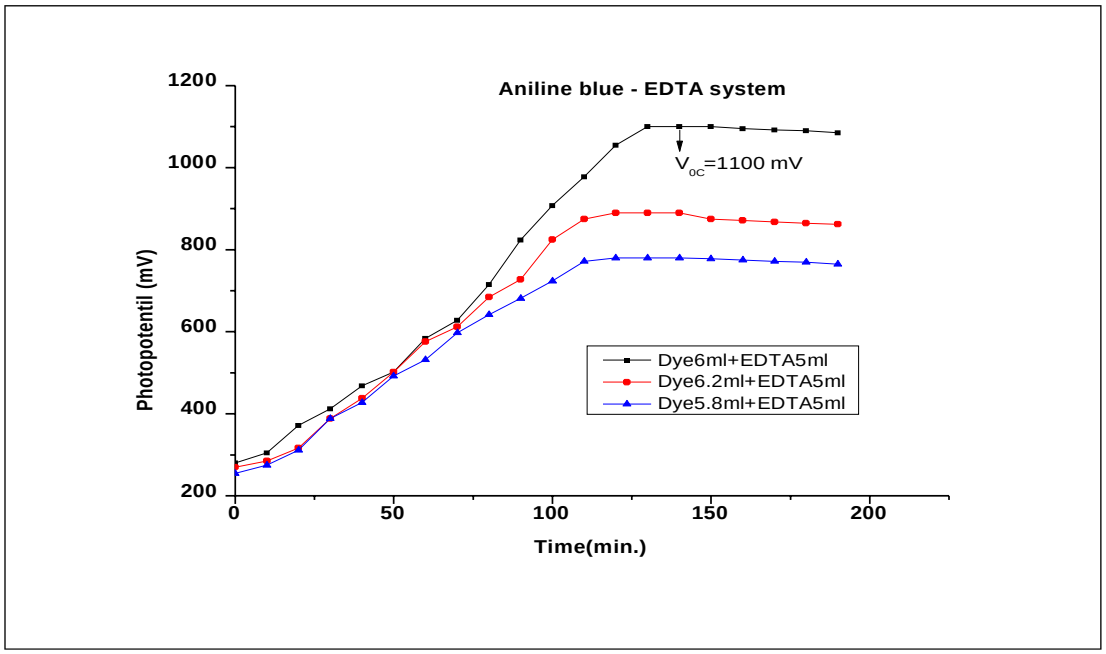


Fig.3.1 Effect of potential and time on different solution of Alcian blue dye

Study of (i-v) Characteristics during charging of the cell

Characteristics of electrical parameters; voltage in an open circuit (V_{OC}) and current in a short circuit (i_{SC}) were observed when the cell is placed under direct light sources. A digital multi -meter is used for both the measurement of photo potential and photocurrent and from this digital multi-meter itself, we measure short circuit current (i_{SC}= 350µA) and open circuit voltage (V_{OC}= 1100 mV). Through the use of carbon linked in the circuit of a digital multi-meter through which an external load was supplied, between these two extreme values, the photo potential and photocurrent values were noted. According to Fig.3.2 the current-voltage (i-v) characteristics of the photo galvanic cell with the maximum power at Power Point (P_{PP}= 102.85µW) Aniline blue -EDTA system.

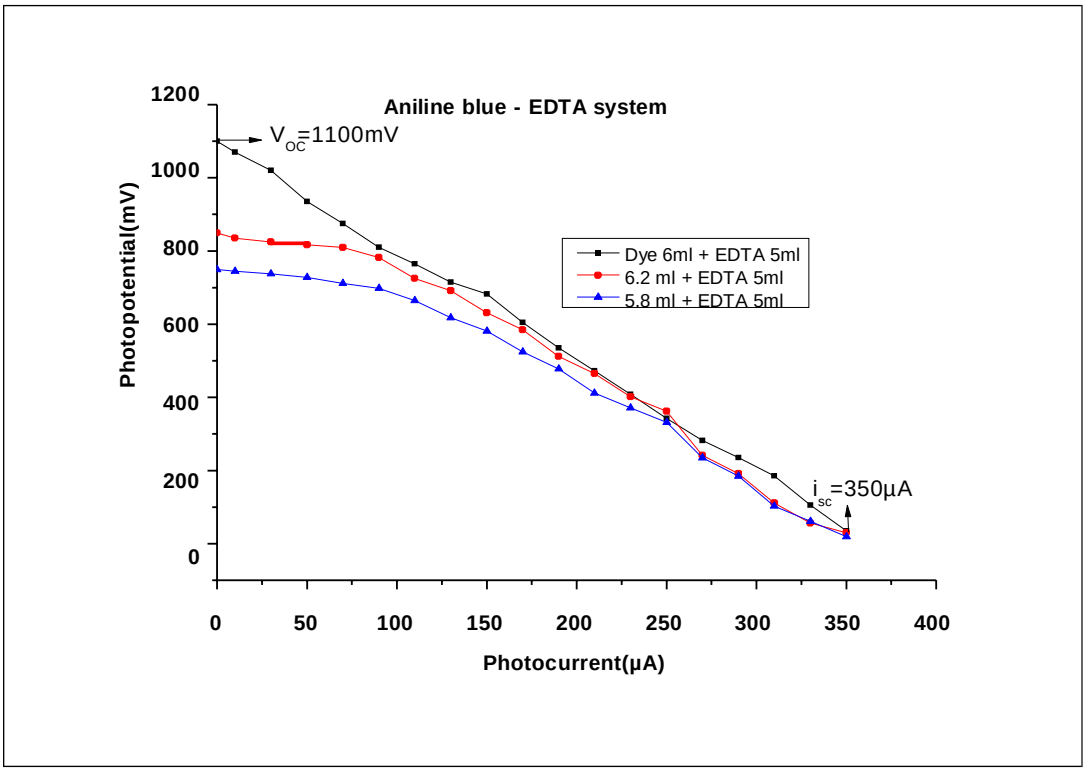


Fig.3.2 Photocurrent and photo potential (i-v) characteristics curve for different solution of Aniline blue dye and EDTA system

Fill factor

From the (i-v) curve, we get the highest values of open circuit voltage (V_{OC}) and short circuit current (i_{SC}), and from this (i-v) curve, the value of the fill factor was determined to be 0.26, which comes out of this formula which comes out of this formula, graphically represented in Fig.3.2.

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

In this formula, V_{OC} is open circuit voltage, and i_{SC} is short circuit current, i_{PP} and V_{PP} are current and potential at the power point, respectively.

Study of potential, current and power at power point of the cell

The shunt is adjusted at 30µA of photocurrent, with a differential between photocurrent and photo potential that is continuously rising. The cell's maximum output is 102.85µW, with a power point at potential (V_{PP}) of 605 mV and a power point at current (i_{PP}) of 170µA. Fig.3.3 shown graphically, represents the study of photo potential and power with the photocurrent of the cell.

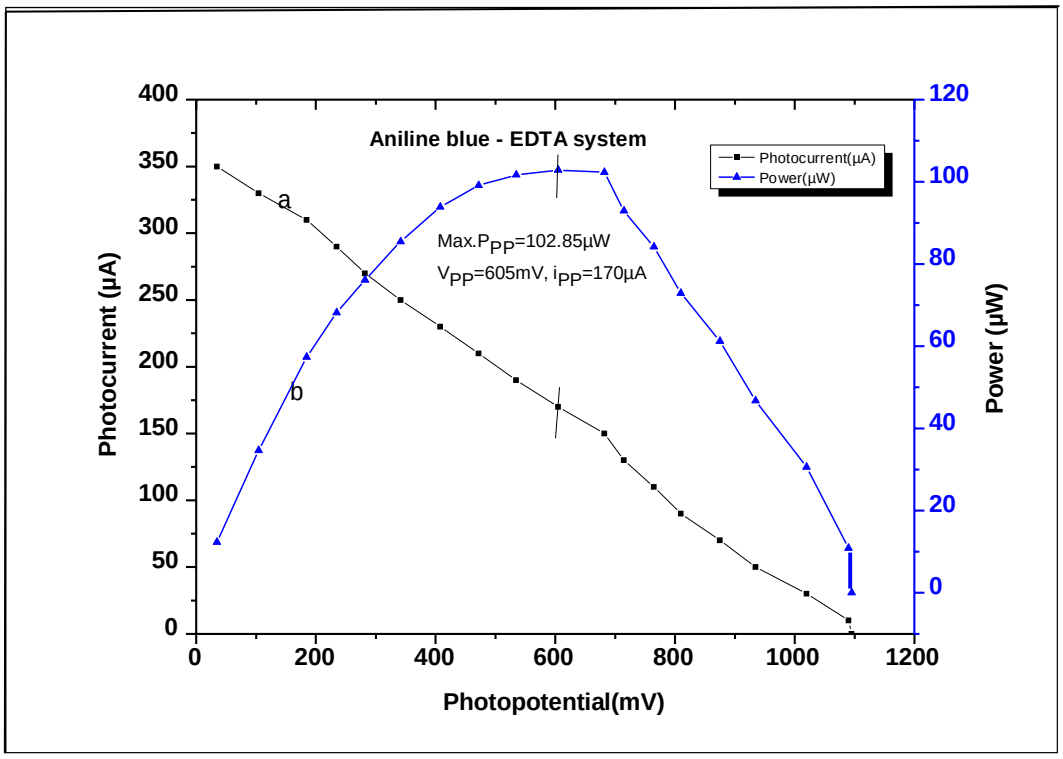


Fig.3.3Variation of potential and current with power

Effect of variation in EDTA concentration

During the experiment, the photo potential was found to increase as the concentration of the reductant [EDTA], rose until it reached a maximum value. The cell electrical output was seen to diminish as the EDTA concentration was increased further. With a rise in EDTA concentration, it was discovered that the system's photo potential and photo current increased. For a specific value of EDTA concentration [0.61×10^{-4}M], a maximum value was reached, which is graphically depicted in Fig.3.4.

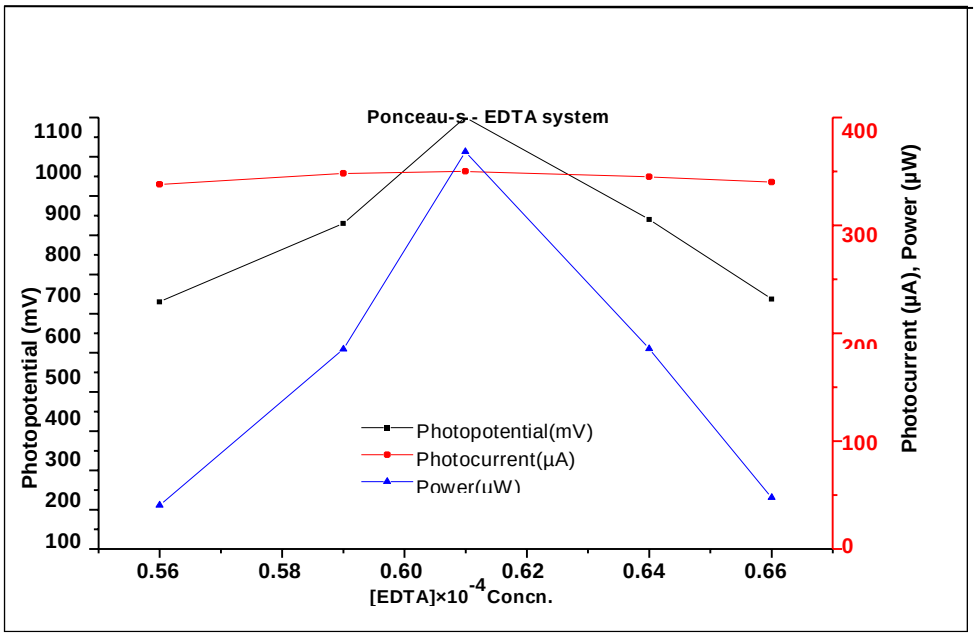


Fig.3.4Variation of concentration of [EDTA] with power of potential and current

Effect of variation in dye concentration

All factors other than dye concentration were evaluated for their impact on cell performance. It was shown that when dye concentration increased, the cell electrical output reached a maximum for a specific amount of dye concentration, after which it began to decline. With increasing dye concentration, it was discovered that the system's potential and current increased as well. For a specific dye concentration of [1.46×10^{-3}M], a maximum value was obtained, which is graphically depicted in Fig.3.5.

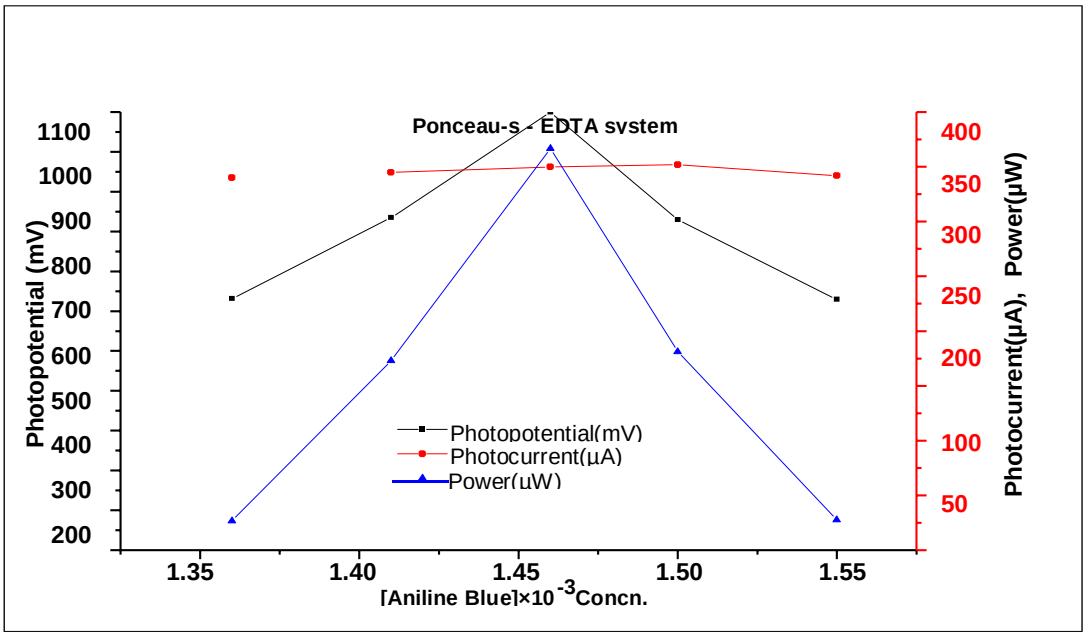


Fig.3.5 variation of Aniline blue dye concentration for photo potential and power with photocurrent

Storage capacity (performance) of the cell

After stopping the illumination as soon as the potential achieves a consistent value, an external load was applied to the photo galvanic cell to measure its performance. Maximum power is used to set this reading, and the shunt is adjusted using photocurrent and photo potential. As soon as the light is turned out, photo potential, photocurrent, and power all gradually diminish. The time it takes for maximum power to fall to half in the dark, or $t_{1/2}$, is used to measure storage capacity (performance). The half-life of the cell has been found to be 140 minutes. The formula- was used to calculate the cell's conversion efficiency, which was found to be 3.95%. Fig.3.6.show Graphically representation of Storage capacity (performance) for Aniline blue dye and EDTA system

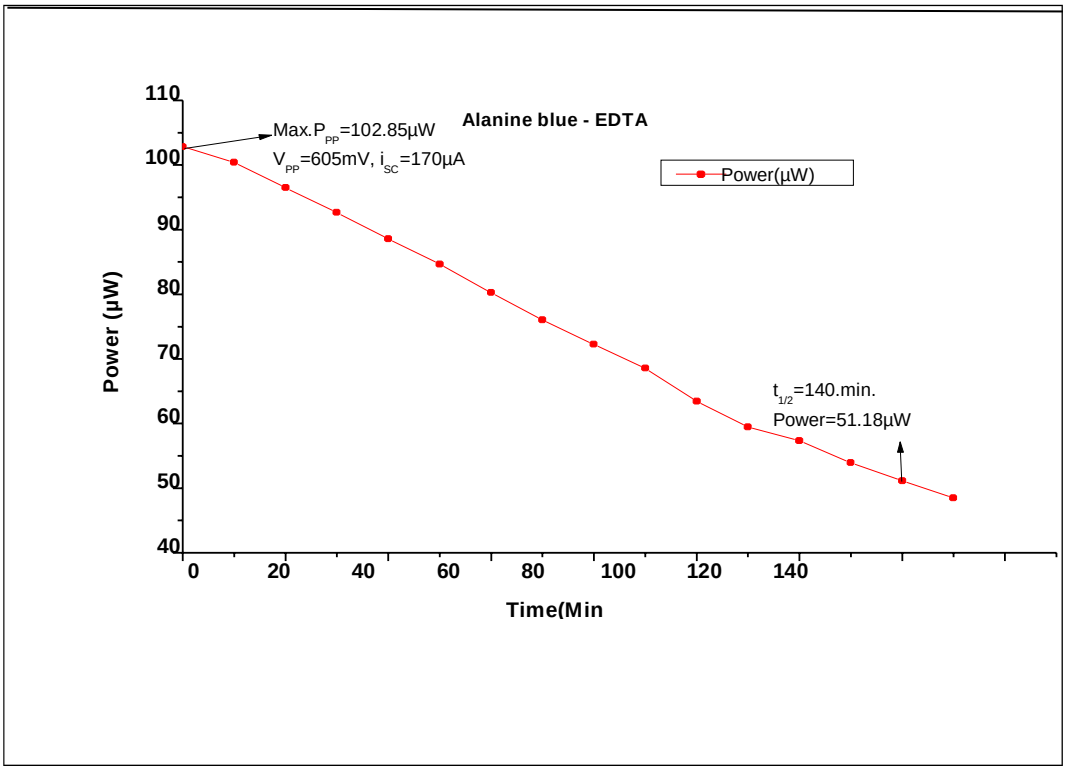


Fig.3.6 Storage capacity (performance) curve for Aniline blue dye and EDTA system

Conversion efficiency of the cell

The function of energy incident, which is transformed into electrical energy and is defined as determining the conversion efficiency of a solar cell, graphically represented in Fig.3.6

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

Where V_{PP} and i_{pp} are the power point at potential and current respectively, and A is the area of platinum electrode (0.25cm^2). Solar efficiency of this Aniline blue – EDTA system is 3.95%.

4.THE PERFORMANCE OF THE CELL

Table 1: All parameters are observed result in performance of the cell in table-

Parameters	Observed result
voltage on an open circuit (V_{oc})	1100 mV
Current on an short circuit (i_{SC})	350 µA
Storage capacity ($t_{1/2}$)	140 min.
Conversion efficiency	3.95%
Fill factor	0.26

Power point at potential (V_{PP})	605mV
Power point at current (i_{pp})	170 µA
Maximum power (P_{PP})	102.85µW
Photo potential (Δv)	820mV

5. CONCLUSIONS

The findings suggest that Aniline blue can be successfully employed as a photo sensitizer in a photoelectrochemical cell. The cell conversion efficiency is 3.95%, and it has a 140 minute operating time at full power in the dark. The advantage of having built-in storage capacity is found in photoelectrochemical cell.

6. ACKNOWLEDGEMENTS

Authors are grateful to the Head of the Department of chemistry, Jai Narian Vyas University, Jodhpur for providing research facility.

7. REFERENCES

1. A. Kumar, K.R.Genwa, A. Sonel, Applied Energy, **86**(9), 1431-1436 (2009),https://doi.org/10.1016/j.apenergy.2008.11.026.

2. K.R.Genwa, M.Genwa, Solar Energy Materials and Solar Cells, **9**, 522-529, (2008),https://doi.org/10.1016/j.solmat.2007.10.010.

3. C. P. Sagar, K.R.Genwa, Energy Conversion and Management, **66**, 121-126, (2013),https://doi.org/10.1016/j.enconman.2012.10.007.

4. K.R.Genwa, A.P.Singh, Asian Journal of Chemistry, **29**, 1215-1219, (2017),https://doi:org/10.14233/ajchem.2017.20394.

5.K. R. Genwa, A. Kumar, International Journal of Renewable Energy Technology,**3**, 174-188, (2012), http://org/10.1504/ IJRET. 2012. 045625.

6. K.M.Gangotri, P.Koli, U.Sharma,Renewable Energy, **37**, 1250-1258, (2012),https://doi.org/10.1016/j.renene.2011.06.02.

7. K.M.Gangotri, K.K.Bhati, International Journal of Electrical, *Power and Energy Systems*, **33**, 155-158, (2011), https://doi.org/10.1016/j.ijepes.2010.08.001.

8. K.M.Gangotri, U.Sharma, P.Koli, Fuel, **90**, 3336-3342, (2011),https://doi.org/10.1016/j.fuel.2011.06.036.

9. K.M.Gangotri, V. Indora,Solar Energy, 84, 271-276, (2010),https://doi.org/10.1016/j.solener.2009.11.007.

10. K.M.Gangotri, P.P.Solanki, Journal of Energy Sources, Part A, **35,** 1467-1475, (2013), http://org/10.1080/15567036.2010.523758.

11.,R. C. Meena, K.M.Gangotri, Journal of Photochemistry and Photobiology A: Chemistry, **141**, 175-177, (2001), http://org/10.1016/51010-6030 (99).

12.P.Gangotri, K.M.Gangotri, Journal of Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, **35,** 1007-1016, (2013), http://org/10.1080/15567030903077980.

13.S.L.Meena, N.Kumar, P.K.Meena, Journal of applicable Chemistry,**7** (6) 1682-1690, (2018).

14.P.P.Solanki, K.M.Gangotri, Solar Energy, **85,** 3028-3035, (2011),http:// org/ 10.1016/ j.solener.2011.08.043.

15.M.Chandra and R.C.Meena, International Journal Chemical Science, **8**, 1447-1456, (2010), http: //10.5897/IJPS11.302.

16.M.Chandra, A.Singh, R.C.Meena, International journal of Physical Science, **7,** 5642-5647(2013),http:// org /10.5897/IJPS11.302.

17.P.Koli, International Journal of Ambient Energy,**40,** 868-874(2019), http://org/10.1080/01430750.2018.1437565.

18.S.P.Singh, K.R.Genwa, Asian Journal of Chemistry, **29,** 1215-1219(2017), http://org/ 10.14233/ajchem.2017.20394.

19.K.M.Gangotri, C.Lal, JurnalPower and Energy, **24**, 365-371,(2005), https://doi.org/10.1002/(SICI)1099.

20.C.Lal, S.Yadav, Energy Sources, Part A, **32,** 1028-1039, (2010), https://org/10.1080/15567030802606228

21. K.Meena, S.R.Saini and R.C.Meena, Chemical Science international journal, **18**, 2153-2158, (2017), http: //10.5281/zenodo.203821.

22. S.L.Meena, S.R.Saini, and R.C.Meena, Advance in Chemical Engineering and Science,**7**, 125-136,(2017),http:// 10.4236/aces.2017.72010.

23. S.L.Meena, P.K.Meena, Journal of Advanced Scientific Research, **12**, 110-116,(2021),http://org/10.55218/JASR.s2202112215.