INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

Study of Electrical Output in Photogalvanic Cell for Solar Energy Conversion and Storage: Lauryl Glucoside-Tartrazine-D-Fructose System

Jayshree Rathore[1]*, Arya Rakesh Kumar[1], Pratibha Sharma[1], Mohan Lal[1]

1 Photochemical laboratory, Department of Chemistry, Faculty of Science, Jai Narain Vyas University, Jodhpur (Rajasthan) 342001, India

OPEN ACCESS

Received: 01-03-2022

Accepted: 09-05-2022

Published: 29-06-2022

Citation: Rathore J, Rakesh Kumar A, Sharma P, Lal M (2022) Study of Electrical Output in Photogalvanic Cell for Solar Energy Conversion and Storage: Lauryl Glucoside-Tartrazine-D-Fructose System. Indian Journal of Science and Technology 15(23): 1159-1165. https://doi.org/10.17485/IJST/v15i23.493

* **Corresponding author**.

photochemistrylabjnvu@gmail.com

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Abstract

Objective: The present study is focusing on the role of surfactant in photogalvanic cells and how photons from sunlight can be used as a driving force for energy solar energy conversion and storage. **Methods:** An H shaped cell was designed for study of electrical output in solar transformations**.** Electrical circuit was proposed by using of dye, reductant, surfactant, NaOH, double distilled water (DDW), multi-meter, calomel electrode, 250 k roistered, saturated calomel electrode, platinum electrode, carbon pot, resistance key, digital pH meter, microammeter, and 200 W tungsten bulb. A detailed reaction mechanism for the proposed photogalvanic cell (PG Cell) for generating photocurrent and photocurrent has been studied. PG Cells were studied for the solar energy transformation system. **Findings:** PG Cells were studied by using different parameters via photocurrent, photopotential, conversion efficiency, fill factor and cell performance. The above values are as follows: 388.0 □A, 1141.0 mV, 0.7995%, 0.5389 and 129.0 minutes. Electrical output of the cell has also been observed for tartrazine, D-Fructose and lauryl glucoside systems. Potential at power point, Potential at open circuit, power point of cell (pp) and current at short circuit were also studied. The obtained values are as follows: 1133 mV, 1523 mV, 435.321 and 544μA. **Novelty:** The photogalvanic is an emerging field of research for conversion and storage of solar energy. This study employs lauryl glucoside-tartrazine-D-fructose system for better electrical output which is also an eco-friendly natural dye system. The observed results are better in cell performance ($t_{1/2}$) and reduction in cost (INR 9531.38 / USD 125) of the photogalvanic cell for its commercial viability.

Keywords: Photogalvanic cells; solar energy conversion; storage; lauryl glucoside; tartrazine

1 Introduction

The fossil fuels like wood, coal, kerosene, etc. are reaching towards their complete depletion. The non-renewable sources of energy have their own limitations. The scientific community is compelled so is search out the renewable source of energy to feed the whole world with non- polluting nature and commercially viability. Thus, the solar energy is the best option to fulfill the energy demand. It was necessary and proposed to carry out experimental work under the solar parameters. Detailed literature surveys about different photogalvanic cell have been used in solar transformation for best results. Solar energy is already becoming cost competitive with solar power and better storage capacity, the day is not far when renewable energy will compete with coal-based power. However, over the next few decades, world will have to significantly reduce its coal and oil used to accelerate climate action. Currently, about more than half of world energy demand is met by two fossil fuels -coal and oil. A huge proportion of world electricity generation comes from thermal power, most of which is coal based. For Industrial development and agricultural activities, Energy is a key role for humanity in modern society and demanded day by day as riding environment. Although photogalvanic cell and photovoltaic cells are used for solar energy conversion and storage but photovoltaic cells have the least storage capacity whereas photogalvanic cells having very good storage capacity and due to this reason present research project has been taken under study.

First of all, (1925) the action of light on the ferrous iodine iodide equilibrium was studied [(1)]. The photogalvanic effect I (1940) was studied in the photochemical properties of the thionine-iron system [(2)]. The efficiency of iron thionine system (1959) was observed for photogalvanic cell [(3)]. With respect to total illumination, thin layer iron–thionine photogalvanics (1978) was observed in electrodic phenomena at the anode [(4)]. Use of thionine ethylene diamine tetra acetate (EDTA) system in photogalvanic cell (1989) was observed for solar energy conversion and storage [(5)]. The use of miscelles (1999) in photogalvanic cells for solar energy conversion and storage: cetyl trimethyl ammonium bromide-glucose-toluidine blue system was studied [(6)]. The studies of the micellar effect (2010) on photogalvanics: solar energy conversion and storage–EDTA-Safranine O-TWEEN-80 System was mentioned [(7)]. A comparative study (2011) on the performance of photogalvanic cell with different photosensitizers for solar energy conversion and storage: D-Xylose-NaLS system was studied [(8)]. Reports on mixed surfactant (2013) with photogalvanic cells for solar energy conversion and storage: D- xylose methylene blue systems were reported [(9–11)]. Photogalvanic effect was studied (2015) for PG cell containing mixed surfactant (NaLS+Tween-80), methylene blue as a photosensitizer and xylose as reductant for solar energy conversion and storage [(12)]. Study of surfactant in photogalvanic cell (2017) for solar energy conversion and storage was reported for electrical output [(13)]. Better study (2018) was done in photogalvanic effect in photogalvanic cell containing single surfactant as DSS, Tatrazine as a photosensitizer and EDTA as reductant for solar energy conversion and storage [(14)].

Recently, Pooran koli (2021) has studied on sudan-I dye and fructose chemicals based photogalvanic cells for electrochemical solar energy conversion and storage at low and artificial sun intensity [(15)]. A detailed literature survey (2020-2021) about different photogalvanic cell has been used in solar transformation for better results [(16–18)]. Different group of scientist (2021) reported formic acid reductant-sodium lauryl sulphate surfactant enhanced photogalvanic effect of Indigo Carmine dye sensitizer for simultaneous solar energy conversion and storage [(19)]. Koli et al. reported modified and simplified (2022) photogalvanic cells: solar energy harvesting using bromo cresol green dye with different electrodes and cell dimensions was also studied for better cell performance [(20)]. They have used different photosensitisers, surfactant and reductants in these PG cells but combination of lauryl glucoside, Tartrazine and D-fructose system has not been investigated and not attention has given for better electrical output. It is thought that such a system (Lauryl glucoside- Tartrazine-D-fructose system) might produce a PG cell with enhanced electrical output and performance. In addition, this system will special attention to better performance ($t_{1/2}$) and reduction in the cost of the PG cell for its commercial viability, therefore, the present study was undertaken.

2 Methodology

2.1 Material required

Dye-tatrazine, reductant - D-fructose, Surfactant-lauryl glucoside, NaOH (1N), Double distilled water (DDW), Multi-meter, Calomel electrode, 250 k Roistered, H shaped glass tube, Saturated calomel electrode, Platinum electrode, Carbon pot, Resistance key, Digital pH meter, Microammeter, and 200 W tungsten bulb.

2.2 Experiment method

The present research study on PG Cell is studied by H shaped glass tube which was fabricated. The total volume of experimental set was 25 ml including solution dye surfactant and reductants. the electrical circuit was completed by using calomel electrode,

250 k roistered, H shaped glass tube, A saturated calomel electrode platinum electrode carbon pot, (resistance) key, digital pH meter and microammeter, and 200 W tungsten bulb. During experiments, water filter was used for IR light. One limb of H shaped glass tube was connected with calomel electrode and another limb was connected with platinum foil electrode. The pH of the solution was adjusted and measured by a pH meter. H–Type PG cell was fabricated with different surfactants, dye and reductant solutions were used for investigation. The experimental set up for methodology is shown in Figure 1.

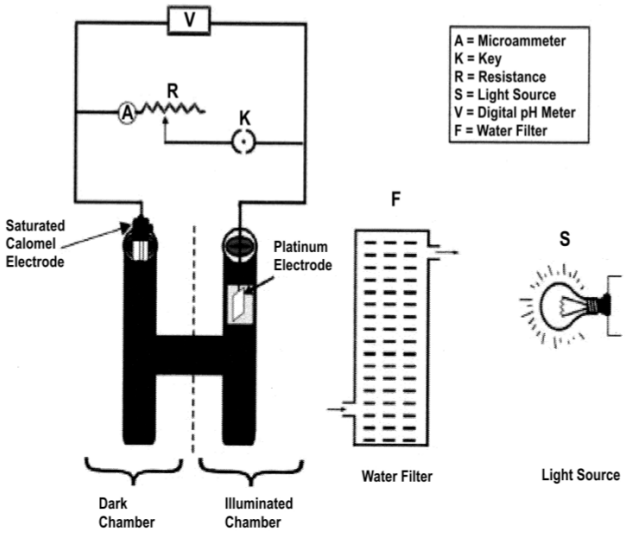

Fig 1. Experimental set up of photogalvanic cell

3 Result and Discussion

3.1 Effect of variation of lauryl glucoside concentration on the PG-CELL

During experiment stage solar, electric output was increased on increasing the concentration of lauryl glucoside and reached to optimum position (at p^H 12.09) and on subsequent decrease on increasing of lauryl glucoside concentration. On a lower concentration range of lauryl glucoside concentration, less ability to solubilize the molecules for electron transfer process in hydrophilic hydrophobic interaction. In contrast, at a higher concentration range of lauryl glucoside concentration, there are a larger number of surfactant molecules being available for electron transfer process in hydrophilic hydrophobic interaction which may reduce electron transfer. At the intermediate range of lauryl glucoside concentration there are significant effects on electrical output for the photogalvanic system. This is because surfactant can help to separate photoproducts through hydrophilic–hydrophobic interaction of the micelles interface. The observed results are shown in Tables 1, 2, 3, 4 and 5.

3.2 Effect of variation of tatrazine (dye) concentration on the system

During experiment stage, solar electric output was increased on increasing the concentration of tatrazine and reached to optimum position and on subsequent decrease on increasing of tatrazine concentration. On a lower concentration range of dye, the low number of dye limits the absorption of the light source, so the electrical output is low. In contrast, at a higher concentration range of dye molecules, there are so many molecules present that the desired light source does not reach the molecule near the electrode. At intermediate range of dye, there are optimums molecules present that the optimum light source does reach the molecule near the electrode and maximum photopotential, maximum photocurrent, and maximum power were obtained. The observed results are shown in Tables 1, 2, 3, 4 and 5.

3.3 Effect of variation of D-fructose (reductant) concentration on the system

During experiment stage, solar electric output was increased on increasing the concentration of D-fructose and reached to optimum position and on subsequent decrease on increasing of tatrazine concentration. On a lower concentration range

of Reductant, a smaller number of reductant molecules being available for electron donation to dye to form the cationic form. In contrast, at a higher concentration range of Reductant, there are a larger number of reductant molecules being available for electron donation to dye to form the cationic form which hinders the methylene blue. At intermediate range of Reductant concentration, there are optimum numbers of reductant molecule present that form favourable condition for semi or leuco form of dye molecules to obtain the results. The observed results are shown in Tables 1, 2, 3, 4 and 5.

Table 1. Effects of variation of tartrazine concentration on electrical output of photogalvanic cell

Concentration of dye taken for experiment: Tartrazine X 10^{-4} M)	Observed results: Photopotential (mV)	Observed results: Photocurrent (μA)
1.20	837	377
1.40	883	407
1.60	935	442
1.80	888	410
2.00	833	380

Table 2. Effects of variation of fructose concentration on electrical output of photogalvanic cell

(D-fructose$\times 10^{-4}$)	Photopotential (mV)	Photocurrent (μA)
2.15	816	381
2.20	886	410
2.25	934	439
2.30	889	406
2.35	819	379

Table 3. Effects of variation of lauryl glycoside concentration on electrical output of photogalvanic cell

(Lauryl glucoside x 10^{-4})	Photopotential (mV)	Photocurrent (mV)
1.72	817	382
1.77	882	413
1.98	935	440
1.76	873	410
1.68	821	379

Table 4. Electrical output of photogalvanic cell:

S. No.	Time (Min.)	Power (mW)
1	35.0	137.76
2	40.0	133.11
3	45.0	129.33
4	50.0	124.47
5	55.0	119.98

Table 5. Comparison of present study with Previous reports

S. No.	parameters	Tartrazine, D-fructose, Lauryl glucoside	NaLS, Tween-80, Methylene blue, Xylose	NaLS, CTAB, Methylene blue, Xylose	DSS, Tartrazine EDTA
		Present Study	Past studies		
1	Conversion efficiency	0.7995%	0.5313%	0.4326%	0.6163%
2	Storage capacity	129.0 minutes	100.0 minutes	90.0 minutes	100.0 minutes

Continued on next page

Table 5 continued

3	Fill factor	0.5389	0.3024	0.2770	0.2800
4	Photopotential	1133.0 mV	645.0 mV	655.0 mV	493.0 mV
5	Photocurrent	388.0 mA	210.0 mA	190.0 mA	130.0 mA

3.4 Current–voltage (i-V) characteristics of the photogalvanic cell

By using, following formula fill factor of PG-cell was calculated (Figure 2).

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

Where: Potential at power point (V_{pp}) =1133 mV, Current at power point (i_{pp}) =388 μA, Potential at open circuit (V_{oc}) =1523 mV, Current at short circuit (i_{sc}) =544μA, Value of fill factor (h)= 0.5389, The power point of cell (pp) = 435.321

3.5 Cell performance and conversion efficiency

By using, following formula fill factor of PG-cell was calculated (Figure 3)

$$Conversion\ efficiency = \frac{V_{pp} \times i_{pp}}{A\ 10.4 mW cm^{-2}} \times 100\% \ldots\ldots (2)$$

Where: Photopotential at power point ($V_{pp,}$), Photocurrent at power point (i_{pp}), Electrode area for pg cell (A).

3.6 Mechanism of photovoltage and photocurrent generation in a cell

Illuminated chamber (at platinum electrode): During experiment, dye molecule gets excited by absorption of sun light and converted in to semi or leuco form. Reductant molecule gets in its oxidized form and subsequently semi form of dye molecule loss the electron and retuned into its original state.

Chemical reaction at illuminate chamber

$TZ \rightarrow TZ^{*}$ ….(i)

$TZ^{*} + F \rightarrow TZ + F$ …. (ii)

Chemical reaction at platinum electrode:

$TZ \rightarrow TZ + e$ …. (iii)

Dark Chamber: At counter electrode: TZ molecule accept an electron from electrode and converted into TZ^{-} and at termination stage, TZ^{-} converted into TZ molecule and oxidized form of F combine with TZ molecule to give original dye and reductant molecule and the cycle will go on.

$TZ + e \rightarrow TZ^{-}$... (iv)

$TZ^{-} + F^{+} \rightarrow TZ + F$ ...(v)

Where: TZ = Tartrazine dye molecule, TZ^{*} = Excited dye molecule, TZ^{-} = Semi form of dye molecule, F =fructose reductant molecule, F^{+} = Oxidized form of the reductant,

3.7 Comparison with past studies

It also observed that the photogalvanic cell with present system has conversion efficiency and storage capacity, 0.7995% and 129.0 minutes respectively. These values are relatively higher in comparison to previously reported cells containing single surfactant as DSS, Tartrazine as a photosensitizer and EDTA as reductant for solar energy conversion and storage(0.6163% and 100.0 minutes), Mixed Surfactant (NaLS+CTAB), Methylene blue as a Photosensitizer and Xylose as Reductant (0.4326% and 90.0 minutes), Mixed Surfactant (NaLS+Tween -80), Methylene blue as a Photosensitizer and Xylose as Reductant (0.5313% and 100.0 minutes), Micellar Effect on Photogalvanics: Solar Energy Conversion and Storage–EDTA-Safranine O-TWEEN-80 System(0.1469% and 20.0 minutes)developed by Rathore Jayshree and Lal Mohan (2018), Gangotri KM and Mohan lal (2013), Lal Mohan and Gangotri KM (2012) and Gangotri and Gangotri (2010), respectively. These observed values are (0.7995% and 129.0 minutes) relatively lower in conversion efficiency but higher in storage capacity in comparison to recently reported photogalvanic cells containing formic Acid reductant-Sodium Lauryl Sulphate Surfactant enhanced photogalvanic effect of Indigo Carmine dye sensitizer for simultaneous solar energy conversion and storage (27.79% and 115.0 minutes), Modified and simplified photogalvanic cells: Solar energy harvesting using bromo cresol green dye with different electrodes and cell dimensions (9.02% and 70.0 minutes), developed by Koli et al. (2021), and Koli et al. (2022), respectively. Therefore, the photogalvanic cell containing tartrazine lauryl glucoside D-fructose system is more efficient than existing cells. The efforts are still needed to enhance the conversion efficiency as well as storage capacity along with reduction in the cost of the photogalvanic cell by selecting suitable substances.

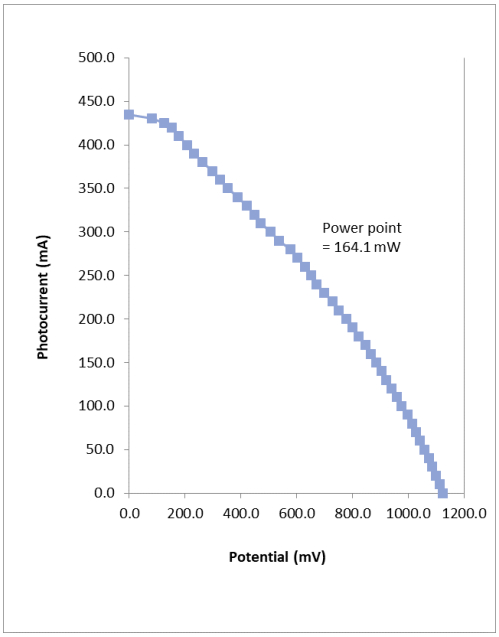

Fig 2. Current-voltage (i-V) curve of the cell

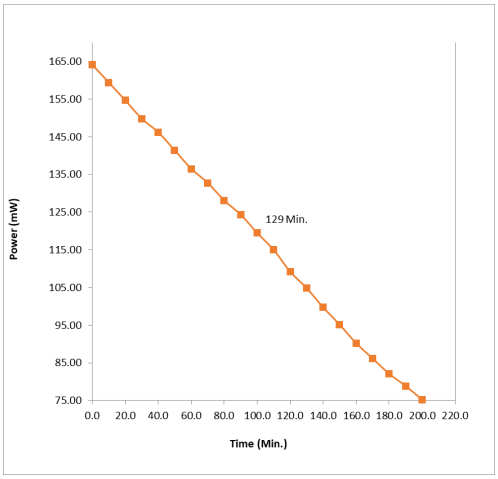

Fig 3. Cell performance

4 Conclusion

4.1 Novelty of work

On the basis of observed results, we are concluded that the single surfactant affected photogalvanic cell more than mixed surfactants. The single surfactant has not only enhanced the conversion efficiency but storage capacity of photo galvanic cells. The exhaustive efforts still have the scope to enhance electrical output as well as storage capacity of photogalvanic cells along with reduction in their cost to get commercial viability. The conversion efficiency, $t_{1/2}$ and fill factor are recorded as 0.7995%, 129.0 min. and 0.5389 respectively in PG system. Potential at power point, Potential at open circuit, power point of cell (pp) and current at short circuit were also studied. The obtained values are as follows: 1133 mV, 1523 mV, 435.321 and 544μA.

4.2 Limitation of present study and Future scope of present study

Solar energy is already becoming cost competitive with solar power and better storage capacity. The day is not far when renewable energy will compete with coal-based power. A huge proportion of world electricity generation comes from thermal power, most of which is coal based. The theoretical conversion efficiency of PG cell is about 25-30%, but observed conversion efficiencies is quite low (0.7995%) due to dye based photochemical environment. This limitation encountered in the area of development of PG cells has discussed time to time. However, over the next few decades, world will have to significantly reduce its coal and oil use to accelerate climate action. Currently, about more than half of world energy demand is met by two fossil fuels -coal and oil.

References

1) Keightley RE, Gardner WE. The action of light on the ferrous iodine iodide equilibrium. *Journal of the Chemical Society*. 1925;127:258–269. Available from: https://doi.org/10.1039/CT9252700258.
2) Rabinowitch E. The Photogalvanic Effect I. The Photochemical Properties of the Thionine-Iron System. *The Journal of Chemical Physics*. 1940;8(7):551–559. Available from: https://doi.org/10.1063/1.1750711.
3) Peter D, David R, Hobart N, Litchin N, Dale E, Hall A, et al. Sensitization of an iron-thazinaphotogalvanic cell to the blue: An improved match to the insolation spectrum. *Solar Energy*. 1977;19(5):567–570. Available from: https://doi.org/10.1016/0038-092X(77)90113-X.
4) Hall DE, Wildes PD, Lichtin NN. Electrodic phenomena at the anode of the totally illuminated, thin layer iron-thionine photogalvanic cell. *Journal Electrochemical Sociaty*. 1978;125(9):1365–1371. Available from: https://iopscience.iop.org/article/10.1149/1.2131679/meta.
5) Suresh AC, Sadhna K, Sushila L, Rameshwer A. Use of thionine- EDTA system in photogalvanic cell for solar energy conversion. *Journalof Photochemical and Photobiological A: Chemistry*. 1989;48(1):87092–87095. Available from: https://doi.org/10.1016/1010-6030(89)87092-3.
6) Gangotri KM, Meena RC, Meena R. Use of miscelles in photogalvanic cells for solar energy conversion and storage: cetyl trimethyl ammonium bromide-glucose-toluidine blue system. *Journalof Photochemical and Photobiological A: Chemistry*. 1999;123(1-3):34–43. Available from: https://doi.org/10.1016/S1010-6030(99)00034-9.
7) Prerna G, Gangotri KM. Studies of the Micellar Effect on Photogalvanics: Solar Energy Conversion and Storage-EDTA-Safranine O-TWEEN-80 System. *Arabian Journal of Science and Engineering*. 2010;35(1A):19–28. Available from: https://doi.org/10.1021/ef9000709.
8) Bhimwal MK, Gangotri KM. A comparative study on the performance of photogalvanic cells with different photosensitizers for solar energy conversion and storage: D-Xylose-NaLS systems. *Energy*. 2011;36(2):1324–1331. Available from: https://doi.org/10.1016/j.energy.2010.11.007.
9) Lal M, Gangotri KM. A Comparative study the performance of photogalvanic cells with mixed surfactant for solar energy conversion and storage: D-Xylose - Methylene Blue system. *Research journal of Recent Science*. 2013;2(12):19–27. Available from: http://www.isca.in/rjrs/archive/v2/i12/4.ISCA-RJRS-2013-254.pdf.
10) Gangotri KM, Mohan L. Study of Photogalvanic Effect in Photogalvanic Cell containing Mixed Surfactant (NaLS+CTAB). *Research Journal of Chemical Sciences*. 2013;3(3):20–25. Available from: http://www.isca.in/rjcs/Archives/v3/i3/4.ISCA-RJCS-2012-227.pdf.
11) Mohan L, Gangotri KM. Study of Photogalvanic effect in Photogalvanic cell containing mixed surfactant (NaLS+Tween-80), Methylene blue as a photosensitizer and Xylose as Reductant. *Research Journal of Recent Sciences*. 2013;2:76–81. Available from: http://www.isca.in/rjrs/archive/v2/iISC-2012/15.ISCA-ISC-2012-4CS-94.pdf.
12) Lal M, Gangotri KM. Study of Photogalvanic effect in Photogalvanic cell containing mixed surfactant (NaLS+Tween-80), Methylene blue as a photosensitizer and Xylose as Reductant for solar energy conversion and storage. *Campus Books International India*. 2015;p. 32–44.
13) Saini SR, Meena SL, Meena RC. Studies of Surfactant in Photogalvanic Cell for Solar Energy Conversion and Storage. *Advances in Chemical Engineering and Science*. 2017;07(02):125–136. Available from: https://doi.org/10.4236/aces.2017.72010.
14) Jayshree R, Mohan L. Studied on Study of photogalvanic effect in photogalvanic cell containing single surfactant as DSS, Tartrazine as a photosensitizer and EDTA as reductant for solar energy conversion and storage. *Research Journal of ChemistryandEnvironment*. 2018;22(6):53–57. Available from: https://worldresearchersassociations.com/Archives/RJCE/Vol(22)2018/June2018.aspx.
15) Koli P. Sudan-I dye and Fructose chemicals based photogalvanic cells for electrochemical solar energy conversion and storage at low and artificial sun intensity. *Arabian Journal of Chemistry*. 2021;14(2):102918–102918. Available from: https://doi.org/10.1016/j.arabjc.2020.102918.
16) Wu T, Qin Z, Wang Y, Wu Y, Chen W, Zhang S, et al. The Main Progress of Perovskite Solar Cells in 2020–2021. *Nano-Micro Letters*. 2021;13(1):152–152. Available from: https://doi.org/10.1007/s40820-021-00672-w.
17) Zhao C, Tang CG, Seah ZLL, Koh QM, Chua LL, Png RQ, et al. Improving organic photovoltaic cells by forcing electrode work function well beyond onset of Ohmic transition. *Nature Communications*. 2021;12(1). Available from: https://doi.org/10.1038/s41467-021-22358-y.
18) Chen Y, Du C, Sun L, Fu T, Zhang R, Rong W, et al. Improved optical properties of perovskite solar cells by introducing Ag nanopartices and ITO AR layers. *Scientific Reports*. 2021;11(1). Available from: https://doi.org/10.1038/s41598-021-93914-1.
19) Koli P, Pareek RK, Dayma Y, Jonwal M. Formic Acid reductant-Sodium Lauryl Sulphate Surfactant enhanced photogalvanic effect of Indigo Carmine dye sensitizer for simultaneous solar energy conversion and storage. *Energy Reports*. 2021;7(7):3628–3638. Available from: https://doi.org/10.1016/j.egyr.2021.06.022.
20) Koli P, Dayma Y, Pareek RK, Kumar R, Jonwal M. Modified and simplified photogalvanic cells: Solar energy harvesting using bromo cresol green dye with different electrodes and cell dimensions. *Journal of Electroanalytical Chemistry*. 2022;904:115942–115942. Available from: https://doi.org/10.1016/j.jelechem.2021.115942.