Advancements in Photogalvanic Cells: Towards Efficient Solar Energy Conversion and Storage by Use of Dye, Reductant, and Micelles in Alkaline Media

Jaidev Kumar[1], Deepak Pareek[2], Mahesh Kumar Bhimwal[3]
[1,2,3]*Department of Chemistry, JJT University, Jhunjhunu, Rajasthan*

Abstract-Photogalvanic cells are a type of solar cell that converts solar energy into electrical energy by the direct electrochemical process. Photogalvanic cells are made up of four main components i.e. reductant, surfactant, dye, and micelles. The reductant is a substance that donates electrons to another substance. In a photogalvanic cells the reductant is typically an organic molecule, such as glucose or ascorbic acid. The surfactant is a substance that lowers the surface tension of a liquid. In a photogalvanic cells, the surfactant helps to form micelles, which are spherical aggregates of surfactant molecules. The dye is a substance that absorbs light and emits photons of a different color. In a photogalvanic cells, the dye absorbs sunlight and uses the energy to excite electrons from the reductant. The micelles are spherical aggregates of surfactant molecules. In a photogalvanic cells, the micelles help to concentrate the dye and reductant molecules, which increases the light absorption efficiency and electron transfer processes. In present, photogalvanic cells are under consideration for better performance but they have more potential to achieve more efficient and cost-effective way to convert solar energy into electricity than traditional silicon solar cells.

Keywords: Solar Energy; Conversion Efficiency; Photogalvanic cell; Storage Capacity

1. INTRODUCTION

Solar energy is most abundant and renewable energy sources on the earth. It is estimated that the amount of solar radiations that reaches on the Earth's surface in one hour is more than enough to meet the worlds energy needs for a year. There are a number of different ways to convert solar energy into electricity, but one of the most promising is through the use of photogalvanic cells. In fiorst photogalvanic effect was observed by using thionine system (Rabinowitch, 1940). These are the type of solar cells that uses for conversion of sunlight into electrical energy in a direct electrochemical process.

Photogalvanic cells are made up of four main components: a reductant, a surfactant, a dye, and micelles. The reductant is a substance that donates electrons to another substance. In a photogalvanic cells, the reductant is typically an organic molecule, such as glucose or ascorbic acid. The surfactant is a substance that lowers the surface tension of a liquid. In a photogalvanic cell, the surfactants help to form micelles, which are spherical aggregates of surfactant molecules. In a photogalvanic cell the micelles help to concentrate the dye and reductant molecules, which increase the efficiency of the light absorption and electron transfer processes. Dye surfactant interaction is also helpful in the study of photogalvanic effect (Ameta et al., 1990) by using azure c -glucose system (Khamesra et al, 1991), Sodium lauryal sulphate system (Ameta et al., 1998), EDTA-methylene blue-azure B system (Gangotri and Lal, 2001,), Nitrilotriacetic acid- azure B system (Genwa and Gangotri, 2001), NaLS- ascorbic system (Genwa and Chouhan, 2004), EDTA-methylene blue system (Gangotri and Lal, 2005), Cango red-EDTA system (Kumari et al., 2009), EDTA- new methylene and safranine o system (Yadav and Lal, 2010), Rose Bengal- D-xylose -NaLs system (Gangotri and Bhimwal, 2010), EDTA- safranine O-DSS system (Gangotri and Gangotri, 2010), EDTA-azure B system , Gangotri et al., 2010), whereas a comparative system were observed by Bhimwal and Gangotri, 2011. The optimum efficiency of PG solar cell was studied by using brilliant black PN-ammonium lauryl sulphate-EDTA system (Genwa and Chouhan, 2012). A mixed reductant system with micelles were studied by using azur a as photosensitizer (Gangotri et al., 2011). The improvement of the conversion efficiency were studied by Bhimwal et al. 2013, Mahmoud et, al. 2014, & 2015, Saini et al., 2017. Recently, Bhimwal et al.(2022, 2024) studied the photogalvanic effect in solar system with new combination of dye, reductant and surfactant and also study use of nanomaterial's in solar system.

2. MATERIALS AND METHOD

2.1 Materials: A suitable dye, reductant and surfactant (micelles) are used in very little amount (very low concentration) i.e. dye as M/5000, reductant and surfactant M/1000 in alkaline media are used for solar energy conversion by Photogalvanics. Different types of dyes which are used in photogalvanic cell

Ru-based complexes (N3): Ruthenium–based complexes, like N3 are widely recognized for their efficient light absorption and electron injection capabilities, making them prevalent in photogalvanic cells.

Porphyrin Dyes: Porphyrin–based dyes, inspired by natural chlorophyll pigments, exhibit strong light absorption in the visible range making them useful in solar cells.

Carotenoids: It often found in plants, algae, and bacteria are known for their behavior to absorb light in the blue and green area of spectrum region.

Phthalocyanine Dyes: It based dyes possess excellent stability and strong absorption properties in the near – infrared region, making them suitable for solar energy conversion.

Natural Dyes (e.g.,Chlorophyll, Anthocyanins): In an effort to promote sustainability and environmental friendliness, researchers are investigating the possibilities of these naturally occurring dyes, which include anthocyanin from fruits and flowers and chlorophyll from plants, for use in solar cells.

Azo Dyes: Azo dyes are organic compounds with the functional group R−N=N−R′, typically aryl and substituted aryl groups. They are a significant family of synthetic dyes, not naturally occurring. Azo dyes make up 60-70% of all dyes used in food, textile industries, and light absorbing substance with some containing two or three azo groups.

2.2 Method:
The overall process of solar energy conversion in a photo galvanic cells are as follows:
1.Sunlight is absorbed by the dye molecule.
2.The excited dye molecule transfers an electron to the reductant.
3.The reductant radical donates an electron to the counter electrode.
4.The electron flows through the external circuit back to the dye molecule, completing the electrical circuit. This process generates a direct electric current, which can used to power electrical devices.

3. RESULT AND DISCUSSION

3.1 Role of reductant, surfactant, dyes and micelles in photo galvanic cell:-
All main components of a photo galvanic cell plays an important role in the conversion of sunlight into electrical power.

Reductant:-The reductant donates electrons to the excited dye molecule. This creates a positively charged dye radical and a negatively charged reductant radical.

Surfactant:-The surfactants helps to form micelles, concentrate the dye and reductant molecules. This increases the efficiency of the light absorption and electron transfer processes.

Dye:-The dye absorbs sunlight and uses the energy to excite electrons from the reductant.

Micelles:- The micelles also help to keep the dye and reductant molecules stable and prevent them from aggregating .This is important for maintaining the efficiency of the photogalvanic cell.

3.2 Advantages of photogalvanic cells:-

Photogalvanic cells have a number of advantages over traditional silicon solar cells, including:-

Higher efficiency:- Photogalvanic cells have the potential to be more efficient than silicon solar cells. This is because photogalvanic cells can convert a wider range of wavelengths of light into electricity.

Lower cost:-Photogalvanic cells are made from relatively inexpensive materials ,which makes them potentially more cost –effective than silicon solar cells.
Flexibility:-Photogalvanic cells are flexible and can be made into a variety of shapes and sizes. This makes them suitable for a wide range of applications, such as portable electronics and building-integrated photovoltaic.

3.3 Disadvantages of photogalvanic cells:
Photogalvanic cells are still under development, and they have a few disadvantages compared to traditional silicon solar cells:
Durability:- Photogalvanic cells are not as durable as silicon solar cells. This is because the dyes used in photogalvanic cells can be degraded by sunlight and moisture.
Stability:- The efficiency of photogalvanic cells can decrease over time as the dyes degrade. Whereas, reductant is a substance that donates electrons to another dye substance. In a photogalvanic cell, the reductant is typically an organic molecule, such as D-xylose, glucose or ascorbic acid. When the reductant donates an electron to free form of dye molecule, it creates appositively charged dye radical and a negatively charged reductant radical. The dye radical is then able to transfer the electron to the counter electrode, which completes the electrical circuit and generates an electric current. The reductants are required for the operation of a photogalvanic cell, and without it, no electricity would be generated.

These are the example of reductants that may be used in photogalvanic cells.

- Glucose,
- Ascorbic acid,
- Oxalic acid,
- Trimethyl amine,
- Ethylenediaminetetraacetic acid (EDTA),
- D-Xylose

The choice of reductant will depend on a number of factors,such as the type of dye being used ,the desired efficiency of the photogalvanic cell and the cost of the reductant. A number of studies have been conducted on the role of these four essential components i.e. reductant, micelles(surfactant), dye, and micelles in photogalvanic cells. These findings indicate that the stability and efficiency of the cell can be significantly impacted by the selection of these components. The use of DSS as a surfactant in a photogalvanic cell containing methylene blue as dye and D-xylose as reductant, for instance, was found to significantly increase the overall efficiency of the cell. This is because metal/surfactant complexes, or Metal Organic Ionic Framework (MOIF), are based on the ionic interaction of $[Co(NH3)6]3+$ and Dioctyl sulfosuccinate (AOT)/Sodium dodecyl sulfate (SDS). Whereas, Koli et al. (2020) observed that the use of fructose system in a photogalvanic cell containing Sudan I dye have high conversion efficiency i.e. 11.49 %.
Researchers are still working on developing new and improved reductants, surfactants, dyes, and micelles for photogalvanic cells. The goal of observation is to find components that are efficient, stable, and inexpensive.

CONCLUSION

Photogelvanic cells have the potential to be a more efficient and cost –effective way to convert solar energy into electricity than traditional silicon solar cells. However, photogalvanic cells are still under development and more research is needed to improve the efficiency and stability of these cells. The study of reductant, surfactant, dye, and micelles (surfactant) in photogalvanic cells for conversion of sunlight into electrical power is an important area of research.

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