Dye Sensitized Solar Cells for The Transformation of Solar Radiation into Electricity

KEYWORDS  
Solar Cell, Clean Energy, Natural dyes, Photosensitizers

ABSTRACT  
The requirement for energy is ever increasing in recent days due to the rapid urbanization and industrialization, and the need for the innovation of clean energy and eco-friendly technologies is of prime importance in the present scenario. Solar energy is abundant in nature and is a promising alternative due to its remarkable benefits on comparison with the other available renewable energy technologies. Dye Sensitized solar cell commonly referred to as DSSC, is a third generation solar cell and it is basically used for the conversion of abundantly available solar energy into electrical energy. In this paper, a crisp review has been made on DSSC and its working principle with special emphasis on the various natural dyes and their reported conversion efficiencies.

Introduction  
Solar radiation is the abundant source of energy on earth. The conventional silicon based solar cells are not widely preferred due to their high production cost and efficient manufacturing techniques. Dye sensitized solar cells (DSSC's) have gained considerable attention due to their eco friendly nature, attractive appearance, economical fabrication procedures and ease of manufacture. It is a growing and an intense research field with a potential in the framework of non-conventional energy technologies. DSSC's are the modern devices used for the conversion of solar energy into electrical energy based on the sensitization of the wide band gap semiconductor. It was first developed by Grätzel and his coworkers in 1991 at Swiss federal institute of technology, Lausanne, Switzerland.

Objective of the paper  
Aims to understand the concepts related to DSSC's and to analyze the various methodologies adopted by researchers involved in DSSC field to explore the solar cell applications with special emphasis on the natural photosensitizers.

Components of a DSSC  
The DSSC consists of the following components

1. Semiconductor film Electrode
2. Electrolyte
3. Counter electrode
4. Photosensitizer

Semiconductor film Electrode  
The semiconductor serves as a carrier onto which the dye molecule with suitable anchoring groups are absorbed. The wide band gap semiconductor materials such as Titanium dioxide (TiO₂), zinc oxide (ZnO), and tin dioxide (SnO₂) have been reported by researchers for their large band gap and high electron mobility. Titanium dioxide is well preferred due to its wide availability, non-toxic nature, biocompatibility, and good chemical stability under visible irradiation. Doctor blade technique, screen printing, electrophoretic deposition etc. are the most widely used techniques for forming the titanium dioxide thin films.

Electrolyte  
The Electrolyte is an essential component in a DSSC which mediates the electrons between the photo electrode and the counter electrode. The electrolyte used influences the essential parameters such as short circuit current density (JSC) and the open circuit voltage (VOC). The commonly used electrolyte is iodide/ tri iodide (I⁻/I₃⁻). In addition, room temperature ionic liquids (RTILs) have been reported as alternatives. Solid state electrolytes possess high mechanical stability and simple fabrication. Quasi solid electrolytes were developed which involves a combination of both the solid and liquid electrolyte with the aim of eliminating the drawbacks associated with solid state electrolytes. Various additives are also added to the electrolyte to improve the open circuit voltage and to increase the stability.

Counter Electrode  
The Counter electrode should possess good electro catalytic activity and it serves the purpose of transferring the electrons from the external circuit to the redox electrolyte. Carbon (C) has been reported as the material for the preparation of counter electrode. Platinum (Pt) is the desired material for DSSC applications and various research groups have fabricated the cells with platinum counter electrodes to achieve the best conversion efficiencies.

Photosensitizer  
The dye molecule is used as a photosensitizer in the performance of a DSSC. It serves as the absorber of sun’s radiation and plays a vital role in increasing the efficiency of the cell. A typical photosensitizer must possess the following requirements.

1. Strong absorption in the visible region
2. It must carry appropriate attachment chemical groups to bind strongly with the semiconductor surface
3. Capable of injecting the electrons upon excitation
4. It should be more stable in order to withstand many turnover cycles
5. It should be cost effective in nature

Working principle of a DSSC  
DSSC is a regenerative solar cell. The absorption of light from the light source by the dye molecule which acts a photosensitizer initiates the process of generating electric power. After the light absorption and excitation, an electron from the excited state of the dye molecule is injected into the conduction band of the Titanium dioxide semiconductor layer. The electrons that are injected travel through the semiconductor layer into an outer electrical circuit to generate electric current. The dye that has lost the electron is in turn regenerated and returned back to the normal state by the electron donation from the electrolyte used in the cell. The iodide is regenerated by the reduction of the tri iodide at the counter elec-
Dye as a photosensitizer

The structure of the dye plays an essential role in DSSC’s. Some of the dyes reported in DSSC’s are:

- Synthetic Dyes
- Inorganic metal based dyes
- Synthetic Dyes
- Natural Dyes

The main drawbacks associated with the Ruthenium based dye is its expensive nature, poor availability, require skilled synthesis and poses major environmental threat.

Metals free Squaraine dyes

The conversion efficiency of organic dyes has increased significantly and it is comparable with the Ruthenium dyes. Squaraine dyes are investigated for their wide range of 400-800 nm. The synthetic routes have been developed to synthesize both symmetrical and unsymmetrical squaraine based dyes with the aim of improving the efficiency. Recently, a high efficiency of 13% is reported with Porphyrin based dye by Prof. Grätzel with Cobalt (II/III) electrolyte under AM 1.5G solar simulation.

The main drawbacks associated with the Ruthenium based dye is its expensive nature, rare availability, require skilled synthesis and poses major environmental threat.

Metal free Squaraine dyes

The conversion efficiency of organic dyes has increased significantly and is comparable with the Ruthenium dyes. Squaraine dyes are investigated for their wide range of 400-800 nm. The synthetic routes have been developed to synthesize both symmetrical and unsymmetrical squaraine based dyes with the aim of improving the overall conversion efficiency of the DSSC. Dye sensitized solar cells prove to harvest the abundantly available solar radiations. Natural dyes can be used effectively as photosensitizers due to their low cost, non-toxic nature, cost effective extraction procedure and wide availability. Though the efficiencies reported with the extracted natural dyes are considerably lower than with the synthetically produced ruthenium dyes and other organic dyes, the values are academically interesting and hence the search for novel natural photosensitizers can be carried out so as to explore its applications in harnessing solar energy and to achieve a considerable efficiency. Thus incorporating naturally extracted dyes in DSSC’s paves a way for sustainable development and a greener environment.

Conclusion

Dye sensitized solar cells prove to harvest the abundantly available solar radiations. Natural dyes can be used effectively as photosensitizers due to their low cost, non-toxic nature, cost effective extraction procedure and wide availability. Though the efficiencies reported with the extracted natural dyes are considerably lower than with the synthetically produced ruthenium dyes and other organic dyes, the values are academically interesting and hence the search for novel natural photosensitizers can be carried out so as to explore its applications in harnessing solar energy and to achieve a considerable efficiency. Thus incorporating naturally extracted dyes in DSSC’s paves a way for sustainable development and a greener environment.

Table - Reported efficiencies of some naturally extracted dyes

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