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Natural green pigments to transform sunlight into electricity

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ABSTRACT

Sunlight is the most promising source of energy to meet the demands of the growing population. The conventional silicon based photovoltaic devices are replaced by the novel dye sensitized solar cells due to their remarkable benefits. Since the inception of this novel device, enormous research has been focused in order to enhance the conversion of solar energy into clean electricity. Various synthetic and natural dyes have been tested as photo sensitizers since more than two decades. In this paper, we have discussed the principles involved in the dye sensitized solar cell and natural pigments preferred with special focus on the chlorophyll pigments for photosensitization and their reported efficiencies.

Keywords: Solar energy, photo sensitizer, chlorophyll, efficiency, natural pigment

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INTRODUCTION

The most pressing problem in the present world is the generation of toxic gases into the atmosphere due to the combustion of fossil fuels which has led to the global climatic changes. Clean energy is the most essential need for any society and the world is in great need for renewable sources of energy. One of the most challenging renewable resource is the clean and freely available solar power to replace the conventionally preferred fossil fuels [1, 2]. Dye sensitized solar cells (DSSC) were first invented by Prof. Michael Gratzel and his coworkers in 1991 [3]. This novel technology lies in between second and third generation solar cells [4]. DSSC have gained considerable attraction due to its simple fabrication procedures, low cost, environment friendly nature and reasonable conversion efficiencies [5].Since the invention of this innovative technique, various researchers have worked on it and reported reasonable conversion efficiencies.

A DSSC basically consists of a wide band gap semiconductor layer such as titanium dioxide onto which a layer of dye with suitable anchoring groups is strongly attached. The dye molecule acts as a photo sensitizer and initiates the process of generating electric power. On absorbing sunlight, the electron from the monolayer of the charge transfer dye is transferred to the conduction band of the nanocrystalline semiconductor layer and flows through the circuit to produce electric energy. The redox couple used in the photo electrochemical cell donates the electron to the oxidized dye thereby regenerating the dye molecule. The electrolyte is in turn generated in the cell [6-10].

A photo sensitizer plays a major role in determining the overall conversion efficiency of the device and some of the essential requirements of a photo sensitizer are its intense absorption in the visible and near infra red regions, ability to bind itself to the semiconductor layer with suitable anchoring groups, its stability to withstand numerous oxidation and reduction cycles without undergoing any degradation, cost effectiveness etc [5, 6, 11]. Since more

than two decades, the advancement in dye sensitized solar cell technology is observed to be tremendous and has attracted various researchers in this unique field.

Dyes as sensitizers

2.1 Synthetic Dyes

Ruthenium metal based sensitizers are well recognized as efficient dyes for photosensitization owing to their photo electrochemical properties and good stability thus making it suitable for DSSC applications. The most preferred stable ruthenium based sensitizers are N719 and black dye possessing an efficiency exceeding 11% under AM 1.5 irradiation [12, 13]. Though, ruthenium sensitizers are reported for their high conversion efficiencies, few drawbacks limit their practical application such as rare availability, cost involved, skilled synthesis and purification procedures involved[5, 12]. Other than ruthenium based dye molecules, porphyrin based sensitizers are also explored in DSSC's. A porphyrin sensitizer employing cobalt based redox electrolyte was reported to exceed 12% efficiency [14] .Other than metal based dyes, squaraine dyes have been tested as photo sensitizers due to their high extinction coefficient, photoconductive nature and intense fluorescence. They show intense absorption in the near infra red region thus making it suitable in DSSC [15, 16].

2.2 Natural pigments

In recent days, natural dyes obtained from the various parts of the plant have been explored as sensitizers due to their special features such as easy attainability, environment friendliness, low cost involved etc. Pigments such as chlorophylls and anthocyanins have been widely investigated as sensitizers in recent days. Anthocyanins are flavonoid pigments which are responsible for producing vibrant colours in most of the flowers, leaves and fruits. They possess 2-phenyl benzopyrylium (flavylium) ion core structure and they are reported to appear red in acidic medium and blue in basic medium [5, 17,18] .

3. Chlorophyll pigments

Chlorophyll pigments play a vital role in the process of photosynthesis and distributed in most of the parts of the plant. Chlorophyll a and chlorophyll b are the important types of chlorophyll generally present in all photosynthetic plants and algae. The magnesium ion present at the centre of chlorophyll molecule makes it unique and plays an essential role in the absorption of light [17, 19]. Chlorophyll dyes are widely investigated for absorption in the visible region and hence preferred for sensitization [20]. Different strategies have been adopted to enhance the efficiency of chlorophyll dyes. Chlorophyll dyes in their crude form are not as efficient as cocktail dyes [18].Table 1 shows some of the natural sources for extracting the dyes and their reported efficiencies.

Table 1: Few reported chlorophyll and anthocyanin based dyes and their reported efficiencies

Dye source	Pigment present	Solvent used for dye extraction	Efficiency reported	Ref
Hierochloe Odorata	Pheophytin a	Ethanol	0.46	21
Torulinium Odaratum	Pheophytin a	Ethanol	0.32	21
Dactyloctenium aegyptium	Pheophytin a	Ethanol	0.24	21
Pomegranate leaves	Chlorophyll	Alcohol	0.597	22
Mulberry fruit	Anthocyanin	Alcohol	0.548	22
Spinach	Chlorophyll	Ethanol	1.131	23
Ipomoea	Chlorophyll	Ethanol	0.278	23
Wormwood	Chlorophyll	Ethanol	0.538	24
Purple Cabbage	Anthocyanin	Ethanol	0.75	24

4. Future Scope

Dye sensitized solar cells are the best alternatives to replace the traditional silicon based solar cells. Various pigments are widely distributed and abundant in natural sources which are yet to be explored in this novel technology. Though the efficiencies reported for most of the natural based dyes are reported to be less than 1%, by adopting different strategies such as purification of the crude extracts, mixing with other natural dyes may enhance the overall conversion efficiency of the dyes. Thus, natural dyes are promising photo sensitizers in this unique technology.

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