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Similarities between photosynthesis and the principle of operation of dye-sensitized solar cell

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Photosynthesis is the process of converting light energy into chemical energy and storing it in the bonds of sugar; while the operational principle of the dye-sensitized solar cell involve the absorption of light by a dye adsorbed by a photoanode. Electrons are released when the dye is illuminated. The comparison done here showed that there exist a lot of similarities between photosynthesis and the principle of operation of a dye-sensitized solar cell.

Key words: Photosynthesis, dye, solar, cell, similarities.

INTRODUCTION

Dye-sensitized solar cell is a new technology that generates electricity when exposed to sunlight. This technology has opened a new area of research interest for scientists. Currently researchers are working to improve on the photon-to-current conversion efficiency of the dye sensitized solar cell. Some researchers have varied the chemical composition of the dye (Ruthenium complex) with the aim of improving the photo-to-current conversion efficiency (Kuang et al., 2007). It is believed that there exist some similarities between photosynthesis and the operational principle of any dye-sensitized solar cell. Dye-sensitized solar cell, as mentioned above, requires sunlight before it can generate electricity. In the same way, plants require sunlight before they can produce sugar. Before we look into the similarities proper, we need to first look at the various concepts under investigation.

PHOTOSYTHESIS

Photosynthesis is the process of converting light energy to chemical energy and storing it in the bonds of sugar (Pessarakli, 2002). This process occurs in plants and some algae (Kingdom Protista). Plants need only light energy, CO_2, and H_2O to make sugar. The process of photosynthesis takes place in the chloroplasts, specifically using chlorophyll, the green pigment involved in photosynthesis (Farabee, 2007). Photosynthesis takes place primarily in plant leaves, and little to none occurs in stems, etc. The parts of a typical leaf include the upper and lower epidermis, the mesophyll, the vascular bundle(s) (veins), and the stomates. The upper and lower epidermal cells do not have chloroplasts, thus photosynthesis does not occur there. They serve primarily as protection for the rest of the leaf. The stomates are holes which occur primarily in the lower epidermis and are for air exchange: they let CO_2 in and O_2 out. The vascular bundles or veins in a leaf are part of the plant's transportation system, moving water and nutrients around the plant as needed. The mesophyll cells have chloroplasts and this is where photosynthesis occurs (Raghavendra, 2000).

Chlorophyll looks green because it absorbs red and blue light, thus making the red and blue colors invisible to our eyes. It is the green light which is not absorbed that

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finally reaches our eyes, making chlorophyll appear green. However, it is the energy from the red and blue light that are absorbed and invariably used for photosynthesis. The green light as can be seen is not absorbed by the plant, and thus cannot be used during photosynthesis. The overall chemical reaction involved in photosynthesis is:

$6CO_2 + 6H_2O$ (+ light energy) $\rightarrow C_6H_{12}O_6 + 6O_2$.

This is the source of the O_2 we breathe. It therefore becomes necessary for government at all level to check the act of deforestation going on in the country (Farabee, 2007).

There are two parts to photosynthesis:

1. The light reaction: It happens in the thylakoid membrane and converts light energy to chemical energy (Dahik, 2011). This chemical reaction must therefore need the presence of light before it can occur. Chlorophyll and several other pigments such as beta-carotene are organized in clusters in the thylakoid membrane and are involved in the light reaction. Each of these differently-colored pigments can absorb a slightly different color of light and pass its energy to the central chlorphyll molecule to do photosynthesis (Blankenship, 2002).

2. The dark reaction: It takes place in the stroma within the chloroplast, and converts CO_2 to sugar. This reaction does not need light directly for it to occur, but the products of the light reaction. The dark reaction involves a cycle called the Calvin cycle in which CO_2 and energy from adenosine triphosphate are used to form sugar (Blankenship, 2002).

DYE-SENSITIZED SOLAR CELL

Dye-sensitized solar cells are nanoparticulate photovoltaic cells that generate electricity when exposed to sunlight (Reijnders, 2009). Dye sensitized solar cells offer the prospect of very low-cost fabrication and present a range of attractive qualities that will facilitate market entry (Grätzel and Durrant, 2008). In most cases, the dye-sensitized solar cell is called in conjunction with the word: “mesoscopic” as: dye-sensitized mesoscopic solar cell. The word mesoscopic refers to a small scaled size (usually nanoscaled size). The standard dye-sensitized solar cell that uses Titanium oxide as its anode is often times called: Gratzel cell (Reijnders, 2009). This is because Michael Grätzel was the one who first developed a workable dye-sensitized cell based on Titanium oxide anode and a Rheutenium Dye. Grätzel received a millennium technology prize award for his work in 2010 (Hollister, 2010).

The progress realized recently in the fabrication and characterization of nanocrystalline materials has opened up vast new opportunities for the dye-sensitized solar cells. The Dye sensitized mesoscopic solar cells achieves optical absorption and charge separation processes by the association of a sensitizer (dye) as light-absorbing material with a wide-bandgap semiconductor (TiO_2) of nanocrystalline morphology (O’Regan and Grätzel, 1991). Dye-sensitized solar cells are said to be photo-electrochemical cells that make use of electrolytes in place of semiconductors. A sketch of the mesoscopic dye-sensitized solar cell is given in Figure 1.

In the working of the cell, when the sensitizer dye is illuminated, it releases electrons which are injected by a fast process into the conduction band of the titanium oxide (TiO_2) anode. As can be seen from Figure 2, the sensitizer dye is attached to the surface of the mesoporous titanium oxide nanocrystalline thin film. Photoexcitation of the sensitizer dye results in the injection of an electron into the conduction band of the TiO_2. The injected electron transports through the anode towards the external terminals where they could be utilized by a load. On the other hand, the sensitized dye becomes ionized after release of electrons. This ionized dye is regenerated by electron donation from the electrolyte (Grätzel and Durrant, 2008). The electrolyte on its own is regenerated by the transparent conducting oxide glass coated with platinum. The electrolyte in the Grätzel cell is an iodide (triodide) redox couple dissolved in a liquid organic solvent.

COMPARING PHOTOSYNTHESIS IN PLANT WITH THE OPERATIONAL PRINCIPLE OF THE DYE-SENSITIZED SOLAR CELL

The leaf of a plant represents the dye in the dye-sensitized solar cell. Under illumination, the dye in the dye-sensitized solar cell releases electrons which are transported through the anode to the external terminals for utilization (Figure 1). Similarly, under illumination by sunlight, the leaf of a plant releases sugar and oxygen. The oxygen goes into the atmosphere through the stomates while the sugar ($C_6H_{12}O_6$) is stored in the upper and lower epidermis through the vascular bundles. It can be observed that in both cases the products of the reactions (electrons, oxygen and sugar) are transported to areas of need. The electrons are transported through the anode to the external terminals, while the oxygen and the carbohydrate are transported through the stomates and the vascular bundles respectively. The chemical reaction involved in photosynthesis is given as:

$6CO_2 + 6H_2O$ (+ light energy) $\rightarrow C_6H_{12}O_6 + 6O_2$

while that involve in the operation of dye-sensitized solar cell is given as:

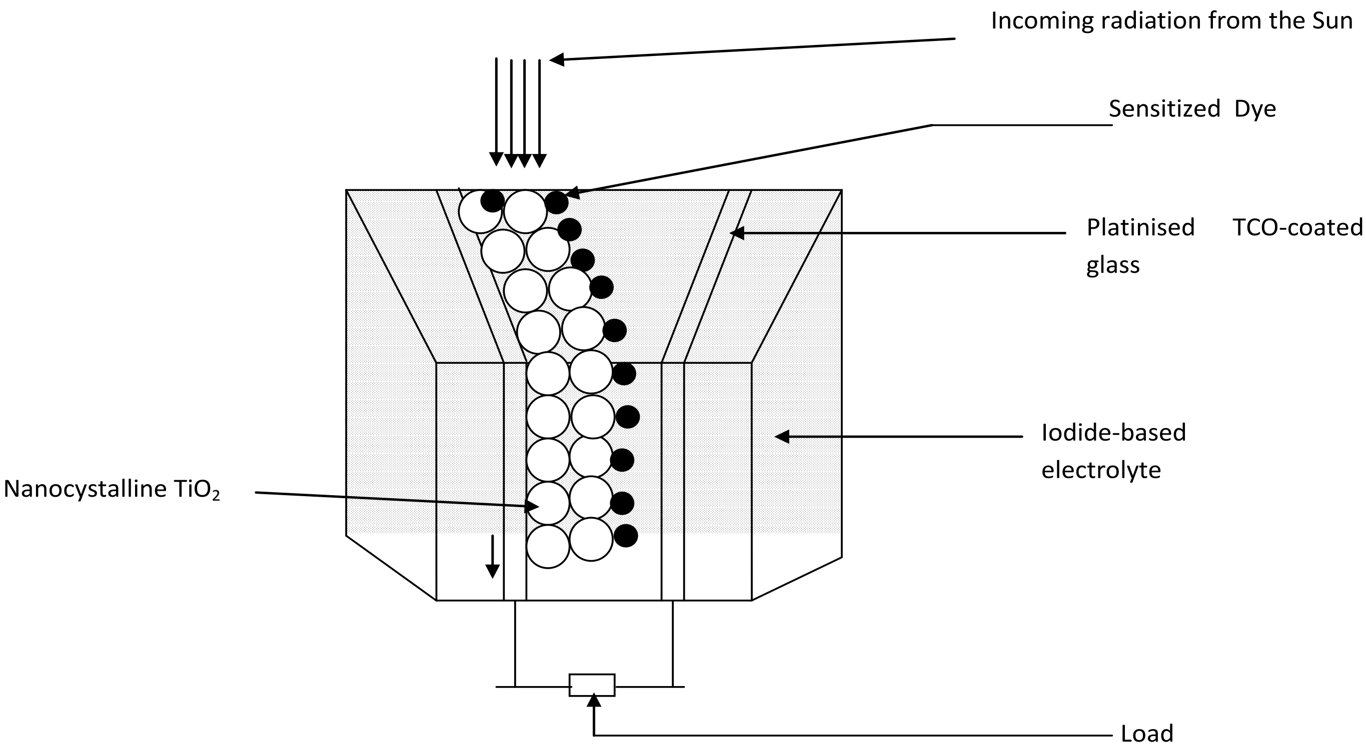

Figure 1. A sketch of the mesoscopic dye-sensitized solar cell.

D_c + light → $D_c^+ + e^-$
$D_c^+ + 2I$ → $D_g + I_2^-$
$2I_2^-$ → $I_3^- + I^-$

SIMILARITIES

The aim of the study is to deduced the similarities between photosynthesis and the operational principle of dye-sensitized solar cell. Following the study, it was observed that both processes need light from the sun to fuction. In both cases, there is absorbtion of energy from the sun. In dye-sensitized solar cell, the absorbed energy is needed to release of electrons from the dye, whereas in photosynthesis, the absorbed energy is used to generate carbohydrate and oxygen from the leaf. In both cases there is transportation of the products down to areas of needs. In dye-sensitized solar cell, the electrons are transported through the anode to the external terminal where they are utilized, whereas the carbohydrate generated during photosynthesis is transported through the vascular bundles of the plant to the upper and lower epidermis where they are stored for use. The oxygen generated goes into the atmosphere through the stomates. In both cases there are certain chemical reactions that are involved. For photosynthesis, the chemical reaction occurs in the leaf; whereas the reaction for dye-sensitized solar cell occurs at the

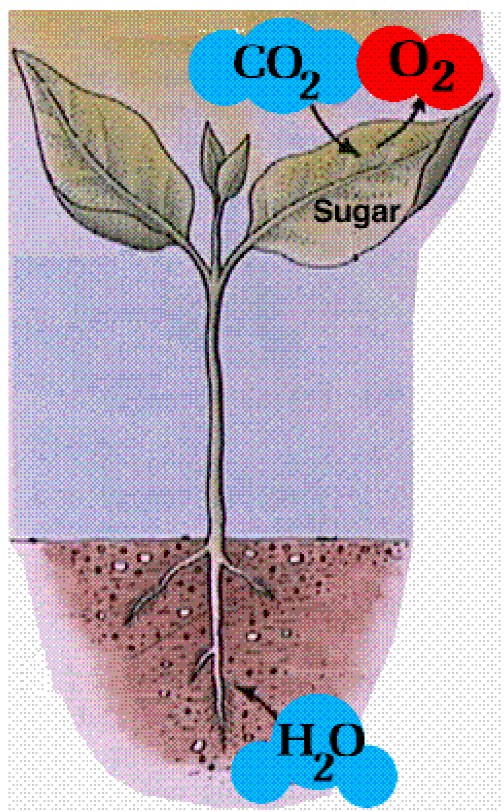

Figure 2. Photosynthetic process.

interface between the dye and the electrolyte. Both photosynthesis and the operational principle of dye sensitized solar cell are environmental friendly, since pollutants are not released in both processes. Lastly there is conversion of energy from light to electricity (in Dye-sensitized solar cell) and from light to chemical (in plants). In essence, in both cases there is conversion of light energy to other forms energy.

CONCLUSION

Having compared photosynthesis in plants and the operational principle of dye-sensitized solar cell and seen that they have similar feature, it is worthy of mentioning that dye-sensitized solar cell is a technology to be embraced. More researches should be carried out in this field of study that is mimicing photosynthetic process in its operation. For when dye-sensitized solar cell is fully adopted, the problem of 'carbon emmission' will be greatly reduced. And by this our environment would be protected.

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