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Natural dyes for dye sensitized solar cell: A review

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ABSTRACT

Dye sensitized solar cell converts visible light into electricity using sensitization of the cell. Performances of dye sensitized solar cells are mainly based on dye used as a sensitizer. Now a days study of dyes extracted from natural resources is the main concern for researchers. Application of natural dyes is a promising development in the field of this technology. Natural dyes are cutting down high cost of metal complex sensitizers and also replacing expensive chemical synthesis process through simple extraction process. Natural dyes are abundant, easily extractable, safe material causes no environment threat. These can be extracted from flowers petals, leaves, roots and barks in the form of anthocyanin, carotenoid, flavonoid and chlorophyll pigments. This review discusses development of natural dyes and their effect on various performance parameters of dye sensitized solar cell.

1. Introduction

The fossil fuels such as oil, natural gas and coal are the main sources of energy used all over the world. These sources will be depleted in future due to their ease of application in transport (except coal). Moreover, the burning of the fossil fuels emits ton of carbon dioxide that pollute the environment and also change the climatic conditions. The development of renewable sources of energy may lead towards clean green technology for a healthy environment. Solar, wind, hydro, biomass and geothermal are main sources of the renewable energy, each of them have their merits and demerits also [1]. The solar energy is the most fundamental renewable energy source accessible today as it provides energy for all living creatures on earth through the process of photosynthesis for growth and development. However, it also varies geographically on the earth. A key advantage of solar energy is that it can be easily harnessed at domestic and commercial level. Solar energy not only benefits individual owners, but also the environment as well. Solar radiation can be directly converted into useful heat or electricity. Electricity is a form of energy that can be made most easily available. Hence, scientists and engineers today seek to utilize solar radiation directly in generating electricity through economic devices [2].

A photovoltaic cell converts solar radiations directly into electrical energy. The first generation of solar cell consists of monocrystalline silicon solar cell as shown in Fig. 1 [3]. Silicon is the best material employed for fabrication of the crystalline solar cells. It is abundant material and safe for the environmental. These crystalline solar cells are fabricated by Czochralski method. These solar cells are made up of silicon wafers and the efficiency of these solar cells is higher than other solar cells. However, their fabrication cost is very high which makes high overall cost of commercially available crystalline solar cell. The performance of crystalline solar cell is affected by the temperature and thus affects the efficiency of the cell [4].

The thin film solar cells are referred to second generation of the solar cell. These are basically amorphous silicon solar cell. The solar materials used in thin films are in the powder form that makes the cell more flexible and light in weight. The structure of thin film solar cell is shown in Fig. 2. The main obstacle in front of thin film solar cell is the less efficiency. Cadmium telluride (CdTe), Copper indium gallium selenide (CIGS) and amorphous silicon (*a*-Si) are the various categories of thin film solar cells [5].

The generation of dye sensitized solar cell (DSSC) is considered as the third generation of the solar cell. The efficiency of these solar cells is more than thin films while less as compared to the crystalline solar cells. The first dye sensitized solar cell was fabricated by O'Regan and Gratzel in 1991 [6]. The structure of the DSSC consists of a titanium dioxide layer (semiconductor) coated photo anode electrode, a counter electrode used as a cathode, a sensitizer and an electrolyte as shown in

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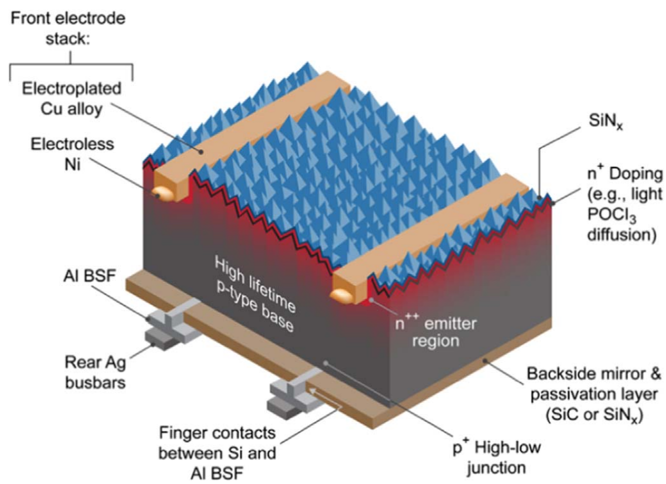

Fig. 1. Structure of monocrystalline solar cell [4].

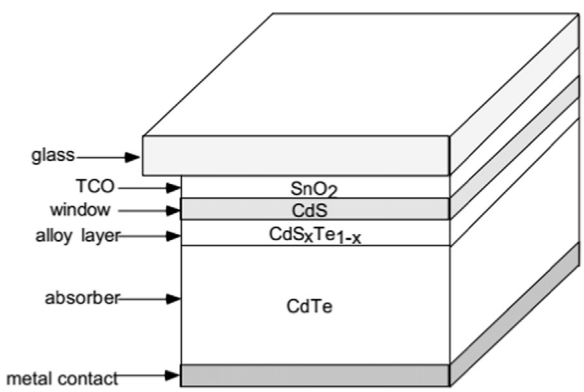

Fig. 2. Structure of thin film solar cell [5].

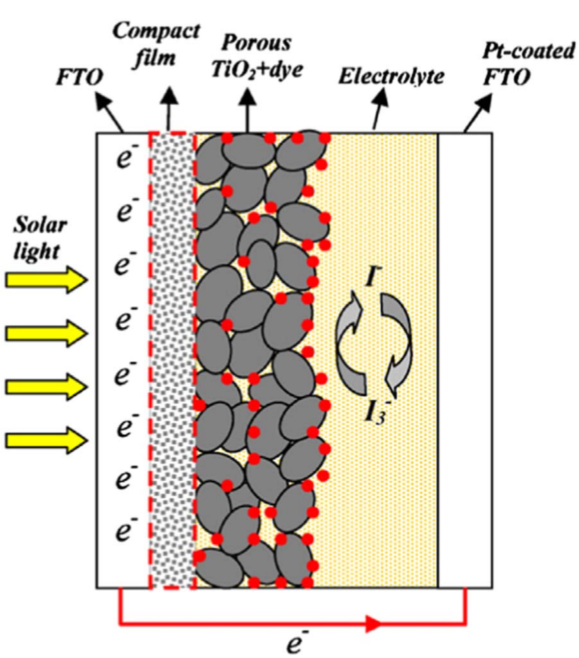

Fig. 3. Structure dye sensitized solar cell [7].

Fig. 3 [7, 8].

Intensive research has been done in the development of synthetic/natural dyes for solar cell in last two decades but there is lack of compiled information in this field. In this communication, the advancement in 3rd generation of solar cell is discussed with the detailed comparison of synthetic and natural dye solar cells. Variety of sensitizer is discussed being key parameter that affects performance of DSSC. This article also covered the advancement of technology in natural dyes. Various parameters have been suggested to enhance cell efficiency in this review. Finally, potential research area of DSSC is also recommended for future development. This review would be very fruitful to the researcher, scientist and academician of this area. Recent developments in NDSSC and their performance with future scope are discussed in Table 1.

1.1. Performance parameters of DSSCs

The performance of dye solar cell is generally evaluated by the different parameters of the cell such as open circuit voltage, short circuit current, fill factor, maximum voltage and maximum current of the cell. Each parameter is discussed in detail as follows [22,23]:

1.1.1. Open circuit voltage

The open circuit voltage (V_{oc}) of the solar cell is defined at the open terminals of the cell. As the temperature of the cell increases, the V_{oc} decreases. The V_{oc} of the cell is expressed as follows:

$$V_{OC} = V_t \ln\{(I_{sc}/I_o) + 1\} \quad (1)$$

1.1.2. Short circuit current

The short circuit current (I_{SC}) can find at the short circuit terminals of the cell. The short circuit current increases with increase temperature. Following expression shows the I_{SC}:

$$I_{SC} = I + I_O\{\exp(V/V_t) - 1 \quad (2)$$

1.1.3. Fill factor

The fill factor (FF) of the solar cell can be defined as the ratio of actual power (product of maximum voltage; Vm and maximum current; Im) to the dummy power (product of V_{oc} and I_{sc}).

$$FF = V_m I_m / V_{oc} I_{sc} \quad (3)$$

1.1.4. Efficiency

The efficiency of the solar cell can be defined as the ratio of electrical power to the optical power incident on the cell. It can be expressed as follows:

$$\eta = FF.\ V_{oc}.\ I_{sc}/\text{Incident optical power} \quad (4)$$

where,

V_{oc} – Open-circuit voltage,
I_{sc} – Short-circuit current,
V_m – Maximum value of voltage,
I_m – Maximum value of current, and
V_t – Terminal voltage of the cell
η – Efficiency of the cell

1.2. Comparison between synthetic and natural dye

Synthetic and natural sensitizer can be compared on the basis of various parameters such as cost of cell, environment issues, stability problem, maximum absorbance, efficiency of the DSSC, availability of the resources and fabrication method the cell as discussed in Table 2.

The metal complex sensitizer synthesized from complex fabrication method while natural sensitizers are prepared from flowers, leaves and roots etc using simple ethanol, methanol or water extraction process thus less costly as compared to synthetic dyes.