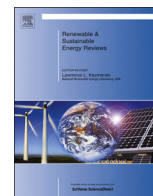




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Review on the development of natural dye photosensitizer for dye-sensitized solar cells



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ABSTRACT

Dye-sensitized solar cell (DSSC) provides credible alternative concept for inorganic solid-state photo-voltaic devices. The conversion efficiency of DSSC is mainly based on the dye coated on the porous semiconductor TiO₂ film. The use of natural dyes in solar cells is a promising development to this technology because it cuts down the high cost of noble metals and chemical synthesis. Therefore, this type of solar cell has attracted considerable attention from the academic and industrial communities. Numerous kinds of pigments, such as anthocyanin, carotenoid, chlorophyll, and flavonoid, extracted from various plant components, such as leaves, fruits, and flowers, have been tested as sensitizers. The photostability of the DSSC sensitizer material must be capable of undergoing many redox cycles without decomposition, and must also have the ability to carry attachment groups, such as phosphonate or carboxylate, to promptly graft it to the TiO₂ oxide. This paper highlights and discusses the development of natural dye photosensitizers and the mechanisms affecting the dye stability.

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1. Background and development of dye-sensitized solar cells

Solar energy is the source of nearly all energy on earth. Among all the renewable power sources, solar energy is the most easily exploitable, inexhaustible, quiet, and adjustable to enormous applications [1,2].

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Photovoltaic (PV) is a device that directly converts sunlight into electricity without pollution, sound, or moving parts, thereby making it long lasting and dependable. PV is an elegant method that takes advantage of the sunlight [3,4]. The basis on the mechanism of PV devices depends on the charge concept that separates at an interface of two materials with different conduction mechanisms [5]. The history of PV surfaced in the 19th century when Charles Fritts fabricated the primitive photovoltaic cell composed of selenium and a thin layer of gold [6,7]. After 1873, the first panchromatic film, rendering realistic images into black and white, followed the great work of Hermann Wilhelm Vogel, in which he discovered a method for increasing the photographic emulsion sensitivity and associated silver halide emulsions with dyes to produce black and white photographic films. Silver halides are insensitive to much of the visible light because they have band gaps at 2.7–3.2 eV. This achievement can be considered the first significant study on the dye sensitization of semiconductors [8,9].

In 1905, Albert Einstein described how photon absorption causes photoelectric effect, and was awarded the Nobel Prize in 1921 [5]. Russel Ohl fabricated silicon solar cell in 1941. In 1954, Bell Lab announced the production of silicon solar cells with over 6% efficiency [10]. The schematic of the silicon cells, which are merely silicon (semiconductor) p–n junctions, is shown in Fig. 1. When n-type and p-type semiconductors are joined, a motion of

electrons and holes across the junction occurs until equilibrium is reached. This phenomenon is called the equalization of the Fermi energy level in the materials. N-type semiconductors obtained through the addition of pentavalent impurity atoms (doping), such as phosphorus, arsenic, and antimony, share free electrons, thereby significantly increasing silicon conductivity. The addition of trivalent impurity atoms, such as boron, gallium, and aluminum, which has one valence electron less than the silicon atoms, creates P-type semiconductors [11,12].

First generation is a term that refers to the p–n junction photovoltaic, typically made from mono- and poly-crystalline silicon doped with other elements [13,14]. Both single (mono) and multi (poly)-crystalline photovoltaic require long fabrication processes and enormous amount of silicon materials. The PV devices that have recorded the highest efficiency are the first generation cells based on mono crystalline silicon. However, these cells have high fabrication cost and composition [15]. From 1954 to 1960, Hoffman developed a method to increase the PV cell efficiency from 2% to 14% [16].

Thin film photovoltaic cells are the second generation of PV devices based on amorphous polycrystalline compound semiconductors. Historically, amorphous silicon (A-Si), cadmium telluride (CdTe), and copper indium gallium selenite (CIGS), and to date, thin-film polycrystalline silicon, have been regarded as key thin-film candidates, among which the CdTe thin film technology is the most expensive [17,18]. The three types of thin film cell structures include mono or single junction, double or twin junction, and multiple junctions. The main difference among these structures is the number of p–i–n junction layers. Depositing thin material layers with various band gaps improves cell efficiency, but increases cost due to several processes or methods involved in depositing each layer of materials during fabrication.

However, the efficiency of these cells is less than the efficiency of wafer-based silicon solar cells that currently dominate the commercial PV market [19]. Numerous scientists are working on the development of thin film devices that decrease the high cost of production and improve the efficiency of cells [20,21]. The first and second generations of PV devices are fundamentally constructed from semiconductor materials [22,23].

The development of low-cost PV cells has been the topic of intensive research over the last three decades. The third generation PV cell technologies differ from first and second generation technologies by looking forward to optimize the efficiency and notably decrease costs [24–26]. Most of the third generation solar

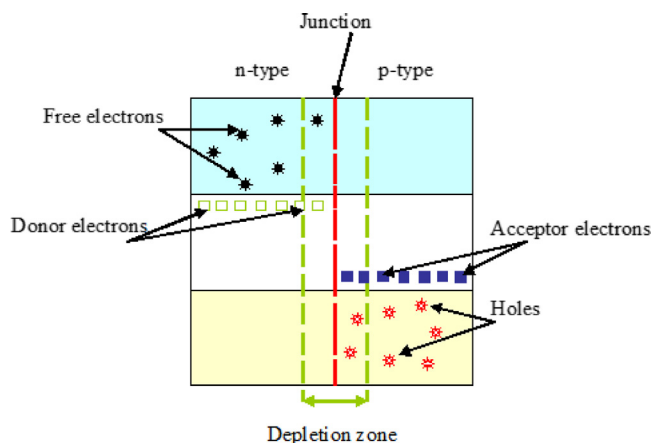


Fig. 1. Schematic diagram of a crystalline Silicon cell [19].

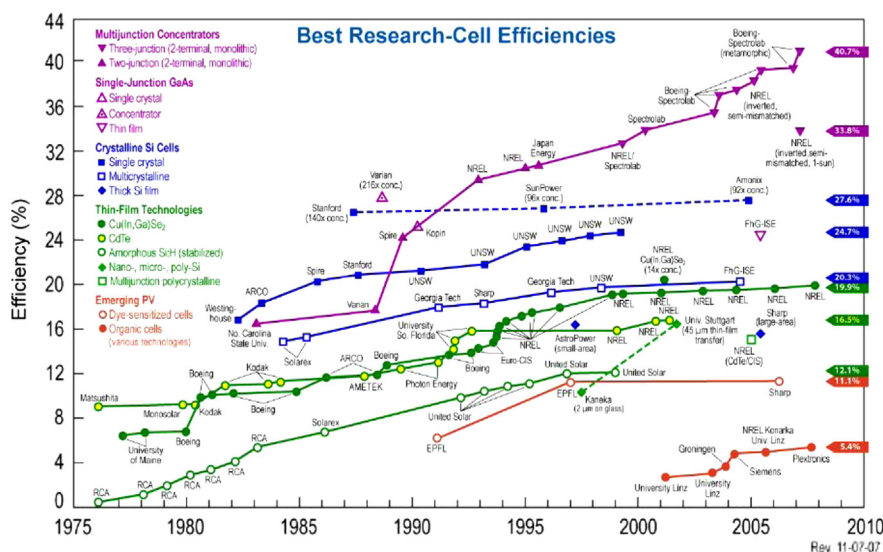


Fig. 2. Chart of photovoltaic cell developments from 1975 to 2010 [5].

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