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Nanomaterials for Dye Sensitive Solar Cells: A Literature Review

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Abstract

In this work, the progress in nanomaterials for dye-sensitized solar cells is surveyed. The survey shows that the majority of exploratory investigations are focused on the role of dye-sensitized solar cells in changeable nanomaterials. The photoelectrochemical system's favourable impact These exploratory research, in reality, have certain methodological concerns. According to these investigations, the literature has consistently generated contradictory results, and no one has come to a conclusion about the phenomenon's reality.

Keywords: DSSCs, Nanoparticles,Nanocomposites, TiO2, Electrical energy.

Introduction

Demand for energy is anticipated to double by 2050 and quadruple by the end of this century. Global political, economic, and environmental stability can only be maintained if there is an abundance of energy [1]. Fossil fuels, on the other hand, will run out eventually since they are a nonrenewable resource. There has been a lot of interest in renewable energy, particularly solar energy, because it turns solar energy directly into electrical energy without causing any environmental harm [2].

Recently, scientists have been interested in harnessing sunlight, beneficial chemical changes, or converting light directly into electrical energy for many years. Many academic and industry labs are currently interested in dye-sensitized solar cell research and development [3]. Many of the characteristics of DSSCs are unique and crucial in the field of low-cost photovoltaic energy. This literature review aims to provide an overview of the performance characteristics of all DSSC components, including nanomaterial composites and particles.

Its chemical stability, excellent conductivity, anticorrosive property and inexpensive cost make carbon-based counter electrodes a suitable option for Pt-based ones. Metal oxide film is a common component in DSSC for improving dye absorption, transport, and charge carrier separation [4].

An important consideration in achieving peak performance is the use of mesoporous TiO_2 as the development electrode and light scattering layer. In order to compensate for the reduced photon

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conversion produced by a thin mesoporous TiO2 layer, an ordered light scattering layer is proposed [6].

Due to its durability, chemical stability, strong electrocatalytic activity for reducing triiodine, and high electric conductivity, platinum was frequently utilised as a counter electrode for this purpose [5].

In 1991, O'Regan and Gratzel brought DSSCs to the literature with a PCE of 7.9 percent.

Literature Survey

Those gold nanoparticles were employed as a capping layer over an anatase TiO2 film that was coated using a DC sputtering process that was used as a photo-electrode by Beula et al An extra absorption band at 397-500 nm associated with the surface plasmon resonance was discovered in the TiO2-Au film's absorption spectra [4], in addition to the photoanode's predicted characteristics and absorption band. Solar cells containing TiO2-Au photoanodes that were dye-sensitized achieved a 4.8 percent short-circuit current density, which is 69 percent more efficient than those made with TiO2 without capping. The higher cell performance is likely due to the faster transmission of excited electrons, the separation of charge carriers, and the lower recombination rate of electron holes in the electrode produced by the inclusion of a gold capping layer [7].

Graphene-based nanocomposites, according to Oh et al (2020), can be used as flexible, transparent displays for electrical gadgets. However, graphene-based nanocomposite power conversions are superior than those of indium tin oxide. Due to its capacity to enable multiple components in existing solar cells, graphene's total power conversion efficiency may be improved significantly. In tandem solar cells, graphene may serve as an electron acceptor and intermediary layer [8]. Researchers have tweaked the structure to generate new kinds of light-harvesting materials based on the features of graphene and graphene-based compounds.

For dye-sensitized solar cells, Manaa et al (2019) used a mix of sophisticated statistical physics modelling and density functional theory [9] to analyse the adsorption of paprika dye on TiO2 surface. The microscopic adsorption process was effectively modelled using a statistical physics technique that employed a monolayer model with four energies. The adsorption modes, geometries, and energies of the paprika dye on TiO2 are of special interest to researchers. The density functional theory simulation found that paprika dye adsorption on the TiO2 surface involved three alternative binding modes: monodentate coordination via hydrogen atom bond, monodentate coordination via oxygen atom bond, and bidentate coordination via two oxygen atoms [10]. Furthermore, calculations suggest that the paprika dye and TiO2 adsorption is boosted by the bidentate coordination mode via the two hydroxyl and ether functional groups involved in the adsorption.

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TiO2 nanoparticles were synthesised using a new sol gel technique, which resulted in nanoparticles with a consistent sulphur content of 0.05 percent and a wide range of copper concentration from 0.1 to 0.5 percent, according to Gupta et al (2020). XRD data showed that anatase TiO2 crystalline phase was formed in all synthesised samples with a crystalline size smaller than 11 nm. By examining TiO2 using UV-Vis spectroscopy, it was discovered that co-doping with Cu/S changed its optical characteristics, allowing for a greater amount of absorption in the visible light spectrum. [11] EDAX examination verified that the co-doped TiO2 nanoparticles had a purity of 99.999%, as well as the presence in the stoichiometric ratio of titanium, oxygen, and copper. Cu/S co-doped TiO2 has shown the greatest power conversion efficiency of 10.44% with a considerably enhanced short circuit current density of 22.05 mA/cm2 in photovoltaic experiments in the presence of simulated solar radiation. The proper particle size, expanded surface area, increased dye adsorption, and therefore improved short circuit density are all factors that contribute to improved power conversion efficiency. On the other hand, an undoped TiO2 nanoparticle-based DSSC achieved 6.37 percent efficiency and a short circuit current density of 14.85 mA/cm2 with its power conversion efficiency.

ZnO and TiO2 coated FTO glass serve as photoelectrodes for dye-sensitized solar cell manufacturing, according to Adenigba et al. (2020). This enhances power conversion in the process of fabrication. The cell free extracts of Coelastrella sp MG257917 were also used to manufacture silver nanoparticles. UV-vis spectroscopy was used to investigate the effect of varied nanoparticle quantities and varying dye loading times on the optical characteristics of the modified photoanode. Using a light intensity of 100 mW/cm2 in the dark and light, the cells were tested for their solar to electrical conversion efficiency. The spherical nanoparticles have a diameter of 21-105 nm. According to an EDX analysis, silver was shown to be the most abundant element (97.96 percent). TiO2 loading duration was 15 hours, and the optimal ratio of CO-AgNPs to TiO2 was 1:2. The biosynthesized CO-AgNPs cells had a solar to electrical conversion efficiency of 1.09 percent under light and 0.95 percent in the dark, while the TiO2 cell had a solar to electrical conversion efficiency of 0.03 percent under light and 0.004 percent in the dark [12].

In the presence of D-mannitol, Enizi et al (2020) effectively customised the crystal architecture of TiO2 for use in dye-sensitized solar cells using a low temperature hydrothermal technique. The generated nanocrystallites of A-TiO2 were subjected to physical tests and found to have a remarkable power conversion efficiency of 6.0 percent, outperforming commercial anatase-TiO2 (CA-TiO2: 5.7 percent) and rutile-TiO2 (R-TiO2) achieved without D-mannitol (3.7 percent) [13]. In addition, using the A-TiO2 catalyst, a clever technique was established to produce pharmaceutically essential C-3 alkylated 4-hydroxycoumarins via various activated secondary alcohols in a solvent-free and heat/visible light environment. It has also been shown that the A-TiO2 catalyst may be reused up to five times without any degradation, which is a significant improvement over previous studies and demonstrates the uniqueness of the synthesised A-TiO2.

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C-3 alkylated 4-hydroxycoumarins with a 95 percent yield and good selectivity were produced by the A-TiO_2 catalyst's interaction with both coupling partners.

Photoelectrochemical research continues to focus on the utilisation of broad-spectrum solar energy, according to Bai et al. (2020). Nanomaterials aided by upconversion nanomaterials doped with transition-metal ions have been shown to increase wide spectrum absorption and scattering characteristics in dye-senitized solar cells for the first time [15]. [15] Using a Fe^{3+} doping concentration of 2 mol%, the materials show better upconversion luminescence than CeO_2:Yb/Er samples and 33.3 per cent greater efficiency in photoelectric conversion than pure P25 electrodes [16]. This is attributed to the nanomaterials' unique light scattering properties and excellent dye absorption capacity [15]. CeO_2:Yb/Er upconversion material Fe^{3+} transition metal ions can be used to improve photoelectric conversion efficiency.

According to Zhang et al. (2020), the counter electrode plays a critical role in facilitating the transition of an electrolyte redox pair from an oxidised to a reduced state. Electrocatalytic materials developed to replace the usual platinum counter electrode have received interest for their efficiency and cost effectiveness. Materials such as Gama-MoC/Ni@NC were employed in this investigation. Pyrolysis of molybdate, oxalate, melamine and nickel salts resulted in the formation of this substance. The power conversion efficiency of this composite catalyst is 5.26 percent, which is the same as that of the standard Pt counter electrode (5.65 percent). Due to a simpler and less expensive synthesising process, the PCE of gama-MoC/Ni@NC-based DSSC is comparable to that of Pt.

Molybdenum disulfide thin films were deposited onto a fluorine doped tin oxide (FTO) glass substrate using pulse mode electrochemical deposition at room temperature and ambient pressure, according to Ye et al. (2020). An effective counter electrode for DSSCs may be made from a large number of edge planes, as shown by HR-TEM studies, which show that poly nanostructural 2D MoS_2 with short-range order nanostructure offers many active sites. While using dye-sensitized TiO_2 working electrodes and an iodine-based electrolyte, the DSSC equipped with poly nanostructural 2D MoS_2 counter electrodes showed comparable photovoltaic conversion efficiency to the Pt counter electrode (6.43 percent) under illumination of AM 1.5 (100 $mWcm^{-2}$) [18]. [18]]

Conclusions

The purpose of this work is to investigate the link between nanomaterials and dye-sensitized solar cell conversion efficiency. Research on the link between nanocomposites, renewable energy, electricity consumption, and economic growth is becoming more prevalent in the scientific literature. There is a lot of attention on developing, developed and rising countries in this body of work. In order to implement successful energy and environmental policies, policymakers must fully grasp the link between renewable energy usage and economic growth.

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The results of these research suggest that no one has reached an agreement about the existence or direction of a causal link between these factors and their effects. Because of this, the author should focus on new techniques and aspects as well as new nanomaterials to achieve greater personal gratification and a better knowledge of the link between energy use and economic growth.

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