

Dye Sensitized Solar Cells Based on Extracted Natural Dyes and Synthetic Dyes with Nanocomposite Material

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Abstract

Producing dye sensitised solar cells in their original colours required a number of different techniques. Plants and berries were used to extract these dyes. The DSSCs were manufactured by recycling the old dyes. It was clear that the efficiency of the power conversion was deteriorating. TiO₂ mesoporous films' potential applications were also studied. This study employed electrochemical impedance spectroscopy to examine the interactions of natural dyes with TiO₂. Bi₂O₃ nanoparticles incorporated onto TiO₂ photoanodes to rise competence. Electron microscopy utilised to look at Bi₂O₃ nanoparticles (TEM). X-ray diffraction experiments verified that the synthesised silver nanoparticles had a face-centered cubic lattice structure. Our transmission electron microscope found nanoparticles with sizes between 20 and 50 nm. Bi₂O₃-TiO₂ had a nanospherical shape with a high porosity. The investigation was carried out with both of these microscopes. During the lengthy investigation, this was discovered. Bi₂O₃-TiO₂ included titanium, bismuth, and oxygen, as determined by EDX examination. Producing green silver nanoparticles using Bi₂O₃ and TiO₂ catalysts (1, 2, and 3 weight percent). It's no secret that solar cell efficiency has risen dramatically in recent years. An additional 12.1 percentage points were added to the maximum open-circuit voltage, whereas only 10.7 percentage points were added to the maximum short-circuit current density. The efficiency of the power conversion process was seen to deteriorate over a week.

Keywords: Photoconversion, Bi₂O₃, TiO₂, DSSCs, solar cell

INTRODUCTION

The advancement of human civilization relies on reliable energy production, and fossil fuels are the greatest choice. Fossil fuels cannot be replenished, hence their extinction this century is certain. Since it converts solar energy directly into electrical energy with minimal impact on the environment, renewable energy, particularly solar energy, must have drawn a lot of interest as a solution [1]. As a stable and secure energy source, DSSCs are being researched. This gadget functions effectively, has low installation costs, and is environmentally friendly. Conducting surface, dye, photoanode, catalyst, and electrolyte are all parts of DSSC. The photoanode is the component that affects voltage gain the greatest. There have been several photoanode materials tested [2]. Both Zn and TiO₂ have undergone extensive research.

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Basic calculations were done for the density of state and the building of electronic bands (DOS). After LC doping, DFT predicts a small bandgap and a good conductivity [3]. The results of the tests

showed that the LC expansion in (ZnO + LC) and (TiO₂ + LC) had an impact on the structure, morphology, and PCE. Expanding LC in ZnO/TiO₂ enhances porosity and surface area while lowering electron retrograde dispersion to improve colour stacking and light harvesting. These innovations boost (TiO₂ + LC) PCE by 104% and (ZnO + LC) PCE by 38% when compared to ZnO-based DSSC.

To boost co-sensitized solar cell PCE, photosensitizers with high open photovoltage (V_{oc}) must be promoted. Dan Zhang first created the 4-bis (dodecyloxy). -(1,1'-biphenyl) -4'-bis (dodecyloxy) -N-phenyl-1,1'-biphenyl-4-yl-2',4-bis (dodecyloxy) N -(1,1'-biphenyl-4-yl) Bis (1,1'-biphenyl) -2',4 1,2,5 Thiadiazol-4-yl benzoic acid and corrosive 4-(benzo[c]4-(benzothiadiazol-4-yl) benzoic acid. Dye-sensitized solar cells (DSSCs) may obtain an open-circuit voltage of 1.24 volts with a 130 mV deficit and an ideality factor of 1.08 by using "MS5 with the copper (II/I) electrolyte." Under AM1.5 G, 100 mW cm² solar light, MS5 co-sensitized with XY1b, resulting in an efficient and stable DSSC with a PCE of 13.5%. The co-sensitized solar cell (2.8 cm²) has a 34.5 percent PCE in medium light, making it a desirable light-harvesting fuel source for low-power devices. Also For dye-sensitized solar cells, semi-transparent TiO₂/graphene photoanodes are produced at room temperature via electrophoretic deposition and pressure (DSSCs). The power conversion efficiency (PCE) of the DSSC is increased by pressure by 18.4 times compared to inflated equipment. PCE was improved by graphene in compressed film by 28.8%. Consolidation of graphene and packaging improve film transport. A film's permeability may be decreased by compacting it, which may also "increase molecule-to-molecule interactions" and boost the effectiveness of power conversion and light transmission. A different charge transport route is provided by fused graphene's outstanding ability to carry charges. More PCE by 6% [3] Another DSSC was produced using mesoporous P-25 TiO₂ nanoparticle film sensitised with N719 dyes. TiO₂ nanoparticle sheets were treated using TiCl₄ to improve the device's performance. While successive exposure after TiCl₄ treatment boosted DSSC PCE, O₂ plasma preparation of untreated TiO₂ film decreased productivity. TiO₂ nanoparticle solar cells that have been dye-sensitized produce 8.35% PCE when treated with TiCl₄ and O₂ plasma [Xin et al. 2011] SGT-028 and SGT-029 are two porphyrin-based DSSC sensitizers that Haoran Z created and synthesised. BTD is replaced by one alkylated BTD unit in SGT-029 instead of two D—A porphyrin sensitizers. Its tight bunch and long alkyl chains, together with its optical and electrochemical characteristics, work together to improve PCE in comparison to SGT-021. Similar to SGT-021 dye, both porphyrin sensitizers feature an absorption window and energy band hole. The benchmark porphyrin sensitizer SGT-021 generated a power conversion energy (PCE) of 12.7% after DSSC augmentation, whereas SGT-028 produced a PCE of 9.1% with a typical AM 1.5G light output. The greatest PCE ever for an SGT-021-based device is 12.7%.

EXPERIMENTAL MATERIALS

Bi₂O₃-TiO₂ nanocomposite is created using bismuth nitrate pentahydrate, nitric acid, NH₄OH, Rhodamine 6G dye (Figure 1), and ethanol solution. In order to create solutions, deionized water is used.

Precipitation of Bi₂O₃-TiO₂ Nanocomposite

A nanocomposite of Bi₂O₃ and TiO₂ formed. First, anhydrous ethanol was used to spread bismuth nitrate penta-hydrate (Solution A). Ethanol was used in "Ti [OCH (CH₃)₂]₄" as Solution B. Solution A and Solution B are both present in the beaker. The pH was increased by nitric acid by around 9. 5 mL of NH₄OH is continuously stirred at room temperature to solubilize it. The mixture was collected before being added to with water and ethanol. For 12 hours, the precipitate is autoclaved at 100°C. This powder was calcined at 450°C for 4 hours [4].

Ruthenium Dye Composition

Construction and Measurement of DSSC

For 24 hours at room temperature, TiO₂ and Bi₂O₃-TiO₂ coatings are submerged in ruthenium dye solution. Its surface cannot be soaked without dehydrating. This photoelectrode is autoclaved and then

connected to the counter electrode to create a cell. The cell receives this electrolyte solution via a gap that is sealed in the direction of the counter electrode, where capillary action evenly distributes it. The normal cell is activated by the dye (Figure 2).

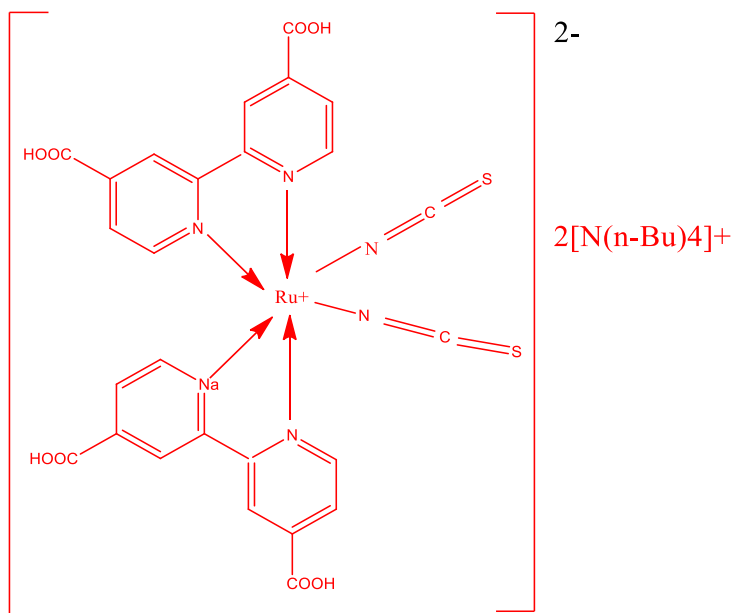


Figure 1. Chemical structure of Ruthenium dye.

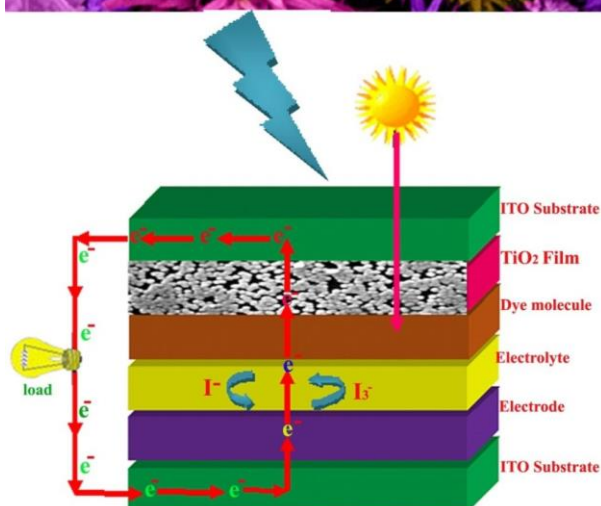


Figure 2. Photographical image of fabricated.

RESPONSE

Characterization

Each wavelength band between 800 and 200 nm of the UV-vis absorbance spectra were recorded using the Shimadzu UV1650PC recorder. Nanoparticle shape and content were validated by HR-TEM utilising a PHILIPS CM200 and FEI Quanta FEG 200 apparatus at 25°C. It takes 18 seconds for each spectrum. An X'PERT PRO type X-ray diffractometer was used by Pan Analytical to get Cu Ka XRD spectra. PL spectra were examined using a Perkin-Elmer LS 55 fluorescence spectrometer at room temperature. A Hitachi-U-2001 spectrometer was used to measure UV spectral parameters. Shimadzu UV1650PC recording spectrometer was used to detect UV-vis absorbance spectra. We measure the wavelength at 800–200 nanometers using a 10-mm quartz cell. The test drug's antibacterial activity is ascertained after 30 minutes of dissolution in DMSO (200 mg/mL). The CHI 60 AC electrochemical analyzer from CHI Devices Inc. was used to conduct CV observations.

In the $\text{Bi}_2\text{O}_3\text{-TiO}_2$ nanocomposite, only Ti, Bi, and O were detected by EDX. Its presence is shown by HRTEM micrographs of mixed 100 nm nanoparticles with a 0.281 nm particle size distribution and a nanospherical orientation. Figure 3 shows the XRD spectra of TiO_2 and $\text{Bi}_2\text{O}_3\text{-TiO}_2$. TiO_2 peaks in crystal structure spectra [5] are clearly visible.

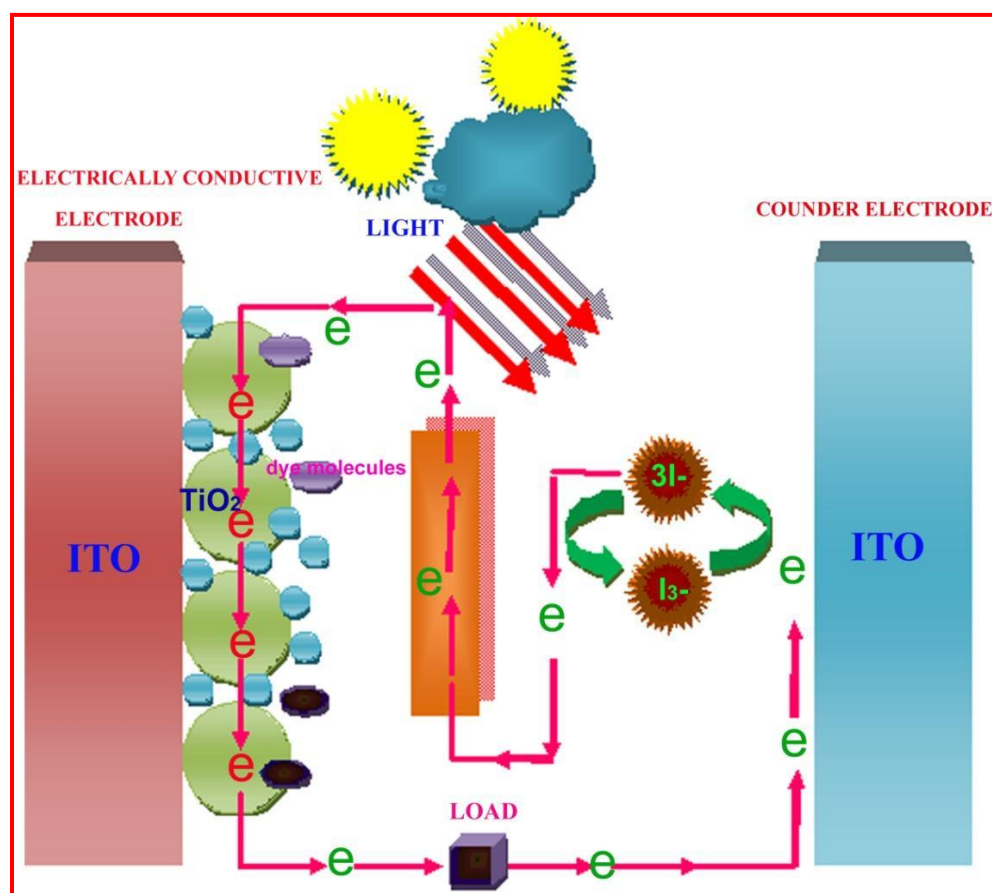


Figure 3. Schematic diagram of the dye-sensitized solar cells (DSSC's) solar cell.

Performance test by DSSC

This semiconductor directly transforms solar energy into electricity. A 120 W Xenon (Xe) lamp was utilised in the DSSC performance test to replicate sunlight (A.M. 1.8), and an I-V analyzer (Keithely 2450) was used to monitor current vs. voltage. The open-circuit voltage (V_{oc}), short-circuit density (J_{sc}), fill factor (FF), conversion factor (CF), and efficiency (n%) were all shown on the I-V curve (Figure 4). Based on the I-V curve, fill factor (FF) is defined as $I_{max} \times V_{max} / I_{sc}$. I_{max} and

V_{max} are the maximum output current and voltage, whereas I_{sc} and V_{oc} are the short-circuit current and open-circuit voltage, respectively. $n = I_{sc} \times V_{oc} \times FF/P_{in}$. Photons gauge the effectiveness of energy transmission [6].

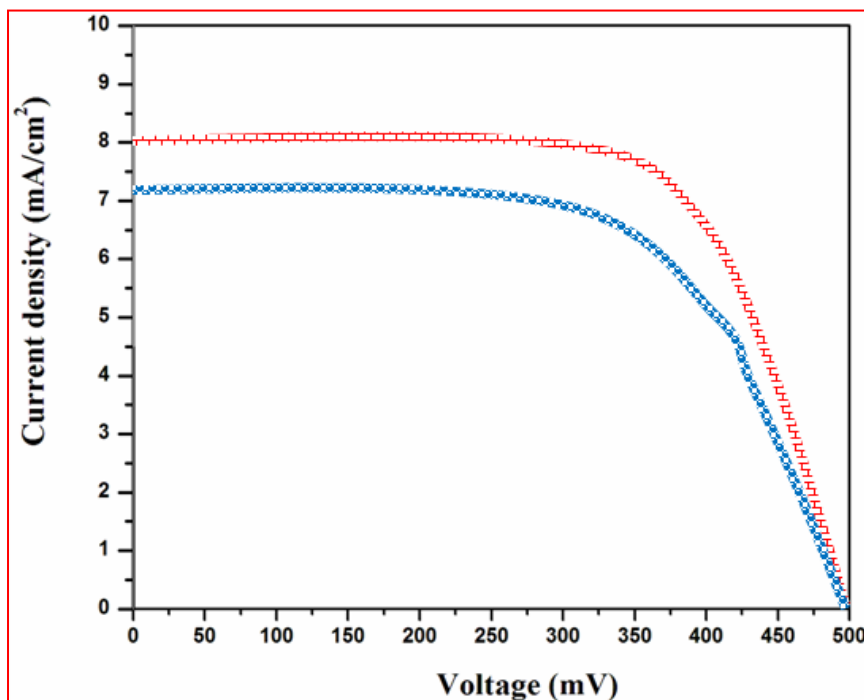


Figure 4. Current Density –voltage (I–V) curves for the DSSC's fabricated from (a) TiO_2 coated GCE in 0.1 M KCl and (b) Bi_2O_3 - TiO_2 nanocomposite material GCE in 0.1 M KCl.

Measurement of DSC Efficiency

TiO_2 was enhanced and used more effectively to improve dye-sensitized solar cells. Wider and larger TiO_2 surfaces enhance dye loading and electron transport [7]. Spectrum response of dye-sensitized solar cells is influenced by dye absorption (its effectiveness in sensing light and absorbing photons). The quantum yield throughout the whole charge injection procedure was utilised to gauge the device's effectiveness [8]. This amount may be measured experimentally using UV lamps and a monochromatic light source (a single wavelength source) [9].

$$I_{sc} = f(\lambda).$$

$$I_{sum} \lambda d\lambda \propto 0$$

$$IPCE = 1240(I_{sc}/)$$

Where;

The incident irradiance as a function of wavelength is given by I_{sum} .

I_{sc} : is the short-circuit current (mA/cm^2).

The incident radiant flux (W/m^2) is denoted by: Φ .

Its overall solar into electric power conversion effectiveness of the DSSC was therefore expressed as:

$$\eta = P_{max}/P_{in} = I_{sc} \cdot V_{oc} \cdot FF/P_{in}$$

Where;

The Fill Factor (FF) is the specified ratio = $I_{\text{max}} \cdot V_{\text{max}} / I_{\text{sc}} \cdot V_{\text{oc}}$.

Solar cell performance characteristics include ISC, VOC, FF, and conversion efficiency.

This study will focus on three DSSC designs: one with TiO_2 as the oxide, one with ZnO as the oxide, and one with both oxides. Each design makes use of conductive glass and natural colour (derived from raspberry juice) (regular glass coated with ITO). 20 days of testing will be used to compare the impact of the materials on both prototypes.

Synthetic Dye-Sensitized Solar Cells for Photovoltaics

On an FTO-plate glass substrate, TiO_2 and $\text{Bi}_2\text{O}_3\text{-TiO}_2$ nanocomposites were deposited as a photoelectrode. TiO_2 and a nanocomposite of Bi_2O_3 and TiO_2 coloured with ruthenium make up standard solar cells (535-bisTBA, N719). (N719) The maximum short-circuit current density (8 mA/cm^2), open-circuit voltage (500 mV), fill-factor (0.94), and efficiency over TiO_2 (7.2 mV) were achieved by the $\text{Bi}_2\text{O}_3\text{-TiO}_2$ nanocomposite cell utilising dye as a sensitizer (1.7 percent). It is electrocatalytic to use the $\text{Bi}_2\text{O}_3\text{-TiO}_2$ nanocomposite [10, 11].

[NBDSSCs]

Electrocatalytic $\text{Bi}_2\text{O}_3\text{-TiO}_2$ nanocomposite exist. Anthocyanins are compatible with DSSC technology, which has led to the development of natural dye-sensitized solar cells. Weak acids called anthocyanins are present in flowers, fruits, leaves, stems, and roots. Sarawak's state fruit is dabai. Peels from *Canarium Odontophyllum* contain anthocyanin. In Borneo, mangosteen and wild mangosteen are grown. Anthocyanin is found in fruit skin [12–14]. The photoelectrochemical characteristics of photosensitizers like "Black Olive" (*Canarium Odontophyllum*), "Mangosteen" (*Garcinia mangostana*), and "Wild Mangosteen" are examined in this work (*Garcinia Hombroniana*). A natural colour called "blueberry" (*Vaccinium Myrtillus*) was used. This research seeks to investigate the photoelectrochemical characteristics of anthocyanin-based DSSCs. We also looked at different dye concentrations, light sources, and counter electrodes.

The natural objects shown were cut into 0.5 cm by 0.5 cm fragments. Crushing materials in distilled water and removing solids produces natural colouring solutions. With distilled water, the samples were crushed until a coloured solution was produced. After the solids were taken out, the residual solution was put to use as a dye sensitizer. Using natural dye as a control (0.3 mM). Anthocyanin-containing photosensitizers.

Electrochemistry of Naturally dye-sensitized Solar Cells (DSSCs)

On fluorine-doped glass, $\text{Bi}_2\text{O}_3\text{-TiO}_2$ photoelectrodes are deposited (FTO-plate). A synthetic film coloured with fruit extract anthocyanin is used in conventional solar cells. Absorption is enhanced by enlarging the conjugated system of the hydrophobic spectator. From 400 to 650 nm, IPCE is more than 70%. This $\text{Bi}_2\text{O}_3\text{-TiO}_2$ based cell has a fill-factor (ff) under air mass (AM) of 0.671, a maximum short-circuit current density (J_{sc}) of 9.0 mA/cm^2 , a maximum open-circuit voltage (V_{oc}) of 750 mV, and efficiency (7.0 percent). Short-circuit electron transport is increased by $\text{Bi}_2\text{O}_3\text{-TiO}_2$ nanomaterial [15–17]. The DSSC in nature has a higher electrochemical activity.

CONCLUSION

The synthetic photovoltaic [SBDSSCs] and natural photovoltaic [(NBDSSCs)] characteristics of $\text{Bi}_2\text{O}_3\text{-TiO}_2$ nanocrystalline are necessary for its electrochemical applications. However, the electrical conductivity of $\text{Bi}_2\text{O}_3\text{-TiO}_2$ is higher than that of TiO_2 . The results demonstrated increased electrochemical activity in dye-sensitive solar cells that were made spontaneously. Even while DSSCs based on natural dyes were useful, those based on the N719 dye were far more so. Increased efficiency of the natural dye DSSCs might be attributed to their high current density values. When

comparing DSSCs manufactured from natural dyes, solar cells coloured with a coffee-based dye performed the best (0.45% efficiency). Due to its low electrical resistance and the strong absorbance qualities of the coffee-based dye-loaded DSSC, this solar device was able to reach the high current density values that eventually translated to a high degree of device performance. Overall, natural dyes as DSSC sensitizers hold promise due to their improved efficiency, reduced environmental impact, reduced production costs, and the potential for bespoke polychrome modules. When compared to the status quo, DSSCs seem like a promising option.

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