Fabrication of a new photo-sensitized solar cell using TiO2/ZnO Nanocomposite synthesized via a modified sol-gel Technique

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Abstract

The current research synthesized was carried out using a modified sol-gel Technique for titanium dioxide (TiO2) and zinc oxide (ZnO) nanocomposite. The morphology and optical properties of the synthesized nanocomposite were examined using a transmission electron microscope (TEM) and UV-Visible spectroscopy. The structure of the synthesized nanocomposite was proved using X-ray Diffraction (XRD). The particle size of the ZnO/TiO2 nanocomposites was found to be range between 11 to 27.37 nm. The product of TEM has proof of the inclusion in the ZnO matrix of spherical TiO2 particles. Also found were TiO2 sections attached to the ZnO-like rod-like particles., the ZnO / TiO2 Nanocomposites had better optical absorbing properties. The nanocomposite has been used to create a new photosensitizer solar cell with the efficiency of energy conversion of approximately 4.6%, using (E)-ethyl 4- ((4-nitrobenzylidene)) aminobenzoate as organic photo-sensitized (OPS) by (ITO/ TiO2/ZnO nanocomposite/POS/iodine/ silver (Ag) nanofilm/ ITO).

Keywords: solar cell, ZnO/TiO2 nanocomposite, modified sol-gel, organic photo-sensitized.

Introduction

Nanoscience is one of the emerging sciences which had an overwhelming appeal for scientists in all fields of life to concentrate on [1-6]. This research has become the most exciting and important field as it has high expectations and large opportunities [7-9]. semiconductor oxides have been modified in recent years to achieve the necessary properties for the intended purpose [10-12]. Specific methods have been employed such as doping and hybridization to improve the properties of these oxides, The synthesis of 1D nanostructures is one of the methods, for example, ZnO is known to have a variety of morphologies of nanostructures such as nanoneedles, nanocombs,
and nanostructures [13-15]. Doping is another way to improve their characteristics. Research has shown that adding second metal oxide increases the spectrum of the light harvest to increase more electron pairs. To improve its photocatalysis, transition metals like nickel, copper, lanthanum, and vanadium have been doped into TiO$_2$ [16-20]. Finally, semiconductor oxides were incorporated into their network to form composites with improved properties. Nevertheless, much work has been done in the past on the combination of TiO$_2$ and ZnO. ZnO and TiO$_2$ have both wideband gaps that only absorb UV light at 385 nm [21-23]. A composite can absorb − in 400 nm visible light and thus improve photoreaction [24]. The problem of electron-hole recombination can be overcome by an increase in the charge separation in the composite. It is proving beneficial to combine the two oxides to create a nanocomposite with improved physicochemical properties as ZnO and TiO$_2$ have a similar pH. Second, they also have approximate energy gap and nearly the same energy levels [25-28]. In the context of global warming, energy requirements, and fossil fuel decline, the development of clean and renewable energy technology plays a crucial part. One of the most feasible technologies is to turn solar power directly into electricity through solar cells [29,30]. According to its quick production process, low manufacturing costs and environmentally friendly benefits photo-sensitive solar cells are an alternative to traditional silicon-based solar cells. The photo-sensitized solar cell is a promising potential for silicon-based solar cell replacement. The performance of modern Photo-sensitized solar cells is becoming more and more competitive with advances in nanostructured semiconductors, high-performance sensitizers, and robust electrolytes [31]. Simple treatment, cheap materials, and a wide range of applications are a breakthrough for the development of the new photovoltaic cells on the Photo-sensitized solar cell market. The inverted device architecture in organic solar cell configurations has greater longevity than conventional architecture due to the use of air-stable high-work metal as an anodic electrode. The inverted device in organic solar cell configurations is longer than traditional architecture [32-34].

Zinc Oxide (ZnO) is the only one that is considered a good type of inorganic material that is given extensive attention to its quality features and novel applications in a wide field of expertise and devices. This has chemical, piezoelectric, pyroelectric, catalytic, and optoelectronic properties. In the making of optoelectronic sensors, displays and photovoltaic devices ZnO’s optical features play a significant role. The first semiconductor in Photo-sensitized solar cell development was this material. This material, ZnO is close to the titanium dioxide (TiO$_2$) bandgap and conductivity bands. ZnO’s mobility is higher than TiO$_2$, which helps the transportation of electron. In recent years, the use of ZnO and TiO$_2$ in a solar cell has significantly increased. The material was widely studied and synthesized with various morphologies [35-38]. Nanocomposites start as absorbed photon energy in a haliconductor with the advance of an electron from the valence band into the conduction band vacant. The electron is stimulated, and the valence band rises, creating electron and hole pair (e$^-$ and h$^+$)[39, 40]. In the present research, we have considered hybrid approaches to increase the performance of organic Photo-sensitized solar cells using the combinations of TiO$_2$/ZnO synthesized by a modified sol-gel technique with an organic compound as a Photo-sensitizer.

**Experimental**

**Materials:**

Before further purifying, all of the chemicals are qualitative and used as obtained. from Sigma-Aldrich.

**Synthesis of ZnO/TiO$_2$ nanocomposite**
In a modified sol-gel method, TiO$_2$\ZnO nanocomposite has been synthesized by adding 25 ml of 0.01 mole TiO$_2$ nanopowder to 25 ml of zinc-acetate dehydrate with magnetic stirring at 80 °C for 6 h. The pH has been adjusted to 11.5 after cooling at room temperature by gradually adding about 10 ml (drop by drop) of 1 M sodium hydroxide solution, stirring at 60 °C for 60 minutes. The gel product has been extracted and de-ionized water washed many times, and then dehydrated at 105 °C and calcinated at 550 °C for 3 h.

**synthesis of an organic photosensitizer**

The organic compound ((E)-ethyl 4-((4-nitrobenzylidene)amino) benzoate has been produced using the Microwave irradiation Method (Scheme1). Ethyl-4-aminobenzoit (30 ml, 0.001 mole) has added to 4-nitrobenzaldehyde (30 ml, 0.001 mole) using ethyl alcohol as a solvent. The blend was mixed and irradiated for 1 minute at six hundred watts microwave. The mixture was then cooled for 60 minutes in an ice bath. Dark yellow participants were isolated and recrystallized by cold methanol multiple times.

![Scheme 1. Procedure to synthesized organic photosensitizer (Schiff base compound)](image)

**Fabrication of organic photo-sensitized solar cell**

ITO glass (Indium tin oxide coated Glass) that has properties 10 ohm resistant and 85 % transmission was washed in an ultrasonic bath several times with ethanol, and deionized water, and then dried with an air blower for the extraction of the impurities. The following method was used to create an organic photo-sensitized solar cell (2 X 1 x 0.1 cm). 0.6 g of ZnO\TiO$_2$ nanopowder was mixed with 30 ml of ethyl alcohol to form a colloidal solution of the nanocomposite. The photoanode is collected with the colloidal solution using a dropper in the conductive side of the glass, then, for half an hour in the air, annealed at 200 °C. Upon cooling ZnO\TiO$_2$ nanocomposite, it was immersed overnight in ethanol at room temperature, using a solution of 0.3 M (OPS). The silver nanofilm is covered by an electrode counter with a conductive glass side. [41]. The electrolyte solution (I$^-$/I$^3$) was drop penetrates between photoanode and counter electrode to the working space by capillary action. Using binder clips, both electrodes were held together [see Fig 1].
Results and discussions

Fig. 2 presents the Nano ZnO\TiO₂ sample XRD pattern as synthesized. The sample of nano ZnO\TiO₂ is defined by standard JCPDS 01-082-1438 hexagonal structure. Only one reflection peak of Ti atom is present (2θ = 37.6° as figure 2). Observed in ZnO\TiO₂ nanocomposite, small atom integration in ZnO lattice sites Ti⁴⁺ ions are substituted for Zn²⁺ ions [42]. Due to the high diffracting peaks in XRD are higher and more symmetrical in the peak areas, the nanocomposites are highly crystalline and close to those reported by other researchers [43,44]. The Scherrer equation has been used to determine the crystallite size [45]:

\[ D = \frac{K \lambda}{\beta \cos \theta} \]  

Where, D is the crystallite size, K constant equal 0.9, λ is a wavelength of Cu-Kα radiations (0.15406 nm), β is the full width of the diffraction peak at half maximum (FWHM) and, θ is the angle of Bragg diffraction. The crystallite size ZnO\TiO₂ nanocomposite was 15.21 nm.
Fig. 3 exhibits the TEM images of ZnO-TiO$_2$ nanocomposite calcinated in the air at 550 °C for 3 h. Around homogeneous, sphere-like particles seemed to disperse well according to the XRD test, with an average size of around 26.12 nm.

The ZnO / TiO$_2$ UV-Vis spectra are shown in fig. 4. The absorption spectrum shows that the ZnO / TiO$_2$ nanocomposite absorption edge was 401 nm. The equation (Eg
\[ \frac{1240}{\lambda} \] was used for calculating the band gaps [26,27]. The bandgap of TiO\textsubscript{2} \textbackslash ZnO nanopowder was 3.1 eV.

![UV-Visible spectra of TiO\textsubscript{2} \textbackslash ZnO nanopowder](image)

Figure (4) UV-Visible spectra of TiO\textsubscript{2} \textbackslash ZnO nanopowder

Fig. 5 indicates the produced ((E)-ethyl 4-(4-nitrobenzylidene)amino) benzoate FTIR spectrum. With our group's ongoing desire to develop reliable, efficient, and environmentally friendly synthesis strategies for organic compounds obtained from Benzocaine, we report in the current study on the microwave-assisted synthesis of Schiff base compound, So further properties and characteristics of this compound were studied by IR spectroscopy of elementary analysis. The configuration of this compound was verified by their physical and spectroscopic properties. The compound's FTIR spectrum reveals the absence of (NH\textsubscript{2}) stretching bands at (3226, 3422) cm\textsuperscript{-1} and presence of (C = O) stretching bands at (1702) cm\textsuperscript{-1}, (C = N) stretching bands at (1632) cm\textsuperscript{-1} and NO\textsubscript{2} group stretching at 1509 cm\textsuperscript{-1} (asymmetric) and 1345 cm\textsuperscript{-1} (symmetric).

![FTIR spectrum of the Schiff base compound](image)
Figure. (5) FTIR spectrum of organic compound

The photosensitized solar cell parameter

fig 6. View the parameter of the photo-sensitized solar cell as a working electrode based on ZnO/TiO$_2$ nanocomposite synthesized. A solar simulator is made up of a 100mW / cm$^2$ halogen lamp for lighting the solar cell. Also, the solar cell energy conversion efficiency was measured:

$$\eta = \frac{p_{\text{max}}}{p_{\text{in}}} = \frac{V_{\text{oc}} \cdot J_{\text{sc}} \cdot FF \cdot P_{\text{in}}} {p_{\text{in}}} \times 100 \quad (2)$$

Where, $V_{\text{oc}}$ = photovoltaic open circuit, $J_{\text{sc}}$ = short circuit density, and $P_{\text{in}}$ = light power. The fill factor (FF) is also indicated by:

$$FF = \frac{V_{\text{max}} \cdot J_{\text{max}}}{V_{\text{oc}} \cdot J_{\text{sc}}} \quad (3)$$

Where, $V_{\text{max}}$ = maximum output voltage and $J_{\text{max}}$ = the and the current density, [12].

The solar cell parameters are $V_{\text{oc}} = 0.62 \text{ V}$, $J_{\text{sc}} = 0.017 \text{ A/cm}^2$, $V_{\text{max}} = 0.306 \text{ V}$, $J_{\text{max}} = 0.015 \text{ A/cm}^2$, and $FF = 0.435$. The conversion Efficiency is 4.6 %. by curent- voltage characteristics, the high parameter (circuit current and open-circuit voltage) are observed in our photo-sensitized solar cell. This is due to the ZnO/TiO$_2$ molecular structure (favorable for electron/hole pair separation) and redox-electrolyte diffusion rates.

Figure. (6) the properties of the photo-sensitized solar cell

Conclusion

One significant benefit of using the hexagon-shaped nanocomposite over all the other nanocrystalline geometric shapes is that their six arms can be easily attached to create a porous network. Branched nanocomposite increases the production of electrons in photovoltaic cells relative to other nanomaterials. The modified sol-gel technique was used in this project to synthesized ZnO/TiO$_2$ nanocomposite and diagnosis by transmission electron microscope and X-ray Diffraction. the size of ZnO/TiO$_2$
nanocomposite, about 11 to 27.37 nm. That whole-synthesized ZnO-TiO$_2$ nanocomposite bandgap is 3.1 eV which calculated by UV-Visible spectroscopy. The nanocomposite was used to create new photosensitization solar cells with a power conversion efficiency of approximately 4.6 %, using OPS as a photo-organic sensitizer.

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