Characterization and Fabrication of nanowires as a photoanode electrode for DSSC

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Abstract. In this paper enhance the improved efficiency of dye-sensitized solar cell by the development of a TiO₂ nanowires photoanode electrode and the counter electrode as a conductive polymer PEDOT: PSS / MWCNT nanocomposite. The photoanode electrode characterized by FESEM, XRD, DRS, TEM, BET-BJH and Raman spectroscopy. The performance of DSSC has been achieved by using N₃ with estimation the full photovoltaic parameters, the dye-sensitized solar cell demonstrated an open circuit voltage of 0.303 V and the fill factor 0.62 under the one sunlight irradiation.

Keywords: photoanode, band gap, Raman, Conductive polymer, and DSSC.

Introduction

The dye sensitize solar cell is a complex system that converts light into electricity [1]. The possession of titanium dioxide for high electrical insulation constant (ε=80 for anatase) has made it a good electrostatic shielding of the excited electrons that are injected on the surface of titanium dioxide, which comes from the oxidation of dye molecules and thus prevents the process of a union before the dye molecules are reduced by receiving the electrons produced from the oxidation process of the electrolyte [2]. The high surface area of the nanostructure such as nanowire reflects performance improvement of DSSC [3]. After un injection of the electron from the excited state of dye to the photoanode (such as the nanowire oxide) it will provide a direct path which in turn prevents the electron from recombination, high surface area and direct contact of the electron movement provided by the dense network nanowire [4]. It is also known that titanium dioxide has a high conversion efficiency of photo electrics compared with other oxides such as ZnO, Fe₂O₃ and In₂O₃ as well as with composite oxides such as 15 Graphene-MOF and 14 AL-ZnO. It also possesses photochemical stablility and is non-toxic, and therefore has become one of the best materials for application in electronic devices[5]. The present work involves study the efficiency of dye-sensitized solar cell after constructed it from nanowire the photoanode and the MWCNT/PEDOT: PSS as a counter electrode.
Experimental

Preparation TiO<sub>2</sub> Nanowire

Titanium dioxide nanowire was prepared using commercial titanium dioxide P25 (3 grams). It was mixed with 150 ml sodium hydroxide (10 M) water solution with continuous stirring for 15 minutes at room temperature and then placed in a Teflon-lined autoclave and heated for 12 hours at 160 °C and after cooled at room temperature and the resulting precipitate is washed with diluted hydrochloric acid (0.1M) and deionized water several times and then dried by drying oven at 80 °C and for 2 hours followed calcination by furnace at 700 °C for 1 hour.

Assembly of DSSC

Radiation for activation of ITO glass by U.V source, then fabrication of photoanode via electrophoretic deposition of TiO<sub>2</sub> nanowires which dissolved in a mixture of isopropanol, ethanol, iodine in acetone and acetylacetone solution. After that, the immersion of thin film in 5×10<sup>-4</sup> M of N<sub>3</sub> in acetonitrile at room temperature for 24 h. The counter electrode of MWCNT/PEDOT:PSS on ITO glass collects with the photoanode and fill up by the electrolyte included "0.5 M N-methyl-N-butyl-imidazolium iodide (BMI) + 0.1 M LiI + 0.05 M I<sub>2</sub> + 0.5 M 4-tert-butylpyridine" (TBP) in acetonitrile. The last step after the injection of electrolyte between two electrode performance of the DSSCs while the solar cells were irradiated with a light source at 100 mW/cm<sup>2</sup> [3]

Results and Discussion

Figure 1 illustration XRD patterns of the TNWs prepared at hydrothermal temperatures at 180° C for 12 hours, where XRD data a typical diffraction peaks corresponding to the reflection of the standard pure anatase TiO<sub>2</sub> material (JCPDS Card No.21-1272) a major peak centered at 25.35° can be ascribed to the (101) facet of anatase TiO<sub>2</sub>. No characteristic peaks of other impurities which indicates that the product has high purity [6]

![Figure 1](image-url)
In the Figure 2 illustrates Raman scattering spectra for titanium dioxide Nanowire where Raman peaks are located at (145 (Eg) 396 (B1g) 638 (Eg) cm$^{-1}$) and correspond to the typical peaks of the Anatase titanium dioxide [7].
Figure 3 Shows FE-SEM images and EDX spectra of TiO$_2$ NWs

From the Figure. 3 (a, b) represents the SEM images of TiO$_2$ Nanowire with different magnification images the diameter ranging 74.97-94.03 nanometer and the length 676.36 nm. Figure 3 (c) Shows Quantitative analysis of the EDX spectra in the Figure the presence of oxygen and titanium elements which can be taken as evidence of existence TiO$_2$ NWs.

Figure 4: TEM image of TiO$_2$ nanowire (obtained by the calcination at 700 °C for 1 hour).
Figure 4 The strength of the magnification showed that Nanowire had a rough surface and tended to form packets of nanowire as well as the appearance of small amounts of molecules. This was due to treatment with hydrochloric acid and deionized water after calcification and Procedure another calcination [8].

![Figure 5a](image1.png)

**Figure 5 a:** Isotherm adsorption-desorption nitrogen of TiO$_2$ nanowire according to the BET method.

![Figure 5b](image2.png)

**Figure 5 b:** Distribution of pore size of TiO$_2$ nanowire according to the BJH method.

It is clear from the Figureure 5 (a, b) The N$_2$ adsorption – desorption isotherms of the TiO$_2$ nanowire sample three was III type and the hysteresis loop not present. The (BET) surface area of TiO$_2$ nanowire is 8.849 m$^2$/g, pore volume 2.0332 cm$^3$(STP) /g and the BJH pore diameter is 12.52
nm compared with TiO$_2$ P25 Degussa (surface area 56 m$^2$/g, pore volume 0.250 cm$^3$ (STP)/g and pore diameter 17.50 nm) [9], pore size distribution with peak at 12.52 refers the presence of a mesoporous structure (2-50 nm).

Figure 6 (a): DRS spectra of TiO$_2$ nanowire

Figure 6 (b): Tauc plot for TiO$_2$ nanowire

Figure 6 a,b show the estimation of the optical band gap of the titanium dioxide nanowire after calcination. The calculation results show that the band gap is 2.82 eV that better than the report about TiO$_2$ NWs [10-15]. Thus, TiO$_2$ nanowires which used as photoanode electrode and MWCNT / PEDOT: PSS as a counter electrode "composites of conductive polymer" of the dye sensitized solar cell that instructs in the present study. Moreover, the electric parameters of the DSSC such as $V_{oc}(mV)$, $J_{sc}(mA)$, and the fill factor (FF) estimated 303 mV, 0.31mA, 0.62, respectively. It clear from the FF result the dye sensitized solar cell appeared a high conversion of electric energy with MWCNT/PEDOT: PSS counter electrode with the TiO2 nanowires that prepared in the present study.
Conclusion

Titanium dioxide nanowires was prepared as a photovoltaic electrode to reduce band gap energy of semiconductor and increase the electric output of the DSSC. In addition, used the MWCNT with a conductive polymer "PEDOT: PSS" as the counter electrode to obtain fill factor near to 0.62.

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