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ENHANCEMENT OF DYE SENSITIZED SOLAR CELL EFFICIENCY USING TiO_2/NiO NANOCOMPOSITE THIN FILM

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ABSTRACT

In this study, TiO_2/NiO nanocomposite was prepared using dry mixing method. The cell were fabricated using TiO_2/NiO as a semiconductor layer deposited on transparent ITO conductive glass (Indium-doped tin oxide, InO_2: Sn) using spin coating technique. The working electrode was then immersed in the solution of N-719 (Ruthenium) dye at room temperature for 24 h. A thin film of platinum (Pt) deposited on the ITO-glass substrate was applied as the counter electrode. The structures, morphological and optical properties of the films, were examined using X-Ray Diffraction (XRD), Field Emission Scanning Electron Microscopy (FESEM) and UV-VIS spectrometer respectively. The photovoltaic properties of DSSC were studied under an incident irradiation of 100 mW/cm^2. The energy conversion efficiency (η) of the DSSC with TiO_2 and TiO_2/NiO was 0.3% and 0.4 % respectively.

Keywords: Dye-Sensitizer Solar Cell; TiO_2/NiO thin films; Spin coating; energy conversion efficiency

INTRODUCTION

Nowadays, harvesting energy from sunlight become most important research area using photovoltaic technology after Micheal Grätzel reported in 1991[1]. A DSSC is formed of a nanocrystalline metal oxide semiconducting layer deposited on a transparent indium doped tin oxide (ITO) conductive glass, adsorbed dye on the semiconducting material, counter electrode and an electrolyte containing iodide and triiodide ions. Recently, several methods have been utilized to modify the structure of the working electrode (TiO_2 electrode) to improve the performance of the DSSC [2–3]. The attempts have been made to increase the solar power efficiency minimizing the charge recombination processes. In order to minimize the charge recombination, it is imperative control of electron transfer from nanocrystalline films and conducting ITO to redox medium. When p-type NiO and n-type TiO_2 integrates, a p–n junction will be formed between p-NiO and n-TiO_2. Theoretically, when p-type semiconductor NiO and n-type semiconductor TiO_2 form p–n junctions, the inner electric field will be formed in the interface. Formation of a n–p junction between TiO_2 and NiO oxide layers contributes to the enhanced photocurrent, photovoltage, fill factor and efficiency. In addition to the junction effect, NiO acts as a barrier for charge recombination leading to higher cell performance. In this study, the nanocomposite of TiO_2/NiO was prepared by mixing TiO_2 particles with nano-sized NiO powder using ball mill followed by sol-gel method. The influence of NiO in the energy conversion efficiency of DSSC was investigated.

EXPERIMENTAL

Preparation of photoanode TiO_2/NiO Thin Films

TiO_2/NiO thin film was prepared by ball milling the commercial TiO_2 (Degussa, P25) powder with nano-sized nickel (Ni, 99.9%, 20nm) particle to get the TiO_2/NiO composite particles. Then the composite TiO_2/NiO was sonicated with addition of deionized water, acetyl acetone and ethanol. Finally, 1 drop of triton-x 100 was added to the solution. The resulting solution was spin-coated on pieces of ITO transparent glass with an area of 10×10 mm^2 at a rate of 2000 rpm for 30 seconds. The films are annealed in furnace at 500 °C for 60 min.

Assembling of dye-sensitized solar cells

The dye-sensitized solar cell was fabricated by immersing the photoanode in ethanol-based commercial N719 (Sigma-Aldrich) dye solution for 24 h to ensure that the dye adsorbed into the TiO_2 porous film adequately. Then the photoanode of TiO_2 film and the platinum (Pt) counter electrode were sandwiched and sealed by using a Surlyn (Dupont) thermoplastic frame (25 µm thick) to assemble the DSSC. The space between the two electrodes was filled with a commercial electrolyte purchased from Solaronix (Iodolyte MPN- 100, Switzerland).

Measurements

The film crystallinity was analysed with X-ray diffraction Diffractometer (Siemens D-5000) with CuKα irradiation (λ=1. 5406 Å). The surface morphologies of the photoanode thin films were analyzed by a FESEM (Zeisz Supra, 3–30 kV) unit. The band gap of the TiO_2/NiO thin films was obtained using an ultraviolet-visible (UV-Vis) 900 Lambda Spectrometer (Perkin-Elmer, Wellesley MA, USA). Photovoltaic characteristics have been performed using GAMRY INSTRUMENTS G300 using physical electrochemistry software under simulated AM 1.5G solar illumination using a 100 mW/cm^2.

RESULT AND DISCUSSIONS

Crystallinity and Structural Analysis

Figure 1 shows the X-ray diffractogram pattern of TiO_2 and TiO_2/NiO thin films. The peak appeared for both in the pattern at (101), (004), (200), and (211) belongs to anatase phase as compared with JCPDS 78-2486. While peaks at (110), (101) and (211) were denoted for rutile phase as compared with JCPDS 86-0147. Besides the peaks of anatase and rutile, the diffractogram of TiO_2/NiO (b) thin films also show peak of nickel oxide at 2θ = 43.12 correspond to the diffraction from (400) plane (JCPDS 89-5881). This result demonstrates that the metal Ni powder turns into p-type NiO during the process of dry mixing [4].

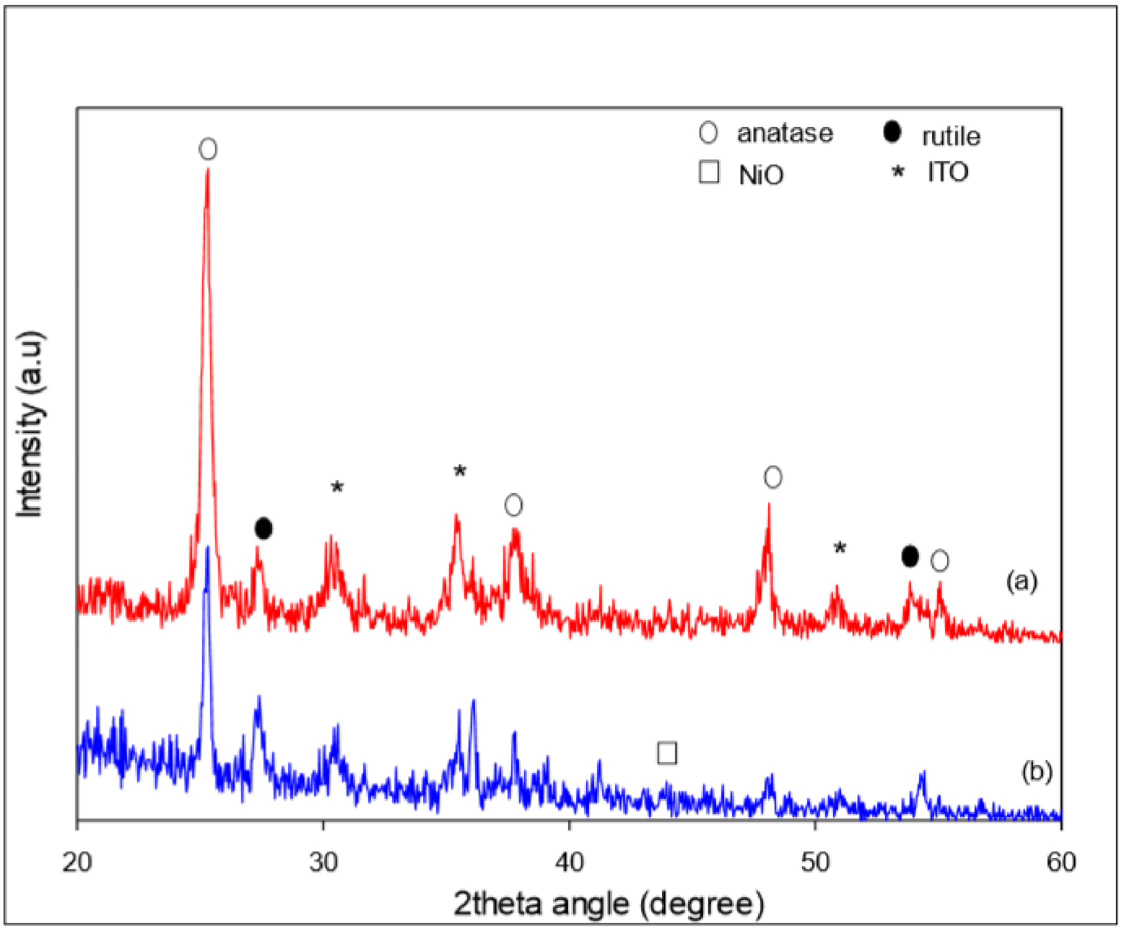

Figure 1: X-ray diffraction patterns of (a) TiO_2 thin film and (b) TiO_2/NiO thin film

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Morphological Analysis

Figure 2 shows the FESEM micrographs of (a) TiO_2 and (b) TiO_2/NiO thin films. As shown, both films shown porous structure. The porous TiO_2 film is to increase the level of dye absorption and to minimize the electron loss through the cell circuit [5]. The thin films from (a) TiO_2 shows the particle size about 20 – 80 nm while particle size for (b) TiO_2/NiO about 20 – 250 nm. The thickness of the active layer with (a) TiO_2 is 1.786 µm while the thickness for active layer with (b) TiO_2/NiO is 4.142 µm. Wang et. al observed that the optimum film thickness for absorbing the dye (such as N719) was in the range of 15 – 18 µm [6]

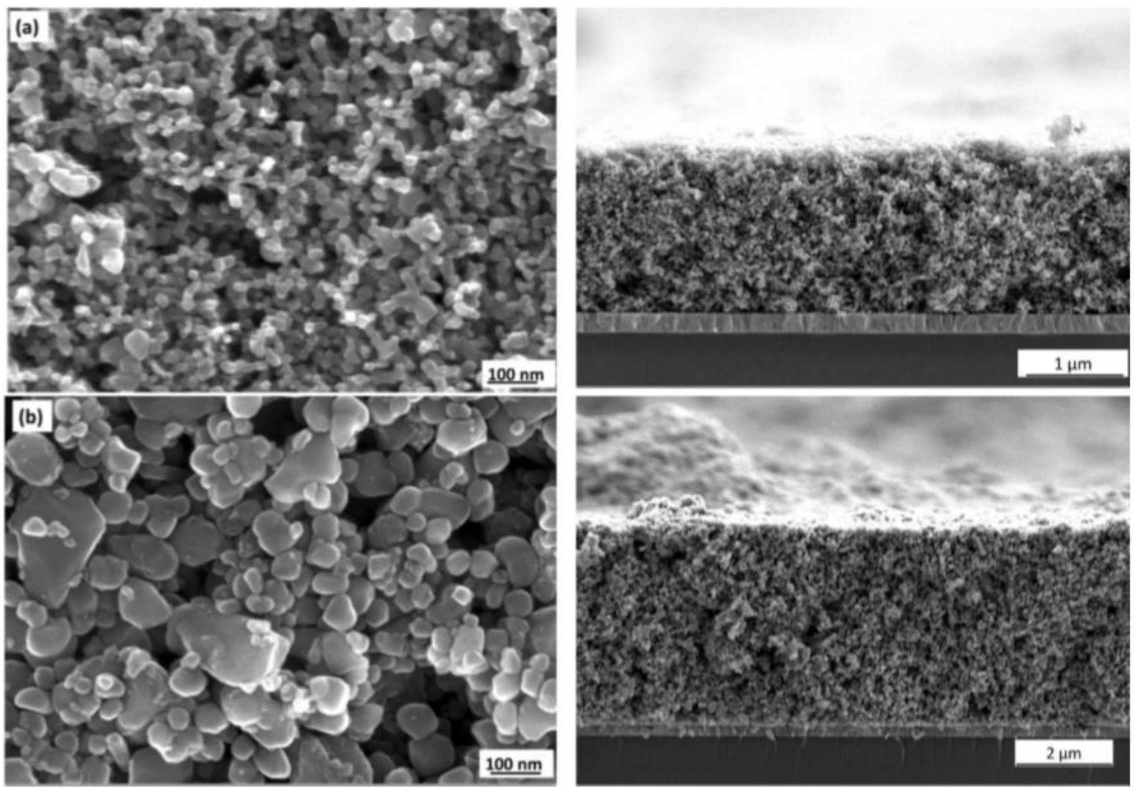

Figure 2: FESEM images of (a) TiO_2 thin film and (b) TiO_2/NiO thin film

Band Gap Analysis

Figure 3 show absorbtion spectra of the TiO_2 and TiO_2/NiO photoelectrodes. The absorbanced slightly increased with the adding of Ni powder. The increased absorbtion led to enhanced light harvesting and thereby increased short circuit photocurrent for the DSSCs as reported by L. Li et. al. [7].

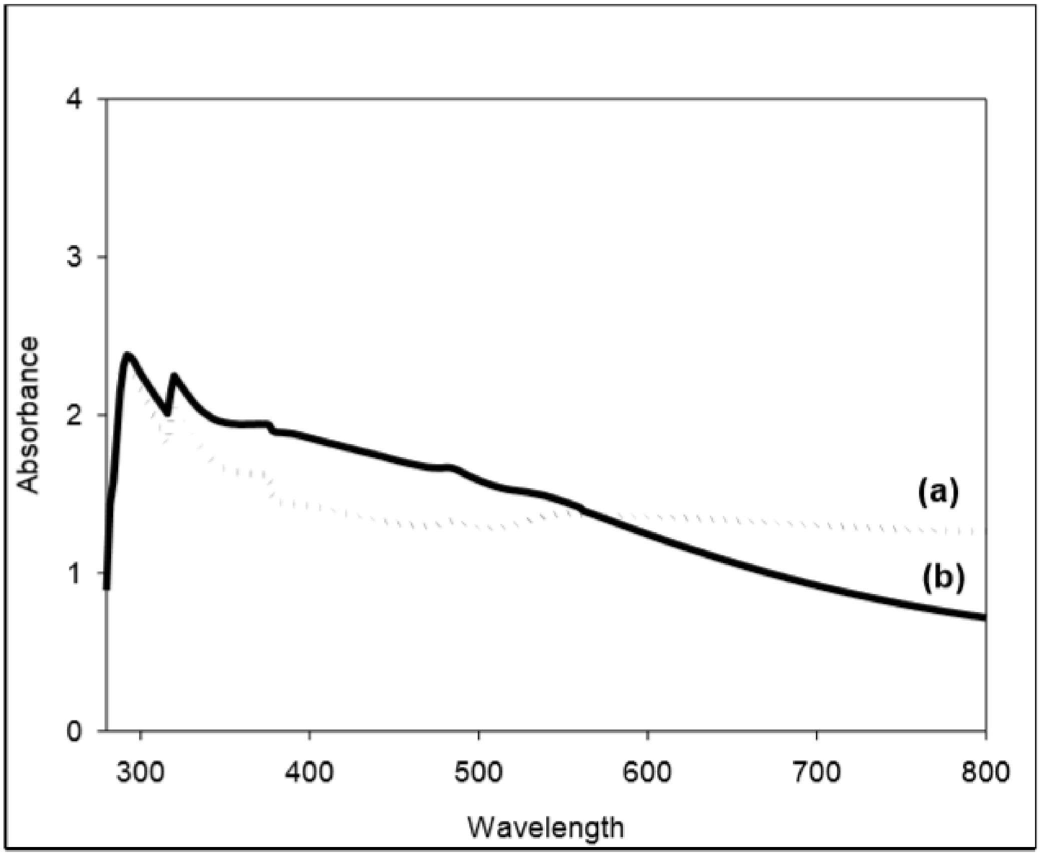

Figure 3: UV-Vis Spectra of (a) TiO_2 thin film and (b) TiO_2/NiO thin film

The band gaps of semiconductor materials are closely related to the wavelength range absorbed. Figure 4 shows that the increased of absorption wavelength of studied TiO_2/NiO films correspond to a decrease of the band gap. With TiO_2/NiO (a) having shorter band gap, it is easier to move excited electron from the valence band to the conduction band on the surface [7]

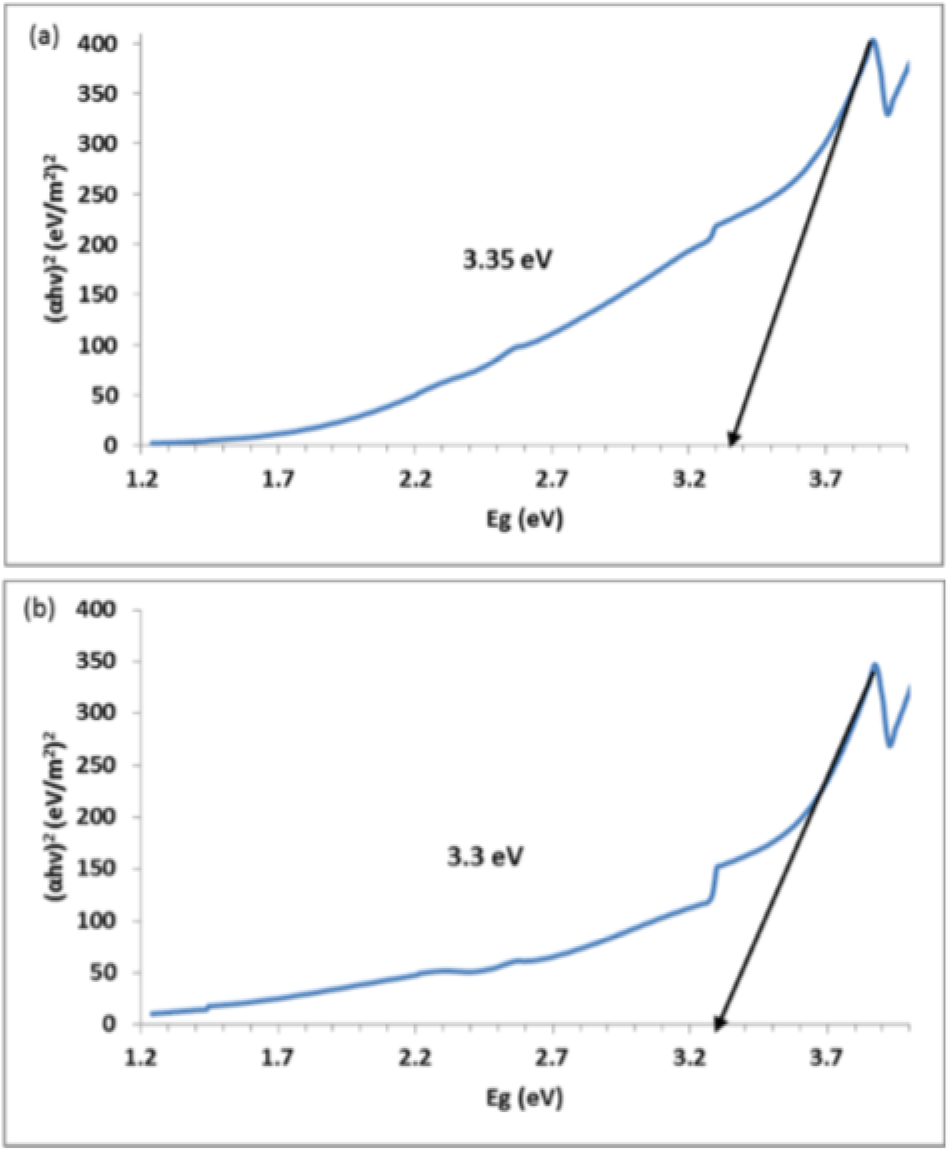

Figure 4: Band gaps of (a) TiO_2 thin film and (b) TiO_2/NiO thin film

V_{oc}. J_{sc}, η and J-V Curve of DSSC

Figure 5 shows J-V characteristic of the cells fabricated using TiO_2 and TiO_2/NiO electrodes under 100 mW/cm^2. As shown in the Table 1, it is clearly shows that the addition of Ni to TiO_2 particles enhance V_{oc} and η as compared to using TiO_2 electrode. The short circuit current density (J_{sc}) for TiO_2 electrode is higher compared to TiO_2/NiO electrode can be explained due to the agglomeration of TiO_2/NiO composite particles in the thin film may decrease the transportation rate of the electron [2].

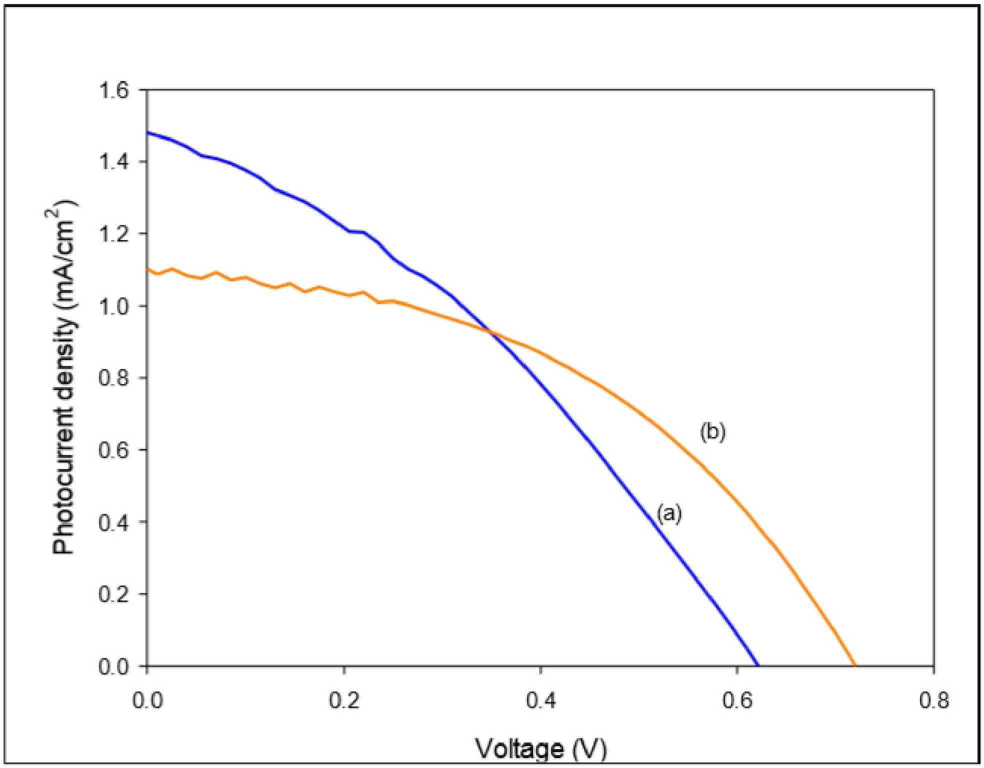

Figure 5: J-V characteristic of the cell (a) TiO_2 and (b) TiO_2/NiO at illumination intensity of 100mW/cm^2

Table 1: Performance of solar cells fabricated from TiO_2 and TiO_2/NiO electrodes

Sample	J_{SC} (mA/cm^2)	V_{oc} (V)	P_{max} (mW/cm^2)	FF %	η %
TiO_2	1.5	0.622	0.3	35.12	0.3
TiO_2/NiO	1.1	0.72	0.4	45.14	0.4

CONCLUSION

In this study the results show that additions of Ni to TiO_2 helps in enhancing energy conversion efficiency (η) from 0.3 to 0.4 %.

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