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Potato Skin Dye Sensitizer for Dye-sensitized Solar Cells Using SnO_2-ZnO Photoelectrode

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Abstract:

(x)SnO_2-(1-x)ZnO powder was mixed two difference ratios (50 mol% : 50mol%) and (25 mol% : 75 mol%) by simple technique solid state at 1000℃ for 3h. To get the homogeneous and small scale particle, mechanochemical milling process was performed. XRD technique was used to examine the crystal structure and phase identification of samples. As a result of XRD, it was found that SnO_2 and ZnO were clustered at 1000℃. SnO_2-ZnO Sol Solution was coated onto ITO coated glass substrate by Single Wafer Spin Coating method at 2000 rpm. The dye from potato skin was extracted by citric acid at 110℃ for 30 min. UV-vis spectrometer was used to observe optical properties of potato skin extract. To form the SnO_2-ZnO photoelectrode, the films were immersed in potato extract for 10 h. Carbon counter electrode was prepared and both electrodes were offset together with binder clip to form DSSC architecture. I-V characteristic of (x) SnO_2 - (1-x) ZnO cells were measured under illumination. The fill factor was calculated to be 0.52 and 0.54,respectively. The conversion efficiencies were determined to be 2.49% to 2.84 % for respective cells. The cell exhibited the potential to be a low-cost photovoltaic option.

Keywords
Photoelectrode, Potato Skin Dye, Conversion efficiency, Fill factor

1. Introduction

Silicon based solar cells were the most popular before the emerging of dye-sensitized solar cells. These solid-state junction devices have dominated photovoltaic industry. Since Grätzel et al. developed dye-sensitized solar cells (DSSCs), a new type of solar cells, in 1991 [1], these have attracted considerable attention due to their environmental friendliness and low cost of production. DSSCs use an organic dye which is extracted from plants to imitate the manner in which plants and certain algae convert sunlight into energy. Though these solar cells are still in relatively early stages of development, they show great promise as an inexpensive alternative to costly silicon solar cells and an attractive candidate for a new renewable energy source [2]. The advantages of DSSC are that it can be engineered into flexible sheets, low cost ofsensitization material production, ease of fabrication and low process temperature [3]. DSSCs are composed of a nanocrystallineporous semiconductor electrode-absorbed dye, a counter electrode, and an electrolyte containing iodide and triiodide ions. Numerous metal complexes and organic dyes have been synthesized and utilized as sensitizers [4]. In DSSCs, the dye as a sensitizer plays a key role in absorbing sunlight and transforming solar energy into electric energy [5]. In recent years, third-generation Dye-Sensitized Solar Cells (DSSCs) have been developed, which are receiving an increasing amount of attention from researchers because of their low-cost materials. The operational principle of DSSCs isvery simple: Photons interact with dye molecules to create excitons, which rapidly split to form electrons and holes. Electrons are attracted toward the photoelectrode and holes are transported by redox species at the nanoparticle surface in the electrolytes used in the DSSC [6]. Dye-sensitized solar cell (DSSCs) is low cost alternative to inorganic to semiconductor photovoltaic devices [7]. Tin oxide and zinc oxide are transparent conductive oxide. These materials present an optical transmission of about 80%.Their band gaps are large, comprised between 3,2 and 4.6 eV. They are used in microelectronics as thin films in gas sensor and mainly at the surface of solar cells as antireflective layers [8]. In this research, dye-sensitized solid-state solar cell, in which the liquid electrolyte, commonly applied in photoelectrochemical cells, was replaced by SnO_2-ZnO as the hole conductor and compared the performance of the solar cells with anthocyanin extracted from potato skin. This extracted dye was characterized by UV–vis absorption spectra. The photovoltaic properties of the DSSCs using potato skin extracts as sensitizers were studied.

2.Experiment

Preparation of SnO_2-ZnO Binary System

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(1-x) ZnO and SnO_2 (x = 50, 25 mol %) were mixed by solid state mixed oxide route. Mechanochemical milling process was performed to form the homogeneous and small particle size. Dry ball milling was performed for 5 h. After ball milling, it was mesh- sieved by 3-stages mesh and uniform particle sized powder was formed. (1-x)ZnO and SnO_2 (x = 50, 25 mol %) were annealed at 1000°C for 3 h in O_2-ambient. X-ray diffraction (XRD) was employed to study the crystal structure and phase analysis of all samples. The block diagram of sample preparation was shown in Fig. 1.

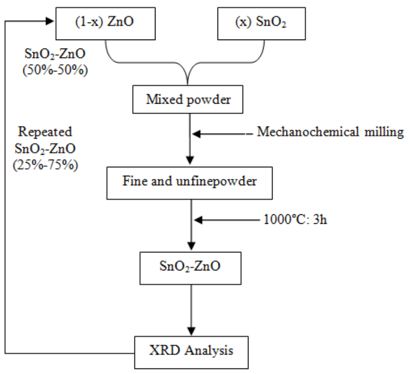

Fig.1 Block diagram of preparation for SnO_2-ZnO binary oxide

SnO_2-ZnO paste Preparation

SnO_2-ZnO paste was produced in the laboratory by using 6 g of SnO_2-ZnO powder, 9 ml nitric acid, a few drops of deionized water and a surfactant. Firstly, 9 ml nitric acid and 6 g of SnO_2-ZnO powder were mixed in a mortar and pestle. After grinding for 30 min, a few drops of deionized water and a surfactant (dish washing detergent) were added in a mortar and pestle. Suspension was then stored and allowed to equilibrate for 15 min. SnO_2-ZnO paste was formed.

Growth Mechanism of SnO_2-ZnO Film

Two drops of the white SnO_2-ZnO paste solution were applied on the area 1 in^2 window of glass slide by using a roller with quick downward sweeping motions. The glass of SnO_2-ZnO paste was placed on the oven at 450 $^{\circ}$C for 1 h and 30 min. The glass of SnO_2-ZnO paste was dried at room temperature.

Potato Skin Dye Extraction

Dye was made by potato skins. Potato skins were ground in a mortar and pestle then squeezed. The red solution of potato skin was sieved with the filter paper. After sieving for 1 h, this solution was turned to red solution. The red solution of potato skin was boiled at 100°C. After boiling, the solution was cooled down and then sieved for 3 times with the filter paper. Finally, the color of dye changed into reddish brown color.After sieving, 40 ml of dye solution and 4 ml of ethanol were mixed together. They were annealed for 2 h with heat controller at 100°C. After cooling down at the moment, they were sieved with the filter paper and potato skin dye extraction was achieved.

Preparation of carbon catalyst

Soot was used as carbon catalyst counter electrode. Firstly, 11.64 g of soot were put in a mortar and pestle. Then, 3 ml of hydrochloric acid (HCl) was poured drop by drop into a mortar and pestle. After grinding for 1h, the carbon solution was retained. It was used as a catalyst. The glass plate was coated by using spray method. The substrate temperature was 200°C. The glass plate was dried on the oven for 30 min.

Preparation of Iodine solution

2 g of iodine and 10 ml of ethanol were mixed in a beaker. The mixture was dissolved for 30 minand brown solution was obtained. By this time, the solution of potato skins was put in the petrify dish. The SnO_2-ZnO coated slide should have soaked in this solution for 1h and 30 min. SnO_2-ZnO Film was soaked in dye solution. It was dried on the oven for 1h at 100°C.

DSSC Architecture

Carbon coated glass plate was placed face down on the SnO_2-ZnO coated glass plate. The two glass plates must be slightly offset. Binder clips were used to keep the two slides together. One drop of a liquid iodine solution was then added between the slides. Capillary action will stain the entire inside of the slides. Then, the cell was measured both the voltage and the current output of the cell in the sun light. Ageing effect of SnO_2-ZnO dye sensitized solar cell was studied by measuring within one year.

Results and Discussion

XRD Analysis of SnO_2-ZnO powder

Structural properties of SnO_2-ZnO powder were examined by XRD technique. It was performed using monochromatic Cuk_{α} radiation (λ=1.54056 Å) operated at 40kV (tube voltage) and 30 mA (tube current). Simple was scanned from 10°C to 70°C in diffraction angle, 2θ with a step – size of 0.01^{o}. Fig. 2 (a) showed the spectrum of SnO_2- ZnO powder (SnO_2: ZnO = 50 mol%: 50 mol %). Fig. 2 (b) showed the spectrum of SnO_2-ZnO powder (SnO_2: ZnO = 25 mol%: 75 mol %). The crystal systems of SnO_2-ZnO binary structure with different composition at 1000°C for 3 h were listed in Table 1.

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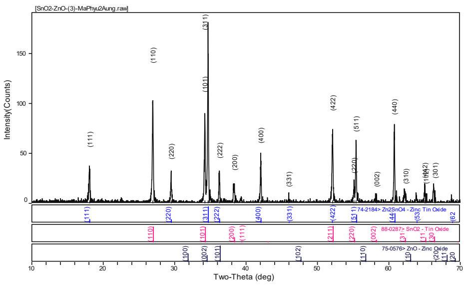

Fig. 2 (a) XRD profile of SnO_2-ZnO powder (SnO_2:ZnO=50 mol%:50 mol%)

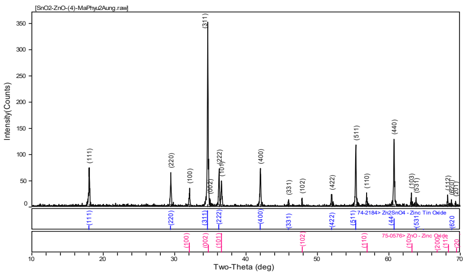

Fig. 2 (b) XRD profile of SnO_2-ZnO powder (SnO_2-ZnO=25mol%:75mol%)

Table 1 Crystal system of SnO_2-ZnO structure

(x)SnO_2-(1-x)ZnO Composition "x" (mol %)	System
50	Cubic
25	Cubic

UV-vis Analysis

The absorption spectrum of red potato skin dye was obtained from (UV-vis) spectroscopy. The wavelength range of spectrum lays between 300 nm to 700 nm. The intense peak absorption at 340 nm (100°C) was shown in Fig 3.

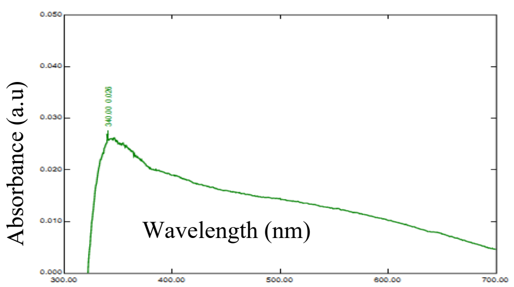

Fig. 3 Absorption spectra of potato skin dye extract

I-V Analysis

The current-voltage characteristics at different molar ratio of SnO_2-ZnO were represented in Fig 4. This figure showed the solar cell behavior of red potato skin dye sensitized solar cell. The maximum power point was obtained by tangential point on I-V curve. By drawing the maximum power point onto Y-axis, the maximum current (I_m) obtained. The detail analysis of short circuit current (I_{sc}), maximum current (I_m) and voltage (V_m), open circuit voltage (V_{oc}), conversion efficiency (η_{con}) and fill factor (F_f) of red potato skin sensitized solar cell at different molar ratio were shown in Table 2.

Table 2 Photovoltaic performance of SnO_2-ZnO based potato skin dye-sensitized solar cells

SnO_2-ZnO	J_m ($\mu A/cm^2$)	V_m (mV)	J_{sc} ($\mu A/cm^2$)	V_{oc} (mV)	Efficiency (%)	Fill factor (F_f)
50%-50%	110	33.8	159	44.7	2.49	0.52
25%-75%	119	35.8	163	48.4	2.84	0.54

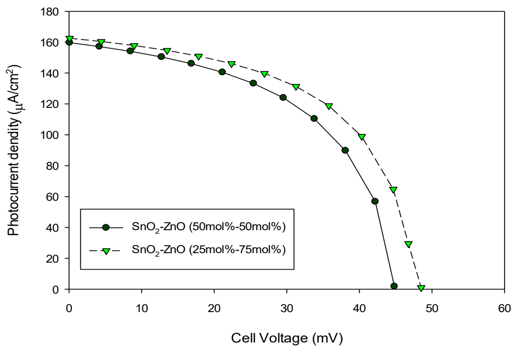

Fig. 4 Current-voltage characteristics curve for SnO_2-ZnO based on red potato skin DSSCs with different molar ratios

Conclusion

Preparation and characterization of SnO_2-ZnO powder have been implemented. As a result of SnO_2-ZnO (50 mol%:50 mol %), it was obvious that Zn-ion was clustered around SnO_2 powder and its crystal symmetry was observed to be cubic. From the XRD result of SnO_2-ZnO (25 mol%:75 mol%), it was obviously observed that Sn-ion was clustered around ZnO lattice and its crystal symmetry was also cubic. The incident light to electric energy conversion efficiency was found to be 2.49% for SnO_2-ZnO (50%-50%) photo-electrode and 2.84% for SnO_2-ZnO (25%-75%) photo-electrode. The experimental finding resulted from this research work indicated that the DSSCs with SnO_2-ZnO (25 mol%:75 mol%) was better performance than that of SnO_2-ZnO (50 mol%:50 mol %). The fill factor of both DSSCs was quite reliable for design consideration and leads to industrial skill. Thus, it meets the standard of the special requirements for the development of cost effective DSSCs with natural dye colourant.

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