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# Binary Oxide Photoelectrode with Coffee Natural Dye Extract for DSSC Application

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**ABSTRACT:** $SnO_2$ (x)- ZnO(1-x) binary system with two different $SnO_2$ composition (x= 3, 5 mol%) were prepared by solid state reaction at high temperature employed as photoanode for dye sensitized solar cell(DSSC) fabrication. $SnO_2$-ZnO binary oxide was characterized by X-ray diffraction(XRD) and UV-VIS Spectroscopy to examine their structure and optical properties. High performance carbon electrode was prepared onto glass and used as counter electrode. Coffee powder was used as natural dye-sensitizer. The improvement in device efficiency was achieved by larger $SnO_2$ composition. The overall power conversion efficiency increased from 0.18% for $SnO_2$:ZnO (3:97mol %) device to 0.26% for a device with $SnO_2$:ZnO (5:95mol %) photoanode.

**KEYWORDS:** Binary oxide, XRD, DSSC, conversion efficiency, fill factor.

## 1 INTRODUCTION

A dye-sensitized solar cell (DSSC, DSC) is a low-cost solar cell belonging to the group of thin film solar cells [1,2]. It is based on a semiconductor formed between a photo sensitized anode and an electrolyte, a photoelectrochemical system. The DSSC has a number of attractive features; it is simple to make using conventional roll-printing techniques, is semi-flexible and semi transparent which offers variety of uses not applicable to glass-based systems, and most of the materials used are low-cost[1-5]. In the fabrication of DSSCs, the choice of the metal oxide material and the transparent electrode is crucial to obtain efficient light harvesting, charge separation, and extraction. $TiO_2$ has been widely studied for efficient DSSCs [6-8], and a power conversion efficiency of 11% was reported [9]. Moreover, ZnO nanoparticles were investigated for DSSCs [9-15]. DSSCs fabricated using ZnO nanoparticles have achieved the second highest efficiency after $TiO_2$ [12-16]. Another crucial parameter in the fabrication of DSSCs is the sensitizing dye. Due to the dye significant role, considerable interest has been directed towards the development and improvement of new families of organic dyes and of metal complexes[11-15]. These complexes have a number of interesting features such as good absorption, long excited lifetime, and highly efficient metal-to-ligand charge transfer. The disadvantages of these complexes are high cost and sophisticated preparation techniques. Therefore, alternative organic dyes such as natural dyes have been studied intensively[13-18]. The main features of natural dyes are their availability, environmental friendly and low in cost[16-18]. In this research, $SnO_2$-ZnO binary oxide transparent films were prepared by spin-coating technique. Structure, optical and photovoltaic properties of $SnO_2$:ZnO binary oxide photoelectrode with the coffee natural dye extract (DSSC) was studied.

## 2 Experimental Procedure

$SnO_2$ and ZnO were separately observed by XRD to examine their purification. $SnO_2$(x) and ZnO (1-x) (x = 3, 5 mol%) were mixed and ball-milled for 20 h to get homogeneous powder . It was mesh-sieve with 3-step mesh to choose the small scale and uniform powder. It was annealed at 800 °C for 1 h and $SnO_2$-ZnO composite powder was successfully formed. Flow chart of experimental procedure for $SnO_2$- ZnO binary oxide powder was shown in Fig 1. After that $SnO_2$- ZnO binary oxide powder, 3 ml of methoxyethanol ($CH_3OCH_2CH_2OH$) was stirred with magnetic stirrer and these $SnO_2$-ZnO binary oxide solution was refluxed at 100°C by water bath for 1 h. After cool down at room temperature $SnO_2$-ZnO binary oxide paste was formed. Finally $SnO_2$-ZnO binary oxide paste was coated on glass substrate by spin coating. The flow chart of experimental procedure for $SnO_2$-ZnO binary oxide film was shown in Fig 2.

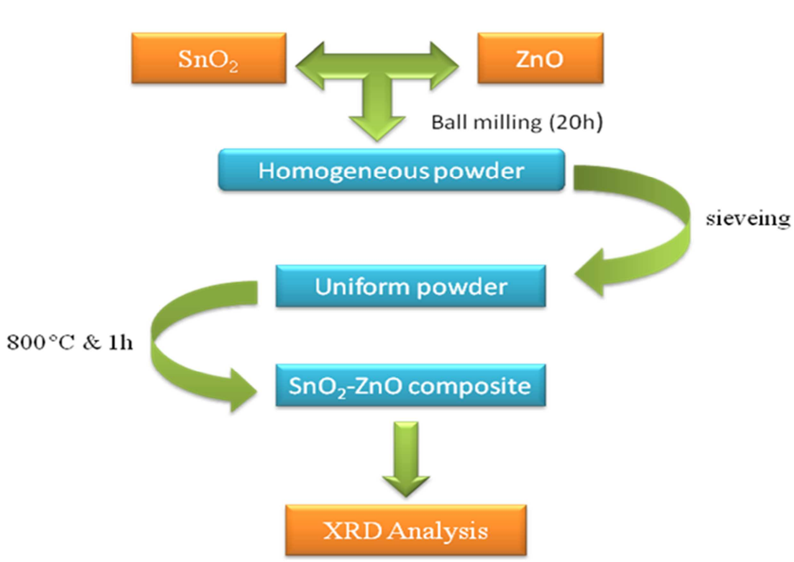



Fig 1 Flow chart of experimental procedure for $SnO_2$- ZnO binary oxide powder

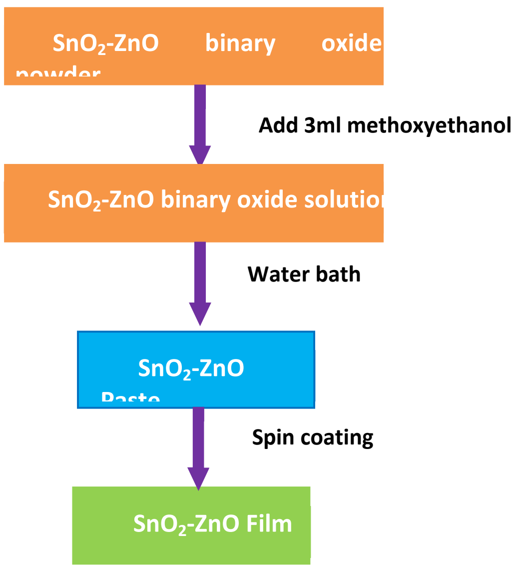



Fig 2 Flow chart of experimental procedure for $SnO_2$- ZnO binary oxide film

### 2.1 Preparation of Natural Dye-Sensitizer

Coffee seeds were used as natural dye-sensitizer in this work. Firstly, coffee seeds were ground in grinding machine and obtained the coffee powder. The powder was squeezed by blander for fine powder formation. And then, acetone was added into specimen for coffee solution and it was sieved by filter paper. After sieving, coffee solution was annealed with heat controller at 100 °C for 20 min. After cooling, it was sieved with the filter paper and coffee solution was obtained. Flow chart of experimental procedure for coffee natural dye sensitizer in pH level 5 was shown in Fig 3.The UV-Vis Spectroscopy was used to examine the optical properties of coffee solution. Fig 4 showed absorption properties of coffee dye extract solution. It could absorb near visible region and the optical band gap values obtained was 4.09 eV.


Fig 3 Flow chart of experimental procedure for coffee natural dye-sensitizer

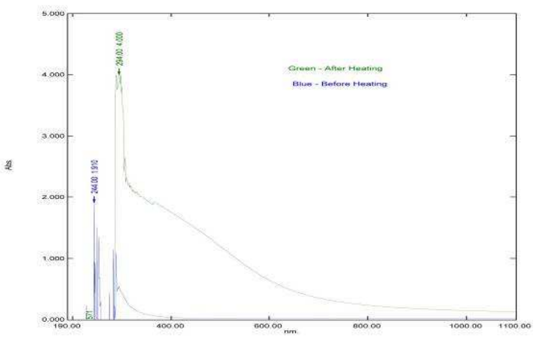



Fig 4 Absorption spectrum of coffee dye extract in pH level 5

### 2.2 Preparation of DSSC (Dye-Sensitized Solar Cell)

The black carbon was dispersed into the mixture solution of water and ethanol. After dispersion, carboxymethyl cellulose was also added and adhesive carbon paste was formed. It was coated onto glass substrate and annealed at 80 °C for 30 min. The glass plate was dried on the hot plate for 30 min. By this time, the coffee solution was put in the dish. The $SnO_2$-ZnO binary oxide coated slide should have soaked in this solution for 1 h and 30 min. It was dried on the hot plate for 1 h at 100°C, the slider was ready for use. Iodine solution was prepared for electrolyte. Carbon coated glass plate was placed the face downward on the $SnO_2$-ZnO binary oxide coated glass plate. The two glass plate 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 strain the entire inside of the slides. In this study, the cell was measured both the voltage and current output of the cell under halogen lamp.

## 3 RESULTS AND DISCUSSION

### 3.1 XRD ANALYSIS

Fig 5 (a-b) showed the XRD spectrum of $SnO_2$-ZnO binary oxide powder at 3:97 mol% and 5:95 mol%. The upper site of XRD profile was represented the observed $SnO_2$-ZnO spectrum while the lower site indicated the JCPDS (Joint Committee on Powder Diffraction Standard). All of diffraction peaks were consistent with hexagonal wurtzite structure for ZnO and tetragonal structure for $SnO_2$.Thus ZnO and $SnO_2$ were examined to be composite binary oxide form at both compositions. Table 1, showed the value of lattice parametre, bond length, hexagonality and crystallite site data of $SnO_2$-ZnO binary oxide powder.

Table 1. Lattice parametre, Bond Length, Hexagonality and Crystallite site data of $SnO_2$:ZnO Binary Oxide Powder

| Specimen | Lattice Parametre | | Bond Length (Å) | Hexagonality (c/a) | Crystallite size (nm) |
|---|---|---|---|---|---|
| | a (Å) | c (Å) | | | |
| $SnO_2$:ZnO (3:97 mol %) | 5.74 | 4.27 | 3.64 | 0.74 | 70.31 |
| $SnO_2$:ZnO (5:95 mol %) | 5.45 | 4.36 | 3.36 | 0.79 | 63.94 |

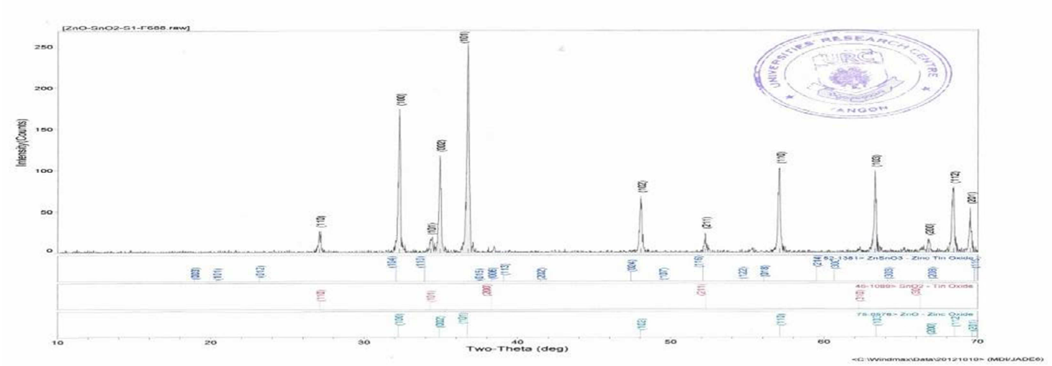



Fig 5 (a) XRD spectrum of $SnO_2$:ZnO (3:97mol %) binary oxide powder

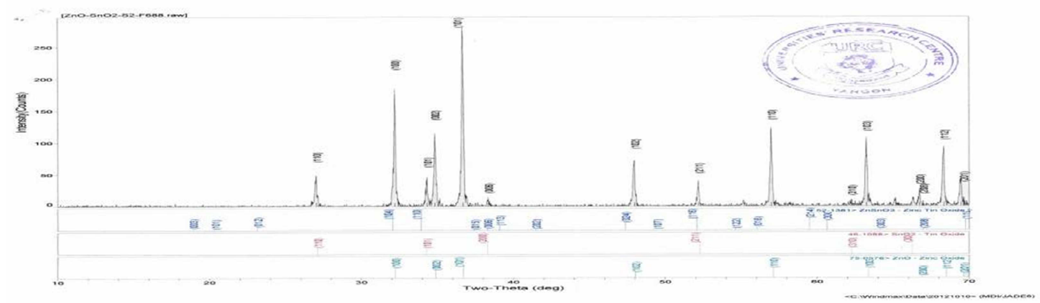


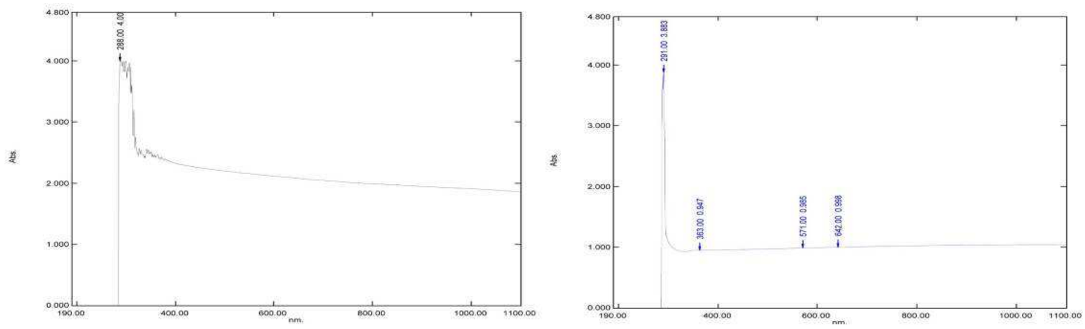

Fig 5 (b) XRD spectrum of $SnO_2$:ZnO (5:95 mol%) binary oxide powder

### 3.2 Optical Properties

Fig 6(a-b) illustrated the absorption spectra for $SnO_2$-ZnO binary oxide films. The absorbance was over 60% in the visible region for all samples. It could be seen from figure that absorption edge near 300 nm. The absorption edge shifted to longer wavelength as the various $SnO_2$-ZnO compositions. The optical band gap values obtained were summarized in Table 2.

Table 2. Optical Band Gap of $SnO_2$-ZnO binary oxide

| Specimen | Optical Band Gap (eV) |
|---|---|
| $SnO_2$:ZnO (3:97 mol %) | 3.91 |
| $SnO_2$:ZnO (5:95 mol %) | 4.08 |



(a) (b)

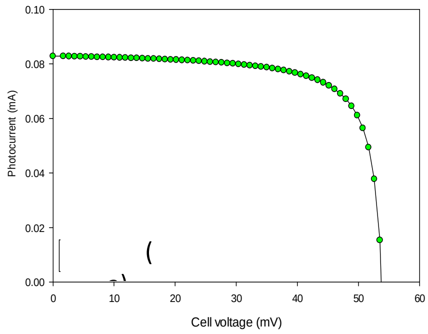
Fig 6 Absorption spectrum for $SnO_2$:ZnO(a) 3:97 mol % (b) 5:95 mol % binary oxide films

### 3.3 Photovoltaic Properties

Fig 7 (a-b) , showed the I-V curves of $SnO_2$-ZnO binary oxide photoelectrode DSSC cells under illumination(8104 lux). The summarized photovoltaic parameters for the two DSSCs were listed in Table 3.

Table 3 Photovoltaic parameters of $SnO_2$-ZnO photoelectrode with coffee dye sensitizer extract

| Specimen | $I_{sc}$ (mA) | $V_{oc}$ (mV) | FF | η(%) |
|---|---|---|---|---|
| $SnO_2$:ZnO (3:97 mol %) | 0.08 | 54 | 0.75 | 0.18 |
| $SnO_2$:ZnO (5:95 mol %) | 0.06 | 105 | 0.73 | 0.26 |



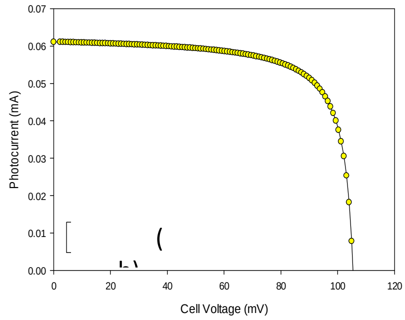




Fig 7 I-V curve of $SnO_2$:ZnO (a) 3:97 mol% and (b) 5:95 mol% binary oxide DSSC

## 4 Conclusion

$SnO_2$-ZnO binary oxide transparent films were prepared by spin-coating technique. From the results of powder analysis, $SnO_2$-ZnO binary oxide fine powder was formed at given temperature. The optical band-gap of $SnO_2$-ZnO binary oxide photoelectrode was same as the coffee dye extract for $SnO_2$-ZnO (5:95 mol %). Therefore, the efficiency of $SnO_2$-ZnO (5:95 mol %) was examined to be larger than that of $SnO_2$-ZnO (3:97 mol %). It might be attributed to the larger amount of $SnO_2$ into ZnO. The results showed that $SnO_2$-ZnO and coffee natural dye exhibited a promising application in the preparation of dye sensitized solar cell.

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