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The Effect of Post-Heating Temperature on of the Efficency Of Dye Sensitized Solar Cell (DSSC) with Using ZnO Thin Film and Dye from Dutch Eggplant Fruit (*Solanum betaceum*)

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Abstract. Synthesis of Dye Sensitized Solar Cell (DSSC) was successfully carried out using ZnO thin film and Red Dutch eggplant fruit (*Solanum betaceum*) as a sensitizing (dye) coloring molecule. Preparation of ZnO thin film was carried out on Indium Thin Oxide (ITO) glass substrate using sol-gel spin coating method with 1800 rpm rotation speed and post-heating with temperature variations of 400, 450, 500, 550 and 600°C. The results of the characterization of ZnO thin films with XRD showed all the crystal structures in the form of hexagonal wurtzite and ZnO crystal size of at least 24.1 nm at 400°C. UV-Vis characterization results showed the smallest energy band gap 3.20 eV at 600°C. The maximum efficiency of DSSC is 0.019 86 % at a temperature of 500°C.

Keywords: *Dye Sensitized Solar Cell* , *ZnO Thin Film* , *Dye from Dutch eggplant fruit*

4

1. Introduction

Dye sensitized solar cell (DSSC) is one of the potential candidates for next generation of solar cells, this is because it does not require high-purity material so that the cost of its production process is relatively low. The absorption of light in DSSC is carried out by dye molecules, and the separation of charges by inorganic nanocrystal semiconductors has a wide band gap. Semiconductors with a wide band gap will multiply electrons flowing from the conduction band to the valence band, which makes the photocatalyst reaction chamber and absorption by the dye will become more so that the spectrum becomes wide [1]. Dye used as a sensitizer can be either natural dye or dye synthesis. Dye naturally comes from fruits and plants, whereas synthetic dye generally uses organic metal based ruthenium complexes, containing heavy metals that are not good for the environment and quite expensive [2]. An interesting development of this solar cell technology is that this solar cell consists of a layer of nanoparticles (TiO_2 or ZnO) soaked in a photosensitizer [3].

The material used in this study is Zinc Oxide (ZnO) which usually appears as a white powder, almost insoluble in water. ZnO is a II-VI type-n semiconductor material that has band gap of 3.37 eV and excitation binding energy of 60 meV in room temperature and one type of metal that is in great demand in various types of applications such as sensors, solar cells and nanodivices [4 - 6]. In a previous study, ZnO layer with temperature variations (400, 450, 500, 550 and 600°C) was added with dye of Dutch eggplant fruit resulting in a maximum efficiency of 0.150% at 550oC [1]. Other studies



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with variations of ZnO coating and dye using Dragon fruit produced a maximum efficiency of 0.03% in 3 layers of ZnO thin film [7].

2. Experiment

Sol-gel synthesis was carried out by dissolving Zinc acetate dehydrate 4.0 grams into isopropanol solvent 35.42 ml then stirring with magnetic stirrer and DEA 1.92 ml was added. The solution in the form of 'gel' was then dripped on the ITO glass substrate with spin coating speed of 1800 rpm. Then the heating was done with post-heating temperature variations of 400, 450, 500, 550 and 600°C with a heating time of 30 minutes to form ZnO thin film samples. For each sequence of experiment of post-heating temperature, dye that extracted from the duct eggplant fruit is dripped on to the film and left for 24 hours. Each sample was stacked with a layer of carbon electrodes then clamped with a paper clip and connected to a series circuit to determine the value of current and voltage

3. Result and Discussion

3.1 ZnO Thin Film Crystal Structure

X-ray diffraction (XRD) diffraction pattern ZnO thin filmsamples result synthesis with sol-gel spin coating for temperature post-heating 400,450,500,550,and 600°C show in Figure 1. The figure shows that all ZnO crystal structures are hexagonal.

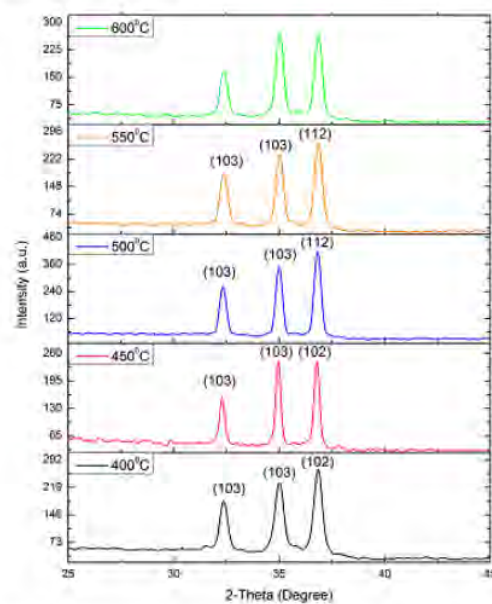


Figure 1. XRD spectrum of ZnO thin films with temperature post-heating 400, 450, 500, 550 and 600°C

ZnO crystal size for post-heating variation temperature 400, 450, 500, 550 and 600°C, were obtained using the Scherrer equation [8]:

$$D = \frac{0.9\lambda}{\beta \cos\theta} \quad (1)$$

where D is the crystal size, λ is the wavelength, β is FWHM (full width half maximum), θ is the diffraction angle whose results are shown in Table 1.

Table 1. ZnO thin film crystal size with post-heating temperature variations

Post-heating temperature (°C)	Phase	Peak		Crystal size (nm)
		2θ (degree)	FWHM (degree)	
400	ZnO	34.9904	0.30920	24.1
450	ZnO	34.9853	0.24640	33.8
500	ZnO	36.8627	0.30650	27.3
550	ZnO	36.7973	0.26010	32.2
600	ZnO	36.8307	0.31860	26.3

Based on Table 1, the crystal size at each calcination temperature ranged from 24.1 - 33.8 nm. These results indicate that the difference in crystal size obtained is not too significant

3.2 Optical Properties of ZnO Thin Films

The spectra of transmittances and absorbances of ZnO thin film samples with post-heating temperature variations from the UV-Vis test are shown in Figure 2 and Figure 3.

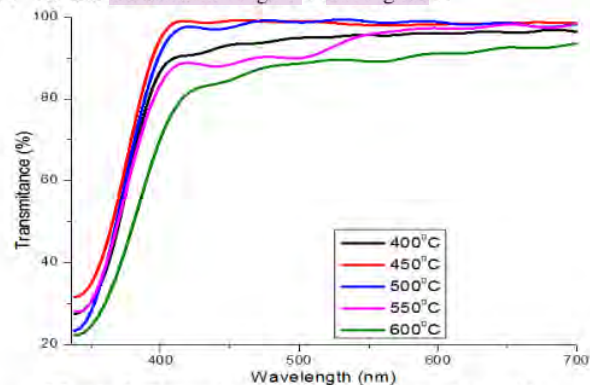


Figure 2. Transmittance spectrum for samples with Post-heating of 400,450,500,550 and 600°C.

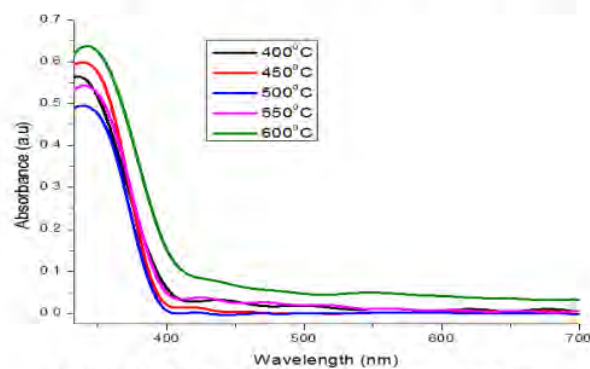


Figure 3. Absorbance spectrum for samples with Post-heating of 400,450,500,550 and 600°C

Transmittance spectrum curves for samples with post-heating temperatures of 400,450,500,550 and 600°C shown in Figure 2. The figure shows a sharp increase in transmittance values in the wavelength range 350 nm to 400 nm and stable at wavelengths > 400. Figure 3 shows a sharply decrease in absorbance value which occurs in the wavelength range 350 nm to 400 nm and stable at wavelengths > 400 nm. This indicates that the wavelength is the working area of the ZnO thin film.

The increase in temperature of the post-heating along with the increase in the transmittance value is in accordance with the heating mechanism, where the higher the heating temperature there will be a process of compaction of a set of powders and a strong bond between the granules and pores between the granules[9].

The energy band gap of the ZnO thin film with a variation of post-heating temperature of 400,450,500,550 and 600°C was obtained from the slope of the straight line fitting whose results are shown in Figure 4. The figure shows the ZnO thin film band gaps which is also shown in Table 2

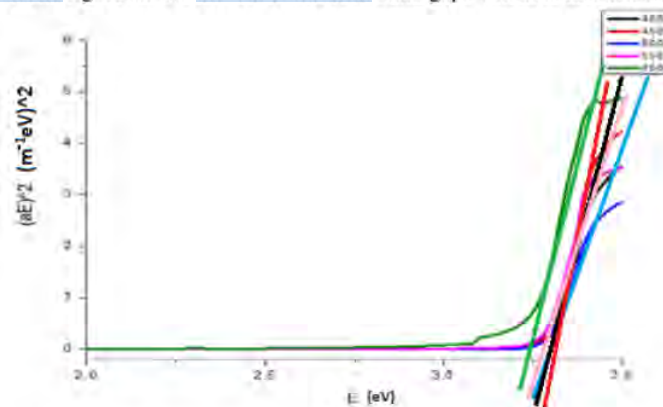


Figure 4. Curve $(\alpha h\nu)^2$ as a function of energy with variation post-heating temperature

Table 2 . Energi band gap ZnO thin film for post-heating temperature

post-heating temperature (°C)	Energy band gap (eV)
400	3,25
450	3,26
500	3,25
550	3,22
600	3,20

The increase in *post-heating* temperature causes a decrease in the width of the energy band gap, this is due to the increase in heating temperature will increase the occurrence of compaction and growth of grain particles accompanied by reduced border density between particles formed. When the heating temperature is increased, the energy supply for the coalition becomes quite large, and more crystalline grains will coalesce, which will further from better crystallization with a smaller energy gap. This is consistent with previous studies which stated that the increase in heating temperature along with the decreasing width of the energy band gap

3.3 Dye-Sensitizer Solution

11

The extract of Dutch eggplant fruit tested by UV-vis is shown in Figure 5. The figure shows the absorbance value of Dutch eggplant fruit is around 2.8 with a wavelength of around 285 nm. The absorbance value of this high Dutch eggplant fruit shows the high concentration of dye solution in absorbing the radiation given energy. The higher the absorbance value, the higher is the absorption of sunlight photons and the greater is the electrical energy.

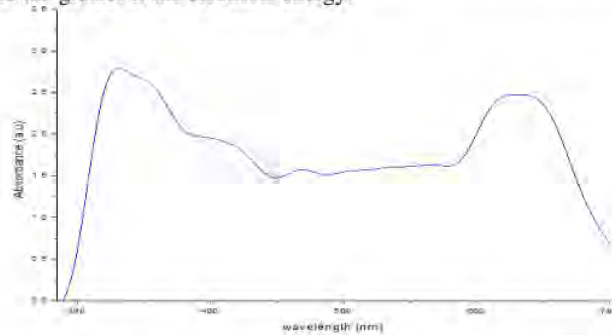


Figure 5. Graph of wavelength vs absorbance of fruit Dutch eggplant

3.4 DSSC Efficiency

Electrical tests are carried out on DSSC prototypes, with an electrical measuring instrument which aims to obtain the value of the voltage and the current density that is used to calculate the efficiency of the DSSC. Efficiency is the percentage of power ratio produced by DSSC compared to the power produced by the sun to illuminate the earth.

$$\eta = \frac{P_{max}}{P_{light}} \quad (2)$$

$$P_{max} = V_{max} \times J_{max} \quad (3)$$

The magnitude of the voltage value, the current density and the efficiency DSSC obtained are shown in Table 3.

Table 3. Rated voltage, current density and efficiency of DSSC

T (°C)	Vmax (mV)	Jmax (mA / Cm ²)	Pmax (w / Cm ²)	Pin (w / Cm ²)	Ef (%)	FF (%)
400	0.15	0.16422	0.002217	36.5	0.00607	15.1699
450	0.25	0.02000	0.050000	36.5	0.01370	34.2127
500	0.25	0.02900	0.007250	36.5	0.01986	32.2222
550	0.15	0.02250	0.020000	36.5	0.00046	22.3602
600	0.25	0.98890	0.247220	36.5	0.00673	33.1594

The efficiency value of DSSC increased from 400 to 500°C, and then dropped to a temperature of 550°C and then increased at a temperature of 600°C. The maximum efficiency value of DSSC is

0.019% at 500°C post-heating temperature. The results obtained in this study are different from the results of research using ZnO thin films and dye from Dutch eggplant fruit (*solanum betaceum*) [1].

4. Conclusion

Based on the results, it can be concluded that all crystal structures are hexagonal wurtzite and the minimum ZnO crystal size is 24.1 nm at 400°C. Transmittance and absorbance spectrum curves show an increase in the transmittance value which is quite sharp and a fairly sharp decrease in the wavelength range 350 nm to 400 nm and is stable at a wavelength > 400. The smallest energy band gap is 3.20 eV at 600°C. The maximum efficiency of DSSC is 0.019% at a temperature of 500°C.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7
