Conference Paper

Effect of Growth Temperature on ZnO Nanorod Properties and Dye Sensitized Solar Cell Performance

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Abstract Nanostructure of semiconductor materials zinc oxide (ZnO) is widely used in fabrication of solar cell devices. The performance of such devices is strongly depending on the nanostructures of the thin films used. In this paper reports the effect of growth temperature during synthesis of one-dimensional (1-D) anatase ZnO nanorod arrays through hydrothermal process facing their structure, morphology, and optical properties. The ZnO nanorod was first synthesized use the solution concentration and time fixed at 0.04M and 1 hour. The growth temperature were varied from 70, 80, 90 and 100 °C. The effect of growth temperature on the structural, morphology, and optical absorption of ZnO nanorod were studied by using X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), and UV–vis spectroscopy. The regularity, diameters, heights, and surface densities of the ZnO nanorods were increased with the growth temperature.The optimum results of FESEM characterizations showed that the grown ZnO nanorods have diameters of 64.14 ± 8.3 nm, heights of 363.72 ± 34 nm and surface densities of 182 numbers/μm^2 which was obtained at temperature of 90 °C. The optimum ZnO nanorod film was utilized as photo anode in dye sensitized solar cells. The DSSC yielded Jsc of 0.86 mA/cm^2, Voc of 0.49 V, and FF of 38 %, resulting in PCE of 0.16 %.

Keywords: growth temperature, one-dimensional, ZnO nanorod array, DSSC

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Received: 1 August 2016
Accepted: 18 August 2016
Published: 6 September 2016

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Selection and Peer-review under the responsibility of the ICoSE Conference Committee.

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1. Introduction

Research efforts on one dimensional (1-D) ZnO nanostructures such as nanorod still have high interest rates since a few decades ago because it has unique properties for many applications such as sensor, solar cell, electronics devices and etc.[1]. Numbers of scientific papers related on the ZnO nanostructure whether fundamental or practical application has become the evidence of their popularity. One of the main aspects in this research is to synthesize the ZnO nanorod with regular rod, small diameter, higher, and optimum of their surface densities but also an improved quality of their optical and electronic properties. Tian, Voigt [2] mention the extended and oriented nanostructures are desirable for many applications. Besides, the direct fabrication of complex nanostructures with controlled crystalline morphology, orientation and surface architectures remains a significant challenge.

Previously, oriented carbon nanotubes and ZnO nanorod shave been prepared by high-temperature vacuum deposition techniques. However, this method makes the structure of ZnO becomes damaged and increase the preparation cost. A variety of methods have been reported for fabricating arrays of aligned ZnO nanostructure, including vapour phase transport, metal organic chemical vapour deposition (MOCVD),and hydrothermal processes. However, vapour-phase transport and MOCVD usually require single-crystal substrates and high operation temperature.

In this paper, ZnO nanorod was provided through a hydrothermal process and the effect of the temperature during preparation step to their properties and DSSC performance is also investigated. This research is expected to find the lowest temperature to produce a better ZnO nanorod and applied of them on DSSC device with better performance and low cost.

2. Experimental

ZnOnanorods arrays were prepared on FTO glass substrates which were pre-coated with ZnO nanoparticles using hydrothermal process. ZnOnanorods which first seed layers prepared by alcohothermal process which contain of zinc acetate (Zn $(H_3COO)_{2.}$H2O) (98%, Sigma Aldrich) in ethanol to form ZnO seeded-substrate. The ZnO seeding substrate was subject to annealing at 350 °C in air for an hour and followed by immersing them in closed vial containing zinc nitrate hexahydrate (99%, Sigma Aldrich) and hexamethyl-tetramine (99%), Sigma Aldrich) in DI water. Next, the final concentration of that solution was maintained at 0.04 M and then inserts them in heating drying oven with various temperature such as 70, 80, 90 and 100^{o}C for 1 hour. The detail of the ZnOnanorods preparation processes has been described very well elsewhere [3, 4]. The resultant ZnOnanorod were characterized by X-Ray diffraction (XRD), Halo DB-20 UV-Vis spectrometer, and Carl Zeiss Supra 55VP field emission scanning electron microscopy (FESEM) to investigate their composite-structure, optical absorbance properties and morphology as well. Besides, the current (J)–voltage (V) curve of cell underactive area of 0.23 cm^{2}was recorded by a Keithley model 237 measurement, which were presented in the "Result and discussion "section.

ZnOnanorod will be used as photo anode in dye sensitized solar cells (DSSC). Installation of a DSSC solar cell device was made by clamp the photo anode with counter electrode and put insulating material between of them. Furthermore, the electrolyte is injected into the active area to make the DSSC device can work to convert sunlight coming through photo anode to become electric current. The DSSC performance of the solar cell with active area of 0.23 cm^2 was investigated by current–voltage measurement under 100 mW/cm^2 simulated AM 1.5 G sunlight using Gambry 1000 interface measurement unit.

The electrolyte used is s standard iodolyte. Dye solution prepared by dissolving 7.0 mg powder dyes N-179 in 20 ml of ethanol to a concentration of 0.3 mM. The counter electrode was used of 40 μl a liquid plastisol which in-situ coated on the FTO substrate

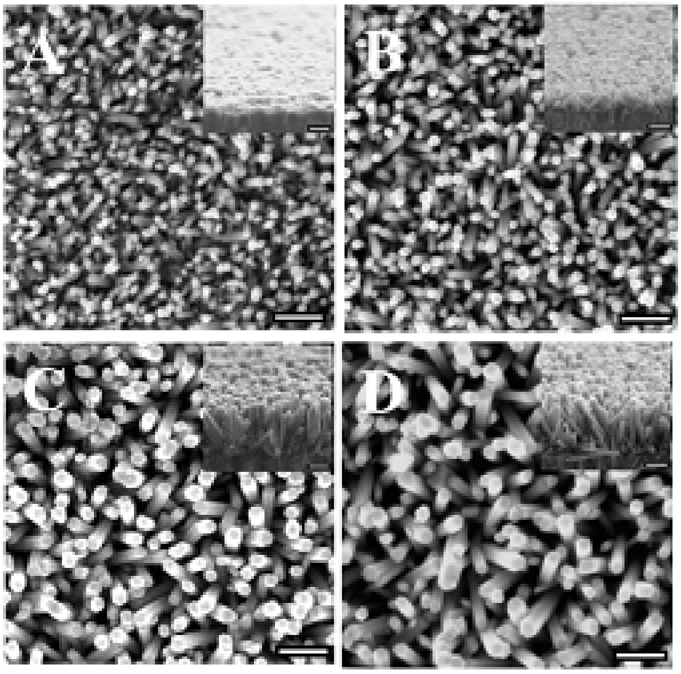

Figure 1: FESEM image variations in temperature (A) to 70, (B) 80, (C) 90 and (D) 100 ° C with scale bar 200 nm. The inset picture in each image shows a cross-sectional FESEM micrograph of the corresponding image (scale bar in 200 nm).

at 2000 rpm for 30 seconds. The same step was repeated up to 3 times on each substrate where each of them heated at 100 ° C for 10 minutes. Next, that substrate was annealed at 450^{o} C for 1 hour. Prior to the installation of solar cell devices do, photoanode consisting of ZnOnanorod grown on FTO soaked into 20 ml of N-719 dye solution with a concentration of 0.3 mM, for 2 hours. This immersion is carried out in a dark room, as N-719 is very sensitive and unstable under light radiation, photo anode left to dry in the air and kept so in this process photo anode is not exposed to light.

3. Result and discussion

The ZnONanorods has been successfully synthesized by using hydrothermal process. Fig. 1A shows the ZnOnanorods FESEM image on FTO grown at 70^{o}C followed by annealing at 350^{o}C for 1 h. In this case, the ZnOnanorod has not been formed perfectly. Meanwhile, by increase of grown temperature to 80^{o}C causes the ZnONanorod has been start to grow on the FTO substrate with average diameter about 33.69 nm (see Fig. 1B). Furthermore, this average diameter increases to 64.14 nm when it was grown at 90^{o}C with a uniform size and regular form as shown in Figure 1C. Lastly, the increase in the growth temperature to 100^{o}C even made a reduced the average diameter to 55.64 nm with irregular and not uniform size.

Fig 2. shows the XRD peaks of ZnOnanorods which was prepared by using a variety of grown temperature. This it found that the S70 sample XRD peaks observed are too weak which mean the growth processes has not occurred properly at this temperature. Nanorod growth started to grown with better form in samples S80 and S90. The sample

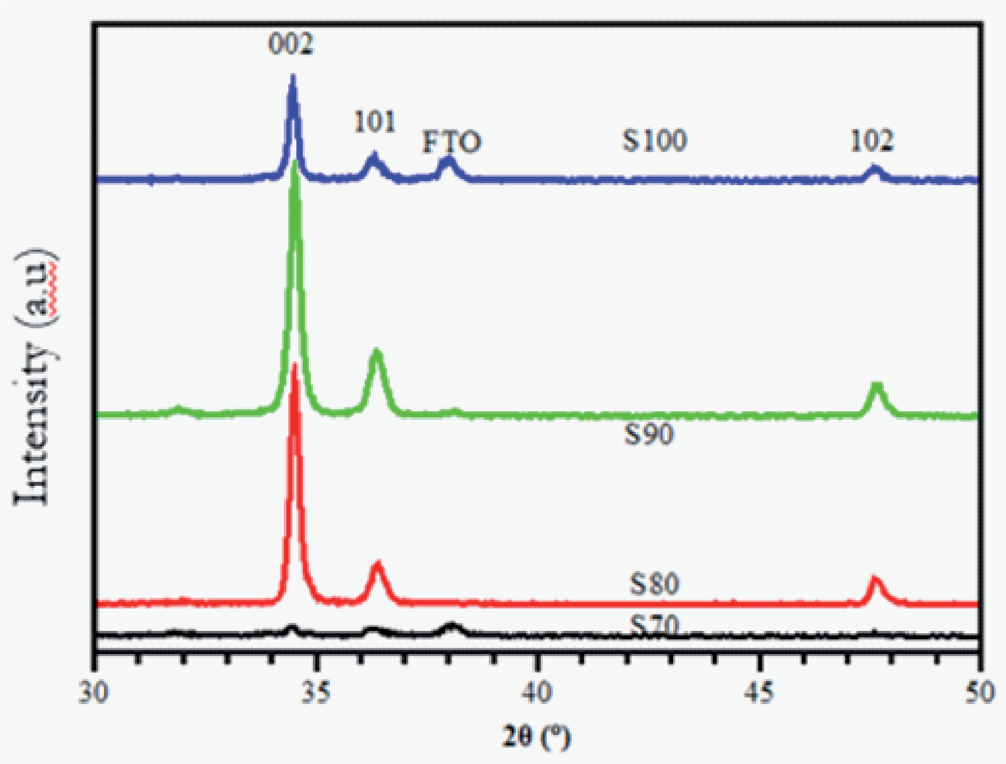

Figure 2: XRD spectra of ZnO nanorods at grown temperature of 70, 80, 90 and 100°C..

Label Samples	Voc (mV)	Jsc (mA/cm^2)		PCE (%)	FF (%)
S80	0.44	0.40		0.06	0.34
S90	0.49	0.86		0.16	0.38
S100	0.47	0.71		0.12	0.35

Table 1: DSSC performance parameters of ZnO nanorod grown at the growth temperature variations.

S100 shows the higher and there are additional peaks of FTO substrate. This means that, the growing process began to fail because of the water solvent boiling begins at a temperature of 100°C. As can be seen from these spectra, 3 main peaks namely at 2θ= 34.50, 36.50, and 47.80 where obtained. According to JCPDS file: No. 84-1286 for ZnO the peak was shown above associated with plane of (002), (101), and (110) phase. It was found that only the ZnO peak was detected in those spectra, showing the preparation step does not affect the impurities occurred. Besides, the border peaks show the formation of ZnO nanostructure, which good accordance with previous report [1, 5]. The intensity of the ZnO (002) increases and the peak width decreases with the growth processing time increased.

Figure 3 shows the current density–voltage (J–V) graph of DSSC constructed with plastisol as counter electrode under illumination of a simulated AM 1.5 G sunlight at 100 mW/cm^2. A typical DSSC exhibited a short circuit current density (Jsc) of 0.16 mA/cm^2, an open circuit voltage (Voc) of 0.49 V, and a fill factor (FF) of 38% which was obtain at sample S90. The detail of the DSSC parameter of the sample was described at table 1.

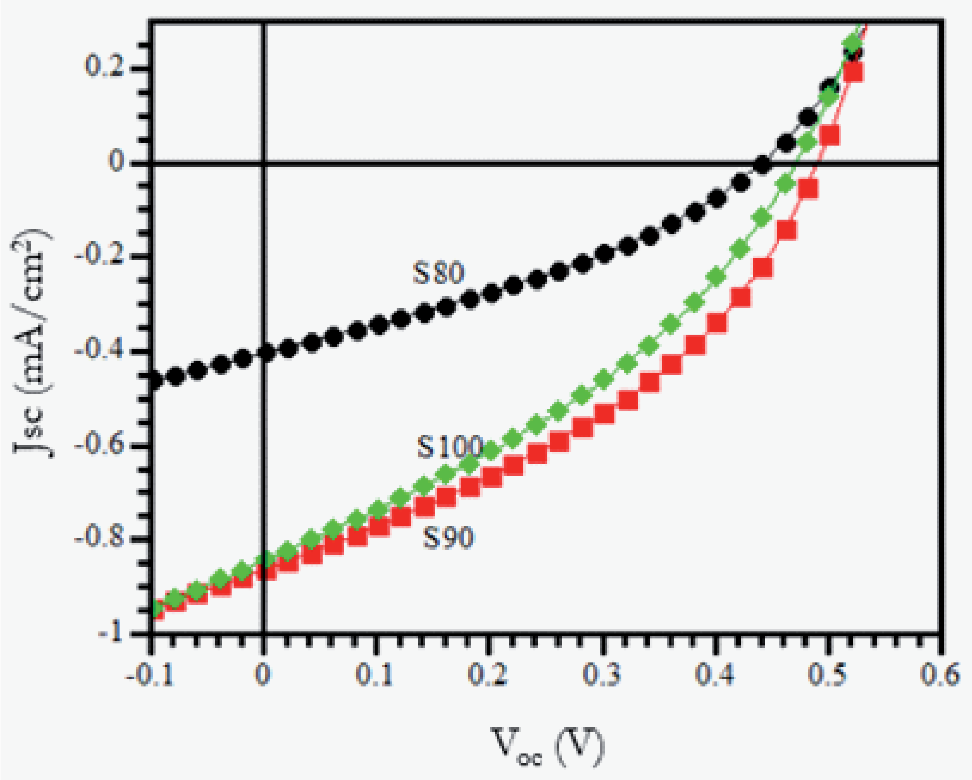

Figure 3: JV curve of a solar cell DSSC devices ZnO nanorod in bright conditions by varying the growth temperature.

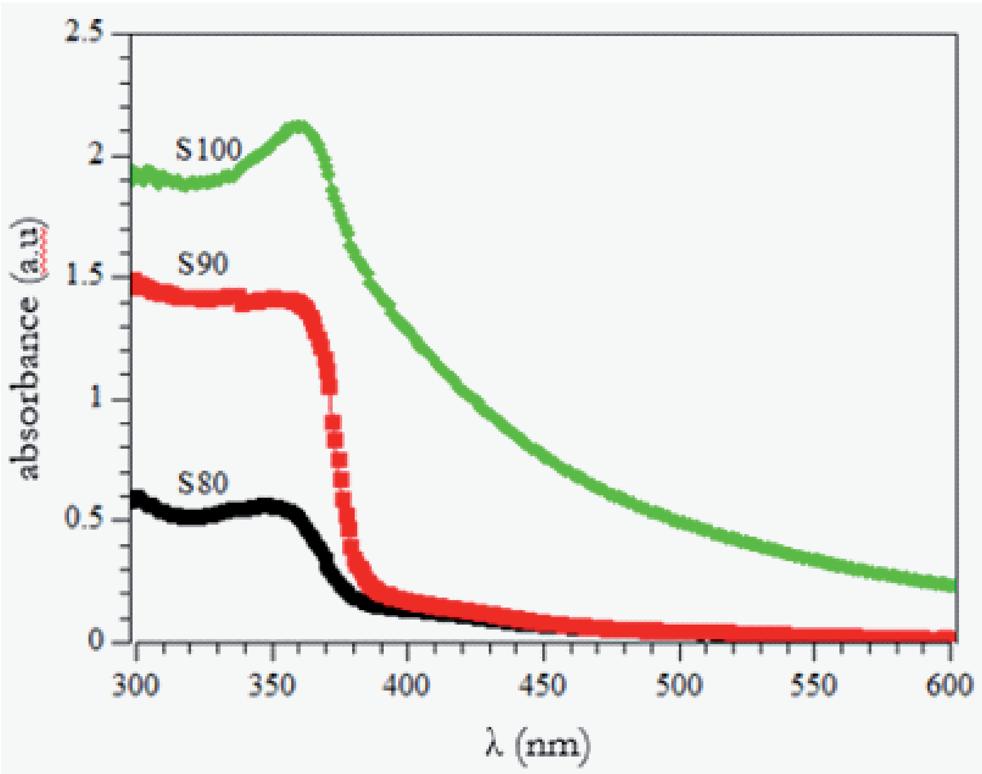

Figure 4: The optical absorption spectrum of ZnO nanorod grown by varying the growth temperature.

Fig 4 shows the optical absorption spectrum of ZnOnanorod grown with the growth temperature variations. The optical absorption of sample S80 and S90 is the same as the optical absorption variations sample first. While the S100 has the highest intensity of the sample, which corresponds to the sample has the highest elevation nanorod. Optical absorption for the S100 has a shoulder that is shaped like a top, which may be due to sample density nanorod has a small, high altitude that makes it easy to apply thermal vibrations of optical radiation

4. Conclusion

The study on the implementing of ZnONRs parameter at various growth temperatures have been performed. The broad peak, and clearly XRD spectra confirm the effect of ZnO nanorods formation. The best photovoltaic performance of DSSC with platisol as a counter electrode which exhibited the J_{sc} of 0.86 mA/cm^2, V_{oc} of 0.49 V, and FF of 38 %, resulting the PCE of 0.16 % was obtained at ZnONRs which prepared at growth period of 1h, growth temperature of at 90^{o}C.

5. Acknowledgment

This work has been carried out with the financial support by The Ministry of Science Technology and Innovation Malaysia under research grant Science Fund: 03-01-02-SF0836.

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