

Fabrication and Electrical Properties of ZnO Nanorods on ITO

Mohammad Aiman Mustaffa¹, Fara Ashikin Ali^{2,*} and Faiz Arith¹

¹Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

²Faculty of Electrical and Electronic Engineering Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding e-mail: fara@utem.edu.my

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ABSTRACT – Piezoelectric nanogenerator is one type of energy harvester as it can generate energy by using a mechanical force. ZnO has received lot of attention as a nanostructured material because of its unique properties, hence suitable for various applications. Thus, this paper presents the fabrication procedures for three samples of ZnO nanorods on ITO using hydrothermal method and their electrical properties. Results show the ZnO nanorods are grown on ITO after 5 h annealed. The highest average of diameter and length of the grown ZnO are 558 nm and 6.64 μm , respectively, after 7 h annealing. On the other hand, a linear characteristic of I-V characteristic is observed for each sample, hence, showed the higher conductivity of the ZnO nanorods.

1. INTRODUCTION

Piezoelectric materials are well known as one that used for energy harvesting applications [1]. Numerous piezoelectric materials have been studied such as barium titanate (BaTiO_3), zinc oxide (ZnO), and polyvinylidene fluoride (PVDF). Of them, ZnO has received a lot of attention as it has uniaxially oriented variants of nanostructures with multi-dimensions, including nanowires, nanorods, nanosheets, nanodiscs and thin films, economic growth on crystalline, biologically compatible as well as environmental friendly material [2-3]. ZnO based nanogenerator transfer mechanical energy to kinetic energy and vice versa, therefore, it is utilized for many applications such as sensors, transducers, and actuators.

In order to fabricate ZnO nanostructures with the same morphology, various synthesis methods have been reported [4]. One of them is a hydrothermal method. The hydrothermal method has gained popularity due to its simplicity and tolerable growth conditions. In addition, since the synthesis is carried out in aqueous solution, the growth temperatures are less than the boiling point of water [5]. Therefore, this paper presents the fabrication of ZnO nanorods using the hydrothermal method and their electrical properties.

2. METHODOLOGY

2.1 Synthesis of ZnO nanorods

This paper used indium tin oxide (ITO) as it displays higher conductivity and heat stability. The 2 cm x 2 cm in size of ITO was ultrasonically cleaned in

ethanol for 10 min, rinse with deionized water and dried for 5 min at 100 °C on a hot plate. The ZnO seed layer was deposited onto ITO using hydrothermal method. The seeding solution was prepared by using 1 mM zinc acetate dehydrate ($\text{Zn}(\text{O}_2\text{CCH}_3)_2 \cdot 2\text{H}_2\text{O}$) and 1 mM sodium hydroxide (NaOH) in ethanol. Initially, 0.013 g of zinc acetate dehydrate was dissolved in 60 ml ethanol and 0.003 g of NaOH was dissolved in 60 ml ethanol, separately. Both were stirred for 300 rpm in 30 min at 60 °C by magnetic stirrer and let to cool. Then, additional 60 ml ethanol was added to the zinc acetate solution. The NaOH based solution was added drop wise of 1 ml into zinc acetate solution with constant stirring of 300 rpm at 60 °C. Next, the solution was heated by double boiling process at 60 °C for 3 h. Finally, the seeding solution was deposited onto ITO and then annealed at 90 °C for 3 h to eliminate water and strengthen the electrical connection between ITO and ZnO seed layer.

For the ZnO nanorods growth process, 10 mM zinc nitrate hexahydrate ($\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$) and 10 mM hexamethylenetetramine ($(\text{CH}_2)_6\text{N}_4$) were used. 4.462 g of zinc nitrate hexahydrate and 2.103 g of hexamethylenetetramine were combined and dissolved in 500 ml deionized water. 50 ml of the growth solution was then poured into a petri dish which contained the previous sample. Then, annealing process was performed in an oven at 90 °C for 5, 7 and 9 h.

2.2 Characterizations of ZnO nanorods on ITO

The morphological properties and electrical properties of ZnO nanorods on ITO were studied by scanning electron microscopy (SEM) and Keithley multimeter, respectively.

3. RESULT AND DISCUSSION

Figure 1(a), (b) and (c) illustrate the SEM images for ZnO nanorods growth in 5, 7 and 9 h, respectively. It can be observed that the ZnO nanorods structure begin to shape after 5 h of growth and form a clear nanorod structure after 9 h annealed. The diameters and lengths of the ZnO nanorods after 5, 7 and 9 h annealed are shown in Table 1.

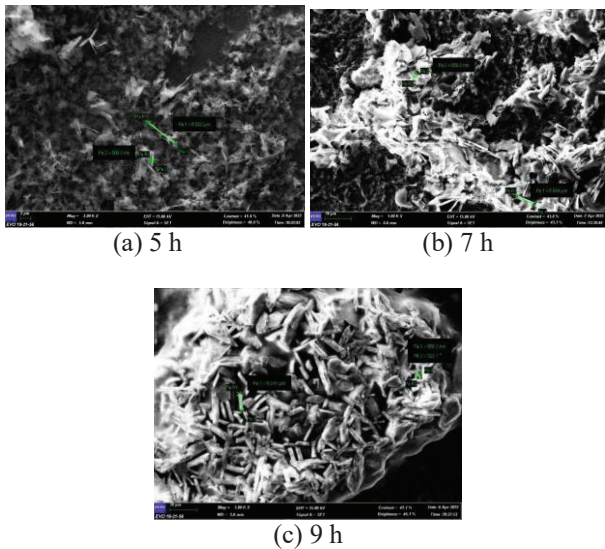


Figure 1 Structural image for ZnO nanorods grown at various annealing time

Table 1 ZnO nanorods parameters

Growth Time [h]	Diameter [nm]	Length [μm]
5	569	6.52
7	558	6.64
9	558	6.24

However, based on the SEM images, the smooth vertically aligned ZnO nanorods on ITO are difficult to determine. It might be due to the unstable produced nanostructures in the hydrothermal aqueous solution. This factor may cause the ZnO nanorods recombine, aggregate, and accumulate to form a bigger structure as shown in Figure 1.

Besides, the I-V characterization was carried out to analyze the conductivity of ZnO nanorods grown on ITO. Figure 2 shows the I-V characteristic for each sample. A linear characteristic was observed in these samples. It might be due to the small energetic barrier for the carrier. In addition, the highest current was 9.9 mA at 7 h annealed.

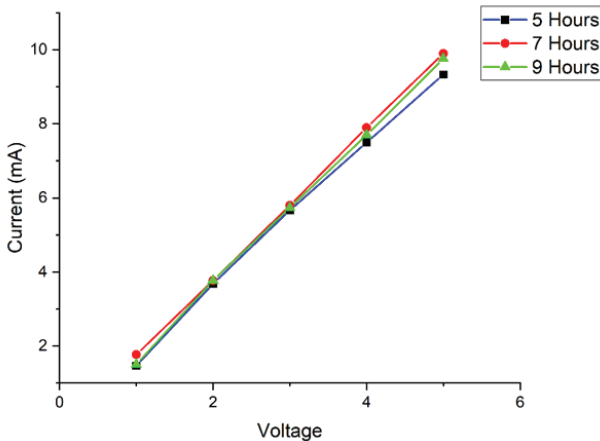


Figure 2 I-V characteristic of ZnO nanorods on ITO

4. CONCLUSIONS

In conclusion, this paper presents the fabrication of ZnO nanorods on ITO and their electrical properties. The ZnO nanorods was fabricated by using the hydrothermal method. Based on the SEM images, it was observed that the growth of ZnO nanorods on ITO started after 5 h annealed and above. On the other hand, the electrical properties were studied and showed a linear characteristic for each sample, hence, showed the higher conductivity. Therefore, the ZnO nanostructures are attractive candidates for applications as a piezoelectric nanogenerator.

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