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ZINC OXIDE NANORODS GROWTH BY CHEMICAL AND PHYSICAL VAPOUR DEPOSITION METHODS FOR SENSOR APPLICATIONS

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any other degree or qualification.

I hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

Zinc oxide (ZnO) has gradually become on demand semiconductor electronic devices application such as gas sensor, surface acoustic wave (SAW), solar cells and so on. It is found to be a versatile functional material that has a wide variety of growth morphologies. One of common morphology is nanorods which has been explored in this research. The conductivity and transparency of pure ZnO could be enhanced by doping with Aluminium (Al). Although the ZnO and Aluminium doped-zinc oxide (AZO) nanorods have been acknowledged as semiconductor devices by many researchers, the application of the grown nanorods to the existing commercialized semiconductor devices are limited, probably due to the incompatibility of lab-based wet process with the dry-process of existing complementary metal oxide semiconductor (CMOS) technology based manufacturing. In addition, ZnO functionality as sensing membrane for pH and oxygen (O_2) gas sensing have not yet been thoroughly investigated. In this work, metal-catalyzed growth of ZnO and AZO nanorods using thermal vapour deposition (TCVD) and also RF-sputtering were explored. The work also involves characterizing the grown nanorods and optimizing the deposition condition prior to application in O_2 gas sensor and extended-gate field effect transistor (EGFET) for pH sensing. Through the investigations, it was found that the ZnO nanorods growth by TCVD is the best when the catalyst annealing temperature was 15 min and the catalyst thickness was 15 nm. It was also found the gold (Au) catalyst was better compared to platinum (Pt) since the growth of ZnO nanostructures is more stable on Au catalyst compare than on Pt catalyst. Therefore, the further investigation on AZO growth by sputtering method was done by implementing the best ZnO nanorods growth parameter obtained from TCVD method. From the results, un-uniform AZO nanorods were grown on 5-nm Au catalyst at the RF power and deposition temperature of 200 W and 300 °C, respectively. The best sample obtain from both deposition were further investigated for pH sensing measurement and O_2 gas sensor. From the pH measurement test, it was found that sensitivity of ZnO nanorods sensing membrane is 19.2 mV/pH while AZO nanorods sensing membrane is 58 mV/pH. The sensitivity of AZO nanorods sensing membrane deposited by sputtering is better compared to the ZnO sensing membrane and it was close to the sensitivity allowed by Nerst equation (59.6 mV/pH). From the O_2 gas sensing test, the results shows that, the sensitivity of AZO nanorods toward O_2 gas flow is higher compared to the AZO thin films.

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CHAPTER ONE
INTRODUCTION

1.1 RESEARCH OVERVIEW

Zinc Oxide (ZnO) is great interest for various semiconductor electronic device applications. Its powerful optical characteristics such as direct and wide band-gap (Eg = 3.37 eV) in the near UV spectral region [1] and large free-exciton binding energy of 60 meV [2, 3] which allows excitonic emission process happens at or even above room temperature, makes it favourable for optoelectronic devices [4, 5]. It is also a unique material that exhibits semiconducting and piezoelectric dual properties, suitable for a wide range of applications such as piezoelectric devices [6], varistors [7], surface acoustic wave devices [8], transparent conductive oxide electrodes [9] and sensing membrane of extended-gate field effect transistor (EGFET) [10].

ZnO is found to be a versatile functional material that has a wide variety of growth morphologies such as nanocombs,-belts, and -tetrapods [11-13], besides the more common morphologies such as nanowires, -rods and nanotubes [14-16]. Nanostructures have the ability to improve the device performance while allowing smaller design and are able to greatly increase the sensor sensitivity due to the large area ratio of the sensing layer. Besides that, the doping impurity onto pure ZnO can enhance the performance of pure ZnO. Aluminum is a preferred material since it have several advantages such as low cost, nontoxicity and abundant of raw material [17].

Deposition methods and the variation of the parameters and growth conditions are mainly the cause of different types of nanostructures morphologies. Nanostructure of ZnO are usually synthesized by various kind of deposition methods such as chemical vapour deposition (CVD) [18], spray pyrolysis [19] and sol-gel [20]. Besides that, the nanostructures also have been deposited using physical vapour deposition such as evaporation, ion beam and also sputtering [21-23]. Although nanotechnology-based researches and reports are mushrooming, however, very little successfully penetrate into the manufacturing and commercialization zone. One of the possible factors is due to the incompatibility of research lab-based processes with the