UNIVERSITI TEKNOLOGI MARA

FABRICATION OF MONO AND DUAL LAYERED ZINC OXIDE NANOROD ARRAY-BASED HUMIDITY SENSORS

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ABSTRACT

Humidity sensors have been fabricated using undoped, iron (Fe)- and tin (Sn)-doped zinc oxide (ZnO) nanorod arrays, and dual layered Sn-doped ZnO/SnO_2 core-shell nanorod arrays. These nanorod arrays were deposited on aluminum (Al)-doped ZnO seed layer-coated glass substrate. The nanorod array properties and the fabricated humidity sensor performances were analysed using field emission scanning electron microscopy (FESEM), transmission electron microscopy (TEM), X-ray diffraction (XRD) measurement, ultraviolet-visible-near-infrared (UV-vis-NIR) spectrophotometer, two-point probe current-voltage (I-V) measurement, and humidity sensor measurement system. In this study, several parameters were studied regarding the growth of ZnO nanorod arrays for humidity sensor application, including different doping elements (Fe and Sn), different Sn concentrations, different immersion times and different SnO_2 coating times. Based on this analysis, it can be concluded that the performance of the humidity sensor was closely related to the impurities, nanorod dimensions (i.e., the diameter and length), crystallinity, and surface condition. In addition, Fe- and Sn-doped ZnO nanorod array-based humidity sensor were successfully fabricated using immersion method. Based on the sensor performance, both doped samples have good response to humidity. However, Sn-doped ZnO nanorod array-based humidity sensor possesses superior sensitivity to humidity. The optimisation on concentration of the Sn-doping was conducted. Sn-doped ZnO nanorod array-based humidity sensor at 1.0 mM Sn concentration produced the best sensitivity to humidity of 3.04 compared to other samples. Furthermore, the study on immersion time was also conducted. Sn-doped ZnO nanorod array-based humidity sensor immersed for 60 min was observed to produce the best sensitivity to humidity with the sensitivity of 3.92. It is concluded that fabrication of ZnO nanorod arrays using 1.0 mM Sn concentration at 60 min immersion time able to produce the best humidity sensor. Furthermore, surface decoration to the ZnO nanorods surface was also conducted by coating with SnO_2 using immersion method. The decorated nanorod arrays possessed rough surface and high porous. The humidity sensitivity of dual layered Sn-doped ZnO/SnO_2 core-shell nanorod array-based humidity sensor immersed for 3 min was observed to increase up to 5.29. Throughout this study, it was found that the performance of the fabricated ZnO nanorod arrays-based humidity sensor, particularly developed with the aligned Sn-doped ZnO nanorod arrays and dual layered Sn-doped ZnO/SnO_2 core-shell nanorod arrays, displayed very promising and good sensitivity to humidity.

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CHAPTER ONE
INTRODUCTION

1.1 ZINC OXIDE AS HIGH POTENTIAL SEMICONDUCTING MATERIAL

Zinc oxide (ZnO) is a combination of transition metal zinc (Zn) of group 12 with oxygen (O) of group 16 in periodic table forming an ionic bonding compound semiconductor. ZnO is commonly known as n-type semiconducting material with high energy band gap of 3.37 eV and have a large exciton binding energy of 60 meV at room temperature [1]. The high energy band gap can be excited by short wavelength emission such as ultraviolet (UV) light. In certain condition, ZnO can exhibit p-type conductivity through doping with certain material such as nitrogen. However, it is difficult to obtain p-type ZnO due to self-compensating effect, deep acceptor level and low solubility of acceptor dopant ions [2].

ZnO appear in white powder form, having low solubility in water. Other advantages such as nontoxicity, thermal stability, high porosity, large specific surface-to-volume ratio, have become the reason of ZnO suitable to be used in various applications such as optoelectronic devices, solar energy photo catalysts sensors [3]. A stable hexagonal wurtzite structure consist of tetrahedrally coordinated four – O or four – Zn atoms, having lattice constant of a = 3.25 Å and c = 5.2 Å with ratio c/a = ~1.60 close to ideal hexagonal cell (1.633) [4]. Figure 1.1 is the ball and stick illustration of hexagonal wurtzite structure of ZnO [4]. The ZnO structure does not have the center of symmetry and perpendicular along the c-axis.