UNIVERSITI TEKNOLOGI MARA

GROWTH OF VERTICALLY ALIGNED NB-DOPED ZNO NANORODS ON SEEDED SUBSTRATES VIA SONICATED SOL-GEL IMMERSION FOR HUMIDITY SENSOR APPLICATIONS

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ABSTRACT

The goal of this study is to grow vertically aligned Nb-doped ZnO nanorods on seeded substrates for humidity sensor applications, utilizing the sonicated sol-gel immersion method. This research was structured into three stages: the preparation and optimization of Nb-doped ZnO thin films on glass as seeded substrates via the sonicated sol-gel dip-coating method, the growth of Nb-doped ZnO nanorods on these substrates, and the fabrication of a humidity sensor on the optimum sample. The initial stage focused on optimizing the crystalline structure, specifically targeting the (002) plane texture coefficient and minimizing surface roughness to provide an excellent template for the growth of vertically aligned nanorods. The parameters were investigated sequentially, starting with the number of layers, followed by annealing temperatures, and concluding with annealing times. Characterization instruments used included FESEM, EDX, AFM, XRD, and UV-Vis spectrometer. The optimum sample was achieved with six layers, an annealing temperature of 450°C, and an annealing time of one hour. In the second stage, the seeded substrate position during the immersion process was first optimized, with 90° identified as the optimal tilt for growing vertically aligned nanorods. Parameters such as the amount of dopant, immersion time, annealing temperatures, and annealing times were then independently varied. The instruments used for characterization included FESEM, EDX, HRTEM, XRD, UV-Vis, and I-V curve measurements. The optimum parameters were established as 0.3 at. %, 90 minutes, 500°C, and 60 minutes, respectively, for each parameter. In the final stage, using the optimum parameters identified in the previous stage, vertically aligned Nb-doped ZnO nanorods were fabricated on seeded substrates as humidity sensors. The sensor's performance was assessed using a laboratory humidity chamber based on resistivity changes in response to relative humidity levels ranging from 40% RH to 90% RH. Compared to sensors utilizing pristine ZnO nanorods, the Nb-doped sensors exhibited improved performance, with sensitivity increasing from 156 to 197, enhanced stability, and a decreased recovery time from 414 to 354 seconds. These findings highlight the potential of Nb-doped ZnO nanorods not only for humidity sensing but also for applications in environmental monitoring, industrial process control, and healthcare devices requiring precise humidity detection.

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TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Nanotechnology

Materials are made up of atoms. The atom consists of positively charged protons and neutrally charged neutrons in its nucleus, surrounded by negatively charged electrons. The properties of a material highly depend on the arrangement of its atoms. Nowadays, many advanced devices are fabricated based on studies of material properties on a small scale.

The term 'nanotechnology' is believed to have been introduced by Taniguchi in 1974 [1]. It refers to the characterization, design, production, and application of materials, devices, and systems by controlling their shape and size at the nanoscale. The prefix ‘nano’ comes from the Greek word ‘nanos’, meaning ‘dwarf’ [2]. The nanoscale typically covers a range from 1 to 100 nm. Nanotechnology focuses on the development and practical use of structures and devices at the nanometer scale. The study of the nanoscale began with a talk by Richard P. Feynman titled 'Plenty of Room at the Bottom,' delivered to the American Physical Society in Pasadena in 1959 [3].

Nowadays, many countries invest in nanotechnology research, recognizing its potential benefits across various fields such as medicine, healthcare, defence, and electronics. Nanotechnology is critically important across numerous fields due to its ability to manipulate materials at the atomic and molecular levels, enabling breakthroughs that significantly enhance efficiency and performance. In healthcare, nanotechnology allows for targeted drug delivery, improving the efficacy of treatments like cancer therapies while minimizing side effects [4]. In the energy sector, it contributes to the development of more efficient solar cells and energy storage systems, promoting sustainable energy solutions [5]. Additionally, nanotechnology plays a vital role in environmental protection, enabling advanced nano sensors for pollutant detection and water purification technologies that can remove harmful contaminants [6]. Beyond these applications, nanotechnology enhances the strength, durability, and functionality of materials, leading to innovations in industries like electronics, textiles, and manufacturing. Overall, the ability to precisely control and engineer materials at