UNIVERSITI TEKNOLOGI MARA

SYNTHESIS, CHARACTERIZATION AND DEVELOPMENT OF REDUCED GRAPHENE OXIDE INCORPORATED ZINC OXIDE NANOCOMPOSITE FOR CELLULOSE-BASED HUMIDITY SENSING APPLICATION

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ABSTRACT

In this study, the practicality of utilizing zinc oxide (ZnO) nanostructured powder as a humidity-sensitive sensing material for resistive humidity sensors was investigated. The impurity amalgamation and construction of nanocomposite with the introduction of reduced graphene oxide (rGO) have been explored to enhance the pristine ZnO nanostructured powder-based humidity sensor performance. Pristine and impurities-induced nanostructured powder have been successfully synthesized through a benign and facile low-temperature ultrasonicated solution immersion method. The humidity sensor was constructed by a simple and inexpensive brush printing technique which employed cellulose filter paper as a substrate, synthesized nanostructured powders or nanocomposite as sensing material, and transparent paper glue as a binding agent. The structural, morphological, and chemical changes of the synthesized nanostructured powder were characterized through X-ray diffraction, field emission scanning electron microscopy, high-resolution transmission electron microscopy, energy dispersive X-ray spectroscopy, Raman spectroscopy, and X-ray photoelectron spectroscopy. The ultraviolet-visible diffuse reflectance spectroscopy and reflection electron energy-loss spectroscopy were conducted to assess the optical properties and energy band gap of the sensing material. The electrical attributes were analyzed using two-probe current–voltage measurement systems. The humidity sensing performance of the fabricated humidity sensor was examined in a humidity chamber equipped with measurement devices and data logging systems. The results suggest that the humidity sensor utilizing pristine ZnO nanostructured powders exhibits a humidity sensitivity of 4.95 ± 0.11 MΩ/%RH with a sensor response of 97.08 ± 0.11 %. Through the doping approach, the immersion time for aluminum (Al) and tungsten (W) impurity concentrations were optimized. The sensitivity, sensor resistance ratio and sensor response of the fabricated humidity sensors utilizing impurities-induced was further enhanced. The 4h-immersed Al-doped ZnO (Al:ZnO-4h) nanostructured-based humidity sensor had a maximum sensing response of 98.72 ± 0.04 and demonstrated the highest sensitivity of 5.37 ± 0.04 towards humidity variations from 40% RH to 90% RH. Meanwhile, the humidity sensor utilizing 1.5 at.% W-doped ZnO (W:ZnO-1.5) nanostructured powder exhibited an impedance change of over 2.5 orders of magnitude, with a high sensor resistance ratio, sensitivity and sensing response of 118.79 ± 1.12, 9.89 ± 0.03 MΩ/%RH and 99.16 ± 0.01, respectively. For the nanocomposite approach, the optimized weight percentage of rGO was introduced to the pristine and impurities-induced nanostructured powders. The assessed sensor resistance ratio, sensitivity and sensing response of nanocomposite sensing materials were found according to the following sequence: rGO/W:ZnO > rGO/Al:ZnO > rGO/ZnO. The rGO/W:ZnO with 1.0 wt.% rGO content has the highest sensor resistance ratio, sensitivity and sensing response of 249.61 ± 0.97, 12.67 ± 0.06 MΩ/%RH and 99.61 ± 0.02, respectively. This is due to the presence of oxygen vacancy defects and oxygen-related chemical bonds on the surface of the nanocomposites with the occurrence of the dopant impurity cations which yields enhanced sensor performance. Moreover, the increase in the surface-active area, reduction in sensing membrane resistance, and the synergistic effect at the interface of the heterojunction augmented this improvement. As conclusion, this study proposed that the resistive humidity sensor utilizing nanocomposite sensing materials yields enhanced and outstanding humidity sensing performance.

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TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Nanomaterials: Building Block in Nanotechnology

The rapid development of technology particularly in the field of nanotechnology is now beginning to demonstrate various discoveries that arouse a sense of fascination and the potential quality in this field. With the encouragement and stimulation from various parties, nanotechnology now becoming one of the core areas of the country's accomplishment and success stories. As an interdisciplinary discipline, nanotechnology combines the classical instinctual, mathematics, computational, engineering and materials sciences knowledge to the process of controlling, synthesizing, and building different materials structures, systems, and components [1]. Not only are all measurements made and taken on a nanoscale scale, but the discipline of nanotechnology has gained unique significance in applications in the present technological world. Nanotechnology is associated with the molecular/atom-level manipulation of materials and is defined as technology developed at the nanoscale dimension of 1 to 100 nm (1 nm = 10^{-9} m). Produced on a scale ranging from a single atom or molecule to submicron dimensions, nanotechnology aims to address needs in a variety of domains with the assistance of applied physics, chemistry, and engineering principles, researchers are now able to arrange and manipulate atomic and molecule structures for a variety of applications, depending on the objectives and results of the research outcomes. Because there is a high demand and potential in numerous fields, including the domains of electronic devices, biotechnology, optoelectronics, and others, prior discoveries and research have provided the strength and basis for present researchers to continue the efforts of past researchers [2,3].

Due to the numerous benefits, nanomaterial technology research and development has recently attracted plenty of interest. In areas including healthcare and biomedical, transportation, food safety and packaging, communications, agriculture, information technology, oil and gas, wastewater treatment and more, adopting electrical appliances and electronic devices that employ nanomaterials has provided a positive and significant impact on the quality of living and everyday activities [4–11]. Additionally, the utilization of nanomaterials in technology may assist in conserving resources due to their greater efficiency, widespread usage, miniature size, less