

UNIVERSITI TEKNOLOGI MARA

**FABRICATION AND
CHARACTERIZATION OF
SOLUTION-IMMERSION GROWN
NICKEL OXIDE NANOSTRUCTURE-
BASED FILMS FOR HUMIDITY
SENSOR APPLICATION**

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PhD

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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 own 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 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.

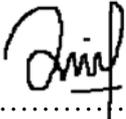
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ABSTRACT

Humidity sensors are essential devices for use in controlling environmental moisture in sectors that include electronics, medical, food processing, agricultural, and automotive industries. Apart from that, humidity sensors are also useful in household usages, especially in electrical appliances. Due to the high demand for humidity sensors, low cost, facile synthesis, and excellent performance humidity sensors are required. In this study, resistive humidity sensors from p-type nickel oxide (NiO) nanostructure-based films were fabricated using a facile sol-gel spin coating and immersion method. This p-type metal oxide was considered an alternative because of its distinctive properties, and it has rarely been intensively studied, especially in humidity sensing applications. The NiO seed layer was introduced to act as catalysts for the growth of NiO nanostructures on the glass substrates, replacing conventional indium-doped tin oxide or fluorine-doped tin oxide layers. These sensors were fabricated based on several approaches such as undoped (UD) NiO, manganese (Mn)-doped (MD) NiO, and a novel zinc oxide (ZnO)/NiO nanocomposite. The properties of the sensors were characterized based on the morphological, structural, optical, electrical, and humidity sensing via field emission scanning electron microscopy, field emission transmission electron microscopy, energy-dispersive X-ray spectroscopy, Brunauer-Emmett-Teller, X-ray diffraction, ultraviolet-visible spectroscopy, two-probe current-voltage, Hall effect, and humidity sensor measurement. The results showed that the highly porous NiO nanosheet/nanocarnation-flower-like (NSNC) structure, which was immersed for 2 h and annealed at 500 °C, exhibited the highest sensitivity of 257 due to the high conductivity and its good crystal parameters. The stability of this sample was seen to be lower at higher operating temperatures despite its increased sensitivity. The sensitivity of the NiO NSNC-based humidity sensor was further enhanced to 292 by doping with 1 atomic percent (at.%) Mn (1.0MD) and annealed at 400 °C. The increment in humidity sensitivity of the 1.0MD film is caused by an increased surface area compared to the UD NiO. The UD and MD NiO surface areas were recorded at 5.17 m²/g and 11.6 m²/g, respectively. The humidity sensing performance further improved to a sensitivity of 312 with a novel ZnO/NiO nanocomposite configuration. This nanocomposite-based heterostructure film offers a heterogeneous interface and synergistic effect to capture more water molecules during sensing activity. Nevertheless, the sensitivity and stability are worsened when this sample is exposed to high operating temperatures. Throughout this study, it was found that the performance of the NiO-based humidity sensor, particularly the sensor developed with the novel ZnO/NiO nanocomposite demonstrates the highest sensitivity value.

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