UNIVERSITI TEKNOLOGI MARA

FABRICATION OF HUMIDITY SENSOR USING TA-DOPED TIO_2 NANOFLOWER AND TA-DOPED TIO_2 NANOFLOWER/RGO NANOCOMPOSITE

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Thesis submitted in fulfilment
of the requirements for the degree of
Doctor of Philosophy
(Electrical Engineering)

College of Engineering

March 2023

ABSTRACT

In this work, the feasibility of using nanostructured titanium dioxide (TiO_2) film as a sensing element of a resistive-type humidity sensor was explored. Flower-like TiO_2 nanostructure have been successfully prepared on glass substrate using a combination of radio frequency (RF) magnetron sputtering and modified solution immersion methods, eliminating the need for fluorine-doped tin oxide (FTO) substrate and autoclave. The TiO_2 seed layer was deposited on a glass substrate using RF magnetron sputtering to replace the FTO substrate for TiO_2 nanostructures growth. The properties of the prepared flower-like TiO_2 nanostructure films were characterised using field emission scanning electron microscopy (FESEM), energy dispersive X-ray spectroscopy (EDS), high-resolution transmission electron microscopy (HR-TEM), X-ray photoelectron spectroscopy (XPS), X-ray diffraction spectroscopy (XRD), Raman spectroscopy, reverse double beam photoacoustic spectroscopy (RBD-PAS), Hall-effect measurement, contact angle measurement, and humidity sensor response measurement. Humidity sensor fabricated using this flower-like TiO_2 nanostructure has showed excellent sensor response due to the immense surface area provided by the unique structure. The effect of Tantalum (Ta) doping on the characteristics of TiO_2 nanoflower was also examined. Evolution of TiO_2 structure from nanoflower to microsphere was observed with the addition of Ta, leading to the improvement of humidity sensor response. The optimum Ta doping concentration is at 3.0 at.% which yielded humidity sensor response of 53,909%. Reduced graphene oxide (rGO) has also been added to the TiO_2 nanoflowers to produce nanocomposite with enhanced humidity sensing performance. A solution containing rGO was prepared and drop-casted onto TiO_2 nanoflowers. The nanocomposite recorded maximum sensor response of 39,590%. Finally, to assess the combined effect of Ta-doping and rGO addition, Ta-doped TiO_2 microsphere/rGO nanocomposite have been prepared. The humidity sensor fabricated using the material exhibited maximum humidity sensor response of 232,152%. In summary, the improved humidity sensor performance can be attributed to enhanced surface area, increased oxygen vacancy sites, reduced electrical resistivity, and formation of Schottky junction. The findings from this study suggest that this type of material has the potential to be employed to fabricate high sensitivity humidity sensing device.

ACKNOWLEDGEMENT

Firstly, I wish to thank my main supervisor, Associate Professor Ir Ts Dr Mohamad Hafiz bin Mamat for all the guidance and advise which have made the completion of my study possible. It has been a pleasure working under your supervision and to be one of your students. Thank you also to my co-supervisors, Associate Professor Ir Ts Dr Syed Abdul Mutalib and Dr N. Vasimalai for all the helpful insights and suggestions.

My appreciation also goes to the management and supporting staff of NANO-Electronic Centre (NET) and NANO-SciTech Lab, Institute of Science (IOS) who have provided the facilities and assistance during sampling and characterization. Special thanks to my colleagues and friends namely Farariyanti, Fadzleen, Syakirin, Shamsul, Al Hadi, Rohanieza, Dayana, and etc. for helping me with this project. The fond memories will always be in my heart.

Finally, this thesis is dedicated to my parent and all my family members that have been very supportive of me. Especially my lovely wife, Hamizura and our children, Lukman and Arissa who have always supported me during my PhD journey. Without your help and understanding, none of this would be possible.

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CHAPTER ONE

INTRODUCTION

1.1 Research Background

Humidity is one of the important parameters affecting our everyday life. It is defined as the measurement of the amount of water molecules in our surrounding. Accurate measurement of this parameter is becoming increasingly crucial as the monitoring of humidity is needed in various fields including food preservation, agriculture, semiconductor fabrication, weather forecasting, health screening and so on. Humidity is often measured using humidity sensor or hygrometer. There is an apparent need to improve the sensitivity of humidity sensor in order to cater for the industry demand.

1.2 Titanium Dioxide (TiO_2): Characteristics and Applications

Titanium dioxide (TiO_2) is a compound semiconductor with multitude of unique characteristics which makes it stands out as the popular material in various application. It is reported that in the year 2019 alone, the production of TiO_2 have surpasses 3 billion tons [1] with China as its main producer. It is an environmentally friendly material with high chemical and physical stability. It is also hydrophilic in nature due the presence of Ti^{3+} and oxygen vacancies defect sites. The bandgap energy is relatively wide, at around 3.0-3.2 eV [2].

This transition metal oxide is also known as titania and its molecules comprise of a Ti atom and two O atom. It can occurs in three phases namely anatase, rutile, brookite [3]. Both anatase and rutile have tetragonal structure while the brookite is of orthorhombic structure as shown in Figure 1.1. In both types, octahedron of 6 O^{2-} ions surround Ti^{4+} ion [4]. The stable nature of both anatase and rutile enable them to be frequently used in various applications.