

**EFFECT OF ZrO₂ ON THE STRUCTURE, HARDNESS AND
HUMIDITY SENSING PROPERTIES OF TiO₂-ZrO₂**

SITI NURUL SHAHMIMIE SULAIMAN

**Final Year Project Submitted in
Partial Fulfilment of the Requirement for the
Degree of Bachelor of Science (Hons.) Physics
In the Faculty of Applied Sciences
Universiti Teknologi MARA**

JULY 2017

ABSTRACT

EFFECT OF ZrO₂ ON THE STRUCTURE, HARDNESS AND HUMIDITY SENSING PROPERTIES OF TiO₂-ZrO₂

The influence of ZrO₂ on the structural, hardness and humidity sensing properties of the TiO₂ ceramics were investigated. The samples were prepared by the conventional ceramic method. The samples were characterized on their structure, hardness and humidity sensitivity. Analysis on the hardness properties has been carried out using Vickers hardness and bulk density method. It shows that hardness of samples do not affected by the bulk density. Field Emission Scanning Electron Microscopy (FESEM), X-ray Diffractometer (XRD) and impedance spectroscopy method were used for characterization the microstructure and sensing properties of samples. The average grain size shows significant difference between each samples. The XRD analysis support the characteristic of the average grain size of the samples. The ratio of impedance indicate the sensitivity of samples. Sample with ZrO₂ addition of 20 wt% have the highest ratio of impedance and sensitivity for ceramic composite rather than other samples at two different %RH which is 56 %RH and 27 %RH.

TABLE OF CONTENTS

| | Page |
|--|-------------|
| ACKNOWLEDGEMENTS | iii |
| TABLE OF CONTENTS | iv |
| LIST OF TABLES | v |
| LIST OF FIGURES | vi |
| LIST OF ABBREVIATIONS | vii |
| ABSTRACT | viii |
| ABSTRAK | ix |
| | |
| CHAPTER 1 INTRODUCTION | |
| 1.1 Background of study and problem statement | 1 |
| 1.2 Significance of study | 4 |
| 1.3 Objective of study | 4 |
| | |
| CHAPTER 2 LITERATURE REVIEW | |
| 2.1 Ceramics | 5 |
| 2.1.1 Type of ceramic | 5 |
| 2.2 Ceramics based sensing materials | 8 |
| 2.2.1 TiO ₂ as sensing materials | 9 |
| 2.2.2 Composite TiO ₂ | 10 |
| | |
| CHAPTER 3 METHODOLOGY | |
| 3.1 Samples preparation | 12 |
| 3.2 Samples characterization | |
| 3.2.1 Density measurement of TiO ₂ -ZrO ₂ | 13 |
| 3.2.2 Hardness measurement of TiO ₂ -ZrO ₂ | 13 |
| 3.2.3 Structure and phase determination of TiO ₂ -ZrO ₂ | 15 |
| 3.2.4 Morphology and microstructure investigation | 15 |
| 3.2.5 Impedance measurement and humidity sensitivity determination | 16 |
| | |
| CHAPTER 4 RESULTS AND DISCUSSION | |
| 4.1 Bulk density of TiO ₂ -ZrO ₂ | 18 |
| 4.2 Hardness analysis of TiO ₂ -ZrO ₂ | 19 |
| 4.3 Phase and crystal structure of TiO ₂ -ZrO ₂ | 20 |
| 4.4 Morphology and microstructure of TiO ₂ -ZrO ₂ | 22 |
| 4.5 Impedance analysis for humidity sensing properties of TiO ₂ -ZrO ₂ | 24 |
| | |
| CHAPTER 5 CONCLUSION AND RECOMMENDATIONS | 29 |
| | |
| CITED REFERENCES | 30 |
| APPENDICES | 34 |
| <i>CURRICULUM VITAE</i> | 42 |

LIST OF FIGURES

| Figure | Caption | Page |
|--------|--|------|
| 3.1 | Schematic indentation fracture pattern of an idealized Vickers Palmqvist crack system. | 14 |
| 3.2 | Nyquist diagram and the contributions of various properties. | 17 |
| 4.1 | Bulk density of different TiO ₂ -ZrO ₂ composites by addition difference wt% of ZrO ₂ . | 18 |
| 4.2 | The change of Vickers hardness against addition of ZrO ₂ . | 19 |
| 4.3 | X-ray diffraction patterns of TiO ₂ -ZrO ₂ ceramic sintered at 1300 °C. | 21 |
| 4.4 | Field emission scanning electron microscopy micrographs of TiO ₂ -ZrO ₂ ceramics pellets with different weight percentage composites at magnification 10000x with addition of ZrO ₂ . | 23 |
| 4.5 | Nyquist plot of TiO ₂ -ZrO ₂ ceramic pellets measured under relative humidity of 56 %RH. | 25 |
| 4.6 | Nyquist plot of TiO ₂ -ZrO ₂ ceramic pellets measured under relative humidity of 27 %RH. | 26 |
| 4.7 | Bode plot of TiO ₂ -ZrO ₂ ceramic pellets of real imaginary against frequency for 56 %RH and 27 %RH. | 27 |
| 4.8 | Ratio of Z'_{dry}/Z'_{wet} against frequency. | 28 |

CHAPTER 1

INTRODUCTION

1.1 Background of study and problem statement

A sensor is a device that detects and responds to some type of input from physical environment such as light, heat, motion, moisture and pressure. Sensors have become an integral part of all advance technology in recent years (Jain *et al.*, 1999). Pressure sensors, temperature sensors, biosensors, gas sensors, motion sensors and humidity sensors are few examples of sensors (Chen and Lu, 2005; Patel *et al.*, 2012).

Humidity sensing materials have been extensively studied as it is the heart of humidity control devices. Humidity sensors needs to be studied because it is important in human life and industrial applications amongst assorted type of sensors (Kim *et al.*, 2005; Traversa, 1995; Rittersma, 2002; Chen and Lu, 2005; Zhang *et al.*, 2010). Humidity sensor senses, measured and reports the relative humidity in the air, and humidity measurement is important in the modern industrial applications (Tripathy *et al.*, 2014; Su *et al.*, 2015; Sikarwar and Yadav, 2015; Jung and Ji, 2014).

Ceramics are preferable rather than polymers and composites as humidity sensing materials because of their chemical and physical stability in the environment, which is suitable for applications, processing ability and