DESIGN AND FABRICATION OF $BaTiO_3$ HUMIDITY SENSOR USING THICK FILM SCREEN PRINTING TECHNIQUE

By

WAN SUHAIMIZAN BIN WAN ZAKI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATION

This thesis is dedicated to my parents and the one i love for their constant support, love and guidance during all moments of my life.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: **Rahman Wagiran, M.Sc.**

Faculty: **Engineering**

Thick film sensor technology has been recognized as an important technology in sensor manufacturing for the last decade. The technology contributes to the sensor development with the exploitation of the film itself as a primary sensing device. Most ceramic materials have been investigated as a humidity sensor mainly on porous structure prepared by thick film technology. These films have microstructure properties similar to those of sintered porous bodies, but the dimensions of the sensing devices can be reduced, which then can be used in hybrid circuits.

In this work, two types of analyses will be made based on Barium Titanate ($BaTiO_3$) dielectric material. The First one is to analysis the electrical properties of $BaTiO_3$ material in bulk and thick film forms and second analysis is to characterize thick film $BaTiO_3$ for a humidity sensor at room temperature. The $BaTiO_3$ powder was prepared through solid state reaction using a raw material Barium Carbonate ($BaCO_3$) and Titanium Dioxide ($TiO_{2)}$. The thick film paste was prepared by mixing an organic vehicle with the sintered powder in appropriate ratio. The paste was then screen printed onto a ceramic substrate in an interdigitated electrode

pattern using DEK J1202 screen printing machine. The dielectric property of $BaTiO_3$ was investigated by varying the frequency in the range of 10Hz to 10 MHz using the Impedance Analyzer. The characterization of the thick film sensor with response to the Relative Humidity (%RH) was carried out in the Humidity Climatic Chamber in the range of 20%RH to 95%RH. LCR meter and PIC conditioning unit was used to measure the response of the $BaTiO_3$ thick film sample with the changes of the Relative Humidity..

The results showed that the dielectric response of the $BaTiO_3$ material in bulk and film samples are the same, based on the quasi dc concept. A smaller gap of interdigitated electrode pattern gave a higher response in dielectric properties compared to the bigger gap. The $BaTiO_3$ thick film sensor showed decrement in resistance and increment in capacitance with respect to the increases of Relative Humidity (RH). The voltage-humidity characteristic of the sensor showed a good linearity and the sensor response time is faster than the recovery time. The PIC conditioning circuit is designed to convert the analogue voltage into digital value and display the measurement result through Liquid Crystal Display (LCD) to make the system more user-friendly. As a conclusion, $BaTiO_3$ thick film shows a good promising material to be used as a humidity sensor based on thick film screen printing technology.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MEREKABENTUK DAN FABRIKASI $BaTiO_3$ PENGESAN KELEMBAPAN MENGGUNAKAN TEKNIK CETAKAN FILEM TEBAL

Oleh

WAN SUHAIMIZAN BIN WAN ZAKI

Jun 2006

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Teknologi pengesan filem tebal telah dikenalpasti sebagai satu teknologi yang penting dalam fabrikasi pengesan untuk beberapa dekad yang lalu. Teknologi tesebut telah menyumbang kepada pembangunan pengesan dengan mengeksploitasikan filem tersebut sebagai pengesan primer. Kebanyakkan bahan seramik yang telah dikaji sebagai pengesan kelembapan tertumpu kepada pembentukkan struktuk bahan yang poros. Filem tebal mempunyai cirian mikro-struktur yang sama dengan struktur poros badan bahan kepingan yang di bakar, tetapi dimensi ukuran pengesan filem dapat dikecilkan untuk kegunaan dalam litar hibrid.

Dalam kajian ini, terdapat dua bentuk analisis dilakukan terhadap bahan dielektrik Barium Titanate ($BaTiO_3$). Analisis pertama adalah pencirian dielektrik bahan $BaTiO_3$ dalam bentuk kepingan tebal dan filem tebal dan analisis kedua adalah analisis cirian filem tebal $BaTiO_3$ sebagai pengesan kelembapan pada suhu

bilik. Bahan $BaTiO_3$ disediakan melalui tindak balas keadaan solid yang terdiri dari campuran bahan asas Barium Karbonat ($BaCO_3$) dan Titanium Dioksida (TiO_2). Dakwat filem tebal $BaTiO_3$ pula dihasilkan melalui campuran bahan organik pembawa dan bahan $BaTiO_3$ melalui nisbah yang tertentu. Dakwat ini diskrin cetakan keatas alas seramik yang mempunyai konfigurasi jejari elektrod menggunakan mesin skrin cetakan filem tebal DEK J1202. Cirian dielektrik bagi bahan $BaTiO_3$ diukur dengan mengenakan frekuensi diantara julat 10Hz hingga 10MHz menggunakan *Impedance Analyzer*. Cirian filem tebal $BaTiO_3$ sebagai pengesan kelembapan dijalankan didalam bekas kelembapan *Climatic* dalam julat kelembapan Relatif (RH) antare 20%RH hingga 95%RH. LCR meter dan PIC litar keadaan digunakan untuk mengukur tindakabalas filem tebal bahan $BaTiO_3$ terhadap perubahan kelembapan relatif tersebut.

Keputusan kajian menunjukkan bahawa mekanisme cirian dielektrik bahan $BaTiO_3$ dalam bentuk kepingan tebal dan filem tebal adalah sama, iaitu berdasarkan konsep semi-dc (*quasi-dc*). Jarak pemisah antara dua elektrod yang dekat menunjukkan perubahan cirian dielektrik yang lebih tinggi dibandingkan dengan jarak jejari elektrod yang lebih besar. Filem tebal pengesan kelembapan $BaTiO_3$ menunjukkan penurunan nilai rintangan dan peningkatan nilai kapasitan dengan peningkatan nilai kelembapan relatif (RH). Cirian graf voltan-kelembapan menunjukkan lenkungan linear yang baik dan pengesan kelembapan memberikan masa tindak balas yang lebih pantas dibandingkan dengan tindak balas pembalikkan pengesan. Penggunaan Mikro-pengawal PIC sebagai isyarat keadaan membolehkan isyarat voltan analog ditukar kepada nilai digital dan hasil keputusan pengukuran kelembapan dipaparkan melalui paparan cecair kristal

(*liquid crystal display*) menjadikan sistem ini lebih mesra pengguna. Kesimpulannya, filem tebal $BaTiO_3$ menunjukkan potensi yang baik untuk dijadikan bahan dalam pembuatan pengesan kelembapan menggunakan teknologi filem tebal.

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Many thanks also goes to all my colleagues and UPM support staff.

I certify that an Examination Committee has met on 30 June 2006 to conduct the final examination of Wan Suhaimizan Wan Zaki on his Master of Science thesis entitled "Design and Fabrication of the $BaTiO_3$ Humidity Sensor using Thick Film Screen Printing Technique" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for equations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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WAN SUHAIMIZAN WAN ZAKI

Date:

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LIST OF ABBREVIATIONS

Å	**Angstrom**
AC	**Alternating Current**
Al_2O_3	**Aluminum Dioxide**
$BaCO_3$	**Barium Carbonat**
$BaTiO_3$	**Barium Titanate**
BCD	**Binary Code Decimal**
A/D	**Analogue to Digital**

C	**Celsius**
CMOS	**Complementary Metal-Oxide Semiconductor**
CVD	**Chemical Vapor Deposition**
DC	**Direct Current**
DIL	**Dual in Line**
DA	**Data Acquisition**
ESL	**Electro-Sciences Laboratories**
FET	**Field Effect Transistor**
g	**gram**
Hz	**Hertz**
IC	**Integrated Circuit**
IDE	**Interdigitated Electrode**
I/O	**Input/output**
kHz	**kilo Hertz**
LCD	**Liquid Crystal Display**
m	**meter**
MHz	**Mega-Hertz**
min	**minute**
ml	**mililiter**
mm	**millimeter**
mV	**miliVolt**
OH	**Hydroxide**
pF	**pico Farad**
R_{ref}	**Reference Resistance**
R_{sen}	**Sensor Resistance**

RAM	**Random Access Memory**
RH	**Relative Humidity**
RISC	**Reduce Instruction Set Computer**
ROM	**Read Only Memory**
rpm	**round per-minute**
SMU	**Source Measurement Unit**
sec	**second**
SEM	**Scanning Electron Microscope**
SPWM	**Sinusoidal Pulse Width Modulation**
SSFCL	**Solid State Fault Current Limiter**
SSTS	**Solid State Transfer Switch**
SVC	**Static VAR Compensator**
TiO_2	**Titanium Dioxide**
V	**Volume**
V_{out}	**Voltage Output**
V_{p-p}	**Volt Peak to Peak**
V_{ref}	**Voltage Reference**
wt	**weight**
XRD	**X-Ray Diffraction**
µm	**micrometer**