

**DESIGN AND FABRICATION OF BaTiO₃ 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**

June 2006

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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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 (BaTiO₃) dielectric material. The First one is to analysis the electrical properties of BaTiO₃ material in bulk and thick film forms and second analysis is to characterize thick film BaTiO₃ for a humidity sensor at room temperature. The BaTiO₃ powder was prepared through solid state reaction using a raw material Barium Carbonate (BaCO₃) and Titanium Dioxide (TiO₂). 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 BaTiO₃ 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 BaTiO₃ thick film sample with the changes of the Relative Humidity..

The results showed that the dielectric response of the BaTiO₃ 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 BaTiO₃ 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, BaTiO₃ 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 BaTiO₃ PENGESAN KELEMBAPAN MENGGUNAKAN TEKNIK CETAKAN FILEM TEBAL

Oleh

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Teknologi pengesan filem tebal telah dikenalpasti sebagai satu teknologi yang penting dalam fabrikasi pengesan untuk beberapa dekad yang lalu. Teknologi tersebut telah menyumbang kepada pembangunan pengesan dengan mengeksploitasikan filem tersebut sebagai pengesan primer. Kebanyakan bahan seramik yang telah dikaji sebagai pengesan kelembapan tertumpu kepada pembentukan struktur bahan yang poros. Filem tebal mempunyai cirian mikrostruktur 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 (BaTiO₃). Analisis pertama adalah pencirian dielektrik bahan BaTiO₃ dalam bentuk kepingan tebal dan filem tebal dan analisis kedua adalah analisis cirian filem tebal BaTiO₃ sebagai pengesan kelembapan pada suhu

bilik. Bahan BaTiO₃ disediakan melalui tindak balas keadaan solid yang terdiri dari campuran bahan asas Barium Karbonat (BaCO₃) dan Titanium Dioksida (TiO₂). Dakwat filem tebal BaTiO₃ pula dihasilkan melalui campuran bahan organik pembawa dan bahan BaTiO₃ melalui nisbah yang tertentu. Dakwat ini diskriminasi cetakan keatas alas seramik yang mempunyai konfigurasi jejari elektrod menggunakan mesin skrin cetakan filem tebal DEK J1202. Ciri dielektrik bagi bahan BaTiO₃ diukur dengan mengenakan frekuensi diantara julat 10Hz hingga 10MHz menggunakan *Impedance Analyzer*. Ciri filem tebal BaTiO₃ sebagai pengesan kelembapan dijalankan didalam bekas kelembapan *Climatic* dalam julat kelembapan Relatif (RH) antara 20%RH hingga 95%RH. LCR meter dan PIC litar keadaan digunakan untuk mengukur tindakbalas filem tebal bahan BaTiO₃ terhadap perubahan kelembapan relatif tersebut.

Keputusan kajian menunjukkan bahawa mekanisme ciri dielektrik bahan BaTiO₃ 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 ciri dielektrik yang lebih tinggi dibandingkan dengan jarak jejari elektrod yang lebih besar. Filem tebal pengesan kelembapan BaTiO₃ menunjukkan penurunan nilai rintangan dan peningkatan nilai kapasitan dengan peningkatan nilai kelembapan relatif (RH). Ciri graf voltan-kelembapan menunjukkan lengkungan linear yang baik dan pengesan kelembapan memberikan masa tindak balas yang lebih pantas dibandingkan dengan tindak balas pembalikan 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 BaTiO₃ menunjukkan potensi yang baik untuk dijadikan bahan dalam pembuatan pengesan kelembapan menggunakan teknologi filem tebal.

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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 BaTiO₃ 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.

WAN SUHAIMIZAN WAN ZAKI

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LIST OF ABBREVIATIONS

Å	Angstrom
AC	Alternating Current
Al₂O₃	Aluminum Dioxide
BaCO₃	Barium Carbonat
BaTiO₃	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
TiO₂	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

