UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF PORTABLE CERAMIC GAS SENSOR

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) with Honours.

by

NURHAFIZA BINTI FADZIL
B050810326

FACULTY OF MANUFACTURING ENGINEERING

2011

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Development of Portable Ceramic Gas Sensor**

SESI PENGAJIAN: 2010/11 Semester 2

Saya **NURHAFIZA BINTI FADZIL**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia yang termaktub di dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☑ TIDAK TERHAD

Disahkan oleh:

Hafiza

Alamat Tetap:

NO 58, Persiaran Tmn Melati,

Tmn Melati. Setapak

W.P. Kuala Lumpur.

Tarikh: 19/05/2011

PENYELIA PSM

DR. JARIAH BINTI MOHAMAD JUOI
Pensyarah Kanan
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka

Tarikh: 19/5/2011

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled "Development of Portable Ceramic Gas Sensor" is the results of my own research except as cited in references.

Signature	:	....
Author's Name	:	NURHAFIZA BINTI FADZIL
Date	:	19 MEI 2011

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the Degree in Bachelor of Manufacturing Engineering (Engineering Materials) with Honours. The member of the supervisory committee is as follow:

....

Supervisor

DR. JARIAH BINTI MOHAMAD JUOI
Pensyarah Kanan
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka

ABSTRAK

Pengesan gas karbon monoksida daripada motorsikal telah digunakan pada zink oksida, pencantuman zink oksida/kuprum oksida, dan lapis zink oksida/kuprum oksida. Bahan tersebut dihancurkan dengan menggunakan lesung batu *pestle* dan ditapis dengan menggunakan penapis bersaiz 40µm. Saiz zarah bagi serbuk zink oksida dan kuprum oksida ditentukan dengan menggunakan mesin analisa zarah. Kesemua sampel dihasilkan didalam bentuk pil dengan menggunakan mesin *uniaxial dry pressing* pada tekanan 2 tan/cm^{3}dan mesin *cold isostatically pressing* pada tekanan 28427.4 psi dan dipanaskan pada suhu 800°C selama 3 jam. Sampel lapisan zink oksida/kuprum oksida pula dihasilkan dengan mengenakan tekanan berturut-turut pada serbuk zink oksida dan kuprum oksida didalam acuan dan dipanaskan pada suhu 800°C pada selama 3 jam. Sampel itu ditambah dengan pengikat seperti *glycerol* dan *stearic acid* untuk menguatkan lagi *green body*. Semasa pemanasan dilakukan, bahan pengikat tadi di bakar keluar pada suhu 295°C untuk glycerol dan 388°C untuk *stearic acid* selama 30 minit dengan kadar pemanasan sebanyak 2°C/minit. Pengaruh daripada pemanasan dikaji dengan menggunakan *SEM* dan *XRD*. Respon daripada gas karbon monoksida diukur dengan menggunakan multimeter dan konsenstrasi daripada gas diukur dengan menggunakan alat analisa gas. Kajian diamati bahawa pencantuman zink oksida dan kuprum oksida menunjukkan sensitiviti yang tinggi pada gas karbon monoksida berbanding zink oksida tulen. Gas karbon monoksida akan meningkat dengan meningkatnya kelajuan daripada motosikal dan arus.

ABSTRACT

Sensing of carbon monoxide (CO) from motorcycle was carried out for pure ZnO, ZnO/CuO heterocontact, and layered ZnO/CuO heterocontact. The materials were crushed using pestle agate mortar and sieved at 40µm mesh. The particle size of powder for ZnO and CuO were observed using particle analyzer machine. All the samples were fabricated in the form of pellet using uniaxial dry pressing for 2 tonnes/cm^3 and cold isostatically press at 28427.4psi and sintering at 800°C for 3 hours. The layered ZnO/CuO samples were fabricated by sequentially pressing ZnO and CuO powders in a die followed by sintering at 800°C for 3 h. The samples were added with binder such as glycerol and stearic acid to provide strength of green body. During sintering, the binder were burn out at 295°C for glycerol and 388°C for stearic acid for 30 minute with heating rate 2°C/ minute. The effect of sintering was characterizing using SEM and XRD. The responses of CO gas were measured using multimeter and concentrations of gas were measured using gas analyzer. The study observed that ZnO/CuO heterocontact showed higher sensitivity to CO gas than pure ZnO. CO gas will increase with increased speed from motorcycle and current.

DEDICATION

To my beloved parents for their boundless love and repeated encouragement

To my family members
for their wonderful support and concern.

ACKNOWLEDGEMENT

Firstly, I would like to express my sincere gratitude to my supervisor, Dr.Jariah Binti Mohamed Juoi for their guidance, support, comments, and discussions. With their help, this research work has improved tremendously.

My appreciation also goes to the material lab technicians, Encik Sarman, Encik Azhar, Encik Hairul, and also Encik Safarizal for providing me with the necessary equipment to help in this final year project.

A big thank you goes to all my friend seniors and juniors, who have directly and indirectly contributed towards the success of this project. Thank you for making my study of Bachelor Degree at UTeM a memorable and enjoyable one. In truth, only Allah can reciprocate all the kindness. May Allah bless you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Al_2O_3	-	Aluminum Oxide
AIN	-	Aluminum Nitride
$BaTiO_3$	-	Barium Titanate
BeO	-	Beryllium Oxide
B_4C	-	Boron Carbide
C	-	Carbon
CIP	-	Cold Isostatically Pressing
CO	-	Carbon Monoxide
CO_2	-	Carbon dioxide
CH_4	-	Methane
CuO	-	Copper Oxide
F	-	Fahrenheit
Fe_2O_3	-	Iron (III) Oxide
HCl	-	Hydrogen Chloride
H_2S	-	Hydrogen Sulfide
K	-	Kelvin
MgO	-	Magnesium Oxide
$MgCr_2O_4$	-	Magnesiochromite
MPa	-	Megapascal
N_2O	-	Nitrous Oxide
NH_3	-	Ammonia
NOx	-	Nitrogen Oxide
O_3	-	Trioxygen
PuO_2	-	Plutonium (IV) Oxide
PLZT	-	Polarized Lead Zirconium Titanate
ppb	-	part per billion
ppm	-	part per million
rpm	-	Revolution per minute

SEM	-	Scanning Electron Microscope
SiC	-	Silicon Carbide
Si_3N_4	-	Silicon Nitride
SnO_2	-	Tin Dioxide
SOx	-	Sulfur Dioxide
$SrTiO_3$	-	Strontium Titanate
ThO_2	-	Thorianite
TiO_2	-	Titanium Dioxide
TiC	-	Titanium Carbide
UO_2	-	Uranium Dioxide
V_2O_5	-	Vanadium (V) Oxide
XRD	-	X-Ray Diffractor
Y_2O_3	-	Yttrium Oxide
ZnO	-	Zinc Oxide
ZrO_2	-	Zirconium Oxide
°C	-	Celsius
µm	-	Micrometer
β-Al_2O_3	-	β Aluminium Oxide

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In recent year, world awareness on environmental problems continues to increase. The continuous release to the atmosphere of chemical pollutants, originating mainly from combustion processes, is the main cause of the deterioration of environmental quality. The development of new methods to air monitor polluted gases in the air is of primary concern for the knowledge of the extension of the environmental deterioration. Measurements of gas concentration in air are being carried out mostly by analytical instruments, which are precise, but also very costly. They often cannot be placed on-site and need long periods for data acquisitions. Table 1 shows the global environmental problems such as acid rain, the green house effect, and ozone layer destruction

Table 1.1 : Global Environment Problems and Related Substances

Environmental problems	Related substances
Acid rain	NOx, SOx, HCl
Greenhouse effect	CO_2, CH_4, Fluorocarbon, N_2O, O_3
Ozone layer destruction	Fluorocarbon, Hydrocarbon
Offensive odor	H_2S, NH_3

Gases are used in many industrial or domestic activities. In the last decade, the specific demand for gas detection and monitoring has emerged particularly as the awareness of the need to protect the environment has grown. There are many types of hazardous gas such as carbon monoxide, sulfur dioxide, hydrogen sulfide, ammonia, methane, nitrogen dioxide, and many more. With growing the population that the more reliant on automobiles, chemicals, and other potentially hazardous substances, air pollutants can cause major health problems to your health. Some obvious causes of air pollution maybe came from car, but there are many not so obvious products that may use every day that are potentially damaging to healthcare (Fitzpatrick, 2006).

Nowadays, many types of sensors have been developed such as mechanical and electromechanical sensors, thermal sensors, magnetic sensors, radiation sensors, electro analytical sensors, smart sensors, and the latest biosensors. All these sensors are used based on their type. In addition, it also used to detect environmental pollution such as air pollution, noise pollution, light pollution, soil pollution, visual pollution, radioactive contamination and also water pollution.

In this research, function of ceramic sensor is to detect carbon monoxide (CO) gases that are the one of hazardous gases in Malaysia. The type of ceramic material that used for this research is Zinc Oxide (ZnO) and Copper Oxide (CuO). The sensors are going to be produced using powder processing method, sintering, electrical, and testing using XRD and SEM.

1.2 Problem Statement

The detection of hazardous gases is a common need in industrial and domestic environments. The term “hazardous” includes both toxic and combustible gases. Many applications, such as home safety, do not require an exhaustive analysis of the gas, but an alarm level detection (Mandayo, *etc al*, 2002)

Carbon monoxide is one of the hazardous gases. It can found from unvented kerosene and gas space heaters; leaking chimneys and furnaces; back-drafting from furnaces, gas water heaters, wood stoves, and fireplaces; gas stoves; generators and other gasoline powered equipment; automobile exhaust from attached garages; and tobacco smoke. The gas is harmful when breathed because it displaces oxygen in the blood and deprives the heart, brain, and other vital organs of oxygen. Large amounts of CO can overcome in minutes without warning-causing to lose consciousness and suffocate. According to Occupational Safety and Health Administration (2002), besides tightness across the chest, initial symptoms of CO poisoning may include headache, fatigue, dizziness, drowsiness, or nausea. Sudden chest pain may occur in people with angina. During prolonged or high exposures, symptoms may worsen and include vomiting, confusion, and collapse in addition to loss of consciousness and muscle weakness. Symptoms vary widely from person to person. CO poisoning may occur sooner in those most susceptible: young children, elderly people, people with lung or heart disease, people at high altitudes, or those who already have elevated CO blood levels, such as smokers. Also, CO poisoning poses a special risk to fetuses.

1.3 Objectives of Study

The main aim of this research is to develop ceramic gas sensor using compacted of ceramic oxide. This objective is focus on:

i. To produce ceramic oxide gas sensor.
ii. To characterize of the sintered ceramic oxide.
iii. To compare the ZnO/CuO heterocontact sensor with layered ZnO-CuO ceramic sensor.

1.4 Scope of Study

This research was started with preparation of zinc oxide and copper oxide powder. This study is focus on the development of ceramic sensors using oxide powder to detect carbon monoxide gases for preserving the environment.

1.5 Importance of Research

This research will contribute to development ceramic gas sensor for detecting CO gas such as hazardous gases. Material that use for this ceramic sensor is ZnO and CuO. The function of ceramic gas sensor is to detect carbon monoxide. Besides that, it's also used to avoid air pollution. It's because at some concentrations, accidents such as angina, impaired vision, and reduced brain function may result. At higher concentrations, CO exposure can become to fatal.

CHAPTER 2

LITERATURE REVIEW

This chapter discuss on related study based on the previous research conducted by other researchers on development of ceramic sensors. The literature review mainly focused on the theory of ceramic materials and the process of the ceramic sensors.

2.1 Ceramic Materials

In this research ceramics is the important material to develop a sensor. Ceramic means a combination of covalent, ionic, and sometimes metallic. They consist of arrays of interconnected atoms and there are no discrete molecules. The majority of ceramics are compounds of metals or metal –loids and nonmetals. Most frequently they are oxides, nitrides and carbides. Richerson, (2002) states that “most solid materials that aren’t metal, plastic, or derived from plants or animals are ceramics”. Another that, ceramics also can define for compound of metallic and nonmetallic elements. Ceramic can divided into two parts: traditional ceramics and also advanced ceramics. The applications for these materials are diverse, from bricks and tiles to electronic and magnetic components. For traditional ceramics and glasses, familiar applications include structural building materials (e.g., bricks and roofing tile), refractories for furnace linings, tableware and sanitaryware, electrical insulation (e.g., electrical porcelain and steatite), glass containers, and glasses for building and transportation vehicles. The applications for which advanced ceramics have been developed or proposed very diverse and this area expected to continue to grow at a reasonable rate (Rahaman M.N, 2003). Table 2.1

illustrates some of the applications for advanced ceramics. These applications use the wide range of properties exhibited by ceramics. The functions of ceramics products are dependent on their chemical composition and microstructure, which determines their properties (Carter and Norton, 2007).

Table 2.1 : Application of Advanced Ceramics Classified by Function (Rahaman, M.N, 2003)

Function	Ceramic	Application
Electric	Insulation materials (Al_2O_3, BeO, MgO)	Integrated circuit substrate, package, wiring substrate, resistor substrate, electronics interconnection substrate
	Ferroelectric materials ($BaTiO_3$, $SrTiO_3$)	Ceramic capacitor
	Piezoelectric materials (PZT)	Vibrator, oscillator, filter, etc. Tranducer, ultrasonic humidifier, piezoelectric spark generator, etc.
	Semiconductor materials ($BaTiO_3$, SiC, ZnO-Bu_2O_3, V_2O_5 and other transition metal oxides)	NTC thermistor: temperature sensor, temperature compensation, etc. PTC thermistor: heater element, switch, temperature compensation, etc. CTR thermistor: heat sensor element Thick-film sensor: infrared Varistor : noise elimination, surge current absorber, lightning arrestor, etc. Sintered Cds material: solar cell SiC heater : electric furnace

		heater, miniature heater, etc.
	Ion-conducting materials (β-Al_2O_3, ZrO_2)	Solid electrolyte for sodium battery ZrO2 ceramics : oxygen sensor, pH meter, fuel cell
Magnetic	Soft ferrite	Magnetic recording head, temperature sensor, etc.
	Hard ferrite	Ferrite magnet, fractional horse power motors, etc.
Optical	Translucent alumina	High-pressure sodium vapor lamp
	Translucent Mg-Al spinel, mullite, etc.	Lighting tube, special-purpose lamp, infrared transmission window materials
	Translucent Y_2O_3-ThO_2 ceramics	Laser materials
	PLZT ceramics	Light memory element, video display and storage system, light modulation element, light shutter, light valve
Chemical	Gas sensor (ZnO, Fe_2O_3,SnO_2)	Gas leakage alarm, automatic ventilation alarm; hydrocarbon, fluorocarbon detectors, etc.
	Humidity sensor ($MgCr_2O_4$-TiO_2)	Cooking control element in microwave oven, etc.
	Catalyst carrier (cordierite)	Catalyst carrier for emission control
	Organic catalyst	Enzyme carrier, zeolites
	Electrodes (titanates,	Electrowinning aluminium,

	sulfides, borides)	photochemical processes, chlorine production.
Thermal	ZrO_2, TiO_2	Infrared radiator
Mechanical	Cutting tools (Al_2O_3, TiC, TiN, others) Wear resistance materials (Al_2O_3, ZrO_2) Heat resistance materials (SiC, Al_2O_3, Si_3N_4, others)	Ceramic tool, sintered CBN; cermet tool, artificial diamond; nitride tool Mechanical seal, ceramic liner, bearings, thread guide, pressure sensors Ceramic engine, turbine blade, heat exchangers, welding burner nozzle, high frequency combustion crucibles
Biological	Alumina ceramics implantation, hydroxyapatite, bioglass	Artificial toot root, bone and joint.
Nuclear	UO_2, UO_2-PuO_2 C, SiC, B_4C SiC, Al_2O_3, C, B_4C	Nuclear fuels Cladding materials Shielding materials

The property of ceramics is further shown by the following observations addressing the six categories of functional properties: (1) thermal chemical, (2) mechanical, (3) thermal conduction, (4) electrical, (5) magnetic, and (6) electromagnetic. Considering mechanical performance, many ceramics have high stiffness and high melting points, reflecting the strong atomic bonding. While stiffness generally decreases with increasing temperature, as for other materials, it is typically an important attribute of many ceramics across the temperature spectrum (Rice R.R, 2003).