DESIGN CONSIDERATION OF MICROHEATER STRUCTURE FOR MICRO DEVICES APPLICATIONS

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A project report submitted in partial fulfilment of the requirements for the award of the Degree of Bachelor Electronics Engineering (Electronics Industry)

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JUNE 2015

UNIVERSTI TEKNIKAL MALAYSIA MELAKA

FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN

PROJEK SARJANA MUDA II

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ACKNOWLEDGEMENT

In the name of Allah, the most gracious, the most merciful, all praise and thanks are due to God, the Almighty for his guidance, protection, sustenance and innumerable favours which he has bestowed upon me. I would like to take this opportunity to express my utmost gratitude to the people who have directly or indirectly involved in my thesis.

Proceeding with no particular order, I would like to thank Assoc. Prof. Dr. Abd. Rani Othman (Dean of Faculty of Electronics and Computer Engineering), Dr. Mohd Shakir bin Md Saat (Head of Department electronic Industry) Dr Kok Swee Leong (PSM Committee).

I would like to express my sincere appreciation to my thesis supervisor, Dr Norihan Abdul Hamid for the encouragement, guidance, friendship and kindly advice. She had shared lots of information regarding to the microheater knowledge and always helped me when facing obstacles.

In addition, I also indebted to university library for the facilities provided which was including the references and journals sources that are important in completing my thesis. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions where their view and comment are useful indeed. However, unfortunately it is not possible to list all of them. Eventually, special thanks and I also grateful to my family members for the moral support and sacrifices.

ABSTRACT

For past few years, microheater has been widely investigated because of their extensive applications in gas sensors, flow rate sensors and other micro system. Basically, the optimum performance of microheater can be determine by low power consumption, low thermal mass and better temperature uniformity. The design consideration of microheater structure using polymer based material for micro device application is performed in this thesis. The purpose of this project is to define which polymer based material and other suitable material will be used to form the heater device through sputtering and micro device fabrication process. For the design consideration, COMSOL Multiphysics 4.4 is used to perform and implement the simulation analysis in purpose to get the optimum performance of microheater and to determine the best polymer based material to be chosen as main material for fabrication process. As a result, for microheater substrate, polyimide material produced the highest output temperature, while gold material give the highest temperature for heating element. Meanwhile, in term of uniformity output temperature, polysilicon is always the best. The collected data are recorded and perform in graph analysis.

ABSTRAK

Untuk beberapa tahun kebelakangan ini, mikro pemanas dikaji dengan meluas disebabkan pengaplikasiannya dalam sector industri untuk mengenal pasti dan merekod gas, kadar aliran dan pelbagai sistem mikro yang lain. Secara amnya,untuk keputusan dan prestasi yang optimum, mikro pemanas boleh dinilai dari segi penghasilan penggunaan tenaga yang rendah, jisim haba yang rendah dan keseragaman penghasilan suhu. Dalam tesis ini, pertimbangan terhadap reka bentuk dan bahan kimia yang digunakan untuk pemanas mikro telah dikenalpasti.. Bahan berasaskan polimer dan bahan lain mengikut kesesuaian telah digunakan untuk membentuk peranti pemanas melalui proses fabrikasi peranti pemercikan dan mikro. Untuk analisis litar simulasi bagi penghasilan suhu yang seragam bagi aplikasi sensor gas, perisian COMSOL Multiphysics 4.4 digunakan. Keputusannya, bagi substrat mikro pemanas, material 'polyimide' menghasilkan suhu tertinggi, manakala material emas menghasilkan suhu tertinggi bagi elemen pemanas. Sementara bagi fator keseragaman penghasilan suhu, 'polysilicon' adalah yang terbaik. Kesemua data telah direkod dan dihasilkan dalam bentuk graf.

TABLE OF CONTENT

IV RESULTS AND DISCUSSIONS

LIST OF TABLE

LIST OF FIGURE

LIST OF NOMENCLATURE

SYMBOLS	DEFINITION
FEM	Finite Element Method
FEA	Finite Element Analysis
mW	milli Watt
PCR	Polymerase Chain Reaction
MEMS	Micro-electro mechanical system
GUI	Graphical User Interface
CAD	Computer Aided Design
MBT	Model Builder Tree
Pt	Platinum
Au	Gold
PTFE	Polytetrafluoroethylene
PolySi	Polysilicon
2D	2 Dimensional
3D	3 Dimensional
Ts	thermal stress

SYMBOLS	DEFINITIONS
h_air	heat transfer film coefficient
t_glass	substrate thickness
V_in	Input voltage
NDIR	Non-dispersive infra-red
AC/DC	Alternating current/ direct current

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Background

A large demand exist for small gas sensor for measuring the various gas constituents that are present in automotive exhaust. Gas sensor also play a major role in measurement of gases for environmental monitoring, industrial safety and home land security. High performance and portable gases sensing devices are employed to avoid and reduce human exposure to dangerous gasses in industrial, plants and other possible exposed environments that are hazardous in nature. The efficient use of gas sesnsor is mainly related with its characteristics of performance and its design. [1] In this thesis, design consideration of micro-heater applications will be focused on. Microheater is an important part of the gas sensor as it functions to provide a specific temperature that is required by the sensor. The operating temperature for a commercial Figaro Taguchi semiconductor gas sensor is 400°C with the heater power consumption of 300 – 830 mW. [2] The designed heater will be useful for application such as MEMS based gas sesnsor using inorganic material, Polymerase Chain Reaction (PCR) device and others [3].

In the thesis, application of micro-heater of gas sensors are specified. The gas sensor consists of a microheater, a sensing electrode and sensing material. At the

specific temperature required by the sensor, the resistance of the sensing material changes in the presence of the target gas. The change of resistance of the sensing material is then detected by the sensing electrode and subsequently property changes in the electrode give output to the sensor of which target gases are present.

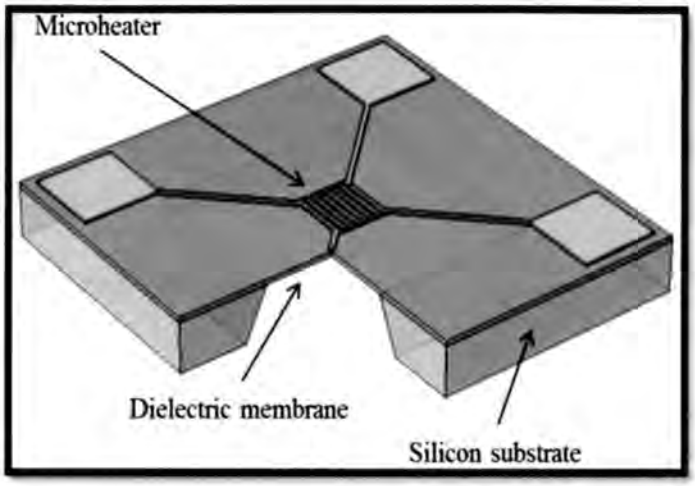

Figure 1: Typical structure of microheater

Figure 1 shows the typical structure of a microheater. Platinum is a common material used for microheater because of its stable temperature coefficient of resistance and accuracy [2].

There are various design used for heating element of the microheater. Generally the heater is designed in the shape of meander or spiral. In order to achieve the best output temperature with a temperature uniformity, designs of micro-heater and material used is one of the most influential aspect. Besides, the bottom line in the design and manufacture of modern gas sensors is the transfer from ceramic to thin film gas sensors [5]. A thin film is a layer of material ranging from fractions of a nanometer to several micrometers in thickness. Electronic semiconductor devices and optical coatings are the main applications benefiting from thin film construction [6]. This transfer provides new opportunities for further miniaturization, low power consumption and cost reduction of gas sensors. Thus, for this project, two designs of microheater with respect to the different material for substrates and heater element were experimented.

The aim of this project is to obtain the best material used for membranes and heater elements that produced a higher output temperature with respect to the temperature uniformity. A thermal electric finite element method (FEM) analysis was used to investigate the thermal properties of individual electrically driven the micro-heaters. From the result obtained, a suggested material used that effect the uniformity, temperature distribution will be recommended.

1.2 Problem Statement

For a microheater to achieve a higher output temperature with respect to the uniformity, design consideration of the microeater itself plays an important role of the result. Other than design, material used for the microheater design also affect the performance of the design. In product development, it has been observed that a product design undergoes three stages. The first stage is the conceptual design where the stress is on proof of concept, usually in the form of a physically demonstrable idea or principle. The second stage may be called an embodiment design, where the goal is to realize a prototype using first-cut approximate analysis and optimization methods and is accomplished using approximate material properties. The third design is the final stage of detailed design and analysis where the emphasis is on rigorous analysis using commercial tools such as Finite Element Method (FEM) and optimization technique.

In design, the requirement of optimal performance usually translate into optimization of geometry (shape), topology, and mass of the subcomponent or the structure. In fact, material selection is usually dictated by the availability and ease of processing of the material. However, recent intense research in materials has brought out several materials and process that show very good promise of result. This increase in material space provides an opportunity to designer to evaluate which materials is the best for enhancing the performance of devices and select a material for optimal result. [7].

For a better temperature output produced, the main factor to be concerned on the characteristic of the material being used is the thermal conductivity and the electrical conductivity of the circuit.

1.3 Objectives

The objectives of this project are:

i. To study and investigate parameters that influence microheater performance
ii. To study the microheater characteristics of producing high temperature
iii. To analyse the most suitable polymer based material and other material in producing high and uniform output temperature.
iv. To recommend the best material in sizing and costless in fabrication process based on the applications.

1.4 Scope of Project

This project is expected to simulate and analyse the best result of polymer based material and other material that can give the optimum output temperature. The optimum temperature produced is based on device requirement such as higher or uniformity output temperature. The AC/DC, heat transfer and structural mechanics module of COMSOL Multiphysics (FEM) package is used to run and analyse the simulations.

1.5 Methodology Synopsis

Methodology is a method or procedure that will be used to achieve the objectives of the study. In this thesis the methodology consists of seven steps which are objective, scope and requirement, model construction, model characterization and analysis, simulation experimentations, data gathering and analysis, and optimization of design consideration.

The objectives and scope was explained earlier in this thesis. Firstly, the study of parameters influence for microheater characteristic was focused. Polymer based materials and other materials has been chose in microheater structure simulation to study and analysis the effect of material characteristics in providing higher or uniformity output temperature..

Different polymer and other material characteristics of producing temperature are analysed and observed. The different design are developed with few geometries are selected and analysed. From the result obtained, the best geometric design will be proposed for the clean room device fabrication.

1.6 Thesis Structure

There are five chapters in this final year project thesis. Chapter 1, a briefly explain about project description, problem statement, scope and methodology. The explanations about main idea and objective are cover in introduction and project objective. Problem identification statements are discussed. The scopes and outlines of reports are also presented in this chapter.

In chapter 2, information and theoretical regarding the project are discussed. These chapter known as literature review. Some basic theory and background of study were explained. The definition of gas sensors, micro heater and few designs of microheater are introduced and further explanations were describes.

Methodology of the whole project are discussed in chapter 3. In this chapter, the ways the project being developed were explained stage by stage. Each part of project development was shown in this chapter. The case study that has been conducted through the proper analysis about the micro-heater design and characteristics are explained.

Result and discussion of the project are explained in Chapter 4. In this chapter, results and analysis from the design consideration are discussed. Moreover, the design with respect to consideration of material used in the simulation were analyse. The discussions during the project development are recorded based on the obstacles and problem arise.

Chapter 5 conclude the whole project. In this chapter, the specific parameter used in microheater fabrication are presented. Future recommendation of the specific material used on producing a high temperature with better uniformity were included. Reference and appendixes were inserted at the end of this thesis as the proof of the guidance and project references.