ANALISIS KAEDAH UNSUR TERHINGGA PEMBUNGKUSAN SISTEM MIKRO-ELECTRO MEKANIKAL BAGI PENDERIA

(FEA MEMS PACKAGING FOR SENSOR)

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ACKNOWLEDGEMENT

With the name of Allah S.W.A, I start this Final Year Report content, may this effort in Allah blessing. Amin.

Firstly, I would like to give highest appreciation and very thankful to my parent, whom this project carried out from the beginning until its end, give me a motivation, morality support, advice and help. Infinity thankful also to my project supervisor, Assc. Prof. Dr Ishak Hj. Abdul Azid, which give me outline and guidance associates with the idea, advice and support to me in order to finish my final year project report. Also a lot of thankful to Mr. Heng Wah, master student under Assc. Prof. Dr Ishak Hj. Abdul Azid for his guidance and support.

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ABSTRACT

Mechanical characteristics of a sensor microbeam based on resonance frequency for gas detection and their dependence on the geometry and materials is investigated in this paper.

These microbeam structures will be modeled in Finite Element Analysis software (ANSYS 7.0). The microbeam structures investigated in this work are formed from six microcantilevers and a microbridge design. Each of the microcantilevers has differences in their dimensions. While the microbridge will be analyzed in different materials. All of six microcantilevers also will be analyzed in these different materials to define the best result. Each of these structures has a specific resonance frequency, which varies as a function device shape, structure mass and the physical properties of its component materials. The microbeam structures are then will be simulating in ANSYS 7.0 software to measure its resonance frequencies value. Parametric studies for the microcantilever also will be investigated. Preliminary results shows the shorter microcantilever have higher resonance frequency than the longer ones using polysilicon material, and silicon nitride material give the higher resonance frequency modes for microbeam structure design than other materials. These results will be verified with experimental result in journal.

The packaging technique also will be applied to this sensor depends on its requirements and applications. This packaging technique will be discussed roughly in this paper.

ABSTRAK

Ciri-ciri mekanikal bagi sebuah rasuk penderia mikro berdasarkan frekuensi resonanya untuk pengesanan gas dan kebergantunganya pada faktor geometri dan bahan yang digunakan telah dikaji di dalam tesis ini.

Struktur rasuk mikro yang dikaji terdiri dari enam rasuk julur dan satu rasuk anjung mikro. Setiap rasuk julur mikro mempunyai perbezaan dari dimensinya. Sementara itu, rasuk anjung micro akan dianalisis menggunakan bahan yang berbeza seperti polysilikon, silikon oksida, silikon nitrat dan aluminium. Semua enam rasuk julur mikro ini juga akan dianalisis dengan bahan yang berbeza. Semua rasuk julur ini akan dimodelkan didalam perisian ANSYS 7.0. Setiap struktur ini mempunyai frekuensi resonan yang spesifik yang bergantung kepada bentuk alat, beban struktur dan ciri-ciri fizikal bagi bahan komponenya. Struktur rasuk mikro ini kemudianya akan disimulasikan dengan perisian ANSYS 7.0 bagi menentukan nilai frekuensi resonanya. Keputusan yang telah diperolehi menunjukan rasuk julur yang lebih pendek memberikan nilai frekuensi resonan yang lebih tinggi, dan bahan silikon nitrat memberikan nilai frekuensi resonan yang lebih tinggi berbanding bahan lain.

Teknik pembungkusan juga akan diaplikasikan kepada sensor ini bergantung kepada keperluan dan kegunaanya.

CHAPTER 1

INTRODUCTION

1.1 Project Introduction

This project is about analysis for design, material(s), structures and fabrication technique for MEMS devices changes depending upon the devices requirement and applications of their sensor. As a result, the packaging technique also will be applied depend on these factors.

An available sensor obtained from a journal: Ioana Voiculescu, and Mona Zaghloul, George Washington University, Dept. of Electrical & Computer Engineering, Washington, DC 22052 USA (2001).

ANSYS 7.0 (Pro Engineer) software was used for modeled and simulates the sensor microcantilevers and microbridge resonant frequency and the result will be verified with data from the journal. The microcantilever and microbridge has a specific resonant frequency, which varies as a function of device shape, structure mass, and the physical properties of the compound materials.

Various MEMS packaging technologies for different application particularly sensor will be investigated. This packaging technique will be applied to the development of an available sensor. The packaging technique will be discussed roughly in this paper.

1.2 Design, Material, Structures and Fabrication for Available Sensor

Design, materials, structures and fabrication for available sensor was taken from a journal (Refer Ref. [1]). The microbeam of this sensor (six microcantilevers and a microbridge) will be applied for further analysis. The journal discussed about the design, fabrication, and modeling of an electrostatically actuated transducer that is operated in a resonant mode. The transducer is designed for gas sensor applications. The microstructure with high-aspect ratio laminated beam or bridge suspensions, have been fabricated using a 0.6 μm three metal, double poly CMOS process. The fabricated chip was post processed by a sequence of two maskless dry etching steps. A thin sorbent polymer layer is included in the design of the microbeam chemical sensor. The devices were designed to provide a relatively large surface area to coat with the sorbent polymer. Gas sorption in the polymer layer can be monitored as a function of the resonance frequency of the device. The device frequency is measured by piezoresistors mounted in a Wheatstone bridge configuration. The fabricated sensors are intended for use in monitoring hazardous gases and vapors. In order to optimize the device resonance frequencies, a variety of microbeam structures were designed with different dimensions. These structures were modeled with a finite element analysis program. A number of selected structures were fabricated in a single chip design [1].

1.2.1 Sensor Introduction

Chemical sensors are important for a variety of industrial and environmental applications, for example, in the detection of hazardous chemicals, on line process monitoring for the food, perfume, and beverage industries, and in medical applications [1].

A typical configuration for a chemical sensor includes a sorbent layer deposited on an active area of a transducer. The interaction of a gas and the sensor results in an electrical signal that can be readily monitored. Pneumatic connections are normally required to allow air to flow over the chemical sensor. Conventional chemical sensors utilize transducers which are relatively large and have millimeter sized dimensions. The advent and maturation of MEMS based technology now offers many opportunities to dramatically reduce the size, cost, and power consumption of chemical sensors. Current state of the art chemical sensor systems are hand held [1].

1.2.2 Sensing Principle of the Microbeam Gas Sensor

A microbeam chemical sensor consists of two key components: a gas sorptive layer such as a polymer, and the microbeam transducer. The microbeam structures designed in this work are formed from six cantilevers and a bridge design. Each of these structures has a specific resonance frequency, which varies as a function of device shape, structure mass, and the physical properties of the component materials. A sorptive layer of polymer is coated on the microbeam, and the sorption of different gases is monitored as a shift in the device frequency. The corresponding mass increase normally leads to a decrease in the beam resonance frequency. The microbeam gas sensor is a resonating microbalance, and the sorbed gas molecules are literally weighed as a function of the device frequency [1].

The sorbed amount of gas depends on the specific gas-polymer interaction and the gas concentration in the environment. The gas molecules diffuse into the polymer until a dynamic equilibrium is reached. For gases that are strongly bound to the polymer, desorption can be facilitated by the operation of a heater. In an array format with different polymer coated devices, the pattern of responses or fingerprint that results from a gas exposure can be used to identify the gas [1].

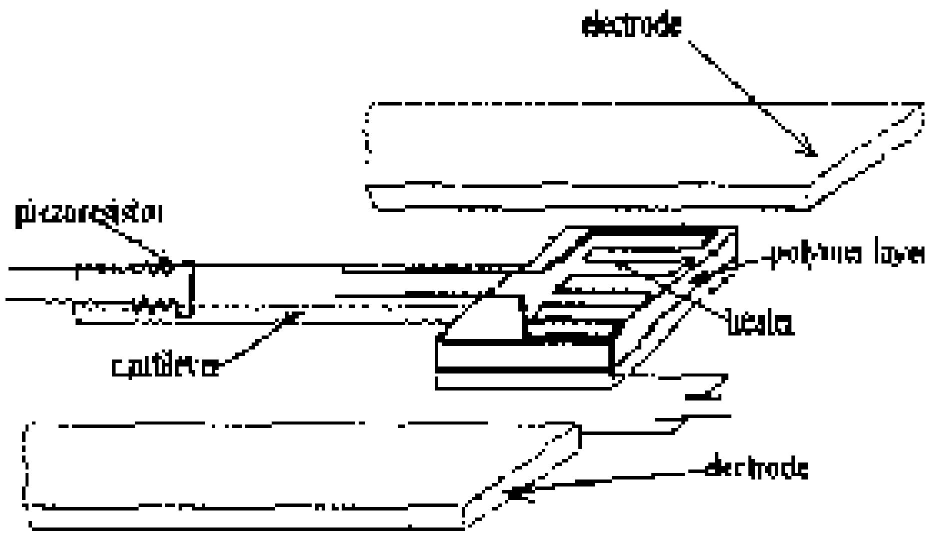


Figure 1.0 Microcantilever gas sensor

The transducer of interest in this work is a microbeam, which is operated as a resonating microbalance, shown in Fig.1.0. Electrostatic actuation is used to operate the cantilever in a resonant mode, and the resonance frequency is measured by a set of piezoresistors connected in a Wheatstone bridge configuration. Only the beam tip is used for polymer coating. The microbeams, which act as resonating microbalances, were processed using complementary metal-oxide silicon (CMOS) technology. In this journal, the Camegie Mellon University (CMU) CMOS MEMS fabrication process was used [1].

1.2.3 Design and Fabrication of CMOS Gas Sensor Chip

The chip was designed in CMU-CMOS technology using MEMSCAP-Xplorer software installed under Cadence. Typical die size for this process is 2.5 mm by 2.5 mm. The foundry used in this work is based on the Austrian Microsystems **(AMS)** process (0.6 μm, 3-metal, 2-poly CMOS). On the chip there are six cantilever gas sensor designs, with different dimensions and shapes, and a bridge gas sensor. In the device design, silicon heaters were included to thermally heat the device as needed. In addition, the design includes piezoresistors that are mounted in a Wheatstone bridge configuration. The micrograph of the whole chip after post processing is shown in Fig. 1.1. On the micrograph of the chip the cantilevers are not visible because they are out of focus due to the cantilever curling. Multiple beams on the same structure are designed with suitable gaps to perform the RIE [1].

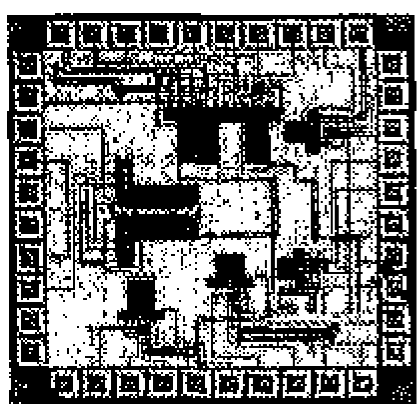


Figure 1.1 Micrograph of the postprocessed chip. Note, the six cantilevers and the bridge are not visible, because of the device curling.

The actuation of the cantilevers and the bridge are driven electrostatically, using two sets of interdigitated fingers. The three metal layers allow thicker and heavier devices with higher operating resonance frequencies. The fingers, which are flat, are wired to the ground pad. The comb fingers, which are tilted out of the device plane, are wired to a bonding pad, which is connected to an alternating drive voltage. The resulting attractive electrostatic force allows the tilted comb fingers to align with the plane of the device. The resonant frequency is monitored with a highly symmetrical on-chip Wheatstone bridge arrangement. Each device on the fabricated chip includes a Wheatstone bridge. The full Wheatstone bridge has two resistors placed on the microbridge [Fig. 1.2] or on the cantilever [Fig.1.5] and the other resistors is situated on neighboring cantilevers, which are designed to balance the Wheatstone bridge [1].

The combination three metal layers, which provides the minimum curling after device release, was used for the cantilever beams and the bridge gas sensor design. The curling of the structure cannot be neglected though, and at its peak reaches 12 μm, as shown in Fig. 1.3. In comparison, the cantilever thickness is estimated to be 4.2 μm.

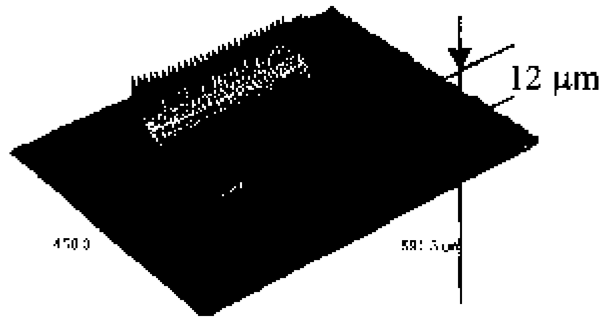


Figure 1.2 Interferometer image of the microbridge. The curling of the structure is noted at 12 μm.

For the bridge structure, only one design was included in the chip. A scanning electron microscope (SEM) image of the bridge gas sensor, shown in Fig. 1.3, again reveals the tilting of the interdigitated comb fingers, which facilitate the electrostatic actuation of the micro bridge. The interdigitated fingers are arranged on the both sides of the bridge. The central plate will be covered later with the gas sorbent polymer. A polysilicon heater included in the bridge structure will allow gas desorption by thermal heating if required [1].

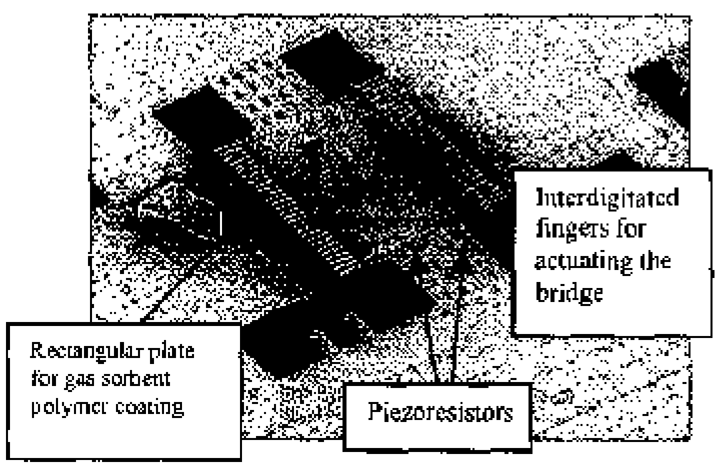


Figure 1.3. SEM image of the bridge gas sensor showing the interdigitated fingers in and out of the plane of the device.

To optimize the cantilever gas sensors we designed six cantilevers on the chip, with different shapes and dimensions, in addition to the single bridge gas sensor design. Short, thick, and wide cantilevers are preferred for higher resonance frequencies with large surface structures to maximize the area for polymer coating and subsequent gas sorption. In this regard, the length (L), and the width (W) of the cantilevers, are varied in order to determine the optimal dimensions for these structures, see Fig. 1.4. L is varied between 100 μm and 225 μm, and the range for W is from 40 μm to 70 μm.

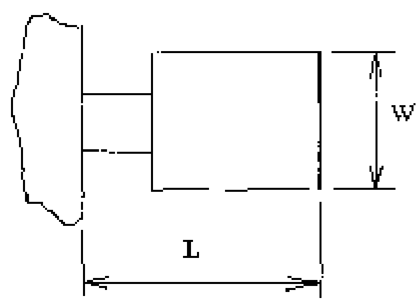


Figure 1.4 Variable cantilever dimensions L and W

An SEM image of the shortest cantilever is shown in Fig. 1.5. The interdigitated fingers are designed to be close to the end of the cantilever structures.

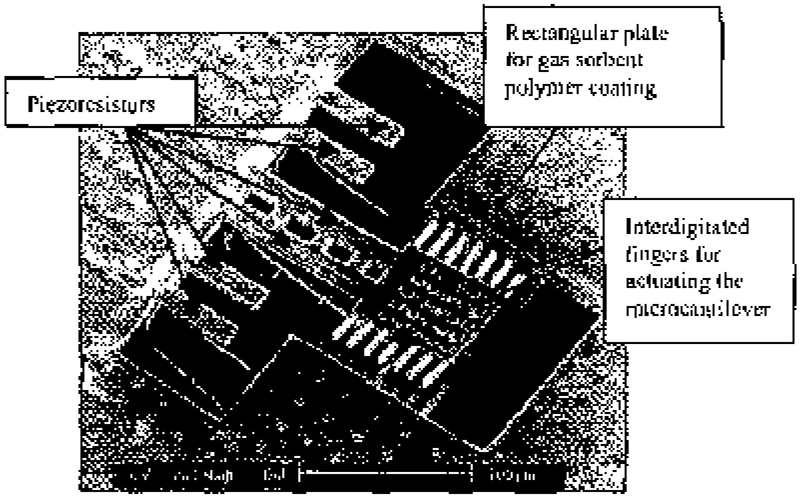


Figure 1.5 SEM image for variable cantilever dimensions L and W.

1.3 MEMS Packaging

The packaging of MEMS devices and systems needs to improve considerably from its current primitive state. MEMS packaging is more challenging than IC packaging due to the diversity of MEMS devices and the requirement that many of these devices be in contact with their environment. Currently almost all MEMS development efforts must develop a new and specialized package for each new device. Most companies find that packaging is the single most expensive and time consuming task in their overall MEMS product development program. As for the components themselves, numerical modelling and simulation tools for MEMS packaging are virtually non-existent. Approaches which allow designers to select from a catalogue of existing standardized packages for a new MEMS device without compromising performance would be beneficial [4].

A typical electrical subsystem package includes: (1) core devices, such as chips and wires; (2) housings, which include mounting points; (3) electrical connections and pass-throughs; (4) covers, which provide access and then sealing after closure; and (5) external features for mechanical attachment and thermal transfer. New packages for MEMS-based subsystems will also include unique, sometimes multichannel, other-than-electrical pass-throughs for mechanical, optical, fluid, thermal, chemical, and nuclear energy transfer. Systems of components that are based on SAS (sensor, actuator, and subsystem) will also require additional packaging innovations related to information buses or other means of communication, less obtrusive fixation methods, local information processing nodes, and others specific to networked systems. Innovative assembly and testing procedures will be necessary to complete the manufacture of new products [8].

The definition of package requirements is also a complex process. Just a few necessary features include: geometry (size, shape, attachment), abuse tolerance (vibration, impact, acceleration), interconnection methods (regime, density, dynamics, delay), thermal (isolation, temperature range, control), life (maintenance requirements, fatigue, operational range), chemical effects (corrosion, intrusion), shielding (RF, nuclear, thermal), and economy (original and life cycle cost) [4].

The Fig. 1.6 below includes a review of procedures in terms of fabrication processes, packaging, assembly, and testing. Procedures are applied along the progression of systems from subsystems to components to complete systems. Note that in each area tests might be required to validate manufacturing success. Note also that the design of new PAT (packaging, assembly, and testing) systems will be an integral part of the overall system design. Greater attention to analysis, modeling, simulation, and subtesting will be necessary [8].

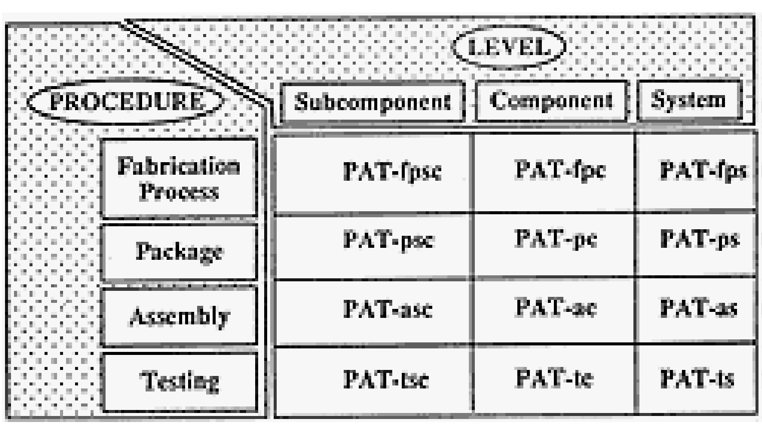


Figure 1.6 PAT processes occur in all procedures and at all levels.

Packaging systems can be classified according to levels of sealing enclosure. Table 1.0 reviews levels in terms of open or closed -- rigid, flexible, sealed or exposed.

CLOSED - Rigid or with Flexure

- Closed - Rigid
  - Acceleration, Temperature, Light, Vibration, EM Fields
- Closed - Flexure (for mechanical pass-through)
  - Pressure, Strain, Drag, Tactile

OPEN - Moving Seal or Direct Contact

- Open - Sealed (large motion)
  - Angular Rotation, Linear Displacement, Combinations
- Open - Exposed to External Contact (with materials)
  - Chemical (pH, pO_2, pCO_2, etc.), Electrochemical

Table 1.0 Packaging levels

1.4 ANSYS (Finite Element Analysis)

ANSYS is a general purpose Finite Element Modeling (FEM) package for numerically solving a wide variety of mechanical problems. These problems are including static or dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems. ANSYS is one of finite element analysis (FEA) method [7].

ANSYS also is a numerical method of analyzing complex multi-physical (structural or thermal) problems. Either linear or non-linear simulations can be performed in order to predict the behavior of the structure through numerical interpretations [7].

ANSYS uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned a certain density throughout the material depending on the stress levels in that particular area [7].

For this project, ANSYS using finite element method was used to model, simulate and define resonant frequency for sensor's microcantilever and bridge. The microcantilever and bridge has a specific resonant frequency, which varies as a function of device shape, structure mass, and the physical properties of the compound materials. This microcantilever and bridge was used for gas sorption detection.

1.5 Literature Review

The microelectromechanical system (MEMS) integrates mechanical elements, sensors, actuators, and electronics onto a common silicon substrate by applying so called microfabrication that is similar to the CMOS fabrications in microelectronic industry. The technological developments in this arena have rapidly advanced and diversified in the past few years. However, the devices should be free from residual stresses that are present in the course of the packaging processes and additional stresses during thermal cycling. It will be therefore essential to understand the origin of the stress and its evolution in improving reliability of MEMS packaging systems. Approaches to study the packaging stresses, numerical modeling and simulation tools such as finite element method (FEM) are also implemented. One advantage of this simulation tool is that it can aid to explore a much larger range of parameter space (temperature, materials, geometry, electrical, etc.) than is practical experimentally. The collective information is used to better understand certain experimental observations, and also to steer into the development of the improved packaging system. FEA is a numerical method of analyzing complex multi-physical (structural or thermal) problems. Either linear or non-linear simulations can be performed in order to predict the behavior of the structure through numerical interpretations [3].

Packaging techniques used in micro electro mechanical systems (MEMS) borrow heavily from those developed for microelectronics. Similarities include hermeticity and chip level integration techniques such as Multi-Chip-Modules. Differences include a unique set of failure modes due to the mechanical nature of MEMS. These failure modes are still not well understood [4].

Although the challenges of MEMS packaging has been known for some time, little published research has been achieved to compile data and work towards meeting these challenges. A disproportion exists between the high cost of packaging for MEMS sensors and the minimal resources invested on MEMS packaging research [4].

The importance of the process analysis is not limited to the performance quality control. The cost of MEMS packaging typically accounts for a substantial amount of the manufacturing cost of the device [3].

CHAPTER 2

METHODOLOGY

2.1 Overview

This project is about analysis of resonance frequencies for available sensor, a MEMS device. This sensor changes depending upon its requirement and applications, the packaging technique also will be applied depends on these factors. This packaging technique will be applied to the development of an available sensor.

The microbeam structures investigated in this work are formed from six microcantilevers and a microbridge design. For the microcantilevers, each of it has differences in their dimensions. All the microcantilevers have same thickness 4.2 μm, but different in length (L), and different in width (W). The length range for the microcantilevers is between 100 μm to 225 μm, and the width range is between 40 μm to 70 μm. Fig. 1.4 shows the microcantilever shape roughly and Fig 1.1 shows the six microcantilevers placed on the chip for gas detection. Fig 2.0 below shows the arrangement for the microcantilever (refer to the appendix A for absolute dimensions of microcantilever). Microcantilever 1 has the shortest length (L) but biggest width (W), and microcantilever 6 has the longest length (L) but smallest width (W). The variation in these microcantilevers dimension is for getting the larger surface areas for gas detection for various resonance frequencies.

While, the microbridge will be analyzed using different materials such as polysilicon, silicon oxide, silicon nitride and aluminum to define the highest resonance frequency without changing its dimension. The dimension for microbridge shown in Fig. 2.1. All of six microcantilevers also will be analyze in these different materials to define the highest resonant frequencies for the microcantilevers. Results from the simulation will be verified with result in the journal.

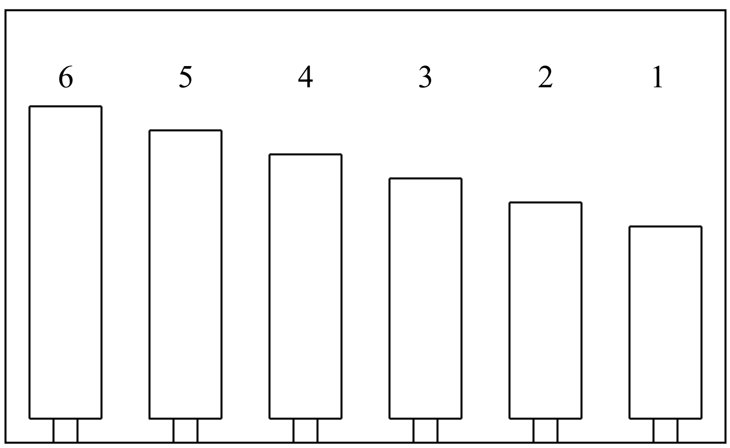


Figure 2.0 Arrangement for the microcantilevers

The various dimensions for microcantilevers will gave various resonance frequencies value. The variation is necessary because it will provide effective sensor because the microcantilevers can detect various gas that have various mass and concentration.

All the microcantilevers and microbridge have its own resonance frequency. It is easy to get an object to vibrate at its resonance frequencies [9]. This analysis is about to define the resonance frequency for these microbeams. Generally, an object vibrate without interference at a rate determine by its physical characteristics, including its mass, tension, and stiffness. When set into vibration, it will always vibrate at its own specific frequency, which is its resonance frequency [9]. Electrostatic actuation is used to operate the microbeams in a resonance mode of vibration, and the resonance frequency is measured by a set of piezoresistors connected in a Wheatstone bridge configuration. The frequencies at which each microbeam vibrates most easily (its resonant frequencies) are determined by several factors, including mass and stiffness. Stiffer objects have higher resonant frequencies, whereas more massive ones have lower frequencies, and when mass is increases, the resonance frequencies will decreases [9].

Modes are associated with structural resonances vibration in the microbeams. Modes are inherent properties of resonant structures. Modes only change with changes in the physical properties (mass, stiffness), it do not have unique values. Each mode is defined by its modal frequency [9]. In this analysis, first four resonance frequency modes for microbridge will be simulating, which means first four resonance frequency when microbridge operate in its first four different type of vibration. It is because only one microbridge is fabricated in this sensor, the structure of microbridge was fabricated to vibrate in different type.

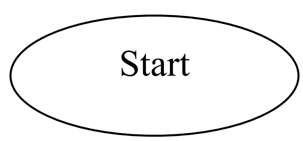
When there is gas absorp at sorbent polymer layer on the microbeam, the resonance frequency for the microbeams will change depends on mass changes. The changes will be detected by piezoresistors connected in a Wheatstone bridge configuration.

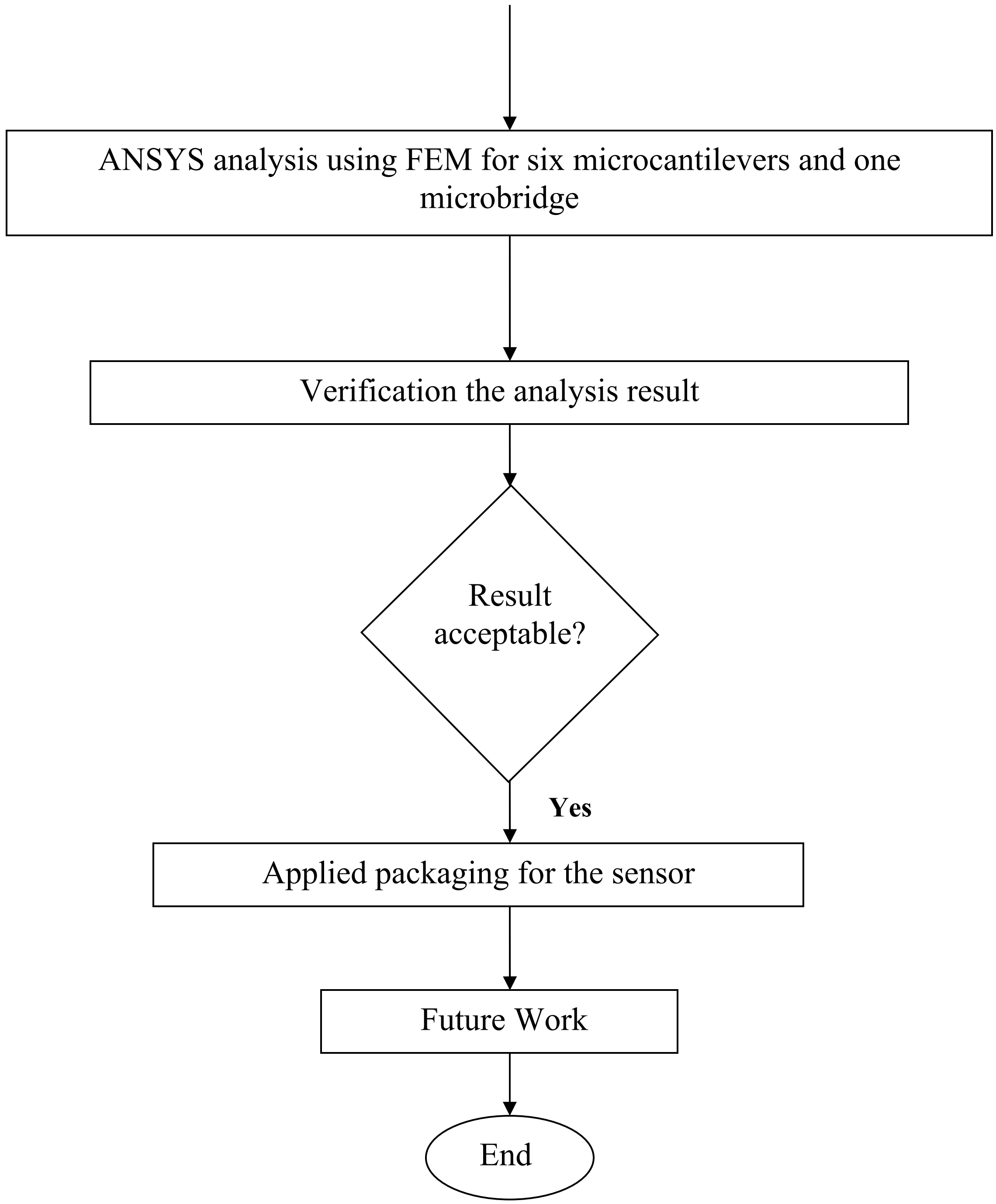
The devices were design to provide a relatively large surface area to coat with the sorbent polymer. Gas sorption in the polymer layer can be monitored as a function of the resonance frequency of the devices. A sorptive layer of polymer is coated on the microbeam, and the sorption of different gases is monitored as a shift in the device frequency. The corresponding mass increase normally leads to a decrease in the beam resonance frequency. The microbeam gas sensor is a resonating microbalance, and the sorbed gas molecules are literally weighed as a function of the device frequency.

ANSYS 7.0 (Pro Engineer) software was used for modeled the six microcantilevers and a microbridge. The simulation will be performed to define the resonance frequencies for each microcantilever using different dimensions and materials and first four resonance frequency modes for the microbridge using different materials. This simulation results will be verified with result in the journal.

After the simulation, packaging technique will be applied to this sensor. The packaging technique will be applied to this sensor depends on its requirements and applications. This packaging technique will be discussed roughly in this paper.

2.2 Flow Chart





2.3 Simulation with ANSYS Software

In the ANSYS 7.0 window (Pro Engineer), 3-D model analysis was developed for six microcantilevers and one microbridge. The design followed the actual dimensions given in the journal. For the microcantilevers, each of it have differences in their dimension (refer appendix A for absolute dimension for each microcantilever). All the microcantilevers have same thickness 4.2 µm, but different in length (L), and different in width (W). The length range for the microcantilever is between 100 µm to 225 µm, and the width range is between 40 µm to 70 µm. Microcantilever 1 has the shortest length (L) but biggest width (W), and microcantilever 6 has the longest length (L) but smallest width (W). While, for the microbridge, the modeled was done for four type materials: polysilicon, silicon oxide, silicon nitride and aluminum with same dimension (Fig. 2.1). All of six microcantilevers also will be modeled in these different materials. Then, the simulation will be applied for each of microcantilevers and microbridge modeled. The purpose of the simulation is to define the resonance frequency for the microcantilevers depends on different dimension and materials for each microcantilever and first four resonance frequency modes for the microbridge depends on different materials.

The simulations were performed without the polymer coating. The mesh elements of all analyzed microcantilevers and the microbridge are made using tetrahedral elements (SOLID 92). The mechanical properties of the different thin-films materials, such as Young's Modulus, density, and thermal conductivity for the microcantilevers and the microbridge are approximated from Table 2.0 below.

Material	Young Modulus E [GPa]	Density ρ [g/cm^3]	Thermal Conductivity λ [W/mK]
Polysilicon	168	2.3	28
Silicon Oxide	74	2.2	1.4
Silicon Nitride	320	2.8	3
Aluminium	72	2.7	236

Table 2.0 Young Modulus (E), Density (ρ), and Thermal Conductivity (λ) of the thin film materials as used for the Finite Element Simulation.

For the microbridge, ANSYS simulation of the resonance frequency modes is shown in Fig. 2.1 below. The corresponding bridge SEM image is shown in Fig. 1.3. Microbridge is a beam that fixes both of its ends and it has larger plate in the middle of the beams.

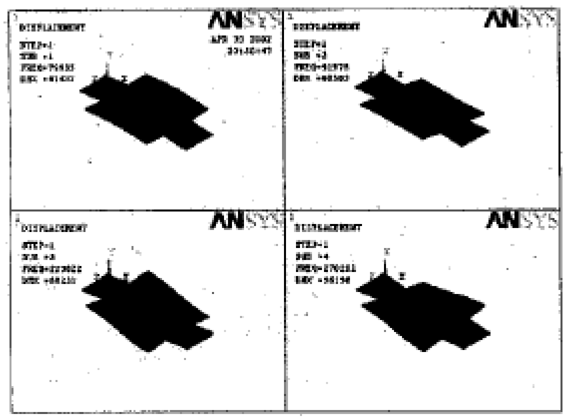


Figure 2.1 ANSYS simulation of the resonance frequency of the bridge design. Only the first four lower modes are graphically represented. The bridge dimensions are: beam length 120 μm, beam width 100 μm, plate length 280 μm, width 280 μm, and thickness 4.2 μm.

CHAPTER 3

RESULT AND DISCUSSION

3.1 Verification of Microcantilever

This chapter discussed the result obtain from the simulation result on ANSYS software. This result will be compare with journals result.

	$f_{journal}$ (kHz) [Result from journal]	f_{ANSYS}(kHz) [polysilicon]	f_{ANSYS}(kHz) [silicon oxide]	f_{ANSYS}(kHz) [silicon nitride]	f_{ANSYS}(kHz) [aluminum]
Microcantilever 1	380	379	252	280	120
Microcantilever 2	250	243	206	223	109
Microcantilever 3	180	173	121	146	93
Microcantilever 4	150	141	104	123	76
Microcantilever 5	115	108	87	97	72
Microcantilever 6	100	96.4	63	71	43

Table 3.0 Comparison result for microcantilevers with different dimensions and materials with result from journal.

Table 3.0 shows the comparison result for resonance frequencies between journal and simulation in ANSYS 7.0 software for six microcantilevers using different dimensions and materials (refer appendix A for absolute dimension for each microcantilever and Fig. 2.0 for its arrangement). Error between 0.26% and 6% occur from this verification result for polysilicon microcantilevers. It is clear that polysilicon is the best material for microcantilevers design and microcantilevers in the journal also use this material for its fabrication based on the similarity for both results. This result is acceptable and that means the analysis have been done is correct. Further analysis and packaging technique can be applied.

3.2 Parametric Studies on Microcantilever

Six microcantilevers was modeled on ANSYS 7.0 software for different dimensions (refer appendix A for absolute dimension of the microcantilevers). In this regard, the length (L), and the width (W) of the microcantilevers, are varied in order to determine the optimal dimensions for these structures (Fig. 1.4). Range for L is between 100 μm and 225 μm, and the range for W is from 40 μm to 70 μm. Microcantilever 1 has the shortest length (L) but biggest width (W), and microcantilever 6 has the longest length (L) but smallest width (W). The variation in these microcantilevers dimension is for getting the larger surface areas for gas detection for various resonance frequencies.

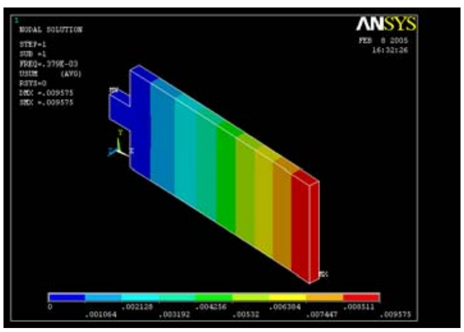
Each of these microcantilevers has a specific resonance frequency, which varies as a function device shape, structure mass and the physical properties of its component materials. For that purpose, each of these microcantilevers will be simulating on ANSYS software to define its resonance frequency in different materials: polysilicon, silicon oxide, silicon nitride, and aluminum.

3.2.1 Varied Dimension (L and W)

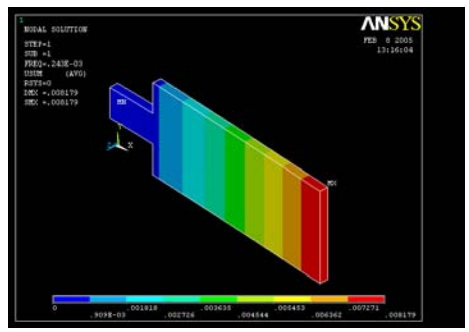
The length (L), and the width (W) of the microcantilevers, are varied in order to determine the optimal dimensions for these structures. Range for L is between 100 μm and 225 μm, and the range for W is from 40 μm to 70 μm. Microcantilever 1 has the shortest length (L) but biggest width (W), and microcantilever 6 has the longest length (L) but smallest width (W).

The simulation below shows the resonance frequencies for all six microcantilevers varied dimensions using different materials. The colors shows the deflection distribution, where the red one is for the highest deflection, while the blue one for the lowest deflection.

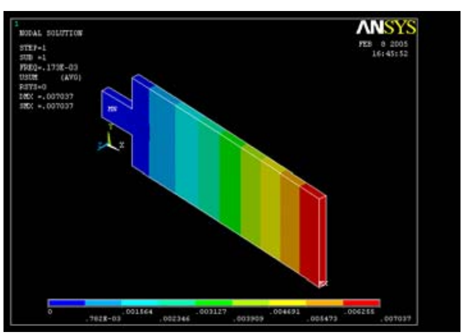
Simulation for Polysilicon Microcantilevers;



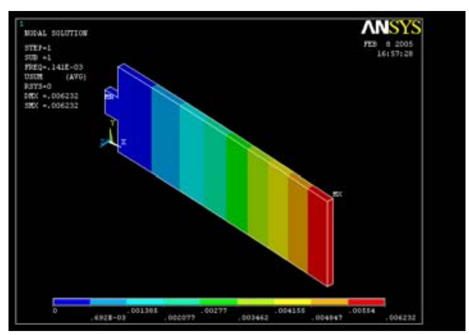
Microcantilever 1



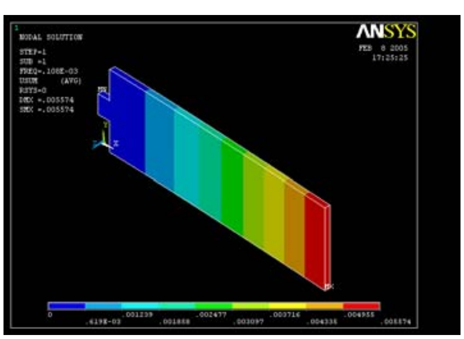
Microcantilever 2

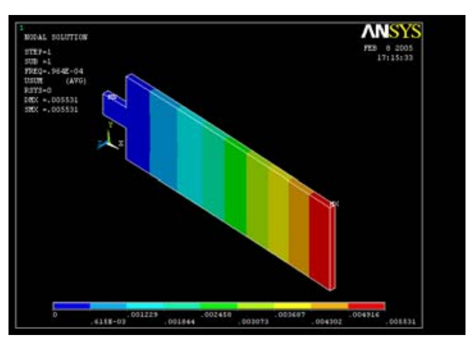


Microcantilever 3



Microcantilever 4





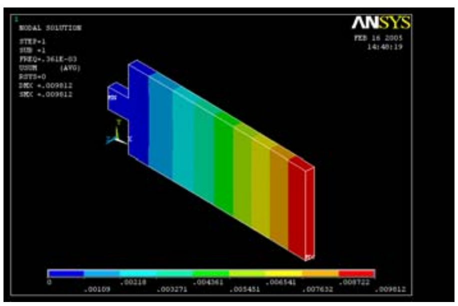
Microcantilever 5 Microcantilever 6

Figure 3.0 Simulation for polysilicon microcantilever for all six microcantilevers.

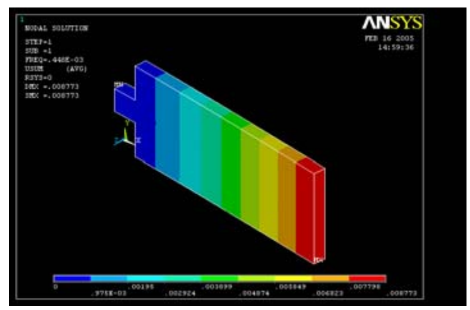
	Resonance Frequency, f_{ANSYS}(kHz)[Polysilicon]
Microcantilever 1	379
Microcantilever 2	243
Microcantilever 3	173
Microcantilever 4	141
Microcantilever 5	108
Microcantilever 6	96.4

Table 3.1 Resonance Frequencies result for polysilicon microcantilevers.

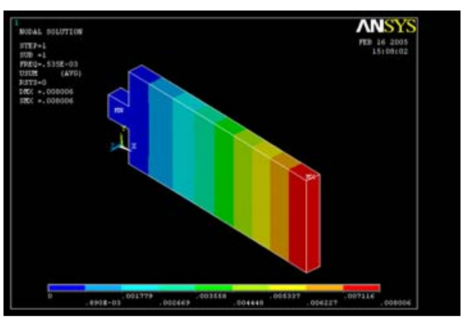
Simulation for Silicon Oxide Microcantilevers;



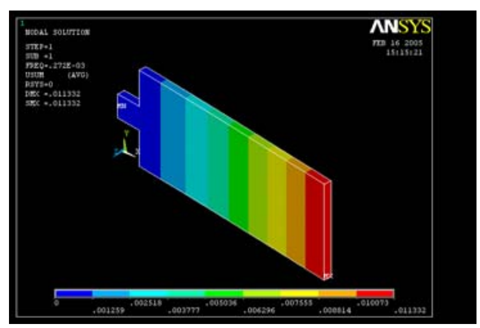
Microcantilever 1



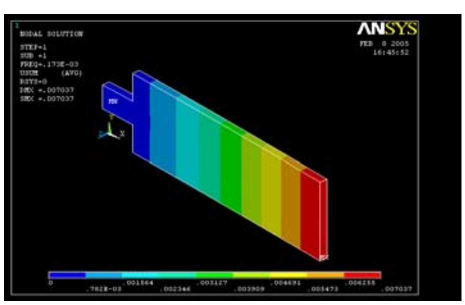
Microcantilever 2



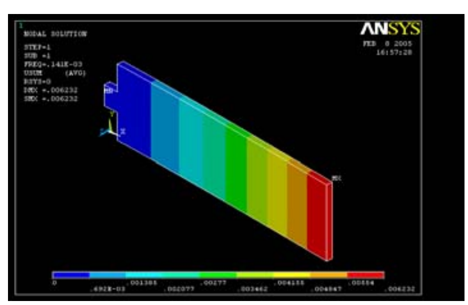
Microcantilever 3



Microcantilever 4



Microcantilever 5



Microcantilever 6