BE PROJECT
Report
$VIII^{th}$ **Semester (CBGS)**

MICRO-TCD GAS SENSOR: DESIGN OPTIMIZATION, SIMULATION AND ANALYSIS

Submitted in partial fulfillment of
the requirements of the term work for subject BE PROJECT

Submitted by

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Certificate

This is to certify that this is a bonafide record of the project presented by the students, whose names are given below, during Semester VIII in partial fulfillment of the requirements of the degree of Bachelor of Engineering in Electronics Engineering.

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Date:	**Date:**

Seal of the Institute

Abstract

TCD (Thermal Conductivity Detector) is a MEMS-based device which acts as a gas sensor on application of external voltage.The dimensions required for such micro bridge used in TCD were obtained from earlier study. Project aims at designing TCD with optimize geometry and use it for a gas sensing application. Analysis of such a model was done in coventoware wherein analysis of this sensor for gas sensing was not possible.We realized that ANSYS software is also used for MEMS simulation and gives better visualization. We aim at detail simulation on ANSYS and also like to incorporate limitation of fabrication process through our simulation. We also aim at analyzing the various gases and there concentration by observing the change in resistance of TCD.

Project covers the stress analysis of the optimized geometry and transient response of the proposed model. Hence, modelling and analysis of TCD in ANSYS software with its results are presented in this report.

Acknowledgement

We would like to thank Prof. Prashant Kasambe, Electronics Engineering Department, Sardar Patel Institute of Technology, for giving us the opportunity to work on this project and helping us whenever necessary. Without his apt suggestions and constructive criticism, we would not have been able to realize our project to completion.

We would like to extend our sincere thank to Dr. S. S. Rathod, Dean Academics, H.O.D. Electronics Department, Dr. R. G. Sutar, Deputy H.O.D. Electronics Department and Dr. Prachi Gharpure, Principal, S.P.I.T. for providing us resources needed for completing this project. Also we would like to thank our lab assistants and non-teaching staff for their constant support.

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Sagar Zoting
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Contents

List of Figures

List of Tables

Chapter 1

Introduction

Micro ElectroMechanical Systems, i.e., MEMS technology is a field that deals with devices in micron range, which can be used as sensor or actuators. The existing macro devices can be minitiarized into MEMS devices, enhancing their electrical and mechanical properties. Microheater is one such MEMS device, which can generate high amount of temperature on application of external electrical voltage. Our project aims at designing, simulating and fabricating a fast and low power MEMS based microbridge, which is a special type of μheater. Micro-bridge works on the the principle of Joules Heating, i.e. I^2Rt. Hence, high length to cross sectional area ratio is desired, leading to a bridge-like structure. However,higher resistance can limit the current and thus introducing one of many trad-offs in the design. Another trade-off exists between power consumption of the bridge and its response time. This is achieved by selecting appropriate materials at every layers and designing optimized geometrical structures. Designing of the structure involves selecting geometry of microbridge. The aim was to design a structure, which had maximum Joules heating (I^2Rt). Thus, the resistance of microbridge structure is an important parameter. This is decided by the resistivity of the material used as the heating element. This increased temperature, can lead to thermal as well as mechanical stresses. Hence, the choice of surrounding materials should be such that these effects are minimised. The final temperature and the speed of response are a function of the dimensions of the microbridge.

1.1 Motivation

The motivation behind this project is to study the behavior of MEMS devices and fabricate. Also to observe the different parameters that can affect the performance of the device such as environment, trench size, structure, material used etc. Develop the device that has minimum power consumption and fast response.

1.2 Problem Statement

A combined and comprehensive analysis of power consumption and time response was difficult to find in the resources we found. Also, a systematic approach for simulation of a device on ANSYS software was not available, along with optimisation of simulation and design parameters. Thus through our work we try to deal with both the parameters power consumption and time response at once.

To design TCD for minimum power consumption and fast response using MEMS simulation software.

- Study of the power consumption and transient response equations for the device size.
- Deciding the trench window size for the device.
- Study and design the dimension parameters for the manufacture.
- Verification of the device behavior (transient response, resistance and temperature) in different gases and its different concentration.
- Simulation optimization.

Chapter 2

Literature Review

A lot of research has been done for fabrication of a micro-heater for gas sensing applications and thermal conductivity detectors. In this section, we have have discussed a few papers which deal with their design and fabrication.

- The work done by P. Bhattacharya in his review report "Technological Journey Towards Reliable Microheater Development for MEMS Gas Sensors: A Review" compared different geometrical structures of the microheater, with respect to their efficiency.However, use of micro-hotplates consume higher power than micro-bridge but have a uniform heating profile over the area.

- Alireza Mahdavifar, Milad Navaei, Peter J. Hesketh, Melvi Findlay, Joseph R. Stetter and Gary W. Hunter, in "Transient thermal response of micro-thermal conductivity detector"(μTCD) for the identification of gas mixtures: An ultra-fast and low power method, studied the power consumption of a micro-thermal conductivity detector and analytically proved it. Micro-heater was used as a gas sensor and its characteristics under different gases were seen. The power consumed by their bridge was 2mW for temperature of 573K.

- "Multilayer microheater based on glass substrate using MEMS technology" by Wen-Yang Chang and Yu-Sheng Hsihe describes the microheater on a glass substrate for 771K. The material used for microheater was Platinum with power requirement of 2.35W.

- The work done in the "Fast response integrated MEMS microheaters for ultra low power gas detection " by Qin Zhoua, Allen Sussmana, Jiyoung Changa, Jeffrey Donga,b, Alex Zettl and William Mickelsona was dedicated to the derivation time constant of a microbridge. The time constant obtained by their microbridge is 33μs.

Chapter 3

ANSYS Software

3D model will be designed based on geometrical parameters obtained from the results on Matlab. Simulation of the same model is carried out on the ANSYS Software. Various physical parameters such as physical stress,thermal stress, etc. will be analyzed using simulation. Successful MEMS suppliers verify all aspects of their designs with simulations before sending them to the fab. ANSYS is an integrated suite of design and simulation software that has the accuracy, capacity, and speed to address real-world MEMS designs. The suite has many MEMS specific features for modeling and simulating a wide range of MEMS devices, including inertial sensors (accelerometers and gyros), microphones, resonators, and actuators. The included field solvers provide comprehensive coverage of MEMS-specific multi-physics, such as electrostatics, coupled electro-mechanics, piezoelectric, piezoresistive, and damping effects.

3.1 Simulation Steps

1. Open the software ANSYS. Start-up window will display list of analysis systems that can be performed in ANSYS. Select Thermal-electric analysis system as this analysis includes application of temperature and voltage.Upon selecting this a window will pop up showing the contents of the analysis system which needs to be performed.

2. Now select on Engineering data.If no engineering data is selected by default Structured steel is assigned to the material.So here,for the development and design of the model following materials are required: Silicon, polymide,Silicon Nitride, Polysilicon, Gold and different gases for environmental conditions. This materials are assigned to the different sub structures of model.

3. If any material is not available in the ANSYS library, then using a basic properties of the material we can create user defined library.In the inbuilt material library polysilicon file was absent, So we created polysilicon file and added different properties.

4. After completing the engineering data section our next step is design model. In this we can import the model from the CAD, coventorware as well as we can develop in the inbuilt modeler. So, we used spaceclaim modeler to develop the model.The spaceclaim is easy to use like CAD software.

5. After developing the model the objective is to assign the materials to their respective structure.Silicon is assigned to the substrate of the model. Polymide is assigned to the

base of the μbridge. μbridge is made up of the Crystalline Poly-silicon. then we need to cover the bridge using silicon nitride because we need to minimize the conduction losses.

6. Now our actual model is ready. The main part of the simulation is to define the fine element i.e. minimum size of the model we can take in account so the simulation will me efficient.This phenomenon is called meshing. In the ANSYS there are many types of meeshing technique like linear, parabolic,quadratic.We can control the resolution of the meshing. we can make meshing fine,coarse and medium. As ANSYS have smart meshing tool. The meshing results are generated automatically.

7. After generation of the meshing for simulation we need to apply the different potential at different points.So the joules effect we can see.The simulation is about the temperature at the different points in the model.This temperature is observed at surface and this surface temperature is going to be affected by the surrounding air.So, we define problem as convection and set film coefficient for the surrounding air.

8. In solution section, we define temperature parameter. After that we can change the input type , amplitude. After clicking solve the graph and simulation is observed. This observed simulation is time dependent.So, if the input is variable according to the time temperature will change time to time.

Chapter 4

Work Done

4.1 Process Flow

Figure 4.1: Silicon Substrate

Figure 4.2: Deposition of Polyimide Layer

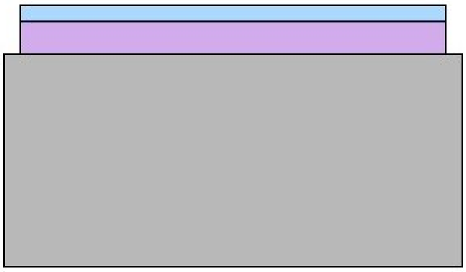

Figure 4.3: Deposition of Silicon Nitride Layer

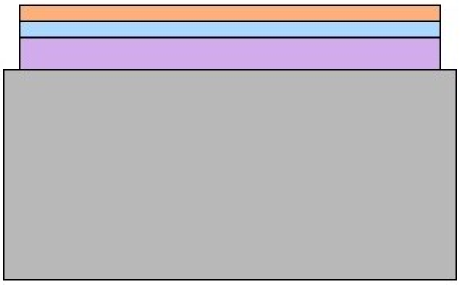

Figure 4.4: Deposition of Polysilicon Bridge

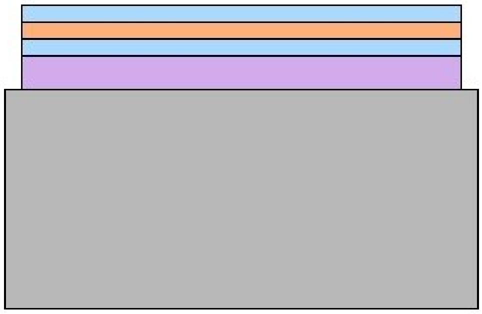

Figure 4.5: Deposition of Silicon Nitride

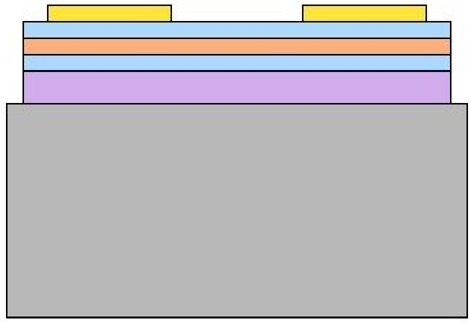

Figure 4.6: Deposition of Gold Contacts

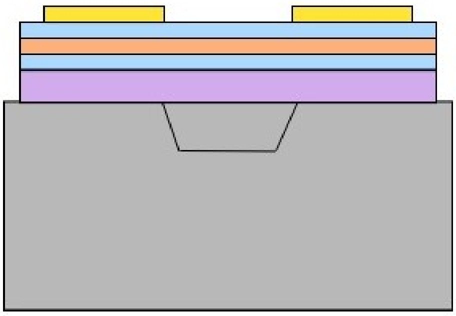

Figure 4.7: Final Geometry with Trench

4.2 Design and Development of TCD in ANSYS

Process flow divided in two parts:

1. Model construction and designing.
2. Material assigning and model developing.

4.2.1 Construction and Designing of Model

1. Create the cuboid of dimension of [Length breadth Hight]=[2mm 1mm 500μm].

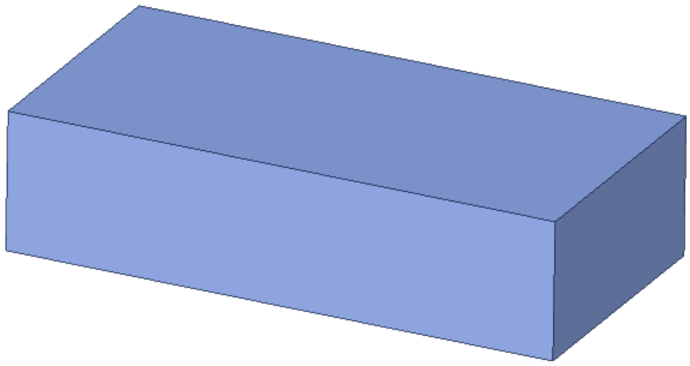

Figure 4.8: Silicon Substrate

2. Now the base for bridge created that will act as thermal insulator.It will be symmetrical about bisecting line of the substrate length and width.For the contacts base, dimensions will be [AREA]=[500μm * 500μ]. the bridge sections dimension will be [Length Breadth Thickness] = [100μm * 8μm * 10μm]

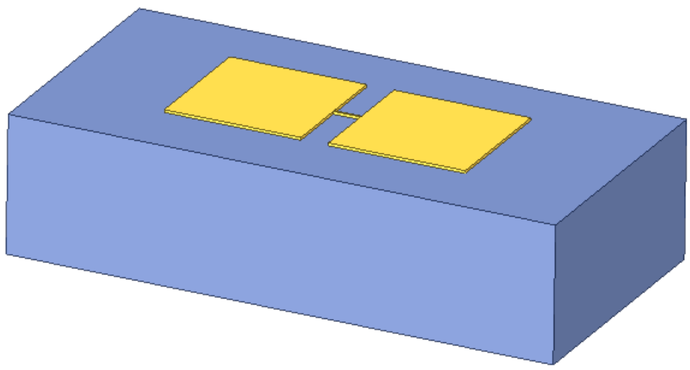

Figure 4.9: Polymide Layer applied

3. Development of the silicon nitride cover for the polysilicon which will act as electrical insulator. Dimesions will be same as the polyimide but the thickness will be 1μm.

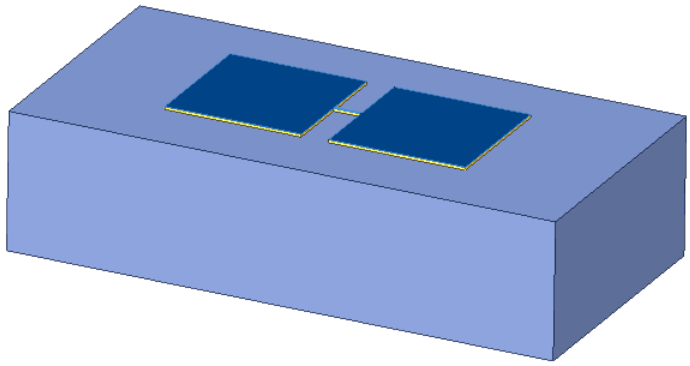

Figure 4.10: Silicon Nitride Layer

4. Now the polysilicon is layer added which is very thin so silicon nitride will cover it from all side. dimensions will be contacts square [AREA] = [500μm * 500μm] and the bridge dimension will be [Length Breadth Thickness] = [100μm 2μm 0.1μm]

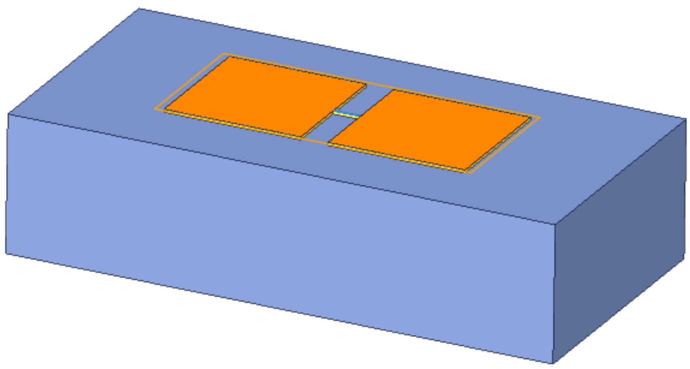

Figure 4.11: Polysilicon Layer

5. As electrical contacts gold is required. By making trench in the contacts and depositing the gold for current flow through the bridge . The gold dimension will be the [Length Breadth] = [300μm * 250μm]

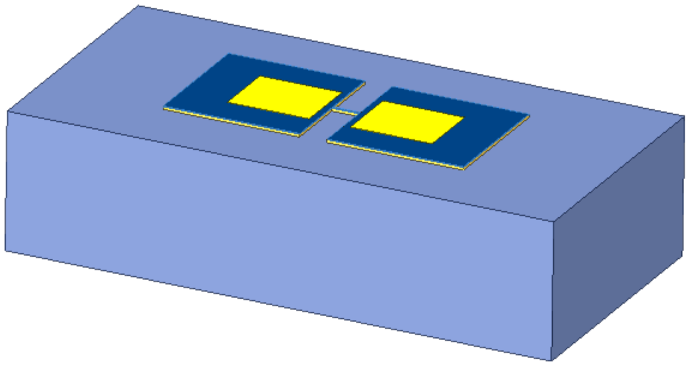

Figure 4.12: Gold Contacts

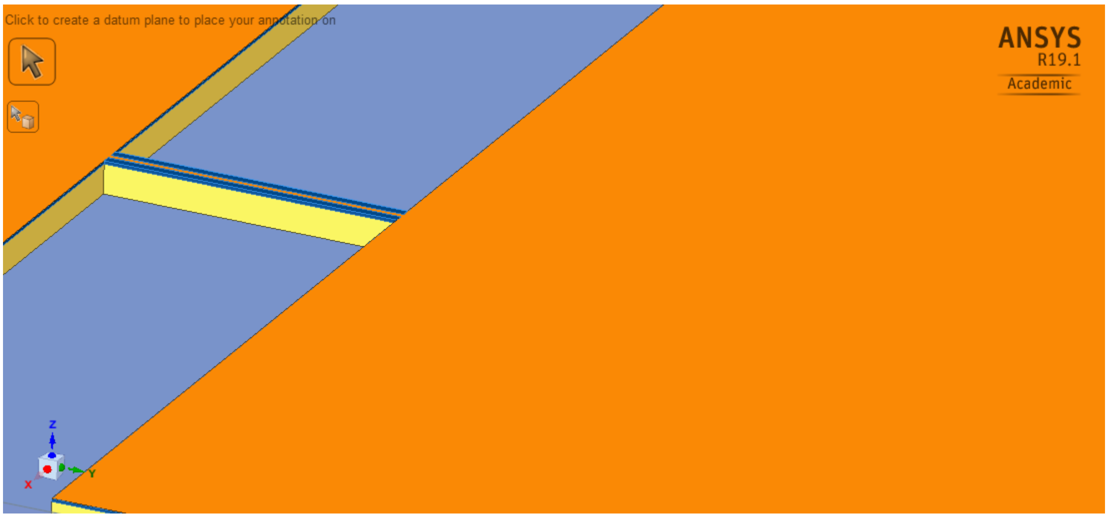

Figure 4.13: View of Polysilicon Bridge

4.2.2 Material Assigning and Simulation Environmental Setup

1. After developing the model we need to add the material in simulation window. First we will assign the silicon as substrate structure. The silicon have a plane [100].Silicon substrate our wafer on which our sensor is going to develop.

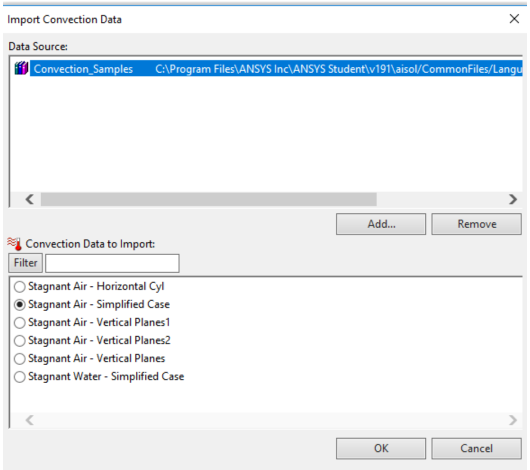

Figure 4.14: Environmental Setup

2. The polyimide is assign at the bootom of bridges layer. Which will act as the thermal insulator. otherwise the heat from the polysilicon will be affect the wafer and the temperature will me decrease.

3. Now the silicon nitride is assign to the bridges which will cover the polysilicon from all side which will protect from the conduction loss . So, basically it will act as electrical insulator.

4. Polysilicon is assign as the heating element. Which will be fitted in between silicon nitride bridges. Polysilicon is used because of its versatility like by changing its doping concentration the conductivity will change, resistivity will change.

5. For the environmental atmosphere we need to add the air. By importing the stagnated air to the simulation file. The results will be according to that.

4.3 Calculations

4.3.1 Calculations for Heat Transfer Coefficient

The heat transfer coefficient or convective coefficient (h), is used in thermodynamics to calculate the heat transfer typically occurring by convection. A simple way to calculate h is to define it through the classical formula for convection, and compare it with a different definition of h, through dimensionless parameters.

$$Gr = \frac{g * L^3 * \beta * (T_p - T_a)}{\eta^2} \tag{4.1}$$

g = acceleration of gravity = 9.81, m/s2
L = longer side of the fin, m
B = air thermal expansion coefficient
Tp = Plate temperature, °C
Ta = Air temperature, °C
n = air kinematic viscosity, is 1.5- at 20 °C. 1.6- at 30 °C

$$Pr = \frac{\mu * cp}{k} \tag{4.2}$$

u = air dynamic viscosity, is 1.81- at 20 °C. 1.86 - at 30 °C
cp = air specific heat = 1005 J/(Kg*K) for dry air
k = air thermal conductivity = 0.026 W/(m*K) at 27 °C

$$Ra = Gr * Pr \tag{4.3}$$

The Nusselt number is given for different flow types as follows:

	Vertical fins		Horizontal fins
Laminar flow	$Nu = 0.59 * Ra^{0.25}$	Upward laminar flow	$Nu = 0.54 * Ra^{0.25}$
Turbulent flow	$Nu = 0.14 * Ra^{0.33}$	Downward laminar flow	$Nu = 0.27 * Ra^{0.25}$
		Turbulent flow	$Nu = 0.14 * Ra^{0.33}$

The Heat transfer coefficient of gases can be given as

$$h_c = \frac{Nu * k}{L} \tag{4.4}$$

Nu = Nusselt number
hc = convective heat transfer coefficient
k = thermal conductivity, W/mK
L = characteristic length, m

	Co_2	He	N2
Dynamic Viscosity	$1.5*10^{-5}$	$2*10^{-5}$	$1.82*10^{-5}$
Density	1.98	0.166	1.2504
Specific heat	$0.846*10^{3}$	$5.1926*10^{3}$	$1.039*10^{3}$
Thermal conductivity	0.017	0.151	0.026

Using this method to find Heat Transfer Coefficient, We found its value for Carbon Dioxide, Helium, Nitrogen as follows (in W/m2°C):

Carbon Dioxide 5.6325

Nitrogen 5.56

Helium 7.8578

4.3.2 Calculations for Power Consumption

The heat loss through conduction of the beam can be estimated as:

$$P_{\text{beam}} \approx \frac{\varepsilon\, \Delta T k w t}{L} \tag{4.5}$$

where T is the temperature difference between the beam center and the anchor, L is the length of the beam, k is the thermal conductivity of the beam material (polysilicon = 32 ohm-1m-1), w is the width of the beam, and t is the thickness of the beam.
The approximate power lost to the surrounding air is given by;

$$P_{\text{air}} = \frac{\pi k_{\text{air}} L}{\ln(L/w)}\ \Delta T \tag{4.6}$$

The total power consumption is:

$$P = P_{\mathrm{air}} + P_{\mathrm{beam}} = \Delta T \left(\frac{\pi k_{\mathrm{air}} L}{\ln(L/W)} + \frac{8kwt}{L} \right) \tag{4.7}$$

Here we consider Kair as thermal conductivity of different gases as mentioned above.

4.3.3 Calculations for Initial and Final Resistance

The initial resistance of the polysilicon can be given as :

$$R = \frac{\rho L}{A} \qquad \begin{array}{l} \rho = \text{resistivity} \\ L = \text{length} \\ A = \text{cross sectional area} \end{array} \tag{4.8}$$

Since the resistance of polysilicon changes with temperature it is given as:

$$R = R_{ref}\,[1 + \alpha(T - T_{ref})] \tag{4.9}$$

Chapter 5

Results

5.1 Geometry Optimization Process

Effect of Insulator Layers

The polysilicon bridge is get heated up when voltage is applied to gold contacts. When polysilicon bridge is not covered by insulator layers the temperature is distributed in silicon substrate causing less temperature change of bridge.
When insulator layers are deposited below and above of polysilicon bridge the temperature of bridge rises significantly and so we can use the layered bridge structure for sensing purpose. The insulating layers used are Polyimide and silicon nitride as thermal insulator and electric insulator respectively.
Results shows the presence of insulating layers reduce transfer of heat through substrate.

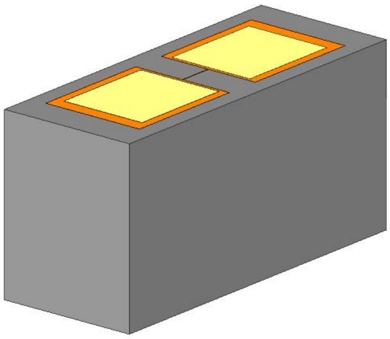

Figure 5.1: Geometry Without Insulating Layers

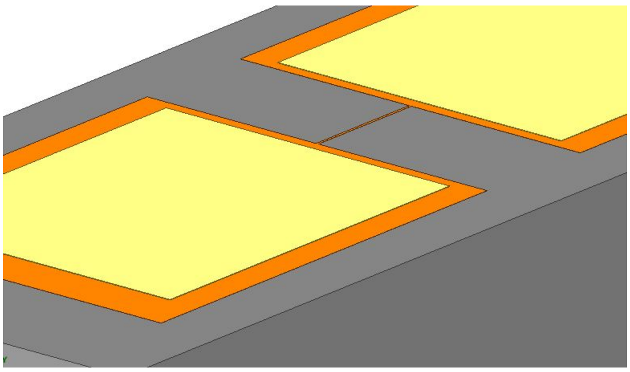

Figure 5.2: Close View of Polysilicon Bridge

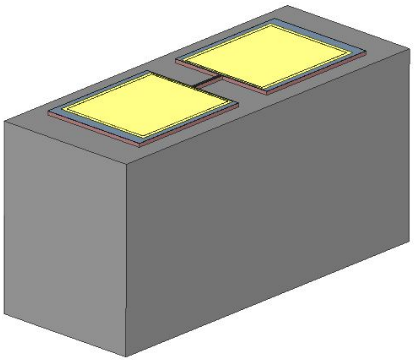

Figure 5.3: Geometry With Insulating Layers

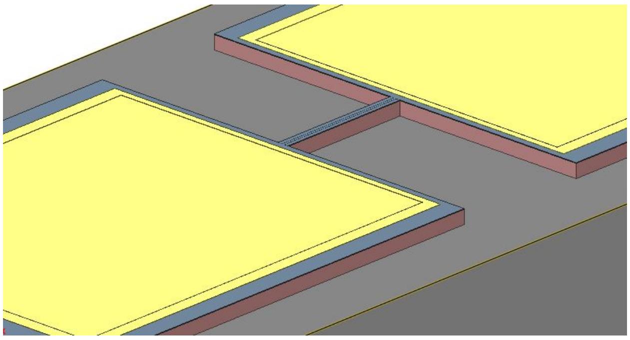

Figure 5.4: Close View of Polysilicon Bridge

The temperature distribution around the polysilison bridge is shown below

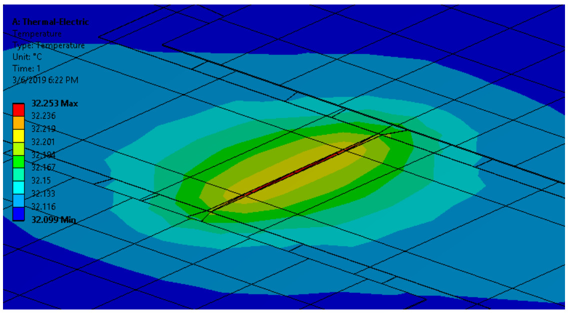

Figure 5.5: Temperature Distribution Without Insulating Layers

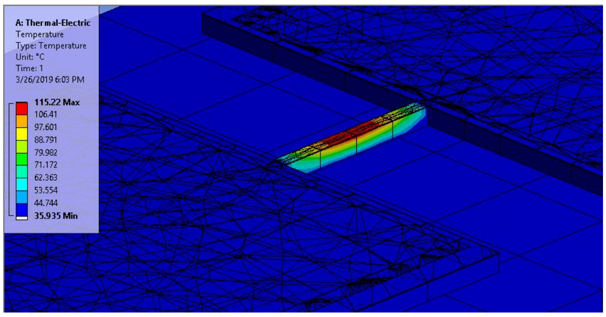

Figure 5.6: Temperature Distribution With Insulating Layers

The results obtained shows that there is significant change in temperature when polysilicon bridge is covered with insulating layers. The maximum temperature reached without insulating layer is 32.253 °C, while insulating layers gives maximum temperature as 115.22 °C

Effect of Trench depth variation (Window Size Variation)

The next modification in geometry is to add trench which will affect the overall rise in temperature. We simulated the models for various trench depths such as 10μm, 15μm, 20μm and 30μm. The results shows that as the trench depth increases the temperature rise also increases till the specific trench depth.So these results can be use for deciding the optimum value of trench depth, practically it will optimize the fabrication process time.

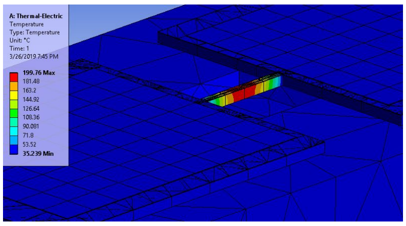

Figure 5.7: Trench Depth 10μm

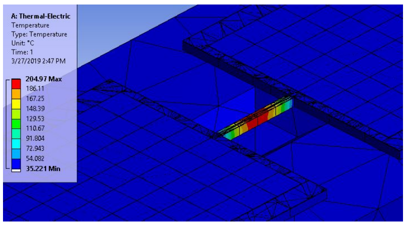

Figure 5.8: Trench Depth 15μm

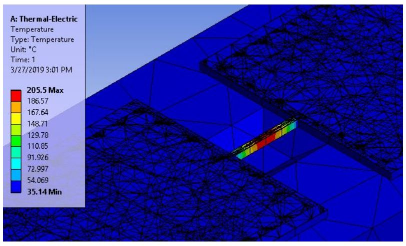

Figure 5.9: Trench Depth 20μm

Table 5.1: Variation in Trench Depth

Trench Depth (μm)	Temperature (°C)
10	199.76
15	204.97
20	205.5
30	205.6

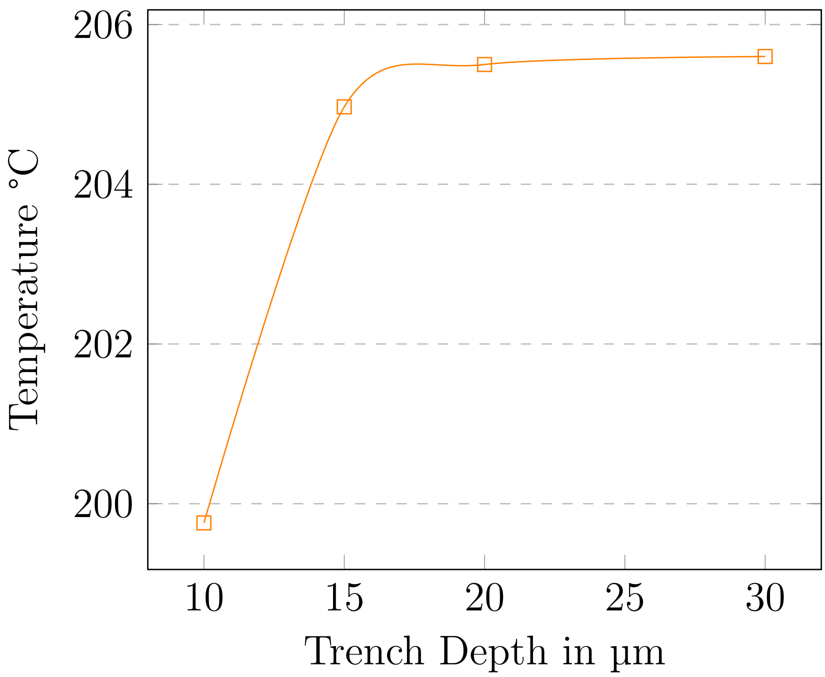

Figure 5.10: Temperature Vs Trench Depth

Effect of Polysilicon Dimension Variation (Length, Width and Thickness)

Effect due to variation in length of polysilicon bridge

To optimize the performance of TCD we need to consider different lengths of polysilicon bridge.Here bridge lengths are varied as 50μm,100μm and 200μm. The polysilicon bridge of length 50um gives the maximum temperature as 237.82 °C, but as bridge length increase the temperature of the beam starts decreasing as shown in Fig.5.15.

Table 5.2: Variation in Bridge Length

Bridge Length (μm)	Temperature (°C)
50	237.82
100	205.5
200	125.11

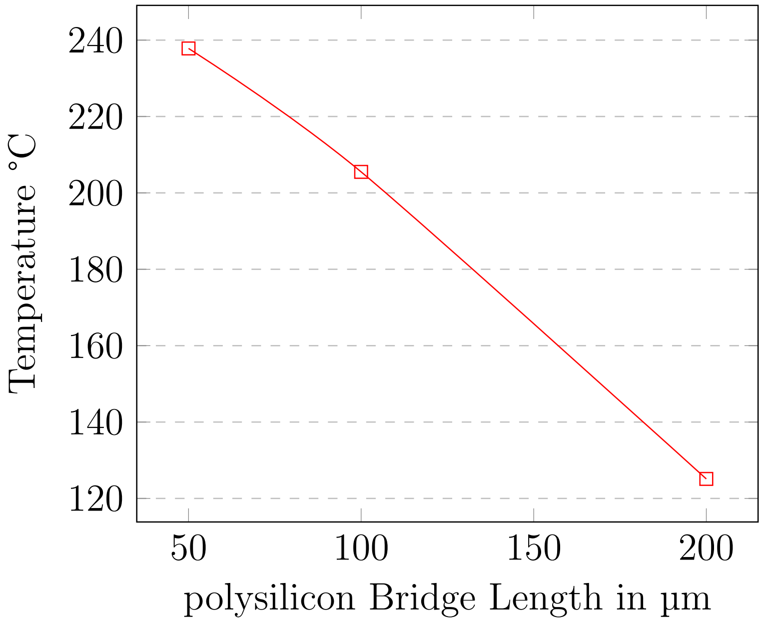

Figure 5.11: Polysilicon Bridge Length Vs Temperature

So, from the above graphical data we can consider 100μm as the optimum bridge length. Now for further modelling and simulations we assumed 100μm as optimized bridge length.

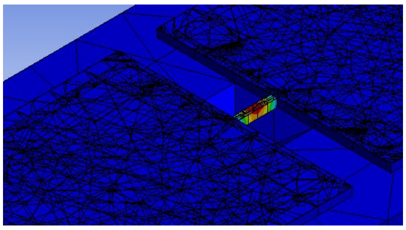

Figure 5.12: Bridge Length 50μm

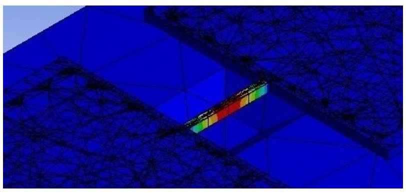

Figure 5.13: Bridge Length 100μm

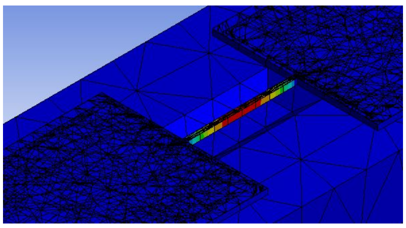

Figure 5.14: Bridge Length 200μm

Effect due to variation in width of polysilicon bridge

Another factor that affects the performance of the μTCD is the width of the multi-layer bridge. We simulated the model for various widths of polysilicon bridge such as 2μm, 5μm and 8μm.

Table 5.3: Variation in Bridge Width

Bridge Width (μm)	**Temperature (°C)**
2	205.5
5	283.98
8	344.3

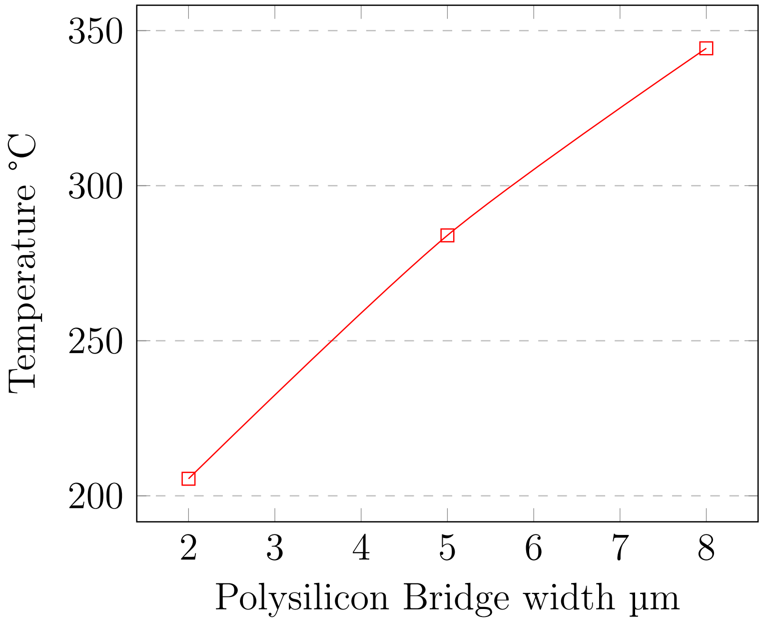

Figure 5.15: Polysilicon Bridge Width Vs Temperature

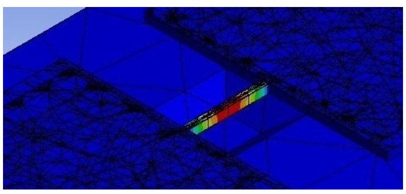

Figure 5.16: Bridge Width 2μm

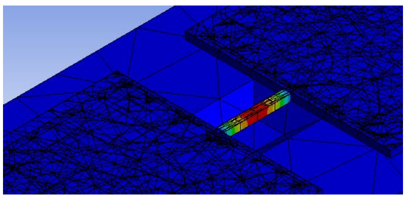

Figure 5.17: Bridge Width 5μm

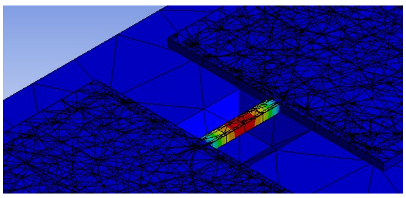

Figure 5.18: Bridge Width 8μm

Effect due to variation in thickness of polysilicon bridge

Similarly, variation in thickness of polysilicon bridge also affects the sensitivity of the uTCD.Here, simulation of 0.1μm,0.2μm and 0.5μm thicknesses of polysilicon bridge are considered.

Table 5.4: Variation in Bridge Thickness

Bridge Thickness (μm)	**Temperature (°C)**
0.1	205.5
0.2	357.21
0.5	711.01

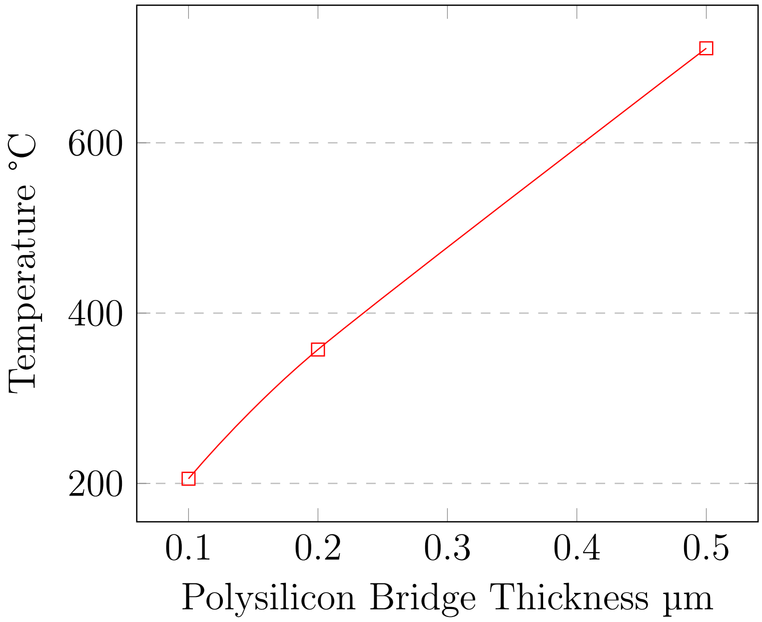

Figure 5.19: Polysilicon Bridge Thickness Vs Temperature

The results obtained suggested that the increment in polysilicon thickness also increases maximum temperature reached by the beam. The maximum temperature reached is 711.01 °C which can damage the other insulating layers such as polyimide and silicon nitride and also power consumption by the TCD also increases when temperature increases.

Considering all these parameters, 0.1um thickness of polysilicon bridge can be considered as the optimized beam thickness.
Results obtained by various polysilicon bridge width shows very less increment in temperature with increase in width. So to reduce the area occupied by the bridge and also to reduce the depositing material eventually the cost of μTCD, the 2μm width can be consider as the optimum bridge width.
Further to determine the optimize bridge length, 100μm polysilicon bridge length can be considered as optimum.

Effect of Polyimide Thickness

Since the polyimide is the thermal insulator , the thickness of polyimide layer also affect the temperature of the polysilicon bridge.
To determine the optimize thickness of the polymide layer, the previously obtained optimized dimensions of polysilicon bridge were considered i.e. length= 100μm, width= 2μm, thickness= 0.1μm.

Table 5.5: Variation in Polyimide Thickness

Polyimide Thickness (μm)	**Temperature (°C)**
5	263.54
10	249.72
20	228.95
30	216.56

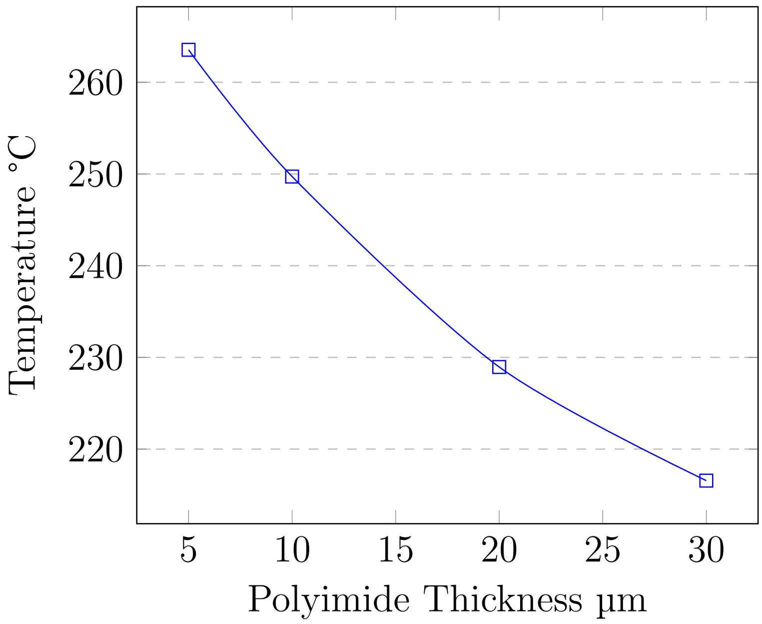

Figure 5.20: Polyimide Thickness Vs Temperature

When the thickness of polyimide is increased the temperature relatively decreases as shown in Table 5.5
At thickness of 10um for polyimide layer the maximum temperature reached is 249.72 °C which can be considered as optimum thickness.

Effect of Silicon Nitride Thickness

The silicon nitride is an electrical insulating layer which covers the polysilicon bridge from both side. The thickness of silicon nitride also affects the temperature distribution around the polysilicon bridge as shown in Table 5.6

Table 5.6: Variation in Silicon Nitride Thickness

Silicon Nitride Thickness (μm)	**Temperature (°C)**
0.1	231.33
0.4	168.05
0.6	144.07

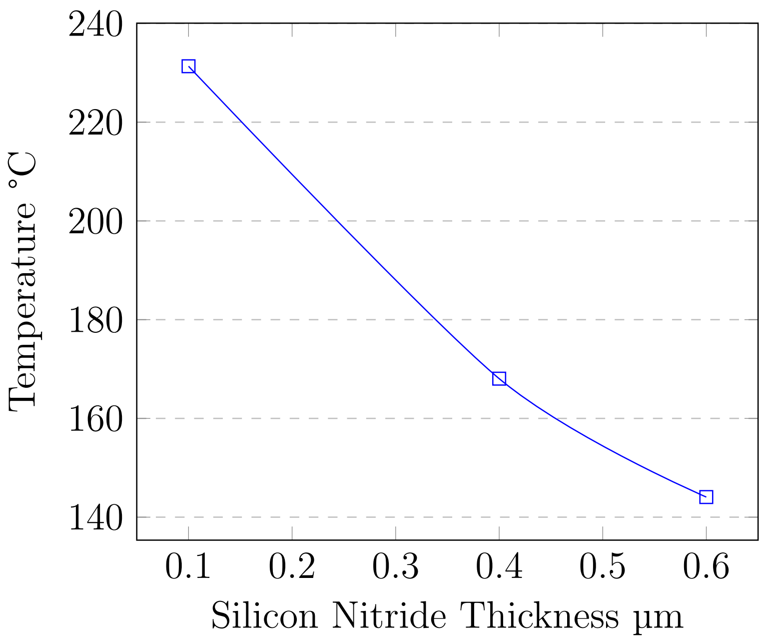

Figure 5.21: Silicon Nitride Thickness Vs Temperature

The thickness of silicon nitride and temperature can be inversely related i.e 0.1μm thickness of Si3N4 gives maximum temperature of 231.33 °C while 0.6μm thickness gives minimum temperature as 144.07 °C.
Since lowest thickness of Si3N4 i.e. 0.1μm gives desirable temperature distribution so it can be considered as the optimum thickness for Si3N4 layer.

Results of Optimized Geometry

The Fig 5.29 shows the optimized multi-layered microbridge with dimensions.

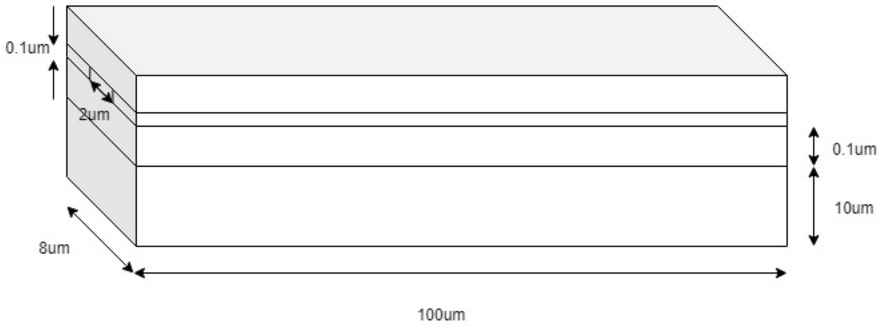

Figure 5.22: polysilicon beam with optimized dimensions

Fig 5.30 shows a plot of observed temperature distribution for different applied voltages. Temperature at joint of the bridge is closed to the room temperature, with the temperature increasing farther away from the joint, temperature at the center of the bridge is maximum because the center point is the farthest from highly thermally conductive solid substrate.

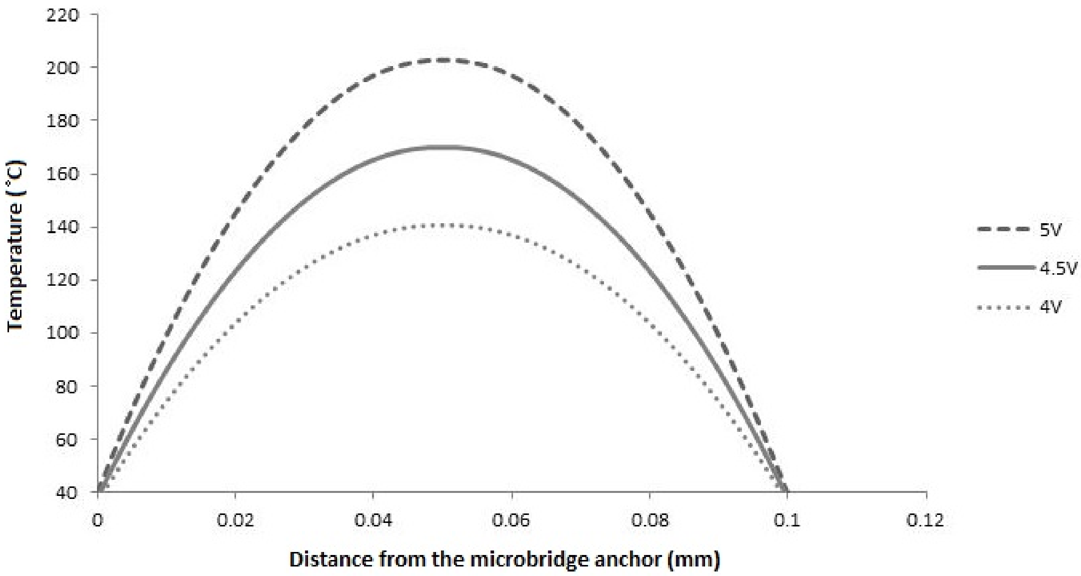

Figure 5.23: Observed temperature distribution along the microbridge in carbon dioxide under various applied voltages

At the center of the bridge the temperature was raised by about 173.03 °C above the ambient temperature,for 5 volts potential. While for 4 volts potential the maximum temperature raised was 110.74 °C more than room temperature.

Table 5.7: Temperature variation with various applied voltages

Voltage Applied to microbridge (V)	**Temperature at center of microbridge (°C)**
4	140.74
4.5	170.15
5	203.03

Fig 5.31 shows the observed temperature distribution on the microbridge surface under applying 5 volts and in presence of carbon dioxide gas, here we model the geometry using quarter symmetry to reduce the simulation time.

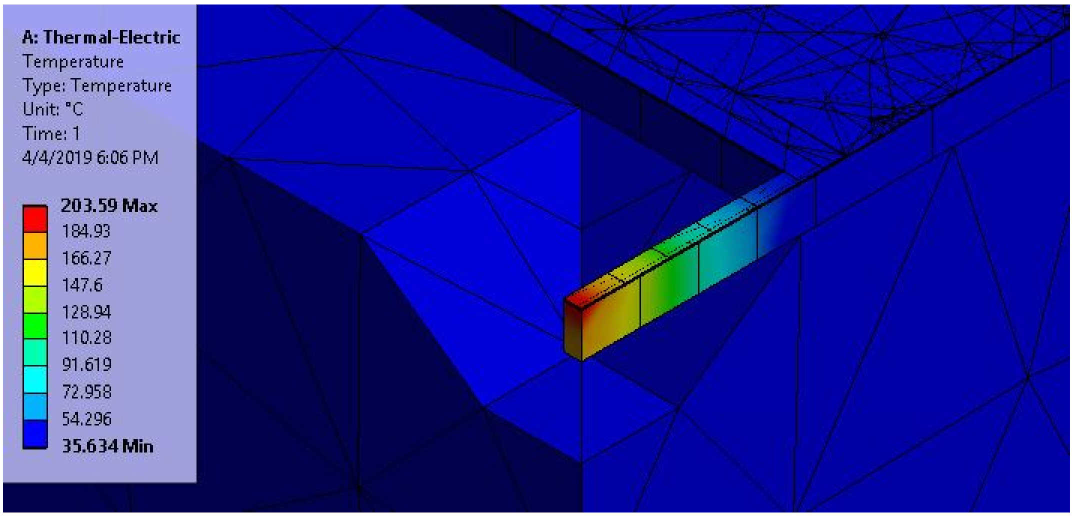

Figure 5.24: Result for quarter symmetric model

5.2 Testing in Different Gas Environment

The optimized geometry can be use for gas sensing purpose. Here we analyze the model for three different gases namely carbon dioxide, nitrogen and helium. Since the thermal conductivity of various gases are different which results in different thermal losses from bridge to air which ultimately results in different temperature change of microbridge as shown in Table 5.7

Table 5.8: Modelling results for maximum temperature, change in resistance and power of microbridge with 5V DC, for different gases

Gas	Maximum Temperature (C)	Resistance Change (kohm)	Power (mW)
Helium	186.11	3.590	
Nitrogen	203.66	3.994	
Carbon Dioxide	203.03	3.979	

The temperature distribution can we also varies when differnt voltages are applied to microbridge. Here we applied 4V, 4.5V and 5V to microbridge, results obtained is graphically shown in Fig.5.31

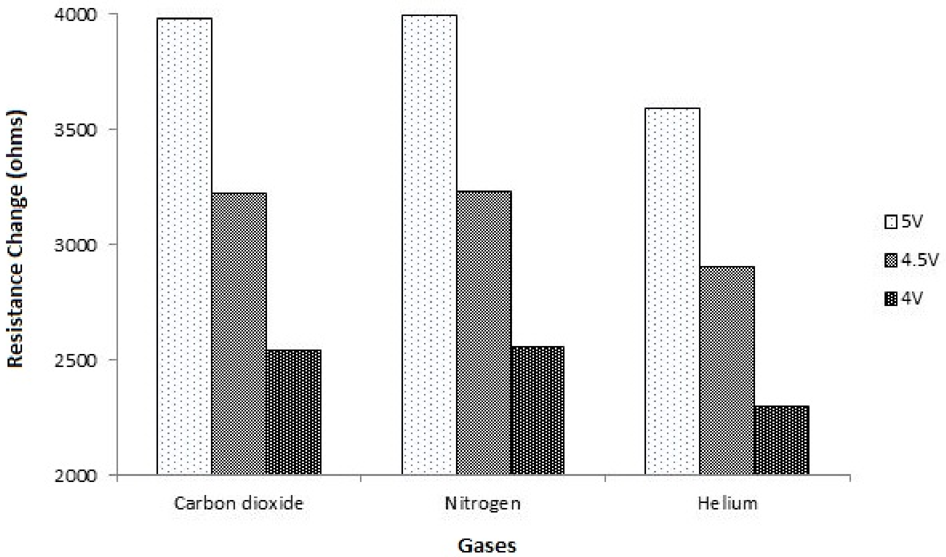

Figure 5.25

5.3 Stress Analysis of Sensor

Since the temperature of the microbridge increases as the voltage is applied at both the ends of microbridge. Initially, there is no deformation in bridge as shown in Figure 5.26 but, the rise in temperature causes the thermal stress in microbridge which causes the deformation of bridge as shown in Figure 5.27

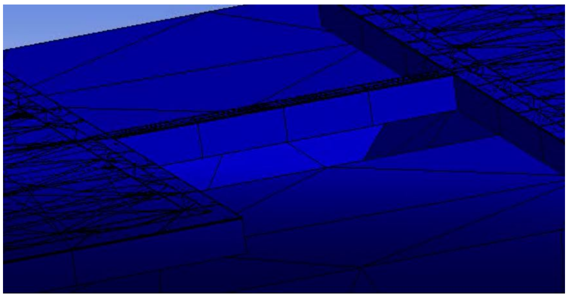

Figure 5.26: Microbridge before voltage applied

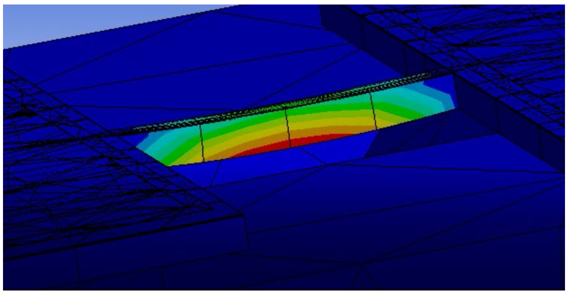

Figure 5.27: Deformation in microbridge due to rise in temperature

5.4 Transient Response of Sensor

5.5 Novel Designs

5.5.1 Cross 45°Bridge Geometry

5.5.2 Polyimide Sandwich Polysilicon Geometry

Chapter 6

Conclusions

This work has acquired a systematic approach to study, analyze, design and simulate micro-TCD. The results are obtained from the simulation.
Earlier the test model was developed and analyzed using Thermal-Electric simulation Environment on ANSYS Software. The modelling of the TCD is done as per the actual fabrication flow.The model was successfully created. It shows the temperature distribution which matches to the nature of the temperature distribution along the beam.
The systematic approach for optimizing geometry was carried out.The optimized device was tested in different gas environment. The results shows that change in resistance depends on respective thermal conductivity of gas. So we can conclude that the optimized model can be used the gas sensing application.

Bibliography

6.1 Reference Paper

[1] P. Bhattacharyya, Member, IEEE “Technological Journey Towards Reliable Microheater Development for MEMS Gas Sensors: A Review” IEEE TRANSACTIONS ON DEVICE AND MATERIALS RELIABILITY, VOL. 14, NO. 2, JUNE 2014 589.

[2] M. Gayake, D. Bodas, S. Gangal/ 2011 COMSOL Conference in Bangalore, “Simulations of Polymer based Microheater Operated at Low Voltage.”

[3] Alireza Mahdavifar1, Milad Navaei1, Peter J. Hesketh1, Melvin Findlay2, Joseph R. Stetter2 and Gary W. Hunter3 “Transient thermal response of micro-thermal conductivity detector (μTCD) for the identification of gas mixtures: An ultra-fast and low power method,” Published online: 26 October 2015.

[4] Qin Zhoua,b,c, Allen Sussmana,b, Jiyoung Changa,b, Jeffrey Donga,b, Alex Zettla,b,c,d,William Mickelsona,b “ Fast response integrated MEMS microheaters for ultra low power gas detection”, Sensors and Actuators A 223 (2015) 67 75 Available online 3 January 2015.

[5] Hasan , and Mona Zaghloul, Electrical and Computer Engineering ,The George Washington University, Washington DC, USA “The Novel Microhotplate: A Design Featuring Ultra High Temperature, Ultra Low Thermal Stress, Low Power Consumption and Small Response Time.”

[6] M. Predanocy1, I. Hotovy1, I. Kosc1, V. Rehacek1, I. Kostic2, L. Spiess3 “SIMULATION, DEVELOPMENT AND CHARACTERIZATION OF PLATINUM MICROHEATER ON POLYIMIDE MEMBRANE.”