Design and Simulation of Platinum Micro Heater for VOC sensing Applications

S Sri Surya Srikanth, B Rajesh Kumar, V.Suresh, V.Jyothi

Abstract: Micro electro-mechanical system (MEMS) technology is flourishing the development of various sensors. Conventionally MEMS devices have been extensively used for upward performance of gas sensors over a period of time. This paper presents the designing of meander shaped microheater with the commercial FEM tool is used for simulation. Microheater is designed for application of VOC sensing applications. As the volatile organic compounds are to be vaporized a microheater is used. The geometric aspects of the microheater state the temperature effects on the VOC's.Thus the dimensions were optimized for uniform distribution of heat across the surface. It was observed from the analytical analysis and FEM simulation that at 2um thickness, Microheater was able to distribute the heat uniformity across the surface.

***Keywords* : Microheater, MEMS, FEM, VOC**

I. INTRODUCTION

The definition gas sensor that determines the information about the neighboring gas atmosphere around the surface that consists of different types of dangerous and toxic gases. The device consists of sensing layer placed on the top of the supporting material on the substance and a signaling unit. Nano crystalline materials were found among the different sensors which find the wide range of $O_{2,}$ H_2, CO and various Volatile organic compounds are under operating temperature range, minimum amount of size, cheap, more sensitivity are the main parameters can be used in various applications.

In this temperature can be the primary factor which determines the sensitivity, selectivity and response time of sensor. The main concern here is chemical gas sensor is a Micro electro-mechanical sensor (MEMS) preconcentrator. MEMS technology is very famous which can be used for gas sensors as it can take minimal power consumption, roughness and small scale importance in dimensions and other gases like O_2 is needed and it is mandatory to be kept mind that at maximum surface level with other dangerous gases which can be carefully regulated, so as to maintain a healthy life. In addition, there are many different types of sensors in which metal oxide gas sensors are much popular because they are having simple normal shape, long lifetime and a major quantity in universe.

One of the major drawback of micro-heater is to attain high temperature (>=300˚C) minimum power consumption is a primary requisite for the sensor with acceptable battery lifetime in many applications.

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***** Correspondence Author

S.Sri Surya Srikanth*,Dept.of EECE,GITAM(Deemed to be University),Visakhapatnam,India. Email:sssrikanth.sathiraju@gitam.edu

Dr.B.Rajesh kumar, Dept. of EECE, GITAM(Deemed to be University),Visakhapatnam,India,. Email: rajesh.burra@gitam.edu

Vasagiri Suresh,,Dept.of EECE,GITAM(Deemed to be University),Visakhapatnam,India. Email: amsuresh@live.in

Dr.V.Jyothi, ,Dept.of EECE,GITAM(Deemed to be University),Visakhapatnam,India.Email: jyothi.vankara@gitam.edu

Sensor device constitute two basic parameters i.e. to sensing the gas in the surrounding area, signaling unit mechanism that shall translate the effects as seen in the sensor to be capable of being measuring signals. Gas sensing can be made by communicating of chemical species along the sensing surface. This chemical species in reaction with the sensing layer will be soaked over a surface and that changes the characteristics of the sensing layer. Hence, Sensitivity will cover a layer towards a particular gas is one of the major concern. When gases communicate with the metal oxide sensing layer, there are few gas molecules are soaked on the surface that changes their characteristics. At certain specified temperature, oxygen ions are soaked on the surface of oxide layer. There are various applications that can design a gas sensors i.e substantial monitoring, Home safety, Automobiles ventilation control, Fire alarm, Leak disclosure, Explosive gas detectors.

II. DESIGN OF MICRO-HEATER

A. NEED OF MICRO-HEATER:

In metal oxide sensor reducing the process which can take place on the sensing layer over the surface that occurs with reference to a standard temperature. The act of reducing the number of free electrons on the layer that can be either low or more intensity of specific conductance on the surface. Preconcentrator is requisite for achieving the minimum temperature of the reactions to be taken place and below mentioned points are to be kept in mind while designing a preconcentrator.

B. UNIFORM HEATING:

Here the heating part must be identically spread all over the surface and there cannot be any hotspots and for regular melting point, irregular heater which can be unequal gaps that can be used. There are various microheater designs which is suitable for micro heater according to the application.

C. LOW POWER CONSUMPTION:

In miniaturization of substances, minimizing power consumption has been an issue, as it should be as minimum as possible. It can be reduced by using cavity below the preconcentrator.

D. MECHANICAL STABILITY

It should be firmly set in nature and able to withstand maximum hotness of temperatures.

MEMS Micro-heaters has ability to generate very high temperature at low power consumption. They also exhibit fast response time. Generally, preconcentrators are having a thin film micro heater coil or wire that can be suspended within silicon for exceptional thermal isolation.

ANALYTICAL ANALYSIS:

Usually, micro-heaters have platform of zinc oxide. The overall surface temperature can be found by calibrating the change in electrical resistance of micro-heater or they have separate electrodes available to measure this temperature. They are suitable to operate at temperature up to 550°C.The calculation of power consumption (P) is as follows:

$$P = \frac{V^2}{R}$$

---------------(1)

In the above formula V can be applied voltage and R is ohmic resistance across two ends of micro-heater. The value of resistance will be found as mentioned below formula for given micro heater geometry:

$$R = \rho \frac{l}{w \cdot h}$$

-------------(2)

Here
ρ is resistivity of microheater material
l can be length
w will be width and
h is height.

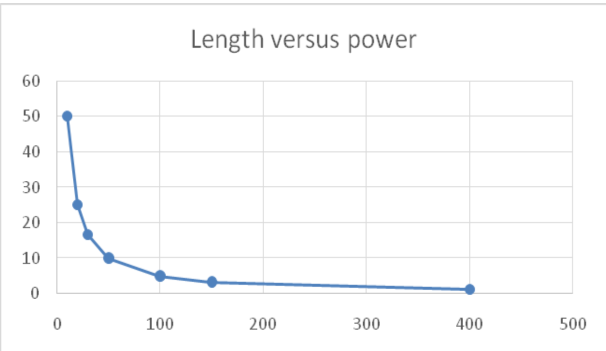
Effect of change in length:

The length is varied and width & thickness, voltage is kept constant. For different lengths, power variations are observed in the table1, it was observed that from simulations that as length increases power decreases linearly. By observing the simulations length of the micro-heater is optimized to100um.

Table1: Theoretical Analysis (using equations 1& 2) heat dissipated for variation in length

S.No	Length(um)	Width (um)	Thickness (um)	resistivity	Voltage(v)	Power (mW)
1	10	10	2	1	5	50
2	20	10	2	1	5	36
3	30	10	2	1	5	42.6
4	50	10	2	1	5	40
5	100	10	2	1	5	28.8
6	150	10	2	1	5	30
7	400	10	2	1	5	20

It is shown in the simulation result as the temperature variations were observed and the corresponding readings are plotted.



Graph1:Length versus power

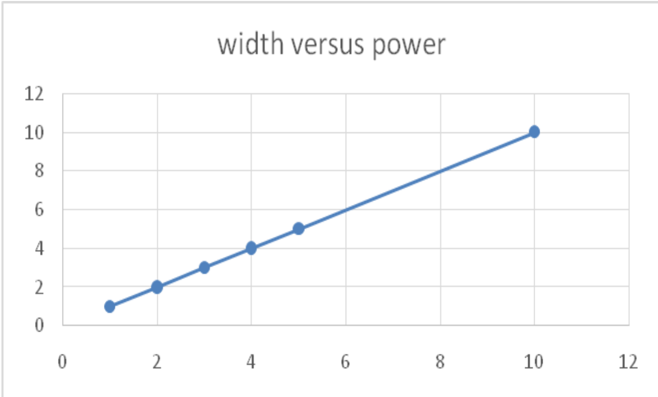
As seen from the graph1 it has been observed that by varying length, heat dissipated from the micro heater is decreases linearly.

Effect of change in thickness:

For micro-heater thickness is most effective dimension parameter. As the thickness varies, width & length of micro-heater is kept constant. From table 2 it was observed that from the simulation that as thickness increases, temperature increases linearly. By observing FEM simulation thickness is optimized to 2um.

Table2: Theoretical Analysis (using equations 1& 2) heat dissipated for variation in width

S.no	Length (um)	Width (um)	Thickness (um)	resistivity	Voltage (um)	Power (um)
1	50	10	2	1	5	10
2	50	5	2	1	5	5
3	50	4	2	1	5	4
4	50	3	2	1	5	3
5	50	2	2	1	5	2
6	50	1	2	1	5	1



Graph 3:width versus power

From graph 3 it has been observed that width is varied ,heat dissipated is linearly increases.

III. DESIGN PARAMETERS OF MICRO-HEATER

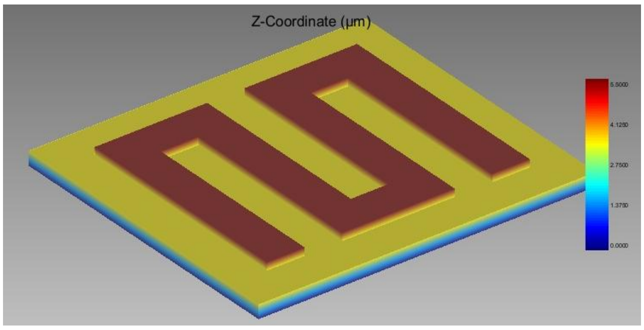


Fig:1Meander shaped microheater fro the applied volatge of 5volts

The micro-heater design is a prior condition to not only curb temperature distribution along the active area also to scale down power usage. The user must select an appropriate temperature distribution so as to choose proper micro-heater geometry and substrate deliberately.

This is always a key design requirement for many researchers. The user should be kept in mind the basic requirements for designing a microheater those are given below:

- Material used
- Homogeneous temperature distribution over the heater
- Mechanical stability and Long life
- Micro-heater geometries
- Under power consumption

Material used:

To choose an ideal material for a microheater there are different types of materials available namely . Platinum (Pt), Gallium nitride (GaN), Gallium arsenide (GaAs), Titanium nitride (TiN), DilverP1 (alloy of Ni, Co, Fe), Poly silicon (Poly-Si) and many metal alloys etc , it is mandatory to select a suitable material for a micro-heater. Mostly, the value of resistivity of the component used for microheater should be maximum.

Uniform temperature distribution over the heater:

It is absolutely necessary for the micro-heater to have better temperature uniformity for proper detection of detected gases. It must be borne in mind that the micro-heater geometry which can divide temperature equally throughout the sensing surface.

Material properties:

s.no	Material	Youngs modulus (GPa)	Poisions Ratio (Constant)	Thermo-Cond (W/cm/deg c)	Dielectric	Resistivity ohm-cm
1	ZNO	210	0.33	0.06	8.3	1
2	Pt	146.9	0.35	0.176	-	1
3	Si	106.8	0.32	1.57	-	1

Mechanical stability and long life:

For having congevity and mechanical strength of micro-heater, we must decrease its stress and displacement. However it is based on the on micro-heater material and its structure. Also the deformation gradient and thermal expansion of micro-heater must be lower so as to achieve more virtuous results.

Micro heater geometrics:

Micro-heater geometries are essential for achieving better temperature uniformity. There are several micro-heater shapes are available and are needed to be looked and simulated to achieve the desired uniformity.

While choosing micro-heater thickness, one should be careful with regards to cut down the heat dissipation losses and power usage. Preferred constituent element materials for heat is zinc oxide and platinum are used as a heater material and base material silicon are used as membrane under the micro-heater.

Low power consumption:

Low power consumption is most important parameter among all especially for battery operated sensors. As we seen that the power consumption equation, by reducing the width and height of micro-heater hyper geometries, increase in resistance and that causes decline in overall power usage. So dimensions of micro-heater are very fault finding in power making more efficient for gas sensor application.

III. RESULT & SIMULATION OF MICRO-HEATER:

To create a simulation for Micro-heater, geometries are analyzed using FEM simulation tool to accomplish maximum temperature uniformity and under power consumption. In the recent study, micro-heater geometry assumptions are prepared with platinum material for thickness of 2 µm. One end preconcentrator is provided with 5 V and other end is at 0V potential is applied.

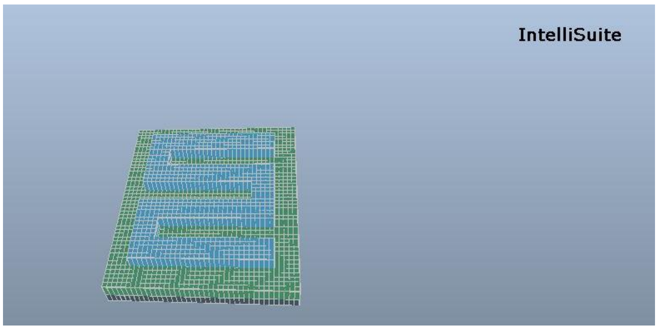


Fig:2 Mesh 5um

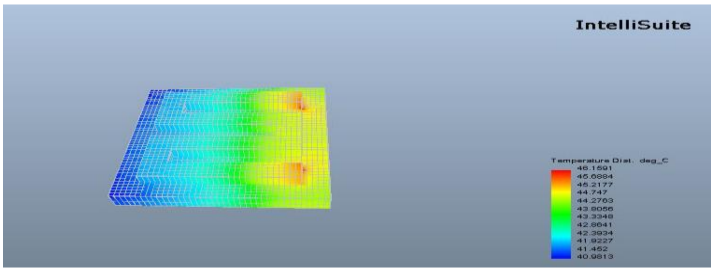
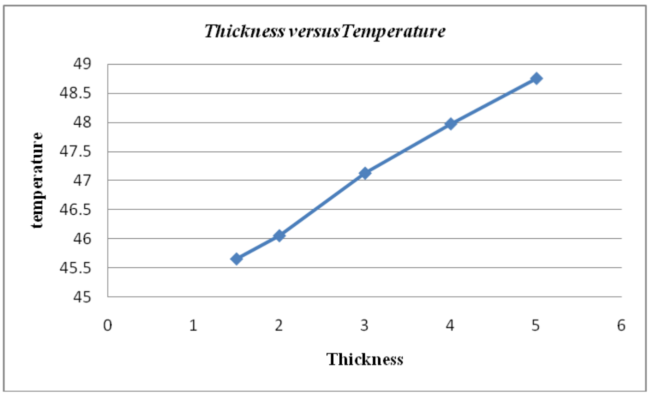


Fig:3 FEM simulation

From the above FEM simulation as thickness is varied temperature increases linearly and power is uniformly distributed across the surface.

Table4:FEM analysis for variations of supply voltage ,observed temperature and heat flux by using the platinum Material

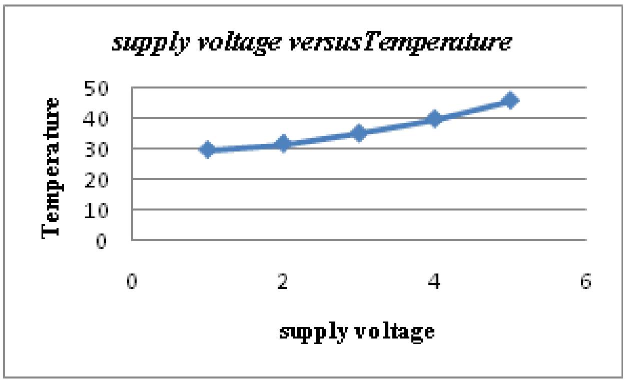
S.No	Supply voltage(V)	Thicknes s (um)	Temperature (^oC)	Heat flux	Avg. temperature (^oC)
1.	5	2	46.05	6.8e^-006	42.7
2.	4	2	39.91	4.3e^-006	37.7
3.	3	2	35.13	2.4e^-006	33.9
4.	2	2	31.72	1.0e^006	31.1
5.	1	2	29.68	2.7e^-007	29.5



Graph:4 Supply voltage versus temperature

Table5: FEM analysis for variations of heater thickness, observed temperature and heat flux

S.No	Supply voltage (V)	Thicknes (um)	Temperature (^{o}C)	Heat flux	Avg. temperature (^{o}C)
1.	5	1.5	45.65	7.3e^-006	42.1
2.	5	2	46.05	6.8 e^-006	42.7
3.	5	3	47.12	7.6 e^-006	44.0
4.	5	4	47.97	6.9 e^-006	45.0
5.	5	5	48.75	7.4 e^-006	45.8



Graph:5 thickness of microheater versus temperature

From graph 4 & 5 it has been observed that as thickness of the heater material is increased then temperature increases linearly with respect to the applied supply voltage.

IV. CONCLUSION

Henceforth, here in this paper meander geometry is chosen for analysis as it provides better temperature uniformity. Platinum material is used for designing and miniature of micro heater. The effects which are seen many thickness of this micro heating element on maximum temperature and heat flux of the heater is evaluated and it was observed that as the thickness of the micro heater is raised from 1.5um to 5um ,then will find the raise in temperature linearly from 45^{o}C to 49^{o}C.So the heat flux depends upon the geometry of micro heater. Hence developed micro heater design is suitable for sensing of VOC's to vaporize the uniform distribution of heat dissipated across the surface.

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AUTHORS PROFILE:

S.sri surya Srikanth received his M. Tech from Andhra University Visakhapatnam from the department of Instrument Technology. Currently he is pursuing Ph. D and also working as an Assistant professor in the Department of EECE, GIT, GITAM (Deemed to be University), Visakhapatnam. His area of Research is MEMS and Microsystems. He has 10 years of experience in teaching for UG and PG level. Some of his research papers were published in various reputed journal papers i.e national and international level. He has member ship in IEEE and MEMS.

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Rajesh Kumar Burra received his B Tech degree in 1999 and M Tech degree in 2004 from the Department of Instrument Technology, Andhra University, Visakhapatnam, India. Currently, he is working as a research scholar in Andhra University, Visakhapatnam, India. He is currently working in GITAM University, Visakhapatnam, India. He is coordinator for the Instrument Society of India (ISOI) Student Chapter GITAM University. During his ten years of experience he has occupied different positions in academia and administration. His research interest is in MEMS and microsystems. He has also worked with MATLAB for different image processing applications. He is also interested in developing new teaching methodologies in the classroom. Some of his education related papers are published in international journals and have been selected in some of the national and international conferences. Some of his research papers are also published in various international journals.

Vasagiri suresh received M.tech degree from the department of ECE ,GIT,GITAM University ,visakahapatnam,India.he is currently working as a JRF in the department of EECE ,GITAM(Deemed to be Univeristy),visakhaptnam.his area of reaserch is MEMS .some of his education related papers are published in national nad international journals and also selected I conferences .

Jyothi Vankara received her M Tech degree in 2004 from the Department of Instrument Technology, Andhra University, Visakhapatnam, India. Currently, she is working as a research scholar in Andhra University, Visakhapatnam, India. She is currently working as Associate Professor in GITAM University, Visakhapatnam, India. During her seven years of experience she has occupied different positions in academia and administration. Her research interest is in biomedical instrumentation. She is also interested in working with MATLAB for different image processing applications and in developing new teaching methodologies in the classroom. Some of her education related papers are published in international journals and have been selected in some of the national and international conferences. Some of her research papers are also published in various international journals.