Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 92 (2016) 213 – 221

Procedia Computer Science

2nd International Conference on Intelligent Computing, Communication & Convergence

(ICCC-2016)

Srikanta Patnaik, Editor in Chief

Conference Organized by Interscience Institute of Management and Technology

Bhubaneswar, Odisha, India

Simulation of low power heater for gas sensing application

Md. Nazibul Hasan[a], Debabrata Acharjee[a], Dhiraj Kumar[b], Arvind Kumar[b], Santanu Maity[b,*]

[a]*Department of Computer Science & Engineering, National Institute of Technology, Arunachal Pradesh-791112*
[b]*Department of Electronics and Communication Engineering, National Institute of Technology, Arunachal Pradesh-791112*

Abstract

This paper presents design, simulation and analysis of a platinum (Pt) based micro-heater for gas sensing applications. Finite element method (FEM) analysis is employed for the purpose of performing the tasks mentioned above thereby investigates the various properties of the high resistive material platinum (Pt) using COMSOL Multiphysics. The Micro-heater is principally designed to ensure minimum power consumption, low thermal mass and better temperature uniformity. Furthermore, the effect of variation of thickness of heating element with created temperature and power consumption of the MEMS micro-heater is observed and evaluated.

Key words: Micro-heater, Finite element method (FEM), COMSOL Multiphysics, gas sensor.

* Corresponding author. Tel.: +91-9436272773.
E-mail address: santanu.ece@nitap.in

Peer-review under responsibility of the Organizing Committee of ICCC 2016
doi:10.1016/j.procs.2016.07.348

1. INTRODUCTION

Nowadays Micro-heater is an indispensable part of various micro-system applications. Micro-heater is a key element of a gas sensor for the detection of individual gas concentration present in the gas mixture, where micro-heater is combined with sensitive sensing element [1-4].The micro heater fundamentally consists of a heating element and a substrate. The heating element is a thin conducting path made of a high resistive material. Akin to any resistive typical resistive heater, the element exhibits joule heating when a current is passed through it. The substrate distributes the heat of the heating element uniformly over its surface.To feature a high temperature operation with low power consumption feature in a MEMS micro-heater requires high efficiency in thermal isolation to minimize heat conduction loss [2].Micro heater. Observations have showed that it has been a common practice to choose platinum as the material for construction of the heating element. The heating element i.e. platinum (Pt) is normally deposited on silicon dioxide (SiO_2) layer [3].

In this paper we have proposed a design of a MEMS micro-heater for gas sensing application. The proposed model is a 3mm x 3mm micro heater constructed using platinum, deposited over a thin layer of SiO_2. In this proposed model we have used platinum (Pt) as a resistive material for our feasibility study because it is a well-known standard material for high temperature heaters, electrically and thermally stable for high temperature operation and easily available for the deposition process.

2. DESIGN AND SIMULATION OF MICRO-HEATER

COMSOL Multiphysicssimulation software is one of the most comprehensive suite of MEMS design tools in the industry. Various parameters of a MEMS device can be investigated and optimized in this simulation environment before actual device fabrication is undertaken. In COMSOL Multiphysics, to design a micro-heater, we have selected the joule heating module.The device consists of a platinum (Pt) resistive layer of 0.001mm thick and 0.1mm width is deposited on a silicon-dioxide (SiO_2) layer. At each end, it has gold (Au) of (0.2 mm x 0.2mm) .when the device is in use, the silicon-dioxide (SiO_2) layer is in contact with surrounding air. All the edges and the sides of the (SiO_2) are thermally insulated.During the operation, the resistive layer i.e. platinum(Pt) generates heat when an electric potential of 0.3 V is applied in one side of the contact pads and the other side of the contact pad is taken as a ground. The heater pattern and its simulated result is depicted in the figure shown below.

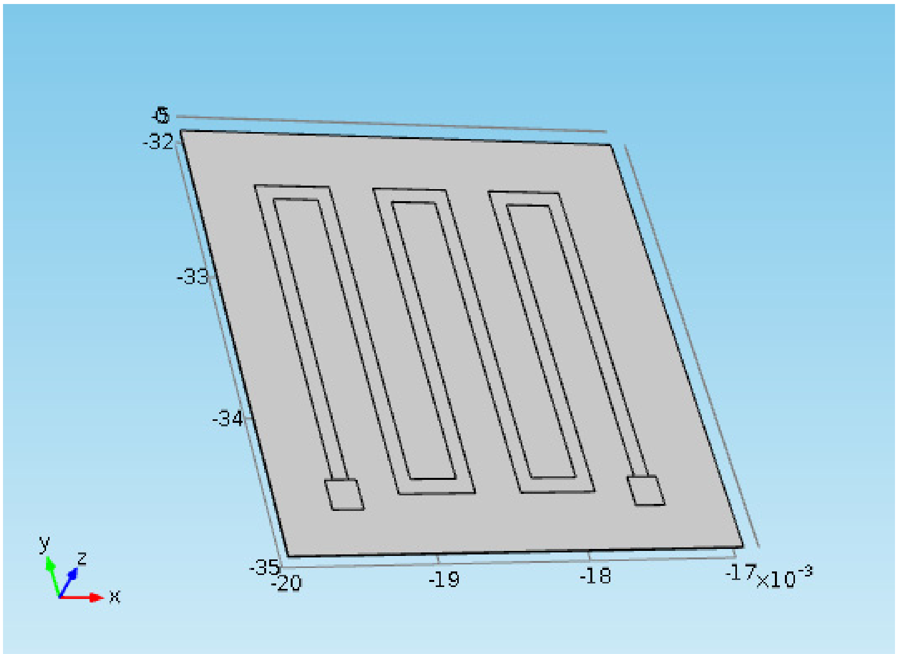

Fig. 1. (a) Heater Pattern using comsol

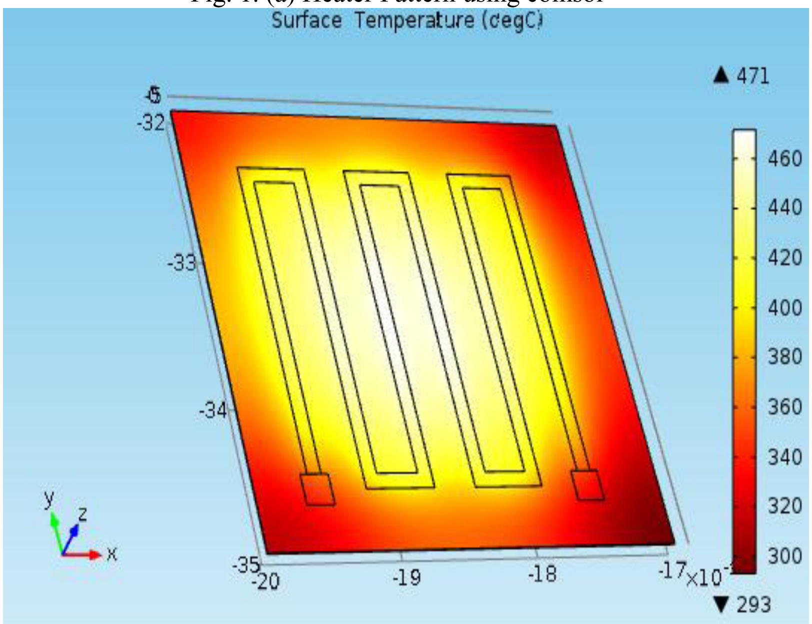

Fig. 1.(b): Simulated result of heater at 0.3 V

The power supplied to the heating circuit is given as:

$$P = \frac{V^2}{\rho}\frac{A}{L} \tag{1}$$

Where, (V) is applied voltage, (R) is the resistance of material, (L) is the length of the material and (A) is the cross section of the heating element. First we calculate the resistance of the heating material and then we calculate the current by using ohm's law. Now from equation (1) we calculate the power consumption by applying the voltage to the input. Here power consumption is directly proportional to the applied voltage and inversely proportional to the resistance of the material.

Now we can calculate the current density of the micro heater and which is given as:

$$J = \frac{V_{in}}{RWd} = \frac{V_{in}}{Wd}\frac{A}{\rho L} \tag{2}$$

Where, (d) is the thickness of the heating material and (W) is the width of the heating material. By using equation (2), we can determine the temperature for a given thickness.

Now according to the equation (3), over the range of temperatures the electric conductivity is a function of temperature T:

$$\sigma = \frac{\sigma_o}{1+\alpha(T-T_0)} \tag{3}$$

Where,

σ_o =Conductivity

T_0 =Reference temperature

α =Temperature coefficient of resistivity

Table1. materials used and their dimensions

Materials used	Dimensions
1.Platinum	(2mm x 0.1mm x 0.001mm)
2. Gold (Au)	(0.2mm x 0.2mm x 0.01mm)
3. Silicon dioxide (SiO_2)	(3mm x 3mm x 0.01mm)

3. Results and discussion

In the figure-2(a) we have shown the voltage versus temperature curve. From this curve we can clearly see that if the applied voltage is increased then the temperature of the heating material is also increased

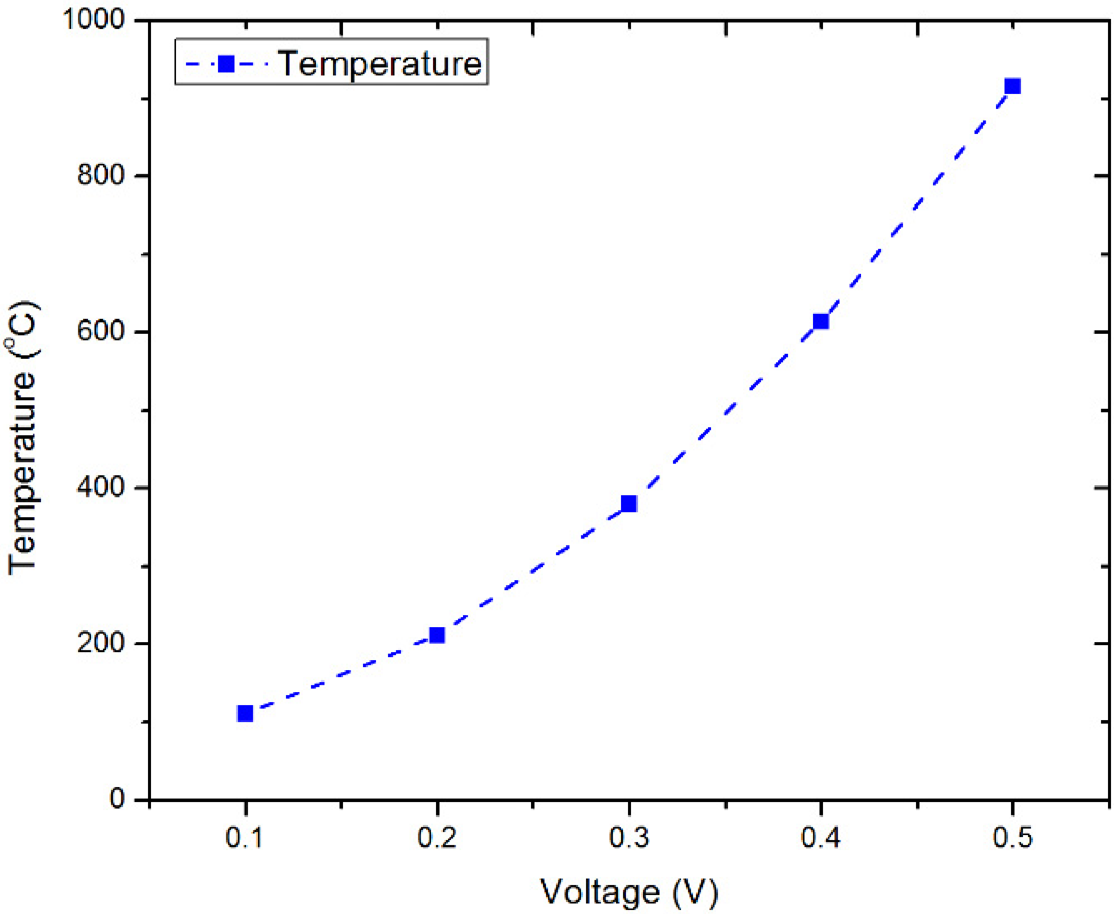

Fig.2. (a): Applied voltage versus temperature curve.

Table 2. Change of temperature with applied voltage

Sl.No.	Voltage (V)	Temperature(^{0}C)
1	0.1	110.92
2	0.2	211.45
3	0.3	378.99
4	0.4	613.55
5	0.5	915.12

In the figure-2(b) we have shown the voltage versus current .If the applied voltage is increased then the current rises linearly.

Table 3. Voltage Vs current

S.lNo.	Voltage (V)	Current(mA)
1	0.1	0.53
2	0.2	1.06
3	0.3	1.59
4	0.4	2.12
5	0.5	2.65

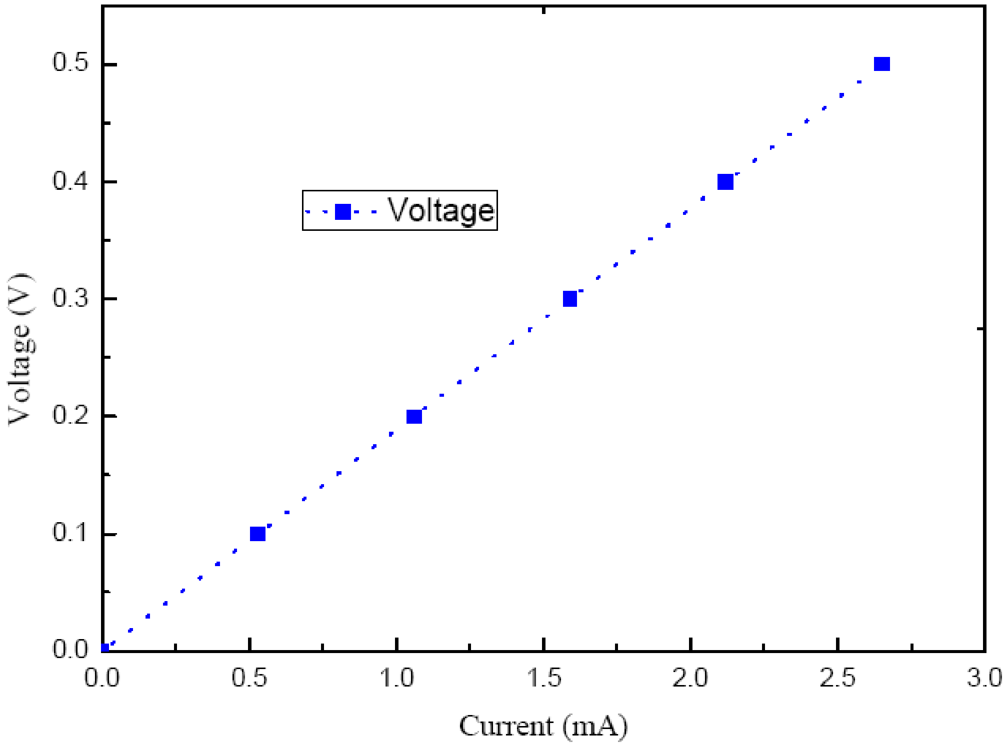

Fig. 2. (b): Applied voltage versus current curve.

In the figure-2(c) we have shown the voltage versus power curve. Since we know that the power consumption is directly proportional to the applied voltage, so from this curve we can clearly see that if the applied voltage is increased then the power consumed by the heater is also increased.

Table 4. Voltage Vs Power

S.No.	Voltage (V)	Power(mW)
1	0.1	0.050
2	0.2	0.212

3	0.3	0.477
4	0.4	0.848
5	0.5	1.325

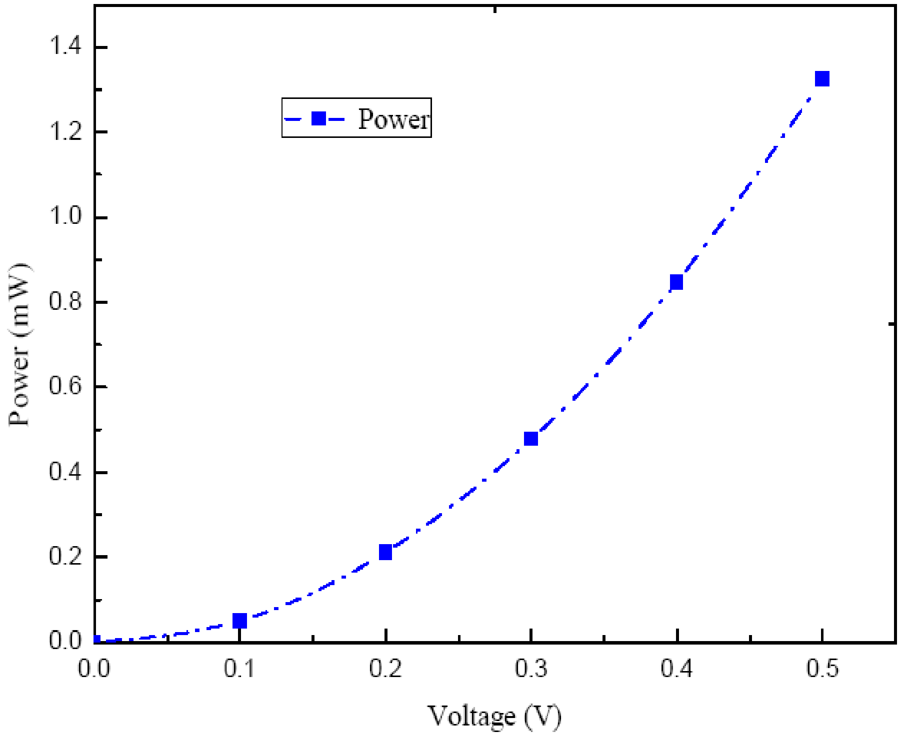

Fig. 2. (c): Applied voltage versus power curve.

In the Figure-2(d) we have shown the temperature versus thickness of the heating material. For a given voltage, if thickness is higher than the crossectional area will be greater. We know that the crossectional area is inversely proportional to the resistance of the heating element which results in higher current .As we know that the joule's heat dissipated is proportional to the square of the current, so rises in current will increase the temperature.

Table 5. Change of temperature with variable heater thickness

S.No.	Thickness of Platinum(Pt)	Temperature(^{0} c)
1	0.001	378.99
2	0.005	380.64
3	0.015	382.31
4	0.020	385.17
5	0.025	387.52

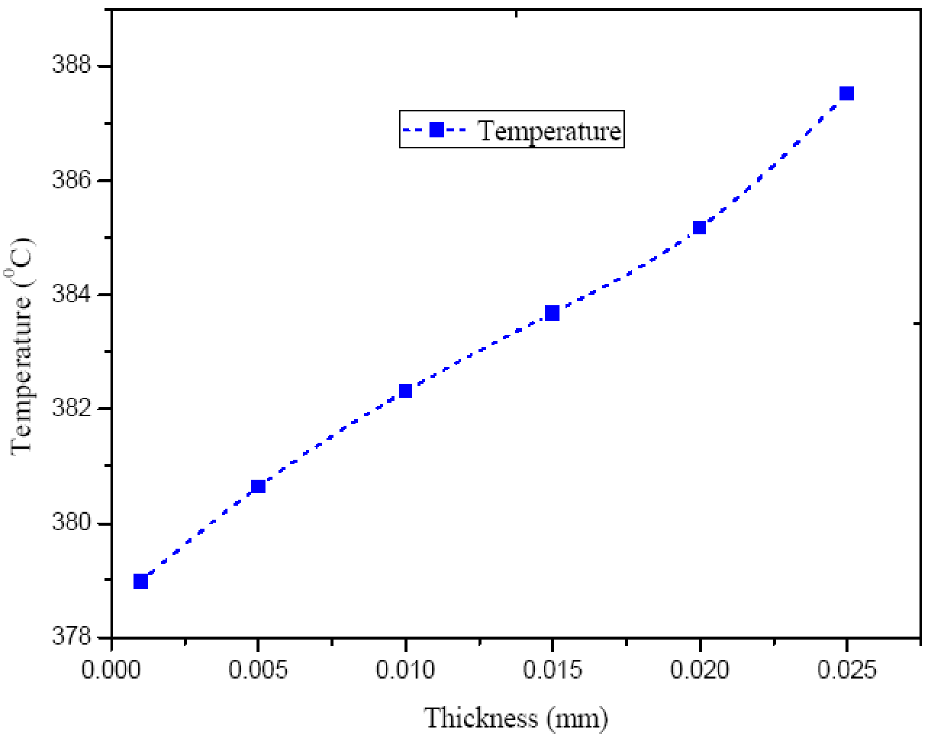

Fig. 2. (d): Temperature versus thickness variation of Platinum (pt)

4. Conclusion

As shown in the results depicted above, the outcomes of the analysis of the proposed micro heater design have shown properties and characteristics that its applications require. The heater generates a high temperature with a remarkably low applied voltage. Only at 0.3V, the micro heater heats up to 378.99 ^{0}C.It consumes a very low power. At 0.3V, it requires only 0.477 mW to drive the heater. The heat generated is uniformly distributed throughout the silicon-dioxide (SiO_2) substrate. The device is therefore quite capable of increasing sensitivity of any gas sensing device.

References:

1. J. Kathirvelan and R.Vijayaraghavan .November 2014. Design,simulation and analysis of Platinum micro-haeters on Al2O3 substrate for sensor applications. Vol. 9, No. 11.
2. VineetBansal,AnialGurjar,Disesh Kumar ,B.Prasad ,2011.3-D Design,Electro-Thermal Simulation and geometrical optimization of spiral platinum micro-heaters for low power gas sensing applications using COMSOL.
3.O.Sidek, M.Z Ishak, M.A Khalid,M.Z Abu Bakar nad M.A Miskam. Effect of heater geometry on the high temperature distribution on a MEMS micro-hot plates.
4. Carmen Moldovan, OanaNedelcu, Per Johandar, Igor Goenaga, David Gomez, PetkoPetkov, Ulrike Kaufmann, Hans-Joachim Ritzhaupt-Kleissl, Robert Dorey, KatrinPersson.Ceramic Micro-heater technology for gas sensors.

5. D. Klaitabtim, T. Lomas, A. Wisitsora-at and A. Tuantranont, Simulation and Experiment of Microheater for a Microfluidic Polymerase Chain Reaction Device, IEEE Conf. Proc., Vol. 2, 450 – 453(2004)
6.Velmathi .G, Ramshanker .N and Mohan .S, Design, Electro-Thermal Simulation and Geometrical Optimization of Double Spiral Shaped Microheater on a Suspended Membrane for Gas Sensing, IEEE Conf. Proc., 1258 - 1262
7.Inderjit Singh and S.Mohan, "3D Simulations and electro-thermal analysis of micro-hotplate designs using Coventorware for gas sensor applications", Proceedings ISSS Conference, (2005)
8. G. Velmathi and S. Mohan, "Design, Fabrication and testing of Microheater with uniform thermal distribution and low power consumption for gas sensor", Proceedings ISSS Conference, (2009)