Electro Thermal Analysis of Micro heater for Lab- on- a- Chip (LOC) applications

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Abstract: The Lab -on -a- chip (LOC) application integrates multiple functionality on a single chip which readily manipulate and delivers the result. Micro Electro Mechanical Systems (MEMS) micro heater is widely used in heating the various Lab -on-a- chip (LOC) application, which has more advantages like long life time, great accuracy, minimum power consumption and compatible to CMOS technology. The in-built micro heater consists of an electrically resistive gold layer of thickness 100 nm deposited on a glass plate. The Micro heater converts the electrical voltage into heat. The amount of heat to be produced by the conductive layer is decided by the dimension, thermal conductivity and electrical resistivity of material. This paper proposes two different design and electro thermal analysis of serpentine shaped micro heater operating at the temperature range of 150^{o} C-200^{o} C using COMSOL Multiphysics. The Micro heater design is solved using Thermal stress and Electric Current Shell solver. The design is optimized to provide uniform temperature with minimum input power.

Keywords: Micro Heater, lab-on-a-chip applications, Micro Reactor

1. Introduction

The in-built Micro Heaters are essential in various Micro Devices such as Micromixers, Micro reactor, Polymerase Chain Reaction (PCR), Temperature Gradient Focusing for Electrophoresis (TGF), digital microfluidics [1] - [5]. The in-built micro heater regulates the temperature in managing the physical, chemical and biological properties with minimal power. embedded Micro-heater.

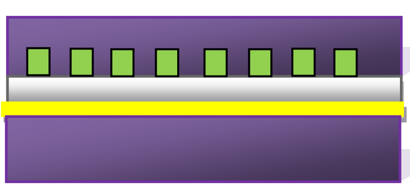

Figure 1 Cross sectional view of Micro-reactor with embedded Micro-heater

In this work, we propose the design and simulation of a Micro-heater which is to be embedded along with a Micro-reactor. The Figure.1 shows the cross sectional view of Micro-reactor with Insert subsections in this manner, as needed. The micro heater consists of an electrically thin resistive Gold layer which is deposited on a glass substrate, and it is sandwiched between PDMS layers. The Micro heater converts the electrical power into heat and the amount of heat to be produced by the resistive layer is decided by its dimension, thermal conductivity and electrical resistivity. The simulation of serpentine shaped micro heater is carried out to study the performance of the micro heater under the operating temperature of 150^{0}C - 200^{0}C using **COMSOL Multiphysics**.

2. Design

The design was optimized to produce the uniform temperature and validated using simulation. The Figure.2 shows the designed Micro-reactor with embedded micro-heater.

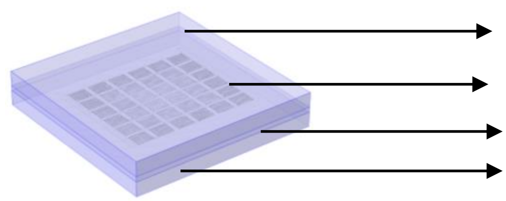

Figure 2 Micro-reactor with embedded Micro Heater

The Micro heater with uniform resistance is designed with device dimension of 3cm x 3cm in order to achieve the heat of 150^{0}C-200^{0}C with the operating voltage range of 3-5V and power consumption less than 2 watts.

The resistance of the heating element can be calculated using the following relation:

$$R = \frac{\rho L}{A} \quad \text{in } \Omega$$

where, ρ is the resistivity of the of the heating element in Ωm
L is the length in cm
A is the cross sectional area in cm^2

To achieve this specification two different design are simulated using COMSOL Multiphysics.

The serpentine shaped gold micro heater with thermal conductivity of 314 W/m-K and Electrical Resistivity as Gold 2.2e-8Ωm was designed with the length 26541.59 µm, width 100µm and the thickness 100nm.The micro heater is connected in array of 3x12 and 6x6 and the dimensions are summarized in the Table 1

Table 1 Dimensions of the Micro Device

Dimensions	Design 1(3x12)	Design 2 (6x6)
Air	29000x29000x8500 µm	29000x29000x8500 µm
PDMS	25000x25000x2000µm	25000x25000x2000µm
Substrate Glass	25000x25000x700µm	25000x25000x700µm
Heating Element Gold	36(26541.59µmx100µmx100nm)	36(26541.59µmx100µmx100nm)
PDMS	25000x25000x2000µm	25000x25000x2000µm

3. Electro Thermal analysis

The Micro heater design was solved using Thermal stress and Electric Current Shell solver. The temperature profile of micro heater was studied for two different design of 3x12 array and 6x6 array. Figure.3 shows the temperature profile of 3x12 micro heater at applied voltage of 2.6V which produces the maximum temperature of 199.6^{0}C with power consumption of 0.456W. The Table.2 shows the summarized temperature profile of the 3x12 micro heater with equivalent resistance of 15Ω was simulated with applied voltage ranging from 2.2 to 2.6V.

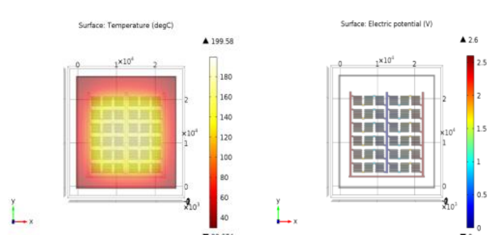

Figure 3 Temperature profile of 3x12 Micro heater at applied voltage of 2.6V

Table.2 Electro Thermal Analysis 3x12 Micro heater for 150-200^{0}C target temperature

Voltage V	Tmax in the heater ^{0}C	Tmax in the substrate ^{0}C	Resistance Ω	Calculated Electrical Power W
2.2	148.58	128.76	14.8139	326.72E-3
2.3	160.53	138.77	14.8139	357.09E-3
2.4	173.02	149.61	14.8139	388.82E-3
2.5	186.03	161	14.8139	421.9E-3
2.6	199.58	171.75	14.8139	456.32E-3

Similarly, Figure 4 shows the temperature profile of 6x6 micro heater at applied voltage of 5V produces the maximum temperature of 196.2^{0}C with power consumption of 0.422W. The table 1.3 shows the summarized temperature profile of the 6x6 micro heater with equivalent resistance of 60Ω was simulated with applied voltage ranging from 4.2 to 5V.

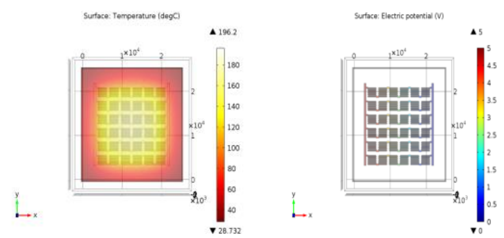

Figure 4 Temperature profile of 6x6 Micro heater at applied voltage of 5 V

Voltage V	Tmax in the heater ^{0}C	Tmax in the substrate ^{0}C	Resistance Ω	Calculated Electrical Power W
4.2	144.23	126.8	59.231	297.8E-3
4.4	156.45	136.5	59.231	326.85E-3
4.5	162.51	142.28	59.231	341.88E-3
4.7	175.69	152.8	59.231	372.94E-3
4.9	189.23	164.48	59.231	405.36e-3
5	196.2	170.4	59.231	422.07E-3

4. Results

The Figure 5(a) shows the Applied voltage versus Temperature graph and Figure 5(b) shows the power consumption versus Temperature graph of 3x12 and 6x6 micro heater array. From the graph we observe 3x12 micro heater produces target temperature of 150°C-200°C at the applied voltage range of 2.2V to 2.6V with power consumption of less than 0.5W. Similarly, 6x6 micro heater produces target temperature of 150°C-200°C at the applied voltage range of 4.2V to 5 V with power consumption of less than 0.5W.

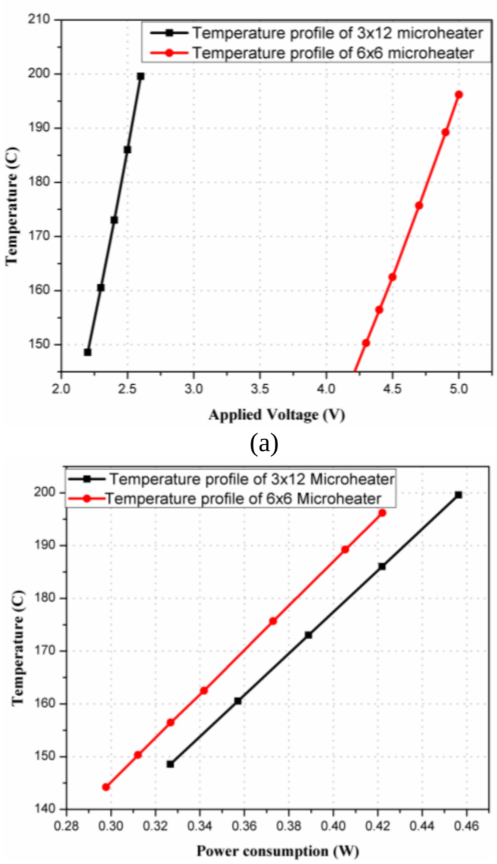

Figure 5 (a) Measured temperature at various applied voltage (b) Measured Temperature at different power consumption

5. Conclusion

In this paper the two different electro thermal design analysis of in-built micro heater have been designed and studied for Lab-on -a-Chip applications using COMSOL Multiphysics. The 3x12 micro heater can be suited to 3V and the 6x6 micro heater array can be suited to 5V operating applications. The integration of micro heater with micro reactor has been found to have a good control over the temperature with lesser power consumption.

9. References

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