Design and Analysis of Micro-Heaters using COMSOL Multiphysics For MEMS Based Gas Sensor

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Introduction: Micro-Heaters are the key components in sub-miniature micro-sensors, especially in gas sensors. The metal oxide gas sensors utilize the properties of surface adsorption to detect changes in resistance as a function of varying concentration of different gases[5]. To detect the resistive changes, the heater temperature must be in the requisite temperature range over the heater area. Hence the sensitivity and response time of the sensor are dependent on the operating temperature of the micro-heater. So their proper design is of critical importance. In this paper, we report on the design and simulation of micro-heaters used in gas sensors with the aim of improving their temperature uniformity [3]. The design has been supported using Electro-thermal Simulations using the COMSOL.

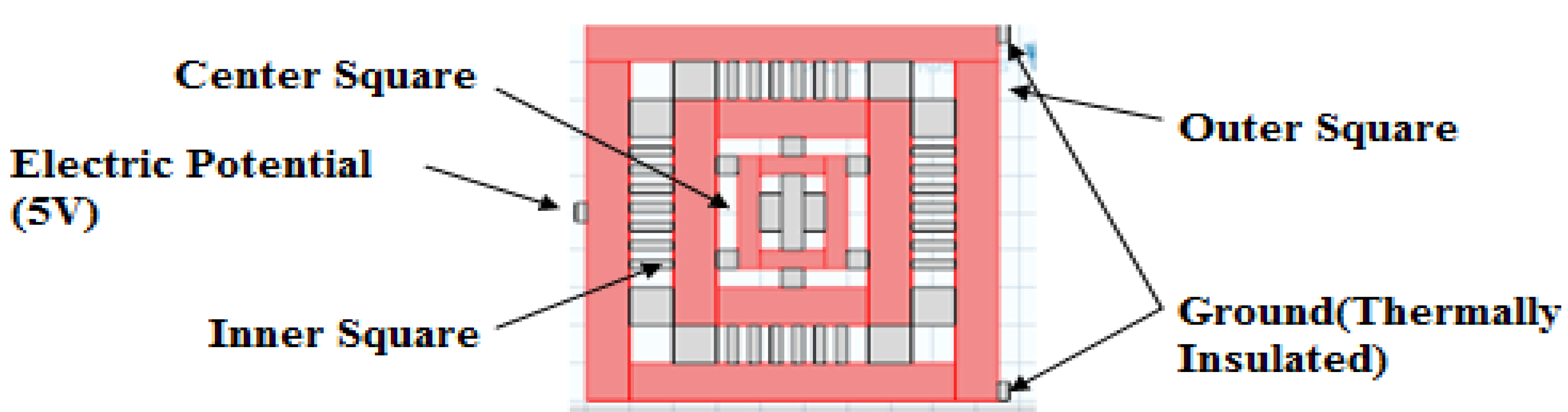


Figure 1: Square Shape Structure Detail

Mathematical Modeling:

The electric field equals the negative of gradient of the potential V. The electric current density J is in turn proportional to the electric field. Due to this electric current, there is resistive heating which is shown to be proportional to the square of magnitude of the electric current density J. Hence the temperature increases. This is referred to as Joule heating [1].

$$Q \propto |J|^2 \qquad (1)$$

The proportionality constant is the electric resistivity ρ or the reciprocal of the temperature dependent electric conductivity. Combining these facts we have

$$\rho = \frac{1}{\sigma} \qquad (2)$$

$$\sigma = \sigma(T) \qquad (3)$$

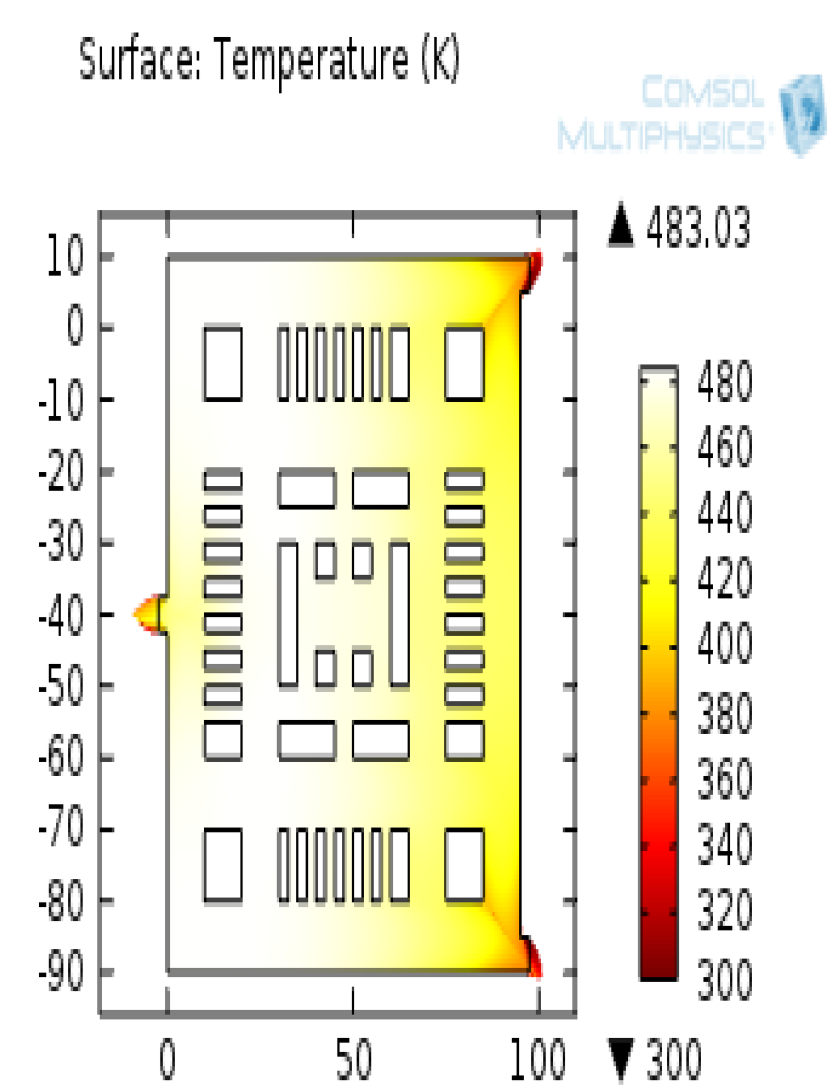
$$Q = \frac{1}{\sigma}|J|^2 = \frac{1}{\sigma}|\sigma E|^2 = \sigma|\nabla V|^2 \qquad (4)$$

Over a range of temperatures the electric conductivity varies with T, governed by the equation

$$\sigma = \frac{\sigma_0}{1+\alpha(T-T_0)} \qquad (5)$$

Where σ_0 is the conductivity at the reference temperature T_0. α is the temperature coefficient of resistivity, which describes how the resistivity varies with temperature.

Results: As the voltage is varied from 0.5 to 5 V in increments of 0.5 V the temperature increases exponentially. The same maximum temperature was obtained for all the structures; however there was a notable difference in temperature uniformity [3].



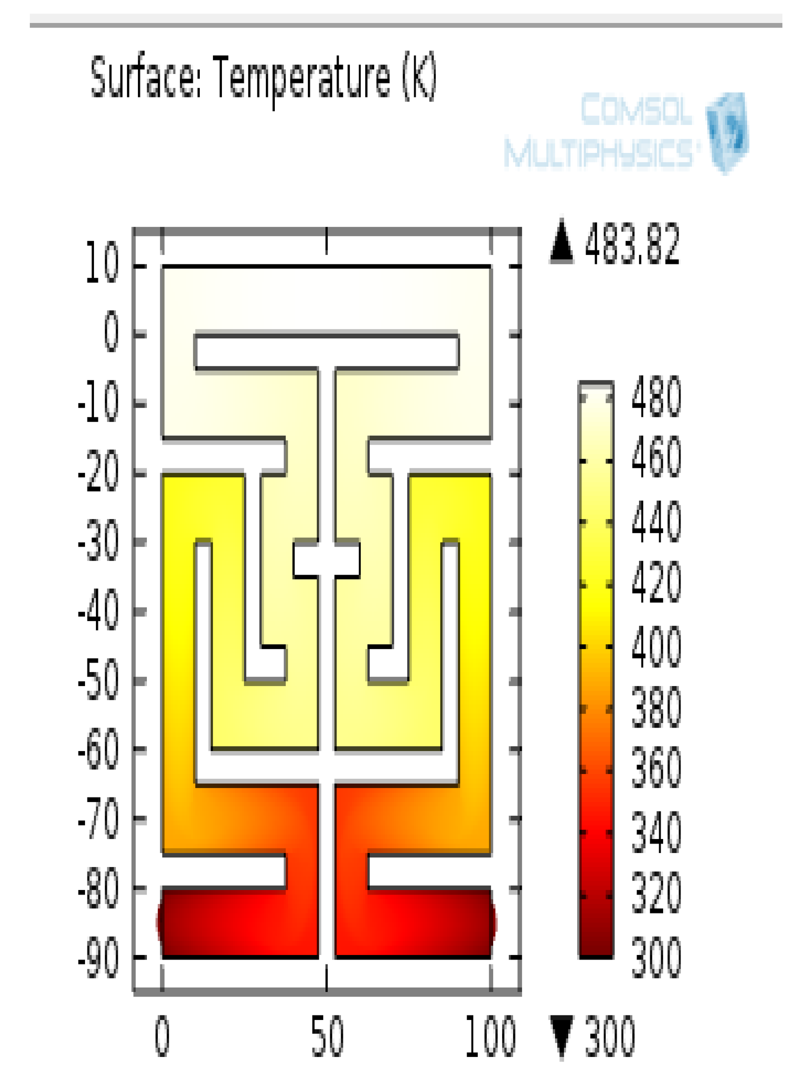


Figure 2: Square shaped **Figure 3: Fan** shaped

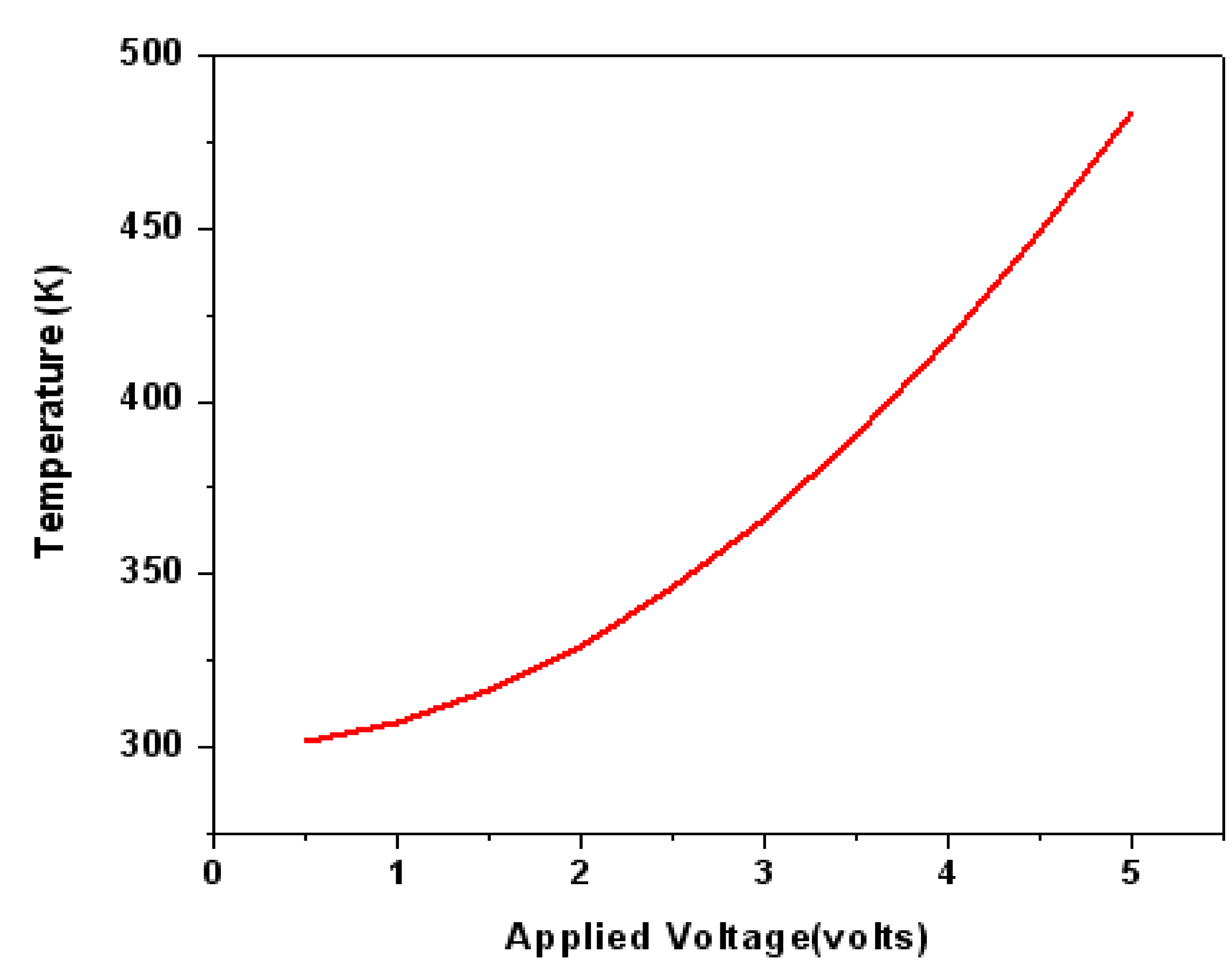


Figure 4:. Maximum Temperature Vs Applied Voltage curvefor Micro Heater of area 100 × 100 µm

Conclusions : The results show the variation of temperature across the structure for the applied voltage. It was found that the Square shape structure gave the best result with 99.51% of the heater area having a temperature greater than 80% of the maximum temperature attained with an average temperature of 456.442 K

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References:

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2. Patil. S.J, D. S. Bodas, A. S. Nassiopoulou, A. Tserrepi, Sensors and Actuators B 95 78 (2003).