3D Stationary and Temporal Electro-Thermal Simulations of Metal Oxide Gas Sensor Based on a High Temperature and Low Power Consumption Micro-Heater Structure Using COMSOL

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Abstract

Metal oxide gas sensors have many qualities that make this kind of sensor one of the most studied in laboratories and used in companies: it is low cost and very sensitive and fast responses to gases. To have these two last characteristics, the sensor must desorb easily the gases molecules in interaction with the sensible layer, what is the role of the micro-heater. The higher the temperature is, the easier the desorption is. To make an embeddable sensor the power consumption must be as low as possible. A compromise should be found between these two parameters. That's why a metal oxide gas sensor, based on a micro-heater structure on a membrane able to work until 550 °C (with a power consumption equal to 60 mW at this temperature), has been developed. The technological process is the following: the bi-layer SiO2/SiNx membrane is grown on a silicon substrate; the heater and sensible electrodes metalization in platinum are deposited by evaporation; a SiO2 passivation layer is grown; the contact open is realized by a wet etching; the membrane is released by a dry etching; the sensitive layer is deposited by inkjet. The electro-thermal simulation of this structure with COMSOL 4.2 has been realized. For this purpose, the Joule Heating physics interface has been used and a stationary study has been executed in order to: check the temperature distribution on the surface (Figure 1), compare the maximum temperature between simulation and measurement for different power consumptions (Figure 2), and observe the influence of a sensitive layer with different thickness on the maximum temperature for different power consumptions (Figure 3). A temporal study has also been done in order to find the time necessary to obtain a stabilized temperature when a voltage step from 0 to 5 V is applied (Figure 4). The goal of these simulations is to design a model representing the real sensor and able to simulate the future evolution before designing it. The results obtained are: a good distribution of the temperature at the surface of the structure with a temperature gradient equal to 70° C between the center and the limit of the open contact; the simulated and measured temperature curves in function of the power consumption are very close for all values with a deviation of less than 25 °C; the influence of a sensible layer on the maximal temperature which decreases of 25 °C for a 0.5 µm ZnO layer and 50 °C for a 1µm ZnO layer; the required time to stabilize the temperature of the membrane is about 60 ms. The purpose of this work was to create a realistic model of our micro-heater. The simulation results are really close to the measurement. Our low power and high temperature structure has been

successfully modeled. In addition, it has been observed that the temperature uniformity is suitable for our application. These results are promising and the model developed will be helpful for the next step in which we will optimize our sensor.

Reference

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Figures used in the abstract

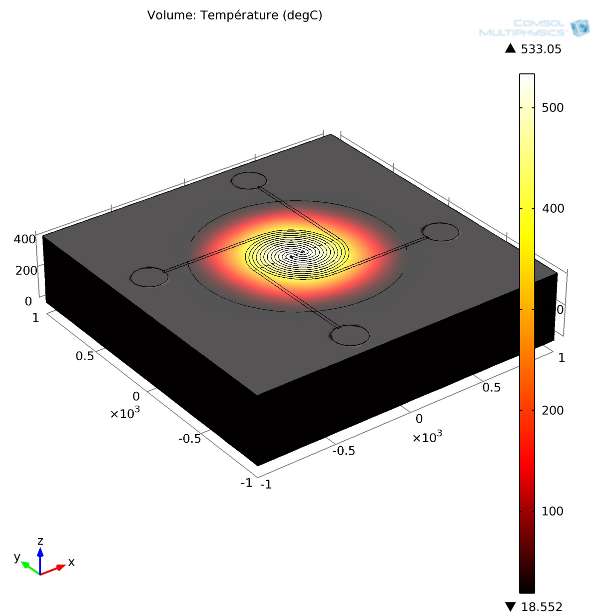

Figure 1: 3D temperature distribution in the micro-hotplate for heater voltage = 5 V.

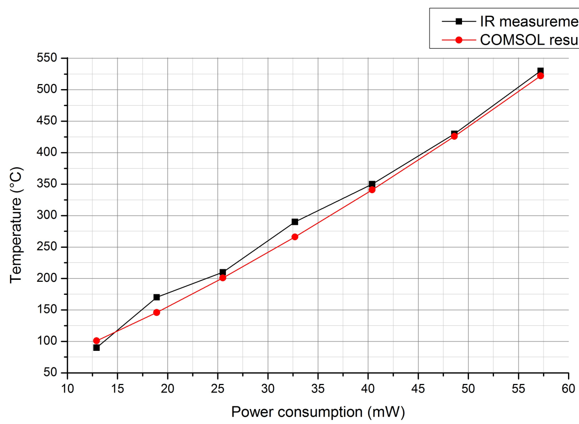

Figure 2: Temperature versus power consumption at the surface of the passivation layer with COMSOL: comparison between simulations and infrared measurements.

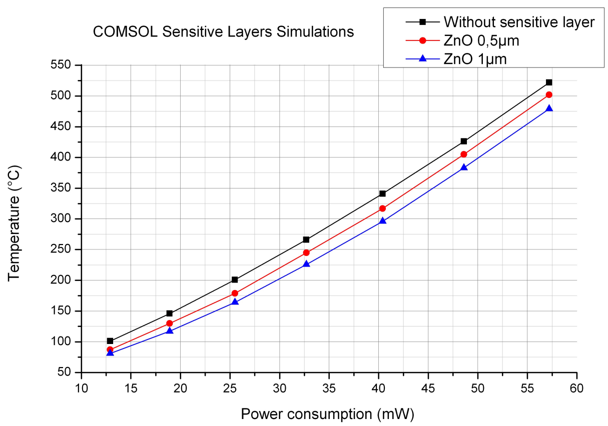

Figure 3: Surface temperature versus power consumption for different thicknesses of ZnO sensitive layer.

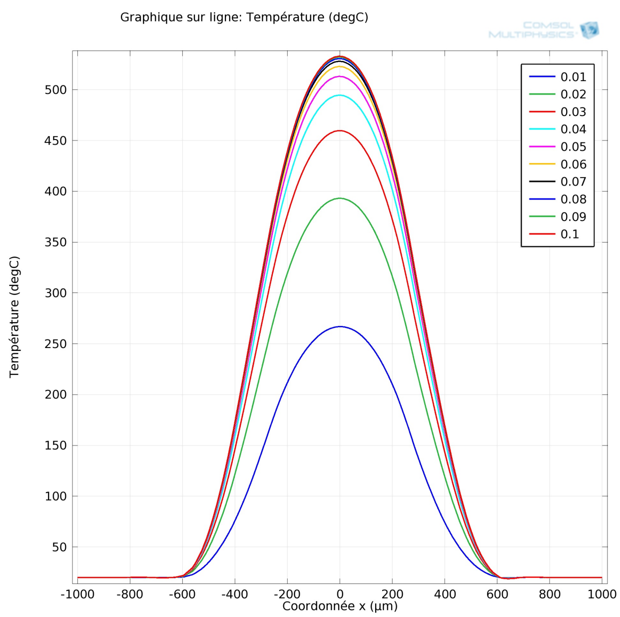

Figure 4: Transient variations of temperature on one lane axis at the surface of the passivation layer for a heater voltage from 0 to 5 V.