Air Convection on a Micro Hotplate for Gas Sensor

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Abstract: Monitoring of indoor CO_2 concentration is of particular interest to detect room occupancy in order to optimise power consumptions of building. Key feature for a wider use of the sensing technic involved the management of the power consumption that is related to the temperature uniformity of the micro hotplate. We improve our electro thermal heater model, tacking in account the convective thermal effect that can be described using the COMSOL Thermal Module in stationary regime. In such a way we can propose an explicit thermal flux law.

Keywords: Electro-Thermal model, Thermal laminar convection, Filament, Hotplate, Gas Sensor

1. Introduction

One approach to monitor the indoor CO_2 concentration is to use optical detection using specific absorption lines of CO_2 molecules in the infrared domain close to 4.2 µm. Such optical sensors include a detector, typically a micro-bolometer, an IR source – such as a hotplate– and a filter to select the interesting band in the black body spectrum of the emitter. All these components are made in well known planar Si technology using MEMS approach. To fabricate a free-standing micro-hotplate, we use Si_3N_4/SiO_2 as supporting layer and TiN/Pt/TiN for and heater layer.

In the past, we have optimised the filament geometry (conductive track width) using a Comsol electro-thermal model [1], figure 1. Though, to describe conductive and convective thermal exchanges in air out of the micro-hotplate, we use the proposed law by [2].

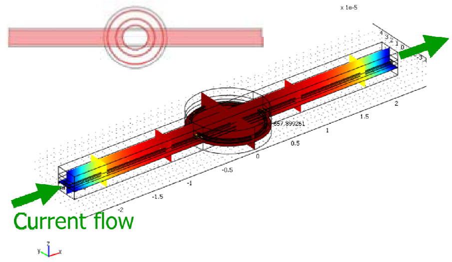

Figure 1. Filament conducting tracks shape (top view in insert) and filament temperature gradient obtain in a first 3D electro thermal model (z dimension magnified by a factor 50, for better accuracy).

However, we experimentally observed that the temperature uniformity was lower than expected [3], as reported in figure 2.

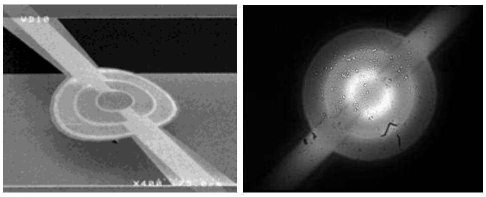

Figure 2. Microscopy images of the realized heated filament, SEM view (left) and IR radiation (right), showing the temperature distribution on the hotplate.

That is why we investigate thermal dissipation related to laminar air convection in stationary regime, using the Comsol thermal module.

2. Model

Considering that the geometry of the hotplate is mainly axi-symmetric, we describe its shape as a thin rectangle having its radius and thickness, 100µm above an infinite substratum.

We use the Comsol air parameters of the heat transfer and laminar flow coupled equations proposed in the thermal module. We describe the boundary conditions with the axial symmetry and outlet and wall conditions. The surface of the hotplate is fixed at 650°C everywhere.

The model provides the temperature and flow velocity in air related to its density gradient, figure 3. Reynolds number appeared sufficiently low (lower than 100) to argue in favor of the used laminar model.

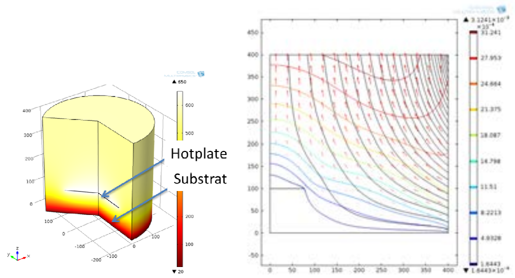

Figure 3. Air temperature around a 150µm diameter hotplate (left) and air flow around (right).

Using Comsol post processing, we analyze the thermal convection flux density on the hotplate surface, figure 4. We notice that the thermal flow is slightly greater on the upper surface, but can be one decade larger at the border of the disc. This phenomenon explains the temperature non-uniformity observed experimentally on devices already designed with a constant thermal flux value.

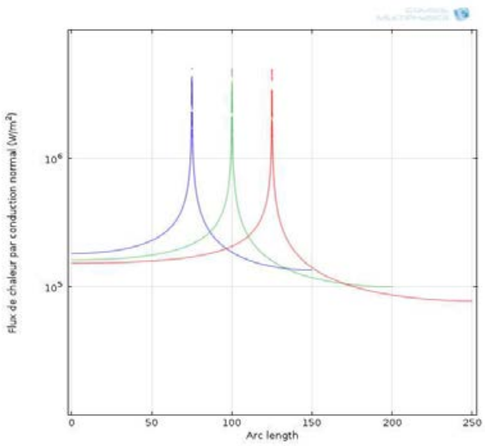

Figure 4. Thermal flux density profile (radius cross deployed) on the hotplate surface for 3 size of hotplate disc: 150µm, 200µm and 250µm diameter.

We also notice that the thermal flux seems not dependent on the disc diameter; so that we can fit it radial dependence by an empiric law - referred to the disc border:

$$flux(r) = flux0 + \frac{a}{(r - rdisc + b)}$$

flux0 is a flux density near the center of the disc rdisc is the disc radius.

We estimate these values of parameters:
flux0=3.8e5 [W/m^2] for 650°C
a=1 [W/m]
b=2.76e-7 [m]

We show on figure 5, the quality of the fit and the initial constant value used in our old model (taking 100µm as specific dimension for thermal diffusion).

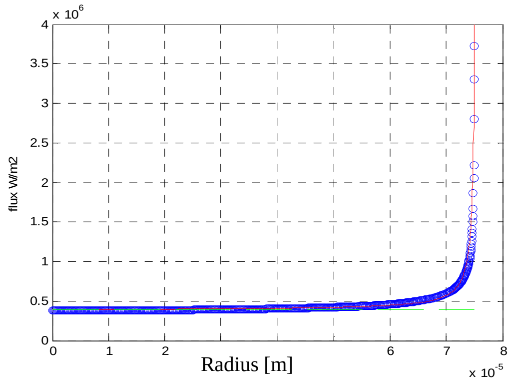

Figure 5. Flux density profile on the top hotplate surface (blue), fitted by the propose 1/r law (red) and the initially used constant value (purple).

We can now introduce the establish law for thermal flux related to air convection in a modify version of our first model to obtain a new electrical stacks design and a better hotplate temperature uniformity.

3. Conclusions

We model the thermal flow to know the heat losses due to air convection near a micro hotplate used in gas sensor applications. We deduce a law to describe this flux density so that we can now introduce it in our already establish electro thermal model of the microfilament to increase its temperature uniformity and till lower its consumption.

5. References

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