Air Convection on a Micro Hotplate for Gas Sensor

Serge Gidon, M. Brun, S. Nicoletti and P. Barritault
Commissariat Energie Atomique, LETI, Minatec Campus
Department Optronique, 38054 Grenoble, France

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. Optical sensors include an IR source that can be a hotplate made in MEMS technology. To optimize the electrical consumption of the filament, one has to design the conductive track's width as done in a Comsol electro-thermal model [1,2], figure 1, however we have to determine the (stationary) convective thermal exchanges in gas around the micro-hotplate.

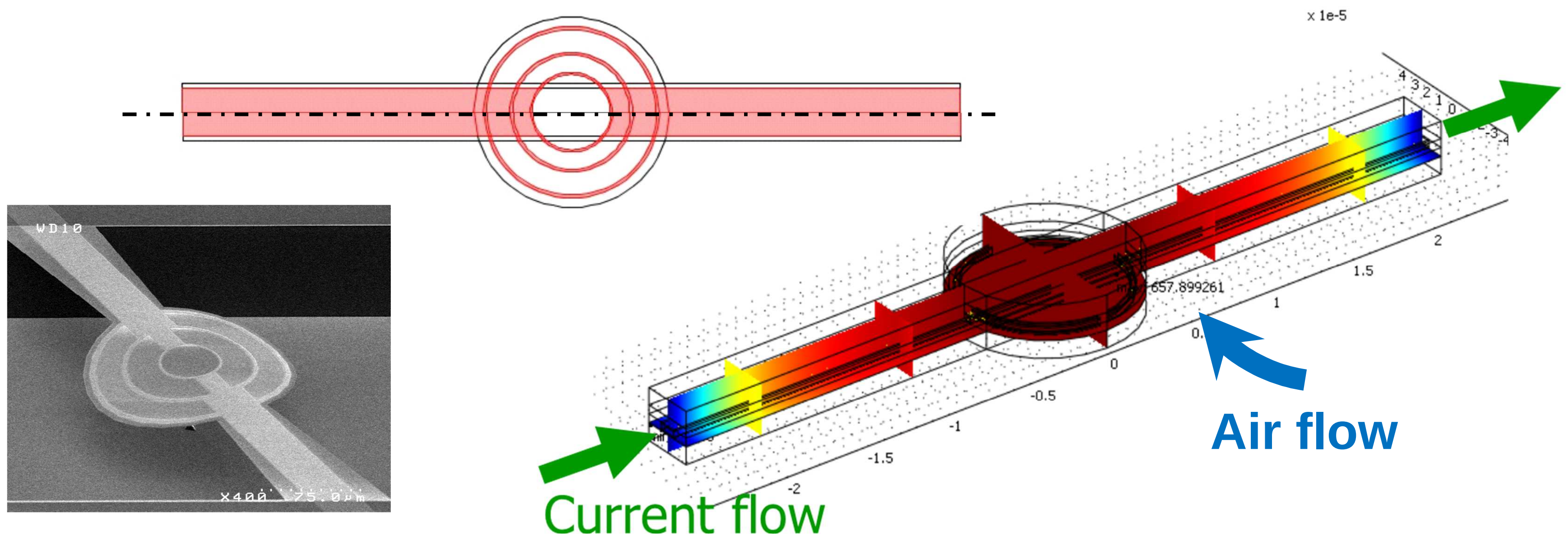

Figure 1. Filament conducting tracks shape and filament temperature gradient obtain in a first 3D electro thermal model (z dimension magnified by a factor 50, for better accuracy) and images of the realized heated filament, SEM view (left)

Computational Methods: Considering that the geometry of the hotplate is mainly axi-symmetric, we describe it in 1D, by a rectangle placed above an infinite substratum, figure 2.

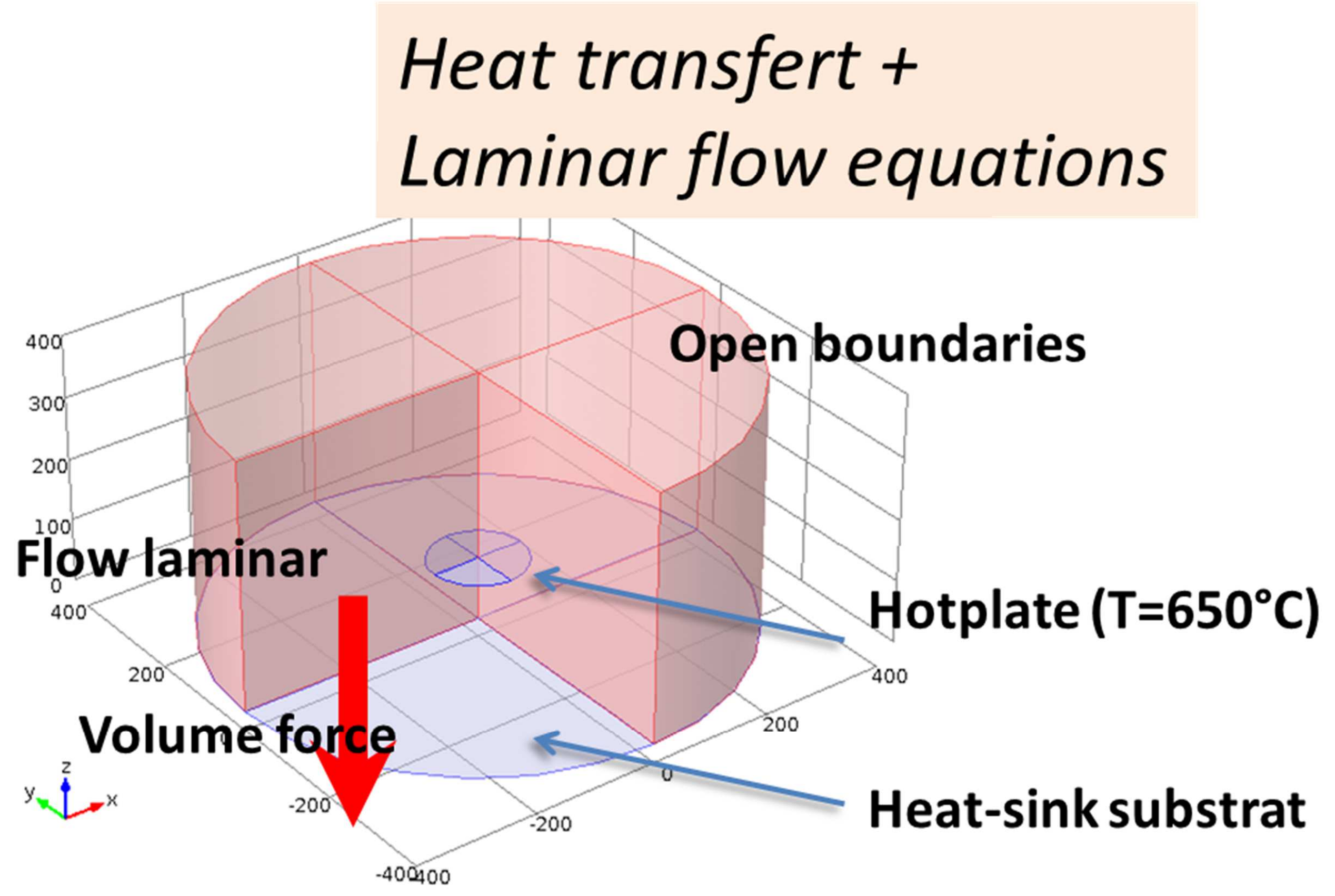

Figure 2. Conditions of the model (1D axisymmetric)

Boundary conditions are 1/ axial symmetry and 2/ outlet or wall conditions. We solve the heat transfer and laminar flow coupled equations using the air material content proposed by Comsol basic module.

The surface of the hotplate is fixed at a constant temperature of 650°C.

Results: The model provides the temperature and flow velocity in air related to its density gradient, figure 3.

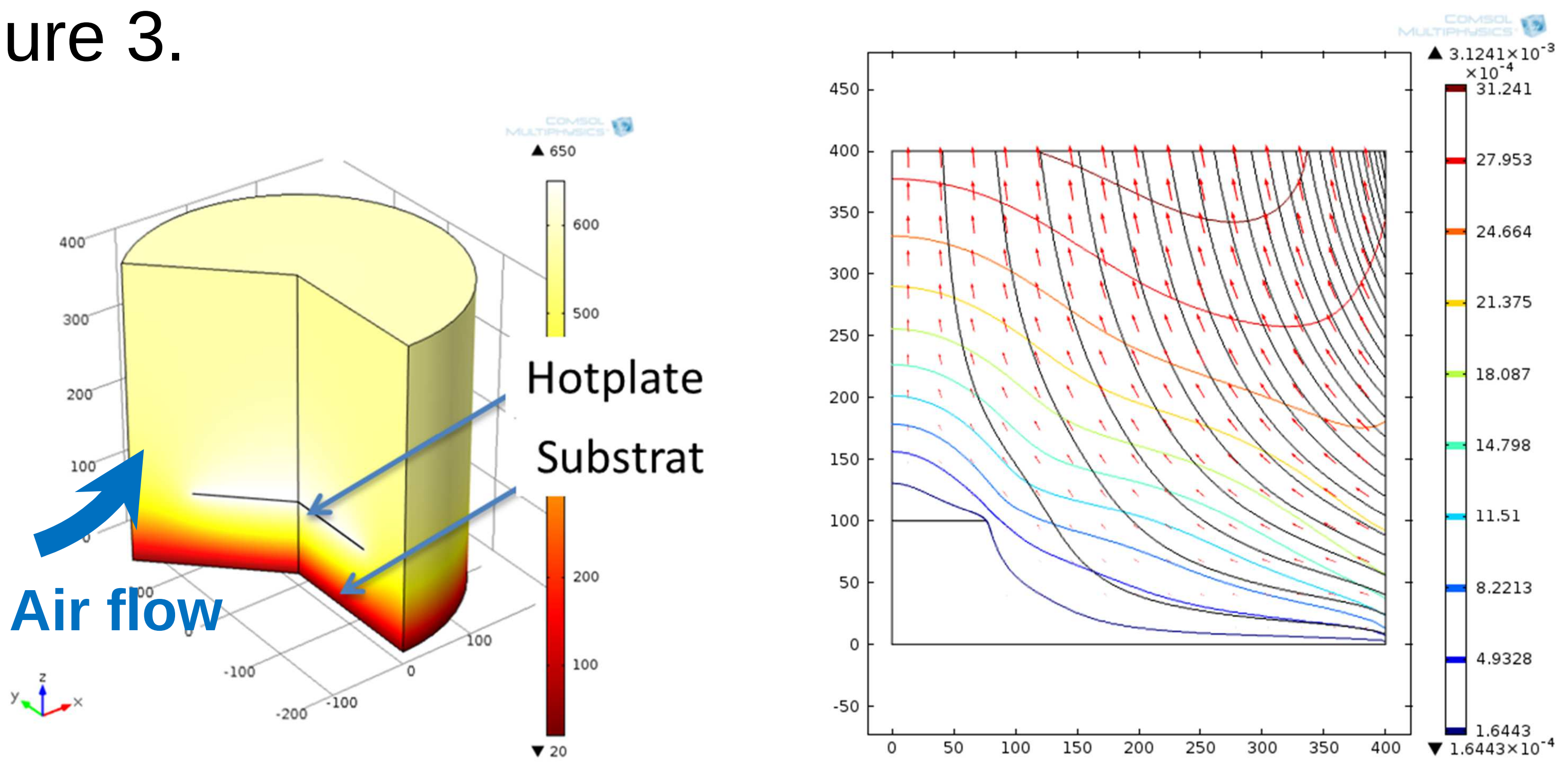

Figure 3. Air temperature around a 150µm diameter hotplate (left) and air flow around (right).

We analyze that the thermal convection flux density on the hotplate surface, figure 4, is slightly greater on the upper surface, but can be one decade larger at the border of the disc.

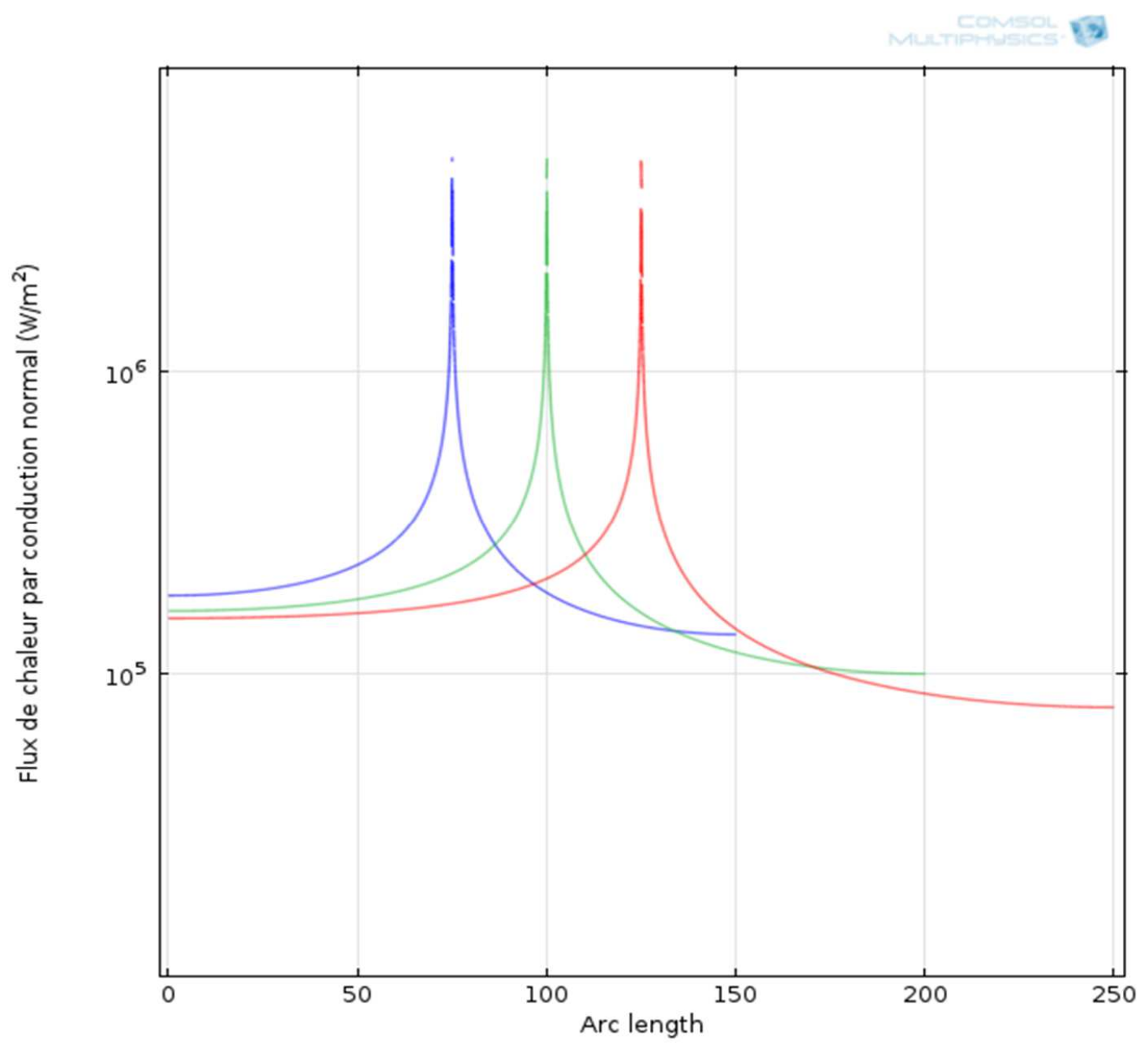

Figure 4. Thermal flux density profile (radius cross deployed) on the hotplate surface for 3 size of hotplate disc: 150, 200 and 250µm diameter.

We propose a phenomenological law of the flux that is rather independent of the hotplate diameter:

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

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]

Conclusions: This thermal flow analysis of the air stationary convection near a micro hotplate used in gas sensor, allows us to establish a semi analytic law of the related thermal losses [1]. It will be added to the electro thermal model of the microfilament to optimize its temperature uniformity and still lower its consumption.

References:

1. S. Gidon, and S. Nicoletti "Optimisation of Filament Geometry for Gas Sensor Application", Comsol Conf 2010.
2. Pierre Barritault, Mickael Brun, Serge Gidon, Sergio Nicoletti, "Mid-IR source based on a free-standing microhotplate for autonomous CO_2 sensing in indoor applications", Sensors and Actuators A 172, 379–385, 2011.

Excerpt from the Proceedings of the 2012 COMSOL Conference in Milan