

# Steady-State and Transient Electrothermal Simulation of Microheater for Gas Sensing

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## Abstract

Microheaters used for gas sensing applications have been studied analytically and experimentally. Previously reported microheaters at COMSOL® conferences have shed light on microheaters' thermal properties, optimized geometries and power consumption—all based on steady-state analysis. In this work, we additionally report transient analysis, i.e., thermal transient response of a microheater to study the time required for a microheater to reach the intended operating temperature. This information is critical to the design of a microheater-based gas sensor, because response time is a key performance parameter.

The figure shows a 3D microheater model built in the COMSOL® Joule Heating Multiphysics, which is part of Electromagnetic Heating found within the Heat Transfer Module. The microheater comprises a glass substrate, SiO<sub>2</sub> layer, platinum interconnects, polysilicon heater and tin oxide sensing layer. The respective thicknesses are 300 μm, 0.5 μm, 1 μm, 1 μm and 0.5 μm. The model incorporates all layers associated with an intended microfabricated gas sensor—making model as realistic as possible. The inset in the figure is a close-up schematic of our double-spiral microheater. The trace width is 5 μm and the respective trace spacing is 2.5 μm. (The heater is at the top center of the glass substrate for uniform heat distribution in the chip.)

We set the reference temperature of the model at room temperature (293 K). Also, we applied a 2.5V DC potential at one of the platinum electrode contact pads, while the other contact pad is grounded. This bias produces a direct current through the polysilicon heater. The heat distribution is a function of this current, which is in turn affected by the polysilicon's temperature-dependent resistivity (which is assumed to be  $2 \times 10^{-3} \Omega \cdot \text{cm}$  at room temperature). To account for this effect, we use a linearized resistivity approximation as a function of temperature for polysilicon (i.e., the polysilicon resistivity increases linearly with temperature).

In order to successfully mesh this 3D model, we first applied 2D triangular meshing on top of each layer, followed by a swept-meshing in the negative z direction. This approach optimizes the solution time for steady-state and transient analyses. We then extracted the volumetric electrical potential and the steady-state temperature distribution results. For a 2.5V potential applied, the maximum steady-state temperature is 960 °C. The time dependent analysis shows that the heater reaches the intended temperature (i.e., 400 °C) in 600 ms.

## Figures used in the abstract

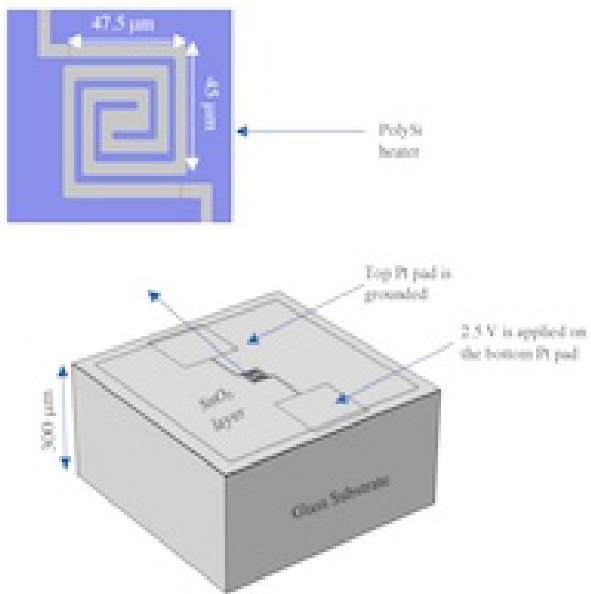


Figure 1: A 3D microheater device model for gas sensing applications. The inset figure depicts the double spiral shape heater geometry.