proceedings

Abstract

Sensing Material Temperature Effect on the Multiple Gas Sensor Sensing Response †

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† Presented at the XXXV EUROSENSORS Conference, Lecce, Italy, 10–13 September 2023.

Abstract: The temperature of the sensing material has a large impact on the tin-oxide gas sensor performance. However, the thermal analysis of gas sensors is often overlooked or only partially included in the studies. The aim of this research was to employ numerical simulations to investigate the temperature effect on the detection of the ethanol in an ethanol/air mixture by positioning multiple electrodes on a single heated membrane. The experimental results validated the electrothermal simulation and indicated a significant temperature effect on the sensor responsivity. Indeed, the decrease in the average sensor temperature from 427 °C to 411 °C increased the sensing response by approximately 75 % during the 5 ppm ethanol mixture flow over the sensor array.

Keywords: tin-oxide sensor; thermal analysis; multiple sensors

Citation: Sitar, A.; Scattolo, E.; Valt, M.; Bagolini, A.; Tosato, P.; Gaiardo, A. Sensing Material Temperature Effect on the Multiple Gas Sensor Sensing Response. *Proceedings* **2024**, 97, 130. https://doi.org/10.3390/proceedings2024097130

Academic Editors: Pietro Siciliano and Luca Francioso

Published: 1 April 2024

1. Introduction

The detection of volatile compounds has become a key aspect for many applications, ranging from agriculture to medicine. Chemo-resistive gas sensors are one of the most promising technologies due to their compactness, high sensitivity and cost-effectiveness. However, these chemo-resistive gas sensors are hindered by their low selectivity. which makes them less suitable for gas mixture detection applications. To overcome this limitation, many studies are exploring the use of multiple sensors, different sensing materials, or functionalization of the materials. One fundamental property that highly affects sensitivity is sensing material temperature, which is unfortunately not given proper attention. The ideal chemo-resistive gas sensor would have a uniform temperature, which is impossible in real operating conditions due to the heat losses. In this work, we focused on the temperature aspect of the sensor sensitivity by numerical simulations and experimental measurements of multiple gas sensors using a tin-oxide sensing layer.

2. Materials and Methods

The multiple gas sensor was micro-fabricated on a silicon substrate by depositing layers of silicon oxide and silicon nitride for the suspended membrane, titanium and platinum for the heater and electrodes and tin-oxide as the sensing material. The device is presented in Figure 1a, in which the overall structure is seen. The titanium/platinum stack was used for measuring the electrodes as well as for the heater meander. The tin-oxide nanoparticles were prepared by a simple sol-gel technique and afterwards screen printed on top of the sensor's membrane.

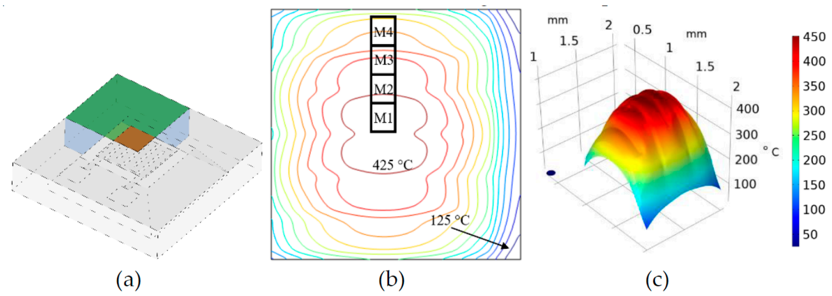

Figure 1. (**a**) Micro-fabricated sensor structure, (**b**) Thermal simulation of the tin-oxide and the M1–M4 sensor locations, (**c**) Thermal simulation presented in a 3D plot at a heating power of 120 mW.

3. Discussion

A heating power of 120 mW was used in the simulations and experiments, which provided enough thermal energy to reach the operating temperature of the sensors, denoted as M1 (highest temperatures) to M4 (lowest temperature), which were positioned as depicted in Figure 1b. The thermal simulation of the sensing tin-oxide material is given in Figure 1b,c. As expected, a large temperature decline is seen from the center to the edge of the suspended membrane.

The next step of our study was to measure the simultaneous sensing response to the ethanol/air mixture of the four sensors ($RM1 - RM4$), defined as $Ri = (Ri{,}air - Ri{,}gas)/Ri{,}gas$. In Figure 2, the response is reported, with the addition of the simulated average temperatures of the tin-oxide. The experimental results clearly show that the highest responses were achieved with the sensors M3 and M2, which had an almost optimal temperature for the task of measuring the low ethanol concentration. The temperature has a large effect on the sensor response, as just a 16 K difference between the average temperature of the sensor M1 and M2 increased the response from 6 to approximately 11.

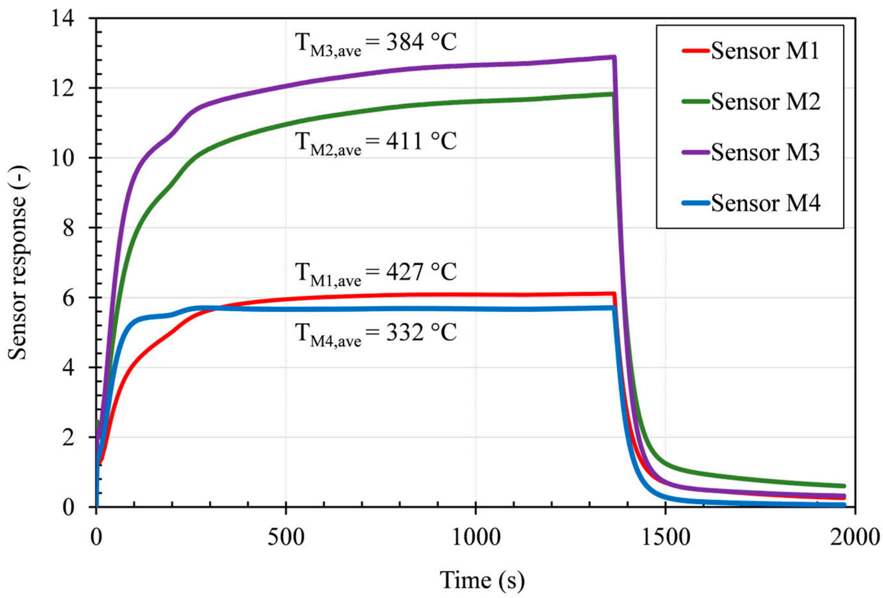

Figure 2. The M1–M4 sensor response after injection of 5ppm of ethanol/air mixture at a constant membrane heating power of 120 mW.

Author Contributions: Conceptualization, A.G. and E.S.; fabrication, A.G., A.B. and E.S., simulations, A.S., experimental analysis, M.V. and P.T.; writing—original draft preparation, A.S.; writing—review and editing, E.S.; visualization, A.S.; funding acquisition, A.G. and A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by: (1) The Fondazione Cassa di Risparmio di Trento e Rovereto, grant number 2018.0281, *Influence and stabilization of oxygen vacancies on nanostructured metal oxides for chemoresistive gas sensing applications/Influenza e stabilizzazione di vacanze di ossigeno in ossidi metallici nanostrutturati per applicazioni di sensoristica gassosa chemoresistiva* (https://invogas.fbk.eu/); (2) the SILICA project, Fondazione Cariverona, grant number 2022.0098; and (3) the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 898940.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data is contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.