DOI 10.5162/EUROSENSORSXXXVI/PT5.174

Chip-set for Chemoresistive Gas Sensors

Kitti Pankász[1], Csaba Dücső[2]
[1] Budapest University of Technology and Economics, Műegyetem rkp. 3, Budapest, 1111 Hungary
[2] HUN-REN, Centre for Energy Research, Konkoly-Thege street 29-33, Budapest, 1121 Hungary

Corresponding Author's e-mail address: ducso.csaba@ek.hun-ren.hu

Summary:
A chip set for development of chemoresistive gas sensors is presented. The basic chip carries three microheaters with resistance measuring electrodes on their top. Manually aligned masking chips enable local deposition of the sensing layer on the heaters' surface. The use of the chip set facilitates the functional characterization of the sensing layer without the need of chip processing capabilities.

Keywords: gas sensors, chemoresistive layers, microheater chip

Introduction

In spite of the half-century long continuous research and the relatively limited practical use of the chemoresistive solid state gas sensors, still large effort is dedicated for development of new sensing materials. New composition of thin layers [1], 3D nanostructures [2] and large variety of sensitizing methods aim at the improvement of sensitivity and selectivity. Although the vast majority of the reported sensors suffer from poor selectivity and dynamics, the promise of extremely low costs and the ppm level sensitivities keep many research groups continuing the development better sensing materials.

As the transduction principle relays on physi-, and chemisorption phenomena the sensors are operated at elevated temperatures. Consequently, to ensure battery backed operation, its power dissipation must be kept as low as possible. Although several laboratories and manufacturers have developed low power consumption microheater structures, their fabrication requires wafer processing lines. Thereby the access to the basic device is limited for many laboratories. In this work we present the first version of a set of microheater chip and aligned local masking chips to facilitate laterally selective deposition of the sensing layers and easy testing the sensor characteristics without the need for the complex technical background.

Results and discussion

1) The sensor chip

The 3.5x3.5 mm^2 chip contains three microheaters of 150µm diameter as suspended on a 500 µm circular membrane. The heater is an embedded Pt filament what encapsulated in a $SiO_2/Si_3N_4/SiO_2$ multilayer structure. The cross section (Fig.1), and the design considerations were reported earlier [3].

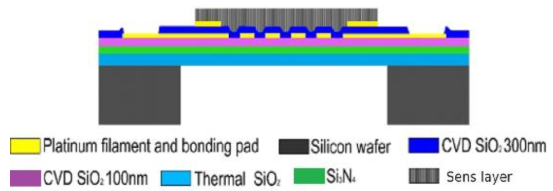

Fig. 1. The cross section of the microheater with the sensing layer on top.

DRIE backside Si etching process provides the membrane release to get the reduced power dissipation as represented in Fig.2.

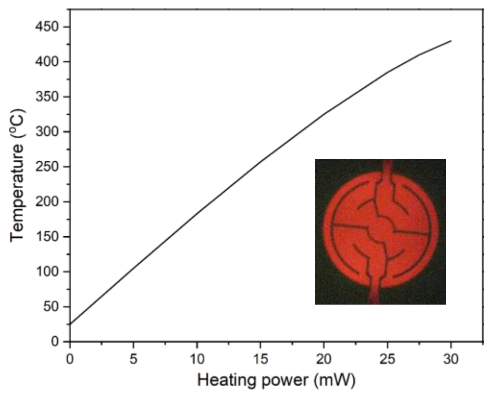

Fig. 2. Temperature-power characteristics of the microhotplate. The colour of the inset demonstrates the temperature uniformity of the heater @ 650°C.

The filament geometry provides uniform (<±3%) temperature distribution over the heated surface. It is visibly demonstrated by the inset of

Fig. 2, showing uniform colour at 650°C. However, according to the long-term tests, de device stability is guaranteed below 500°C.

Pt electrodes are formed on the top of the heater to measure the resistance of the gas sensitive layer. We offer two versions having 10 and 100 µm electrode distances to better match with the characteristic resistivity of the sensor layer. The three independently heated micro hotplates can be operated at different temperatures, thereby accelerates the screening the temperature vs. response characteristics; or setting the same heating power an average response can be calculated to more accurately characterize the sensor properties (Fig. 3).

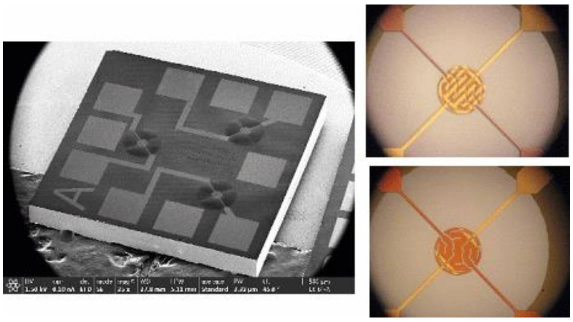

Fig. 3. The chip contains 3 identical microhotplates with 10 µm (top right) or 100 µm (bottom right) electrode distances.

2) Masking for locally selective deposition

Various processes have been reported for formation and deposition of the sensing layers; e.g. PVD and CVD methods as well as droplet or screen-printing techniques from separately synthetized suspensions. In our approach we fabricate masking chips for PVD and CVD layer depositions. Although the wet chemical synthesis of 3D nanostructured sensing materials dominate the current research activity, the proposed setup is partially meets the suspension-associated requirements. The droplet technique inherently provides local deposition, whereas the screen-printing is not compatible with the fragile thin membranes.

Considering the typical substrate temperatures of the conventional thin film PVD and CVD processes, we formed alternative masks for the deposition-through process: a 3D printed plastic version up to 60°C and perforated Si membrane for higher temperatures. Auxiliary chip holder enables the proper alignment of the chip and the mask. The setup is adaptable for both substrate positions (top down or bottom up) in the deposition system (Fig.4).

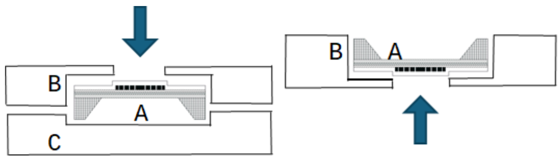

Fig. 4. Substrate positions in the deposition chamber: test chip (A), mask (B), auxiliary holder (C). The arrows indicate the direction of the precursor flow.

Beside the single-chip masks, we also fabricated masking caps for mounted and wire bonded chip. The recessed centre part with three openings is in a close vicinity of the chip surface but the bonding wires remain intact. This ultimate solution may perfectly assist in the R&D work by providing completely ready-to-test devices right after the sensing layer deposition.

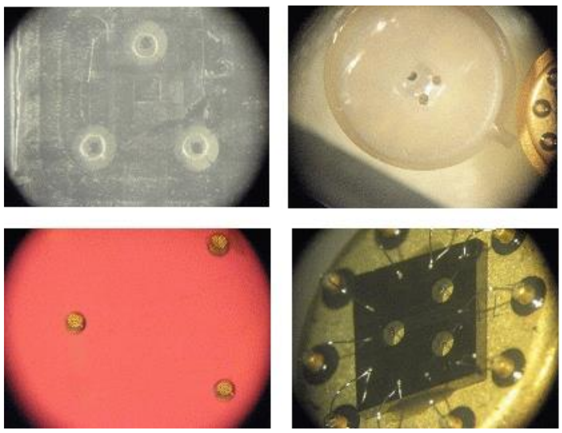

Fig. 5. The three heaters as seen in the vias of the transparent plastic (top left) and c-Si membrane (bottom left) masking elements. The 3D printed masking cap (top right) on a TO mounted chip (bottom right).

References

[1] Mirzaei, A. et al., Room Temperature Chemiresistive Gas Sensors Based on 2D MXenes, *Sensors* Volume 23, Issue 21 November 2023, DOI: 10.3390/s2321882

[2] Galstyan, V. et al. Progress towards chemical gas sensors: Nanowires and 2D semiconductors, *Sensors and Actuators B: Chemical*Volume 35715 April 2022, DOI: 10.1016/j.snb.2022.131466

[3] Biró, F. et al., An analytical method to design annular microfilaments with uniform temperature, Microsystem Technologies, 28(11), pp. 2511–2528, 10.1007/s00542-022-05376-8

Acknowledgement

This work was supported by the Hungarian Ministry of Culture and Innovation via Grant TKP2021-NVA-03.