Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 168 (2016) 293 – 296

Procedia Engineering

www.elsevier.com/locate/procedia

30th Eurosensors Conference, EUROSENSORS 2016

# Miniaturized integrated gas sensor systems combining metal oxide gas sensors and pre-concentrators

M. Leidinger[a*], T. Sauerwald[a], C. Alépée[b], A. Schütze[a]

[a]*Lab for Measurement Technology, Saarland University, Campus A5 1, 66123 Saarbruecken, Germany*
[b]*SGX Sensortech SA, Courtils 1, 2035 Corcelles, Switzerland*

**Abstract**

An integrated microsystem for (indoor) air quality monitoring applications has been realized. By combining a gas pre-concentrator based on metal-organic framework materials and a metal oxide semiconductor gas sensor in a single SMD package, a device for detecting ppb levels of volatile organic compounds was designed, integrated and tested with benzene as a target gas. The system has been characterized in FEM simulations concerning its gas pre-concentration capabilities and behavior. Test measurements were performed using benzene at concentrations in the ppb range. Both the simulations and the measurements show the suitability of the system design for the task. Significantly increased gas concentrations have been observed during thermal desorption from the pre-concentrator after gas adsorption at a low temperature.



Peer-review under responsibility of the organizing committee of the 30th Eurosensors Conference

*Keywords:* indoor air quality (IAQ); gas pre-concentration; volatile organic compounds (VOCs); gas sensor; MEMS

## 1. Introduction

Detecting trace gases in the ppb concentration range is highly relevant for many gas sensing applications, e.g. indoor air quality (IAQ) monitoring. The guideline threshold values for some of the most relevant volatile organic compounds (VOCs) in indoor air are 81 ppb for formaldehyde [1], 1.9 ppb for naphthalene [1], and 1.6 ppb for benzene [2]. While metal oxide semiconductor (MOS) gas sensors can in principle detect VOCs in trace concentrations [3], further increase in sensitivity and selectivity is desired.

Our approach to improve the performance of MOS gas sensors is the combination of such sensors with a pre-concentration device. As pre-concentrator (PC), a layer of a metal-organic framework (MOF) material is deposited

* Corresponding author. Tel.: +49-6881-302-2235; fax: +49-6881-302-4665.
*E-mail address:* m.leidinger@lmt.uni-saarland.de


Peer-review under responsibility of the organizing committee of the 30th Eurosensors Conference
doi:10.1016/j.proeng.2016.11.199

on an additional micro hotplate which is integrated in a miniaturized package together with a single or dual gas sensor element. The target gases adsorb at low temperature on the MOF material and are actively desorbed by heating the pre-concentrator hotplate. This results in a short gas pulse with significantly higher gas concentration at the gas sensor. MOFs were chosen for their very high specific surface area and their stability at temperatures over 300 °C [4].

## 2. Integrated systems

In the pre-concentrator gas sensor systems, the pre-concentrator MEMS hotplate is mounted side-by-side with a single or dual gas sensor chip in an SMD ceramic package, see Fig. 1. The size of the package is 7x5x1.5 mm³.

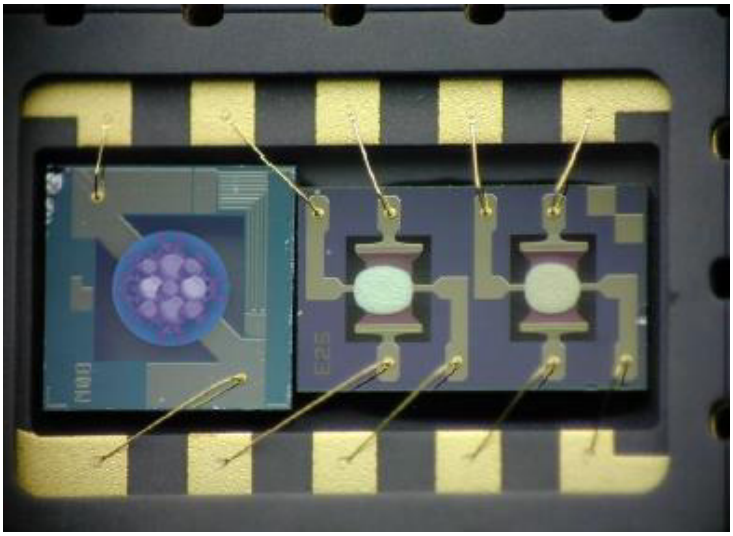

Fig. 1: Picture of the integrated system without the lid. The pre-concentrator is mounted in the left corner; an SGX commercial dual gas senor chip is integrated next to it. [5]

The MOF coated area has a diameter of approx. 800 µm. The systems are capped with a lid which allows gas access only at the side of the pre-concentrator. This places the sensor(s) in a dead-end inside the package. This configuration showed the best results in terms of concentration increase in FEM simulations. The design yields a very compact and cost-effective setup; the close proximity of the pre-concentrator and the gas sensor(s) is a significant advantage for the operation of the system, as gas transport is based on diffusion only.

## 3. Simulations

The integrated system setup was implemented into an FEM simulation tool for evaluation of the theoretical performance of the system and optimization of the operating modes of the single devices. Details on the simulation parameters were described in [6]. Fig. 2 shows the gas concentration distribution in the system at two times in an adsorption / desorption cycle. At the beginning of the simulation run, the gas concentration in the system and in the environment is set to 10 ppb. Fig. 2 a) shows the gas concentration 6.5 s after start of adsorption. At the position of the sensors S1/S2, the concentration has decreased significantly, as the gas has been adsorbed by the PC material. After 300 s of adsorption, the parameters of the pre-concentrator were set to desorption, the distribution of gas 1.5 s after start of desorption is shown in Fig. 2 b). The highest gas concentrations are found in the dead-end where the gas sensors are located; concentration is increased to 275 ppb, an increase of a factor of 27.5.