Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 5 (2010) 25–28
Procedia Engineering
www.elsevier.com/locate/procedia

Proc. Eurosensors XXIV, September 5-8, 2010, Linz, Austria

Gas sensor array system inspired on the sensory diversity and redundancy of the olfactory epithelium

L. Fernandez[a,b], A. Gutierrez-Galvez[a,b,*], S. Marco[a,b]

[a] *Institute of Bioengineering of Catalonia (IBEC),*
[b] *University of Barcelona, Martí I Franqués 1, Barcelona, 08028, Spain*

Abstract

This paper presents a chemical sensing system that takes inspiration from the combination of sensory diversity and redundancy at the olfactory epithelium to enhance the chemical information obtained from the odorants. The system is based on commercial MOS sensors and achieves, first, diversity trough different types of MOS along with modulation of their temperatures, and second redundancy including 12 MOS sensors for each type (12x8) combined with a high-speed multiplexing system that allows connecting 16 load resistors with each and every one of the 96 sensors in about two seconds. Exposition of the system to ethanol, ammonia, and acetone at different concentrations shows how the system is able to capture a large amount of information of the identity and the concentration of the odorant.

Keyword: Gas sensor array; biologically inspired system; redundancy; diversity; MOX sensors; temperature modulation

1. Introduction

The olfactory epithelium of animals is populated with thousands of Olfactory Receptor Neurons (ORNs) that bind different molecular properties of the volatiles depending on the olfactory receptor protein they express. A number of these ORNs express different receptor proteins providing a high degree of diversity. But not all ORNs are of different type since a large number of them express the same receptor protein endowing the ORN population with a high degree of redundancy. These two structural features of the olfactory epithelium play an important role in capturing chemical information from volatiles and conveying it to the following stages of the olfactory system. It is well accepted that receptor diversity mediates odour identification since each odorant elicits a different pattern of activity across different-type [1]. The role of redundancy, beyond that of signal-to-noise and robustness improvement, seems to be related with the encoding of odour concentration. Grosmaitre et al. [2] have recently

* Corresponding author. Tel.: +34 93 4039157
E-mail address: agutierrez@el.ub.es

1877-7058
doi:10.1016/j.proeng.2010.09.039

found that the response of ORNs expressing the same receptor do not respond in the same way to odour concentration. Thus, odorant concentration becomes encoded as an activity pattern across ORNs of the same type.

In this work, we follow the strategy of combining sensor diversity and redundancy to build a chemical sensor array based on MOS sensors. On the one hand, sensor diversity is achieved using 8 different types of MOS sensors and modulating their temperature, which provides additional pseudo sensors for different temperatures [3] (fig. 3). On the other hand, sensor redundancy is obtained by two means: first, including 12 sensors for each type for a total of (12x8=) 96 and; second, using 16 different load resistors with a high-speed multiplexing system to read the response of the sensors trough a voltage divider (12x8x16 = 1536 readouts).

2. Gas sensor array system

Figure 2(a) shows a block diagram of the main parts of the gas sensor array sytem. The system is composed of three main blocks: Odour delivery, Measurement, and Control, which are described below. The role of the odour delivery bock is to dilute the odour or odour mixture to the desired concentration and convey it to the sensor chamber with controlled humidity and temperature. The system is composed of three programmable syringe pumps (KDS200), a humidity/temperature control instrument (MN HCS-401), two odour distributors, a sensor chamber with eight independent channels, and eight electro-valves (Clippard E210C). The syringe pumps control the amount of odorants (up to two) that is mixed with dry air. This mixture is introduced to an instrument that regulates its humidity and temperature to ensure the same conditions during the experiments. A 1 to 8 distributor splits up in a symmetric way the mixture in 8 streams to introduce them in the 8 independent channels of the sensor chamber. At the output of the chamber the 8 streams are brought together with a 8 to 1 distributor.

The measurement block contains the sensor, sensor chamber, and the instrumentation required to capture the sensor responses and connect the sensors to the desired load resistor. The sensor chamber houses 112 commercial sensors including 96 MOS gas (Figure 2(c)) from Figaro and FIS, 8 humidity, and 8 temperature sensors. Temperature and gas sensors, which are resistive sensors, are conditioned with a voltage divider with multiple load resistors for the gas sensors and a fixed load resistor for the temperature sensors. To avoid unnecessary duplications of the load resistors the voltage divider is implemented with two multiplexers (NI PXI 2530) (Figure 2(b)) that select the sensor and the load resistor that is connected at each period of time. The high switching frequency rate of the multiplexers (300 MHz) allows capturing the response of all the combinations of the 96 sensors with 16 load resistances in less than 2 seconds. This block is also composed of a high-speed acquisition card with four analog channels (NI PXI 4462), and two PCBs for the sensors and the load resistances.

Finally, the control block selects and provides power to the sensors and the different electric elements of the delivery system. It includes two power supplies (NI PXI4110, N6705A), an acquisition card with eight digital output channels (USB-3103), and 2 PCBs with power control circuits.

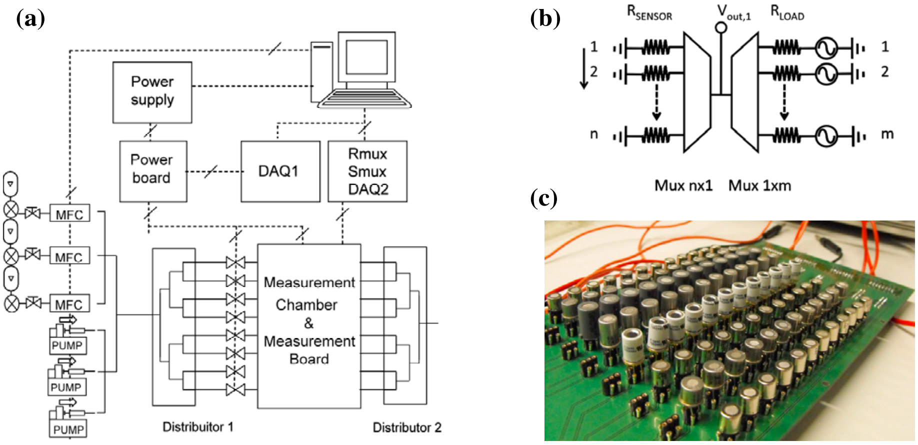

Fig. 1. Gas sensor array system setup (a) Main parts of the gas sensor array system; (b) ; (c) Gas sensor array populated with Figaro and FIS commercial MOS sensors.

3. Results

We have tested the system conducting two experiments to evaluate its ability to encode for the identity and concentration of the chemicals. During these experiments, the heater voltage has been modulated following a ramp profile from 0 to 1 V in 300 s for FIS sensors and from 0 to 5 V in the same time for Figaro sensors. Figure 2(a) shows the response of a FIS sensor during this voltage excitation to 60 ppm of ammonia. The readout of the sensor is performed with a voltage divider using 16 different load resistors ranging from 100Ω-10 k Ω.

In the first experiment, we have exposed the system to four concentration levels of acetone: 30 ppm 60 ppm, 80 ppm, and 120 ppm. Figure 2(b) shows the steady state response of three sensors with the 16 load resistors when presented with the afformentioned acetone concentration levels. The information of the concentration of the gas is captured across the 16 signals generated with the different load resistors.

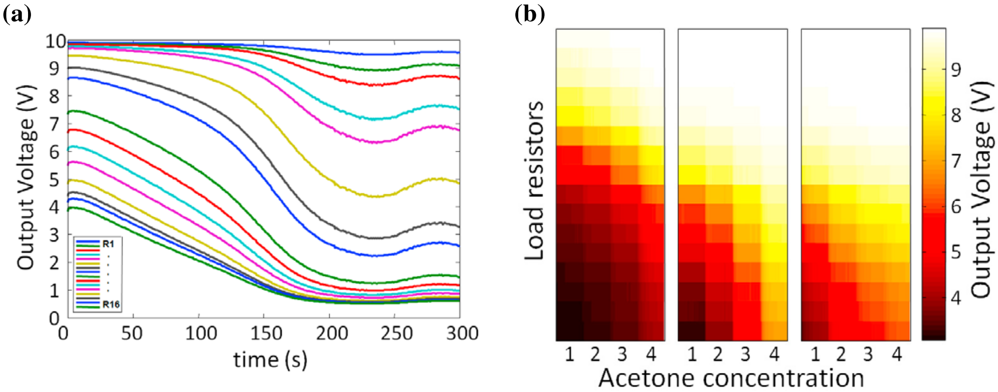

Fig. 2. Gas sensor responses (a) Sensor response of temperature modulated FIS sensor of the array to 60 ppm of ammonia. The temperature of the sensor is modulated with a ramp applying a heater voltage range of 0-1 V; (b) Response of 3 sensors to concentrations of acetone of 30ppm(1), 60ppm(2), 90ppm(3), and 120ppm(4).

In the second experiment, we have presented the system with three different analites: acetone (60 ppm), ethanol (60ppm), ammonia (40 ppm). The high dimensional output of the system is shown in Figure 3, where the steady state response of all sensors is shown for every load resistor value. The pattern of response across sensors and load resistors is specific for each analite.

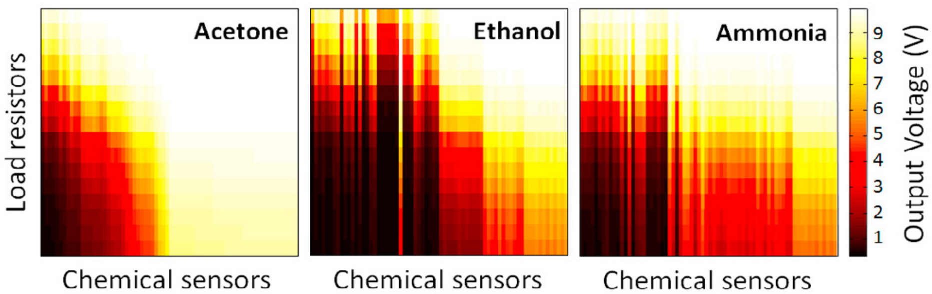

Fig. 3.Response of all chemical sensors combined with all load resistors to three analites : acetone (60ppm), ethanol (60ppm), and ammonia (40ppm)

References

[1] Malnic B, Hirono J, Sato T, Buck L, Combinatorial receptor codes for odors. Cell (1999) vol. 96 (5) pp. 713-723

[2] Grosmaitre X, Vassalli A, Mombaerts P,Shepherd G, Ma, M, Odorant responses of olfactory sensory neurons expressing the odorant receptor MOR23: a patch clamp analysis in gene-targeted mice. Proceedings of the National Academy of Sciences (2006) vol. 103 (6) pp. 1970-1975

[3] Gutierrez-Osuna R, Gutierrez-Galvez A, Powar N, Transient response analysis for temperature-modulated chemoresistors. Sensors & Actuators: B. Chemical (2003) vol. 93 (1-3) pp. 57-66