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► To cite this version:

Bruno Lawson, Virginie Martini, Tomas Fiorido, Marc Bendahan, Rachid Bouchakour, et al.. Cyclical Heating to Reduce Consumption of SnO₂ Sensors for Alcohol Monitoring. The Third International Conference on Advances in Sensors, Actuators, Metering and Sensing ALLSENSORS 2018, Mar 2018, ROME, Italy. hal-03942544

HAL Id: hal-03942544

<https://hal.science/hal-03942544>

Submitted on 22 Jan 2024

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Cyclical heating of SnO₂ sensors for alcohol monitoring at lower power consumption

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Abstract— In this work we study SnO₂ sensor responses under ethanol exposure for alcohol monitoring under continuous and cyclical heating to reduce power consumption. The SnO₂ sensitive thin layer of 50nm have been deposited by magnetron reactive sputtering. The power consumption of SnO₂ sensor during continuous heating was 53mWh (280°C) and in the case of cyclical heating the power consumption was 13.25mWh with a frequency of 16 mHz. The division by four of the power consumption results in a slight decrease in the sensitivity of the sensor.

Keywords : ethanol monitoring, cyclical heating, low power consumption, SnO₂ gas sensor

I. INTRODUCTION

Research field of metal oxide chemo-resistive gas sensor (MOX Sensors) has growing interested by biomedical applications [1] for the detection of VOC (Volatile organic compounds) release by human body. For monitoring alcohol vapor emitted by transdermal perspiration after alcohol consumption [2], SnO₂ metal oxide sensor are used. Tin dioxide is one of the most sensitive layers used for gas detection thanks to its high sensitivity and stability. So in the case of transdermal alcohol monitoring, the main criteria is the higher sensor sensitivity under the minimum heater power consumption to be integrated in mobile component.

MOX sensor requires two voltage inputs, the heater voltage and the sensor bias voltage. The heater voltage allows to maintain the semiconductor at a specific temperature for gas detection and the sensor bias voltage is applied to allow the measurement of the sensor response. The critical point of working with metal oxide semiconductor gas sensor is the power consumption of heater average more than 70mW. In the case of continuous monitoring it is important to decrease heater consumption toward integrated in microsystems like wristband, patch and armband, watch (~5mW). To look for a solution, we propose to use cyclical heating, which is switching on-off the heater and minimize active time of consumption for power saving. Given the high value of the sensitive layer resistance, the power of the sensitive layer is negligible compared with that of the heater.

In order to monitor the transdermal ethanol emission on the skin, we compare the responses of sensor in both case: continuous heating and cyclical heating. The SnO₂ sensors

were exposed to the ethanol vapor with various concentrations ranging from 1ppm to 100ppm

II. EXPERIMENTAL

A. Gas sensor

Tin oxide is an n-type wide-band-gap (3.6eV) metal oxide semiconductor with wide range of applications for various oxidizing or reductive gas/vapor detection. Thin SnO₂ sensitive layers (~50 nm) are deposited by reactive RF magnetron sputtering on Si/SiO₂ transducers with integrated heater and membrane patented by IM2NP laboratory [3] [Fig. 1] and annealed at 500°C during 2h in dry air. The films have been deposited at a pressure of $22 \cdot 10^{-3}$ mbar.

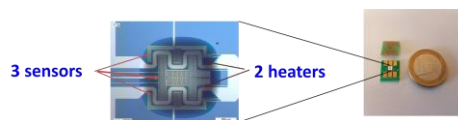


Fig. 1: IM2NP transducer: SiO₂/Si membrane, integrated Pt electrodes and heater

B. Measuring bench

An innovative sensor system calibration is developed with collaboration of O'MICRON society. This platform of sensors characterization generates ethanol and acetone vapors (acetone is one the most interference VOC for alcohol detection in perspiration). The ethanol vapor is generated by heating tubes, it can be generated in a range of 20 ppb to 150 ppm for flow rate of 250 ml/min and relative humidity can be varied between 0% and 90%. Ethanol vapor is carried in test chamber of volume 1.86 ml, where the sensor is polarized via Keithley source-meter for data acquisition and the heater is powered modulates power supply for operating temperature. The sensor response is defined as: R_a/R_g , where R_a is the sensor resistance measured in air and R_g is the sensor resistance under ethanol exposure. Ethanol concentration varied between 1 ppm to 100 ppm every 2 min of exposure for relative humidity of 0%.

C. Cyclical heating

Before apply voltage for cyclic temperature, we used an oscilloscope to visualize the output voltage modulation. Figure 1 show an example of cyclic heating witch has been considered. During 60s (1min) heater off for 45s and switch heater on for 15s and repeated during all the measurement. The period of this cyclical heating: 60s, it frequency is 16 mHz and the cyclical ratio is 0.25.

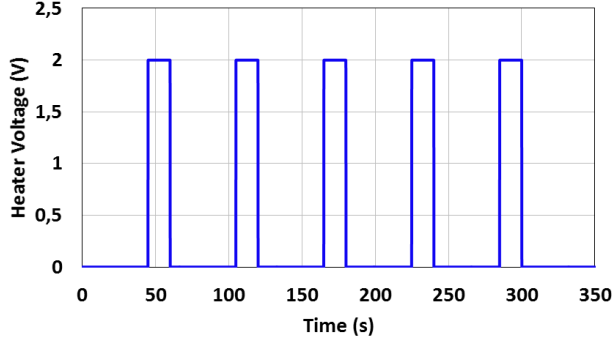


Fig. 2: Cyclical heating applied to SnO₂ sensor

III. RESULTS AND DISCUSSIONS

SnO₂ sensor show a good sensitivity to ethanol mainly for lower concentrations of ethanol and saturated around 70 ppm. Figure 3 show the sensor response in case of continuous heating (53mWh).

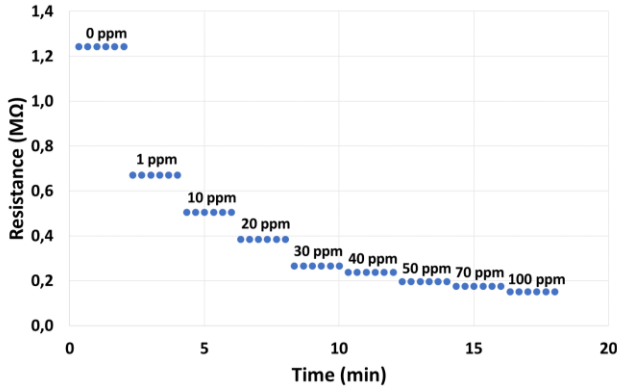


Fig. 3: SnO₂ sensor under different ethanol concentrations: continuous heating

The Figure 4 show the sensor response in case of cyclical heating mode (13.25mWh). The power reduction (By 4) causes a slight decrease in the sensor responses, see Figure 5. In fact in the case of continuous heating the sensor operates at 280°C and 53mW. In the case of cyclical heating, we reduce the heating time and so the power consumption, without reducing the operating temperature (280°C) during the detection process.

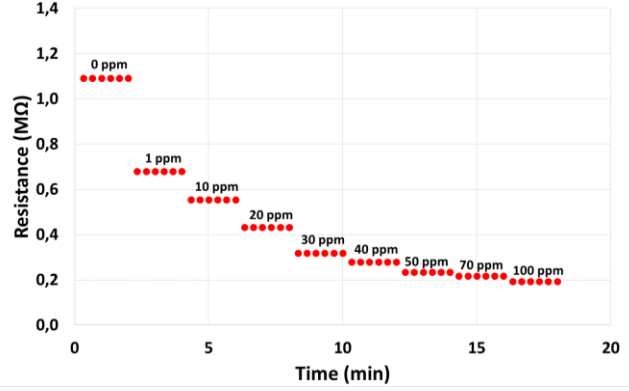


Fig.4: SnO₂ sensor under different ethanol concentrations: cyclical heating

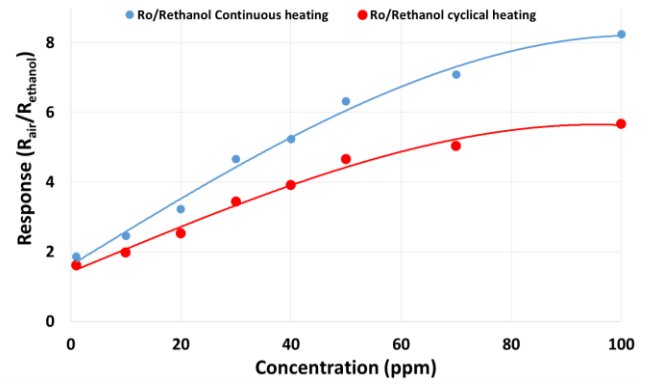


Fig.5: SnO₂ responses comparison between continuous heating (53mWh) and cyclical heating (13.25mWh)

IV. CONCLUSION

This paper describes the efficiency of the cyclical heating in the gas/vapor detection process. This method allow to reduce power consumption in the integrated gas detection microsystems. Thanks to this heating modulation and to the low response time of the microsensors, the energy consumption can be further reduced with only a slight decrease in sensitivity.

V. REFERENCES

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