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# Sub-ppm NO<sub>2</sub> sensing in temperature cycled mode with Ga doped ZnO thin films deposited by RF sputtering

L. Presmanes<sup>1</sup>, V. Gunasekaran<sup>1</sup>, Y. Thimont<sup>1</sup>, I. Sinnarasa<sup>1</sup>, A. Barnabe<sup>1</sup>, Ph. Tailhades<sup>1</sup>, F. Blanc<sup>1</sup>, C. Talhi<sup>2</sup>, Ph. Menini<sup>2</sup>

<sup>1</sup> CIRIMAT, Université de Toulouse, CNRS, INPT, UPS, 118 Route de Narbonne, F-31062 Toulouse CEDEX 9, France

<sup>2</sup> LAAS-CNRS, Université de Toulouse, UPS, INSA, 7 avenue du colonel Roche, F-31031 Toulouse, France

## 1. Abstract

In this work Ga doped ZnO thin films have been deposited by RF magnetron sputtering onto a silicon micro-hotplate and their structural, microstructural and gas sensing properties have been studied. ZnO:Ga thin film with a thickness of 90 nm has been deposited onto a silicon based micro-hotplates without any photolithography process thanks to a low cost and reliable stencil mask process. Sub-ppm sensing (500 ppb) of NO<sub>2</sub> gas at low temperature (50 °C) has been obtained with promising responses R/R<sub>0</sub> up to 18.

## 2. Results

Micro-hotplates have been prepared using photolithographic process. The system is composed by a heating element and sensing electrodes. They are both integrated in membrane in order to have a localized heating and sensing spot onto which the sensitive thin film is deposited. The microhotplates can operate with low consumption and can heat up to 500 °C with a good stability. This system has been already published in [1]. The use of lift-off process to restrict the deposition of the thin film onto central electrodes can lead to the dissolution and/or contamination of the sensitive layer. That's why the photolithographic method was avoided and a stencil mask process was used (Figure 1).

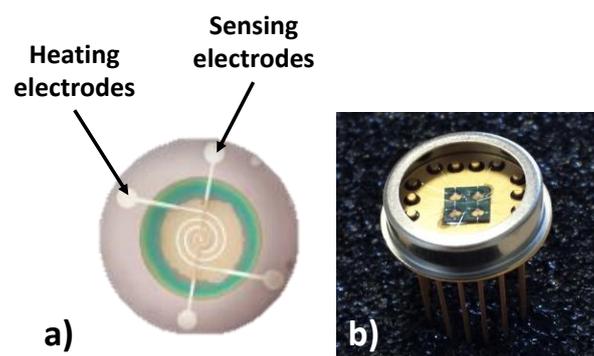


Figure 1: a) top-view of the membrane; b) mounted micro-sensor.

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[1] L. Presmanes, Y. Thimont, I. El Younsi, A. Chapelle, F. Blanc, C. Talhi, C. Bonningue, A. Barnabé, Ph. Menini, and Ph. Tailhades, "Integration of P-CuO Thin Sputtered Layers onto Microsensor Platforms for Gas Sensing", *Sensors*, vol. 17, #1409, June 2017.

The deposition conditions are shown in the Table I.

Table I: *Deposition parameters of ZnO:Ga thin film by RF-sputtering.*

Target material	ZnO:Ga
Power (W)	(4 %at)
Magnetron	30
Argon pressure P (Pa)	Yes
Target to substrate distance	2
d (cm)	7

The measurement protocol used in the test bench is a cycle of heating and cooling steps from 5 mW to 35 mW with a step of 5 mW for 5 min which correspond approximately to 50 °C to 350 °C. The tests were performed with 50% relative humidity. Alternation of air and air with 500 ppb of NO<sub>2</sub> has been applied. In presence of air, the resistance is very low, close to 300 Ω, due the high conductivity of ZnO:Ga. When 500 ppb of NO<sub>2</sub> are injected, the resistance increases strongly up to 7 kΩ at 50 °C. The ratio R/R<sub>0</sub> (where R is the resistance under NO<sub>2</sub> and R<sub>0</sub> the resistance under air) has been calculated using the last points at each temperature step (Figure 2).

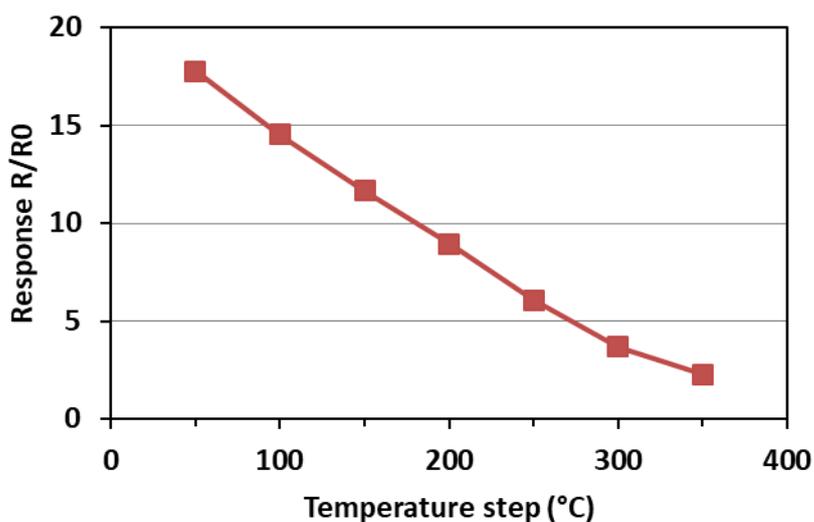


Figure 2: *Response of ZnO:Ga vs temperature step (in cycled temperature mode).*

Unlike the results we obtained in isothermal mode, the response in cycled temperature mode is much higher close to room temperature. Promising results with a response up to 18 for 500 ppb of NO<sub>2</sub> at 50 °C (R/R<sub>0</sub> ~ 36 /ppm) have been highlighted.

### 3. Acknowledgement

This work has received funding from the Program Interreg-Sudoe of the European Union under grant agreement SOE2/P1/E0569 (NanoSen-AQM). This work was also partly supported by the French RENATECH network through technology developments in the CNRS-LAAS cleanroom