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Sub-ppm NO_2 sensing in temperature cycled mode with Ga doped ZnO thin films deposited by RF sputtering

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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_2 gas at low temperature (50 °C) has been obtained with promising responses R/R0 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-of 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).

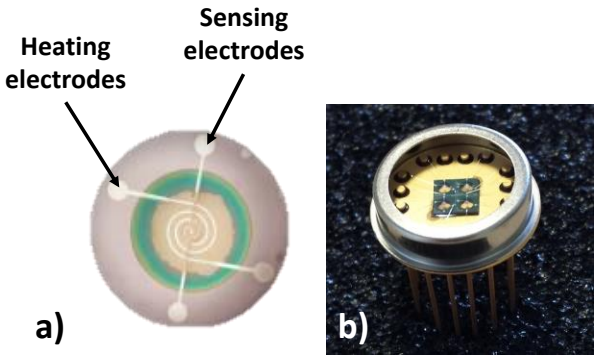


Figure 1: *a) top-view of the membrane; b) mounted micro-sensor.*

[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 NO2 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_2 are injected, the resistance increases strongly up to 7 kΩ at 50 °C. The ratio R/R0 (where R is the resistance under NO_2 and R0 the resistance under air) has been calculated using the last points at each temperature step (Figure 2).

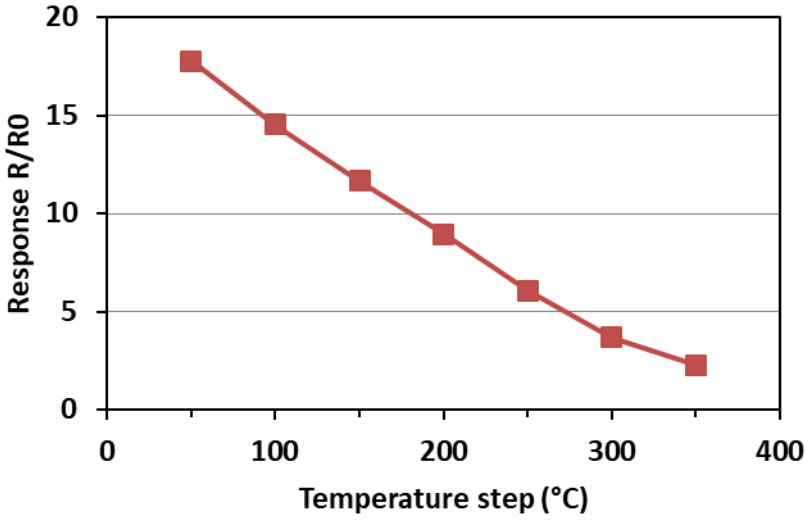


Figure 2: *Response of ZnO:Ga vs temperature step (in cycled temperature mode).*

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_2 at 50 °C (R/R0 ~ 36 /ppm) have been highlighted.

3. Acknowledgement

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