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Abstract

Pulsed Temperature Operation of SnO_2-Based Gas Sensors †

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Abstract: We herein demonstrate the pulsed-mode temperature operation of chemical sensor devices based on thin SnO_2 films, which were synthesized by magnetron sputtering. The gas-sensitive films were integrated on SiN-based micro-hotplate (µhp) chips, which enable operation temperatures up to 500 °C. We compared the gas sensor performance in constant temperature mode with pulsed temperature mode operation towards the test gases carbon monoxide and toluene. In contrast to constant temperature, the pulsed temperature mode operation reveals additional information about the type of test gas.

Keywords: chemical sensors; metal oxides; nanoparticles; temperature modulation

1. Introduction

Nowadays, conductometric chemical sensors based on metal oxides like SnO_2, ZnO, CuO_x, and WO_x are the most promising and investigated types of solid-state sensors [1,2]. Gas sensor devices are of high importance for many applications, where energy-autonomous sensor systems suitable for IoT applications could achieve wide-area pollution monitoring and mapping. Power consumption of such sensor devices, however, is a key performance aspect that is decisive for their application success. Pulsed temperature operation offers much lower power consumption (<1 mW) as compared to conventional DC-mode temperature operation (>30 mW). Moreover, pulsed temperature operation reveals target gas-dependent features in the response, which can be exploited to increase the selectivity of the sensor devices.

2. Methods and Materials

SiN-based µhp chips, which provide a heating structure for operating temperatures up to 500 °C, and electrodes for contacting the SnO_2 films were processed by photolithography with a negative resist mask. Next, the SnO_2 sensing layer with a thickness of 50 nm was deposited by reactive magnetron sputtering of a Sn target in Ar + O_2. Afterwards, the sensors were functionalized with metallic nanoparticles (Ag, Ti, and Cu) synthesized by magnetron sputter inert gas condensation [3] to improve sensitivity and selectivity. The sensor devices were characterized in an automatized setup with synthetic air (80% N_2, 20% O_2, and humidity 50%) as a background gas and a constant flow rate of 1000 sccm. The target gases are carbon monoxide (CO) and toluene (C_7H_8).

3. Discussion

A typical resistance measurement of a sensor device is exemplified in Figure 1a, and the temperature cycling schematics are shown in the lower graph. First, the sensors are heated up to 500 °C for 15 min (DC-mode), the test gas (indicated as a grey column) is

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inserted for 5 min, and the sensors' resistance decreases. Next, the devices are cooled down to room temperature for 10 min; this is followed by three subsequent heating pulses (pulsed mode—1 min), where only the second heating pulse is applied in presence of the test gases. This procedure is executed three times for 5, 10, and 20 ppm test gas concentration. Figure 1b shows in detail the entirely different resistance gradient behavior (emphasized by the blue circle) in pulsed mode operation for 5 ppm CO and C_7H_8.

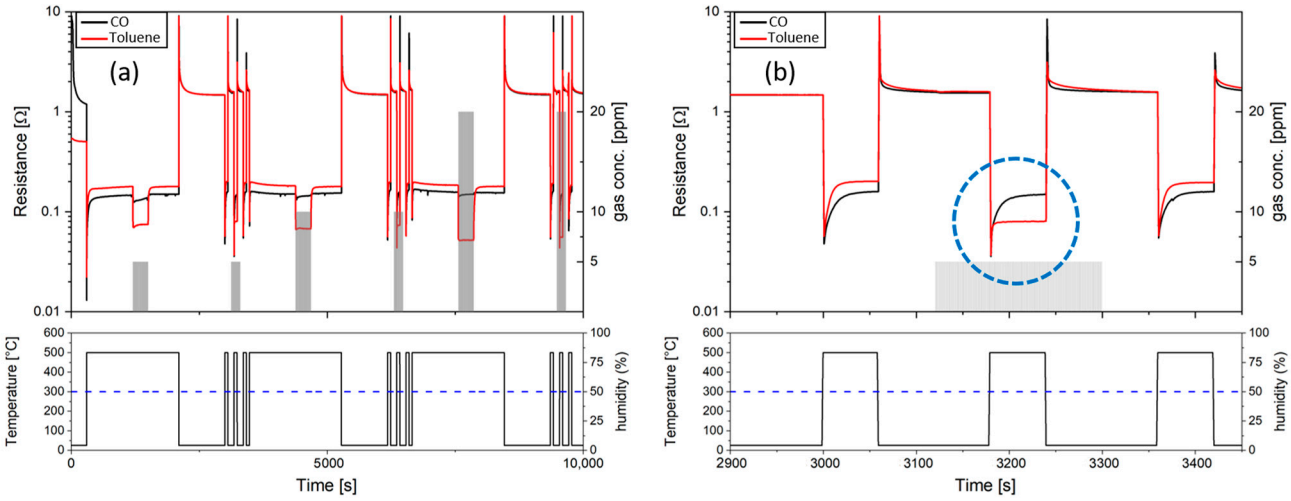

Figure 1. (**a**) Typical resistance measurement in DC- and pulsed-mode T operation for CO and C_7H_8 (5, 10, and then 20 ppm). (**b**) Comparison of pulsed-mode T operation for 5 ppm of CO and C_7H_8.

The sensor response (= resistance decrease) in presence of the test gases is comparable to the DC-mode. However, it is obvious that the shape of the response curves (see blue circle in Figure 1b) is entirely different for CO and C_7H_8. Thus, we conclude that pulsed T-mode operation reveals particular information about the test gas that cannot be derived from DC-mode operation.

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References

1. Barsan, N.; Koziej, D.; Weimar, U. Metal oxide-based gas sensor research: How to? *Sens. Actuators B Chem.* **2007**, *121*, 18–35. [CrossRef]
2. Wang, C.; Yin, L.; Zhang, L.; Xiang, D.; Gao, R. Metal Oxide Gas Sensors: Sensitivity and Influencing Factors. *Sensors* **2010**, *10*, 2088–2106. [CrossRef] [PubMed]
3. Steinhauer, S.; Lackner, E.; Sosada-Ludwikowska, F.; Singh, V.; Krainer, J.; Wimmer-Teubenbacher, R.; Grammatikopoulos, P.; Köck, A.; Sowwan, M. Atomic-scale structure and chemical sensing application of ultrasmall size-selected Pt nanoparticles supported on SnO_2. *Mater. Adv.* **2020**, *1*, 3075–3608. [CrossRef]