


Abstract

Using Mono-, Bi- and Tri-Metallic Nanoparticles to Improve Selectivity and Sensitivity of CMOS-Integrated SnO₂ Thin-Film Gas Sensors [†]

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Abstract: We demonstrate the systematic optimization of SnO₂-based thin-film chemical sensors by using mono-, bi- and tri metallic nanoparticles (NPs) composed of Ag, Pd, and Ru, which are deposited via magnetron sputtering inert gas condensation. The ultrathin SnO₂ films are integrated on CMOS-based micro-hotplate devices, where each chip contains 16 sensor devices in total. We found that the response of the sensor device can be significantly tuned to specific target gases, such as CO and VOCs, by using various types of NPs.

Keywords: chemical sensors; multi-gas sensor; CMOS integration; metal oxides; nanoparticles



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1. Introduction

Nowadays, conductometric chemical sensors based on metal oxides like SnO₂, ZnO, TiO₂ or WO_x are the most promising and investigated types of solid-state sensors [1,2]. A CMOS fabrication approach is key for the realization of smart gas sensing devices with low power consumption and low cost [3]. The use cases for these sensors range from air quality monitoring and breath analysis to sensor networks, which are used for IoT applications. Noble metal nanoparticles (NPs) have been successfully employed to improve both the sensitivity and selectivity of such gas sensors devices [4], which are key performance aspects that are decisive in their application success.

2. Materials and Methods

In this work, we introduce our approach for optimizing hybrid MO_x-NP material combinations toward specific target gases on CMOS-integrated micro-hotplate (μhp) chips [4] shown in the inset of Figure 1, which were developed in collaboration with ams Osram AG. This is a worldwide unique device where a single 4.5 × 4.5 mm² sized chip contains an array of 8 μhps (see Figure 1) for 16 sensors in total. Ultrathin SnO₂ sensing layers are deposited on the CMOS chips using spray pyrolysis technology with a thickness of 50 nm, and further processed via photolithography and ion etching. Each 80 × 80 μm² sized μhp contains two sensors. Finally, the sensors are functionalized with mono-, bi- and tri-metallic NPs (Ag, Pd, Ru, and combinations thereof) via magnetron sputtering inert gas condensation. The sensor devices are characterized in an automatized setup with synthetic

air (80% N₂ and 20% O₂, humidity 50%) as a background gas and a constant flow rate of 1000 sccm. The target gases are carbon monoxide (CO) and a mixture of acetylen, ethan, ethen, and propen (HCMix).

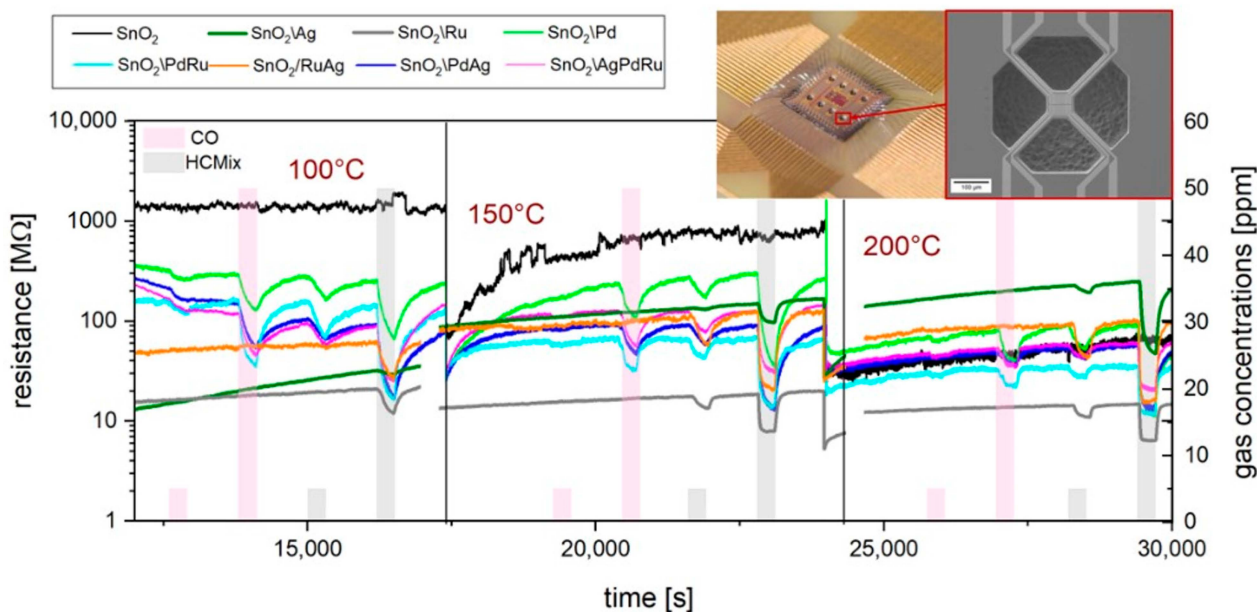


Figure 1. Typical measurements for the bare and functionalized sensors for CO and HCMix (5 ppm, 50 ppm). The inset shows the CMOS-integrated μ hp device for 16 sensors in total.

3. Discussion

A typical resistance measurement for bare and Ag, Ru, Pd, PdRu, RuAg, PdAg, and AgPdRu NP-functionalized sensors toward CO and HCMix gas pulses (concentration: 5 ppm, 50 ppm) is shown in Figure 1 for 100 °C, 200 °C, and 300 °C operation temperatures. While the bare sensors show no response (=resistance decrease) at all to CO and HCMix levels, the NP-functionalized sensors show significantly increased response already at these comparatively low operation temperatures. Moreover, the sensors functionalized with different metallic NPs react differently to the gases, which enables the adjustment of the sensor’s selectivity to specific target gases. This is our strategy toward the development of a multi-gas sensor device: by properly functionalizing the sensors with different NPs, the sensor array (see inset) is capable for the simultaneous sensing of several target gases.

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