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Optimization of SnO_2-Based CMOS-Integrated Gas Sensors by Mono-, Bi- and Trimetallic Nanoparticles †

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Abstract: In this paper, we report on the optimization of SnO_2-based thin film gas sensor devices by mono-, bi- and trimetallic nanoparticles. Ag, AgRu, and AgRuPd nanoparticles are sputter deposited on CMOS-integrated SnO_2-thin film gas sensor devices. The CMOS device is a worldwide unique chip containing an array of eight microhotplates. The response towards the target gas CO was dramatically increased from 10% to more than 70% by using trimetallic AgRuPd nanoparticles.

Keywords: SnO_2; gas sensors; metallic nanoparticles

1. Introduction

Air quality control is a major issue in today's world due to air pollution caused by small particles and dangerous gases [1]. Monitoring potentially harmful gases can be performed by conductometric chemical sensor devices based on metal oxides (MOx). MOx sensors exhibit a high response towards a variety of gases, therefore optimization is necessary to reduce the cross sensitivity and improve selectivity of the devices. Noble metal nanoparticles (NPs) have been successfully employed to improve both the response as well as the selectivity of SnO_2-based gas sensor devices [2,3]. In this paper, we present performance results achieved on SnO_2 thin films integrated on CMOS-based microhotplate (μhp) devices, which have been functionalized with three noble metals: silver (Ag), ruthenium (Ru) and palladium (Pd), and their mixtures.

2. Experiment Description

The CMOS-integrated microhotplate (μhp) chips have been fabricated by ams AG (Premstätten, Austria). This is a worldwide unique device where a single chip integrates an array of 8 μhps [4]. Each μhp contains 2 single sensing layers suitable for 4-point measurement. The SnO_2 sensing layer was deposited by spray pyrolysis technique with a thickness of 50 nm and functionalized with mono-, bi- and trimetallic NPs (Ag, Pd, and Ru) by magnetron sputtering. Gas measurements were performed by an automatized setup with synthetic air (80% N_2, 20% O_2) as a background gas and a constant flow rate of 1000 sccm. A humidity level of 50% was kept constant for all measurements; gas concentration of carbon monoxide (CO) was 50 ppm, and 5 ppm for HCMix (mixture of ethane,

ethene, ethyne, propane). The gas pulse times were kept constant at 5 min, and the time between the pulses was 15 min.

3. Experimental Results

Responses of the bare SnO_2 sensor, and the SnO_2 sensors functionalized with Ag, AgRu, and AgRuPd towards 50 ppm CO concentration are shown in Figure 1a, where "response mean" is an average value measured for four different sensors integrated on a single chip. The response increased from 14% for the bare SnO_2-based gas, to 21% with Ag-NPs, to 30% with AgRu-NPs, and up to a maximum of 73% for AgRuPd-NPs. For five ppm HCMix, the response for NP-based gas sensors decreased—from 65% for the bare SnO_2, to 16%, 19% and 13% for Ag-, Pd-, and AgPd-NPs, respectively. To test sensor stability and repeatability, five pulses of CO were measured in sequence, followed by HCMix, then again five pulses of CO. The results are shown in Figure 1b: all sensors (bare SnO_2 and SnO_2+NPs) exhibited good repeatability. The response of two different sensing layers on a single μhp for AgRu (green) and PdRuAg (blue) also showed good repeatability.

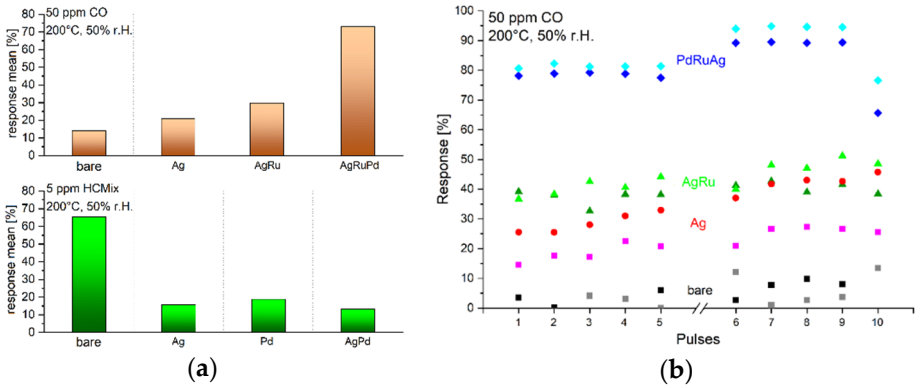

Figure 1. (**a**) Response of the bare SnO_2-sensor and the sensors functionalized with Ag, AgRu, and AgRuPd nanoparticles (NPs) towards 50 ppm of CO and 5 ppm of HCMix in 50% rH, 200 °C; (**b**) stability test of the response—bare SnO_2-sensor and SnO_2+NPs sensors towards 50 ppm of CO in 50% rH, 200 °C.

4. Conclusions

The NPs clearly enhances the response to the target gas CO; the bi- and trimetallic NP mixtures obviously synergize their effects [5]. The reduced response towards HCMix leads to improved selectivity of SnO_2+NPs based gas sensing devices. The next step is to functionalize the 8-μhps device with different NPs in order to adjust the sensitivities to other target gases and to realize a multi-gas sensor device on a single chip.

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Conflicts of Interest: The authors declare no conflict of interest.

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