

## CO<sub>2</sub> Sensor based on Au functionalised CuO thin films

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### Summary:

In this work, we present chemical nanosensors based on ultrathin CuO/Cu<sub>2</sub>O films, which are fabricated by thermal evaporation and subsequent oxidation on SiN-based micro-hotplate chips. The sensors are tested against target gas carbon dioxide (CO<sub>2</sub>). The CuO/Cu<sub>2</sub>O films are functionalized with Au nanoparticles (Au-NPs) stabilized with citrate. The Au-NPs clearly increase the sensor response in particular for CO<sub>2</sub> up to 310%.

**Keywords:** metal oxide, CuO, Cu<sub>2</sub>O, nanomaterials, nanoparticles, gas sensors

### Introduction

Detecting harmful or toxic gases such as Volatile Organic Compounds (VOCs), carbon dioxide (CO<sub>2</sub>), and carbon monoxide (CO) is increasingly important for monitoring air quality both indoors and outdoors, due to their detrimental effects on human health. Conductometric gas sensors are commonly used for this purpose; they work by measuring changes in the electrical conductance of a gas-sensitive material when exposed to different gases. Metal oxides like tin oxide (SnO<sub>2</sub>), zinc oxide (ZnO), and copper oxide (CuO) are widely used in these sensors because of their high sensitivity to a broad range of gases [1]. The performance of these sensors, particularly their selectivity, can be significantly enhanced through surface functionalization with metallic nanoparticles (such as gold, palladium, or platinum) [2, 3]. Recently, we have successfully used gold nanoparticle (Au-NP) solutions to functionalize Cu<sub>x</sub>O-based sensors, resulting in improved CO<sub>2</sub> detection performance [4]. In this study, we investigate the functionalization with Au-NPs of different diameters and how they influence the sensor performance towards CO<sub>2</sub>.

### Sensor Fabrication

The sensing material is composed of ultrathin CuO/Cu<sub>2</sub>O films, which are fabricated by thermal evaporation 50nm Cu and subsequent thermal oxidation. These are used on a silicon nitride (Si<sub>3</sub>N<sub>4</sub>) micro hotplate ( $\mu$ hp) chip with Pt electrodes and heaters. The structuring was done by e-beam lithography, resulting in a circularly shaped (450  $\mu$ m) sensor structure.

### Au-NP Functionalisation

The sensors were functionalised using the drop coating technique with gold nanoparticles (Au-NPs) stabilized in citrate of 20, and 40 nm in diameter. Thus, a drop of 0.2  $\mu$ L is placed on the sensitive layer and dried for 10 minutes. This process is repeated twice to ensure sufficient Au-NPs coverage of the sensitive layer. In Figure 1, the functionalised sensor is displayed.

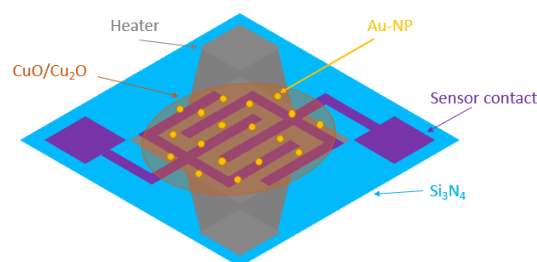


Fig. 1 Illustration of an Au-NP functionalised Cu<sub>x</sub>O film-based gas sensor [5]

### Sensor Characterization & Results

The sensor devices have been operated at 300°C and tested against CO<sub>2</sub>. Synthetic air with 50 % relative humidity level (r.h.) has been employed as a background gas. Cu<sub>x</sub>O sensors functionalised with Au-NPs of different diameter have been compared. Fig.2 shows the electrical resistance behavior of all sensors when exposed to 1000, and 2000 ppm CO<sub>2</sub>. The sensors are heated for 45 min before the measurement to ensure a stable resistance baseline.

Fig.3 compares the responses of the sensors towards 1000 ppm and 2000 ppm of CO<sub>2</sub>. While

pure  $\text{Cu}_x\text{O}$  has no response towards  $\text{CO}_2$  (not shown here), the response to  $\text{CO}_2$  is highly increased with Au-NPs.  $\text{Cu}_x\text{O}$  sensor functionalized with citrate stabilized Au-NPs exhibits the highest response (310 %) towards  $\text{CO}_2$ .

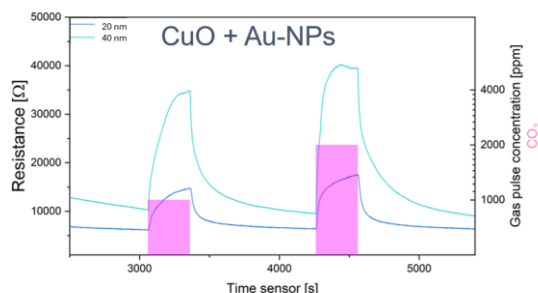


Fig. 2 Resistance measurement during exposure to 1000 / 2000 ppm  $\text{CO}_2$  at 300 °C operation temperature and 50% r.h for sensors functionalised with 20nm and 40nm sized Au-NPs.

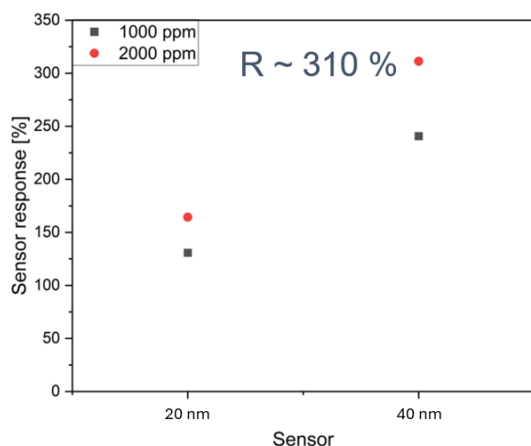


Fig. 3 Sensor response towards 1000 ppm and 2000 ppm  $\text{CO}_2$  at 300 °C operation temperature and 50% r.h for sensors functionalised with 20nm and 40nm sized Au-NPs.

### Conclusion & Outlook

We have shown that the Au-NPs clearly increase the response towards  $\text{CO}_2$ . For an Au-NP size of 40nm we have achieved the highest response up to 310% towards 2000ppm  $\text{CO}_2$ .

We are convinced that the presented pathway for improving the sensitivity towards  $\text{CO}_2$  is a very promising approach for realisation of the first conductometric  $\text{CO}_2$  sensor on the market.

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