Hydrogen Gas Sensor with Capacitor-Like Pt/TiO_2/Pt Arrangement and Nanoporous Top Electrode

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Abstract. The chemiresistive hydrogen gas sensors with capacitator-like arrangement proved to exhibit extremely high responses to hydrogen and at the same time to be more energy efficient compared to sensors with interdigital electrodes operating at elevated temperature. Due to the high intensity of electric field between the electrodes distanced only several tens of nanometres, the response (defined as change of resistance divided by final resistance) of the Pt/TiO_2/Pt capacitor-like hydrogen gas sensor [1] to 1% H_2 in dry air was as high as 10^7 even at room temperature. The response was influenced by the width of the top electrode, with the best results obtained for the narrowest ones ($\lesssim$ 200 nm). However, the baseline resistance of the sensor was more than 10^{12} Ω, which is hardly measurable. This limits the measurable response of the sensor to lower (<1000 ppm) H_2 concentrations, which often remain undetectable.
In this work, to counter this flaw, we propose a modification of the top electrode which decreases the baseline resistance of the device, while retains the advantages of the extremely narrow electrode. This is achieved by replacing the very narrow top electrode by a large-scale nanoporous top electrode formed by annealing a thin PtO_x layer.
The quality of the nanoporous top electrode was fine-tuned by adjusting the thickness of the PtO_x layer and annealing temperature, with subsequent AFM and conductivity measurements. Gas sensing and electrical transport measurements were conducted to verify the expected improvement.
The best results regarding the porosity of the top electrode were achieved for 36 nm thick PtO_x layer annealed at 660°C, where the maximum distance between the nearest pores was 200-300 nm. An increase in sensitivity has been observed compared to the sensors with a single narrow electrode. The sensor reliably detected 3 ppm H_2 at room temperature in dry air and even in humid air (relative humidity = 38%). At elevated operating temperature of 150°C, the response to 1% H_2 in dry air as high as $8{,}1\times10^7$ has been reached.

REFERENCES

[1] T. Plecenik, M. Moško, A.A. Haidry, et. al., Fast highly-sensitive room-temperature semiconductor gas sensor based on the nanoscale Pt-TiO2-Pt sandwich, Sensors and Actuators B: Chemical 207 (2015) 351-361.

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