Micro-patterning layers by flame spray aerosol deposition

A. Tricoli[1], M. Graf[2], F. Mayer[2], S. Kühne[3], A. Hierlemann[3] and S. E. Pratsinis[1]

[1]Particle Technology Laboratory, [3]Physical Electronics Laboratory,
ETH Zurich, CH-8092 Zurich, Switzerland
[2]Sensirion AG, CH-8712 Stäfa Zürich, Switzerland

Keywords: patterning, sintering, nanoparticles, sensors, solid-oxide fuel cells.

ABSTRACT

Here we present a CMOS-compatible, two-step method for deposition and *in-situ* mechanical stabilization of gas sensitive, metal-oxide microlayers on wafer-level. Lace-like highly porous, Pt-doped SnO_2 nanostructured layers are deposited at wafer-level on 69 microsensors. Second, these layers are converted in well-adhered, cauliflower-like structures (figure 1b, inset). The resulting sensor layer performance is characterized using the analytes CO and EtOH on microsensor devices.

1 INTRODUCTION

The development of low-cost, portable, metal-oxide gas sensors with high sensitivity, selectivity and material stability bears considerable scientific and commercial potential (Eranna *et. al.*, 2004). Highly sensitive nano-material synthesis by direct, aerosol-based methods offer unique advantages in comparison to wet-routes including crack-free, highly pure deposits, and the fact that only few process steps are required (Madler *et al.*, 2006). Sputtering, spray pyrolysis, cluster beam deposition, spray pulverization, combustion chemical vapor deposition (Liu *et al.*, 2005) and, recently, flame spray pyrolysis (FSP) have been applied to yield nanostructured sensing layers. The FSP freshly-deposited layers, in particular, consist of highly-porous (98%), loosely interconnected, soft nanostructures (Madler *et al.*, 2006). These, however, can be easily destroyed under mechanical stress and require stabilization. As we have shown lately it is possible to restructure the morphologies of these layer by in-situ annealing reaching higher mechanical stability (Tricoli et al., 2008).

2 RESULTS AND DISCUSSION

Figure 1 shows TEM images of powder samples that were collected on a filter placed downstream of the sensor deposition area from flames A (Fig. 1a, b) and D (Fig. 1c, d). Mostly polyhedral particles are made which are similar to previously FSP-made and vapor-fed, flame-made SnO_2 particles. The number of small particles (d_{TEM} < 10 nm) in the TEM images decreases with increasing FSP flame enthalpy density, in agreement with the decrease in average grain size (SSA) and crystal sizes.

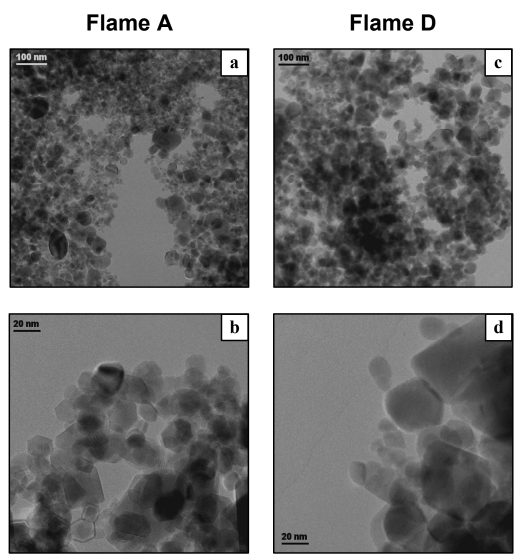

Figure 1: TEM images of SnO2 particles produced by FSP. The particle size increases with increasing flame enthalpy.

Figure 2 shows the resistance of a sensor with a nanostructured, transparent SnO_2 layer (d_{XRD} = 12 nm) at different ethanol concentrations by heating the substrate at 220 °C. The response of the sensor response was in the range of seconds and a stable resistance was reached promptly. The sensor response to ethanol was always large in comparison to previous studies.

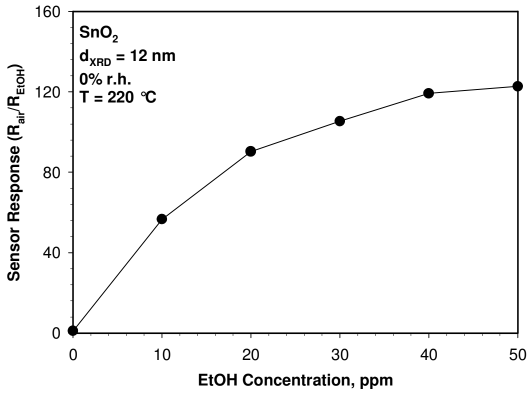

Figure 2: Sensor response to increasing ethanol concentrations.

3 CONCLUSIONS

Uniform, regular, macroporous Pt/SnO_2 layers have been patterned simultaneously on microsensors on wafer-level down to a diameter of 100 µm at 20 µm resolution. Gas microsensors showed a detection limit to CO of 1 ppm and fast response and recovery times. The layers had a large response also to EtOH ranging from 60 to 120 for concentrations varying from 10 to 50 ppm at 220 °C. Recent studies have reduced this to 100 ppb.

Financial support was provided from the Swiss Commission for Technology and Innovation KTI under grant 7745.1 and the ETH CCMX-NANCER program.

Eranna, G., Joshi, B.C., Runthala, D.P., & Gupta, R.P. (2004). *Crit. Rev. Solid State Mat. Sci.*, 29, 111-188.

Madler, L., Roessler, A., Pratsinis, S.E., Sahm, T., Gurlo, A., Barsan, N., & Weimar, U. (2006). *Sens. Actuators, B*, 114, 283-295.

Liu, Y., Koep, E., & Liu, M.L. (2005). *Chem. Mat.*, 17, 3997-4000.

Tricoli, A., Graf, M., Kühne, S., Mayer, F., Hierlemann, A., & S.E. Pratsinis (2008). Adv. Mater, In Press