Micro-patterning layers by flame spray aerosol deposition

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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 multilayers on wafer-level. Lace-like highly porous, Pt-doped SnO\textsubscript{2} nanostructured layers are deposited at wafer-level on 69 microsensors. Second, these layers are converted into well-adhered, cauliflower-like structures (figure 1b, inset). The resulting sensor layer performance is characterized using the analytes CO and EtOH on microsensor devices.

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 nanomaterial 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).

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\textsubscript{2} particles. The number of small particles (d\textsubscript{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 2 shows the resistance of a sensor with a nanostructured, transparent SnO\textsubscript{2} layer (d\textsubscript{XRD} = 12 nm) at different ethanol concentrations by heating the substrate at 220 °C. The response of the sensor 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.


