Route to selectivity: FSP multi-layered MOX films

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The lack of selectivity is the most severe limitation of metal oxide gas sensors. Interfering gases – even in only in trace amounts – and variations in the background level of humidity can significantly affect the sensor signal, causing an uncertainty in interpreting sensor data. Our approaches to increased selectivity are: fine-tuning of the sensing materials – varying the morphology of the metal oxide, dopants, geometry of the contacts, operating temperature and the use of filters. In the latter, gas molecules are passed through a MOX filter which alters the composition of the gas mixture and thus cross-selectivity can be reduced considerably.

We have recently demonstrated a fast and highly reproducible method to directly deposit nanoparticles as highly porous and homogenous films on substrates by thermophoretic deposition from the aerosol phase. The method consists of the nanoparticle synthesis and functionalization (e.g. noble metal doping) by the Flame Spray Pyrolysis (FSP) process, where metal-organic precursors are delivered in the form of droplets and subsequently react in a flame to form a nanoparticle aerosol.

The nanoparticles are directly deposited in-situ on sensor substrates by thermophoretic deposition. The particles are not handled or post-processed before forming the final layer. The complete absence of a nanoparticle suspension makes this process a truly dry and fast (no drying step needed) technology. Furthermore, the method does not require an annealing step after the film has been formed. This leads to highly uniform porous layers of desired nanoparticle composition and height. It also enables the manufacturing of porous multilayer structures, by that offering the possibility of filter integration.

Results will be presented for single and multilayer structures based on n-type materials such as SnO_2, ITO and WO_3. All materials are ultrafine single crystalline with sizes of about 10 nm. These materials can be in-situ functionalized in the FSP process by doping with foreign atoms as in our case of Sb/SnO_2 and/or noble metals for increased sensitivity and selectivity (e.g. SnO_2 with Pd, Pt and Au in various amounts). The presentation will also comprise p-type materials synthesized by FSP on the examples of CuO, Co_3O_4 and MgO.

In summary we demonstrated the potential of flame made doped and undoped n- and p-type metal oxide nanoparticles for gas sensing applications. Using the current knowledge in gas phase mixing of aerosol nanoparticles and their in-situ deposition, the synthesis of complex multi-component layers with high surface area and porosity is possible.