DOI 10.5162/EUROSENSORSXXXVI/PT5.242

Combustion-Aerosol made Chemoresistive Gas Sensors and Devices

Andreas Güntner
Human-centered Sensing Laboratory, ETH Zürich, Sonneggstr 3, 8092 Zürich, Switzerland.

Corresponding Author's e-mail address: andregue@ethz.ch

Summary:
Advances in combustion-aerosol gas sensors enable today mobile health monitoring, on-site food safety assessment and air quality tracking to immediately alert people of potential hazards. This presentation will discuss examples of sensors made by combustion aerosol technology highlighting their distinct advantages over traditional wet chemistry processing. These advantages are traced to combustion's steep temperature gradients and high particle concentrations during sensing particle formation and film deposition. Finally, sensor systems (arrays and filters) and their integration into devices with validation under realistic conditions is presented.

Keywords: Chemoresistive sensor, Gas sensor, Nanotechnology, Porous films, Inorganic materials

Flame-made gas sensors enable today hand-held devices [1] for mobile health monitoring, on-site food safety assessment and air quality tracking to immediately alert people of potential hazards. Therein, combustion aerosol technology has distinct advantages for the assembly of chemoresistive gas sensors compared to their traditional wet chemistry synthesis. These advantages are traced to combustion's steep temperature gradients and high particle concentrations during sensing particle formation. This gives direct access to a plethora of material compositions (e.g. metastable phases, solid solutions, mixed oxides) and fractal-like porous but rigid structures that can lead to unique sensor selectivity, sensitivity and stability along with short response and recovery times [2].

The characteristics of sensing films and their operation determine the performance of gas sensors. Figure 1 summarizes the assembly of flame-made gas sensors. Conventionally they are put together using flame-made metal-oxide particles collected on filters. Then, such particles are suspended in fluids to form slurries or pastes that are screen-printed, doctor-bladed, drop- or spin-coated onto sensor substrates followed by drying and stabilization annealing to form the sensing films. Alternatively, such films are assembled by flame-aerosol deposition onto sensor substrates bypassing all wet-chemistry steps. These films are grown by combustion of appropriate precursors and deposition of either molecular clusters (i.e., Combustion Chemical Vapor Deposition) or particles. During such deposition, the electric resistance of the sensing film can be measured online to optimally determine its thickness and interconnectivity [3].

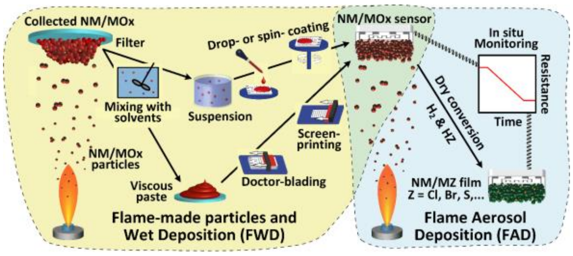

Fig. 1. Gas sensing films by flame-made noble metal / metal oxide particles and their wet chemistry deposition or flame aerosol deposition to sensing substrates with optional resistance monitoring and even in situ reduction (e.g. with H_2) - conversion to non-oxide films. Adapted from [1].

An inherent limitation of flame-made gas sensors is their limitation to metal-oxides due to the oxidizing flame environment. Here, I will discuss how such metal-oxide films can be converted to metal bromides, sulfides or nitrides by post-deposition exposure to reactive gas atmospheres, while preserving the porous architecture of flame-aerosol deposited films (Figure 2). This opens new avenues for unique sensing performance, even at room temperature [4].

In this presentation, recent advances on the design of gas sensors based on metal-bromide (e.g., CuBr) and -nitrides will be presented that enable the quantification of air pollutants like NO_2 and NH_3 down to few part-per-billion concentrations at high relative humidity. We will elaborate on film morphology and material composition effects and discuss structure-function relationships.

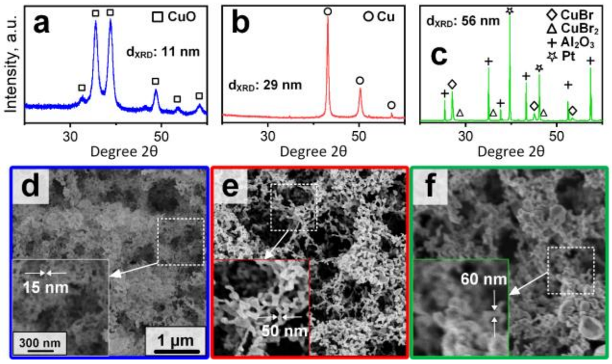

Fig. 2. *XRD patterns of powders (a-b) and when deposited as film (c) by flame spray pyrolysis as-prepared (a), after the dry reduction (b) and bromination (c) together with top-view SEM images of the corresponding films (d-f). Note that a and b were obtained from the powders as the XRD signals of the actual films were too weak. Reference peak positions for monoclinic CuO (squares), cubic Cu (circles), cubic CuBr (diamonds), monoclinic $CuBr_2$ (triangles), cubic Pt (stars) and rhombohedral Al_2O_3 (crosses) are indicated together with crystal sizes of CuO (a), Cu (b) and CuBr (c), as calculated by Rietveld refinement from the XRD patterns. Note that the Pt and Al_2O_3 in c are associated to the substrate. Adapted from [2].*

References

[1] Güntner, A.T., D'Andria M., van den Broek, J. (2023) *Nature Rev. Bioeng.* 1, 385-387; doi: 10.1038/s44222-023-00068-y

[2] Güntner, A.T., Pineau, N.J., Pratsinis, S.E. (2022) *Prog. Energy Combust. Sci.* 90, 100992; doi: 10.1016/j.pecs.2022.100992

[3] Blattmann, C.O., Güntner, A.T., Pratsinis, S.E. (2017) *ACS Appl. Mater. Interfaces* 9, 23926−23933; doi: 10.1021/acsami.7b04530

[4] Güntner, A.T., Pineau, N., Pratsinis, S.E. (2020) *Adv. Sci.* **7**, 1903390; doi: 10.1002/advs.201903390