Highly selective formaldehyde (FA) detection with flame-made gas sensors for indoor air quality monitoring

A. T. Güntner, S. Abegg, K. Wegner, S. E. Pratsinis

Particle Technology Laboratory, Institute of Process Engineering, Department of Mechanical and Process Engineering, ETH Zürich

CH-8092 Zurich, Switzerland. www.ptl.ethz.ch andreas.guentner@ptl.mavt.ethz.ch

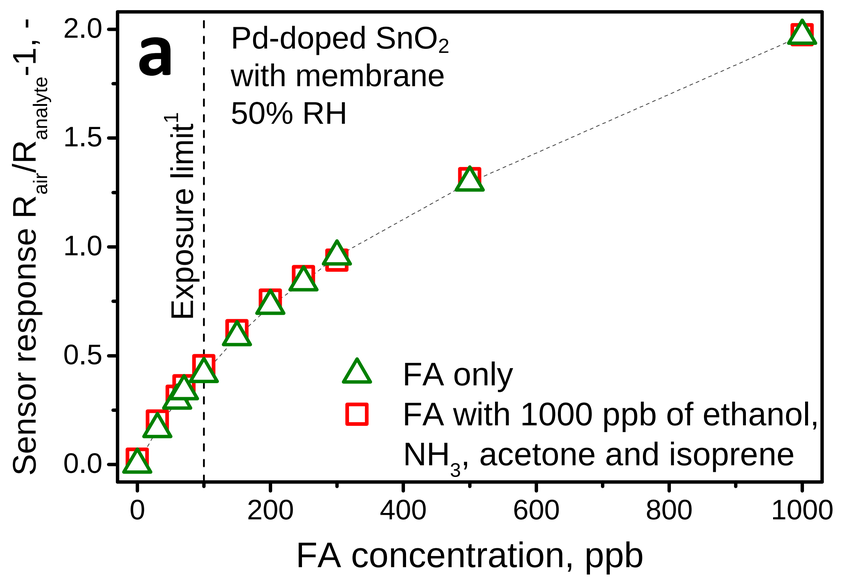
Air quality monitoring

Monitoring gaseous compounds in aerosols is of high interest. Formaldehyde (FA), for instance, is a *carcinogenic* indoor air pollutant released from wood-based furniture, laser-printers or paints,[1] and one of the proposed lung cancer markers in exhaled breath.[2] The recommended indoor air exposure limit should not exceed 100 ppb,[1] but suitable devices to monitor FA emission are missing.

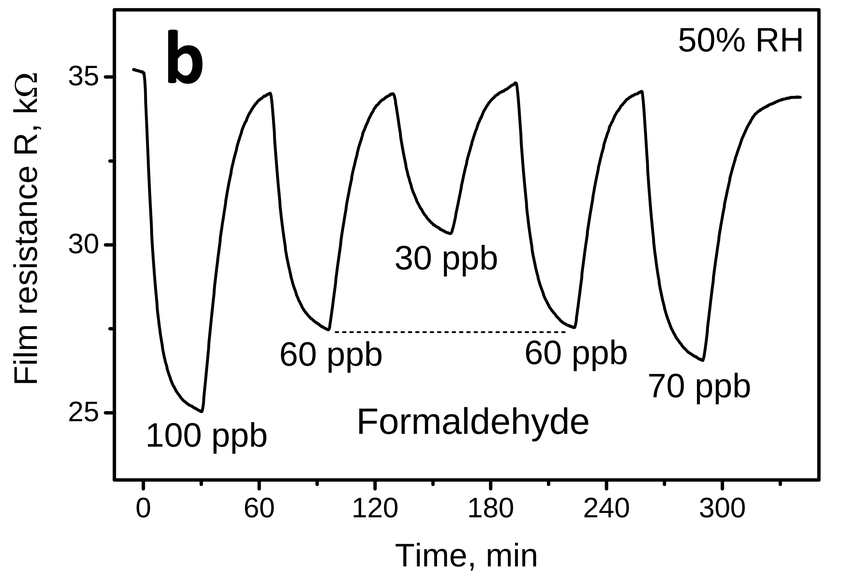
Chemo-resistive metal-oxide sensors made by flame spray pyrolysis (FSP) are quite attractive as they can detect sufficiently low FA levels, offer fast response and recovery times and can be produced cost-effectively.[3] Also, they feature small size and low power needed for integration into autarkic FA monitors. However, they lack selectivity.

Here, a modular sensor system is developed that overcomes this limitation by placing a highly selective membrane ahead of the sensor, enabling ultra-low FA detection in simulated gas mixtures.[4]

Outstanding performance in gas mixture

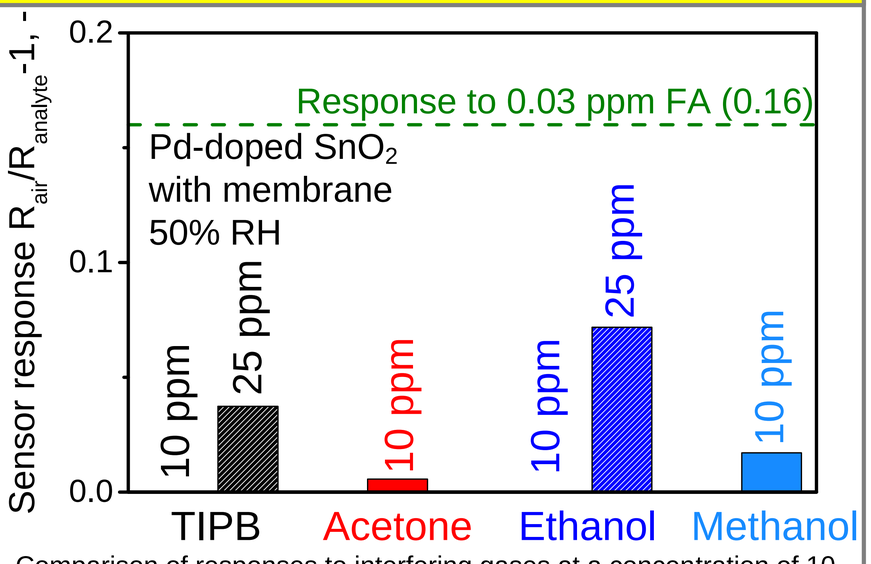


FA calibration curve at 50% RH. The membrane/sensor assembly can accurately detect FA down to 30 ppb even in a gas mixture containing NH_3, acetone, isoprene and ethanol each at 1000 ppb.



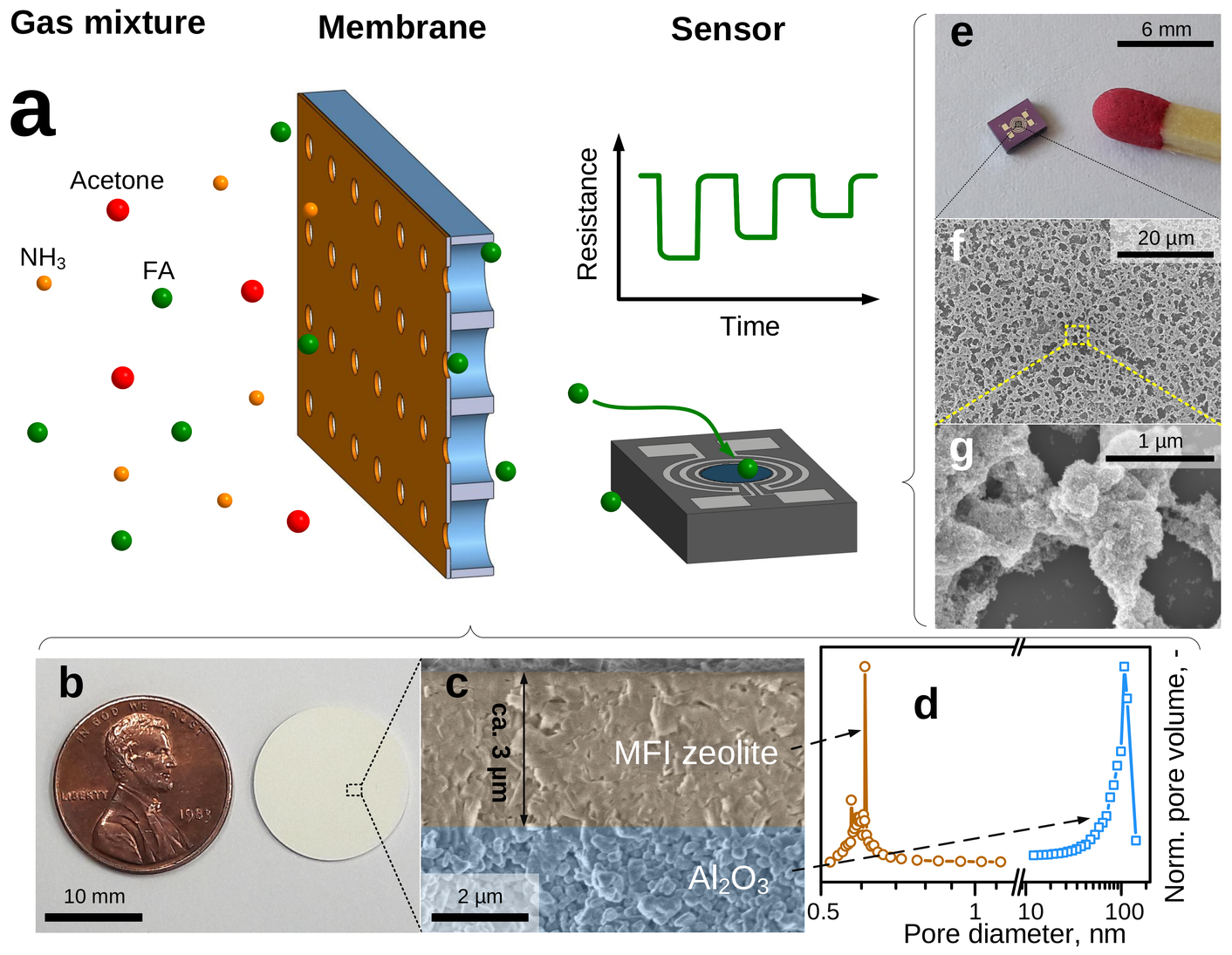
Sensor film resistance upon exposure to 100, 70, 60 and 30 ppb of FA at 50% RH. These ultra-low analyte concentrations below the recommended exposure limit[1] are detected reproducibly with high signal-to-noise ratio (> 70).

Interference at higher concentrations



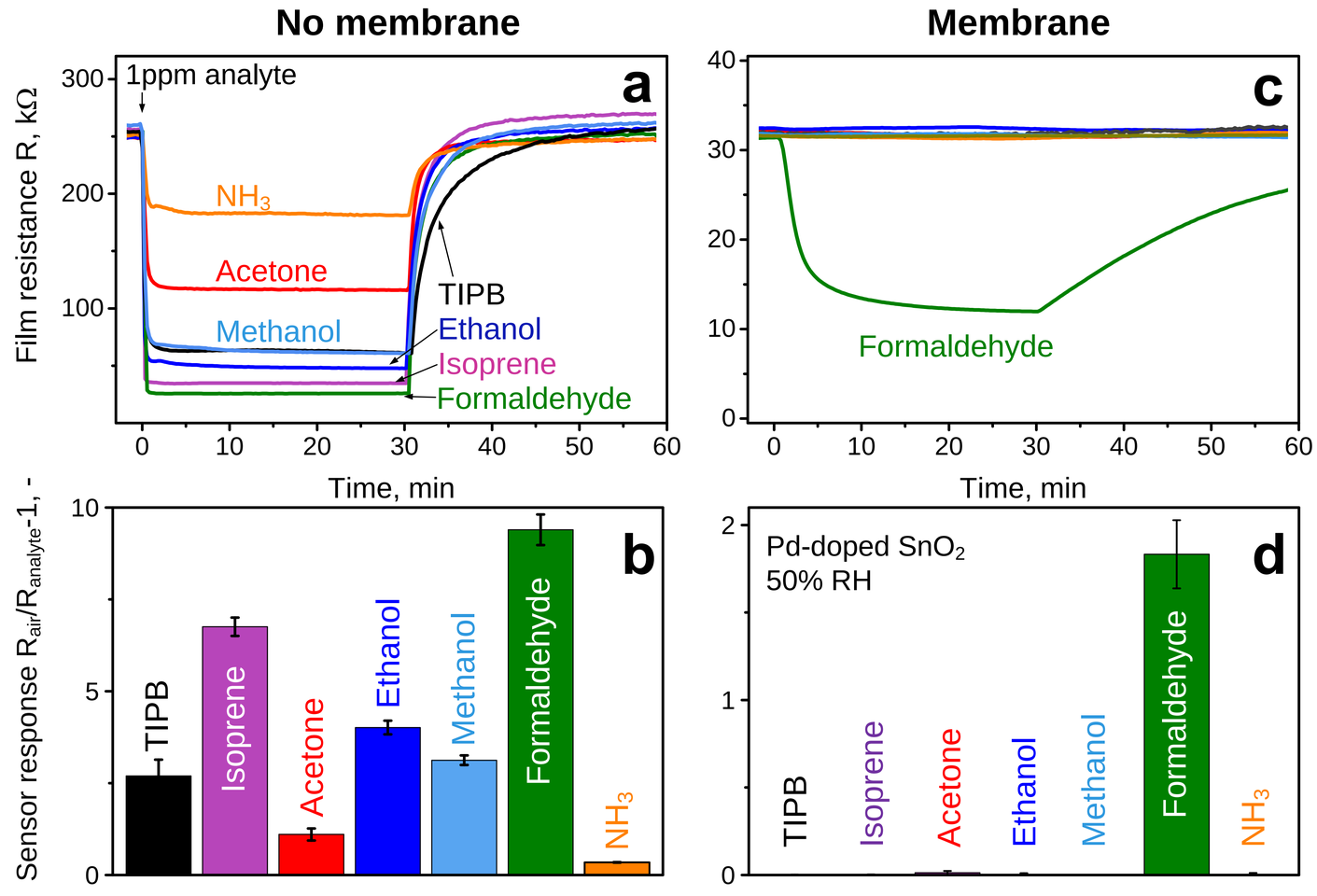
Comparison of responses to interfering gases at a concentration of 10 and 25 ppm and the response to 30 ppb FA. This outstanding selectivity enables FA detection even at much higher interfering concentrations.

Membrane-sensor concept for highly selective FA detection



A microporous MFI zeolite membrane pre-separate the gas mixture by molecular sieving and chemical separation, ideally allowing only FA to permeate. This enables highly selective FA detection with a chemoresistive sensor consisting of flame-made Pd-doped SnO_2 (1 mol%) nanoparticles that aggregate to a fine and extremly porous network.

FA selectivity enhancement by microporous membrane



Real-time resistance and evaluated sensor responses without (a,b) and with the microporous membrane (c,d) tested at 50% RH. Without membrane, the sensor reacts to all tested analytes and cannot selectively detect the target analyte. With the membrane, only FA is detected, enabling selective FA monitoring by this membrane/sensor assembly.

Conclusions

- Unprecedented FA selectivity enabled by combination of MFI/Al_2O_3 membrane with a Pd:SnO_2 sensor
- Sufficiently low FA levels are selectively detected down to 30 ppb in simulated mixtures enabling FA level monitoring
- Easy integration into portable detectors due to small and modular design
- Paradigm change in gas sensor devlopment?

References

1. Salthammer, T., Mentese, S. and Marutzky, R. (2010) Chem Rev, 110 (4), 2536-2572.
2. Hakim, M., Broza, Y. Y., Barash, O., Peled, N., Phillips, M., Amann, A., & Haick, H. (2012) Chem Rev, 112 (11), 5949-5966.
3. Güntner, A. T., Koren, V., Chikkadi, K., Righettoni, M. and Pratsinis, S. E. (2016) ACS Sens, 1 (5), 528-535.
4. **Güntner, A. T., Abegg, S., Wegner, K. and Pratsinis, S. E. (2018) Sens Actuator B-Chem, 257, 916-923.**