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Comparison of gas sensor technologies for fire gas detection

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Abstract

We selected a variety of low-power gas sensors in order to compare their performance with respect to fire detection applications. Gas sensitive field effect transistor (GasFET)-arrays, metal oxide sensors (MOS) and electrochemical cells (EC) were measured in test fire scenarios. Beside the investigation of the performance of the sensor elements itself, we additionally focused on the propagation behavior of different gas components in time and space. For that case we mounted the gas sensors on PCBs which were setup into a vertical "multi-sensor" chain. Comparing the response times at the ceiling, the MOS were the fastest sensors. However they are prone to false alarms due to cross sensitivities to solvent vapors. The response of the GasFET-array was slower but shows advantages with respect to low power consumption and pattern recognition capabilities. The EC carbon monoxide sensor has a good selectivity but a high price comparing to semiconductors. This paper demonstrates the usability of gas sensor technologies for fire detection to enhance the performance of conventional smoke detectors.

Keywords: fire gas detection; gas propagation; gas sensors; GasFET; metal oxide sensors; electrochemical cells; low-power

1. Introduction

For a long time, gas sensors were used for the detection of dangerous gases. They help to alarm people when toxic or explosive gases are present in their environment. In the field of fire detection we believe that gas sensors will be playing a more important role. The latest commercial smoke detectors in buildings have an increased sensitivity by adding electrochemical cells (EC) delivering carbon monoxide gas information beside the well known measurement of infrared light scattering by smoke aerosols [1]. However better lifetime, better pricing compared to ECs and the ability to sense more target gases to

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discriminate events like open fires, smoldering fires and nuisances are needed for wider security applications. Hence the focus on temperature cycled metal oxide sensors (MOS) [2] with pattern recognition algorithms [3] and gas sensitive field effect transistors (GasFET) [4] may lead to cost-effective, reliable and robust solutions for fire detection in buildings.

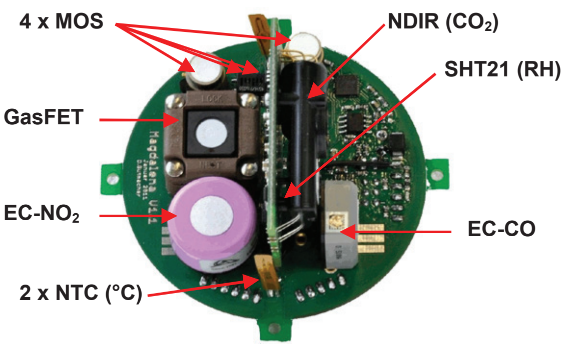
The low-power GasFET is based on a suspended gate FET technology with platinum and copper-phthalocyanine as sensing layers and measures the change of work function at the sensing layer surface. The MOS are based on a resistivity change of a SnO_2 or WO_3-film respectively, using catalytic materials to enhance the detection of reducing and/or oxidizing gas species at operation temperatures between 220-360°C. Due to the low thermal mass of the specific micromachined MOS, the heating period could be reduced to 100 milliseconds for low power operation (< 2.5 mW, with 1s measurement period). The EC sensors are based on three electrode amperometric measurement of gases. Two types of EC sensors with different electrolytes and electrode materials were used to detect CO (sensitivity: ~75nA/ppm) and NO_2 (sensitivity: ~600nA/ppm). They allow the measurement of absolute concentrations, high selectivity and ideal low-power conditions, but suffer from a short lifetime (2-5 years) and a high price (> 10 €).

Fires in buildings produce hundreds to thousands of different gas components which until today are not all known. The main target gases for fire detection are CO, H_2, NO and NO_2 for most fire types. A discrimination of open fires (NO_2 gases) and smoldering fires (CO, H_2 gases) and nuisance (alcohol, water vapor or solvent vapors) should be possible in order to take the right action for extinguishing.

Many simulations and experiments have been performed in the past to better understand the smoke propagation of fires in buildings to calculate optimal alarming and evacuation times [7]. Due to the latest application of gas sensors for fire detection, the same knowledge is crucial for fire gas dynamics in buildings. Therefore more investigations are needed to better understand the fire gas propagation behavior [5][8]. If gases reach the ceiling in higher concentration or faster compared to smoke more human lives could be saved by giving an earlier fire alarm. The following experimental results are focused on the usability of the sensor technologies itself for reliable fire detection as well on fire gas propagation.

2. Experimental setup

In order to compare MOS, GasFET and EC gas sensors, a small sized PCB (Ø 80 mm) was developed to place the sensors close to each other (Fig. 1a). For gas propagation analysis several PCBs formed a "multi-sensor chain" and were deployed in the fire laboratory (volume: 3x3x3 m^3) depicted in Figure 1b.



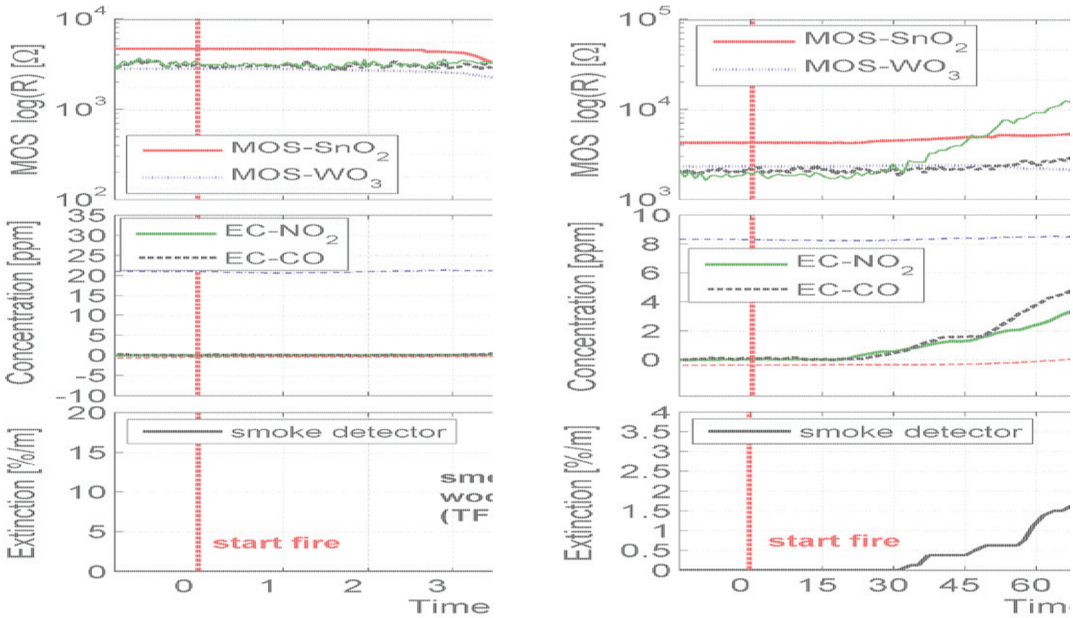
(a)

(b)

Fig. 1. (a) Gas sensor board for digital readout; (b) Sensor boards installed vertically in 30 cm distances in a 3x3x3 m^3 fire test room

3. Experimental results at the ceiling

The following graphs demonstrate a comparison of sensor responses for the sensor board closest to the ceiling of the fire test room. Figure 2a depicts a smoldering wood fire (TF2) which produces mainly CO and H_2 gas. The MOS sensors are the fastest sensors and show a resistance decrease nearly one minute before the smoke can be detected by an optical smoke detector. The platinum PT-GasFET is sensitive to H_2 and shows a quick response in a smaller scale resolution, but the main visible response is slower and starts 3 minutes after the MOS sensors. The EC-NO_2 and the PH-GasFET revealed an unwanted cross sensitivity to other gaseous compounds leading to a “negative” NO_2 concentration which was presumably due to formaldehyde and pyroligneous acids. An open polyurethane foam fire (TF4) is depicted in Figure 2b. It produces a lot of NO_2 gas and black smoke which is hard to detect for optical smoke detectors. The PH-GasFET shows a fast response. While the MOS sensors, that should have a faster response to NO_2 gas, suffer from the balance of CO and NO_2 gases, which results in no resistance change due to the competitive surface reactions on the MOS sensor for at least one minute.



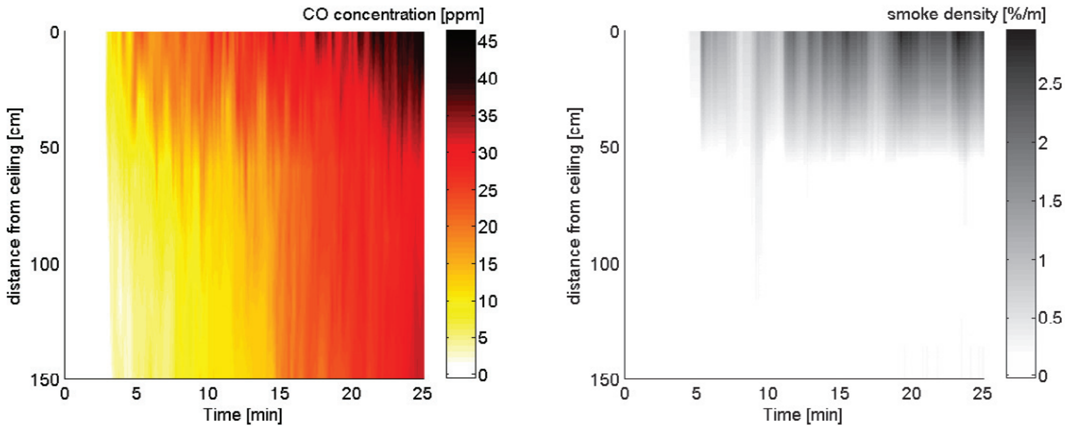
(a) (b)

Fig. 2. (a) Comparison of gas sensor technologies for a smoldering beech wood fire; (b) Open polyurethane foam fire

4. Evolution over time and space

In order to investigate the gas propagation behavior in time and space, the data from the “multi-sensor chain” (Fig. 1b), was interpolated between the sensor boards. As a first result a mesh plot was generated showing the evolution of CO concentration (Fig. 3a) and smoke density (Fig. 3b) depending on the distance to the ceiling (Y-axis) and the time (X-axis). The shown fire is a smoldering cotton fire (10 cotton wicks). This specific fire produces little smoke compared to the relatively higher distributed CO concentration. As can be seen the fire room is slowly filled from the top with CO gas.

Comparing CO gas concentration and smoke density, it is obvious that gas sensors could enhance fire detectors to allow earlier fire alarming and evacuation. In this specific case the convective flow is not high enough to distribute the aerosols from the ceiling downwards in a density that can be seen by an optical smoke detector. We could even think of integrating gas detectors into walls.



(a) (b)

Fig. 3. (a) Evolution of CO gas during glowing smoldering cotton fire (10 wicks); (b) Evolution of smoke compared to Figure 3a

5. Conclusion

This work demonstrated that MOS and GasFET are well suited to be used in conventional fire detectors. Depending on the type of fire a distinction between open fires and smoldering fires is possible. Further research on suppressing cross sensitivities like water vapor has to be taken into account for reliable fire detection to avoid false alarms. The gas propagation measurement showed that gas sensors have advantages compared to optical smoke detectors due to a faster gas distribution depending on the type of fire. Gas sensors could enhance the performance of optical smoke detectors and save human life.

References

[1] A. Duric, H. Ebner, M. Forster, I. Vinage: “Development of a multi-sensor detector for fire detection and life safety applications”, *14th International Conference on Automatic Fire Detection AUBE09*, Duisburg Germany 2009.
[2] Z. Ankara, A. Schütze: “Low power virtual sensor system based on a micromachined gas sensor for security applications and warning systems”, *EUROSENSORS 2008*, Dresden Germany, Proceedings, p. 495-498.
[3] U. Hoefer, D. Gutmacher: “Event Classification Using Single Metal-oxide Sensor Elements”, *14th International Conference on Automatic Fire Detection AUBE09*, Duisburg Germany 2009.
[4] R. Pohle, E. Simon, R. Schneider, M. Fleischer, R. Sollacher, H. Gao, K. Müller, P. Jauch, M. Loepfe, H.-P. Frerichs, C. Wilbertz: “Fire detection with low power fet gas sensors”, *Sensors and Actuators B*, (2007) 669-672.
[5] O. Linden, U. Braun, C. Kubon, H. Hölemann: “Experimentelle Untersuchungen zu den Einsatz- und Einbaubedingungen von Brandmeldern mit Gassensoren“. *Technischer Bericht, Bergische Universtität – Gesamthochschule Wuppertal*, 2001.
[6] J. -T. Meyer, A. Georgiadis, J. Specht, M. Witthaus, K. C. Persaud, A. M. Pisanelli, E. Scorsone: “Detection of significant tracer gases by means of polymer gas sensors“, *13th International Conference AUBE04*, Duisburg Germany 2004.
[7] Fire Dynamic Simulator and Smoke View (FDS-SMV), *National Institute of Standards and Technology (NIST).*
[8] C. Kubon : “Untersuchungen mit Gassensoren für den Einsatz in der Brandmeldetechnik“, Dissertation, Wuppertaler Berichte zum Brand- und Explosionsschutz Band 5, *VdS Schadensverhütung*, 2003.