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Requirements to Gas Sensors in Fire Alarms for Residential Use

1. Introduction

There are fire alarms for two basically different areas of application: The fire alarms for professional application and the fire alarms for residential use. The fire alarms for the professional application are usually operated by a central unit, which analyses and passes the alarms on. Fire alarms for residential use however are single devices for the application in households, which are operated without central unit. Alerting is effected by integrated acoustic and/or optical components.

Fire alarms, which are offered for the two areas of application specified above, differ strongly in their technical level of development. Within the professional area, the frequency of false alarms could be clearly reduced by the introduction of multiple sensor alarm units e.g. the combination of light scattering and thermal sensors. The use of gas sensors as an additional component in multiple sensor alarm units has been discussed very intensively for several years. This invention will further reduce the rate of false alarms. For this there are very promising beginnings, which are already transferred partly into products which are ready for the market.

In contrast to this the technical development of fire alarms for residential use is far back. The majority of the world-wide used alarm units are of the ionization type, a smaller proportion are light scattering smoke detectors. The multiple sensor technology is not represented in fire alarms for residential use so far.

There is a strong motivation for reducing the frequency of false alarms and thus for using multiple sensor alarm units for residential use. It is well-known that unfounded alarming can reduce the acceptance for fire alarms and so the owner often deactivates the alarm unit. To that extent there are serious reasons to increase the reliability of fire alarms for residential use by the application of the multiple sensor technology in particular also by using gas sensors.

This article considers the requirements for gas sensors, which arise form their use in private homes.

2. Environmental conditions

When talking about environmental conditions temperature and humidity have to be mentioned first. In private homes 0°C to +50°C as well as 10% to 90% RH seem to be sufficient. However if garages are added for example, this values have to be extended at least to -25°C to +70°C, which is also typical for industrial applications, as well as 10% to 95% RH.

Besides environmental conditions in operation, also terms of transport are to be considered. The gas sensor may not be destroyed or damaged during the transport, e.g. from the manufacturer to the dealer or from the dealer to the users home. Extreme conditions may occur: The alarm unit can be situated in a car for several days. During a day in stout sun 100°C can be achieved or -40°C in cold winter nights. These conditions have to be taken into account, when defining packaging of the detector.

Since a fire alarm unit is a safety-relevant device, it has to get over all these scenarios without damage or it has to announce its malfunction. The status signal of malfunction however is only the second best solution.

3. Sensitivity, Selectivity, disturbance variables, deceptive alarms

For a gas sensor for this application it is important that it is sensitive to one or more combustion gases. At the same time however it has to be insensitive on possible disturbance variables. The gases CO, CO_2, NO/NO_2 and H_2 seem to be suitable for fire recognition. The following table 1 shows some concentrations of combustion gases which were determined within fire tests according to EN54.

For the application in dwellings the test fires TF1 to TF4 are relevant primarily. A pure plastic fire (TF4) is rather improbable. Textiles (TF3) and wood (TF1/2) will always be involved. As a result it can be counted on a significant high CO-concentration in fire situation. CO_2 and NO/NO_2 occur in higher concentration at open liquid fires than at cellulose fires.

	CO [4]	CO [3]	CO [5]	CO_2[5]	CO_2[3]	NO_2[3]
TF1	230		90	1800		
TF2	50	80	100	880	350	0,15
TF3	300	100	90	1560	600	0,03
TF4	15	19			1500	0,75
TF5	15	27			2100	0,9
TF6	5	25			2000	1,7

Table 1: Measured values of gas concentrations for different fires in ppm [1]

Concerning the measured combustion gases, electrochemical cells, semiconductor gas sensors, NDIR/DIR sensors, optodes and pellistors are suitable for fire detection. Semiconductor gas sensors however have problems with reproducible measuring of small concentrations of CO, as they occur at TF4, TF5 and TF6. Due to their poor sensitivity pellistors are only suitable for certain fire scenarios with high CO production (cellulose fires).

NDIR/DIR sensors provide the best selectivity due to the physical measurement principle of infrared absorption. Optodes and electrochemical cells also provide a very good selectivity on combustion gases. For electrochemical CO cells in particular the highest cross-sensitivities are observed on NO/NO_2 and H_2. These however are also combustion gases and thus they are no real disturbance variables.

Semiconductor gas sensors and pellistors show a very large sensitivity to all inflammable gases and vapours. This can lead to substantial disturbance variables by solvents, lacquer vapour, alcohol vapour, cleaning agents and so on and thus cause false alarms.

At present piezo-electric gas sensors (quartz micro balance) are not suitable for fire detection due to their sensitivity and spectrum of the measurable substances.

Capacitive and resistive gas sensors only got importance in measuring humidity. So far suitable gas sensitive coatings for fire detection are missing, for both types (piezo-electric gas sensors and capacitive /resistive gas sensors).

When using CO concentration as an indication for a fire situation, all other sources of CO potentially cause false alarms. The CO levels, which have to be detected for fire alarm, are in many cases significantly lower than the Threshold Limit Value (TLV) (table 1). Figure 1 shows the CO signal when ten persons smoking in a room of 197 m^3. The CO level is about the same as it can be expected at open liquid fires (TF5/6). Only the combination with an optical smoke detector avoids a false alarm. Other possible sources for CO are e.g. exhaust gases of vehicles and feature fireplaces.

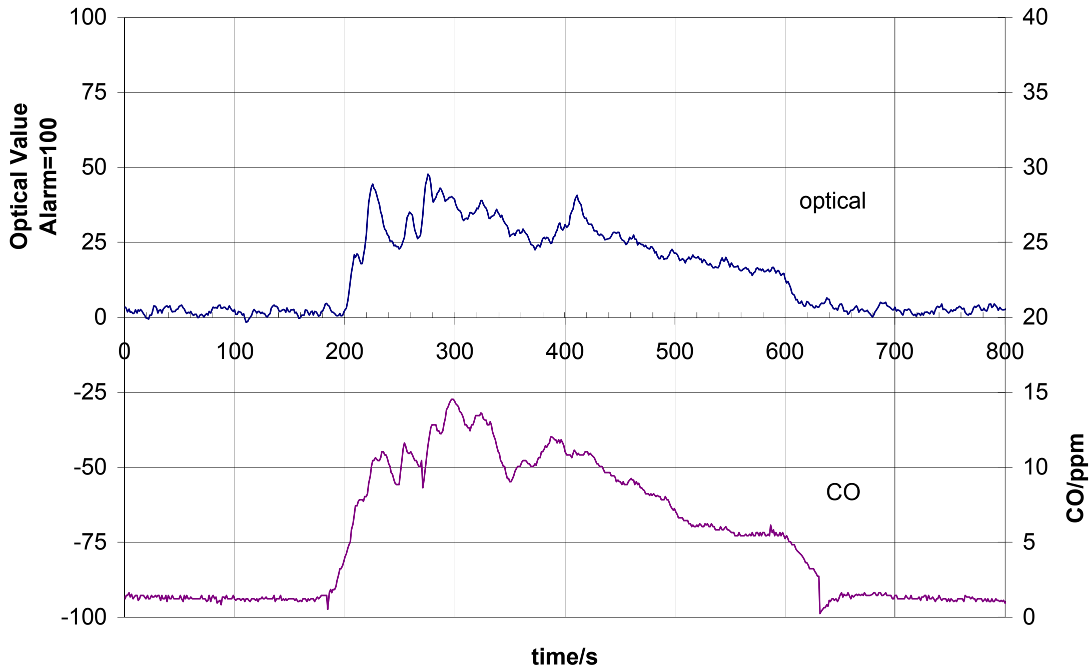

Figure 1: Optical and CO signal when ten persons smoking in a room of 197 m^3.

On the other hand the CO-Signal prevents false alarms from dust, steam, fog and other optical disturbance variables. So an additional gas sensor and in particular a CO sensor considerably improves false alarm behaviour of an optical smoke detector. But a CO sensor on its own would be a poor fire detector.

4. Power consumption

A further important point is the power consumption of the gas sensor in operation. Since fire alarms for residential use are battery powered usually, a very small power consumption is admissible regarding an acceptable lifetime of the battery.

For this reason all gas sensors, which are operated at high temperatures (semiconductor gas sensors, pellistors) and therefore use an integrated heating have to be regard critically. Meanwhile there exist some approaches to reduce power consumption by micromechanical structure and pulsed operation to make battery operation possible [8].

Particularly electrochemical cells and optodes with a power consumption of some µW are best suited for battery-operated devices.

5. Operational reliability, Maintenance

Since in the private area no regular maintenance schedule can be supposed, the lifetime of the sensor must be at least as long as the battery life. This also implicates that fire alarms for residential use are not periodically checked in a way that the sensor is actually exposed to test gas. Here the operability of the alarm unit has to be guaranteed with other measures. This can e.g. be ensured by a self test feature of the gas sensor.

Thus there are two types of self test e.g. for electrochemical cells: Measurement of cell impedance represents a very good indication for the operability of the sensor. In gas measuring equipment for industrial application this is usually regarded sufficient. More sophisticated cells provide the capability to produce hydrogen by electrolysis. This hydrogen causes a real gas signal in the cell. Thus it is guaranteed that the cell actually reacts to gas. This self test can be executed regularly and automatically (e.g. once a day). However it is not suitable for calibrating the cell.

Effects of poisoning by substances from the environment (e.g. silicone) are well-known for semiconductor gas sensors and pellistors. These may cause insensitivity of the sensor. The only chance, to recognise such a poisoning is to test the sensor with real gas. However such a test does not seem to be practicable for fire alarms in private homes.

6. Conclusion

From technical view only an optical smoke detector in combination with an electrochemical cell, with a NDIR/DIR-sensor or with optodes seem to be suited for fire detectors for residential use. The advantage of the NDIR/DIR sensors concerning their high selectivity must be paid by an accordingly high expenditure for the structure, which will not be interspersable however for fire alarms in private homes. Electrochemical cells are high sophisticated and reliable. Optodes on the other hand offer the advantage that several gases (e.g. three) can be measured with one component, which is also clearly smaller than usual electrochemical cells.

7. References

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Sensor Type	Gases	Sensitivity range	Temperature range	Selectivity	Power consumption	Life cycle	Currently used in security systems
Electrochemical Cell	CO, NO_x, NH_3, Cl_2, H_2S, SO_2, HCl, ..	0-300 ppm, 0-200 ppm	"-20 to +50°C"	+	< 10 µW	1-7a	☑
Semiconductor Gas Sensor, Metal Oxide	CO, NO_x, Cl, NH_3, H_2S, ..	0-100 ppm, 0-1000 ppm	"-20 to 80°C"	−−	35 mW to 10 W	1-5a	Residential use only
Capacitive and resistive Sensors (Polymer layer)	H_2O, SO_2 [7]	10 to 95% RH, 10-500 ppm SO2	u.d.	−	100µW to 100 mW	u.d.	Humidity
NDIR, DIR	CO_2, CO, NH_3, N_2O,	1,7 ppm, <1 ppm	"-20 to 80°C"	++	100µW to 100 mW	5-10a	☑
Optodes [6]	NH_3, NO, (CO_2, H_2O)	< 1 ppm	u.d.	+	< 10 µW	u.d.	
piezo-elecric gas sensors (SAW, BAW) [4]	organic substances	0-10 %	u.d.	−	10 to 1000 mW	u.d.	
Thermokathalytic Sensors (Pellistor)	CO, combustible gases	0-2000 ppm Iso-butane, 0-5% CO	"-20 to 80°C"	−−	~500 mW	1-5a	☑

Table 2: Survey Gas Sensors (u.d.: under development)