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Evaluation of commercial metal oxide gas sensors for indoor aeration control

J. Zosel[1], M. Mertig[1], D. Deininger[2], R. Schreiber[3], C. Meyer[3]
[1] Kurt-Schwabe-Institut für Mess- und Sensortechnik Meinsberg e.V., Kurt-Schwabe-Straße 4, 04736 Waldheim, Germany
[2]Renesas Electronics America Inc., Longmont, CO 8050, USA
[3]Renesas Germany GmbH, 01069 Dresden, Germany

Summary:

This work reports on measurements with commercially available metal oxide gas sensors (MOX-GS) in different indoor environments together with infrared CO_2 gas sensors (IR-CO_2-GS). From the temporal courses of the MOX-GS a time-dependent CO_2 concentration is estimated (e(CO_2)) by sensor-specific algorithms, which is compared subsequently with the CO_2 concentration, measured with the IR-CO_2-GS. That calculation is based on the hypothesis that humans exhale volatile organic compounds (VOC) parallel to CO_2, which stimulate the MOX-GS. Therefore, a correlation between VOC and CO_2 concentrations can be derived in populated meeting rooms and offices. Measurements in rooms of different sizes and different numbers of attendees confirmed this hypothesis and indicate the possibility to control air condition (HVAC) systems with e(CO_2)-values as input signals.

Keywords: metal oxide gas sensor, estimated CO_2 concentration, HVAC control

Background, Motivation and Objective

Indoor air quality (IAQ) is of increasing importance for safety and health issues in buildings [1]. Furthermore, an efficient ventilation control in offices, meeting rooms and other indoor environments is fundamental for ideal working conditions and energy saving [2].

Since the air quality is influenced not only by the concentrations of carbon dioxide (CO_2) and humidity (r.H.) but also by the kinds and concentrations of VOC, it is self-evident to investigate beside IR-CO_2-GS also VOC sensitive gas sensors like MOX-GS as signal providers for HVAC control [3]. This approach is also supported by the fact that humans exhale a variety of VOC into indoor air with significant impact to its quality [4].

Description of the Investigation

MOX-GS of the type ZMOD4410 (Renesas Electronic Cooperation) and from two competitors (MX-A/MX-B) were characterized in different indoor air environments of KSI. The monitoring of these sensors was escorted by parallel measurements with four different Infrared (IR)-CO_2-sensors: SCD3x (Sensirion AG), K30 (Senseair) and CM1106 (Cubic Sensor and Instrument Co., Ltd.) and MX1102 (Onset Computer Corporation). Four multi-sensor systems (MSS1-4) equally equipped with the sensors mentioned above were operated simultaneously in different indoor environments (offices, meeting rooms and laboratory) over two months and calibrated at start, middle and end of the measurement campaign. The signals of the investigated MOX-GS were used by algorithms developed by the sensor manufacturer to calculate real-time $e(CO_2)$-values, which were correlated for every investigated sensor with the mean value of the IR-CO_2-GS signals $c(CO_2)_m$. That correlation was quantified by a ratio factor f_c:

$$f_c = \frac{e(CO_2)}{c(CO_2)_m} \quad (1)$$

During a measurement the mean value of f_c ($f_{c,m}$) and its percental standard deviation $SD[\%f_{c,m}]$ were determined in the regions $c(CO_2)_m$ > 1000 vol.-ppm and $c(CO_2)_m$ < 1000 vol.-ppm. This limit is known as a threshold for appropriate indoor air quality [5].

For the calibration of the IR-CO_2-GS dry mixtures of CO_2 in synthetic air were used at room temperature, which were monitored also by an Nicolet 8700 FTIR-spectrometer. The MOX-GS were characterized in humidified mixtures of ethanol in synthetic air at room temperature. Both, for calibration and measurements the sensors were positioned in boxes with closed and open lid, respectively, as shown in Fig. 1.

Results

In Fig. 2 the resistance signals of one MOX-GS are provided for the three characterizations at start, middle and end of the measurement campaign. They show a rapid response to the changes of the ethanol concentration, a nearly horizontal plateau and comparably low deviations between the levels at the higher concentrations, indicating a high reproducibility at the adjusted conditions.

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The signal rise during the starting period of 3 h in every characterization is caused by the usage of ultra clean air, flushing out the trace concentrations of VOC in the calibration box.

In Fig. 3 the maximum, minimum and mean values of $f_{c,m}$ and $SD[\%f_{c,m}]$ are provided for the complete measurement campaign of MSS1-3, which were operated in offices and meeting rooms without HVAC. The nearer the factor $f_{c,m}$ ranges to 1 and the smaller its relative standard deviation $SD[\%f_{c,m}]$ results, the smaller is the difference between the e(CO_2)- and the c(CO_2)$_m$-values. Since all sensors delivered very similar response curves during characterization, the large differences of $f_{c,m}$ and $SD[\%f_{c,m}]$ between the individual MSS come with the response of the algorithms to the measurement conditions in the different rooms. If the e(CO_2)-value is intended to be utilized for the regulation of heating, ventilation, and air conditioning systems (HVAC) regulation, its correlation with the $c(CO_2)_m$-value above 1000 vol.-ppm (shown in Fig. 3) is much more important than below 1000 vol.-ppm. The finding that in that region all three MOX-GS of the MSS 1-3 deliver $f_{c,m}$ values (white lines in Fig. 1) distributed around the value of $f_{c,m}$ = 1 and acceptably low SD values is very encouraging for this application. A comparison of signal courses between measurements with different numbers of attendees in the monitored rooms indicates that the difference between $e(CO_2)$- and $c(CO_2)_m$ values becomes smaller with increasing number of monitored persons. This expectable result was found during all measurements.

References

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Illustrations, Graphs, and Photographs

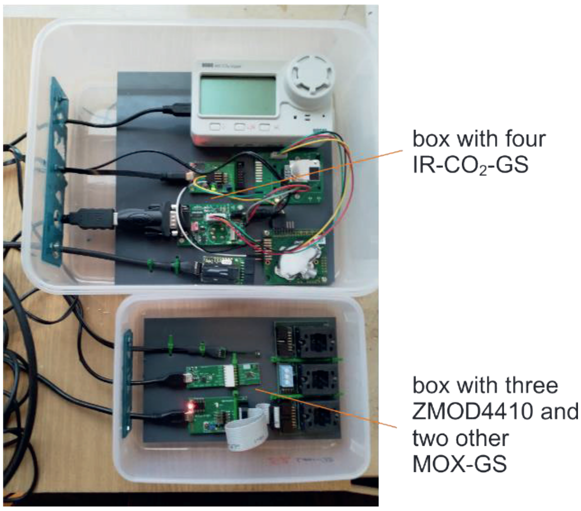

Fig. 1: Image of one of the multi-sensor systems.

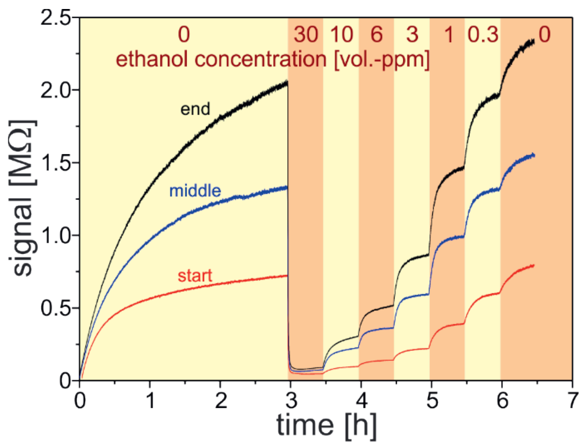

Fig. 2 Response of one ZMOD4410 MOX-GS during characterization in humidified ethanol/air mixtures; r.H. = 30 % at 25 °C.

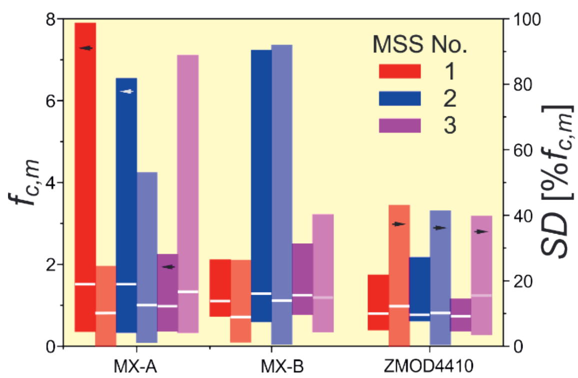

Fig. 3: Ranges of $f_{c,m}$ and $SD(\%f_{c,m})$ for each MOX-GS during the complete measurement campaign, $c(CO_2)_m$ > 1000 vol.-ppm, the mean values of both parameters are indicated with white horizontal lines, the pasty columns indicate the standard deviation *SD* as labelled by the arrows.