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Mathematical Measures for Calibration and Evaluation of Gas Sensor Data

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Summary:
Economic online and in-situ field analyses wait for reliable and economic analytical solutions by sensor systems. This paper presents various innovative mathematical procedures to analyze data from gas sensor systems and gas sensor nets: ProSens - an efficient mathematical procedure for calibration and evaluation of tin oxide gas sensor data, SimSens – a Mathematical Procedure for Simultaneous Analysis of Gases and ProCal - a program for batch-wise calibration of multi gas sensors .

Keywords: Thermo cyclic operation, calibration and evaluation procedure, simultaneous evaluation, batch wise calibration, mathematical procedure

Introduction

There is a growing need of economic online and in-situ field analysis applications like online monitoring of volatile components in chemical and biochemical processes, quality monitoring in food processing, discriminated monitoring of toxic gas leakages, etc. In the last application, it is often necessary to find and locate the source of the leakage. In this context, isothermally operated metal oxide gas sensors (MOGs) with tin oxide as base material are manifold introduced due to their high sensitivity, long-term stability and low price. Their sensitivity to specific gas components, however, cannot be cultivated with high discrimination to others. Therefore, other approaches are necessary like a multi gas sensor array of MOGs [1][2] or thermo-cyclic operation of the MOG. With special chosen additives, the sensor can be adapted according to the gas composition to be measured.

For evaluation of the sensor data, powerful mathematical evaluation procedures for substance identification and concentration determination even in the case of variable environmental conditions like varying humidity are necessary. The calibration of sensor elements is very time consuming and expensive. Even sensor elements which are fabricated batch-wise have to be individually calibrated for good analysis performance. Therefore, economic mathematical calibration procedures are useful to reduce the costs and the scope of calibration measurements. Last not least to locate the source of a leakage also mathematical procedures are needed.

At the Karlsruhe Institute of Technology (KIT) mathematical procedures are developed to meet the above mentioned requirements: ProSens – a mathematical procedure for calibration and evaluation, SimSens – a Mathematical Procedure for Simultaneous Analysis of Gases and ProCal – a mathematical procedure for batch-wise calibration of sensor elements. After some remarks to thermo-cyclic operation of the MOG these procedures will be briefly described in this paper and there performance will be demonstrated in applications with real data.

Thermo-Cyclic Operation

Thermo-cyclic operation means that the working temperature of the sensor element is periodically increased and decreased over the time in a triangular shape. Simultaneous sampling of the conductance values over the time leads to so-called Conductance over Time Profiles (CTP) [3][4][5]. These profiles give a fingerprint of the surface processes with the gas and represent the gas mixture under consideration.

Figure 1 shows the CTPs of some gases at a certain concentration level. It can be clearly seen that the shapes of the various gases are quite different and can be therefore used for substance identification using innovative calibration and evaluation procedures.

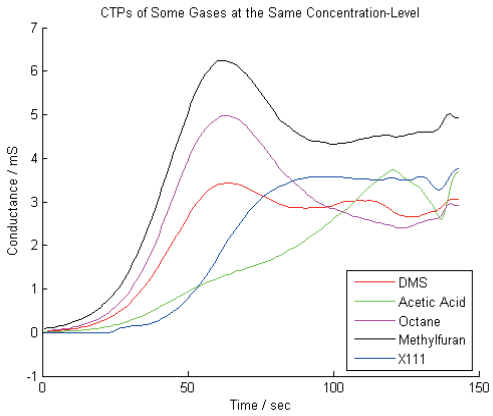

Fig. 1. CTPs of some gases at a certain concentration level

ProSens – a Mathematical Procedure for Calibration and Evaluation

As mentioned above MOGs can be used for ambitious analysis applications when they are thermo-cyclic operated. A mathematical procedure for data evaluation has to identify an unknown gas sample (classification) to avoid misleading results like false alarms and to determine the concentration of the components of the gas sample. Because often varying environmental conditions like varying humidity or varying environmental temperature influence the measurement results this must be incorporated in the evaluation model of the mathematical procedure.

The program ProSens, developed at KIT, was designed to meet the above mentioned requirements. [5].

SimSens – a Mathematical Procedure for Simultaneous Analysis of Gases

To meet the requirements of simultaneously analyzing a multitude of gases or gas mixtures of well-defined composition of components, the procedure SimSens (Program for Simultaneous Analysis of Gases) was developed. SimSens is an extension of ProSens, which was designed to analyze only one gas or one gas mixture. [6]

ProCal – a Mathematical Procedure for Batch-wise Calibration

To meet the requirements of simultaneously analyzing a multitude of gases or gas mixtures of well-defined composition of components, the procedure SimSens (Program for Simultaneous Analysis of Gases) was developed. SimSens is an extension of ProSens, which was designed to analyze only one gas or one gas mixture. [7]

Results

All above mentioned mathematical procedures, developed at the KIT, were tested in numerous application scenarios with real measurement data and yield in all cases a very good performance. The technological transfer is supported by HybridSensorNet e.V. Assembling different new research results for forming a technological base at a higher level, the main goal is thereafter to realize new and innovative intelligent sensor systems.

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