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Selective detection of hydrocarbons in real atmospheric conditions by single MOX sensor in temperature modulation mode

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Introduction

Detection of pipeline hydrocarbons leakage is a valid industrial demand [1]. A deployed network of autonomous miniature micromachined metal oxide semiconductor gas sensors with low power consumption possess a great perspective of practical use in this regard [2,3]. The main obstacle of their high cross sensitivity can be overcome by the implementation of sensor arrays or working temperature modulation in combination of signal processing and nonlinear calibration [4,5]. In this work we demonstrate stable selective detection of propane and methane in low concentrations in the real urban ambient air by the SnO2-based semiconductor gas sensor.

Experimental

Nanocrystalline SnO2 gas sensitive material has been synthesized by flame spray pyrolysis technique. Gas sensors were fabricated on the basis of 2x2x0.15 mm alumina micro-hotplates with the use of α-terpineol as a binder. Measurements were carried out in a flow-through sensor cell with the use of outdoor air with the admixture of methane and propane from certified gas bottles. Gas concentrations varied from 40 to 200 ppm. Sets of data were collected during a series of 24h experiments with variable air temperature and humidity. The measurements were conducted through 2 consecutive months in order to determine the stability of sensor performance. Collected 17 data sets were divided to 10 sets, used for model training and calibration, and 7 sets, used for motel testing. The details of sensors working temperature cycle and gas sensor setup are given on fig. 1

Figure 1. (a) gas sensor setup (b) metal oxide gas sensor working temperature and sensitive layer resistance profile.

Results

The obtained gas sensor resistance profiles, recorded during temperature cycles, demonstrate considerable variance due to effects of ambient air humidity and temperature changes. The application of principal component analysis (PCA) to the raw sensor data did not allow to distinguish between methane, propane and air in any acceptable extent (Fig. 2a). The use of data pre-processing, represented on fig. 2b (baseline cut-off, data scaling, extraction of data points only from 300-500 oC working temperature region), in combination with machine learning algorithm (artificial neural network with 50 neurons in hidden layer, dropout regularization and sigmoidal activation function) allowed to achieve 86% accuracy of identification of methane vs. propane vs. air in real urban air in 40-200 ppm concentration range.

Figure 2. (a) PCA score plots for raw sensor data (b) raw sensor data preprocessing, used for machine learning algorithm.

Conclusions

Data preprocessing allows for compensation of metal oxide gas sensor drift effects during operation in real urban air, caused by variations of weather conditions. Application of machine learning algorithms, based on the artificial neural network approach gives the possibility of selective detection of air pollutants even of very close chemical nature. The presented approach demonstrates the applicability of MOX sensors for application in industrial safety tasks, related to flammable and explosive gases leakage.

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Summary

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