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New transient feature for metal oxide gas sensor response processing

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Abstract

This paper presents the performance of metal oxide gas sensor response processing for the concentration detection of an analyte diluted in a neutral atmosphere. In the field of electronic nose, two applications are generally studied: identification of a gaseous atmosphere from other atmospheres, or the determination of the concentration of one gaseous atmosphere. This second application needs more accuracy either in the measurement set-up or in the response analysis. We propose in this study the performance comparison between two traditional features extracted from the sensor response and a new feature corresponding to the maximum (Peak) of the derivative curve of the time sensor response. The performance of this feature to obtain fast odor concentration identifications is discussed and compared to other traditional features.

Keywords: gas sensor, signal processing; transient feature; concentration detection,; rapid identification

1. Introduction

Electronic noses are intelligent systems that play a constant growing role as general detectors of vapors in many applications. In these devices, the sensor array plays a major role. Several types of sensors can be employed, semiconductor metal oxide based sensors (MOX) are often used, due to their qualities: robust, cheap, and able to react in presence of many organic or inorganic gases. Unfortunately, they are not selective, but a strategic choice of several non selective sensors can improve the selectivity of the system, to obtain a good discrimination of gaseous substances. In this way, an appropriate pattern recognition method must be selected, based on an accurate treatment of the response of all the sensors. The key of a

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fast and successful recognition is the feature extraction method, which needs to extract robust information [1-2] of the sensor response curves. This fast recognition can be obtained from the transient part of the sensor response. In this paper, we propose the performance comparison between the traditional features and a new feature corresponding to the maximum of the derivative curve, obtained in the first minutes of the gas exposure and deduced from the time sensor response, after an adequate filtering.

2. Characterization measurement

An array of seven MOX sensors (from Figaro and FIS) was characterized under different gaseous dilutions from liquid pine essential oil (EO) in synthetic air by using a dynamic flow measurement [3]. To generate different concentrations of pine EO, a constant inflow of synthetic air was bubbling into the liquid oil. Then the outlet flow, containing evaporated EO substances, was combined with a flow of pure synthetic air to have a total constant flow rate (100 ml/min). So the EO concentrations are defined in terms of percent ratio between the EO outlet flow and the total flow. The resistance variation of each sensor was collected in terms of a voltage magnitude using a fast sampling rate (2 samples/sec). The measurement protocol was adjusted and a cycle of 10 minutes exposition of EO volatiles molecules followed by 20 minutes of synthetic air for recovery process was adopted. This procedure allowed us to obtain a good stabilization and recovery of all the sensors after each concentration exposure. More than 20 experiments were made for each studied concentration to constitute a consequent data basis.

The characterization measurements show a good sensibility of all the sensors (Figure 1a) to pine oil vapour even at the lowest concentration. We note a very stable and rapid response of the SP-MW0 FIS sensor. The other sensors have more or less sensitivity and reactivity (corresponding to the slope of the transient part). The analysis of the same sensor responses under different concentrations of pine oil, showed a good evolution of the dynamic and stabilized part of the signal along with the concentration. The Figure 1b shows this observation for the SP-AQ1 sensor, where we can observe the evolution of the stabilized value (Vs) but also the evolution of the transient part of the signal response.

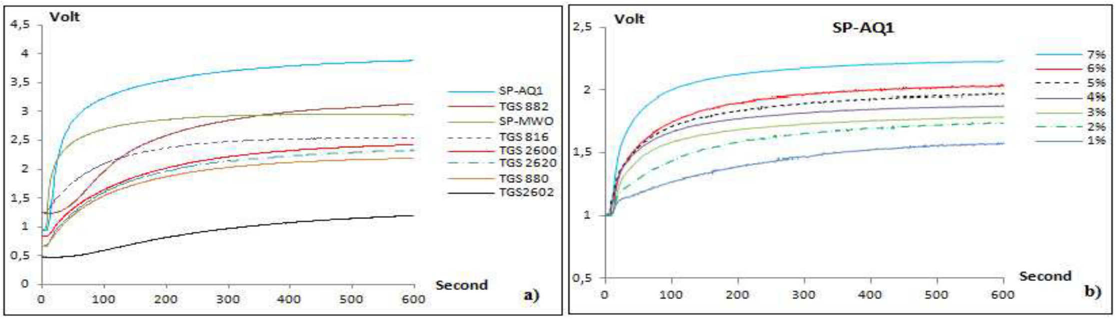

Fig. 1. (a) time-responses of all the sensors to a fixed concentration; (b) responses of one senor to all the used oil concentrations

3. Signal processing and results

In electronic nose application usually a set of selected features, which depend to the measurement protocol, are studied in term of their performance to classify the used substances. To obtain an accurate classification, the selection of the features and their processing are very important. In this study, we have selected principally two traditional features from the time-dependent signal, as the response amplitude named $Vs-V_0$ (where Vs is the final value of the sensor response and V_0 its initial value), and the slope of the dynamic phase calculated during the first three minutes of the gas exposition (named Slope). We have observed that the transient part of the sensor response presents significant evolution in the two cases described on the figure 1a (signal response of all sensors at a fixed atmosphere) and 1b (signal response of one sensor to all the studied concentrations). So, we have selected one new feature corresponding to the maximum value (called Peak) of the signal response derivative curve. This maximum appears for all the sensors in the first minutes of the gas exposition.

For the calculation of this Peak feature, the time-response was first filtered to eliminate signal noises, and then derivated. Several digital filters were tested to optimize the type and the characteristic parameters of the filter to be unique for each sensor and all the exposures. Butterworth type filtering has given the best results. For each sensor, the Peak values show an appreciable variation along with the all oil concentrations (Figure 2).

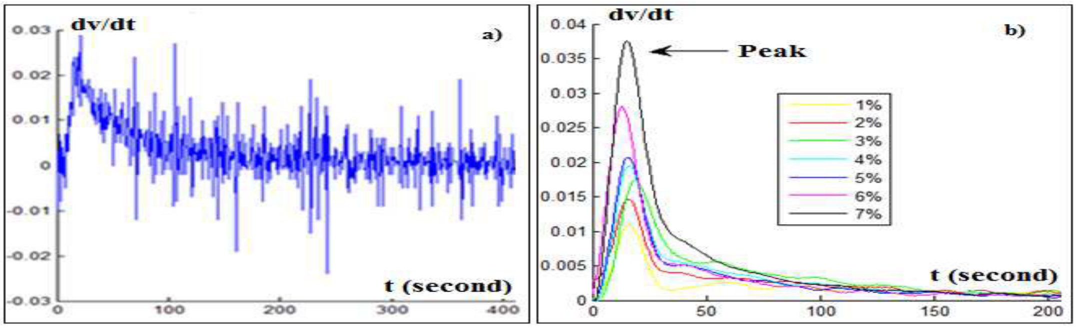

Fig. 2. (a) Example of a derivative curve without filtering; (b) Derivative curve of SP-MW0 for all the used pine oil concentrations

The three selected features are tested for their capacity to differentiate the oil concentrations. In Figure 3 we present the evolution of the V_s-V_0 and the Peak features along with the oil concentrations and for all the sensors. So, to take into account all these informations, the values of each extracted feature must be assembled in a data basis and then treated by classification methods.

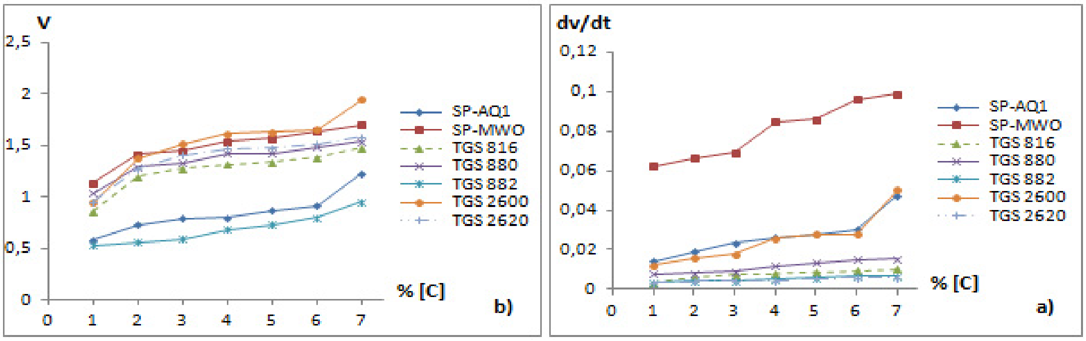

Fig. 3. Evolution of two selected features along with the pine oil concentrations: (a) V_s-V_0; (b) Peak

The capacity of each feature to classify the pine EO concentrations was studied using first the Principal Component Analysis (PCA). This non-supervised statistical method permits us to represent all the observations of a multidimensional data basis in a reduced dimension. Figure 4 presents the PCA results obtained with each selected feature taken separately. In the case of the Slope values the 3, 4, 5 and 6% concentration groups are overlapped and not differentiable. With the V_s-V_0 values the group of 4, 5 and 6% concentrations are very closed and difficult to be distinguished. By using the Peak feature, we obtain a better classification and only the group 4 and 5% are closed. We can then conclude that the new feature Peak is more accurate than the classical features for our application. In addition the Peak is less dependent on the sensor drift (derivation) and it is obtained faster than the other ones. To confirm this finding, the discrimination power of each feature is tested using the supervised Linear Discriminant Analysis. The concentration identification is validated by cross validation technique: a success rate of 95.2% is obtained with the Slope, 99.2% with the Vs-V_0 and 100% when using the Peak feature.

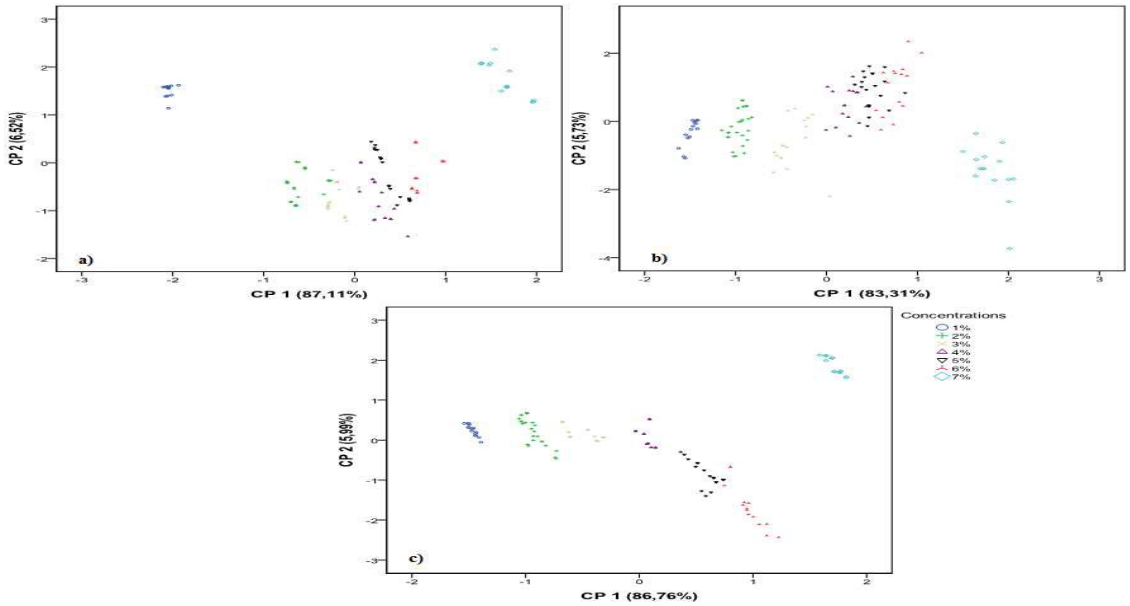

Fig. 4. PCA diagrams obtained with each feature taken separately: (a) Slope; (b) Vs-Vo; (c) Peak

4. Conclusion

We have defined a new feature and highlighted its capacity for a rapid and accurate identification of odor concentrations, comparing to the results obtained from the traditional features used in metal oxide senor response processing. However, the determination of this parameter, deduced from the derivative curve of the time response of the sensors, needs accurate measurement system and adequate signal filtering. This data processing can be easily implemented to the intelligent system like electronic nose.

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