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Comparison of information content of temporal response of chemoresistive gas sensor under three different temperature modulation regimes for gas detection of different feature reduction methods

To cite this article: S M Hosseini-Golgoo *et al* 2017 *J. Phys.: Conf. Ser.* **939** 012005

Comparison of information content of temporal response of chemoresistive gas sensor under three different temperature modulation regimes for gas detection of different feature reduction methods

S M Hosseini-Golgoo[1*], F Salimi[2], A Saberkari[1] and S Rahbarpour[3]
[1] Electrical Engineering Department, University of Guilan, Rasht 41635-3756, Iran
[2] Guilan Science and Research Branch, Islamic Azad University, Rasht, Iran
[3] Electrical Engineering Department, Shahed University, Tehran, Iran
*E-mail: smhosseini@guilan.ac.ir

Abstract. In the present work the feature extraction of transient response of a resistive gas sensor under temperature cycling, temperature transient, and temperature combination methods were compared. So, the heater were stimulated by three pulse (cycling), ramp (transient) and staircase (combination) waveforms. The period or duration of all waves was equal to 40 s. Methanol, ethanol, 1-propanol, 1-butanol, toluene and acetone each at 11 different concentration levels in the range of 100 to 2000 ppm were used as the target gases. The utilized sensor was TGS-813 that made by Figaro Company. Recorded results were studied and heuristic features such as peak, rise time, slope and curvature of recorded responses were extracted for each heater waveform. Results showed that although application of this feature extraction method to all waveforms led to gas diagnoses, best results were achieved in the case of staircase waveform. The combination waveform had enough information to separate all examined target gases.

1. Introduction

Resistive gas sensors (RGS) are widely used for gas detection. RGS is cheap, small, durable and has high sensitivity. Such sensors work at elevated temperatures which are provided by a tiny heater embedded in the vicinity of sensitive surface. Despite their great benefits, the lack of selectivity is one of the great weaknesses of RGSs. The use of multiple sensors in array form is the most common method used to increase selectivity of an RGS. However, some efforts have also been made to establish the selectivity of just one sensor [1-2]. Among the various techniques provided to create selectivity in a single sensor [3-4], modulation of operating-temperature of a sensor can be cited. In this method, the heater element is activated by a time variant voltage [5-6]. Temperature modulation approaches of RGSs can be divided in two main categories: Thermal transient (TT) and Thermal cycling (TC). Also, there are combined methods which benefit from properties of both methods [7].

In the work done by Hiranaka et al, the TT method was applied on the heater of tin oxide based Taguchi Gas Sensor (TGS) [8]. In this method, first the sensor warmed by applying 5V voltage and, then exposed to a polluting gas. By doing this, in response to sensor's transitions, some peaks were created and the timing of their occurrence depends on the type of the target gas and was not depended so much on the target gas concentration. Thus, simply provides the possibility to distinguish between analytical gases which were tested. Y. Kato and et. al [9] applied a thermal pulse to a print tin oxide sensor and observed changes of behavioral disturbance resistance at the sensor's output. S. Bukowiecki and et. al provided TC method for RGS sensors. These researchers applied a sinusoidal heating voltage along with a decline to TGS812 heating gas sensor and observed that the number of the position and shape of peaks is related to the gas identity and the gas density is in relation with domain and frequency of the sinusoidal voltage heater [10]. Hosseini and et. al in line with previous experiments applied a staircase voltage, a combination of two methods of thermal transitions and thermal cycles, to a TGS813 resistive gas sensor. Used gases in this experiment were: Methanol, ethanol, 1-Propanol, 2-Propanol, 1-Butanol, 2-Butanol, iso-butanol, tert-butanol, Neon, pentanol, acetone, and hydrogen, each in 11 concentration levels. They could distinguish the 11 mentioned target gases by feature extraction methods [11]. Also in another essay, Hosseini et. al [12], using this thermal modulation method, conducted a comparison among feature extraction methods and obtained acceptable results.

Considering applied methods for producing fingerprint from sensor transient responses, transient compression methods can be categorized in three: One is sampling method: This method, by sampling of response of sensor, provides dynamic information of the sensor's response in various times in actions or recovery phase. Second is feature extraction methods: these methods compress the transient response using some features of transient response such as ascent time, maximum/minimum slope, and integral time. Third is system identification methods: These methods fit a theoretical model to experimental data and use model parameters as property.

In this work, feature extraction method was used and Innovative features such as peak, rise time, slope and curvature of the recorded response were extracted for each shape of heater waveforms and one can find obtained results in the following.

In the second section, the way of conducting experiments, applying waveforms of sensor's heater and recording their response will be provided. In the third section, the way of extracting feature vector from modeled responses and categorizing obtained features using educational data will be evaluated and expressed. Finally, the conclusion will be presented at section 4.

2. Experiment Method

In this work, six alcohol including methanol, ethanol, 2-propanol, 1-butanol, acetone and toluene were used as target gas and TGS-813 produced by Figaro Company was used as RGS. These sensors possess a tin oxide sensitive layer deposited on a tubular alumina substrate and a tiny heater provides the required operating temperature. Variable voltage level leads to creation of varying operating temperature with time. Resistance of RGS depends to operating temperature of sensor and combination of gas polluted air. The way of changing temperature of sensor's sensitive level through applying three different waveforms is illustrated in Fig.1(a)-(c). These waveforms were selected from three different temperature modulation methods: ramp from TC, pulse from TT and staircase waveform from CT. the main parameters of these waveforms are depicted in fig.1. First, maximum amplitude (MA) voltage is considered rated voltage recommended by manufacturer, i.e. 5V. First time delay (TD0) includes a period of minimum 5 minutes in clean air; the sensor is warmed in TD0 interval. This is because of cleaning sensor's surface from former pollution. After placing sensor into the chamber, sensor's voltage was kept constant to 5V for second time delay (TD). This time includes a 2-minute period in order to reach sensor response to its stable condition. At TD, the heater voltage is declined from 5V to 1V. This is maximum amplitude range (AR) of applied waveforms. Each waveform in pulse duration (PD) of 40 seconds will change its condition and the obtained response will be transferred to computer and this process will be repeated for all gases.

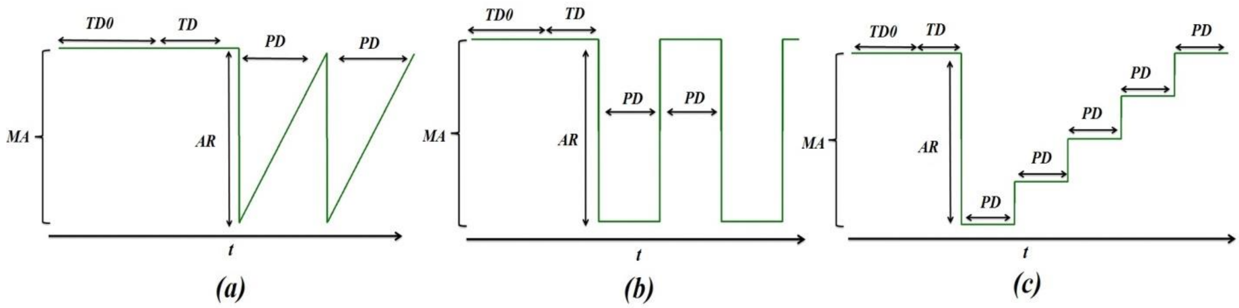

Fig1. The configuration of waveforms of applied voltages to sensor's heater (a) Ramp (b) Pulse (c) Staircase

3. Analysis Method

Fig. 2 illustrates the response of TGS-813 in wide concentration range of six target gases when sensor heater is excited by ramp, pulse, and staircase waveforms. The intended features will be produced in dynamic response of sensor using analysis of multilevel waves. Feature selection is one of the most important topics in pattern categorization and data extraction application. In this regard, innovative features such as peak, rise time, slope, and curvature of recorded response for each waveform were examined. In these figures, three features are considered for each six target gases. For ramp and pulse waveforms in the second peak and for staircase waveform a combination of previous two figures is considered. The first feature at the beginning of the second peak (F1), the second one at the slope of descending curve when heater voltage changes from 5 to 1V (F2) and the third one at the slope of ascending curve when heater voltage varies from 1 to 5V (F3). The results are depicted in Fig.3.

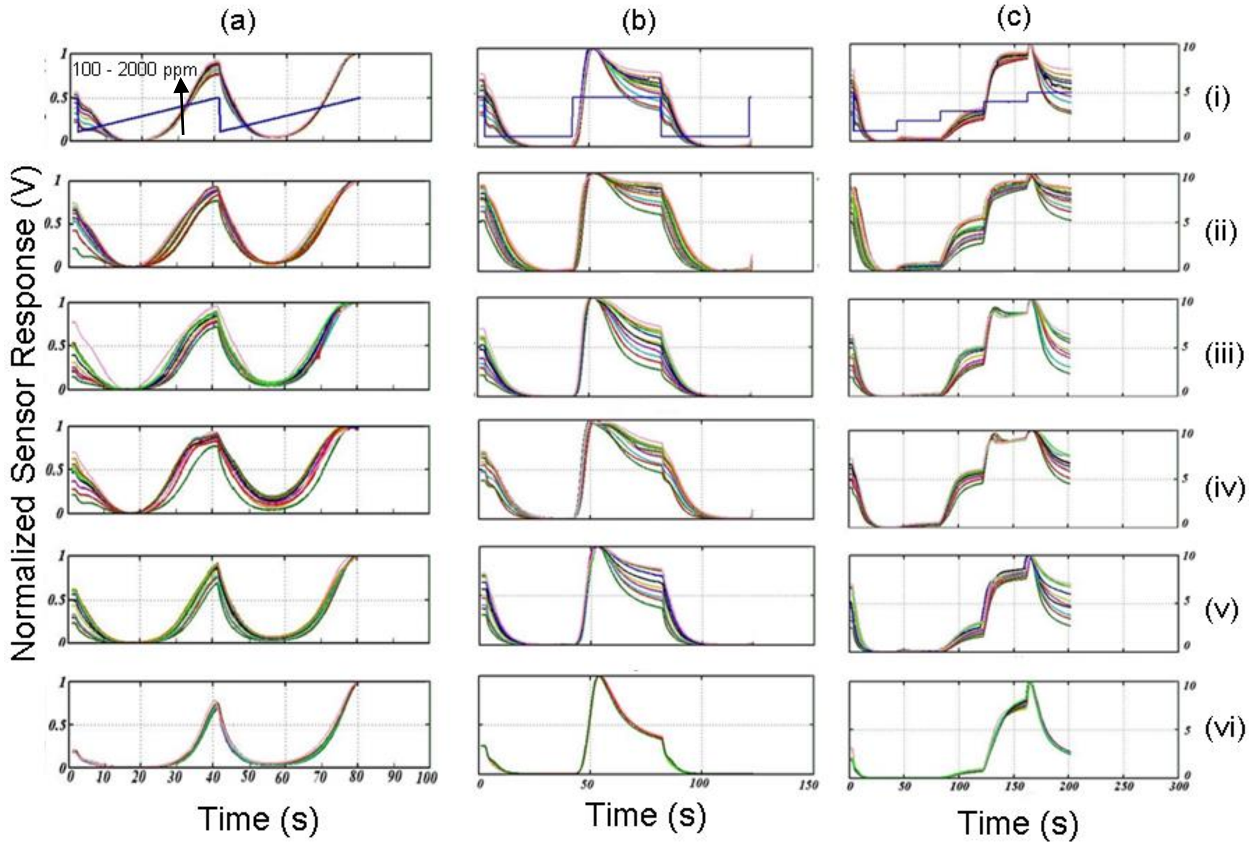

Fig. 2. Temporal sensor response recorded in wide range of (i) methanol, (ii) ethanol, (iii) 2-propanol, (iv) 1-butanol, (v) acetone, and (vi) toluene when sensor heater voltage is excited by (a) Ramp, (b) Pulse, (c) Staircase waveforms. PD of applied waveforms is equal to 40 second.

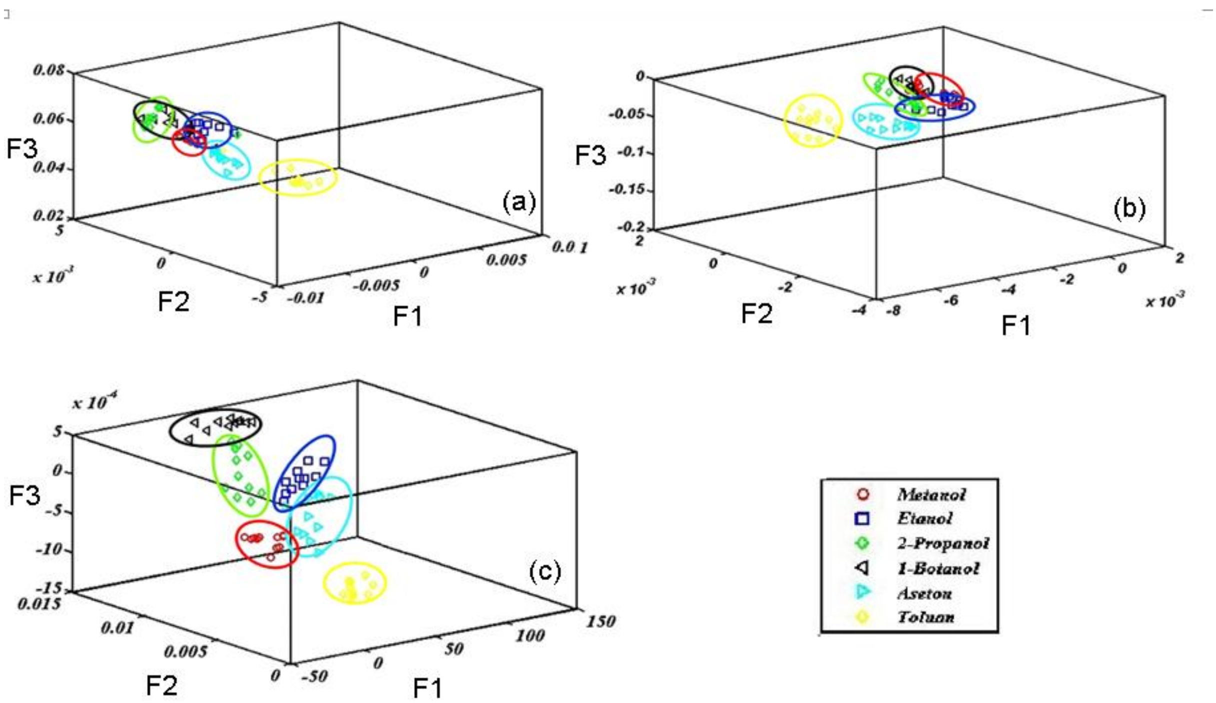

Fig. 3: The representation of feature vectors extracted from sensor responses in exposure to polluted air by methanol, ethanol, 2-propanol, 1-botanol, acetone, and toluene in 3 dimensions for heater waveforms of (a) slope (b) pulse (c) staircase

As can be seen, application of this feature extraction method to all waveforms led to gas diagnoses, best results were achieved in the case of staircase waveform. The combination waveform had enough information to separate all examined target gases.

4. Conclusion

According to fig. 3 it can be expressed that by comparing three waveforms of ramp, pulse, and staircase in thermal modulation, staircase waveform provides the best difference for all 6 gases and using it in this experiment, the 6 gases were distinguished but the other two waveforms distinguished 4 gases of methanol, 2-propanol, acetone, and toluene and the gases of ethanol and 1-bonatol were not separated. Consequently, considering this experiment, the best results are obtained for staircase waveform.

5. References

[1] H.T. Nagle, S.S. Schiffman and R. Gutierrez-Osuna: IEEE Spect. J, Vol. 38 (1998), p. 22.
[2] N. Barsan, D. Koziej, and U. Weimar: Sens. Actuators B VOl. 121 (2007), p.18.
[3] K. Persaud and G.H. Dodd: Nature Vol. 299 (1982), p. 352.
[4] F. Hossein-Babaei and M. Orvatinia: IEEE Sensors J Vol. 4 (2004), p. 802.
[5] F. Hossein-Babaei and S.M. Hosseini-Golgoo: IEEE Sensors J Vol. 8 (2008), p. 1837.
[6] S.M. Hosseini-Golgoo and F. Hossein-Babaei: Meas. Sci. Technol Vol. 22 (2011), P. 35201.
[7] A.P. Lee and B.J. Reedy: Sens. Actuators B Vol. 60 (1999), p. 35.
[8] T. Amamoto, T. Yamaguchi, Y. Matsuura and Y. Kajiyama: Sens. Actuators B Vol. 13-14 (1993), p. 587.
[9] Y. Kato, K. Yoshikawa and M. Kitora: Sens. Actuators B Vol. 40 (1997), p. 33.
[10] W.M. Sears, K. Colbow and F. Consadori: Semicond. Sci. Technol Vol. 4 (1989), p. 351.
[11] S.M. Hosseini-Golgoo, H. Bozorgi and A. Saberkari: Meas. Sci. Technol Vol. 26 (2015), P. 65103.

IOP Conf. Series: Journal of Physics: Conf. Series **939** (2017) 012005 doi:10.1088/1742-6596/939/1/012005

[12] S.M. Hosseini-Golgoo and N. Ebrahimpour: Materials Science and Engineering Vol. 108 (2016), P. 12001.