Correction of Humidity Effect for Detection of Human Body Odor

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***Abstract*-Humidity strongly effects the sensitivity of odor sensors. It is therefore a major problem in the use of electronic nose (E-nose) for most applications including detecting human body odor from armpits, where humidity at the armpits can varies to a large extent due to various human activities. In this paper, we propose both hardware and software approaches to correct the humidity effect. The E-nose was designed to efficiently measure volatile organic compounds generated from human body and was most optimized if both the hardware and software corrections were employed. Principle component analysis (PCA) method was used for pattern recognition and discrimination of human body odor. After humidity correction, our special designed E-nose not only shows the capability in detecting human body odor, but it is also able to classify two different persons who have the same life style and activities.**

I. Introduction

The human body generates unique patterns of volatile organic compounds (VOCs) upon living conditions such as eating, drinking, activities, health or hormonal status [1]. These VOCs released from the human body can give some information about diseases, behavior, emotional state and health status of a person [2]. Also, body odor is one of the physical characteristics of human which can be used to identify people [3]. An example of using the human odor was explained by Jin et al. [4] in 2005. They detected the expiration of a subjective person after drinking to find a moderate amount of alcohol which has a positive effect on the health of the aged. In another example, Natale et al. [5] employed the urine odor to diagnose and control renal dialysis in the patients with kidney disorders. One of the efficient instruments that can detect and monitor the human odor is an electronic nose (E-nose). The first E-nose experiments were conducted in the early 1980s [6]. In principles, E-nose combines a sensing array with a data analysis system. The sensing array consists of several gas sensors which is the main part in detecting odors. In several E-nose systems, metal oxide sensor is widely used due to low cost and user-friendly. However, the metal oxide sensor is very sensitive with humidity that makes it difficult to get precision odor recognition. Therefore, a correction of humidity effect is necessary to ensure minimal response due to humidity when switching from reference to odor sample [7]. In this paper, we present a correction of humidity by using our new hardware- and software-based methods. At first, we have constructed an E-nose based on metal oxide sensors. Then, the effects of humidity and the correction of humidity effects are presented. Finally, the E-nose with removable humidity effects is applied for detecting and classifying the human body odor of difference persons.

II. Experimental

A. Electronic Nose System

The electronic nose system (see Fig.1) was designed to efficiently measure VOCs generated from human body. It consists of three main parts: (i) sensor chamber (ii) air flow system and (iii) DAQ card & measurement circuit.

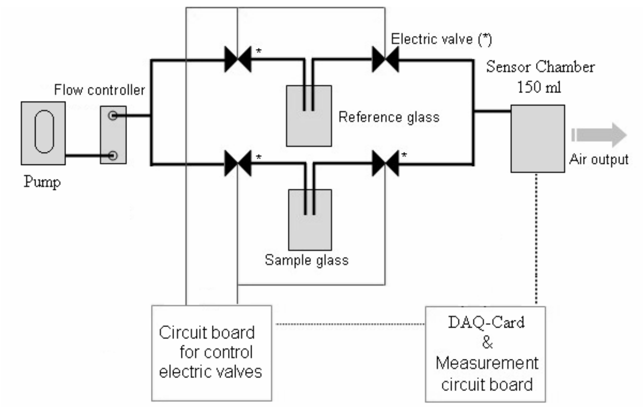

Figure 1. Schematic diagram of electronic nose system.

In the first part, the odor sensor array; TGS 813, TGS 822, TGS 825, TGS 880 and TGS 2602 were housed at the bottom of the chamber. The target gases of each sensor are listed in Table I. Additional temperature and relative humidity sensors were mounted at the bottom of Teflon plate in the chamber. The air carrying the odor molecules was introduced into the 150 ml sensor chamber through a Teflon tube. The caliber is about 2.5 mm. The sensor chamber also has an exhaust Teflon tube which has the same caliber. The second part consists of four electrically controlled solenoid valves, sample and reference glass containers, plastic pipes, and flow controller. It

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is necessary for this type of measurement to switch between a reference and a sample glass containers. Four electrically controlled solenoid valves were used to avoid mixing of the gas from the reference and the sample. Then, the gas from the reference or sample flows to the sensor chamber of which the flow rate was set at 150 ml/min. Finally, in the measurement circuit, data acquisition was realized by a USB-DAQ-Card National Instruments NI USB-6008. The measurement program was written using LabVIEW version 8.2. The measurement circuit uses the voltage divider resistor for each sensor. The sensor outputs were written in a file every 1 second for subsequent analyses.

TABLE I
METAL OXIDE SENSORS AND THEIR RESPECTIVE SENSITIVITIES CONTAINED IN THE SENSOR CHAMBER

Sensor	Target gas
TGS 813	Combustible gases
TGS 822	Organic solvent vapors
TGS 825	Hydrogen sulfide
TGS 880	Cooking vapors
TGS 2602	Air contaminants

B. *Humidity Control*

Most chemical gas sensors are sensitive to humidity. So if two equal samples with a different humidity are measured, the result can be different. There are two ways to solve this problem. The first is a hardware-based method where the sample is managed to have the same humidity as the background. In other words, the reference has the same humidity like the sample: for instances, pure water can be used as a reference when a liquid solution is the sample). To produce constant background humidity in the air flow before splitting into reference and sample line, there is a bottle of water at a specific controlled temperature (see Fig. 2). The second method is software based. A mathematical model describes the resistance at a specific humidity level. So it is possible to delete the effect of humidity directly while the measurement is running. Another way is to save the humidity values and to recalculate the data analysis result. It is also possible to combine the hardware based and software based method to get a maximum preciseness.

C. *Human Body Odor collection*

Human body odors were represented by armpit odors which were collected from 2 men. The experiment time was 5 days with a sample collection of the armpit odors in the morning after waking up and in the afternoon 8 hours after the sampling in the morning. The cotton pads must be in direct contact to the armpit for 10 minutes for each arm and stored in a special sample glass bottles with a screw-on closure. Date and time must be noted on the sample glass bottles. The measurement should be done as fast as possible after collection to avoid changes in odors due to bacteria. During time of experiment, the two men must keep their life and activities in the same pattern, for examples, they have a shower in the evening and in the morning after collecting the sample. They only use deodorant in the morning after taking a shower and only on the right arm, leaving the other side untouched and have no sex and alcohol.

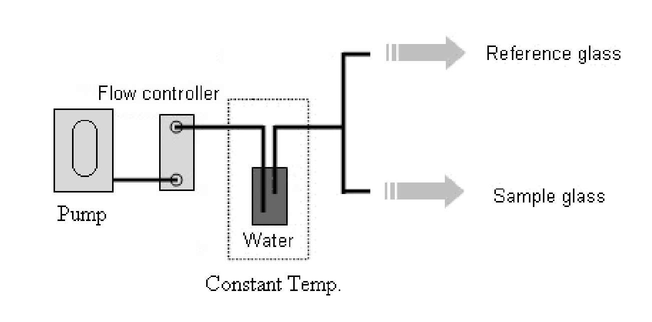


Figure 2. Schematic diagram of humidity control using hardware-based method .

III. RESULTS AND DISCUSSION

A. *Humidity Control*

The humidity [%RH] was varied from 30 % to 80%. Each sensor detects different humidity as shown in Fig. 3. Resistances arisen from humidity of TGS 813, TGS 825, and TGS 2602 sensors are displayed in Fig. 3.1, 3.2 and 3.3, respectively.

The graphs of TGS 822 and TSG880 are not show in this paper of which behaviors is similar to TGS 813. The mathematical models for the resistance relative to humidity of each sensor were employed to fit the data via the following formulation;

Exponential equation of TGS 813;

$$Rs_{813} = 86682.00\exp\left(\frac{-[\%RH]}{29.05}\right) + 55063.48 \quad (1)$$

Exponential equation of TGS 822;

$$Rs_{822} = 24931.58\exp\left(\frac{-[\%RH]}{37.48}\right) + 9054.41 \quad (2)$$

Exponential equation of TGS 880;

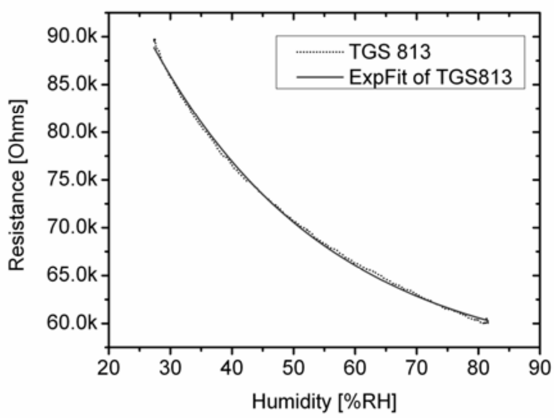
$$Rs_{880} = 90496.88\exp\left(\frac{-[\%RH]}{36.33}\right) + 55135.22 \quad (3)$$

Polynomial equation of TGS 2602;

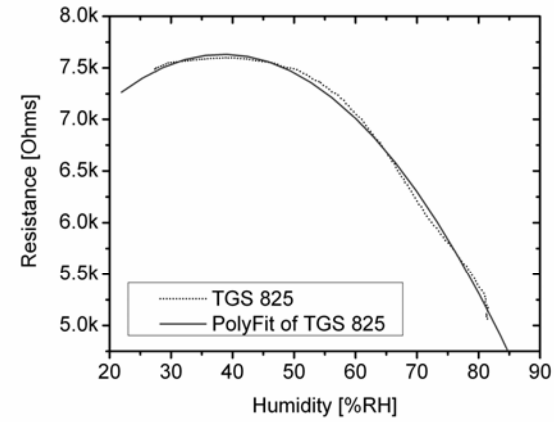
$$Rs_{2602} = 6958.22 + 129.172[\%RH] - 0.9788[\%RH]^2 \quad (4)$$

Polynomial equation of TGS 825

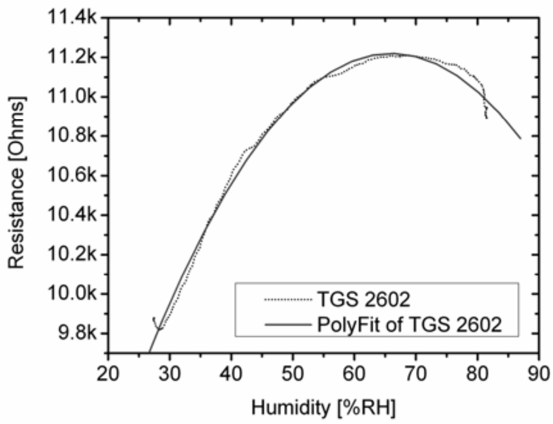
$$Rs_{825} = 5646.63 + 103.26[\%RH] - 1.34[\%RH]^2 \quad (5)$$



(a)



(b)



(c)

Figure 3. Resistance of sensor (a) TGS 813, (b) TGS 825 and (c) TGS 2602 relative to their humidity.

These mathematical models were included in the programs for measurement of the human body odors. The percentage change of the resistance relative to the relative humidity change was recalculated as show in Fig 4. This scheme is defined as software correction.

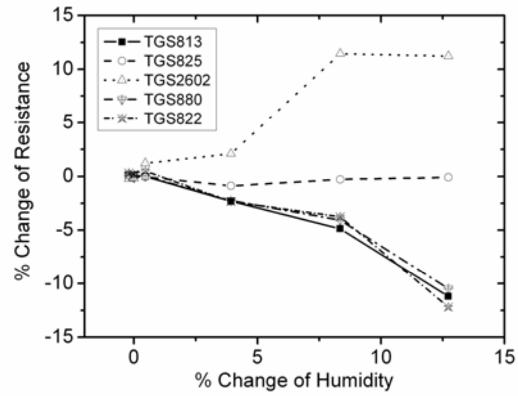


Figure 4. The percentage change of the resistance relative to the percentage humidity change.

From Fig. 4, one can observe that the humidity directly affects the resistance of sensors except for TGS 825. Therefore, it is necessary to remove the humidity effect via software correction during data analysis process.

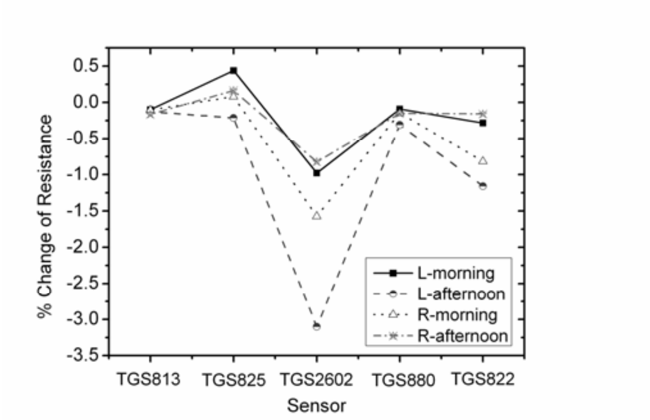
However, to get a maximum preciseness, the hardware correction was employed to reduce the humidity effect (See Fig. 2). The armpit odor of a person on a cotton pad was tested. Table II shows the percentage change of resistance upon varying humidity; 25%, 50% and 75%. From Table II, it indicates that when we put higher relative humidity in the system, the changing of the resistance between the reference (pure cotton pad) and sample (cotton pad with human body odor) according to the humidity change will become less. This will ensure that the E-nose only detects the human body odor not the humidity. Therefore, relative humidity at 75% was added in all experiments for measuring the human body odors.

TABLE II
THE PERCENTAGE CHANGE OF RESISTANCE OF EACH SENSOR UPON VARYING HUMIDITY GENERATED BY HARDWARE CORRECTION

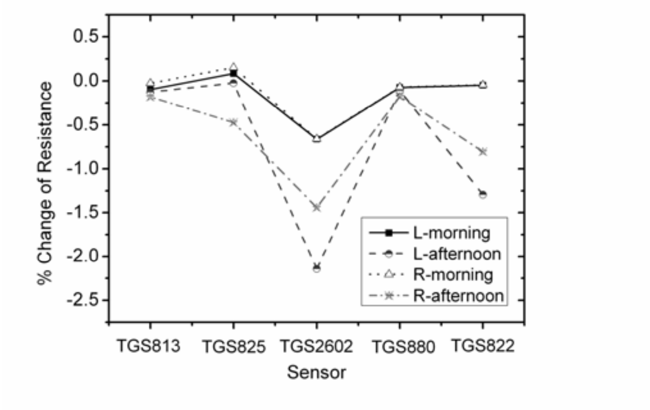
%Hu.	TGS813	TGS825	TGS2602	TGS880	TGS822
25%	-3.166	-2.257	3.587	-3.292	-3.156
50%	-0.609	-0.081	-0.321	-0.885	-1.786
75%	0.164	-0.052	-0.596	0.155	-0.182

B. *Detection and Classification of Human Body Odor*

After controlling humidity effect, human body odors of two volunteer persons were measured during 5 days. Comparison of the percentage change in resistance of each sensor which detects left and right underarm odors in the morning and afternoon of person A and person B (average of 5 days) is presented in Fig. 5a and 5b, respectively.



(a)



(b)

Figure 5. The body odors of (a) person A and (b) person B in morning and afternoon.

From the results, it shows that there are only 2 sensors; TGS822 and TGS2602 which have high sensitivity. These sensors have changing resistance in a range of 1-3 % while the resistance changes of other sensors are less than 1%. Therefore, such sensors may be suitable for detecting human body odor. For analysis odor of each person in the morning and afternoon, these data corresponds with the real situation. In the morning two persons have only a weak odor while the strength of odor increases in the afternoon. When a person use deodorant (the left armpit), the strength of odor generated from bacteria or sweat is reduced comparing with the right armpit (with deodorant).

The data were introduced into the principle component analysis (PCA) method for classification of human body odor. The PCA result is shown in Fig. 6. The first principal component (PC1) explains 74.0% of the total variance and the second principal component (PC2) contributes 21.7% of the variation.

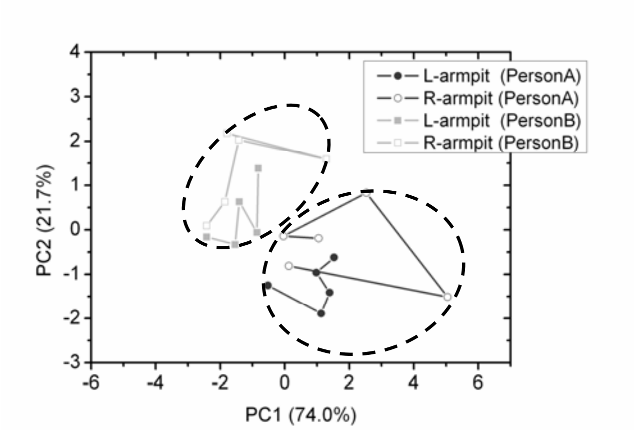


Figure 6. The 2D-PCA of the 2 different persons.

The PCA result shows clear classification of 2 persons. It indicates that each human body has a specific odor pattern although these people have similar life style. As a result, it may be useful in an identification or authentication of a person [8].

IV. CONCLUSION

The humidity is one of the most serious problems in the use of gas odor sensor and detection of human body odor. There are two ways to solve this problem, which are hardware-based and software-based methods. However, to get a maximum preciseness, the hardware based and software based methods were combined. After humidity correction, the E-nose shows the efficiency in detection of human body odor. Combined with PCA method, the E-nose is able to classify the human body odor of two different persons.

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