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# Gas Sensor Array for Quantitative Detection of Gas Mixture

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***Abstract*—two semiconductor gas sensors which are sensitive to methanol and acetone were chosen to form a gas sensor array. Response of sensor array combined with pattern recognition technique of artificial neural network was used to carry out the quantitative analysis of gas concentration in a mixture. Separate gas is injected on gas sensor to understand the sensitivity of sensor upon change in gas concentration. Gas mixture of different acetone and methanol gas composition is prepared and response on sensor array is acquired. The acquired data is a function of concentration profile of gas mixture. Data is pre-processed and given to neural network for quantitative analysis of gas concentration of the mixture. The results show that the system can analyze the gas mixture and produce quantitative data with good accuracy.***

***Keywords*— Semiconductor gas sensor, quantitative detection, sensor array, neural network, pattern recognition.**

## I. INTRODUCTION

During the last 20 years there has been a rapid development of the "*electronic nose"* concept. Electronic nose is an array of chemical gas sensors with a broad and partly overlapping selectivity for measurements of volatile compounds over a sample combined with pattern recognition tools. [1] Since a single gas sensor is always sensitive to several gases, using a gas sensor array qualitative and quantitative analysis of relatively complex gas mixture is possible. There are various applications of sensor array system which includes quality control of food, environmental air quality monitoring, safety and military applications. [2-5] Quantitative detection of a gas mixture using gas sensor array can be divided into the steps: 1.Sensor array response acquisition upon gas mixture injection to obtain the pattern. A gas mixture is detected using gas sensor array and then distinguishing the array response by means of pattern recognition techniques to detect gas volume in the gas mixture. [6]

In this paper, we propose two commercially available semiconductor gas sensor arrays in combination with artificial neural network structure to construct a system for quantitative detection of methanol and acetone. The proposed system is able to estimate the concentration of gas over a wide range with good accuracy.

## II. GAS SENSOR ARRAY SYSTEM

Each gas sensor is sensitive to many gases but with varying degree. If we have n gas components with concentration $c_1,c_2..c_n$ in a gas mixture, then the response of a gas sensor r is expressed as:

$$r = f\,(c_1,c_2,\ldots c_n)$$

The above equation reflects complex cross sensitivity of a gas sensor. When a gas is injected onto the surface of gas sensor, there is a change in resistance which converts into change in voltage. Thus, an output voltage vector is obtained whose value depends upon the concentration of gas species and type of gas sensor used. A Pattern recognition technique receives the output vector of sensor array to estimate the concentration of unknown gas. [7] The formation of mapping relation from sensor responses to gas concentration depends on the self-learning network. In this work, MQ3 and MQ135 are chosen to obtain sensor response for acetone and methanol gases at various concentration levels.

 

## III. ARTIFICIAL NEURAL NETWORK

The neural network is a complex network system connected extensively by the large number of neurons. The interactions between the neurons reflect through the connected weights. The output of neurons is the function of its input.

### *A. Back-Propagation artificial neural network*

The BP neural network is a multilayer feed forward network composed by non-linear neurons. Its structure is shown in Figure 1. Besides input layer A and output layer C in the neural network structure, there is hidden layer B in one layer or multilayer. Input signal propagates from input layer nodes and pass through every hidden layer node in proper order, then to output nodes. Each layer nodes only influence the outputs of next layer nodes. In Figure 1, m and n denote the number of sensors and gas concentrations respectively. The term u denotes the number of neuron in hidden layer. Wir and Vrj denote the connecting weight from ai to br and from br to cj respectively, Tr and θj denote the node threshold of hidden layer and output layer respectively. The weights and threshold are updated repeatedly until the error, difference between target and estimated gas concentration, is minimized. When error reaches the expected value, the learning process of neural network is end and then network can be used to estimate unknown gas concentration.

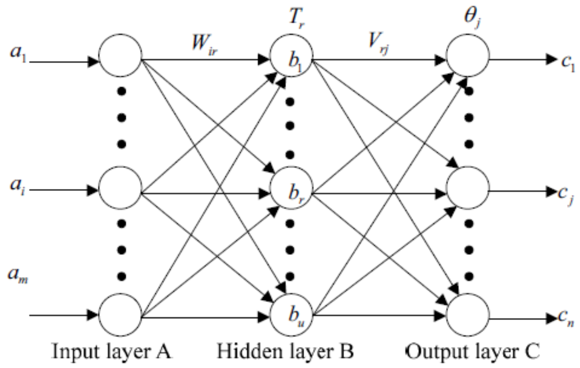


Fig. 1 Structure of Back-Propagation neural network

## IV. EXPERIMENTATION

The sensor array consisting of two MOS gas sensors are placed in a test chamber having volume of 150 ml. Various combinations of acetone and methanol were injected on sensor array and the sensor response is recorded. The volumetric flow was kept constant in the experiment. The steps in experimentation were as follows.

### *A. Preparation of sample*

Experimentation is done on gas sensor by injection of single gas or mixture of gas sample. First, required concentrated solution was prepared in a test tube by adding known volume of solute into water which is used as a solvent. Then, the solution was heated to obtain the required concentration in gas phase. The gas is then collected using a syringe and injected on sensor array.

### *B. Data acquisition*

In the experimental setup, two semiconductor gas sensors, MQ 3 and MQ 135, are selected to construct the array which is sensitive to acetone and methanol. The sensors are excited with 5V regulated power supply and its output voltage is measured across 1kΩ load resistor. These sensors have different sensitivity for both the gases. The concentration of two gases is restricted from 500 ppm to 2000 ppm. The interval was set as 500 ppm. Upon injection of the gas, peak output voltage of gas sensors is recorded.

### *C. Data pre-processing*

The aim of preprocessing is to reduce the interference factor to the maximum and make it possible to compare with each output of different sensor. It includes normalization of the gas concentration and sensor output signal. Concentration and output signal is normalized by given equations.

$C_{nor} = C\text{-}C_{min} /(C_{max}\text{-}C_{min})$

$V_{nor} = V\text{-}V_{min} / (V_{max}\text{-}V_{min})$

Where $C_{nor}$ and $V_{nor}$ are the normalized values, $C_{max}$ and $C_{min}$ are maximum and minimum concentration and $V_{max}$ and $V_{min}$ are maximum and minimum output voltage of sensor. This normalization helps to compensate the temperature sensitivity of sensor.

 

## V. EXPERIMENTATION RESULTS

Experiments were done to understand the sensitivity of gas sensors for acetone and methanol at different concentration. The sensor responses as represented are output voltage which is proportional to the change in resistance of gas sensor upon injection of gas. Figure 2 shows the sensor response of MQ 3 for acetone and methanol gases and gas mixtures at different concentration levels. The response shows a non linear nature. Sensor response of MQ 135 gas sensor was also examined for the same gases as plotted in figure 3. The responses indicate that the gas sensor array is sensitive to both the gases and sensor voltage increases as concentration level increases.

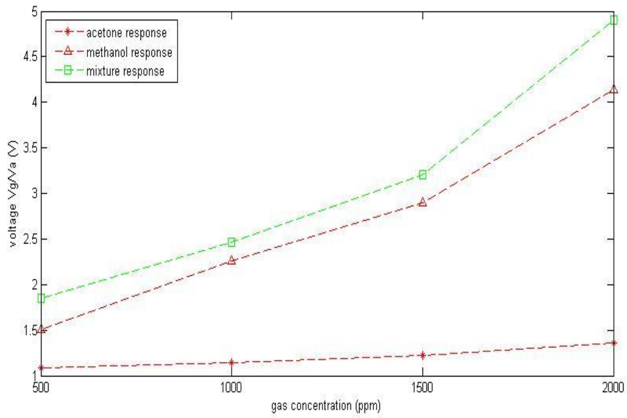


Fig. 2 MQ3 sensor response to individual gas and gas mixture

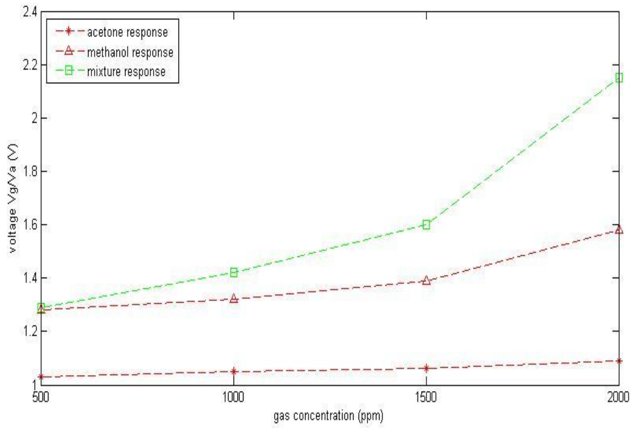


Fig. 3 MQ135 sensor response to individual gas and gas mixture

The sensor responses for gas mixture at different concentration were normalized and inputted to Artificial Neural Network (ANN). The ANN structure has two input neurons which receive the response of MQ 3 and MQ 135 gas sensors, two hidden layers having four nodes each and two output neurons indicating the concentration of acetone and methanol.

Experimental data were selected to train the neural network. Neural network uses the experimental data to estimate the concentration of gas. The error curves of predictive and practical concentrations of acetone and methanol are shown in figure 4 and figure 5. The figures indicate that the ANN structure can approximate the gas concentration in a mixture by knowing the response of gas sensors.

 

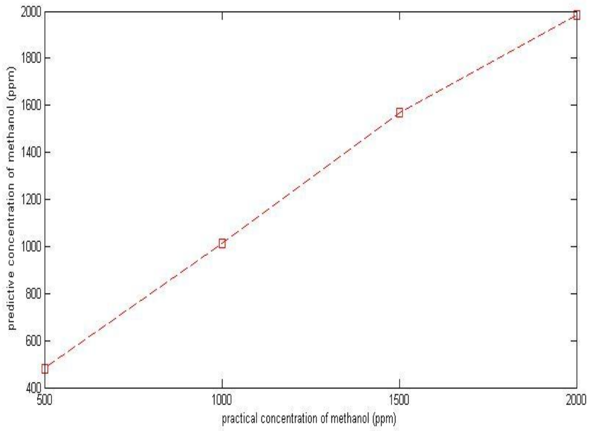


Fig. 4 Predictive error of methanol concentration

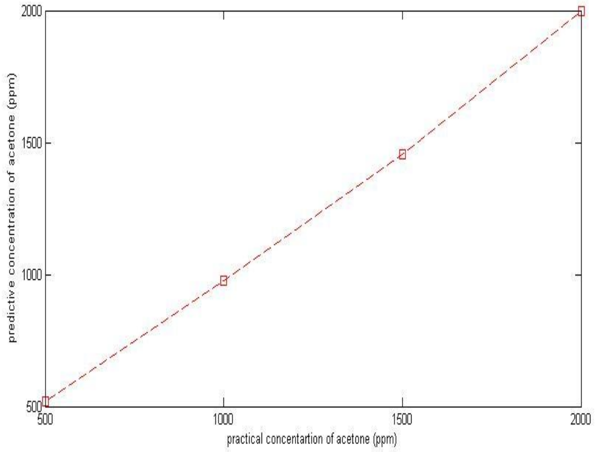


Fig. 5 Predictive error of acetone concentration

## CONCLUSIONS

In the paper, semiconductor gas sensor array is proposed in connection with back propagation neural network to provide quantitative information of gas mixture. Sensitivity of gas sensors for target gases was examined to justify their use in sensor array. Output of sensor array is preprocessed by normalization technique and concentration of gas is approximated using neural network structure. The results showed high correlation between predicted and practical values for different gas concentrations in gas mixture.

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