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THE PROPOSAL OF GAS IDENTIFICATION METHOD BY FUZZY REASONING

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ABSTRACT

We tried gas identification by using one semiconductive gas sensor. As a method of gas identification, we used the fuzzy reasoning with fuzzy set of slope of gas pattern which is divided into arbitary interval. As a result, we got a good successful rate for hydrogen 66.6%, propane 79.1%, butane 100%, methane 100%, city gas 79.1% and alcohol 91.6%, respectively.

NOTE:fuzzy reasoning, gas sensor

INTRODUCTION

Many studies have been done on gas sensors. Numerous detecting systems equipped with gas sensors of sintered powders are commercially available, and they are considerably used in usual domestic affairs. But it is difficult to give them good selectivity of gas species. In order to improve the selectivity, recent studies seems to be directed towards intelligent sensors of having different characteristics for identification of the gas species. Their method is to identify the gas species from response pattern of many gas sensors of different characteristics by using pattern recognition.

In this paper, we propose a new simple identification method of gases by fuzzy reasoning. The sensitivity of sensor depends upon the heater temperature. We made use of characteristics of sensor's output, which is different from each gas, by changing sensor's temperature. By using fuzzy reasoning, we identified the gas species from the characteristics curve of transition response pattern.

EXPERIMENTAL

We showed the hardware constitution of the prototype in Figure 1. The analog signal from the sensor is sent to the personal computer through the output of digital voltmeter at interval of one second. The data are stored at floppy disc.

When we change the heater voltage from standard through the D/A transformation board, the output voltage of each gas , which is dependent upon the gas species, change suddenly. Six gas species (methane, propane, butane, hydrogen, alcohol, and city gas) were used as the sample gases. One commercial sensor (FIGARO 813) was used. Each gas was introduced into a vessel(volume 2.4) through an inlet at the top of the vessel by using a syringe. The volume ratio of the introduced gases were estimated 400-1800ppm.

The identification of gases is done by recognizing the change of transition response pattern. Figure 2 shows a example of transition response pattern of hydrogen, city gas methane,

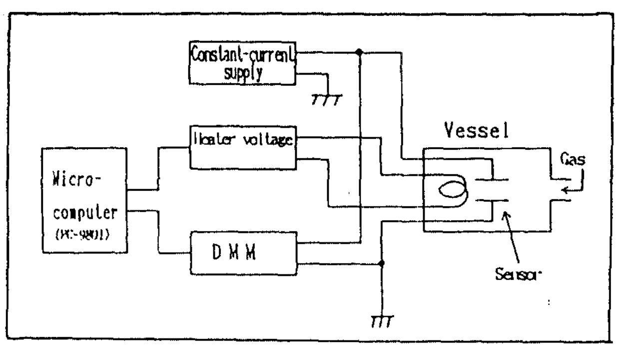


Figure 1 Experimental apparatus used for gas discrimination.

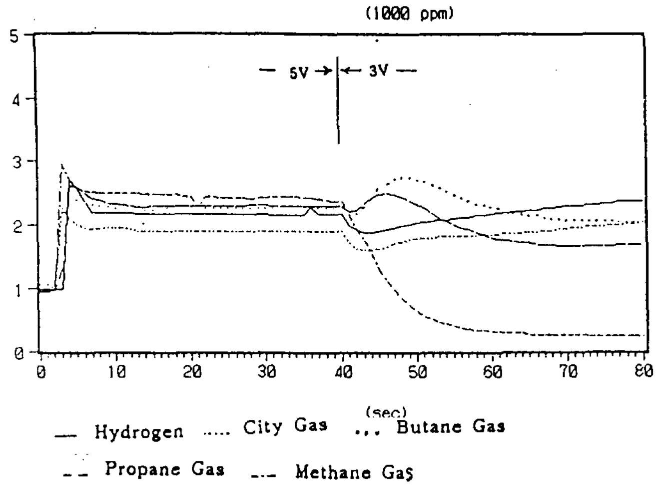


Figure 2 The transition response pattern of output of sensor by changing from 5V to 3V at sensor's temperature.

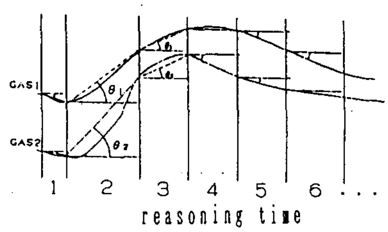
propane and butane. This pattern can be obtained by changing heater voltage from 5V to 3V. The concentrations of the gases were 1000ppm in these patterns. Horizontal axis shows the sequential time data and vertical axis shows the output voltage of sensor. As these transition pattern shows peculiar characteristics of each gas, we can identify gas species by recognizing these pattern.

FUZZY REASONING

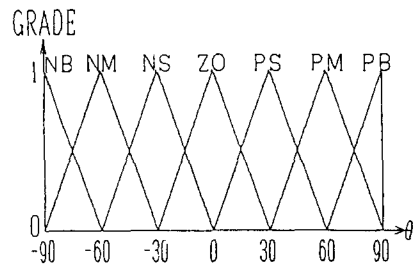
We proposed the identification of gas species by fuzzy reasoning. Membership functions are defined for slope angle at each divided partition , which shows the number of times for inference, as shown in Fig 3. Suppose that this slope angle at one divided partition are defined by fuzzy set A , where its element shows grade of NB to PB. The following matrix R was made on the basis of compositional rule of inference, where each element ai,j represents the grade of membership function of each gas species. Suffix i shows gas species and j shows the label of membership function. In practice, its elements are obtained experimentally by accumulating sufficiently data. Fuzzy sets of output B which element shows gas species may be written as

$$B=A \cdot R \qquad (1)$$

, where each element of matrix B shows the grade of gas species. Now we can get a slope angle from



(a) The transformation to angular value of sensor voltage



(b) Membership functions between −90°∼+90° for fuzzy reasoning system

Fig. 3

sensor's pattern. The decision system of gas species is defined by the following simple rules,

Partition 1: if slope angle is aij then gas is Bi
Partition 2: if slope angle is aij then gas is Bi
|
|
|
Partition n: if slope angle is aij then gas is Bi

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decision : Gas is Bi

This partition shows the number of divided partition.

For each gas species, we calculate respective grade of membership functions for matrix A. Output matrix B can obtained by using eq.(1).

At first, for partition 1, the grades B of 6 gas species can be obtained, respectively. Secondary, the grades B of partition 2 can be obtained. For each gas, the logical product of partition 1 and 2 are calculated. When the calculated grade of each gas become smaller than limitation value, its gas is removed. We repeat this process until gas species is determined.

RESULTS AND DISCUSSIONS

Using the proposed Fuzzy reasoning, wemade computer calculation for the identification of gas species from the experimental data. The results

Table 1 Results of gas discrimination

Gas name	Number of data	Number of fault	Successful rate(%)	Reasoning time(Av.)	Gas name of an error in discrimination
hydrogen	24	8	66.6	8	Alcohol, City gas
propane	24	5	79.1	3.04	Butane
butane	24	0	100	4.78	——
methane	24	0	100	2	——
city gas	24	5	79.1	8	Hydrogen, Alcohol
alcohol	24	2	91.6	5.5	Hydrogen, City gas

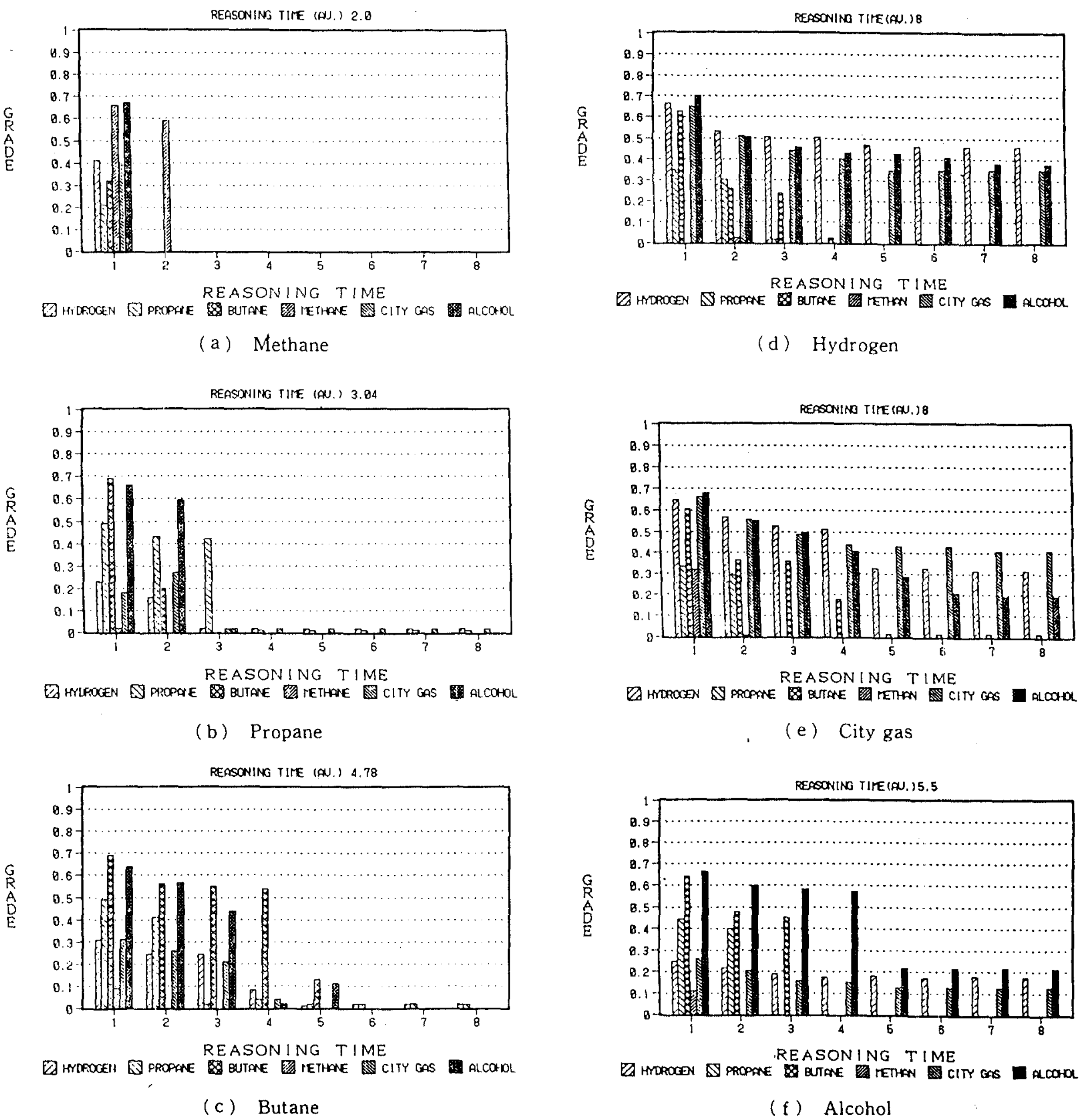

Fig. 4 The gas grade of each reasoning time on the average of 24 times measurement

are shown in Table 1. Rates at the successful identification were considerably high. However this rate for hydrogen was not so high. Its successful rate was 66%. Gas name of an error in identification was alcohol and city gas. Figure 4 shows the gas grade of each reasoning time on the average of 24 times measurements. As the grade of objective gas is highest value for each gas, our proposed method seems to be useful. Though the number of mean inference is 8 times for hydrogen and city gas, there is no change of grade after 5 times of inference. From the present experiment for six gases, we can get the following results.

Methane: methane is identified at least 2 inference times. This pattern is characteristics, compared with their ones of gases. It is easy to identify. The sensitivity gradually decreases after changing from 5V to 3V.

Propane: The characteristics of propane has falling line through rising line , as shown in Fig.2. It is identified at 3 inference times.

Butane: The shape of its pattern is similar to the one of propane. Time showing falling line is later than one of propane. Number of Its inference times is 4.

Alcohol: The grade is very large in rising line where we can identify. Mean number of inference times is about 5.5.

Hydrogen: Though shape of the hydrogen pattern is similar to alcohol and city gas, the rising rate is slight different. The reasoning seems to be carried out at its slight different pattern.

City gas: Main conponents in city gas used in our experiment were hydrogen.
Therefore it is difficult to identify the difference between hydrogen and city gas.

From results of the present experiment for given gases, gas species are successfully identified in all cases. Though gas identification by only one sensor is a very simple method, it is useful method to identify the inflammable gases. Further study is necessary on the sensors and the identification method itself.

SUMMARY

The identification method of gases by using Fuzzy reasoning is proposed in this paper. From results of the present experimental for given gases, gas species are successfully identified in all cases. Though gas identification by only one sensor is very simple method, it is useful method to identify the inflammable gases. We got a good successfull rate for hydrogen 66.6%. propane 79.1%, butane 100%, methane 100%, city gas 79.1% and alcohol 91.6%, respectively. In order to improve the rates of the successful identification, further study is necessary about the sensors and the identification method itself.