DOI 10.5162/IMCS2018/P2GS.19

Catalytic Combustion-Type Gas Sensors Using Fe_2O_3-Based Thin Film as a Temperature Sensing Resistor

Takeshi Nakajima, Tomiharu Yamaguchi, Kazuhiro Hara
Tokyo Denki University, 5 Senjuasahi-cho, Adachi-ku, Tokyo 120-8551 Japan
hara@eee.dendai.ac.jp

Abstract :

Novel catalytic combustion-type gas sensors using Fe_2O_3-based thin film have been developed. The sensor output voltage was enhanced by adopting Fe_2O_3-based film as a temperature sensing resistor which had higher temperature coefficient of resistance than that of Pt. Thin film technology, IC fabrication process and MEMS technology were utilized to fabricate the sensing film and the meander-type heater on an insulating diaphragm. Pd dispersed on γ-alumina and γ-alumina were used for the sensing element and the reference element, respectively. In this study, the target gases were H_2, C_2H_4, C_2H_6, CH_4, C_3H_8 and CO. The sensor was able to detect each gas at low gas concentrations (10 ppm for H_2, C_2H_4, C_2H_6, C_3H_8 and 70 ppm for CH_4).

Key words: catalytic combustion, gas sensor, Fe_2O_3-based thin film, thermistor, MEMS technology

Introduction

Catalytic combustion-type gas sensors have the advantage that it is hardly affected by water vapor and exhibits high gas selectivity to combustible gases. On the other hand, however, they are disadvantageous in that its power consumption is large and it is difficult to detect low concentrations of combustible gases. Various catalytic combustion-type gas sensors such as the one adopting Pd or Pt/titanate nanotube as catalysts[1] and the adsorption/combustion-type one[2] have been studied to improve the characteristics. This paper presents novel catalytic combustion-type gas sensors with improved output voltage using Fe_2O_3-based thin film as a temperature sensing resistor.

Sensor Configuration

A developed sensor is shown in Fig. 1. The material for the sensing film, the heater electrode and the thermistor electrode is Fe_2O_3+TiO_2(5mol%)+MgO(4mol%) , Cr/Pt/Cr and Cr/Pt, respectively. Pd dispersed on γ-alumina and γ-alumina were used for the sensing element and the reference element, respectively.

Sensor Fabrication

All the films were deposited by r.f. sputtering on a Si substrate. The heater and the Fe_2O_3-based film were sequentially deposited so as to be sandwiched between the insulating films. An insulating diaphragm was formed by deep reactive-ion etching of Si.

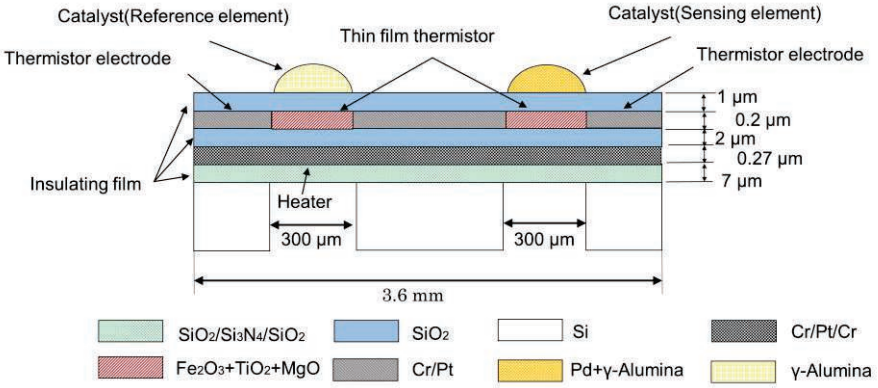

Fig. 1. Cross-sectional view of a developed sensor.

Pd dispersed on γ-alumina was prepared by mixing Pd and γ-alumina nanoparticles in a solution containing PVA, coating it on the top insulating film and sintering at 450°C, while only γ-alumina was coated for the reference element. In this study, 10 wt% of Pd was added to γ-alumina for the sensing element.

Experimental Results

The power consumed by the heater was 68 mW for the sensing element when the operating temperature was 330°C.

The detection circuit is shown in Fig. 2. The output voltage change (ΔV) is defined as eq. (1).

$$\Delta V = V_{air} - V_{gas}. \quad (1)$$

Here V_{air} and V_{gas} are output voltages in air and air containing gas, respectively.

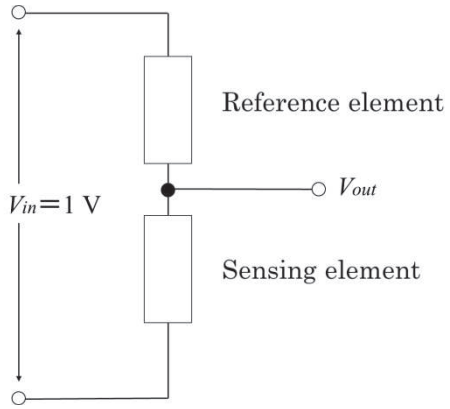

Fig.2. Detection circuit.

The dependence of the output voltage change on the gas concentration is shown in Fig. 3. The operating temperature for each gas was chosen as the one where ΔV was the highest; the operating temperatures are indicated in Fig. 3. It should be noted that the sensor was sensitive at concentrations as low as 10 ppm for most gases and 70 ppm for methane.

Discussion

In this study, conventional catalysts were used and the temperature rise associated with catalytic combustion on the catalysts was detected in a similar way as conventional catalytic sensors. However, combustible gases at low concentrations were able to be detected because the Fe_2O_3-based thin film had much higher temperature coefficient of resistance than that of Pt, which was used as a temperature sensing resistor in conventional sensors.

References

[1] C.-H. Han, D.-W. Hong, I.-J. Kim, J. Gwak, S.-D. Han, K. C. Singh, Synthesis of Pd or Pt/titanate nanotube and its application to catalytic type hydrogen gas sensor, *Sensors and Actuators B*, 128, 320-325 (2007); doi : 10.1016/j.snb.2007.06.025.

[2] Takeo Hyodo, Takumi Hashimoto, Taro Ueda, Osamu Nakagoe, Kai Kamada, Takahiko Sasahara, Shuji Tanabe, Yasuhiro Shimizu, Adsorption/combustion-type VOC sensors employing mesoporous γ-alumina co-loaded with noble-metal and oxide, *Sensors and Actuators B*, 220, 1091-1104 (2015); doi : 10.1016/j.snb.2016.06.065.

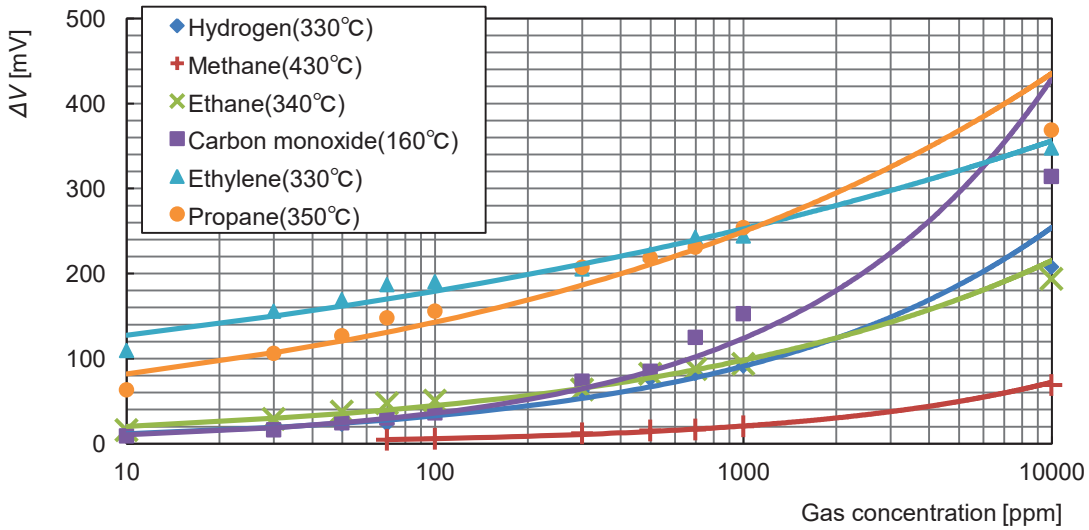

Fig.3. Dependence of the output voltage change on the gas concentration.