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Micro gas sensor by MEMS processes for selective dual gas detection of carbon monoxide and methane

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Abstract

We have designed and fabricated micro platform for gas sensor including micro heater and electrode using micro electro-mechanical system (MEMS) processes, and SnO_2 nanopowder have been mounted on the platform. The fabricated micro platform was 2.5 mm × 2.5 mm in size and power consumptions were 9 mW and 110 mW for CO and CH_4 operation temperatures, respectively. The gas sensing performances for 200 ppm CO and 12,500 ppm CH_4 were investigated at 50 °C and 330 °C.

Key words: MEMS, gas sensor, CO, CH_4, periodic temperature modulation

Introduction

Many researches have conducted to develop the gas sensors using semiconductor metal oxide, and most of applications were limited within safety systems in domestic and industrial areas. However recently, the gas sensors must have a high sensitivity and accuracy, and fast response because of increasing application fields, such as ventilation controls, cooking controls, combustion controls, automobile, and odor detection, etc. [1]. Normally, practical and effective gas detection with semiconductor metal oxide requires an optimized operating temperature [2]. Moreover, low power consumption offers the possibility of wide application. Especially selective detection of carbon monoxide and methane is required for many applications in the field of fuel combustion. Thus, several ways within the electronic interface circuit can be employed for controlling the heater [3].

In our work, a micro platform for gas sensor was designed and fabricated using micro-electro-mechanical systems (MEMS) processes. The semiconductor metal oxide, SnO_2 was used as a gas sensing material. The gas sensing performances of CO and CH_4 of their STEL (short time exposure limit) and %LEL (lower explosion limit) were investigated.

Experiments

The micro platform for gas sensor including micro heater and interdigitated electrode on the membrane was designed as shown in Fig. 1. A p-type Si (100) wafer with 500 μm thickness and 4 inch diameter was deposited by 2 μm thickness SiN_x film on both sides using LPCVD (low pressure chemical vapor deposition). A platinum film with thickness of 200 nm was deposited on the front side of the wafer and micro heater was formed by photolithography. The insulation layer, SiO_2- SiN_x-SiO_2 by PECVD (plasma enhanced chemical vapor deposition) deposited on the micro heater. Then the interdigitated electrodes which were 150 nm thickness of platinum were formed by photolithography. Finally, the membrane formed on the back side of the wafer by anisotropic etching of the bulk silicon using KOH solution.

The sensing material, SnO_2 nanopowder (Tin(IV) oxide, APS 80nm, American Elements) was applied on the interdigitated electrode of the micro platform by screen printing and heat treatment at 400 °C for 1 h. Fig. 2 shows the simple circuit which was operated a gas sensor in the chamber, measured the voltage across

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load resistance (V_{out}) as a sensing signals. The gas sensing properties of the dual gases, CO and CH_4 were investigated as a function of their concentration.

Results and discussion

Fig. 3 shows the power consumption with heater voltage (V_H) of MEMS micro platform. The average power consumptions of MEMS micro platform were typically increased. The measured power consumptions were 9 mW and 110 mW at low and high heater voltages which were corresponded to modulation temperatures, 52.8 °C and 331 °C, respectively.

The gas sensing properties of the CO and CH_4 gases were tested with sensor operation circuit shown in Fig. 4. The output voltage (V_{out}) means a voltage across load resistance and the

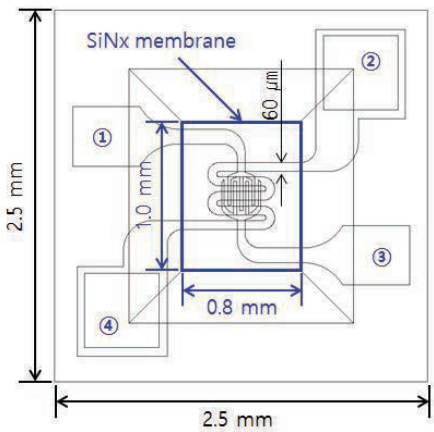

Fig. 1. The design of micro platform for gas sensor (①, ③: interdigitated electrode pads, ②, ④: micro heater pads)

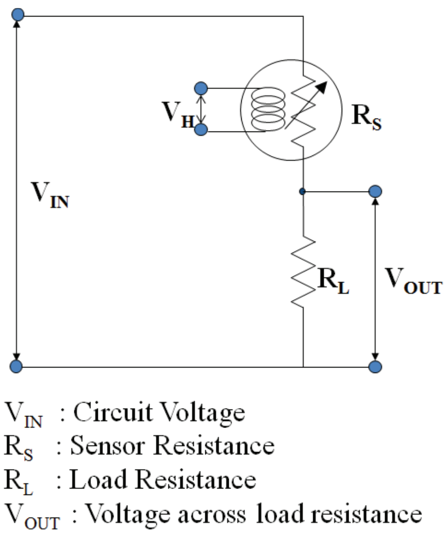

Fig. 2. The simple circuit diagram for gas sensor operation,

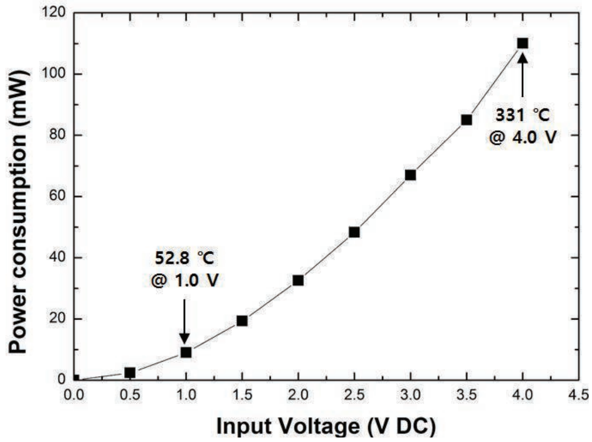

Fig. 3. Measurement of power consumptions with heater voltages (V_H) of the micro platform

V_{out} value was adjusted 0.1 V in air using variable resistor. Different operation temperatures between CO and CH_4 tests were realized through change of applied micro heater voltages (V_H), 1 V for CO and 4 V for CH_4. The gases concentrations for the test were 200 ppm of CO and 12,500 ppm of CH_4 because of correspond to STEL (short time exposure limit) and 25 %LEL (lower explosion limit), respectively. The difference of V_{out} ($\Delta V_{out} = \Delta V_{out,\ gas} - \Delta V_{out,\ air}$) were 349 mV for 200 ppm CO and 1,301 mV for 12,500 ppm CH_4.

Furthermore, compared to Fig. 4 (a) and (b), the response of CH_4 can be seen further sharpness, therefore the response time of CH_4 was faster than that of CO. On the basis of these results, dual gases detection is possible with single gas sensor through the periodic operation temperature modulation.

Conclusion

The micro gas sensors, 2.5 mm × 2.5 mm in size were fabricated by MEMS processes. Their detection characteristics to CO and CH_4 were measured at different operation conditions. The power consumptions of micro platform were 9 mW and 110 mW for 1 V and 4 V of V_H, and their temperatures of micro heater surface were 52.8 °C and 331 °C, respectively. Gas detection performances of single sensor device were investigated for dual gases, 200 ppm CO and 12,500 ppm CH_4. The output signals in the operation circuit were 349 mV and 1,200 mV for CO and CH_4, respectively. Dual gases detection is possible with single gas sensor device through the change of their operating conditions.

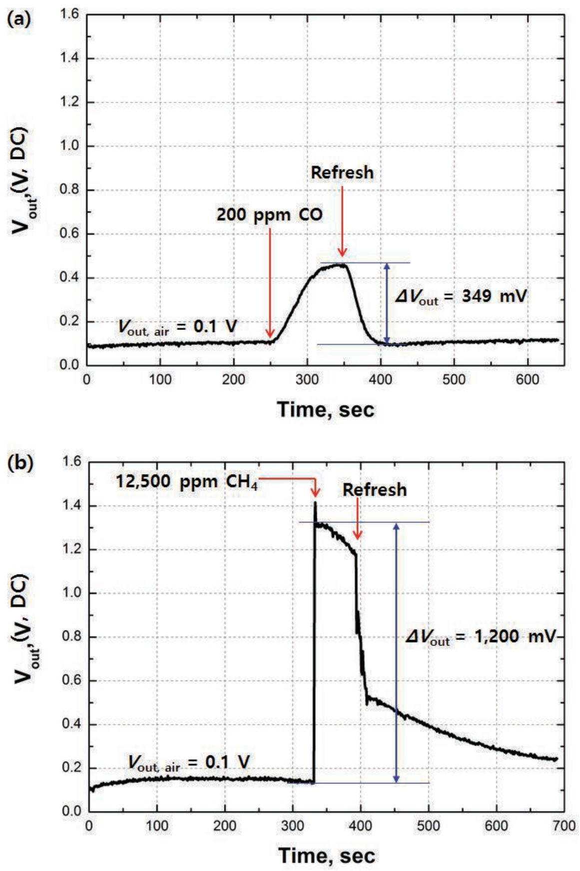

Fig. 4. Gas sensing properties for (a) 200 ppm CO and (b) 12,500 ppm CH_4

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