Micromachined Thermoelectric Hydrogen Sensor

K. Tajima, Y.Choi, W. Shin, N.Izu, I.Matsubara, N. Murayama.

Advanced Manufacturing Research Institute, AIST, Shimo-Shidami, Moriyama-ku, Nagoya, 463-8560, Japan
email: k-tajima@aist.go.jp
http://www.unit.aist.go.jp/amri/

We prepared the micromachined thermoelectric hydrogen sensor with the combination of the thermoelectric effect of SiGe thin film and the Pt-catalyzed exothermic reaction of hydrogen oxidation. The sensor operating at 100°C detected hydrogen for the concentration from 0.01 to 3% in air, with a good linearity of voltage signal versus gas concentration.

Hydrogen is the most attractive and ultimate candidate for a future fuel and an energy carrier, because it burns cleanly, does not require a fuel processor in fuel cells, and is producible from renewable energy resources, such as electricity from solar cells. A common need in this technology area is the ability to detect and monitor gaseous hydrogen, but hydrogen gas sensors that can quickly and reliably detect H_2 over a wide range of oxygen and moisture concentrations are not currently available.

Recently, our research group has demonstrated the basic operation of novel thermoelectric hydrogen sensor [1]. This sensor takes advantage of both thermoelectric, TE, effect and selective catalytic reaction. Using the very well known knowledge that platinum has a high selectivity for H_2 oxidation near room temperature, platinum was used as catalyst layer and SiGe was used as thermoelectric layer, to fabricate the thin-film type sensor device[2, 3]. Micromachined gas sensors are a new generation of sensor technology combining existing integrated circuit fabrication technology with novel deposition and etching processing. This sensor structure provides a platform where the operating temperature can be rapidly changed to achieve desired response characteristics, known as a micro-heater. The combination of thermoelectric hydrogen sensor with the micro-hotplate on a suspended thermal isolation structure has led to hydrogen sensors that demonstrate an array of highly desirable features, such as fast response speeds, high sensitivity, and amenability to mass production.

The first step of sensor manufacture process is to deposit SiGe thin film on the $Si_3N_4/SiO_2/Si$ substrate using RF-sputtering method. Since as-deposited SiGe thin film was amorphous, thermal annealing process was adopted to crystallize SiGe thin film. The platinum micro-heater and the gold electrodes were patterned by photolithography and lift-off technique. The third and last step is the back-side etching using KOH solution and the deposition of the platinum catalyst.

A gas flowing system with a small test chamber was employed to evaluate the hydrogen sensing properties. An IR camera was used to monitor the surface temperature of the element. The temperature data and the voltage signal of the element as well as the gas flow were automatically processed or controlled by a computer. By introducing the mixture gas of hydrogen in dry air and dry air alternately into the measurement chamber with the rate of 100cc/min, Pt catalyst oxidized the hydrogen gas and elevated the temperature of the catalyst evaluated which was monitored using the IR camera. This induces the temperature difference at the thermoelectric SiGe thin film on the membrane, and thermovoltage is read from two ends of SiGe thin film.

Figure 1 shows the hydrogen response of the micromachined thermoelectric sensor at 100 °C and gas concentration. The voltage signal of the micromachined thermoelectric hydrogen sensor for 1% H_2 gas in air was almost same level to previous reports [2, 3], where the temperature gradient developed between the cold- (A) and hot side (B) was also similar to that of microsensors. For 1% hydrogen, the temperature difference, ΔT_{A-B}, b/w cold- and hot side of the microsensor was 3.41 °C at operating temperature of 100 °C. Considering the voltage signal of 0.38 mV, the $\Delta V/\Delta T = 0.111$ mV/K. The relation between gas concentration and voltage signal was linear for this microsensor device structure as shown in Fig.1(b).

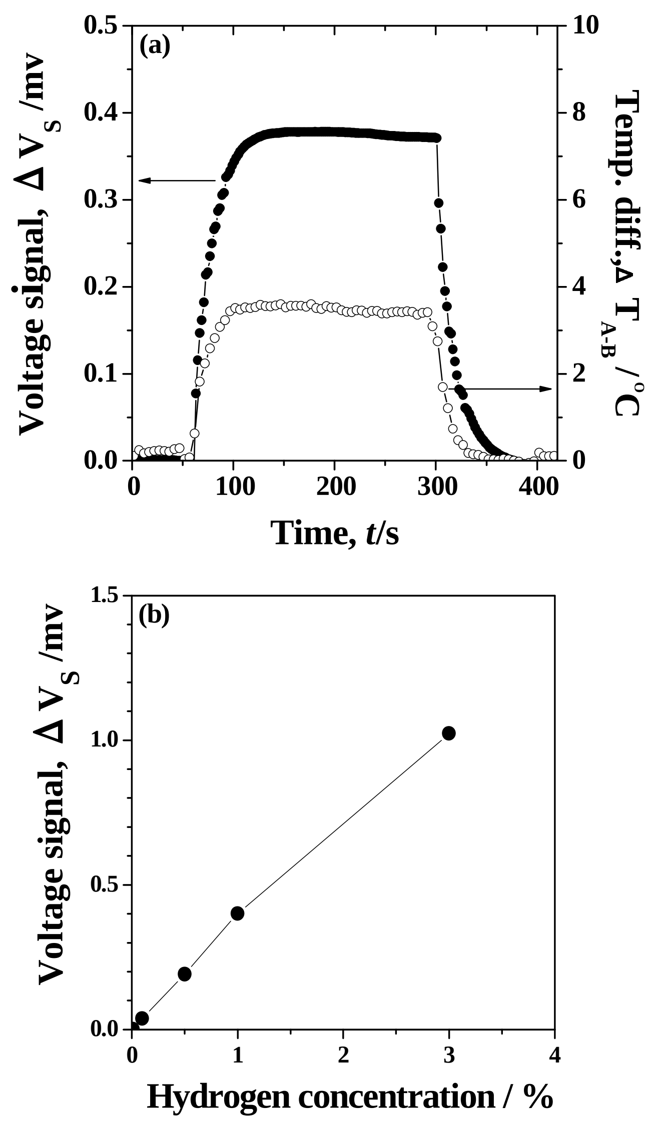

Fig. 1 Hydrogen sensing properties of the micromachined thermoelectric hydrogen sensor, (a) at 100 °C for 1% hydrogen gas in air, (b) for different hydrogen concentration at fixed temperature of 100 °C.

References

[1] Shin, W., Imai, K., Izu, N., and Murayama, N., Jpn. J. Appl. Phys., 2, 40 (2001) pp.L1232-1234.

[2] Qiu, F., Shin, W., Matsumiya, M., Izu, N., Murayama, N., Jpn. J. Appl. Phys., 42 (2003) pp.1563-1567.

[3] Qiu, F., Shin, W., Matsumiya, M., Izu, N., Murayama, N., Sens. Actuators B, 94 (2003) pp.152-160.