Study on the Performance of Sensitive Part of Bridge Type Ultra-Thin Film Hydrogen Sensor

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***Abstract*—A ultra-thin film hydrogen sensor has been developed to deal with effect of the environment, such as temperature. The performance of the hydrogen sensor was evaluated from the dependence of the sensing area, temperature, and the gas selectivity.**

Keywords-hydrogen sensor; ultra-thin film; platinum; bridge circuit.

I. Introduction

A large amount of CO_2 emission of fossil fuels leads us to develop new clean energies, including solar, wind, and hydrogen energy. Especially, hydrogen energy is expected because hydrogen energy can be supplied stably. To develop more secure hydrogen gas supply and utilization technology, early detection of hydrogen gas leakage with high-sensitive hydrogen sensors is required. Recently, hydrogen sensors operating at room temperature, which can operate with low-energy consumption, have been developed. In our group, we have developed a Pt ultra-thin-film hydrogen sensor [1][2]. The electrical resistance changed by dissociation of hydrogen molecules on the surface of the film and injection of electrons into the film. In this study, the developed sensor was diagonally aligned as two components with different resistances which forms a Wheatstone bridge circuit fabricated on the Si substrates and the output voltage of the brigade circuit was measured. Because the resistivity changes by the environmental effect, such as temperature is canceled, so robust detection against the environmental change could be realized. The surface area dependence of the sensitives and the gas selectivity were also evaluated here. In addition, the effects of humidity on the hydrogen sensor were investigated.

II. Experimental

The Pt ultra-thin-film hydrogen sensor is based on the catalytic reaction between Pt and hydrogen. When Pt reacts with hydrogen, electrical resistance is reduced. This change is measured as a voltage. Figure 1 shows the structure of the hydrogen sensor. The hydrogen sensor has a Pt thin film on a silicon substrate with TiN layer. Thus, the Pt thin films formed a Wheatstone bridge circuit. Two diagonal parts of the bridge was coated with alumina to prevent the reaction of hydrogens. By the wire bonding and connectors, the hydrogen sensor was connected to a power supply and measuring instruments. Table 1 shows the shape of one of

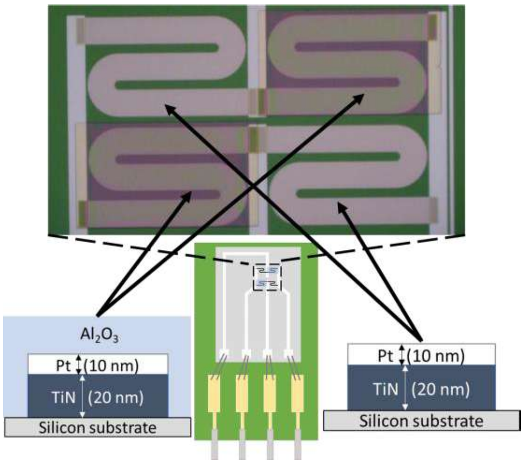

Figure 1. Structure of hydrogen sensor.

TABLE I. SHAPE OF HYDROGEN SENSOR

Sensing area of hydrogen sensor		
Width (μm)	***Length (μm)***	***Area (mm²)***
20	270	5.40×10^{-3}
20	440	8.80×10^{-3}
100	2650	0.265
150	2700	0.405
100	4400	0.440

the four sensing area of the hydrogen sensors. *Width* is the width of the sensing area. *Length* is the length along the electric current of the sensing area. *Area* is the product of *Width* and *Length*.

The output voltage by the Wheatstone bridge circuits of the Pt ultra-thin-film hydrogen sensor can be given by.

$$V = -rE / (200 - r), \quad (1)$$

where V is output voltage, E is supply voltage, and r is rate change of resistance of the sensor without environmental effect, such as temperature. Both resistivities of the coated and non-coated parts of Pt thin film could be changed by the direct environmental effect, therefore the output voltage of the bridge was canceled, while only coated parts were changed by exposure of hydrogen, therefore, the output voltage was changed depends on reactions of the hydrogen.

In this experiment, hydrogen gas was balanced by artificial mixed air which consists of 80%-N_2 and 20%-O_2.

A hot plate was used to heat the copper plate on which the sensor was placed and sealed.

A gas divider was used to adjust the humidity by mixing the gas that was dipped in water and the gas that was not dipped in water.

III. RESULTS AND DISCUSSION

The hydrogen sensor was exposed to hydrogen gas for 5 minutes. Figure 2 shows the sensor response to the hydrogen gas. From this result, the sensor can detect hydrogen gas with a concentration of above 0.1%.

The hydrogen sensor with different area of sensing region was exposed to 1% hydrogen gas for 5 minutes. Figure 3 shows the relationship between the maximum value of the voltage change and the sensing area. The slope estimated by the linear fit was approximately 2.3 mV/mm^2.

The output voltages of the sensor under the temperature between 30 and 90 °C was also and the range of dispersion was 0.31 mV, which was less than 2% of the voltage response of the sensor for 1%-hydrogen gas exposure.

When the humidity was changed from 20% to 70%, the response of hydrogen sensor is significantly decreased. At 20% of humidity, the output voltage was changed 9.5 mV. At 70% of humidity, output voltage of the sensor was changed 2.8 mV.

The output voltages of the sensor for 1%-CH_4, C_2H_6 and CO_2 gas was evaluated to be less than 0.1 mV for all gas types.

IV. CONCLUSION

We developed a highly sensitive and selectivity Pt ultra-thin-film hydrogen sensor. The effect of temperature for Pt could be removed by forming Wheatstone bridge circuits. However, it is difficult to eliminate the effect of humidity. Therefore, we use a sensor package to reduce the effect of humidity.

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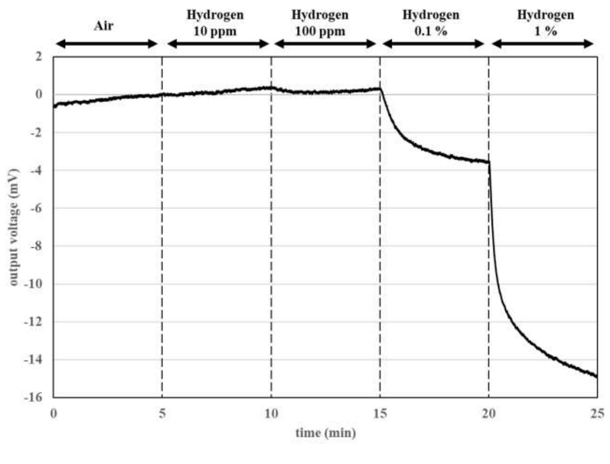

Figure 2. Hydrogen concentration.

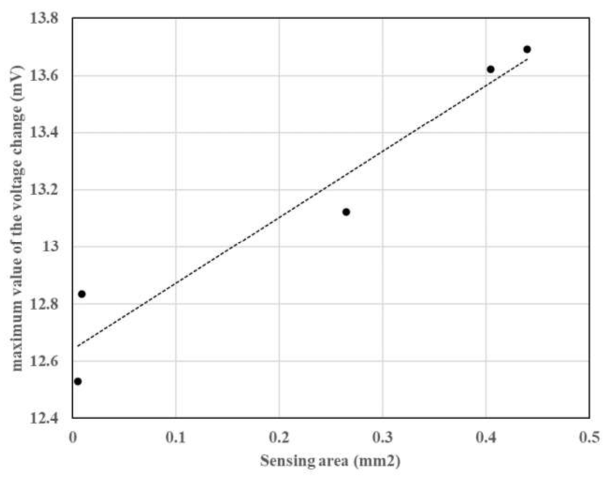

Figure 3. Relationship between sensing area and sensitivity.

 ISBN: 978-1-61208-918-8