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

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IARIA

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Introduction of the presenter

Takahiro Mori

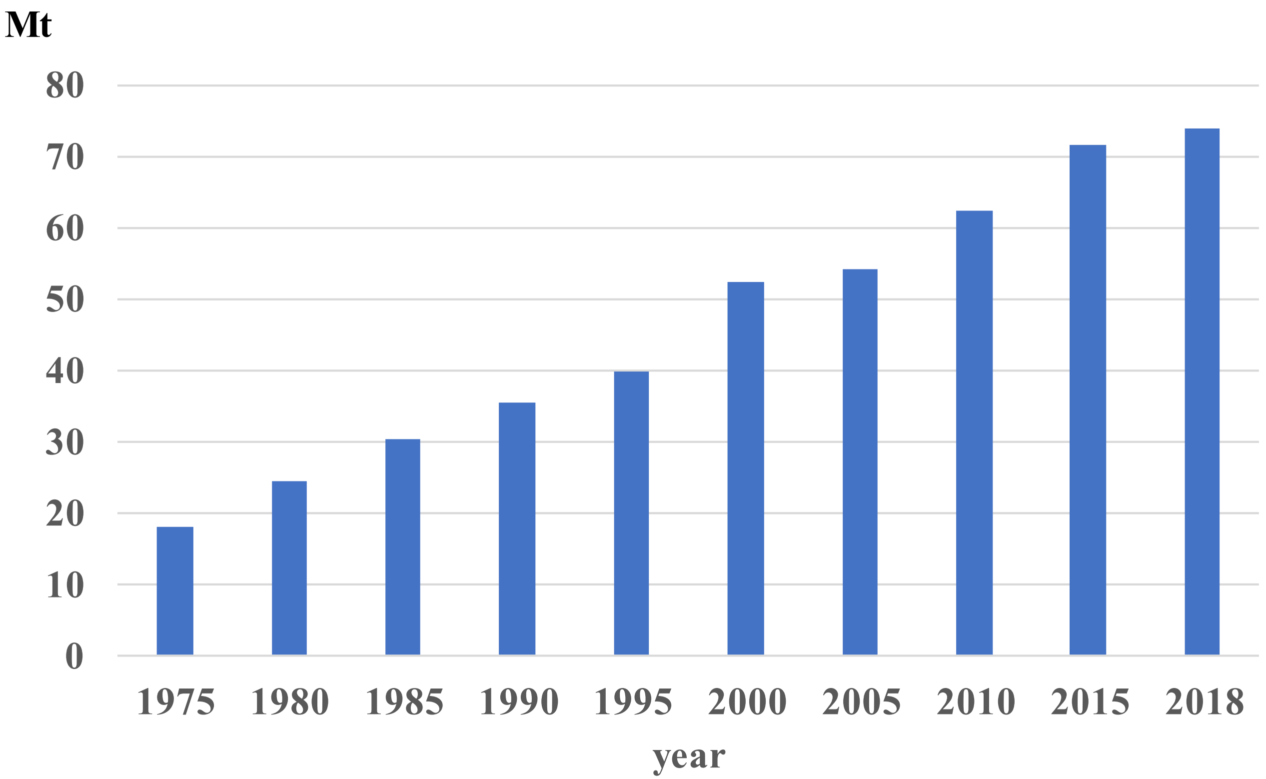
- Education:
  - He received a bachelor's degree from Okayama University in 3.2021
  - Currently, he is a master’s program student at Okayama University
- Expertise
  - Electrical engineering
    - Chemical sensor
    - Semiconductor device

Research background

- A large amount of CO_2 emission of fossil fuels is a major problem
- For example, under the Paris Agreement, countries are required to reduce their CO_2 emissions
- Therefore, problem of CO_2 emission leads us to develop new clean energies, including solar, wind, and hydrogen energy

Demand for hydrogen

- Demand for hydrogen is increasing



Global demand for pure hydrogen, 1975-2018 (IEA, 18,11,2019)

Problems with Hydrogen energy

- Hydrogen energy has two problems
  - Easy to leak from container
  - Wide burning range (4% ~ 75%)

→ **Hydrogen sensor**

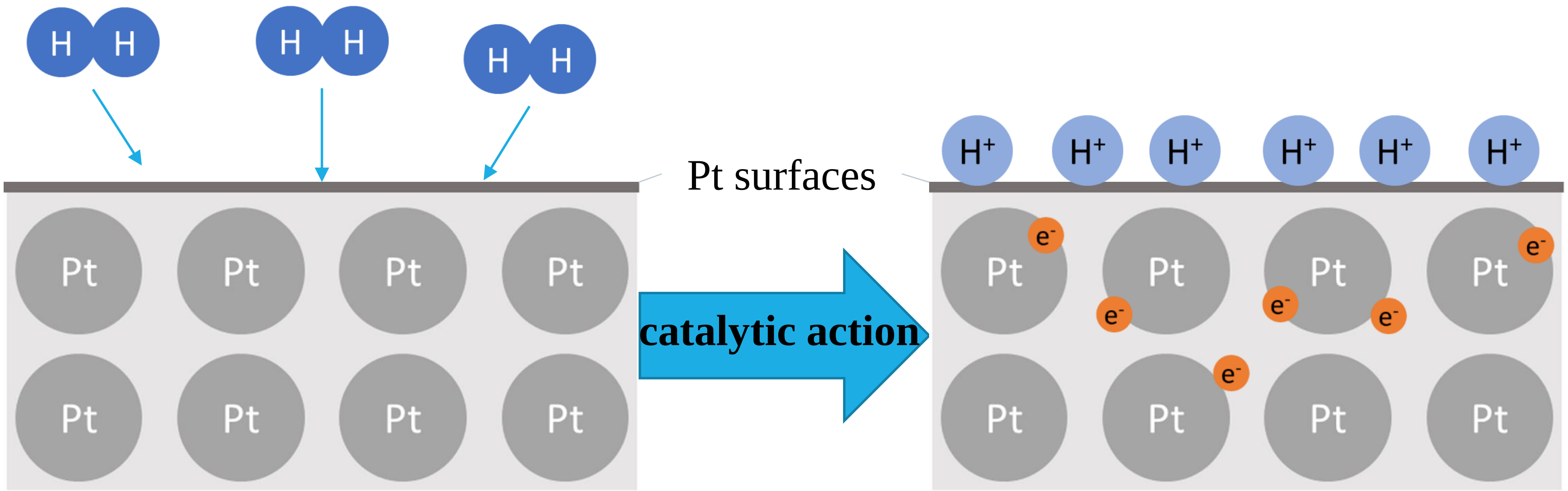
Conventional hydrogen sensor

- There are many hydrogen gas sensors.
  - Semiconductor gas sensor, Catalytic combustion type gas sensor, Thermal conductivity gas sensor
- These sensors can only be used under high temperatures
  - Therefore, they require heaters and power supply for heaters

The Pt ultra-thin film hydrogen sensor can operate without heaters

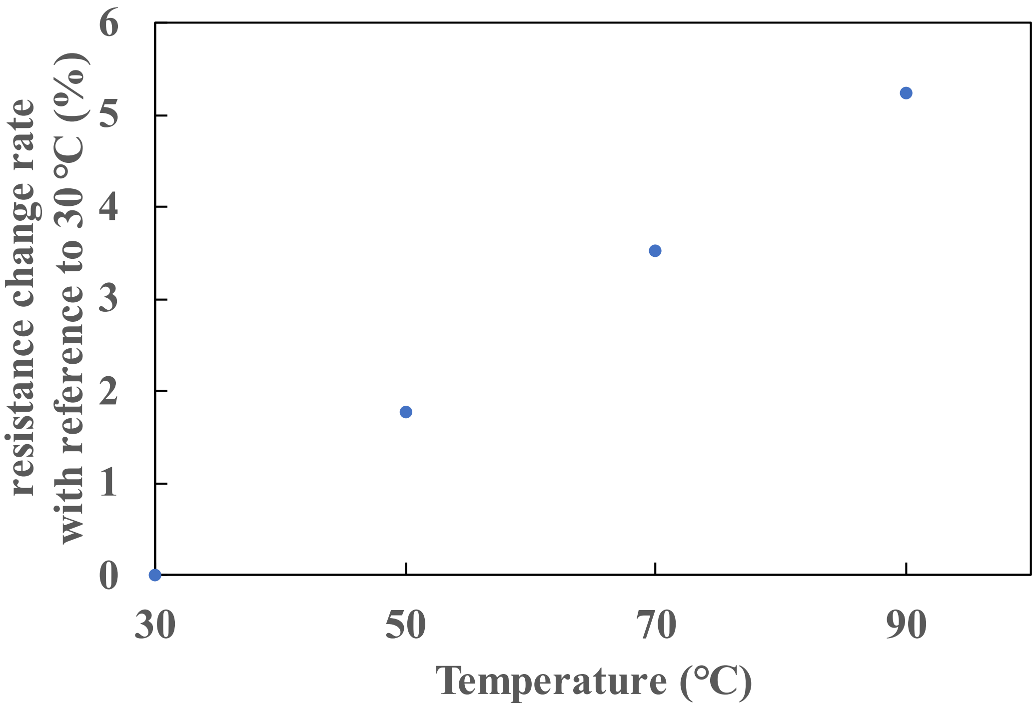
Pt ultra-thin-film hydrogen sensor

- Using the catalytic action of platinum with hydrogen



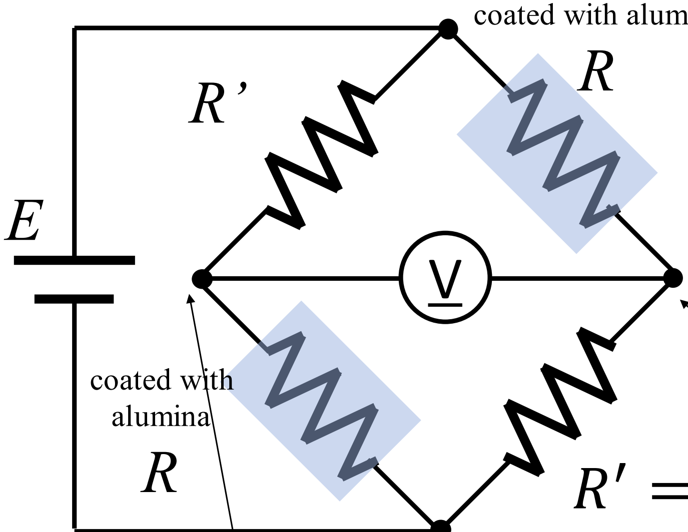
More electrons in the Pt by a catalytic action, the electrical resistance is changed

The problem of the Pt ultra-thin-film hydrogen sensor



- The electrical resistance of the Pt film changes by the temperature, so the output signal of the conventional Pt hydrogen sensors is affected by operating temperature.

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



E: Supply voltage (3 V)
R,R': Resistance of Pt
V: Output voltage
r: Resistance change due to hydrogen

$$V_a = \frac{R}{R + R'} E$$

$$R' = \frac{100 - r}{100} R$$

$$V_b = \frac{R'}{R + R'} E$$

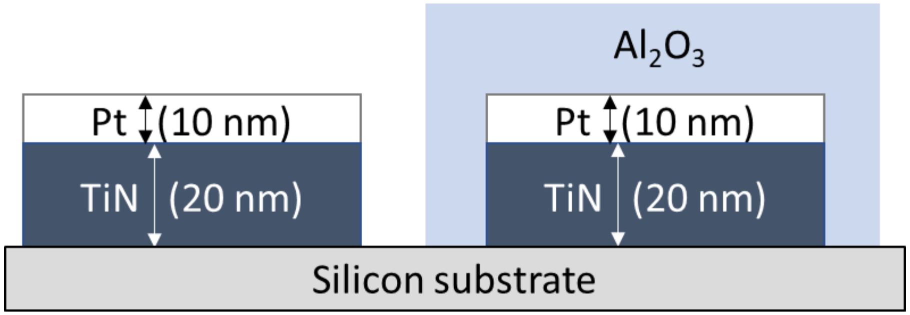
$$V = V_b - V_a$$

$$= \frac{-r}{200 - r} E$$

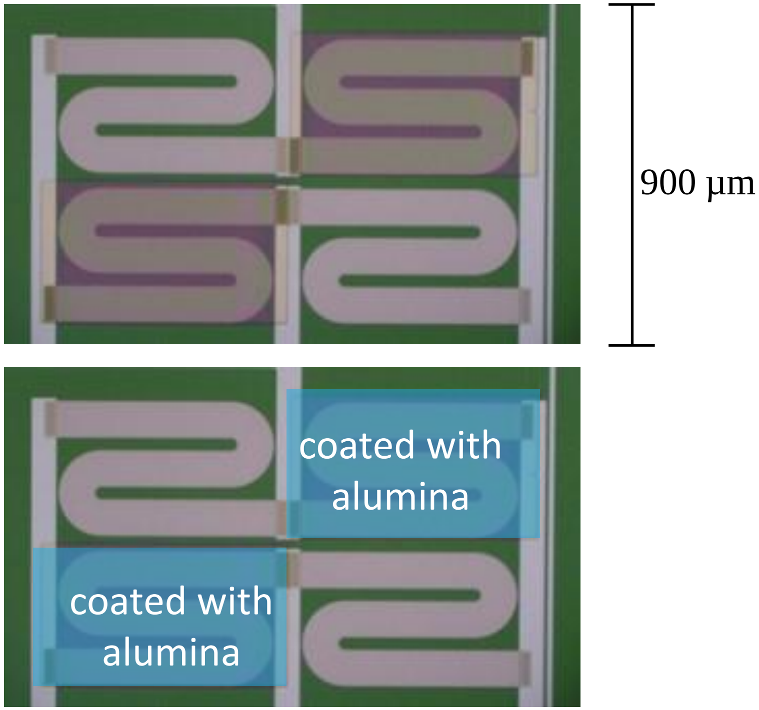
The effect of environment can be reduced

Structure of hydrogen sensor

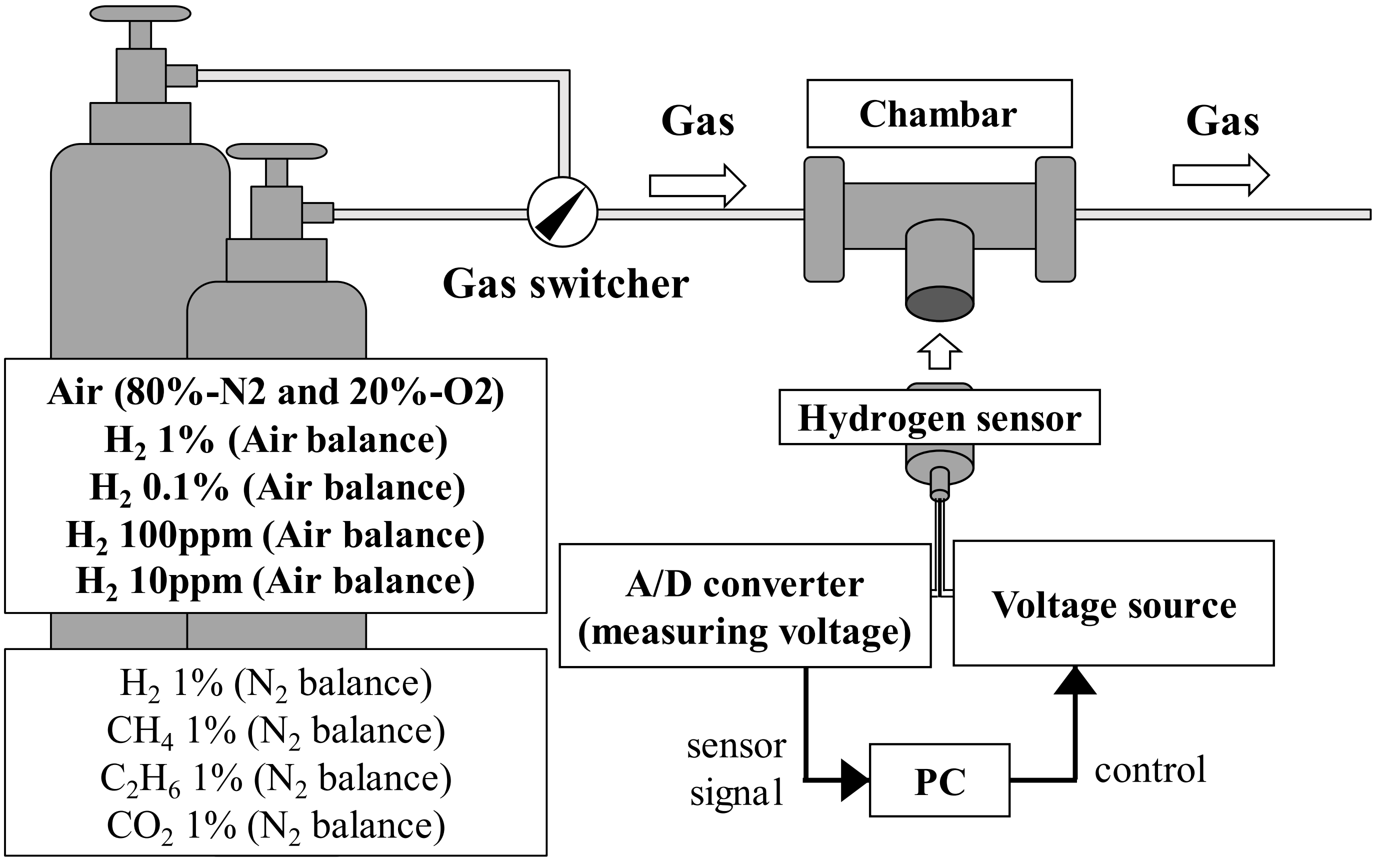
The cross section of the sensor



The surface of the sensor

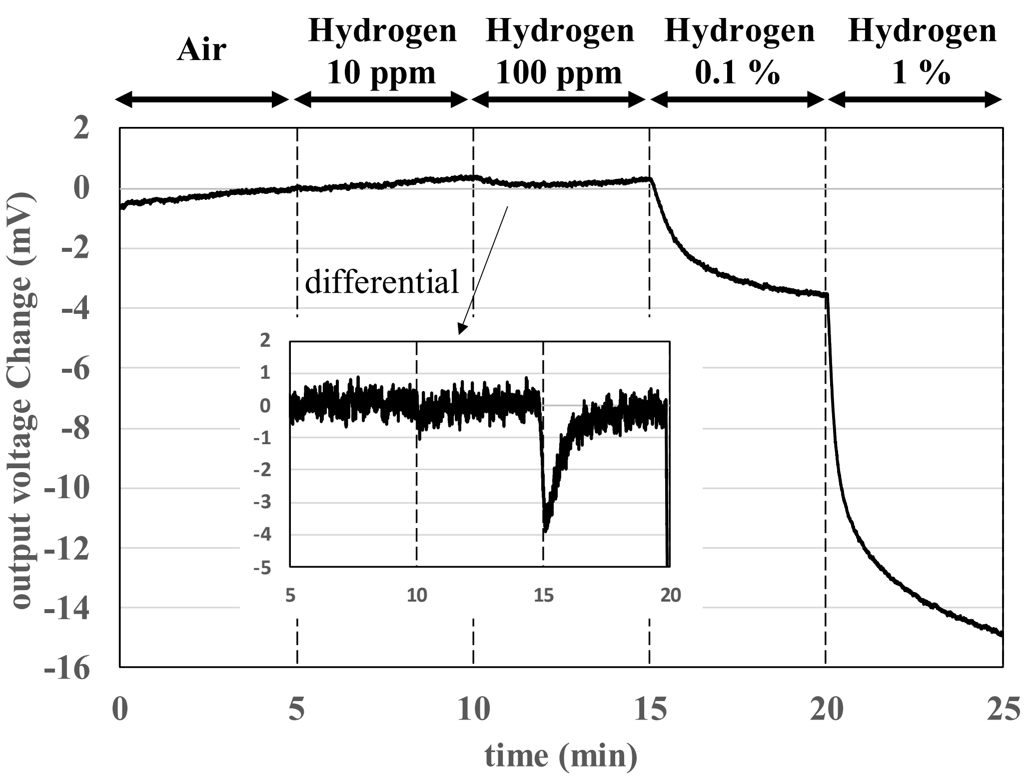


Experimental Equipment



Hydrogen concentration measurement

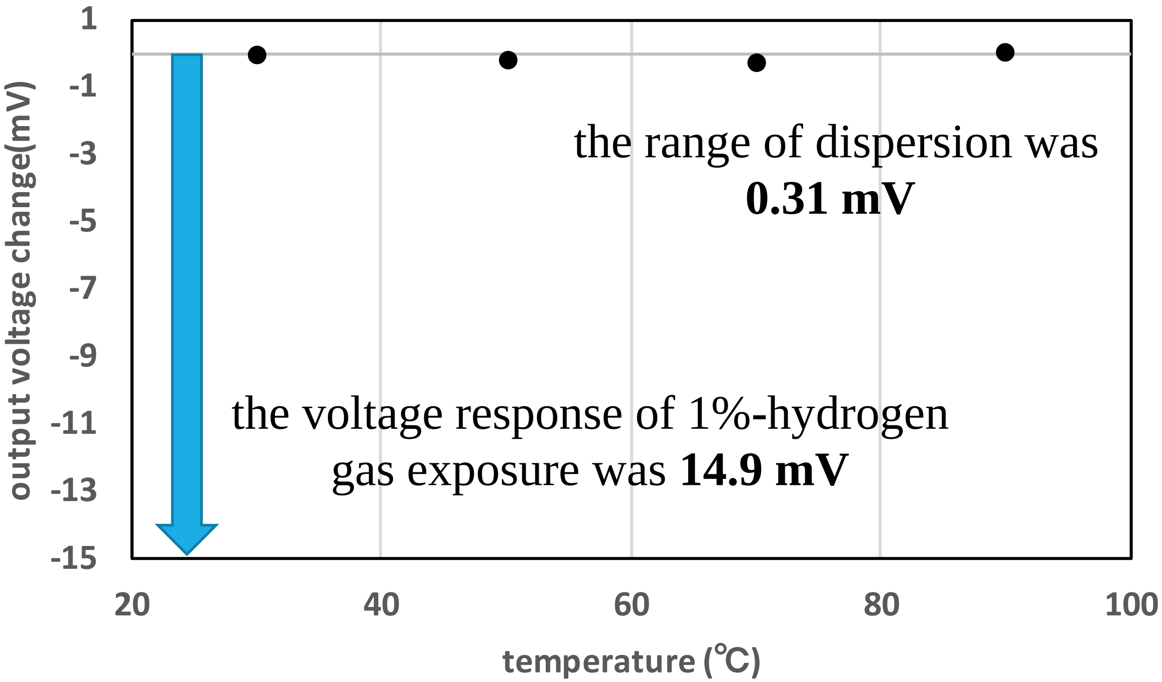
- The hydrogen sensor was exposed to hydrogen gas for 5 minutes each concentration



In this experimental equipment, the sensor can detect hydrogen gas with a concentration of above 100ppm

Temperature dependence

- The hydrogen sensor was exposed to Air for 5 minutes under the temperature between 30 and 90 °C

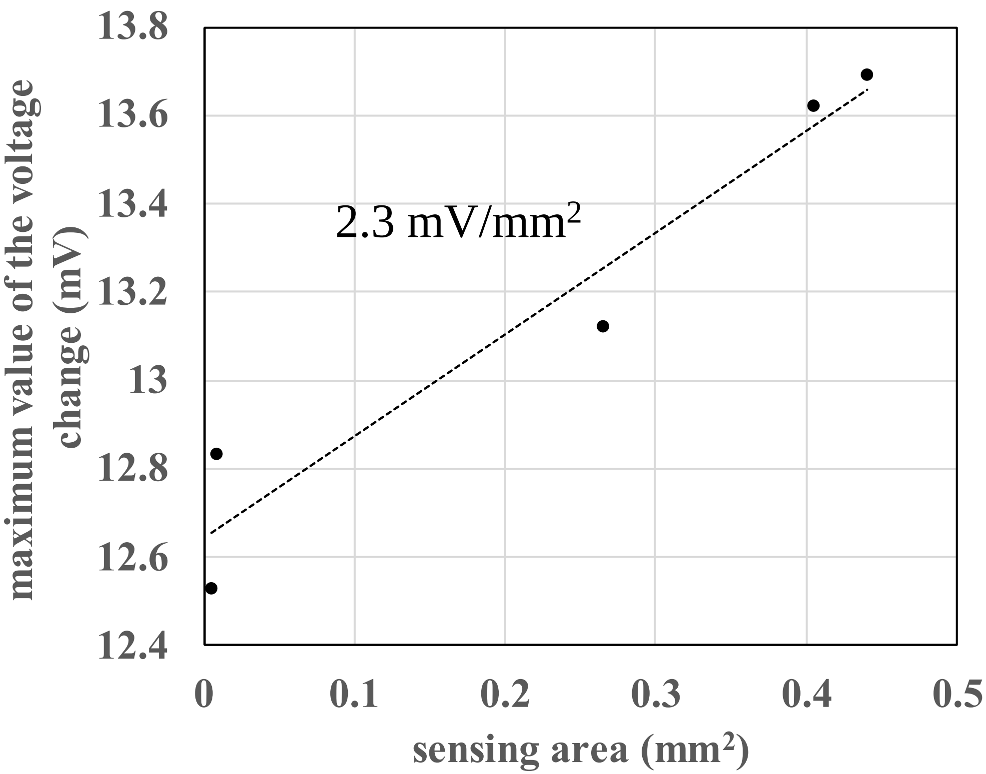


0.31 mV was less than 2% of the voltage response of 1%-hydrogen gas exposure

The voltage drift due to the temperature change could be reduced by forming the Wheatstone bridge circuits.

Surface area dependence of the sensitives

- Each sensor was exposed to 1%-hydrogen gas for 5 minutes

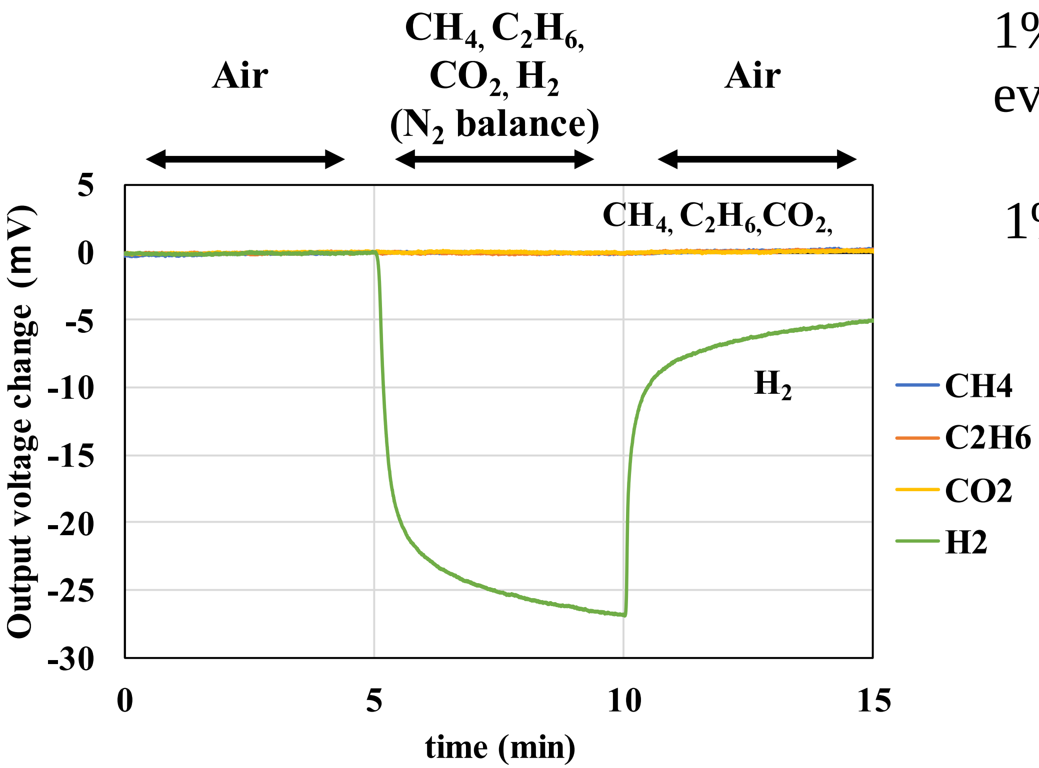


Sensing area of hydrogen sensor		
Width (μm)	Length (μm)	Area (mm^2)
20	270	5.40×10^{-3}
20	440	8.80×10^{-3}
100	2650	0.265
150	2700	0.405
100	4400	0.440

As surface area increases, sensitivity increases linearly

Gas selectivity

- The hydrogen sensor was exposed to CH_4, C_2H_6, CO_2, H_2 for 5 minutes



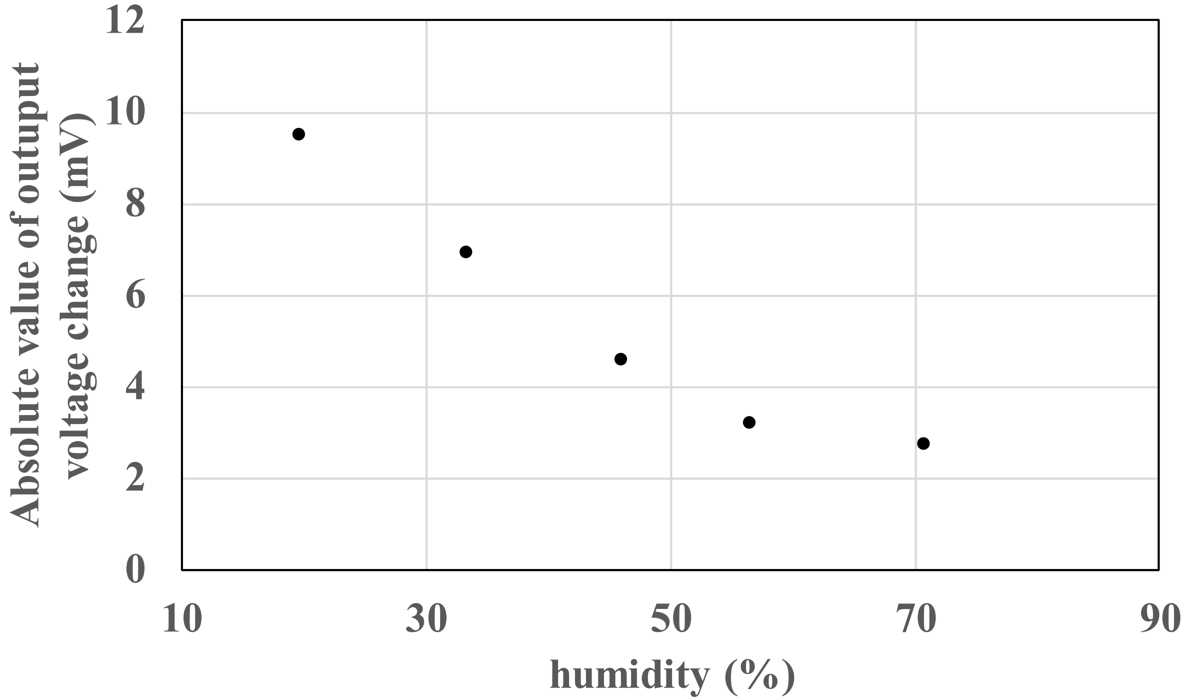
1%-CH_4, C_2H_6 and CO_2 gas was evaluated to be less than 0.1 mV

1%-H_2 was evaluated to 26 mV

The gas selectivity to hydrogen gas was above 260% to 1%-CH4, C2H6, and CO2 gas.

Humidity dependence

- The hydrogen sensor was exposed to 1% hydrogen gas for 5 minutes under the humidity between 20 and 70%



Sensitivity decreased due to humidity

The sensor can operate even under the high-humidity condition of 70%

Conclusion

- We developed a highly sensitive and selective Pt ultra-thin-film hydrogen sensor
- The effect of temperature for Pt can be reduced by forming Wheatstone bridge circuits
- The sensor can be more sensitive by surface area increasing
- Under 70% humidity, the hydrogen sensor can detect hydrogen gas