A Proto-type Hydrogen Sensor using Palladium Nanowire Array
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Molecular hydrogen is a combustible gas that is produced in large quantities by many industries and that has a broad range of applications. In cases where the hydrogen is an undesirable contaminant, a monitor must be able to detect concentrations on the order of parts per millions. In other cases, a monitor must be usable in nearly pure hydrogen. Conventional hydrogen sensors using hydrogen-specific Pd metal have been utilized for measuring the incremental change in electrical resistance of Pd upon hydrogen incorporation. Unlike the conventional Pd hydrogen sensors, however, the present Pd nanowire-array sensor has been designed to measure the hydrogen concentration with the decrement in the electrical resistance when hydrogen is incorporated into Pd nanowires. Even though this hydrogen sensor has already been presented in the literature by the same authors, this paper specially focuses on the fabrication of a proto-type hydrogen sensor with the same hydrogen detecting mechanism. The hydrogen sensing is considered to be due to the swelling of the Pd nanowires as the result of hydrogen incorporation and subsequent narrowing of gaps between the nanowires, so that the electrical resistance through the Pd nanowire array decreases as the result. Using this principle, we have fabricated a proto-type hydrogen sensor utilizing the Pd nanowire array. The proto-type hydrogen sensor has been tested to measure the sensing performance. The effects of other gases influencing on the sensor performance have also been presented in this presentation.

Even though a pioneering work by Walter et al. has initiated the intense interests on the hydrogen sensors utilizing the Pd nanowires, the sensors have not been proven suitable for the hydrogen safety sensors since the sensor could not measure the hydrogen concentrations under 1% efficiently. In order for the hydrogen safety sensor to be utilized for the hydrogen fuel-cell vehicles and hydrogen fuel stations, the hydrogen sensor should conform to some performance requirements such as the response time, measuring range of the hydrogen concentration, immunity from gases other than hydrogen, etc.

In order to measure the electrical resistance of Pd nanowires, two electrical contacts were formed, one on top of the Ti bottom layer and the other directly on top of the nanowires, as shown in Fig 1. The hydrogen concentration was sensed by measuring the changes in the electrical resistance between the top and bottom of Pd nanowires when the hydrogen is introduced to the Pd nanowires. The hydrogen concentration has been varied in a range from 0.01% to 1% which is important for the hydrogen safety sensors. The electrical resistance decreases when hydrogen is incorporated into the Pd nanowires unlike the case of conventional Pd hydrogen sensors. The Pd nanowire hydrogen sensor shows a reasonably fast response time of 10s in the range of 0.1%–1% hydrogen. For the stable operation of the hydrogen sensor, it has been found better to let the sensor aged for some time under hydrogen environment (Fig. 2). The hydrogen sensor has been found not affected by CO₂ and temperature gas (Fig. 3) and Fig. 4. However, the CO gas was found to poison the Pd nanowires so that the hydrogen sensor eventually stopped working (see Fig. 5).

Fig. 1: Cross section of Hydrogen sensor using Palladium nanowires

Fig. 2: Responses of the hydrogen sensor at various concentrations

Fig. 3: Effect of CO₂ gas

Fig. 4: Effect of temperature on the hydrogen sensor performance

Fig. 5: Effect of CO gas

References