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Extended Abstract

Ultra-High Sensitive (Ppt) Gas Sensor Based on the Pulse Heating Using MEMS Technique †

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1. Introduction

High sensitivity and low limit of detection to volatile organic compounds (VOCs) gases are typical properties on the resistive-type semiconductor gas sensors using SnO_2-based materials. In this few decades, semiconductor gas sensors were improved on the point of not only the sensitivity but also both compact and low power consumption by using the micro gas sensors equipped with the microheater and microelectrode using the MEMS (Micro Electronic Mechanical System) technique. Recently, we proposed the micro gas sensor driven in repeating mode of instantaneous heating and cooling (pulse-driving) [1,2]. According to the pulse-driving mode, VOCs gases can introduce into the sensing layer during cooling period, and it improves the utilize efficiency of the sensing layer. Thus, in this study, we aimed to improve the sensor response in low concentration of VOCs gases, SnO_2 based gas sensor was driven under pulse-driving mode with monotonic and two-step heating.

2. Gas Detection Using Monotonic Pulse-Driving Mode

The gas sensing layer repeatedly passes heater-on and -off phases in pulse-driving mode. In the monotonic pulse-driving mode, VOCs gas molecules are diffusing and accumulating into the inside of the sensing layer during heater-off phase, and reacting at deep inside of the sensing layer during heater-on phase. The model of gas diffusion and reaction are schematically described in Figure 1. According to the gas diffusion models, gas diffuses entirely in the sensing layer during heater-off phase. In other words, pulse-driving mode can improve the utilization efficiency of the sensing layer regardless of the porosity of sensing layer. Therefore, it allows to improve the sensor response to VOCs gases. In our recent work, we proposed that SnO_2 based gas sensor can detect 200 ppt toluene by using the monotonic pulse-driving mode when heater-on temperature is set at 250 °C [2].

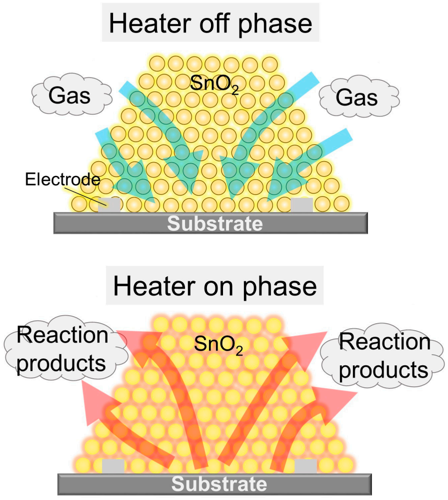

Figure 1. Schematic images of gas diffusion in the sensing layer during heater-on and -off phases.

3. Two-Step Pulse-Driving Mode for Gas Detection

Next, we introduced the two-step pulse-driving as described in Figure 2a to improve the sensor response to VOCs gas using pulse-driving mode. Here, heater temperatures at first step, sensor treatment, was set at 250–400 °C, and second step, sensor operation, was set at 250 °C, respectively. The transient electrical resistance curves in first and second heating period using SnO_2 nanoparticles sensor were shown in Figure 2b. Here, the result that first step temperature was set at 250 °C is same as the result using monotonic pulse-driving mode. It is clear that the electrical resistance at 250 °C in second step are increased with increasing the temperature in first step. According to our previous literature, infinitesimal impurities including in the atmosphere such as coming from the gas cylinder inhibit the oxygen adsorption and decrease the electric resistance in air atmosphere [3]. Additionally, detection process of VOCs gases such as toluene produced incomplete combustion products, and it also plays a role of inhibitor of oxygen adsorption in air atmosphere. Such impurities may reduce the oxygen adsorption amount on the particles surface. Thus, in two-step pulse-driving, the impurities on the particles surface is removed by heating in first-step, and the VOCs gases can be detected in second-step on the pure particles surface. The sensor response to 1–8 ppb toluene using both monotonic pulse-driving and two-step pulse-driving modes are shown in Figure 3. Here, heater temperature of first- and second-step were set at 400 and 250 °C in two-step pulse-driving, respectively, and it was set at 250 °C in monotonic pulse-driving. According to the results, the sensor response toward extremely low concentration of toluene was clearly higher by two-step pulse-driving than monotonic pulse-driving mode. Thus, it is clear that surface condition of particles prepared by first-step heating improved the sensor response to toluene.

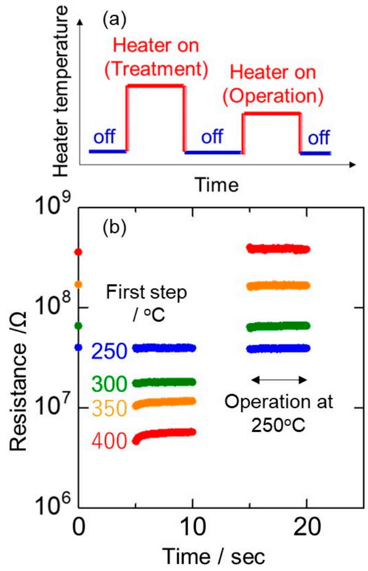

Figure 2. (**a**) Tempearture profile of two-step pulse-driving and (**b**) the electrical resistances in first- and operation-step.

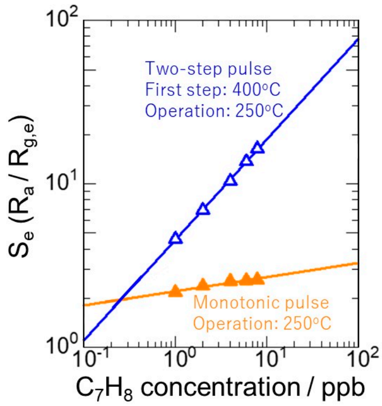

Figure 3. Toluene concentration dependence of the sensor response using monotonic and two-step pulse-driving mode.

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