

Control of Gas Diffusion and Reactivity in Porous Metal-Oxide Gas Sensors Prepared by Ultrasonic Spray Pyrolysis

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Microstructural control of sensing materials is important for improving the performance of semiconductor gas sensors. In particular, porous morphologies have attracted significant attention because they enable simultaneous improvements in gas diffusion and reactivity, thereby enhancing the gas-sensing performance. We have introduced ordered porous structures into metal-oxide particles by ultrasonic spray pyrolysis using polymethyl methacrylate (PMMA) microspheres as a template [1–3]. The interconnected pores facilitate the diffusion of target gases into the sensing layer and increase the number of accessible reaction sites on the oxide surface. Therefore, porous metal-oxide particles are effective sensing materials for controlling both gas diffusion and surface reactivity. In this study, spherical porous metal oxide (pr-MO, MO: In_2O_3 or SnO_2), w wt% In_2O_3 -mixed pr- SnO_2 (pr- $w\text{In}_2\text{O}_3$ - SnO_2 , w : 3–95), and n wt% noble metal (M)-added pr- $33\text{In}_2\text{O}_3$ - SnO_2 ((pr- $n\text{M}$ - $33\text{In}_2\text{O}_3$ - SnO_2), M: Au or Pt, n : 0.5 or 2) powders were prepared by ultrasonic spray pyrolysis employing homemade PMMA microspheres (typical particle size: ca. 70 nm in diameter), and the VOC-sensing properties of thick-film sensors fabricated by using these powders were examined at 250–500°C in air. The magnitude of the response to VOCs was defined as the ratio (R_a/R_g), where R_g and R_a are the resistances in VOCs balanced with air and in air, respectively.

The obtained powders consisted of submicron-sized spherical particles with interconnected pores, which originated from the thermal decomposition of the PMMA microspheres. The pr- $33\text{In}_2\text{O}_3$ - SnO_2 sensor showed the largest acetone response among all the pr-MO and the pr- $w\text{In}_2\text{O}_3$ - SnO_2 sensors in the temperature range examined. Figure 1 shows temperature dependences of the responses of the pr- $n\text{M}$ - $33\text{In}_2\text{O}_3$ - SnO_2 sensors to 50 ppm acetone. The addition of Au or Pt to the pr- $33\text{In}_2\text{O}_3$ - SnO_2 powders improved the acetone response of the pr- $33\text{In}_2\text{O}_3$ - SnO_2 sensor, and the pr-2Pt- $33\text{In}_2\text{O}_3$ - SnO_2 sensor showed the largest acetone response at 350°C among the sensors tested. We also confirmed that the response of the pr-2Pt- $33\text{In}_2\text{O}_3$ - SnO_2 sensor to acetone was larger than those to ethanol and toluene.

The VOC-oxidation behavior and the adsorption of VOCs and their related intermediate species were evaluated using catalytic activity tests with a fixed-bed reactor and diffuse reflectance infrared Fourier transform (DRIFT) spectroscopy, respectively. Catalytic activity tests showed that noble-metal addition, especially Pt, enhanced the catalytic oxidation activity of VOCs. DRIFT measurements confirmed that acetone was more strongly adsorbed on the surface of the Pt-added powder than ethanol and toluene. In contrast to ethanol and toluene, acetone and its partially decomposed intermediates remained on the powder under each gas atmosphere. The details of this will be discussed in the presentation.

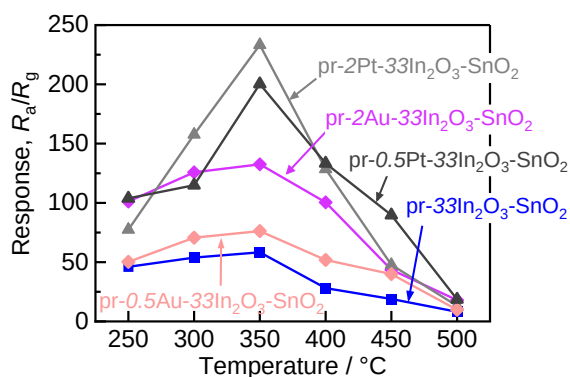


Fig. 1. Operating temperature dependences of the responses of pr- $n\text{M}$ - 33SnO_2 - In_2O_3 sensors to 50 ppm acetone.

Keywords: Semiconductor gas sensor; Acetone; SnO_2 ; In_2O_3 ; Noble metal; Ultrasonic spray pyrolysis; DRIFT spectroscopy

References

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