## Supporting Information

## Ultraselective Toluene Gas Sensor: Nanosized Gold Loaded on Zinc Oxide Nanoparticles

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## Materials characterization and evaluation

The crystal structure of the obtained nanoparticles was evaluated using an X-ray diffractometer (XRD; MiniFlex 600, RIGAKU) with CuK $\alpha$  radiation. The Au loading content on the ZnO surface was evaluated using an inductively coupled plasma atomic emission spectroscopy (ICP-AES; ULTIMA II, HORIBA). For ICP-AES analysis, each Au-ZnO NP sample was dissolved in aqua regia. Transmission images of the obtained nanoparticles were observed using a field-emission scanning electron microscopy (FE-SEM; S-5200, Hitachi) in transmission mode. The microstructure of and cross-sectional images of each sensing layer were also captured using FE-SEM (S-4800, Hitachi). Thicknesses of the sensing layers were evaluated using a surface texture and contour integrated measurement instrument (Surfcom; Tokyo Seimitsu). The state of the Au NPs on the ZnO surface was analyzed using X-ray photoelectron spectroscopy (XPS; KRATOS ESCA-3400, Shimadzu). Pore distributions of the obtained nanoparticles were analyzed through nitrogen (N<sub>2</sub>) gas adsorption/desorption using a specific surface area and pore size distribution analyzer (BELSORP-mini II, Bell, Japan) was estimated from adsorption/desorption isotherms using the Barrett–Joyner–Halenda method.

Hydrogen temperature-programmed reduction (H<sub>2</sub>-TPR) was carried out in flowing 5% H<sub>2</sub>/N<sub>2</sub> gases using a thermal conductivity detector (TCD). Each powder was heated at 400 °C for 1 h under synthetic air flow. After cooling to 40 °C, the atmosphere was replaced with 5 % H<sub>2</sub>/N<sub>2</sub> and then the TPR measurement was carried between 40 and 400 °C at a heating rate of 10 °C·min<sup>-1</sup>.

The electrical properties of the obtained gas sensors were evaluated using conventional gas flow apparatus equipped with a gas mixing system and an electric furnace, as schematically depicted in Figure S-1b. The gas flow rate for the evaluation was set at 100 cm<sup>3</sup>·min<sup>-1</sup>, which was precisely controlled by a mass flow controller (SEC-series, HORIBA STEC). Synthetic air and various target gases were flowed through the quartz-type sensor chamber. The target gases were 200 ppm H<sub>2</sub>, 200 ppm CO, 100 ppm ethanol, 100 ppm acetaldehyde, 100 ppm acetone, and 100 ppm toluene diluted with synthetic air. Each sensor device was attached to the sensor chamber and connected to a standard resistance. We measured the voltage across the standard resistance under an applied direct-current voltage of 4 V to estimate the electrical resistance of the sensors. The voltage across the standard resistance was measured using an electrometer (2701, Keithley Instruments). The sensor was heated in the electric furnace, and the temperature close to the sensor device was monitored using a thermocouple. The sensor response (*S*) was defined as the ratio of the electrical resistance in synthetic air (*R<sub>a</sub>*) to that in a target gas (*R<sub>g</sub>*); i.e., *S* = *R<sub>a</sub>*/*R<sub>g</sub>*.



Figure S-1. Schematic images of (a) the gas sensor device and (b) the measurement apparatus.



Figure S-2. Survey XPS scan of Au(1.5%)-ZnO nanoparticles.



Figure S-3. Temperature-programed reduction of hydrogen using neat-ZnO and Au(1.5%)-ZnO nanoparticles.



Figure S-4. Dependence of the sensing layer thickness on (a) the sensor responses to 100 ppm ethanol and toluene at 377 °C for sensor using Au(0.15%)-ZnO nanoparticles and (b) gas selectivity based on the sensor response to toluene. Thicknesses of thin, standard, and thick sensing layers are in 5-12, 21-32, 35-53  $\mu$ m, respectively.



Figure S-5. Transient sensor response curves to (a) 200 ppm hydrogen, (b) 200 ppm carbon monoxide, (c) 100 ppm ethanol, (d) 100 ppm acetaldehyde, and (e) 100 ppm acetone at 377 °C using sensors containing ZnO and Au-ZnO nanoparticles.