

Design of Sensitive and Selective Gas Sensors using Oxide Nanowire Networks

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Abstract

Highly sensitive and selective gas sensors were designed using oxide nanowire (NW) networks by the control of NW density, the fabrication of NW sensors on the suspended microelectrodes and heater, the load of oxide catalyst, and the coating of nano-scale oxide semiconductor shell layer.

SnO₂ NWs were deposited uniformly over a defined electrode area by coating with a solution containing NWs after patterning with polydimethylsiloxane (PDMS). The hydrophobic PDMS guide wall prevented the outstretching of the deposited solution and the density of NWs could be controlled by manipulating the number of droplets deposited. The high-density NW sensors enhanced the gas response (R_a/R_g for reducing gases and R_g/R_a for oxidizing gases, R_a : resistance in air, R_g : resistance in gas) toward CO, C₃H₈, C₂H₅OH, and NO₂ but reduced the response/recovery speed. The enhancement of gas response by the increase of NW density was attributed to the increase in the number of NW/NW junctions with high variation of resistance upon exposure to gas.

The SnO₂ NW networks gas sensors were fabricated on a microelectrode and heater suspended in a cavity. The sensors showed the selective detection to C₂H₅OH at a heater power during sensor operation as low as 30-40 mW. The gas response and response speed of the SnO₂ NW sensors to 10-100 ppm C₂H₅OH were 4.6-4.7-fold faster, respectively, than those of the SnO₂ nanoparticle sensors with the same electrode geometry. The enhanced gas sensing characteristics of NW networks sensors were explained by the rapid and effective diffusion of analyst gases to the entire sensors surface through the less-agglomerated configuration of NW networks.

The CuO-functionalized SnO₂ NW sensors were fabricated by dropping Cu nitrate aqueous solution and subsequent heat treatment. The CuO coating increased the gas responses to 20 ppm H₂S up to ~74-fold. The gas response of the CuO-doped SnO₂ NWs to 20 ppm H₂S was as high as 809 at 300 °C, while the cross-gas responses to 5 ppm NO₂, 100 ppm CO, 200 ppm C₂H₅OH, and 100 ppm C₃H₈ were negligibly low (1.5-4.0). Moreover, the 90% response times to H₂S were as short as 1-2 s at 300-400 °C. The selective detection of H₂S and enhancement of the gas response were attributed to the uniform distribution of the sensitizer (CuO) on the surface of the less agglomerated networks of the SnO₂ NWs.

The ZnO-SnO₂ core-shell NWs were synthesized by a continuous two-step vapor growth method at different synthesis temperatures. A crystalline 15-20 nm-thick, SnO₂ shell layer was pseudo-epitaxially coated on ZnO NWs. The gas response of the ZnO-SnO₂ core-shell NW sensors to 10 ppm NO₂ reached ~33 times enhancement compared to that of the ZnO NWs at 200 °C. In addition, the ZnO-SnO₂ core-shell NW sensors showed selective detection to NO₂ at 200-300 °C and to C₂H₅OH at 400 °C. The electron depletion at the SnO₂ shell layer and ZnO-SnO₂ interface was suggested as the reason for the enhanced gas response.