TiO_2 Nanowires for Humidity-Stable Gas Sensors for Toluene and Xylene

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ABSTRACT:

The dual-functionality sensor derived from semiconductor metal oxides operating at low temperature for low power consumption and robust stability toward humidity is a striking platform for economic and indoor air-quality monitoring. Therefore, in this work, temperature-dependent selectivity and robust stability toward carbon monoxide (CO), toluene (C_7H_8), and p-xylene (C_8H_{10}) are displayed by various TiO_2 nanostructures synthesized following a facile hydrothermal method. The X-ray diffraction patterns confirmed the tetragonal structure of anatase TiO_2. Surface studies confirmed the different morphologies, such as nanoparticles (TiO_2 nanoparticles (TNPs)), nanowires (TiO_2 nanowires (TNWs)), and sea-urchin-like hierarchically (HHC) arranged TiO_2 nanostructures. Relatively high surface area and interconnected pore distribution were witnessed for TNWs and HHC nanostructures as compared to TNPs. In situ photoluminescence and X-ray photoelectron spectroscopy analyses confirmed the defect states of the nanostructures, and the TNWs possessed the highest concentration of oxygen vacancies and Ti^{3+}, which influenced the dual-selectivity functionality of TNW toward C_7H_8 and C_8H_{10} at 25 and 125 °C, respectively. Additionally, at an optimum working temperature of 25 °C, a response of 2.46 toward 20 ppm CO was witnessed for the HHC-based sensor and was attributed to the available surface area and active sites presented by the hierarchically arranged nanostructures. Cross-sensitivity measurements were conducted in the presence of interfering gases, which showed negligible cross-responses. The long-term stability in the presence of relative humidity and the sensing mechanism underlying the fascinating dual functionality for C_7H_8 and C_8H_{10} vapor detection were discussed in detail. These findings showed that the current sensors can be employed for detection of C_7H_8 and C_8H_{10} in a vastly robust and selective way with insignificant interference from ambient humidity.