Introduction

Hydrogen is one of the most promising sustainable fuels since it produces no air pollutants in fuel cells, but very flammable and could lead to an explosion at a high concentration (4%) in the air.1 As hydrogen is colorless, odorless, and highly flammable under ambient conditions, it must be reliably monitored in real-time during its production, delivery, storage, and utilization. The SnO2 nanocrystals-rGO sensing platform reported in our previous work demonstrated advantages such as tunable sensing performance and room temperature operation.2 Gold doping indicated enhanced selectivity sensing performance against hydrogen gas.3 However, the sensing mechanism remains unclear. It is promising to combine the gold dopant with the SnO2-rGO sensing template to achieve desirable hydrogen sensing performance at room temperature.

Method

Pure rGO sensors

Heterostructure-based sensors

Fig. 1. (a) SEM images of Au-SnO2/rGO sensor. The rGO nanosheets bridging two gold electrodes were modified with well-dispersed SnO2 and Au nanoparticles on the surface. (b) Schematic of the Au-SnO2/rGO sensor device and measurement system.

Fig. 2. Schematic illustration of the current gas sensing test system.

Results

• We define the sensitivity as Response (% = (Ia - Ib) / Ib) x 100), where Ib is the current in the presence of H2 and Ia is the base current in the air.
• The good repeatability of this device is evidenced by the multicycle sensing.
• The hydrogen concentration-related dynamic response curves and the calibration curves are well fitted by the Langmuir isotherm.4

Fig. 3. Responses to 1% H2 of (a) rGO and SnO2-rGO. (b) GO and Au-rGO. (c) Au-SnO2/rGO nanohybrids with different sputtered gold thickness. (d) dynamic response curves of 12s sputtered Au-SnO2/rGO to 100 ppm NOx and 50 ppm H2S. (e) dynamic response curves of 12s sputtered Au-SnO2/rGO to H2 with varying concentrations from 0.04% to 1% in 1 min. (f) Calibration curves of 1 nm Au-SnO2/rGO sensors to H2 gas.

Discussion

• The better recovery performance suggests the oxygen spillover effect than the hydrogen spillover effect.
• The sensors with loaded Au nanoparticles indicate reduced activation energies in both hydrogen adsorption and desorption.

Fig. 4. (a) Schematic band diagrams of Au-SnO2/rGO sensors (top figure) with the heterojunction formation at the interfaces (bottom figure). (b-e) The Arrhenius plot of In (I) vs. 1/T determined from the initial slope of the recovery cycle. Dynamic response curves of (d) Au-SnO2/rGO and (e) SnO2/rGO sensors to 1% H2 in the temperature range 21.6-100°C.

Conclusions

• The Au-SnO2/rGO ternary nanohybrids were designed with improved room temperature H2 sensing performance.
• The sputtered Au nanoparticles enhanced both sensitivity and recovery of the SnO2-rGO template.
• The catalytic effect of Au nanoparticles for hydrogen adsorption and desorption was then revealed through the temperature-dependent sensing test and Arrhenius analysis.
• The availability of such sensors will contribute to promoting a sustainable hydrogen economy, protecting public safety, and enhancing lead-acid battery safety in a wide range of applications.

References


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