SnO$_2$ nanosheets functionalized with PdPt bimetal and their selective detection of carbon monoxide and methane

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Abstract:
PdPt bimetal nanoparticles (~2.7 nm) were synthesized via Pd(acac)$_2$ and Pt(acac)$_2$ reduction in oleylamine with borane tributylamine complex. Then the SnO$_2$ nanosheets with PdPt nanoparticles (NPs) on their surface (0.5, 1, 1.5 wt%) were finally obtained by self-assembly. The composition and morphology of obtained PdPt/SnO$_2$ composites were characterized by XRD, TEM and XPS. Their gas sensing properties were carefully studied to detect hazardous gases (CH$_4$ and CO) in the coalmines. The results demonstrated that 1P-PdPt/SnO$_2$-A composite could not only effectively detect CO at 90 °C, but also detect CH$_4$ at 320 °C. Furthermore, compared with 1P-PdPt/SnO$_2$-B obtained by traditional reduction method, 1P-PdPt/SnO$_2$-A sensor displayed superior CO response (25 to 50 ppm) and CH$_4$ response (5.3 to 1000 ppm) at their optimum working temperature. The dramatically improved sensing performance can be attributed to the enhanced catalytic dissociation of the molecular adsorbate on the PdPt NPs surfaces and the repaid diffusion of the resultant active species to the oxide surface. On the other hand, PdPt NPs with uniform particle size and high dispersion on the oxide surface created more Schottky barrier-type junctions resulting in greater resistance changes during the reaction. Our present results demonstrate bimetal NPs have great potential in improving the gas sensitive performance of metal oxide semiconductors (MOSs).

Key words: PdPt bimetal, SnO$_2$ nanosheets, Cabon monoxide sensor, Methane sensor

Results and Discussion

Fig.1 shows that nearly monodispersed PdPt bimetal nanoparticles (NPs) with diameters of about 2.7 nm were successfully synthesized. The monodispersed PdPt NPs can easily be decorated on the surface of SnO$_2$ nanosheets by self-assembly[1].

Fig.2a displays the dynamic response of 1P-PdPt/SnO$_2$-A sensor to different concentration of CO at 90 °C. It is clear that 1P-PdPt/SnO$_2$-A sensor exhibits the high response (58 to 100 ppm) and excellent response and recovery properties (60/30 s to 100 ppm) at low temperature. Furthermore, Fig. 2b shows that 1P-PdPt/SnO$_2$-A sensor also displays outstanding sensing performance to different concentration of CH$_4$ at high temperature (320 °C).

As is known to all, gas disaster is the main factor restricting the safety production of coalmine, especially the gas like CH$_4$ and CO.
In conclusion, the 1P-PdPt/SnO$_2$-A sensor can simultaneously detect CO and CH$_4$ by adjusting the working temperature, which has a great potential in practical application of coalmine safety. The enhanced gas sensing performance can be ascribed to the catalysis of PdPt NPs and the more Schottky barrier-type junctions.

Fig. 1 TEM image of monodispersed PdPt bimetal nanoparticles and the corresponding size distribution (inset).

Fig. 2 Dynamic response of 1P-PdPt/SnO$_2$-A sensor to different concentration of CO at 90°C (a) and CH$_4$ at 300°C (b).

Fig. 3 Selectivity of the sensor based on as-prepared composite on successive exposure to 1000 ppm CH$_4$ and 50 ppm other hazardous gases in the coalmines at 90°C(a) and 320°C(b).

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Reference