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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 ℃, but also detect CH_4 at 320℃. 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 dramaticly 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℃. It is clear that 1P-PdPt/SnO_2-A sensor exhibites 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 ℃).

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. The lower and upper explosion limits of methane are 4.9% (4.9×10^4 ppm) and 15.4% (1.54×10^5 ppm), respectively [2]. One sensor can detect CH_4 and CO by adjusting the operating temperature, which will greatly increase its availability. Fig.3 shows the selectivity of the 1P-PdPt/SnO_2-A sensor on successive exposure to 1000 ppm CH_4 and 50 ppm other hazardous gases at 90℃ and 320℃. It is obvious that the PdPt funcationalized SnO_2 sensors exhibites the excellent selectivity to CO at 90℃ (Fig. 3a) and CH_4 at 320℃ (Fig. 3b), respectively. In addition, compared with 1P-PdPt/SnO_2-B (17 to 50 ppm CO, 3.8 to 1000 ppm CH_4), 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 due to PdPt NPs with uniform particle size and high dispersion on the oxide surface.

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.

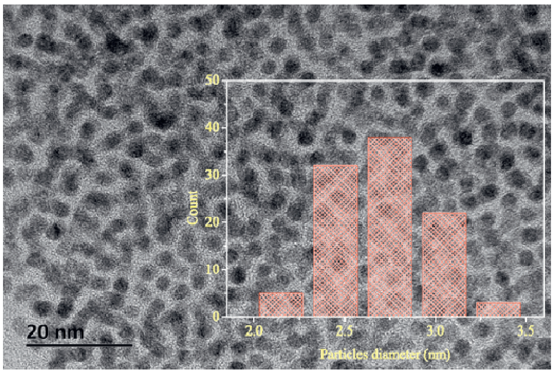

Fig.1 TEM image of monodispersed PdPt bimetal nanoparticles and the corresponding size distribution (inset).

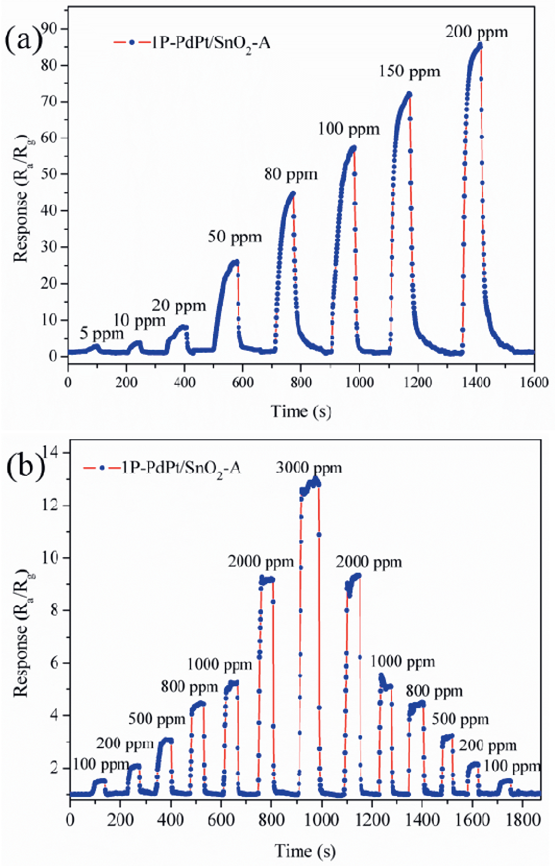

Fig.2 Dynamic response of 1P-PdPt/SnO_2-A sensor to different concentration of CO at 90℃ (a) and CH_4 at 300℃ (b).

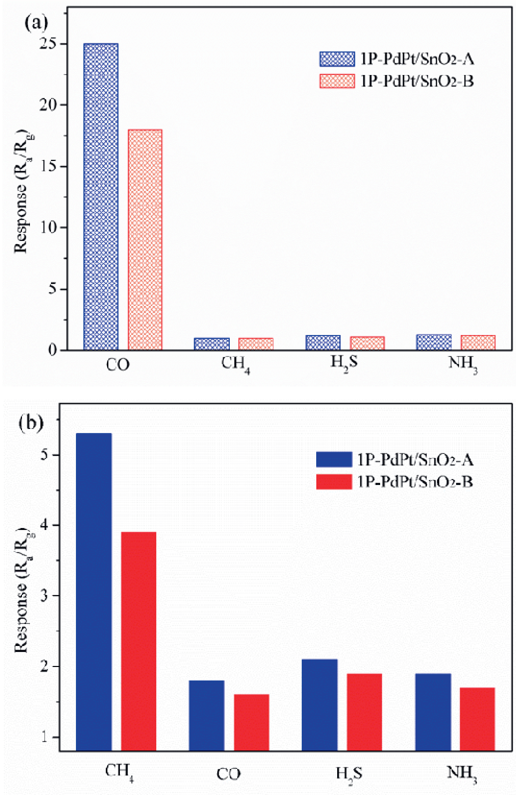

Fig.3 Selectivity of the sensor based on as-prepared composite on successive exposure to 1000 ppm CH_4 and 50 ppm other hazardous gases in the coalmines at 90℃(a) and 320℃(b).

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