Electrolytically Exfoliated Graphene/Flame-spray-made Vanadium-doped SnO$_2$ Composite Films for Nitric Oxide Sensing

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Abstract: The effect of functionalized additives of flame-spray-made SnO$_2$ nanoparticles on nitric oxide (NO) gas-sensing properties were systematically studied by doping with 0.1–2 wt% vanadium (V) and additional loading with 0.1–10 wt% electrolytically exfoliated graphene. Characterizations by X-ray diffraction, transmission/scanning electron microscopy and X-ray photoelectron spectroscopy significantly demonstrated that V-doped SnO$_2$ nanostructures had spheriodal morphology with polycrystalline tetragonal SnO$_2$ phase and vanadium (V$^{4+}$, V$^{5+}$) was confirmed to form solid solution with SnO$_2$ lattice while graphene in the sensing film after annealing and testing still retained high-quality multilayer structure with low oxygen content. The sensing films were prepared by a spin-coating technique on Au/Al$_2$O$_3$ substrates and evaluated for NO-sensing performances (25–1000 ppm) at operating temperatures ranging from 25 to 350°C in dry air. Gas-sensing results indicated that 0.1 wt% V-doped SnO$_2$ evidently catalyzed the highest response at 300°C. While, the additional loading of 0.5 wt% graphene into optimal 0.1 wt% V-doped SnO$_2$ composites led to a drastic response enhancement with shorter response times and fast recovery stabilization at optimal operating temperature of 250°C. The superior gas sensing performances of V-doped SnO$_2$ nanoparticles loaded with graphene may be attributed to large specific surface area of the composite, high density of reactive sites of highly porous non-agglomerated graphene–SnO$_2$ nanoparticle structure and high electronic conductivity of graphene, which allowed fast gas response and recovery. Moreover, detailed mechanisms for the drastic NO response enhancement by V and graphene were proposed based on the formation of graphene/V-doped SnO$_2$ ohmic metal-semiconductor junctions and accessible interfaces of graphene–metal oxide nanoparticles. Therefore, the graphene-loaded and V-doped SnO$_2$ sensor is potential for responsive detection of NO and may be useful for general environmental and biomedical applications.

Reference

Figures

RESULTS: (a) BF-TEM image of the optimal 0.5 wt%G/SnO$_2$ composite, (b) HR-TEM images of multilayer graphene (G), change in resistance under exposure to NO (25-1,000 ppm) of (c) undoped SnO$_2$ and 0.1-2 wt%V-doped SnO$_2$ at the optimal working temperature of 300°C and (d) 0.1-10 wt%G/0.1 wt%V-SnO$_2$ sensors at the optimal working temperature of 250°C.