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Pt- and Pd-nanoclusters functionalized carbon nanotubes networked films for sub-ppm gas sensors

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ABSTRACT

A gas chemiresistor, fabricated onto alumina using multi-walled carbon nanotubes (MWCNTs) networked films grown by radiofrequency plasma enhanced chemical vapor deposition (RF-PECVD) technology, is described for high-performance gas detection, at an operating temperature of 200 °C. Functionalizations of MWCNTs tangled bundle-films with nominally 5-nm thick Pt- and Pd-nanoclusters, prepared by magnetron sputtering, provide higher sensitivity for significantly enhanced gas detection of NO_2, H_2S, NH_3, CO, up to a low limit of sub-ppm level. The measured electrical conductance of the functionalized MWCNTs upon gas exposures is modulated by charge transfer with p-type semiconducting characteristics. Pt- and Pd-nanoclusters functionalized MWCNTs gas sensors exhibited better performances compared to unfunctionalized MWCNTs, making them promising candidates for air-pollutants environmental monitoring. Simple electronic interface for the chemiresistor has been developed with a voltage output of the sensor signal.

1. Introduction

Carbon nanotubes (CNTs) [1,2] have attracted considerable attention and a lot of interest because of their outstanding properties associated to unusual structural, electrical, optical, mechanical and thermal characteristics [3–6] combined in a challenging unique nanomaterial. These properties are essential to make them the most promising candidates for many potential applications in nanotechnology [7], such as field emitters [8,9], field-effect transistors [10], nanoactuators [11], hydrogen storage [12] and nanoelectronics [13]. The carbon nanotubes are also considered ideal building blocks for gas adsorption and chemical gas sensing due to their large specific surface area, hollow geometry, nanosized structure, including high electrical mobility of the charge-carriers in defect-free nanostructures. The study of gas sensing and gas adsorption is a very important topic for both fundamental researches at nanoscale and practical technical applications. An important application of CNTs is their use as highly sensitive nanostructured materials for gas sensors. It has been demonstrated that CNTs can be used to detect very low concentrations of gases [14–19] and vapors [20–23] with maximum performance in terms of high sensitivity, fast response, good repeatability. But the sensing mechanisms involved are not fully understood.

Gas sensors generally operate with different principles – surface acoustic waves [24], bulk acoustic waves [25], field-effect transistors [26], optical fibers [27] – and various gas sensing elements have been remarkably developed with a significant part comprising chemiresistors based on thin-films of metal oxides and conducting polymers, and nanostructures of metal oxides [28]. Carbon nanotube gas sensors can offer important advantages over metal oxides and conducting polymers sensors in terms of higher sensitivity, small sizes for miniaturized sensors, fabrication of massive nanosensor arrays, lower power consumption for wireless applications. However, various important issues remain unsolved. Mainly, the lack of selectivity of carbon nanotubes towards targeted gas analytes; secondly, the poor long-term stability of the CNTs-based gas sensors. The apparent lack of specific interactions between CNTs and gas molecules could be overcome by various strategies based on functionalizations with foreign materials of the nanotubes sidewalls imparting a significant selectivity.

The development of demanding carbon nanotubes gas sensors for air-quality monitoring is very needed for specific sensing applications of toxic gases, at ppb-detection level. Recently, gas sensors based on functionalized carbon nanotubes have been proposed capable of detecting small gas concentrations with high specificity. In fact, successful attempts of CNTs-sensors have been covered by polymers [29,30], enzymes [31], tin oxide layer [22,32], nafion

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