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Praseodymium-cerium oxide nanoparticles directly grown on CNTs walls: technological application in gas sensing

C. Verissimo[(1)*], A. Abbaspourrad[(1)], R. V. Gelamo[(1)], F. P. Rouxinol[(1)], O. L. Alves[(2)] and S. A. Moshkalev [(1)]

(1) Center for Semiconductor Components-CCS, State University of Campinas-UNICAMP, P.O Box 6061, 13083-870, Campinas, SP, Brazil; e-mail: carla@iqm.unicamp.br
(2) Laboratório de Química do Estado Sólido-LQES, Chemistry Institute-IQ, State University of Campinas-UNICAMP, P.O Box 6154, 13083-970, Campinas, SP, Brazil
* Corresponding author.

Abstract – Praseodymium-cerium oxide nanoparticles were synthesized, for the first time, directly on the outerside walls of multi-walled carbon nanotubes. Gas sensing abilities of CNTs/PrCe-oxide material was tested toward H_2S at low temperatures and atmospheric pressure presenting potential for application in this technological field.

In the last years, it has been demonstrated the ability of carbon nanotubes (CNTs) for gas sensing due to a possible charge transfer among nanotubes and gas molecules resulting in electrical conductance changes of nanotubes, which can be used as a detection signal for applications in gas sensor devices. The nanosized scale, large surface-to-volume ratio and low energy consume also make CNTs promising candidates to constitute micro- and nano-devices. To promote or increase sensitivity, as well selectivity, experimental procedures have been developed to modify CNTs by the attachment of metal and metal oxide nanoparticles on nanotube outside walls. Praseodymium-cerium oxide is a very attractive material due to its interesting electronic characteristics and high oxygen ion mobility, which make it a suitable material for sensing devices. In this work, we present for the first time the preparation of praseodymium-cerium oxide nanoparticles grown directly attached on the CNTs walls. Herein, we describe the preparation method, pioneer in the literature, to obtain MWCNTs/PrCe-oxide nanoparticles composite which is suitable for fabrication of field effect transistors devices with high-k material attached on nanotubes, or micro- and nano-gas sensors. Preliminary experiments using MWCNTs/PrCe-oxide hybrid material deposited between metal electrodes shown the ability of gas detection toward H_2S and N_2, indicating the technological potential application of this chemical system .

CNTs were heated in air at 330 ^oC to reduce the content of amorphous carbon and refluxed in nitric acid for 12 h. Metal carbonates were used in a hydrolysis reaction, under controlled pH value, assisted by ultrasonic bath. The final material was filtered and dried at 80 ^oC for 6 h, re-suspended in dimethylformamide and deposited between Au electrodes by dielectrophoresis to constitute sensor devices where decorated CNTs are used to fabricate a chemical resistor.

Thermal gravimetric analysis and infrared spectroscopy confirmed the oxidation of CNTs after acid treatment. High resolution transmission microscopy images showed the formation of crystalline nanoparticles attached all over the nanotubes surfaces after the hydrolysis reaction under controlled experimental conditions (Fig. 1). It was also observed a narrow diameter size distribution around 3-5 nm. PrCe-oxide nanoparticles decorated CNTs deposited on Au electrodes were electrically characterized by IxV curves under different temperatures. An improvement in the resistance was observed at higher temperatures, as well after a previous annealing performed to decrease contact resistance among nanotubes and metal electrodes. Gas sensor devices constituted by CNTs/PrCe-oxide nanocomposites were exposed to H_2S/air mixtures. The significant increase in the sensitivity (~400%) illustrated in Fig. 2, when H_2S was introduced inside the chamber, shows the potential of CNTs/PrCe-oxide chemical system to be employed in gas sensing applications at atmospheric pressure and very low temperatures (~150 ^oC).

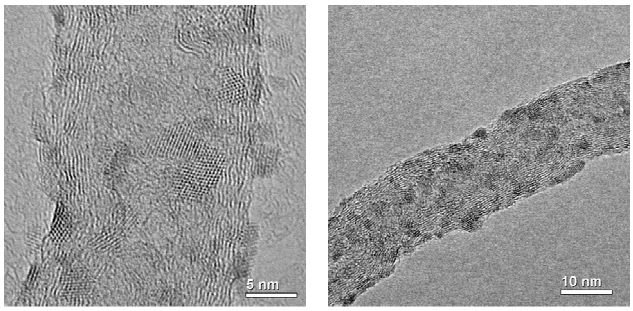

Figure 1: HRTEM images of CNTs decorated by PrCe-oxide nanoparticles.

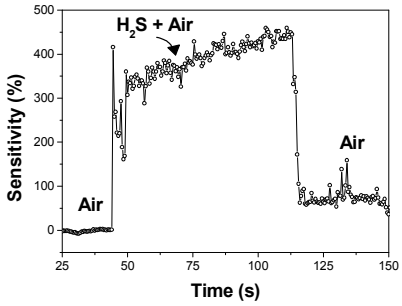

Figure 2: Gas sensing test of CNTs/PrCe-oxide material toward H_2S.