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Nanostructural films of CNTs covered with nanocrystals of palladium

Abstract: SEM (scanning electron microscopy) and TEM (transmission electron microscopy) investigations of CNT-Ni-Pd composite films prepared by a new three step method are presented. This new method consists of a PVD (Physical Vapor Deposition) process by which films with nanocrystalline Ni were obtained, followed by a CVD (Chemical Vapor Deposition) process in which CNT films with included Ni nanoparticles were obtained, and finally, a PVD process where CNTs were covered with carbonaceous-palladium nanograins. SEM images performed in two modes using a LABE (low-angle backscattered electron) detector and a SE (secondary electrons) detector, show the topography and morphology of the material. TEM and HRTEM is further used to characterize the composition and structure of the CNTs. The density of CNTs in the composite films obtained using different technological parameters was also studied.

Keywords: carbon nanotubes, palladium, PVD, CVD, SEM, TEM

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1 Introduction

Recently, carbon nanotubes (CNTs) have been used as chemical sensors, biosensors and hydrogen storing materials due to their unique properties. Their ordered structure makes CNTs an ideal material for gas adsorption. Many groups of researchers have investigated hydrogen storage and hydrogen sensing on CNTs [1,2], and sensing properties of materials composed of CNTs are generally associated with a change in their conductivity. This change is not visible for gases consisting of inert atoms and molecules (such as H_2), and because such molecules do not adsorb on the surface of nanotubes (or adsorb poorly), they do not affect CNT conductivity [3]. In such cases, functionalization of carbon nanotubes with suitable metal nanoparticles provides a solution.

To improve hydrogen adsorption of CNTs, doping of transition metals such as Pd, Ni, Pt [4-6] or Ti [7] is applied. Palladium is the most popular, as it demonstrates selective absorption of hydrogen gas, and the ability to form a chemical species known as a palladium hydride.

Several methods have been developed for the functionalization of CNTs with palladium nanoparticles, including electroless deposition [8], thermal decomposition [9], vapour deposition [10], chemical reduction in supercritical CO_2 solutions [11], impregnation [12] and electrodeposition [13] as well as the arc-discharge in solution process [14].

Nanostructural films containing carbon nanotubes covered with palladium seem promising because their surfaces are highly ordered, and covered with palladium, and may enhance sensing properties towards hydrogen, CO_2, CO and ethylene.

In this paper we present the results of electron microscopy studies of the structure, morphology, and topography of a CNT film, where CNTs were functionalized with palladium in the form of nanoparticles with various diameter.

2 Experimental

Nanocomposite CNTs -Ni-Pd films were prepared by a new, three step method developed in the Tele- and Radio Research Institute. This method consists of:

1. Preparation of initial film composed of a carbonaceous matrix and Ni nanoparticle (PVD process).
2. Chemical modification of the initial film to obtain a film of carbon nanotubes (CNTs) with Ni nanoparticles (CVD process).
3. Covering the CNTs film by carbonaceous-palladium nanoparticles (PVD process).