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Structural, thermal, and electrical properties of carbonaceous films containing palladium nanocrystals

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Abstract Carbonaceous films containing Pd nanocrystals can be applied as active layers in gas sensor applications. In this article we show results of studies of C-Pd films, obtained with two different methods: (1) physical and (2) physical + chemical deposition. First type of film prepared by physical vapor deposition (PVD) process was composed of fullerenes, amorphous carbon, and palladium nanograins. In the second method PVD film was modified in chemical vapor deposition (CVD) process forming a foam-like structure. Both types of films were studied by SEM, TEM, TGA, and electrical characterization (measurement of resistivity versus composition of gaseous hydrocarbons mixture).

Keywords Carbonaceous-palladium film · Carbon foam · Thermal stability · Hydrogen sensor

Introduction

Gas sensors are devices to detect or to measure concentration of different gaseous components in ambient atmosphere. In industrial production of chemical compounds, automotive transport, glass treatment, cryogenic cooling, as well as in petroleum conversion, hydrogen sensors are of great importance because they decide on a work safety and a human life. Requirements of a H_2 sensor are as follows: high sensitivity, fast response, high selectivity, long lifetime, operational safety, and low power consumption. A low electrical power can be achieved by sensor miniaturization. Therefore, researches pay their attention on nanomaterials, which are considered as ideal building blocks for gas adsorption and chemical gas sensing.

Nanostructured materials have developed specific surface area that allows to improve gas sensor sensitivity. Apart from, their small size, density, and weight cause lower consumption of raw materials, thus lower commercial production cost. Recently, carbon nanotubes (CNTs) have been utilized as an active sensing element in detection of hydrogen [1], NH_3, NO_2 [2, 3], and also of volatile organic compounds (such as ethanol, ethyl acetate, and toluene in nitrogen) [4]. CNT active element was built from pristine CNTs [5], CNTs filled with metal clusters [6, 7], and CNTs coated with polymers [2].

The other promising nanomaterials that can be used as gas sensing layers are carbon foams. The carbon foam includes a network of pores into which gaseous atoms or molecules could be adsorbed [8]. The carbon foam resists corrosion and exhibits high mechanical strength and thermal resistance, low density ($0.2 \div 0.8$ gcm^3) due to the presence of micro-, meso-, or macropores. These pores form highly developed surface area (of the order of hundred m^{2}g) [9]. These properties enable to utilize carbon nanoporous materials in gas sensors as active elements or as electrodes in batteries or fuel cells as well as in catalysis, ion exchange, molecular segregation, and insulation. Therefore, new effective production methods of carbon foams are still searched for. Initially, carbon foams were formed by the pyrolysis of thermosetting polymer [10, 11]. At present there are many various precursors for production of lightweight carbon materials such as coal, coal tar pitch,

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