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Interaction of 3D mesostructures composed of Pd-Ni alloy nanowires with low-temperature oxygen plasma

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ABSTRACT

We report that volumetric mesoporous structures obtained via self-organization of Pd-Ni nanowires interact actively with low temperature non-equilibrium oxygen plasma. This interaction leads to strong red incandescence of the composite nanostrucutures. After the plasma-chemical treatment, the X-ray diffraction pattern reveals presence of nanocrystalline nickel (II) oxide phase on surface of the samples. Measurements of electromagnetic response indicate that the samples exposed to oxygen plasma retain metallic type conductivity which is similar to the pristine Pd-Ni samples. Thus our studies indicate that the plasma-chemical treatment yields novel composite 3D hierarchical structures with a highly conductive skeleton of Pd-Ni nanowires covered by a thin nickel (II) oxide semiconducting layer of large surface area. These structures are attractive for applications.

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1. Introduction

We have previously reported on an effective electrochemical method for the fabrication of mesoporous 3D hierarchical structures composed of metallic nanowires [1–3]. These mesostructures are novel objects in which the metal forms a volumetric skeleton of conducting nanowires with an amorphous-nanocrystalline structure [2,3]. Volumetric structures, consisting of nanowires of metals [4] or metal oxides [5], are increasingly attracting the attention of researchers in the field of nanostructured materials. Furthermore, as the next step toward multi-functional materials for efficient electronic devices, composite hierarchical structures containing a robust conductive 3D skeleton of metallic nanowires coated by a semiconducting or insulating layer of a metal oxide are an attractive prospect for applications. Another interesting approach to the composite structures is co-polymerization in a presence of metal oxide nanoparticles [6]. Such polymer matrixes yield an electric conductivity which is, however, significantly less than a typical conductivity of metals such as Ni or Pd that may limit the field of applications. In contrast a standard treatment of the metallic mesostructures obtained via the pulsed electrodeposition in oxygen plasma looks as an effective technological route for the fabrication of 3D composite structures with a highly conducting skeleton. The aim of the presented work is to identify results of the interaction of 3D mesoporous metallic structures composed of Pd-Ni nanowires with a low-temperature non-equilibrium oxygen plasma.

2. Experimental

Metallic 3D mesostructures were fabricated using an electrochemical method [1,2]. The studied samples were exposed to the oxygen plasma in a cylindrical quartz reactor (diameter 95 mm, length 300 mm) with a RF power achieved 100 W. Oxygen flow through the reactor was kept at a rate from 4.5 to 5 ml/min., while the oxygen pressure was between 0.7 and 0.8 mbar. The structure of samples was studied using a Leica M165 C optical stereo microscope and SUPRA 50VP, JEOL 7001F, JEM-2100 scanning electron microscopes. Measurements of the dynamic magnetic susceptibility of the samples at a frequency of 100 kHz and a magnetic field $H \sim 1$ Oe were used for the characterization of their electronic conductivity [7].

3. Results

Fig. 1 presents SEM images of convex-concave mesoscopic 3D structures composed of Pd-Ni nanowires (“seashells”) that were used as samples for the plasma treatment.

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