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Composition of nanocomposites based on thin layers of tin on porous silicon formed by magnetron sputtering

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ABSTRACT

Using scanning electron microscopy and X-ray photoelectron spectroscopy the features of morphology and peculiarities of the surface composition of nanocomposites made of thin tin layers by magnetron sputtering formed on porous silicon with pores size of 50–150 nm. Porous silicon was obtained on n-type conductivity crystalline silicon substrate. The obtained nanocomposites were found differ between themselves by the ratio of the main phases: tin dioxide, sub-oxide and metal tin in a dependence on the thickness of the deposited tin layer. Fraction of the oxidized tin in the phase composition of composites was reduced from the surface to the bulk of the sample. Moreover, it was determined that the deposition of tin nanolayers did not result in a considerable change of the phase composition of porous silicon substrate.

1. Introduction

Currently, materials for multi-sensor systems, versatile optoelectronic facilities, and semiconductor devices are of a serious interest for researchers [1,2]. Porous silicon layer, modified by metal or metal-oxide deposition seems prospective for this kind of the practical applications. Formation of gas-sensitive composite materials with high sensitivity and selectivity, including those ones on the basis of tin matched with conventional silicon technology is also interesting for non-invasive express-diagnostics in medicine [2–4]. Formation of nanoparticles from ferromagnetic metals in the dielectric array is of a certain challenge; dielectric matrix can be used as a substrate for making of the memory cells. In addition, deposition of thin metal-containing layers can improve passage of the current through por-Si layer. Moreover, nanostructures and nanocomposites on the basis of porous silicon, such as metal/por-Si and metal-oxide/por-Si, can demonstrate rather interesting adsorption and optical properties [5–7].

One should also note that the process of production of such MOS-structures and nanocomposites with the use of metal deposition into porous silicon applying conventional techniques such as magnetron sputtering, electrochemical deposition, sol-gel method, is quite cheap and compatible with the routine technologies for manufacturing of silicon semiconductor structures. In a dependence of the deposition technique, thickness and morphology of the obtained film the composition and properties of the incorporated metal-containing layers can vary quite considerably [6,7]. In our work, using X-ray photoelectron spectroscopy and scanning electron microscopy the study of morphology and composition of nanocomposites produced from thin tin layers of different thickness on the surface of porous silicon.

2. Methods for obtaining and investigations of Sn/por-Si nanocomposites

Porous silicon (por-Si) was obtained by electrochemical etching of silicon monocrytalline plates c-Si (100) of n-type conductivity with the resistivity of 0,2 Ω cm. Standard solution on the basis of hydrofluoric acid, isopropyl alcohol and hydrogen peroxide [8] was employed. Anodic etching of the plates was performed for 10 min at the current density of 15 mA/cm^2 followed by washing in pure water and isopropyl alcohol. Porous silicon was formed simultaneously on both sides of a Si plate, tin was deposited on one side in order to obtain nanocomposite Sn/por-Si after 3–5 min required for drying of samples surface.

Deposition of tin films was performed by magnetron sputtering in the plasma-generating medium of argon. Residual pressure in magnetron chamber was of 5*10^{-6} Torr, argon pressure was of 10^{-3} Torr, discharge current was 60 mA, discharge voltage was 380 V. Deposition was performed at room temperature, super-purity tin was applied as a target in this process. Deposition rate of metal film under the experimental conditions was of ~1 nm/sec, according to the calibration

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experiments. The deposition time of tin films on the porous silicon layer was of t=20 s and 50 s

All of the experimental data were obtained after about 6 months from samples preparation. Scanning images of the sample surfaces were obtained with the use of electron microscope JEOL – JSM 6380LV. The study of composition of the samples surface for the original por-Si and nanocomposites (NC) of Sn/por-Si with different thickness were performed with the use of X-ray photoelectron spectroscopy (XPS). Investigations of the samples by XPS technique were made with the laboratory spectrometer produced by SPECS Company, excitation of the spectra was performed with Mg K_α radiation. Analysis of the sample composition in the composites with the use of this technique was performed as in the surface layers ~1 nm, as at the different depth determined by the time of the sample etching. Etching of the sample surface for 1 min and 3 min was realized by argon ions with the energy of 4 keV, ion current density was of 30 μA/cm^2, etching rate of the samples was of 2–2,5 nm/min. Thus, the depth of analysis for the samples with the use of this technique was of ~1–2 to 7 nm.

Processing of the experimental data was performed with the use of the program suite Origin 9.0. Technique for determination of the background line as well as its subtraction according to the algorithms proposed by Shirley [9], were also realized with the use of this program. For determination of the binding energies of core levels for the elements in nanocomposites C1s line of the natural hydrocarbon contaminations on the surface of any sample that was not subjected to a special purification was applied as a reference line that was reduced to the energy of E_b[C1s]=285 eV. Identification of XPS core levels of the elements and their chemical state was performed with the use of the database of X-ray photoelectron spectra kept at the National Institutes of Standards and Technology of the USA [10].

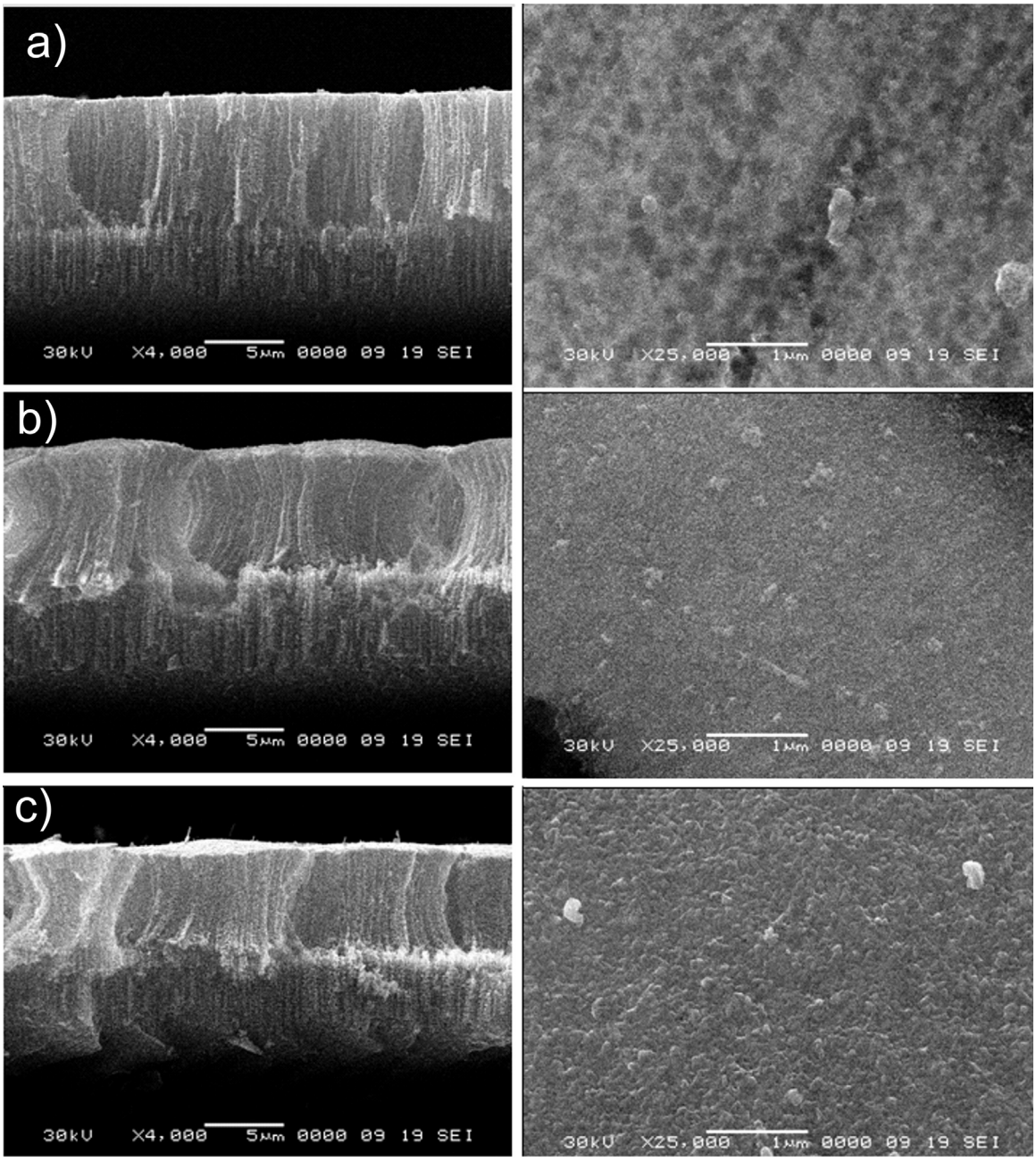

Fig. 1. SEM images of the cleavages (left) and surfaces of the samples (right): a) original porous silicon and nanocomposites of b) Sn/por-Si with thin tin layer and c) more thick tin layer.