Features of adsorption and electrical properties of nanostructured composites based on porous silicon and metal/oxide nanoclusters

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In this paper we present the results of studies of nanoporous silicon matrix with incorporated copper and copper oxide nanoclasters. It is known that the surface of freshly produced porous silicon covered by layer of hydrides silicon. During storage of the structures or thermal treatments in air is a gradual oxidation of the pore surface and replacement hydride layer on oxide. It was found that this layer greatly influences on the pore filling by copper nanoclusters. The copper doped porous silicon was realized by means of electrolysis deposition method. The morphology of surfaces has been researched by means of scanning electron microscopy. This method allows to estimate that the electrolysis deposition copper on porous silicon surface has appearance of clusters. The copper distributing on depth porous silicon was investigated by second ion mass spectroscopy (Fig. 1). It can be seen during the electrochemical method for pore filling have been observed an accumulation of copper at the interface Si_{por}/Si (Fig.1). The morphology of silicon composite was characterised by atomic force microscopy (AFM) and scanning electron microscopy (SEM). The infra red (IR) spectroscopy was used for elemental analysis of gas sensitive composite. It was also found nanoporous silicon doped by Cu and/or CuO_x demonstrates the enhanced adsorboelectric effects in the semiconductor-layered structures. In this case the using of thin catalytic composite metal/Sipor films with d- and sp- metals (Cu, Pd, W) leads to the enhanced adsorption activity and stability to oxidation and ageing process. The physical mechanism has been proposed for explain the observed phenomena. A model based on the combination of hopping and tunneling mechanisms of charge transfer have been proposed.

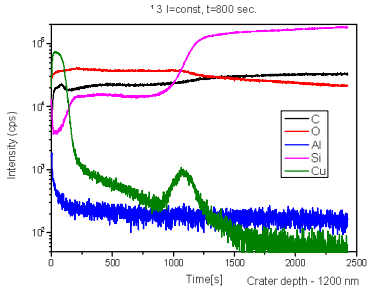

Fig. 1. Second ion mass spectroscopy: distribution of copper in the structure Si_{por}/Si at electrochemical method filling the pores by the metal clusters

Our research has been focused on the preparation and characterization of layered semiconductor structures based on nanoporous silicon (Si_{por}) with embedded clusters of catalytic (Pd, W) and/or noncatalytic (Cu) metals and its oxides (CuO_x, WO_x) by means of current-voltage (I-V) characteristics and high-frequency C(V) method under the adsorption of H_2 and H_2S gases. To uniformly pore filling by metal clusters the thin metal (Pd, Cu, W) films were deposited on the surface of the porous silicon using the magnetron deposition technique at room temperature followed by annealing at 673-873 K in argon during 30-40 min. The distribution of catalytically active metal on the film thickness of porous silicon was studied by the secondary ion mass spectroscopy (SIMS). It can be seen that copper and copper oxide uniformly distributed in the porous silicon layer. The morphology of silicon composite was characterised by atomic force microscopy (AFM) and scanning electron microscopy (SEM). The infra red (IR) spectroscopy was used for elemental analysis of gas sensitive composite.

It was found that the thin film structures with porous silicon filled by palladium and copper clusters are more sensitive to hydrogen, while the filling of the pores by W and WO_3 clusters leads to increased sensitivity to hydrogen sulphide. The physical mechanism has been proposed for explain the observed phenomena. A model based on the combination of hopping and tunneling mechanisms has also been proposed to explain the charge transfer in such structures.