FORMATION OF METAL NANOPARTICLES ON NONMETAL SUBSTRATES FOR HETEROGENEOUS NANOCATALYSTS

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ABSTRACT

In the present study the methods of synthesis and characterization of metal nanoparticles structures of a given size and surface topology on the non-metallic surfaces are described. The main application of such particles can be selective heterogeneous catalysis of chemical reactions or their usage as nucleus of growth centers for different nanostructures (tubes, whiskers, etc.).

The formation of nanoparticles systems on the surface was carried out by two ways: by "thin cutoff plate" method and by vacuum annealing of ultrathin solid films. Metal was deposited on the substrate by thermal evaporation (deposition) in vacuum.

Studies of the samples were carried out using the methods of Auger analysis and scanning electron microscopy. AES detects intense peaks of deposited metals with weak tungsten (the evaporator material), oxygen, carbon and the substrate material elements peaks in chemical composition of the films. The SEM studies reveal the presence of well-defined islet metallic structures on the samples obtained by both methods. For vacuum annealing method a clear correlation between annealing and obtained structures parameters is demonstrated.

Key words: nanoparticles, sputtering, substrates, metal, SEM, nanoislands.

INTRODUCTION

For the last few decades the world is confronted with acute problem of energy- and resource-saving. In this connection, special importance has the introduction of nanotechnology in all fields of industry and everyday life [1]. The chemical industry is no exception. Particularly important here is usage of heterogeneous solid nanocatalysts. Benefits of nanocatalyst to the classic one are the greater efficiency, fewer resources, the ability to selective catalysis. The use of such nanocatalysts is only limited by the high cost of technologies of their production [2].

Thus the goal of this work was to develop a method of synthesis of metal nanoparticles systems of a given size and topology on non-metallic surfaces. The method should be cheap and easily reproducible for the application in large-scale production.

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METHODS OF SAMPLES MANUFACTURING AND ANALYSIS

The most known and rather cheap methods of metallic thin film formation are the methods of vacuum evaporation from the gas phase. In our work we have used the method of thermal deposition of metal on the heated Si (111) substrate.

For the formation of nano-sized (islet) structures in thin film coatings two methods were applied. The first "thin cutoff plate" method consists in creation of artificial barrier for sputtering metal (*Fig. 1*).

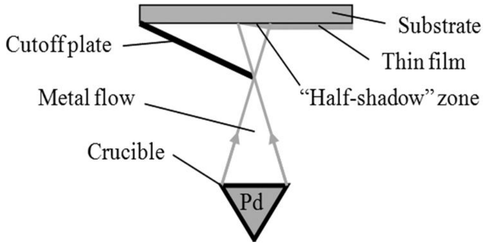

Fig. 1 – A scheme of "cutoff plate" metod

As the barrier a thin cutoff plate located at an angle to the substrate was used. Because of non-point evaporator and thermal diffusion of atoms in the flow a part of deposited material penetrate under the cutoff plate, forming a "half-shadow" zone. Thus the surface of the sample was divided into two zones: a continuous metal film and the clean substrate surface. On the border of these two zones there was a transition region "half-shadow" zone which is a smooth transition between the continuous film and lack of deposited material. The structure of the half-shadow consists of the following specific areas (division is relative): continuous film, a film with open fields and channels, the structure of clusters with three-dimensional island formations, separated zones of nanoislands, nucleus structure.

The second method of islet nanostructure formation is vacuum annealing of ultrathin continuous metal films previously obtained by vacuum deposition [3]. To study the correlation between annealing parameters and parameters of obtained structures series of ultrathin films samples under identical conditions were formed and then they were subjected to heat treatment under different conditions [4]. The initial film thickness for different series was 20 - 50 nm. The following features of nanostructures were studied: the chemical composition (Auger-electron analysis), the characteristic nanoislands size and their surface topology (Scanning electron microscopy). Annealing conditions differ by: maximum annealing temperature T (250 - 450°C), duration of treatment at the maximum temperature τ (60 - 120 min.).

RESULTS AND DISCUSSION

The first method have showed the feasibility of metal nanoisland formations on the non-metallic surfaces. But he had a serious drawback. Nanoisland structures were located only a very narrow region of the half-shadow, that is a useful area was much smaller than the total area of the sample.

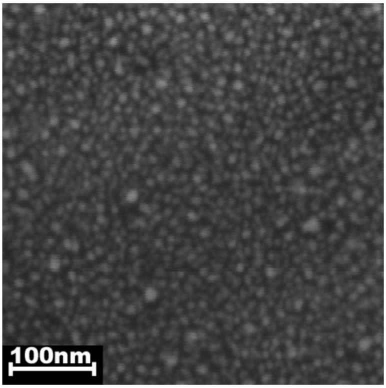

Fig. 2 – SEM pattern of nanoislands structure (*T=450°C, τ=120 min*)

The second method essentially had no drawback of the first method, but in contrast, it requires precise thickness control of sputtered ultrathin films.

Studies of samples by AES detect the presence of intense peaks of deposited metals and weak peaks of tungsten (the evaporator material), oxygen, carbon and the substrate material elements.

SEM studies demonstrate a correlation between heat treatment regimes and samples structure, namely, the treatment time determines the degree of destructing of initial films, the annealing temperature have an effect on the number of nucleation centers of formed islands and as a consequence of their size (see *fig.2* as an example).

CONCLUSIONS

Thus, the possibility of usage of low-cost vacuum deposition methods for formation of metal nanoparticles systems has been confirmed. SEM studies show the presence of similar structures on the samples produced by both methods.

Study of the influence of vacuum heat treatment parameters on the structure of formed nanostructures shows a clear correlation between annealing time and degree of film separation, as well as between annealing temperature and the size of the islands.

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