HIGH-TEMPERATURE SURFACE DIFFUSION OF COPPER ON THE (112) FACE OF TUNGSTEN UNDER CONDITION OF FILM-LAYER GROWTH OF ADSORBED FILM

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ABSTRACT

The phase state of the epitaxial Cu film on W(112) face has been investigated by the method of the contact difference of potentials under condition of film-layer growth. We have determined desorption heat, critical temperature and critical coverage experimentally. The phase diagram has been plotted as well as the temperature dependence of heat of a two-dimensional phase transition "liquid – gas" has been obtained. An exponent of order parameter has been found.

Key words: phase transition, desorption, surface diffusion.

INTRODUCTION

Intensive development of many of today's trends in technology serves as an incentive to study the processes in ultrathin (monolayer) films. Such films are known to cause strong changes in different surface properties. The influence of surface phase transitions on the properties is of particular both theoretical and practical interest [1]. The establishment of equilibrium between the coexisting phases is indispensable in the study of the phase state of the heterogeneous adsorbed film. However, phase transitions can occur in the adsorption systems that are very far from equilibrium, but those in which dynamic processes are stationary.

The methods of equilibrium statistical physics are used in the study of equilibrium and weakly nonequilibrium phase transitions. Such phenomena as nonergodicity of statistical ensemble, the emergence of hierarchical structures, structural relaxation etc can be observed in the case of strongly non-equilibrium condensed matter. Such systems can be studied on the basis of synergetic pattern that represents the evolution of the mutually agreed hydrodynamic modes that parameterize the system [2].

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METHODS OF SAMPLE MANUFACTURING AND ANALYSIS

In the paper, we used the method of the contact difference of potentials to investigate phase transformations in adsorbed layers (adlayers) of copper on the W(112) face and desorption processes that occur in stationary conditions.

The changes of local values of work function are caused by redistribution of copper adatoms due to their desorption and surface diffusion. Metal-on-metal systems are widely used practically. The W(112) face presents particular physical interest due to its strongly anisotropic structure. The face consists of closely packed parallel rows of tungsten atoms, separated by furrows of atomic depth. This structure determines the important features in the lateral atom inter-action, symmetry of two-dimensional adsorbate lattice [3], as well as in the nature of surface diffusion [4]. The aim of our work was to study of desorption characteristics and phase state of copper monolayers on the W(112) face under condition of film-layer growth in wide temperature range. Such data may be valuable to create surfaces with desired properties and management of surface processes. Surface diffusion of copper on the W(112) face at low temperatures has been investigated in our paper [5]. High-temperature diffusion is often accompanied by adatom desorption. For example, in [6-8] it was shown that diffusion coefficients of such adsorbates as strontium and barium in the second monolayer on the (112), (110) faces of tungsten and molybdenum still remain low at temperatures beginning of desorption. Therefore it is impossible to obtain the coverage distributions formed by diffusion in second monolayer, since the adatoms are desorbed before they manage to move a distance greater than the spatial resolution of the experimental method used (1 micron). A completely different situation occurs in the case of diffusion of copper. Different authors have shown that the diffusion growth of copper films on tungsten takes place first layerwise, in other words the Stranski-Krastanov mechanism is implemented. And it is typical both for atomically smooth (110) [9] and atomic anisotropic (112) [5] faces. Desorption is carried out layerwise within the first three monolayers. Copper forms strong bonds with the tungsten. The bonds of adatoms in the second monolayer are weakened by lower layer of copper, and the third geometric monolayer is transitional [10]. Here mutual attraction of the copper atoms becomes very significant for the diffusion of individual atoms on the background of low levels of potential barriers [5]. The adatoms form two-dimensional lattice gas from physical monolayer under desorption, so two-dimensional condensed phases of copper are absent [10]. But film of copper remains heterogeneous in the third monolayer even at temperatures of intensive desorption (there are islands of condensed phase in the background of the lattice gas). It is known that the phase state strongly affects the diffusion characteristics of the adatoms [4], which clearly manifests in the formation of diffusion concentration profiles [5]. We have used this fact to study phase transitions

under conditions where the rate of desorption and diffusion in two different phases are very different.

RESULTS AND DISCUSSION

The zone of heterogeneity on the concentration profiles formed by the diffusion process is allocated by a high concentration gradient due to the strong differences in the values of diffusion coefficients in the two phases. Herewith desorption occurs predominantly from the gas phase. The zone separates the film into two parts. One part is formed by two-dimensional gas and the second – by two-dimensional condensed phase. Desorption is controlled by diffusion of copper in the field of heterogeneous state of the adsorbed film, i.e. by the rate of arrival of material in a zone of intense desorption. We have performed a series of experiments at different temperatures. The obtained information allowed to plot a phase diagram for two-dimensional system "gas – condensed phase", to find the concentration dependence of the heat of desorption, to determine the critical temperature and the critical coverage, to calculate the enthalpy of evaporation of two-dimensional condensed phase and to estimate the value of the exponent of the order parameter.

CONCLUSIONS

If an adsorbate is easily desorbed from the gas phase at diffusion temperatures and desorption from the condensed phase can be neglected, a dynamic equilibrium between the liquid and gas phases is established, which is controlled by the diffusion process. In this case, concentration profile will move with constant velocity toward higher concentrations without changing its shape over time. This allows us to accurately define the concentrations at which phase transitions occur at given temperatures, and to find the critical parameters of the adsorbed film.

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