Structural-phase and Strained State of Vacuum-ARC Mo-N Coatings

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The effect of substrate bias on the structural-phase and elastic stress-strained state during the formation of vacuum-arc deposited nanostructural coatings of the Mo–N system has been studied. An increase in the bias potential leads to (i) predominant [111] orientation of the growing molybdenum nitride crystals with a NaCl-type cubic lattice (γ-Mo$_2$N phase) and (ii) the appearance of a second phase with a body-centered cubic crystal lattice that is characteristic of pure molybdenum. The elastically strained (stressed) state of the coating is determined not only by the conditions of deposition, but also by the mechanical properties of a substrate. In order to provide for formation of coatings in a high-elastic-strained (stressed) state, it is necessary to deposit coatings onto substrates with high elastic modulus, which prevent metal flow at the interface.

Keywords: Vacuum-arc coating, Mo–N system, Negative bias, Structural-phase state, Predominant orientation, Elastic-strained (stressed) state.

1. INTRODUCTION

At the present time, there is a distinct lack of information on the influence of vacuum-plasma parameters process of obtaining the most commonly used nitride coatings deposited in a reactive environment on the formation of phase composition, structure and strained state.

The high sensitivity of the state of coating system Mo-N to the conditions of deposition [1-3] led to the need of studying of the influence of conditions of vacuum-arc deposition on the phase composition, structure and strained state of the formed material.

2. METHODS OF SAMPIE MANUFACTURING AND ANALYSIS

Coatings were obtained by using vacuum-arc apparatus, "Bulat-6". Vaporized material is pure vacuum melted molybdenum. Deposition parameters: arc current I = 105 and 160 A, a constant substrate potential -5V ("floating" potential) –40 V and –200 V, the nitrogen pressure during deposition was 0.03 Pa and 0.2 Pa. Polished substrates made of stainless steel 12X18H9T, nickel (plate 4 mm thick), copper (plate thickness of 5 mm and a foil thickness of 0.2 mm) were used for the deposition. After pumping the vacuum chamber to a pressure of $P_N \approx 1 \cdot 10^{-3}$ Pa a negative bias of 1000 V was applied to a substrate and with an arc current of 105 A cleaning and activation of the surface by means of molybdenum ion bombardment was held for (3 ... 4) minutes.

3. RESULTS AND DISCUSSION

The phase composition by X-ray diffraction (DRON - 3M, the emission of Cu-K$_\alpha$) showed that in low nitrogen pressure of (0.03…0.04) Pa vacuum-arc coatings consist of α-Mo with lattice parameter 0.3152 nm, which have a columnar structure and hardness of (3.5…5) GPa. With increasing of pressure to more then 0.04 Pa traces of high-temperature γ-Mo$_2$N phase and low-temperature β-Mo$_2$N phase appear in the coating composition. Their content increases with increasing pressure.

Higher pressures $P_N = (0,06 ... 0.2)$ Pa lead to the formation of molybdenum nitride coatings Mo$_2$N of two modifications which are identical to the products of interaction of molybdenum with nitrogen according to the equilibrium phase diagram. Along with the high-temperature γ-Mo$_2$N phase with a cubic lattice, low-temperature phase β-Mo$_2$N with a tetragonal lattice is revealed, its content increases with increasing the deposition rate. At a pressure of about 0.07 Pa hardness of coatings reaches its maximum (45 ... 55) GPa. In the coatings with higher hardness the average size of grains (crystallites) is about 15 nm at a value of microstrain 0.4%.

Typical X-ray diffraction spectra of the coatings Mo-N, obtained at pressures of 0.06 ... 0.2 Pa and a low bias (–40 V) are shown in Fig. 1.

If we examine the influence of the thickness of coatings on the appearance of preferred orientation of growth of crystallites γ-Mo$_2$N phase with a cubic lattice (structural type NaCl), then under small thickness ((0.7 − 1.1) microns) texture with the growth axis perpendicular to the surface [100] is formed. This becomes apparent in the relative intensity amplification of diffraction peaks from the planes (200) and (400). In the thick coatings with the thickness of (4.5 − 7) microns the preferred orientation of crystallites with the plane (311) parallel to the growth surface is formed, i.e. with

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the texture axis [311]. It should be noted that the texture formed in the γ-Mo$_2$N phase is a weak texture, as width at half maximum while ψ-scanning of this texture was 30° ($\Delta\psi > 30°$) for a plane (311).
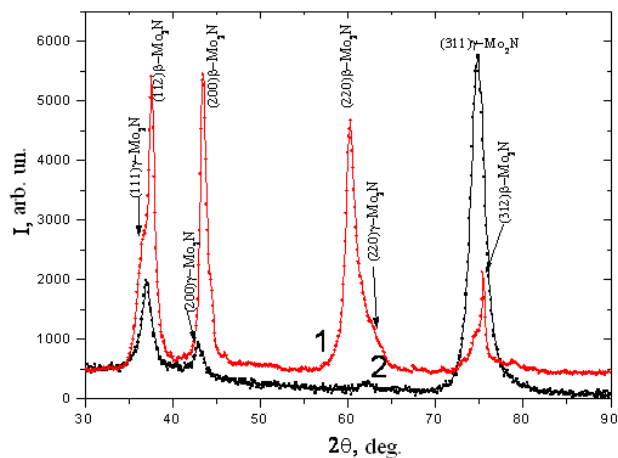

Fig. 1 – X-ray diffraction spectra of Mo-N coatings with low potential for bias (–40 V): 1 – P_N = 0,06 Pa. 2 – P_N = 0,2 Pa

In case of a large potential bias (–200V) secondary sputtering of the nitrogen atoms from the surface leads to the change of phase composition and to appearance of intense diffraction peaks of the solid solution of nitrogen in molybdenum with a *bcc*-lattice.

4. CONCIUSION

An increase in the bias potential leads to predominant [111] orientation of the growing molybdenum nitride crystals with a NaCl-type cubic lattice (γ-Mo$_2$N phase) and the appearance of a second phase with a body-centered cubic crystal lattice that is characteristic of pure molybdenum.

The elastically strained (stressed) state of the coating is determined not only by the conditions of deposition, but also by the mechanical properties of a substrate. Elastic macrostress-deformed state of coatings, determined by the method of multiple inclined surveys, have been contracting. The magnitude of macrodeformation for coatings with the greatest firmness reached high values –1.9 ... –2.0%.

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