About Peculiarities of the Influence of the Negative Bias Potential Applied to the Substrate During the Deposition Process on the Structural State and Properties of the Multilayer system MoN-CrN

V.M. Beresnev1,*, O.V. Sobol2, A.D. Pogrebnjak3, U.S. Nyemchenko4, S.S. Grankin5, V.A. Stolbovoy3, P.V. Turbin1,2, A.A. Meylehover2, M.Ju. Arseenkov6

1 V.N. Karazin Kharkiv National University, 4, Svobody Sq., 61022, Kharkiv, Ukraine
2 National Technical University "Kharkiv polytechnic institute", 21, Fruzne Str., Kharkiv 61002, Ukraine
3 Sumy State University, 2, Rymsky Korsakov Str., 40007 Sumy, Ukraine
4 National Science Center "Kharkiv Institute of Physics and Technology", 1, Akademicheskaya St., Kharkiv 61108, Ukraine
5 Scientific Center of Physical Technologies of MES and NAS of Ukraine, Svobody sq., 6, 61022, Mail Box 4499, Kharkiv, Ukraine
6 National Research University "Belgorod State University", 85, Pobedy Str., Belgorod 308015, Russia

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Applying transition metal nitrides of Mo and Cr, which are characterized by a relatively low heat of formation, as the components of the multilayer coating, the possibilities of elemental and structural engineering of vacuum-arc coatings under the influence of the bias potential U, and the reaction gas pressure P, are revealed. It was found that at a relatively small thickness of the layers of nanometer range, which provides a superhard state of the coatings, the supply of U with the value of above the critical leads to a drop in hardness, which can be explained by mixing of layers at the interphase boundary.

Keywords: Vacuum-arc coatings, Multilayer coating, Hard coatings, Vacuum-arc deposition.

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Using multilayer systems allows to carry out simulation during the deposition, not only for the structural state of each of the layers individually, but also by adjusting the thickness, the type of material and the number of layers in a period; creation of artificial structures with unique functional properties is also possible [1 - 5].

Structure and properties of the coatings based on MoN and CrN in monolayer state may vary in a wide range depending on the potential applied to the substrate and the pressure of nitrogen atmosphere during the deposition process [6, 7]. In connection to this, we can expect considerable sensitivity of structural states and properties of the coatings obtained by combining CrN and MoN as layers of the multilayer system. Thus, the greatest effects can be expected in the nanometer size of the layers, which is due to the high mechanical properties of nitrides in this size range [8, 9].

The samples of multilayer coating were obtained by means of vacuum-arc method by means of the modernized "Bulat-6" installation [10]. The pressure of working atmosphere (nitrogen) during the deposition was P = (7…30) × 10⁻⁴ Torr, the deposition speed was about 3 nm/s. The deposition was implemented from two sources (Mo and Cr) with continuous rotation with a speed of 8 rpm of fixed samples on the substrates, which allowed to obtain layers with a thickness of about 10 nm, with a total amount of layers 960 (or 480 bilayer periods) and total thickness of the coating of about 9 μm during one hour deposition. In the process of deposition the constant negative potential with a value of U = – 20 V, – 70 V, – 150 V and – 300 V was applied to the substrates.

Phase and structural analysis was carried out by means of X-ray diffraction method in the emission of Cu-Kα. The separation of profiles into components was carried out by means of the software package "New Profile". The elemental composition was investigated by energy dispersive method by means of scanning electron microscope FEI Nova NanoSEM 450. The hardness of the coatings was measured by means of durometer DM-8 by micro-Vickers method, at a load on indenter of 0.2 N.

Fig. 1 shows the data of elemental analysis depending on the pressure Pn and the applied negative bias potential U. It can be seen that the content of nitrogen as a light interstitial element in determining way depends on the magnitude of Pn during the deposition (Fig. 1a). The effect of U affects lesser (Fig. 1b) and appears in a relative decrease (due to selective secondary sputtering from the growth surface) of the atomic concentration of nitrogen at high U. It should be noted, that the strengthening of connections between the deposited metal and the atmospheric nitrogen at high pressure Pn leads to stabilization of the coating composition to a substantially larger in magnitude U (Figure 1b, dependence 2).

Increasing the bias potential U leads to a significant increase in uniformity (reduction of dropping component) of the coatings (microscopic image of the morphology on the left of fig. 1c for U = – 20 V, and on the right for U = –150 V).

It should be also noted, that using of pulsed beams to vaporize the material deposited on the substrate allows to eliminates the presence of drop component [11, 12].

beresnev-sct@yandex.ru
The changing the content of nitrogen in the coating depends on: a – pressures during the deposition ($P_N$) at a constant $U_s = -70\ V$; b – from $U_s$ at a constant $P_N = 7 \times 10^{-4}\ Torr$ (curve 1) and $P_N = 3 \times 10^{-3}\ Torr$ (curve 2); c – dependence of the correlation of the atoms Mo/Cr from $U_s$ at $P_N = 7 \times 10^{-4}\ Torr$ (curve 1) and $P_N = 3 \times 10^{-3}\ Torr$ (curve 2) (on the left and on the right side of the graph the images of morphology of the surface at $U_s = -20\ V$ and $U_s = -150\ V$)
gen sublattice due to its smaller content in the coating in comparison with the stoichiometric composition.

The reason of the decrease in hardness with increasing $U_s$ is the intensification of the mixing process in the border area, which leads to the formation of a significant part of the solid solution with low hardness for relatively thin (about 10 nm) layers.

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