

Specific Features of the Microstructure and Properties of Multielement Nitride Coatings Based on TiZrNbAlYCr

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Abstract—Multicomponent nanostructured coatings based on (TiZrNbAlYCr)N with a hardness as high as 47 GPa were obtained by cathodic arc deposition. The effect of partial nitrogen pressure P_N (with constant bias potential $U_b = -200$ V applied to the substrate) on the phase-composition variation, the size of crystallites, and their relation to the microstructure and hardness was investigated. An increase in the nitrogen pressure resulted in the formation of two phases with characteristic BCC (the lattice period is 0.342 nm) and FCC lattices with averaged nanocrystallite sizes of 15 and 2 nm. At a high pressure of 0.5 Pa, crystallites in the FCC phase with a lattice period of 0.437 nm grew in size to ~ 7 nm. The hardness of deposited coatings with larger (3.5 nm) FCC-phase crystallites and smaller (7 nm) BCC-phase crystallites was enhanced considerably.

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High-entropy alloys (HEAs) with at least five atoms of transition and refractory metals are now used extensively in both fundamental (synthesis of new coatings and examination of their properties and structure) and applied (fabrication of products with such coatings and their application in various fields ranging from biocompatible implants to space technology) research [1–6]. The synthesis of HEA nitrides and carbides provides an opportunity to improve such material parameters as their radiation hardness, wear resistance, corrosion resistance, etc. A large number of different multielement alloys (including ones with high entropies of mixing) have already been obtained and studied [7–10], but nitride coatings based on these alloys quite rarely exhibit the needed physical and mechanical properties. Therefore, the problem of synthesis of nitride coatings based on multielement alloys with fine hardness, wear-resistance, and corrosion-resistance parameters remains important. In the present study, a new composition of nitride coatings based on the TiZrNbAlYCr multielement alloy is proposed and the results of examination of their structure and properties are detailed.

Coatings were obtained by cathodic-arc deposition onto stainless-steel substrates at different partial nitrogen pressures (0.05, 0.27, and 0.5 Pa). A Bulat-6 setup was used in these experiments. Constant bias potential $U_b = -200$ V was applied to the substrate in the process

of deposition. Substrate temperature T_s was approximately 300°C, and the distance to the cathode was 200 mm. Multielement coatings were deposited in the direct (unfiltered) flow regime, with the arc current being 100 A and the focusing-coil current being 0.5 A. The deposition was performed using a composite cathode with the following composition: 25 at % Ti, 20 at % Zr, 20 at % Nb, 25 at % Cr, 7 at % Al, and 3 at % Y. An SPS 25-10 spark-plasma sintering setup was used to fabricate this cathode. The deposition time was 1 h, and the overall thickness was 7.0 μm . The structure-phase state of the deposited coatings was studied with an X'Pert PAN analytical diffractometer at a pitch of 0.05°, and the microhardness was measured with a DM-8 tester at a load of 50 g.

The profiles were decomposed into constituent fragments in PowderCell. A JEM-7001 TTLS scanning electron microscope (JEOL) with an EDS microprobe operating in the SEI and Compto modes was used for elemental analysis and to examine the cross sections of coatings.

The results of examination of the surface morphology of coatings obtained under different partial nitrogen pressures (0.05, 0.27, and 0.5 Pa) demonstrate that an increase in pressure results in a reduction in the average size of drop phases on the coating surface: their characteristic size varies from 1.1 μm at 0.05 Pa to 0.2 μm at 0.5 Pa. One of the reasons for this is the

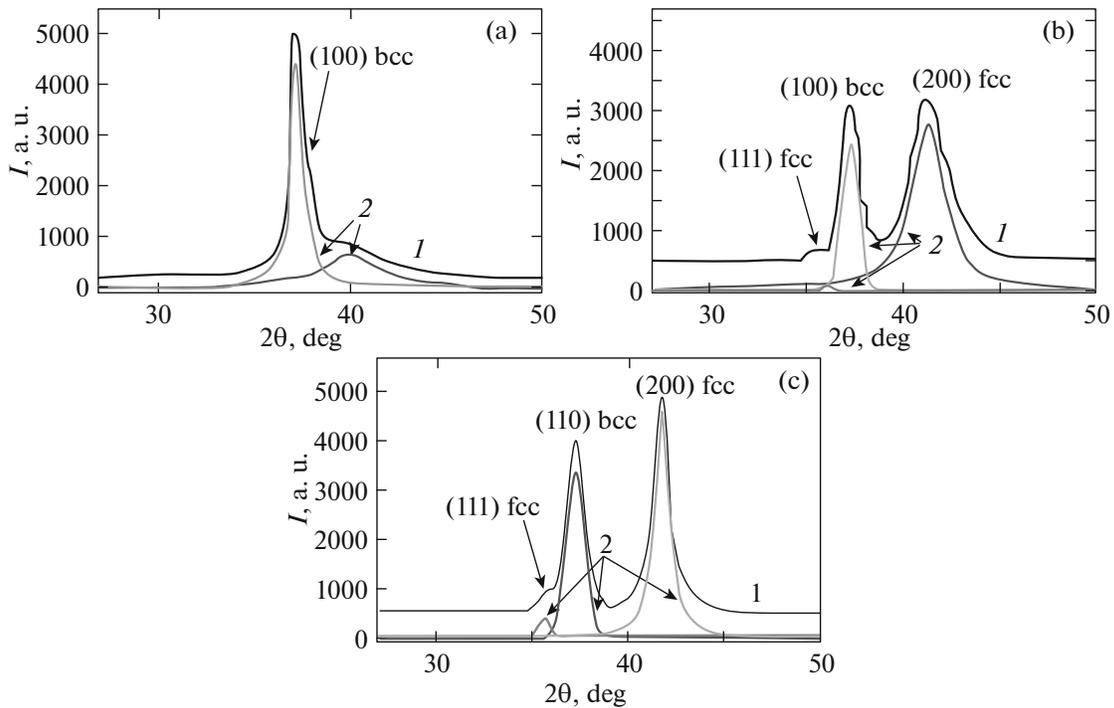


Fig. 2. X-ray of diffraction spectra of (TiZrNbAlYCr)N coatings obtained at $P_N =$ (a) 0.05, (b) 0.27, and (c) 0.5 Pa. The initial spectra (*I*) and the isolated profiles (*2*) are shown.

deposited particles, which is affected by losses in collisions within the interelectrode gap, decreases at higher working gas pressures in the chamber. In addition, coatings deposited under higher pressures are less deformed and more saturated with nitrogen atoms. Nitrogen atoms form chemical bonds with the metal framework and occupy octahedral interstitial sites characteristic of NaCl-type lattices. As a result, they inhibit the shear displacement of planes that causes the formation of stacking faults. The structural transformations that have been noted enhance the hardness of the coating deposited under the highest partial nitrogen pressure (0.5 Pa).

The results of microhardness measurements performed using a DM-8 tester with a load of 50 g show that the Vickers microhardness of (TiZrNbAlYCr)N coatings was $HV_{0.05} = 46.9$ GPa at $P = 0.5$ Pa. Therefore, these coatings may be characterized as superhard.

Thus, the variation of pressure in the deposition chamber from 0.05 to 0.5 Pa affects the morphology of (TiZrNbAlYCr)N coatings. Specifically, the drop component on the condensate surface is suppressed qualitatively and quantitatively at higher pressures. These changes in the structure-phase state translate into differences in mechanical properties. The measurement results suggest that the hardness increases to 46.9 GPa under a partial pressure of 0.5 Pa.

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