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Structure and Physicomechanical Properties of Superhard Multicomponent Multilayer (TiAlCrY/Zr)/(TiAlCrYN/ZrN) Coatings with Double Modulation Period of the Structure

V.Yu. Novikov[1], V.M. Beresnev[2], D.A. Kolesnikov[1], O.N. Ivanov[1], S.V. Lytovchenko[2], O.V. Glukhov[3], D.V. Gorokh[2], A.O. Kozachenko[1], E.V. Krytsyna[1], V.V. Sirota[4]

[1] *Belgorod State National Research University, 85, Pobiedy St., 308015 Belgorod, Russian Federation*
[2] *V.N. Karazin Kharkiv National University, 4, Svobody Sq., 61022 Kharkiv, Ukraine*
[3] *National University of radio electronics, 14, Nauki Boul., 61166 Kharkiv, Ukraine*
[4] *V.G. Shukhov Belgorod State Technological University, 46, Kostyukov St., 308012 Belgorod, Russian Federation*

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The paper describes the acquisition, establishment of mechanisms and patterns of formation of the phase composition and structure of multilayer coatings of the (TiAlCrY)N/ZrN system with a single and of the (TiAlCrY/Zr)/(TiAlCrY)N/ZrN systems with a double modulation period by vacuum-arc deposition. The targets were located along one straight line at equal distances from the perpendicular axis on which the substrates were placed. The rotation of the axis with the substrates was carried out either continuously or with a fixed delay at the evaporators. The coatings of both systems are distinguished by a high degree of laminarity of the layers. The (TiAlCrY)N/ZrN system coatings have a pronounced layered periodic structure in the entire coating volume. The modulation period (total thickness of the bilayer) of such a structure is about 30 nm. Two modulation periods are clearly visible in the (TiAlCrY/Zr)/(TiAlCrYN/ZrN) system coatings. One period approximately coincides with the modulation period of the samples of the (TiAlCrY/Zr)N system and is about 30 nm. The second modulation period is about 1.3 microns. It includes 48 bilayers. The influence of the partial pressure of nitrogen in the chamber on the nitrogen content in the coatings, their hardness and adhesive strength were studied. A significant increase in the hardness of 68.22 GPa and the adhesion strength of the coatings with a double modulation period of the structure was revealed. A fundamentally new technological approach to the process of obtaining multilayer coatings has been proposed.

Keywords: Multilayer coatings, Structure modulation period, Microhardness, Adhesive strength, Phase and elemental composition.

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1. INTRODUCTION

Early studies have shown that films based on nitrides of refractory metals [1, 2] are unique materials for creating multilayer coatings. They have improved physical, chemical, mechanical and tribological properties due to the achievement of the necessary technological parameters, namely, the thickness of the layers in the period??, the partial pressure of the gas atmosphere, the energy factor determined by the magnitude of the displacement potential during precipitation. Thus, one can change the characteristics of the coating obtained by changing its value and type of gas atmosphere. Recently, the concept of creating protective coatings in the form of multi-element multilayer systems [3], which can withstand high temperatures, have a low coefficient of friction, resistance to wear and high surface loads, has been developed. Therefore, the relevance to the creation of new coatings has increased significantly. Despite the large number of studies on the technology of obtaining and studying the properties of multi-element nitride coatings, it is of great interest to use them as layers of a multi-layer coating based on nitrides of multi-element alloys [4].

The purpose of the present work is to obtain multilayer coatings with high mechanical properties by vacuum arc deposition from a material consisting of nitride-forming elements of the metals Ti, Al, Cr, Zr, Y.

2. EXPERIMENTAL TECHNIQUE

The coating was deposited from two cathodes located opposite each other. The first cathode was made of the $Ti_{0.57}Al_{0.36}Cr_{0.06}Y_{0.01}$ alloy. It was produced by vacuum arc melting in an atmosphere of high-purity argon. The obtained ingot was melted down 6-7 times with a cooling rate of about 50 K/s for the final homogenization of the composition. The second cathode was of pure Zr. The formation of a multilayer system was carried out by vacuum-arc evaporation on a Bulat installation by deposition of layers with simultaneously operating magnetrons and a fixed substrate, which rotated at a speed of 8 rpm, turning in the process of working side alternately to one or the other cathode. Two series of samples were made. In the first case, nitrogen was continuously supplied to the chamber in such a way that the residual gas pressure was 0.58 Pa. The time of layered coatings deposition was 1.5 hours. As a result, layers of (TiAlCrY)N and ZrN were formed alternately during the deposition process. The total coating thickness was about 8 microns. The scheme for obtaining the second series of samples was as follows: the substrate, as in the first case, rotated at a speed of 8 rpm. However, the pressure in the chamber was cycled, first 1 minute at $P_N = 0.01$ Pa, then 5 minutes at $P_N = 0.67$ Pa for 3.5 hours. The total thickness of the coatings was $22 \div 25$ microns. Based on the experience of previous studies, the optimal voltage applied to the substrate during the formation of coatings based on

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