ABSTRACT

Mazilin B. O. **Structure and mechanical properties of combined nanocomposite coatings on the basis of ceramic materials**. – Qualification scholarly paper: a manuscript.

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The dissertation work is devoted to solving one of the important problems of modern applied physics and physics of nanomaterials, which is to create a physical and technological basis for the formation of plasma nanocomposite functional coatings based on ceramic compounds and to determine the relationship of structural-phase state of the coatings to the mechanical and physical-chemical properties of the “metal substrate-coating” composites.

The aim of this work is to determine the influence of physical and technological deposition parameters on the formation of functional coatings based on multielement ceramic compounds created by ion-plasma evaporation of materials of different composition.

To achieve the formulated aim it was necessary to solve **the following tasks**:

1. To determine the influence of sputtering and condensation conditions (composition and number of target cathodes, composition and pressure of reaction gas in the chamber, type and level of potential on the substrate, deposition duration) on the synthesis of vacuum-arc and magnetron coatings of different complexity: SiC-AlN, Al_2O_3 and Al_2O_3/ZrO_2, MoCN, TiZrN/TiSiN, (Ti,Al,Si)N.
2. To study surface morphology and determine the elemental and phase composition of the synthesized coatings based on ceramic compounds.
3. To study the influence of the structural-phase state of nanocomposite coatings on their physical and mechanical properties (elastic modulus and stiffness).

4. To study the adhesive interaction of the coatings with the substrate and determine the tribotechnical characteristics of the created functional ceramic coatings.

The object of the research is combined nanocomposite functional coatings based on ceramic materials formed under nonequilibrium conditions from ion-plasma flows.

The subject of research is the regularities of formation of certain structural-phase states in the synthesis of functional coatings based on ceramic materials by condensation from ion-plasma flows, ways to optimize the structural-phase state of coatings to improve the physical and mechanical characteristics.

Methods of formation and research of structural-phase state and properties of coatings: vacuum arc deposition, magnetron sputtering, plasma-electrolyte surface polishing, scanning electron microscopy, optical metallography, X-ray microanalysis, diffractometry and photoelectron spectroscopy, measurement of microhardness, sclerometry, profilometry, tribotechnical tests, thermal effect. Numerous methods and methods of mathematical statistics were used in processing experimental data.

The development of science and technology, improvement and intensification of production processes, where the most modern technologies and equipment are used, impose more and more stringent requirements for the materials involved in the construction of this equipment and the implementation of these technologies. This approach is caused by the increasing importance of economic factors of production, the need to ensure environmental requirements and the conservative use of resources. The use of special coatings in recent decades has been increasingly used to improve and expand the performance capabilities of structural and functional materials. Optimized specialized coatings designed for specific applications can serve as the basis for technical progress in various fields.

The transition of materials science to a new hierarchical level of structure of solids, namely the transition to the nanoscale, to nanomaterials and nanotechnology, has created new prospects for fundamental research and technological applied development in this area.

Today, physical methods of deposition, including those from ion-plasma flows, are widely enough used to form protective coatings of different functional directions. If two- and three-component coatings based on titanium nitride have already become classic, the technologies for creating multicomponent, multiphase and multilayer coatings, including those with nanoscale elements, are developing and are quite actively being improved.

The processes of deposition of condensed coatings from ion-plasma flows after evaporation and sputtering of target cathodes made of materials of different nature (metals, alloys, ceramics, composites) have been studied. The structural-phase state, architecture and properties of the formed ceramic coatings are investigated.

It has been found for the first time that multilayer TiZrN/TiSiN coatings are a composition of TiZrN nanocrystals and TiN nanocrystals embedded in an amorphous SiN_x matrix. For the multilayer coatings formed by TiZrN/TiSiN bilayer compositions, an increase in stiffness from 24.5 GPa to 38.2 GPa was recorded with a decrease in bilayer composition period from 85.9 nm to 20 nm. The modulus of elasticity of the coatings changed similarly to the stiffness, reaching the level of 430 GPa for coatings with a bilayer period of 20 nm.

For the first time, a positive effect of a preformed nitride sublayer of sprayed target material TiZr, TiCr, Cr, Ti on the mechanical properties of different types of plasma coatings containing silicon was shown. The formation of the sublayer practically does not change the stiffness, but leads to an increase in resistance to mechanical destruction and wear. The physical and technological scheme for increasing the adhesive bond strength of the coating to the substrate has been developed for (TiAlSiY)N/CrN type coatings and TiZrN/TiSiN coatings.

For the first time in vacuum-arc multilayer coatings based on (TiAlSiY)N nitride with a mononitride sublayer a superhard state with hardness of 49.5 GPa and wear resistance of about 185 N was realized. The physical factor of formation of a superhard state with hardness 50.5 GPa the carbonitride is the total pressure of 0.4 Pa of a mix of reaction gases $80\%C_2H_2+20\%N_2$.

For the first time coatings based on ceramic materials SiC–AlN, AlN–TiB2–TiSi2, Al_2O_3/ZrO_2 of different functional currents were obtained. It has been proved that the increase of mechanical properties of Al_2O_3/ZrO_2 coating provides nanocrystalline state with average linear grain size less than 100 nm, while the coating retains high dielectric properties. The achieved level of mechanical properties and thermal stability of Al_2O_3/ZrO_2 coatings is sufficient for the application of such coatings as thermal barriers for the protection of aircraft engine turbine blades.

Taken together, the results confirm the conclusion that using both proven deposition techniques – vacuum-arc evaporation and magnetron sputtering – it is possible to create functional ceramic coatings with high mechanical and corrosion properties for use in various areas of mechanical engineering.

From the practical point of view, the combined nanocomposite coatings investigated in the work have demonstrated a high level of mechanical and other physical and chemical properties, which makes these coatings promising for the protection of equipment and device elements of various areas of mechanical engineering, starting with the prevention of wear and destruction of metal, ceramic metal and superhard ceramic cutting tools. to improving tribological characteristics of friction pairs and creating heat resistant coatings of aircraft and missile equipment.

The determination of the connection between the structural-phase state of the coatings and the mechanical and physical-chemical properties of the "metal substrate-coating" composites has expanded and deepened the knowledge about the physical and technological factors for controlling the structural-phase state of solid composites with functional coatings.

Multifunctional protective multi-element nitride coatings (TiAlSiY)N with an additional nitride sublayer created on the cutting tools were tested at the V. Bakul Institute for Superhard Materials of the NAS of Ukraine. Tests demonstrated a 1.5-fold increase in tool resistance of the superhard polycrystalline material based on cubic boron nitride when processing hardened steels, which became the basis for the recommendation to introduce the developed coatings in the production of such cutting superhard tools.

Keywords: ion-plasma coatings, vacuum-arc evaporation, magnetron sputtering, nitride compounds, multilayer coatings, nanocomposites, superhard state, structure, hardness, adhesive strength.