UDC 539.61:621.793

PRINCIPLES OF MULTILAYER FUNCTIONAL COATINGS CREATION BY COMBINED DEPOSITION METHODS

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Received 03.09.2012

The physical principles of the multilayer coatings formation by applying of combined deposition methods of different thickness layers – plasma-detonation and ion-plasma are developed. This method of composite coatings creating will allow receiving coatings with new properties and thus to improve of product performance.
Keywords: combined method, multilayer coatings, plasma-detonation treatment, surface modification.

Разработаны физические принципы формирования многослойных покрытий путем применения комбинированных методов нанесения разных по толщине слоев – плазменно-детонационного и ионно-плазменного. Рассматриваемый метод создания комбинированных покрытий позволит получать покрытия с новыми свойствами и тем самым повысить эксплуатационные характеристики изделий.
Ключевые слова: комбинированный метод, плазменно-детонационная обработка, многослойные покрытия, модификация поверхности.

Розроблено фізичні принципи формування багатошарових покриттів шляхом застосування комбінованих методів нанесення різних за товщиною шарів – плазмово-детонаційного та іонно-плазмового. Метод створення комбінованих покриттів, що розглядається, дозволить отримувати покриття з новими властивостями та тим самим підвищити експлуатаційні характеристики виробів.
Ключові слова: комбінований метод, багатошарові покриття, плазмово-детонаційна обробка, модифікація поверхні.

INTRODUCTION

The modern high-tech production requires new materials with unique properties. These materials include protective coatings deposited using modern technology. The application of modern technology extends the use of protective coatings and can improve their properties. A number of papers are devoted to development of new methods for obtaining of such coatings and studying their properties the analysis of which showed that for obtaining of coatings with high protective characteristics in recent years the most effective are the combined, hybrid methods of modification of the surface layer of materials that combine simultaneously or consecutively two (duplex) or three (triplex) of different technologies. This provides obtaining in the surface layer of compounds with unique properties that cannot be obtained using one of the technologies used.

Great attention has been paid recently to the study of the physical and mechanical properties coatings using different deposition methods. Now for production of new multicomponent coatings used ion-plasma methods (magnetron sputtering and vacuum-arc deposition). The use of different physical deposition techniques, and on their basis – of combined methods, allows to obtain coatings of different composition from the various components and to create functional layered coating.

Great potential in the creation of materials with a wide complex of unique properties have the combined multi-layer coatings feature of which is the difference of physical, mechanical and chemical properties of the different layers. Combined method of the surface modification of solids will allow receiving coatings with new properties and thus improving of product performance.

It is well known that besides execution of direct protective functions of coating to perform a number of tasks in the chemical, engineering and other industries it is necessary restoration the size of parts already working in the industry. For this purpose thick coating which by its composition has mechanical properties exceeding the properties of the base metal is deposited on the product. Usually in such coatings used alloys (powder) of Ni-Cr-Mo [1], hard alloys WC-Co-Cr, Cr_3C_2-Ni [2], oxide ceramics Al_2O_3, $Al_2O_3 + Cr_2O_3$ [3].

The authors of works [4 – 7] with a combination of the two technologies (plasma-detonation technology and magnetron or vacuum-arc deposition with RF discharge) received coatings of two layers. The first layer – powder coating thickness greater than 100 μm (plasma-detonation method) and the second layer – thin ion-plasma coating thickness of about 3 μm. As a result combined coatings of thickness 120 ч 320 μm based TiSiN/WC-Co-Cr; TiSiN/$(Cr_3C_2Ni)_{75}$-$(NiCr)_{25}$; TiAlN/TiN/Al_2O_3; TiAlN/Ni-Cr-Fe-Si-B etc. were formed which had high protective characteristics and allowed to restore the size of worn surface areas. These coatings have the higher physical and mechanical properties such as hardness *H*, elastic modulus *E*, the elastic recovery W_e, the resistance of the material plastic deformation N_3/E_2 and plasticity index of *H*/*E* than the powder coating.

Employing two technologies: a plasma-detonation and a vacuum-arc deposition in a HF discharge, a bilayered micro-nano-structured TiCrN/Ni-Cr-B-Si-B coating featuring high protective characteristics was fabricated [8]. The high properties of the bilayered coating was determined, namely samples have increased wear resistance, which was higher almost by a factor of 27 to 30 and corrosion resistance in NaCl solution, which was almost an order of a magnitude higher in comparison with a stainless steel substrate.

The paper presents a model scheme for the formation of multilayer composite coatings. Use of the combined modification with applying of materials with different physical-chemical and mechanical properties is selected in order to obtain a surface with a complex of desired characteristics (corrosion resistance, wear resistance, hardness, etc.), since individual types of treatment (vacuum-arc or magnetron method) does not always lead to the desired result. In connection with this purpose of the work is the development of physical principles of multifunctional coatings creation by combination of different methods of deposition – plasma-detonation and ion-plasma.

PHYSICAL BASIS OF MULTILAYER COATINGS FORMATION

Applied research problem of modification processes of materials with the combination of different methods of deposition is the improvement of the finished products performance. To provide basic fundamental requirements for coatings in the paper a layered structure of coatings based powder and ion-plasma coatings formed by the combined method using detonation plasma deposition and ion-plasma deposition is proposed.

The proposed approach is to determine the composition and structure-phase state of the substrate and coating ensuring the absence of chemical potentials gradients of all components in the depth of the material taking into account the operating temperature.

If we take the phase diagram of the *A*-*B* system in which from one side possible dissolve of the component *A* to component *B* (в-phase) and on the other side of *B* in *A* (б-phase) than at any temperature the chemical composition of б-phase in the equilibrium state will correspond to the intersection of the line *T* with the line α/(α+в) at a concentration C_α, and the composition of в-phase correspond to the intersection of *T* with a line в/(α + в) at a concentration $C_в$. If α- and в-phases spatially divide relocating the inclusion of one of them on the sample surface and the other leaving in volume while neglecting the surface effects then in the result possible to receive at a given temperature *T* of the thermodynamic equilibrium a spatially inhomo-geneous structure-phase state (fig. 1) in which on the surface of the sample will be mainly в-phase, and in the volume б-phase separated by a two-phase transition region which provides a mechanical chaining of formed phases.

Based on this approach the principle of a multilayer functional coatings creation was developed while the optimum characteristics are realized for a range of loads providing the location of irreversible

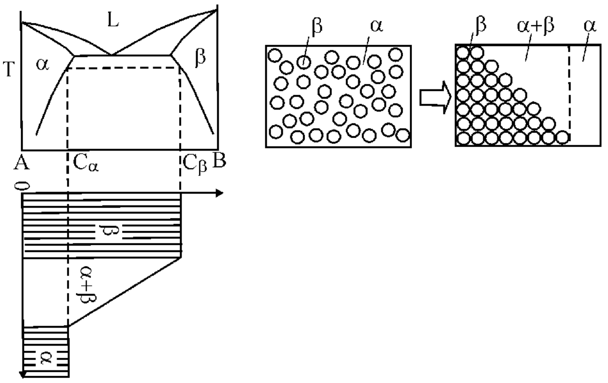

Fig. 1. Diagram of the equilibrium states of the system *A*-*B*, the possible distribution of the phase composition with depth.

deformations in the coating material at insufficient high bearing capacity of the surface due to the influence of the underlying substrate surface (coating). Necessary condition for this is the fact that the multiphase system should include a set of phases that have the properties of both the coating and the alloy.

The basis for the formation of multilayer coatings is the following:

– the external layer should be wear-resistant, have a low friction coefficient, high hardness, good plasticity (multicomponent coatings based on TiN, TiC);
– transition layer providing adhesion strength of the external and the intermediate layer, consisting of the phase external and the intermediate layer;
– intermediate layer should be thermostable and corrosion-resistant;
– transition (lower) layer providing enough a snug fit intermediate layer to the substrate and consisting of components substrate and intermediate layer.

For practicing main stages to create a chemically compatible coating system has been considered which combines the positive properties of coatings with high heat-resistant and corrosion-resistant properties of the ceramic powder, and coatings with high mechanical properties of materials. Combining the positive properties of the coatings available either through the introduction of elements in the surface layer, either through layering of coatings. Taking into account the rugged environment of constructional materials a necessary condition for their long effective work is a high adhesion of the coating to the substrate surface, the low and closed porosity, and the presence of passivating elements such as chromium and titanium.

Thus the construction of the multilayer coating consists of a diffusion layer at the interface with the substrate providing adhesion strength, of the second layer providing the so-called barrier properties and performing the functions of heat resistance and corrosion resistance, as well as multi-component coatings based on refractory metal nitrides which provides wear resistance and antifriction work surfaces (fig. 2).

The use of different physical deposition techniques allows to obtain coatings of different composition from the various components and to create functional materials in the form of layered coatings.

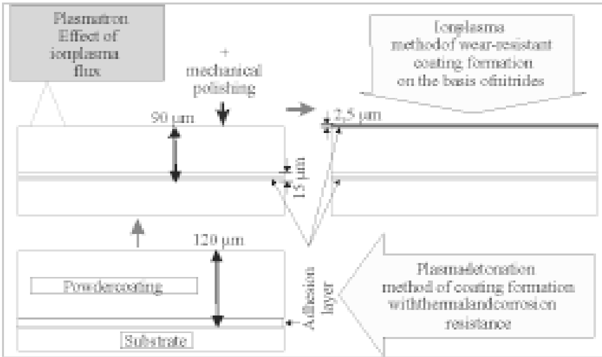

Fig. 2. Scheme for the formation of composite protective coatings.

CONCLUSION

The construction of multilayer coating consisting of a diffusion layer at the boundary with the substrate providing adhesive strength, of the second layer providing the so-called barrier properties and performing the functions of thermal stability and corrosion resistance, and also multicomponent coating based on refractory metal nitrides which provides wear resistance and antifriction working surfaces is proposed.

It is shown that the modification of the surface layer of combined methods of deposition, phase mixing of the individual layers of coatings and films results in a sharp change of operational characteristics such as hardness, wear resistance, fatigue resistance, corrosion and erosion resistance, which ultimately enhances the reliability and service life of parts and tools. These data find confirmation in works of various authors performed on a wide class of materials with a combination of different methods of deposition.

The principles obtained of the multilayer coatings formation can be applied to a wide class of protective coatings and used for development of deposition and modification technologies of nanocomposite, wear-and corrosion-resistant hard coatings.

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