Influence of reaction gases on phase compounds and mechanical properties of coatings based on intermetallics of Ti-Al systems

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Abstract. The influence of various reaction gases on the phase composition and mechanical properties of coatings based on intermetallic compounds of the Ti-Al system was studied. Diffractors of coatings were produced to study properties in the environment of nitrogen, oxygen and acetylene.

1. Introduction

In modern technology, the number of developed and investigated new materials with special properties increases: high hardness, strength, corrosion resistance, heat resistance. Mechanical processing of these materials with existing metal-cutting tools is very difficult. High temperatures in the cutting zone of the material being processed cause rapid wear or breakdown of the metal-cutting tool. To solve this problem, there are applied various solutions, from the development of new materials to cutting tools to special methods of hardening tools. One of which is the application of a wear-resistant coating on a metal-cutting tool.

At present, coatings based on intermetallics of the Ti-Al system attract much attention. Ti-Al systems with different phase compositions are considered as promising materials as protection against various corrosive media, because of their unique properties, for example: high melting point, high oxidation resistance, enhanced physical and mechanical properties [1, 2]. The work [3–5] indicates that the formation of intermetallic compounds is quite promising, since intermetallic compounds have high hardness and, importantly, are a good barrier to diffusion processes, which should contribute to improving the efficiency of cutting tools with coatings. In [6, 7], the phase properties of the cathodes of the Ti – Al – C system with different aluminum contents (20, 25, 30) obtained by the SHS pressing method were studied. Phase analysis of the cathodes obtained showed that the main phase is the MAX phase of the composition Ti₃AlC₂. The cathodes obtained precipitated the coating on the samples by the vacuum-arc method. All the many types of coatings obtained from SHS cathodes are a single-phase cubic two-element nitride of (Ti, Al) N composition, which is a solid solution of aluminum in titanium nitride with a cubic structure of the NaCl type.

After analyzing the existing scientific literature, we can say that today there is work on obtaining coatings based on intermetallic compounds of the Ti-Al system, however, there are practically no comprehensive studies on the deposition of coatings based on intermetallic compounds Ti-Al in nitrogen, acetylene and oxygen.
Therefore, the aim of this work is to study the effect of reaction gases on the phase composition and mechanical properties of coatings based on intermetallic compounds of the Ti-Al system.

2. Experimental procedure
The coating was applied to the upgraded installation NNV-6.6-I1. To study the physicomechanical properties of coatings based on Ti-Al intermetallic compounds synthesized in nitrogen, oxygen, acetylene environment, 4 samples were placed in the chamber; Coatings were applied with the number of layers 120 pcs and 1860 pcs. Microhardness was measured on a DuraScan instrument. Metallographic examination of a Shimadzu XRD – 6000 X-ray diffractometer. Wear resistance was measured on a Nanovea tribometer.

3. Experiment results
Diffractograms of the samples with a coating based on intermetallic compounds of the Ti-Al system deposited in a nitrogen atmosphere are received (figure 1). From both diffractograms with increasing distance from the table axis the intensity of the peak of pure titanium and aluminum decreases, thereby increasing the intensity of the intermetallics TiAl, Ti3Al, as well as TiN. And with an increase in the number of layers, the intensity of TiN increases. In connection with the increase of solid phases in the composition of the coating with increasing distance from the axis of the table and the number of layers and increases the hardness and wear resistance of the coating.

![Figure 1](image1.png)

(a) (b)

**Figure 1.** Diffractogram of coatings based on intermetallic compounds of the Ti-Al system precipitated in the nitrogen atmosphere by the number of layers: (a) – 120 pcs; (b) – 1680 pcs.

Diffraction patterns of coated samples based on intermetallic compounds of the Ti-Al system deposited in an oxygen environment are received (figure 2). From the analysis of diffractograms it can be seen that with increasing distance from the axis of the table, the intensity of pure titanium, aluminum and titanium oxide decreases, thereby increasing the intensity of the intermetallics TiAl, Ti3Al as well as Al2O3 to a distance of 15 cm from the table axis at 22 cm Al2O3 intensity decreases. This can be explained by the fact that when 15s are from the axis of the table, the coating contains the maximum amount of droplet phase, which at 22cm from the axis of the table decreases to a small amount.

Diffraction patterns of samples with a coating based on intermetallic compounds of the Ti-Al system deposited in acetylene environment are received (figure 3). From both diffractograms it can be seen that with increasing distance from the table axis, the intensity of pure titanium, aluminum and titanium oxide decreases, thereby increasing the intensity of the intermetallics TiAl, Ti3Al as well as TiC. As the number of layers in the coating increases, the intensity of TiC increases, and a new peak appears - C60 (Fullerene). In connection with the increase of solid phases in the coating composition
with increasing distance from the axis of the table and the number of layers, the hardness and wear resistance of the coating increases.

![Figure 2. Diffractogram of coatings based on intermetallic compounds of the Ti-Al system deposited in the oxygen environment by the number of layers: (a) – 120 pcs; (b) – 1680 pcs.](image)

![Figure 3. Diffractogram of coatings based on intermetallic compounds of the Ti-Al system deposited in the acetylene environment by the number of layers: (a) – 120 pcs; (b) – 1680 pcs.](image)

The results of measuring the microhardness of coated samples based on intermetallic compounds deposited in different reaction gases are identified (figure 4). It can be seen from the graphs that in all three reaction gases, with increasing distance from the axis of the table, the microhardness of the coating increases. It is also seen that with an increase in the number of applied layers, microhardness also increases. The coating has the highest hardness deposited in acetylene environment. And the smallest coverage deposited in an oxygen environment.

The results of wear resistance measurements are shown are identified (figure 5). Determination of wear resistance of samples using the standard ball-on-disk method (international standard ASTMG 133-95; Standard Test method for linearly reciprocating ball-on-flat sliding wear) using software to determine the amount of wear for calculations the changes in linear dimensions of both samples (ball and disk) before and after the test. It can be seen from the graphs that, just as with microhardness, the wear resistance of coated samples increases with increasing distance from the axis of the table and the number of layers.
Figure 4. Microhardness of coatings based on intermetallic compounds of the Ti-Al system deposited in the environment: (a) – nitrogen; (b) – oxygen; (c) – acetylene.

Figure 5. Wear resistance of coatings based on intermetallic compounds of the Ti-Al system deposited in the environment: (a) – nitrogen; (b) – oxygen; (c) – acetylene.
In addition to the sample of acetylene deposited in the environment, the wear resistance of the sample with the least number of layers per coating showed better wear resistance than the sample with a larger number of layers per coating.

4. Conclusion

Thus, according to the results of the conducted research, it was established that in coatings based on intermetallic compounds of the Ti-Al system synthesized in the environment of various reaction gases:

- with increasing distance from the axis of the table and the number of layers increases the microhardness and wear resistance of the coating
- with an increase in the distance from the axis of the table and the number of layers in the coating, the content of pure titanium and aluminum decreases and the amount of the intermetallic phase and nitrides, carbides, oxides of titanium and aluminum increases, thereby increasing the microhardness and wear resistance
- reduction of the amount of pure titanium and aluminum with increasing distance from the axis of the table and the number of layers due to the fact that with increasing distance from the axis of the table, the time the samples are under the plasma flow decreases, thereby reducing the thickness of the applied layers, while reducing the thickness of the applied layers almost all aluminum in the coating interacts with titanium and forms intermetallic phases, while the content of pure titanium in the coating increases, which forms solid phases of nitrides and carbides of titan.

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