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Nanosize Structure Phase States in the Titanium Surface Layers after Electroexplosive Carburizing and Subsequent Electron Beam Treatment

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***Abstract*—**The peculiarities of the nanoscale structure-phase states formed after electroexplosive carburizing and subsequent electron-beam treatment of technically pure titanium surface in different regimes are established by methods of transmission electron diffraction microscopy and physical mechanisms are discussed.

Electroexplosive carburizing leads to surface layer formation (40μm thickness) with increased (in 3.5 times) microhardness. It consists of β-titanium, graphite (monocrystals 100-150 nm, polycrystals 5-10 nm, amorphous particles 3-5nm), TiC (5-10 nm), β-$Ti0_2$ (2-20nm). After electron-beam treatment additionally increasing the microhardness the surface layer consists of TiC.

***Keywords*—**nanoscale, phase, structure, titanium

I. Introduction

To protect titanium and its alloys from wear different formation methods of titanium carbide coatings on the surface are being currently developed with use of high-frequency currents, laser radiation, electron beams, plasma fluxes and jets. The essence of which lies in the pulse melting and surface layers saturation with carbon, then subsequent crystallization and formation of a strengthening phase of titanium carbide. The formed layers have a metallurgical binding with the base with adhesion at the level of cohesion and at the same time insignificant changes in detail sizes take place.

II. Materials and Study Methods

The titanium surface treatment by pulse laser jets, formed at the electroexplosion of carbon-graphite fibers, leads to the formation of the surface layers the phase composition of which forms a solid carbon solution in titanium, isolated titanium carbide particles and structurally free carbon as fiber particles penetrating deep into the zone of melting and alloying [1] – [3]. This structure brings about the possibility for its further modification with the purpose of graphite dissolution and increase in content of titanium carbide. And here the pulse-periodic treatment of the surface by high-current electron beams is an effective way to do that. The purpose of the present work is to study the peculiarities of the structure-phase states of the carburized layers of technically pure titanium.

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III. Structural Phase Studies Results and their Discussion

Microdiffraction analysis with the use of the dark-field image method and consecutive induction of the micro-electron diffraction patterns allowed to detect the presence of the following phases in the layer under analysis after electroexplosive carburizing of ~40 μm thickness: titanium with bcc lattice β-titanium; titanium carbide of TiC composition; titanium dioxide of β-TiO_2 composition.

The main type of titanium organization is a grain structure. The titanium azimuthal reflection broadening clearly seen in the micro-electron diffraction patterns proves that the grains are fragmented. The sizes of the fragments change within 50…100 nm. In the volume of grains and fragments the dislocation substructure in the form of networks is present. The dislocation scalar density defined by the random linear intercept method is ~$5.6 \cdot 10^{10}$ cm^{-2}.

The second phase constituent of the carburizing zone is graphite which is present in the form of particles of carbon-graphite fibers. The following states are found. First of all, the particles with mono-crystalline structure. Secondly, the particles that have poly-crystalline structure, the crystallite sizes of which change within 100 up to 200 nm. Thirdly, the particles, that have nano-crystalline structure indicated by ring structure of the micro-electron diffraction pattern. The crystalline sizes forming such fragments change from 2 nm to 15 nm. Fourthly, the particles with quasi amorphous structure indicated by ring structure of the micro-electron diffraction pattern where the discreet state of diffraction rings is practically not soluble. The crystallite sizes forming such fragments change within the range from 3nm to 5nm. Fifthly, the particles in which a nano-crystalline structure is formed in the surface layer contacting with titanium. The nano-crystalline structure of the near-surface layer of the carbon-graphite fiber is clearly detected by the methods of dark-field analysis. The

evaluations of the nano-crystalline sizes are about 6…8 nm. Further from the surface of the electroexplosive alloying the inclusion volume fraction of graphite in the form of fibers drops and in the zone of thermal influence they are not found. Graphite in the form of interlayers on the boundaries of crystallization cells is observed only in the layer of a liquid phase alloying of titanium.

Graphite interaction with titanium leads to particles formation of carbide phase. Two variants of their formation are found. Firstly, the titanium carbide particles might be formed on the surface and in the near-surface layer of carbon-graphite fibers. They have an acicular (lamellar) form, the transverse sizes of such particles are ~5 nm, of longitudinal ones – 30 nm. Secondly, the titanium carbide particles might be formed on the surface and in the near-surface layer of titanium grains. The have a rounded (globular) form, the particle sizes change within the range of 4…6 nm.

One more phase formed at the electroexplosive alloying of titanium by carbon-graphite fiber is titanium dioxide of β-TiO_2 composition. Formation of an oxide phase is connected with the presence of residual atmosphere, containing oxygen atoms, in the chamber of the installation for electroexplosive alloying. The particles of an oxide phase have a rounded form, their sizes change from 2 nm to 20 nm.

The subsequent electron-beam treatment provides formation of a continuous carbidized layer at the depth up to 20-30 μm (fig. 1), bellow which the particles of carbon-graphite fibers are found. Apparently, that their dissolution near the surface and conservation in the depth are conditioned by the gradient of a temperature field that exists at the electron-beam treatment.

X-ray diffraction phase analysis of a sample surface after the combined treatment showed (fig. 2) that the surface layer consists mainly of titanium car-bide.

Microhardness on the surface of the alloying zone surpasses its value in volume in 12 times, in the area of dendritic structure - in 3-5 times, in the zone of thermal influence – in 1.5 times. Against the electroexplosive carburizing without the subsequent electron-beam treatment it increases in 3 times (fig. 3).

Thus, it is shown that in the structure of the surface layer after the electroexplosive carburizing numerous particles of titanium carbide are found as well as the particles of carbon-graphite fibers. The subsequent electron-beam treatment leads to dissolution of particles of carbon-graphite fibers near the surface of alloying zone and formation of a continuous titanium carbide layer. The interlayer is strengthened by titanium carbide dendrites in the metal matrix and contains structurally free carbon in the form of graphite. Microhardness on the surface of the alloying zone surpasses its value in the volume in 12 times.

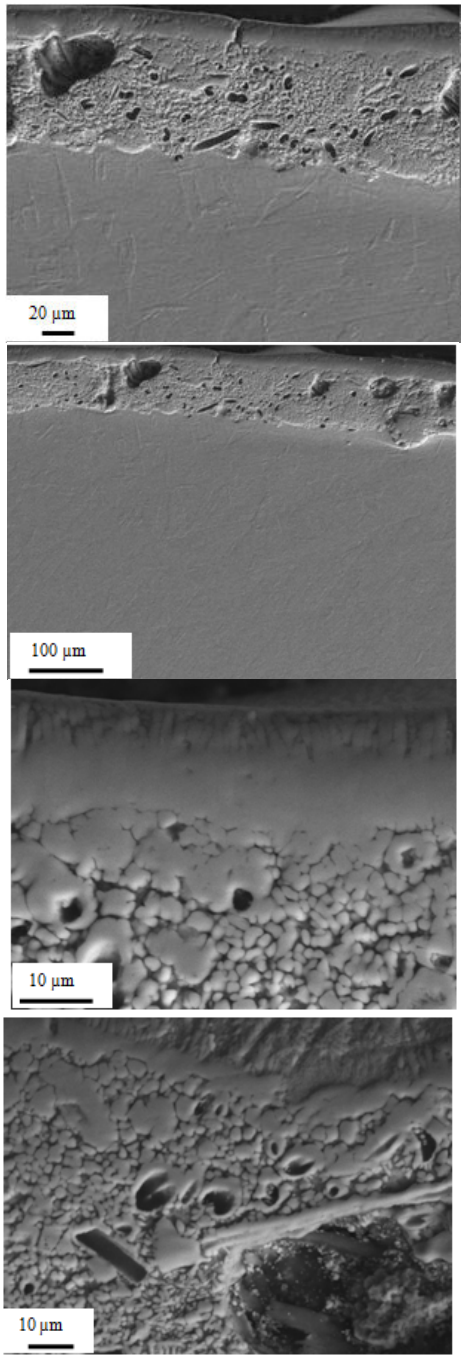

Fig. 1 Structure of the zone of electroexplosive carburizing after electron-beam treatment

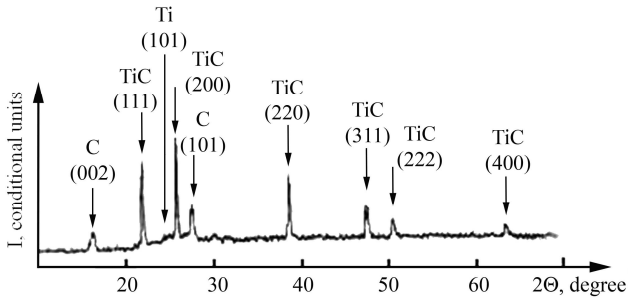

Fig. 2 Diffraction pattern fragment of the surface of electroexplosive car-burizing zone of titanium VT1-0 and subsequent electron-beam treatment

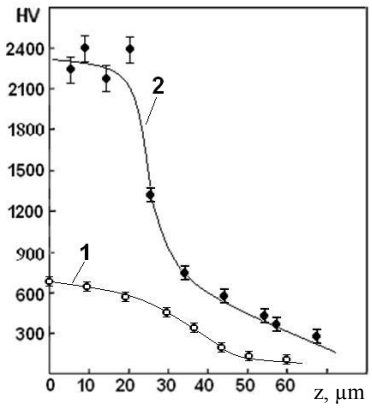

Fig. 3 Distribution of microhardness in the depth of surface layers of titanium VT1-0, subjected to electroexplosive carburizing (1), and subsequent electron-beam treatment (2)

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REFERENCES

[1] E. A. Budovskikh, A. Ya. Bagautdinov, A. V. Vostretsova, V. E. Gromov, "Features of electrical explosion alloying of metals and alloys", *Russian Physics Journal*, vol. 5. pp. 517–530, 2008.

[2] E. A. Budovskikh, S. V. Karpij, V. E. Gromov, "Formation of Metal and Alloy Surface Layers at Electroexp'osive Alloying", *Bulletin of the Russian Academy of Sciences: Physics*, vol. 73. no 9, pp. 1253–1256, 2009.

[3] A. V. Vostretsova, S. V. Karpii, E. A. Budovskikh, V. F. Goryushkin, V. E. Gromov, "Carbidization of titanium alloys in electroexplosive carburization and additional heat treatment", *Steel in Translation*, vol. 37. no. 2. pp. 106–109, 2009.