

Nanosize Structure Shase States of Ti Surface Sayers Sormed Suring Electroexplosive Sarboborating

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The electroexplosive carboborating leads to a significant (up to 12 times) increase in microhardness of the titanium irradiated surface. It is established that the thickness of strengthened surface layer reaches $\sim 125 \mu\text{m}$.

The formation of nanosize structure-phase states in Ti surface layers during electroexplosive carboborating was carried out by methods of scanning and transmission diffraction electron microscopy.

Keywords: titanium boride, coating, microhardness, structure.

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1. INTRODUCTION

The new methods of surface strengthening of titanium with use of concentrated energy flows are being developed nowadays. The main idea of these methods lies in the pulse melting and saturation of the melt by carbon and other elements with subsequent crystallization and formation of strengthening phases [1–3].

The purpose of the present work is to analyze the nanosize structure-phase states and microhardness distribution within the depth of the titanium subjected to electroexplosive carboborating (EEC).

2. MATERIALS AND METHODS OF INVESTIGATION

Technically pure titanium VT1-0 (99.852 Ti, 0.01 Al, 0.02 Si, 0.12 Fe, 0.004 C, 0.004 O₂, 0.004 N₂, 0.004 H₂ (wt. %)) was used as a base material. The pulse plasma jet formed from the products of electrical explosion of carbonic tape with boron powder served as an instrument of the action on Ti surface. The absorbed power density during EEC was 6.5 GW/m².

The analysis of the structure-phase states composition and defect substructure of the modified layers was performed by the methods of scanning and transmission electron microscopy.

3. RESULTS AND DISCUSSION

It is established that the thickness of strengthened surface layers reaches $\sim 125 \mu\text{m}$. The electroexplosive carboborating leads to a significant (up to 12 times) increase in microhardness of the titanium irradiated surface; secondly, the value of microhardness is changed in a nonmonotonic way depending on the distance to the treatment surface.

The performed investigations show that in the Ti surface subjected to electroexplosive carboborating a gradient structure is formed which can be divided into several layers.

Hereinafter these layers will be called as follow: coating (layer C), surface layer (layer I), interlayer (layer II) and transition layer (layer III) (Fig.1).

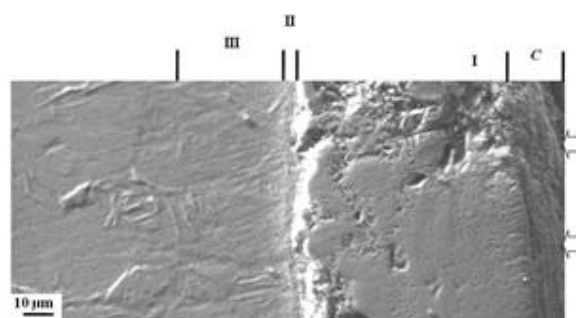


Fig 1 – Multilayer structure formed in the surface layer of the titanium, subjected to electroexplosive carboborating. The surface of treatment is pointed at with arrows

Analysis of the coating structure has proved the fact of the significant heterogeneity of its structure and revealed the presence of a number of phases in the surface layer.

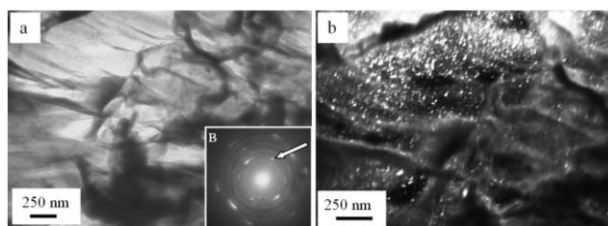


Fig. 2 – Electron microscopic image of the coating structure, formed on the surface of titanium; subjected to electroexplosive carboborating; a – light field; b – dark field obtained in reflection (201) TiB; c - microelectron diffraction pattern, the arrow points at the reflection in which the dark field was obtained; the diffraction rings of graphite (104); (304); (227) and point reflections of β-titanium (plane [110]) are detected on the micro-electron diffraction pattern

The analysis of the coating structure has revealed the presence of the following phases: graphite in the quasiamorphous state, nanosized (5-50 nm) precipitations of titanium boride of TiB composition (Fig. 2), β-titanium, α-titanium crystals of plate morphology (40-350 nm) (Fig. 3 a, d, e), titanium carbide particles (15-25 nm) located in the α-Ti structure (Fig. 3c).

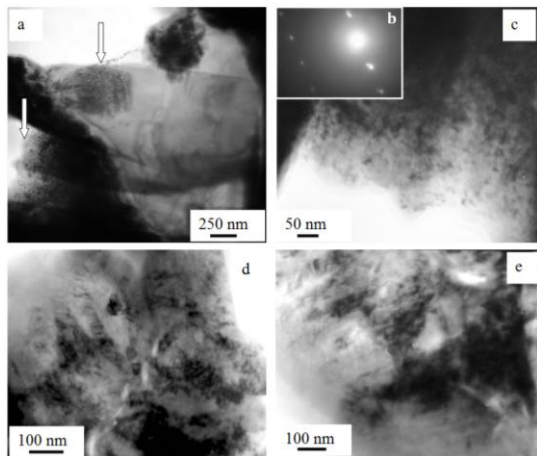


Fig. 3 – Electron microscopic image of the coating structure, formed on the surface of titanium; a, c-e – light fields; b – micro-electron diffraction pattern to (a). In (a) the arrows point at the islands with nanosized inclusions of titanium carbide

The layer of liquid-phase of alloying of titanium by carbon and boron (the surface layer – layer I in Fig. 1) is situated under the coating. The structure of this layer is heterogeneous within the depth and along the section of the alloying surface.

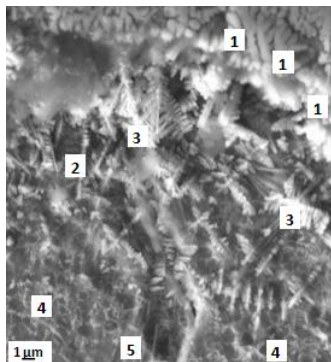


Fig. 4 – Electron-microscopic image of the surface layer structure formed in the titanium subjected to electroexplosive carboborating

The following typical morphological varieties of the surface layer structure are revealed. Firstly, the crystallization cells with the sizes that change within the limits from 250 nm up to 650 nm (Fig. 4, zone 1). Secondly, dendrites of crystallization with the axes of the first (Fig. 4, zone 2) and second (Fig. 4, zone 3) order. Thirdly, the structure of a grain-type; inclusions of the second phase of roundish form are situated along the boundaries (Fig. 4, zone 4). The grain sizes change within the limits from 0.5 μm to 0.8 μm; the sizes of inclusions: from 70 nm up to 200 nm. Fourthly, the structure of a lamellar-type, the transverse sizes of the plates change from 0.8 μm up to 1.5 μm (Fig. 4, zone 5).

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The inclusions of the second phase with sizes up to 100 nm are situated along the boundaries of the plates.

As it can be seen from the analysis of the electron microscopic image in Fig. 4 the revealed structures are located in the surface layer in a definite way. And namely, the cell-type structures are found near the interface of the coating and surface layer; the structures of dendritic crystallization are located in the upper and central parts of the surface layer; the structures of grain- and lamellar-types – in the lower part of the surface layer.

The characteristic image of the structure of cell crystallization, obtained by the methods of transmission electron microscopy is provided in Fig. 5. It is clearly seen that the cells of roundish form are divided by the extended interlayers that have a substructure in the form of a mottled contrast (Fig. 5, b). The sizes of the substructure elements of the interlayers change within the limits from 10 to 15 nm. On the microelectron-diffraction pattern, obtained from the structure of cell crystallization (Fig. 5, c), bright reflections of α -titanium and a large number of reflections of the second phase can be found, among which reflections of graphite, titanium carbide and boride are detected.

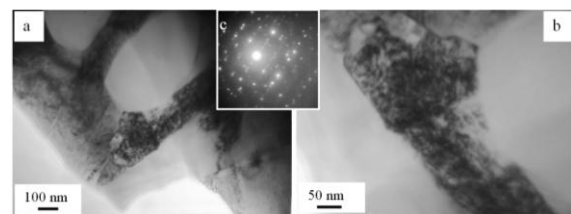


Fig. 5 – Electron-microscopic image of the structure of cell crystallization formed in the surface layer

The surface layer is separated from the transitional one by a relatively thin (2...10 μm) intermediate layer (Fig. 1, layer II). It is evident that the intermediate layer is a layer that separates the layer of the melted material from the layer that is in the process of electroexplosive alloying in the solid state.

The transition layer (layer of thermal influence) is characterized by the increased density of dislocations (about $3.1 \cdot 10^{10} \text{ cm}^{-2}$), distributed chaotically in the grain volume of α -titanium and the presence of titanium carbide particles along the grain boundaries, the reflections of which are found in the micro-electron diffraction patterns obtained from the volume of the material containing the grain boundaries

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