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INFLUENCE OF ALUMINUM IMPLANTATION ON THE STRUCTURAL-PHASE STATE AND HARDENING OF ULTRAFINE GRAINED TITANIUM

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Ion implantation of ultrafine grained (UFG) α-titanium (average grain size – 0.2 μm) was performed on the MEVVA-V.RU ion source at a temperature of 623K, accelerating voltage of 50 kV, ion beam current density of 6.5 mA/cm^2, distance 60 cm from the ion-optic system. The irradiation dose was 1 × 10^{18} ions/cm^2, the irradiation time was 5.25 h. The microstructure and phase composition were studied using an EM-125 transmission electron microscope at an accelerating voltage of 120 kV. The microstructure and phase composition of implanted titanium were studied in the area of modified layer at a depth of 50 – 70 nm from the irradiated surface.

The structural-phase state of α-Ti surface layers in the UFG state was investigated. It has been established that as a result of UFG-titanium irradiation with aluminum ions a polyphase implanted layer is formed on the basis of -titanium grains containing aluminide, oxide and carbide phases. Namely: 1) α-Ti grains having a BCC crystal lattice (spatial group Im3m), having a lamellar shape and located along the boundaries of α-Ti grains; 2) Ti3Al phase, an ordered phase with superstructure D019 and spatial group P63/mmc, having GPU crystalline, formed as lamellar precipitations along the boundaries of α-Ti grains; 3) $TiAl_3$ phase, an ordered phase with D022 superstructure, possessing a DSP crystal lattice with spatial group I4/mmm and localizing as rounded particles in triple junctions and along α-Ti grain boundaries; 4) particles of titanium carbide (TiC) having HCC crystal lattice (spatial group Fm3m), located inside alpha-Ti grains and having rounded shape; 5) inclusions of titanium oxide TiO_2 (otherwise brukite) having orthorhombic crystal lattice (spatial group Pbca), located on the boundaries and inside alpha-Ti grains on dislocations and having rounded shape.

Under ion implantation, the restructuring of the titanium matrix is observed – implantation leads to a decrease in the longitudinal grain size of α-Ti (from 1.9 μm to 0.7 μm), while the grain anisotropy factor decreases by 3 times.

The strength components included in the yield strength have been calculated. It is shown that implantation leads not only to a significant change in the structural-phase state of the material, but also to an additional hardening of almost 2.5 times. The contribution of individual strengthening mechanisms to the total hardening of the alloy is estimated: $\Delta\sigma_n$ - dislocation friction stress in the α-Ti crystal lattice; $\Delta\sigma_h$ - hardening of the α-Ti-based solid solution by atoms of alloying elements (Al, C, O); $\Delta\sigma_l$ - hardening by "forest" dislocations; $\Delta\sigma_D$ - hardening by long-range stress fields; $\Delta\sigma_{OR}$ - material hardening by incoherent particles when dislocations bypass them by the Orovan mechanism; $\Delta\sigma_H$ - hardening due to grain boundaries. It is shown that the share of the contribution is not equal. And the contribution of each of these mechanisms is different. Nevertheless, the main contribution to the total hardening after implantation is made by $\Delta\sigma_{Or}$.

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