

## Article

# Effect of Irradiation with Si<sup>+</sup> Ions on Phase Transformations in Ti–Al System during Thermal Annealing

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**Abstract:** The article deals with the effect of irradiation with Si<sup>+</sup> ions on phase transformations in the Ti–Al system during thermal annealing. An aluminum film with a thickness of 500 nm was deposited on VT1-00 titanium samples by magnetron sputtering, followed by ion implantation. Samples before and after irradiation with Si ions were annealed in a vacuum of 10<sup>−4</sup> Pa in the temperature range 600–1000 °C. It was established that ion implantation reduces the dissolution of Al in α-Ti with the formation of titanium silicides (TiSi<sub>2</sub>, TiSi<sub>3</sub>) and stabilizes aluminide phases Ti<sub>3</sub>Al rich in aluminum. As a result, a composite structure based on titanium silicide/aluminide was obtained on the surface of the sample synthesized by complex treatment: deposition, irradiation with Si<sup>+</sup>, and thermal annealing at the near-surface layers. The formation of the phase-structural state of the implanted layers is associated with the displacement of atoms of the crystal lattice, a result that is reflected in an increase in the size of the crystal lattice and a decrease in microdistortion of the lattice. The opposite effect is observed with increasing temperature. This fact is explained by the relaxation of unstable large grains with an excess of internal energies. At the annealing temperature of 900–1000 °C, a significant increase in microhardness was observed due to silicide phases.

**Keywords:** Ti–Al system; magnetron sputtering; ion implantation; coating; structure

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## 1. Introduction

Intermetallic compounds of the Ti–Al system have high melting point, low density, high modulus of elasticity, resistance to oxidation and fire, and high specific heat resistance [1]. Intermetallic alloys of the Ti–Al system are distinguished by unique structural properties and are considered very promising for aerospace engineering products. The main disadvantages of these alloys are low plasticity at low temperatures and low fracture toughness, which complicate their technological processing and industrial use [2–4]. Consequently, methods of increasing their ductility while maintaining their strength remain serious problems.

In recent years, composite coatings based on the Ti–Al–Si system, obtained by combined methods, have become attractive for many industrial applications due to their properties, such as low friction coefficient, increased hardness, and heat and oxidation resistance, which significantly increase the service life of the products [5–7]. The combination of ion-plasma and ion-beam technologies opens up new possibilities in the formation of effective composite nanostructured and nanolayer films. The prospects of such technologies are due to the possibility of creating various new surface structures with improved physical and mechanical properties [8]. At the same time, the study of the

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