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Investigation of Regularities of High-intensity Ion Implantation in Combination with Subsequent Exposure to the Surface of a High-current Electron Beam

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INTRODUCTION

The presentation presents the results of studies of the features of changes in the elemental composition and microstructure of titanium alloy during high-intensity implantation of nitrogen, aluminum ions of low and ultra-low energy. The influence of the target temperature regimes on the depth distribution of the implanted dopant and the structure of doped and matrix material is studied. The influence of subsequent modification of the ion-doped layer by the action on the surface of the pulsed high-current electron beams of microsecond duration is studied. The work presents the results of the studying the regularities of changes in the depth distribution of alloying elements, microstructure and phase composition of the modified and matrix layers by optical metallography, x-ray spectral and x-ray structural analysis.

EXPERIMENTAL SETUP

High-intensity low-energy ion implantation of Al

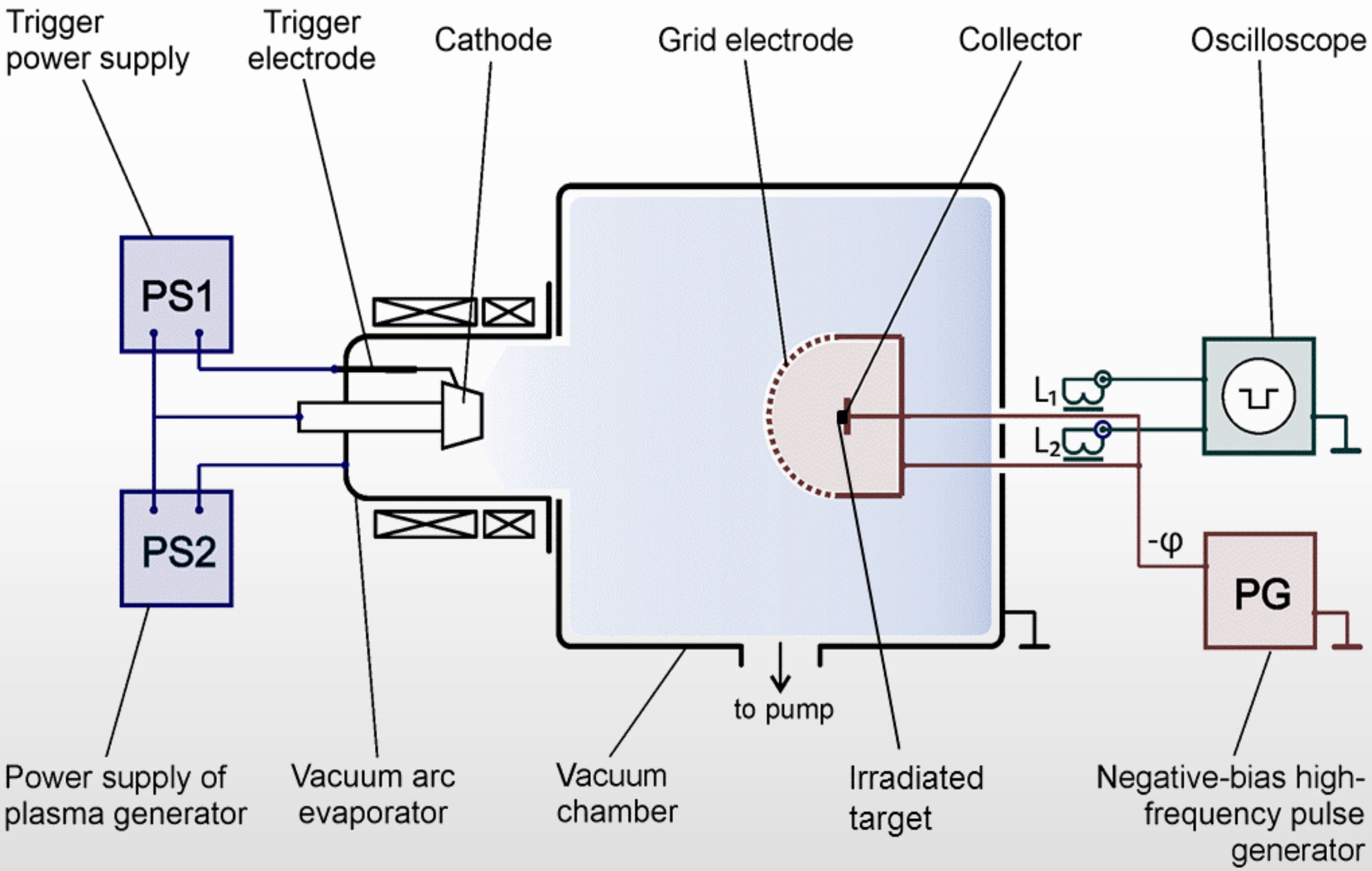

Fig.1. Scheme of experiments on high-intensity low-energy implantation of Al ions.

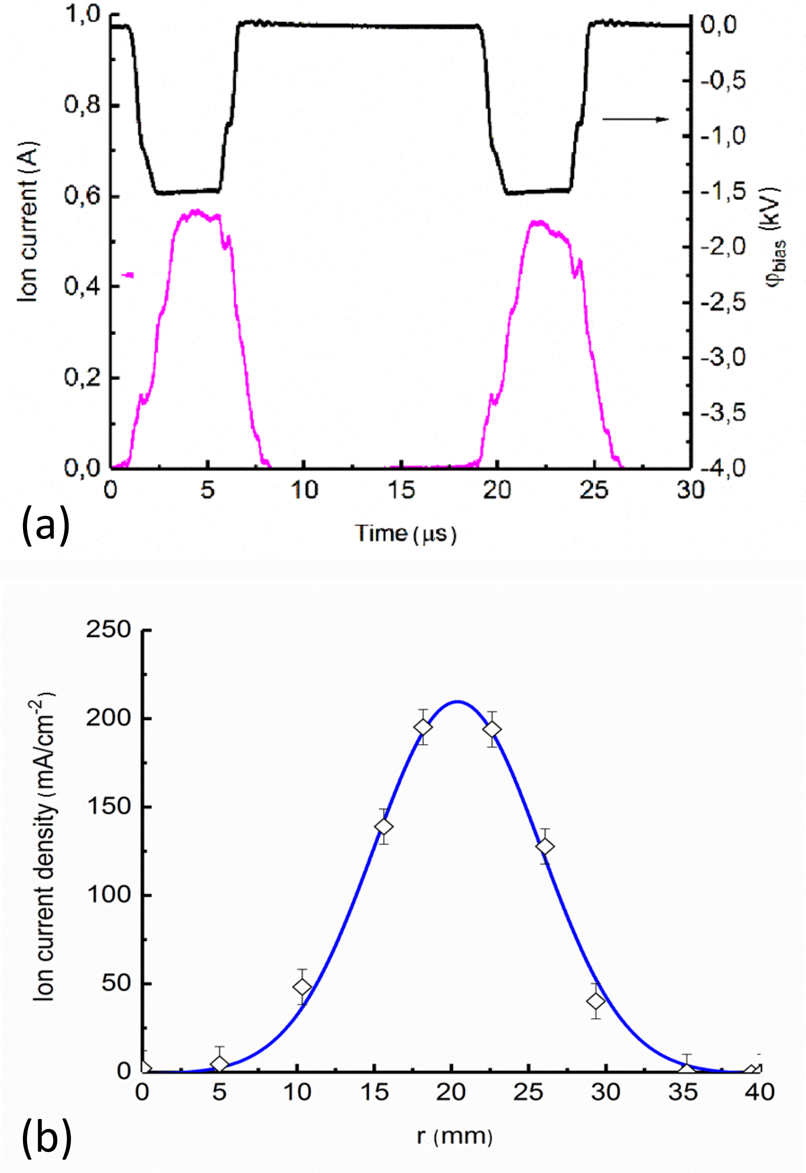

Fig.2. Typical shapes of voltage and current pulses (a) and characteristic ion current density distribution (b).

Surface treatment with a submillisecond intense low-energy electron beam using the "SOLO" electronic source

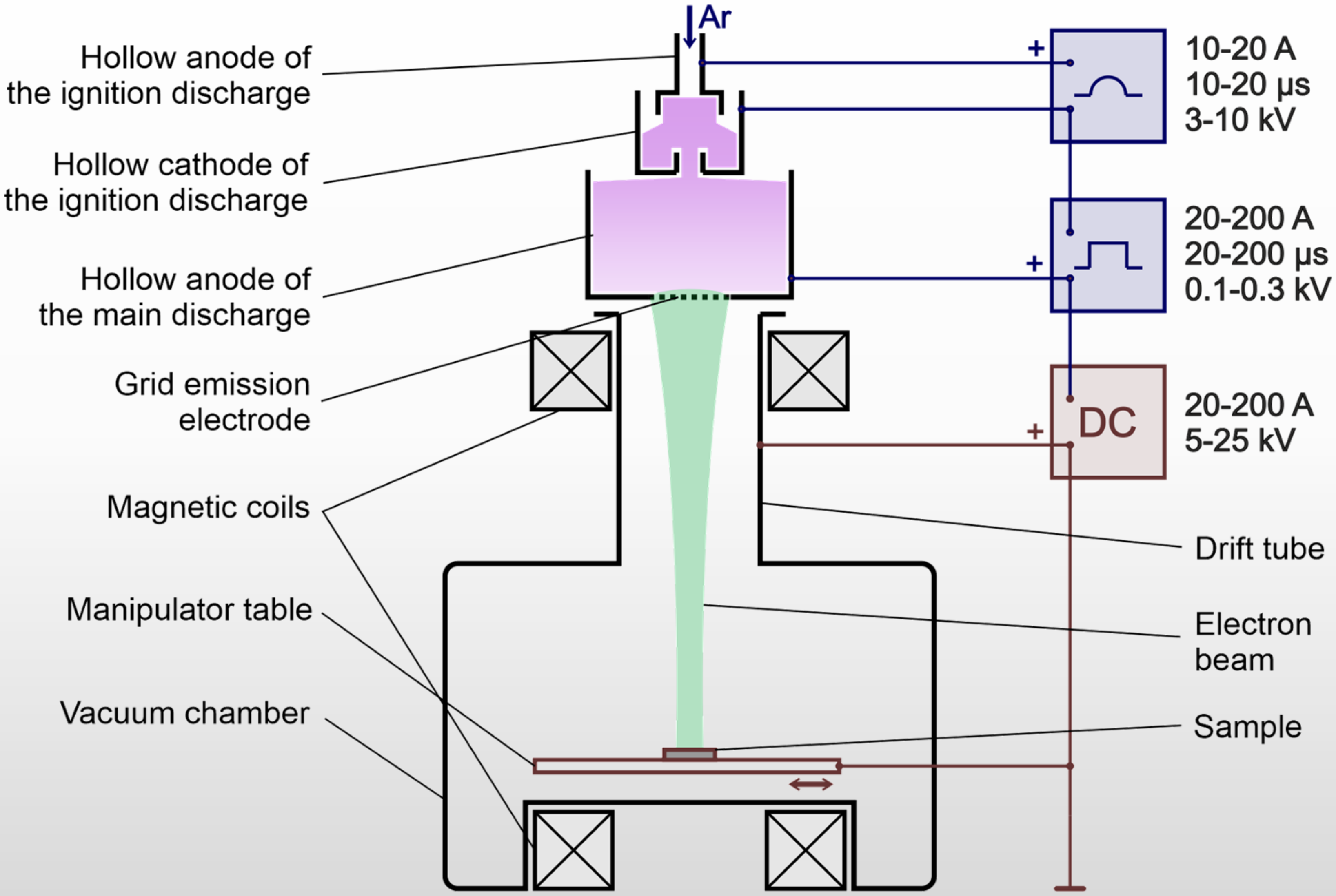

Fig.3. The scheme of the electron source operation.

Results and Discussion

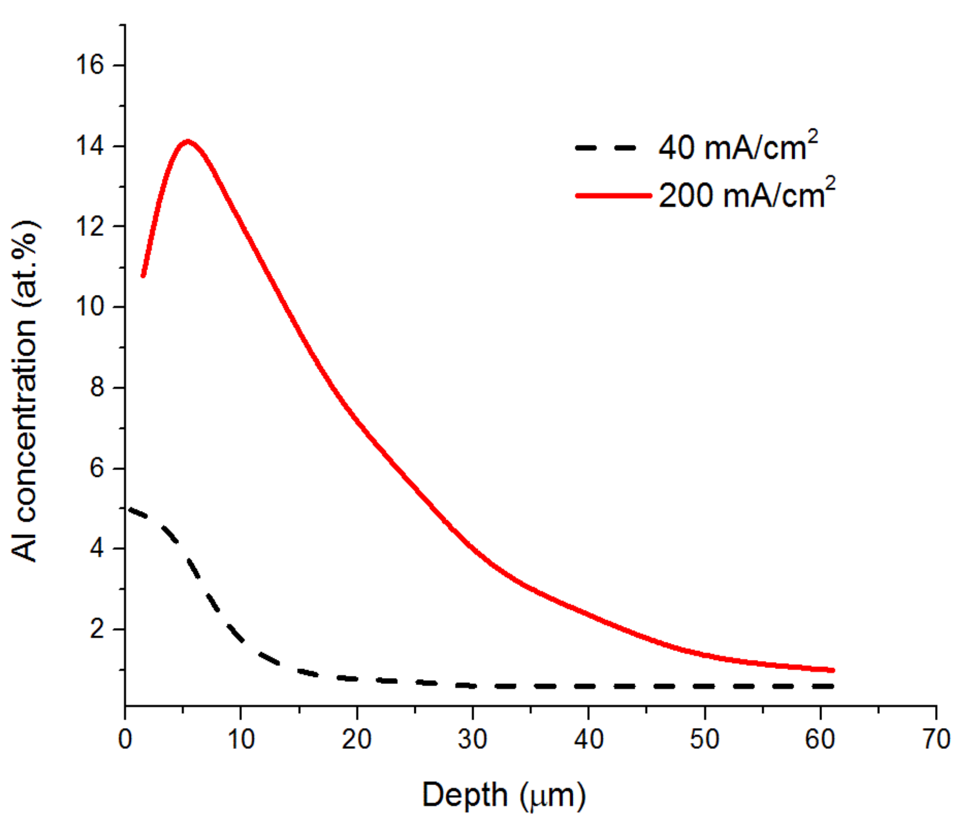

Fig. 4. Aluminum depth distribution profiles.

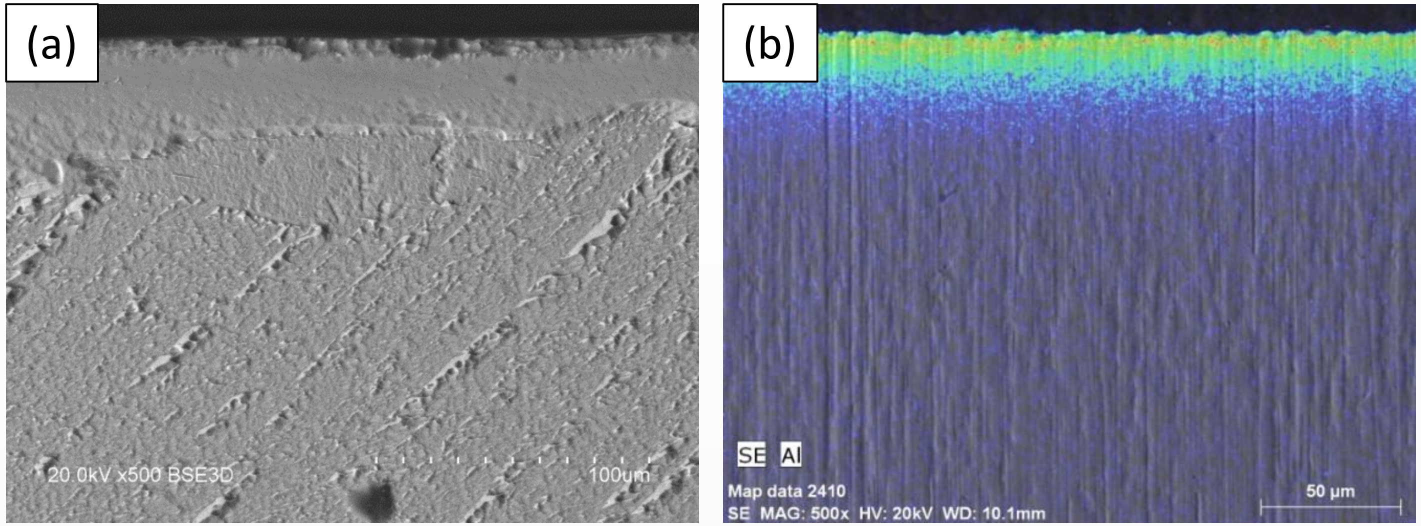

Fig. 5. Microphotograph of sample crossection (a), distribution map of aluminum dopant (b).

X-Ray Phase Composition Of The Sample 200 mA/cm^2

Detected phases	Phase content, mass%	Grid parameters, Å	CSR size, nm	$\Delta d/d*10^{-3}$
Ti	70	a = 2.9232 c = 4.6804	19	2.6
TiAl	30	a = 2.8993 c = 4.7100	60	1.8

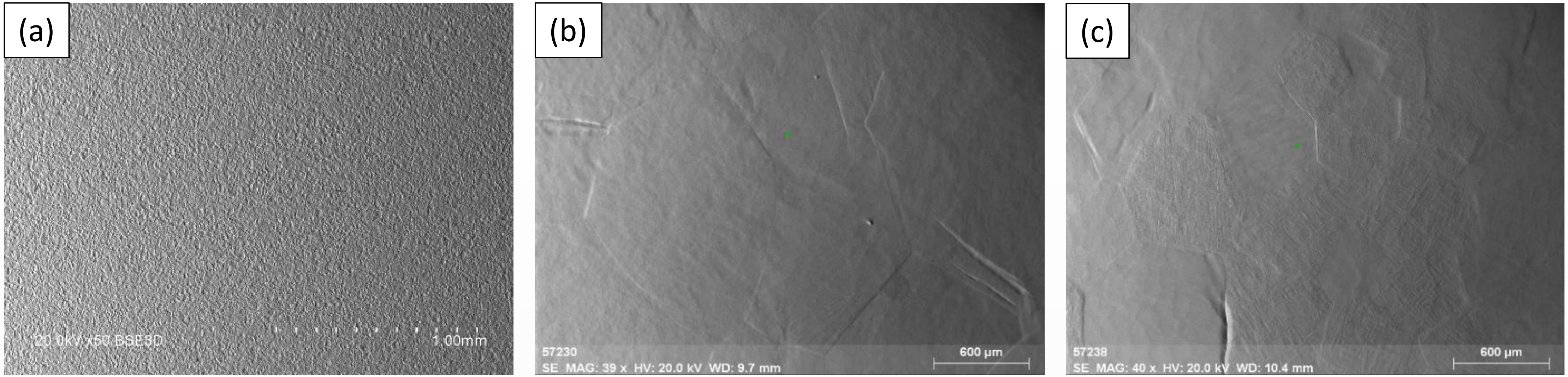

Fig.6. SEM-image of the surface of the initial sample (a) and sample implanted at different ion current densities ((b) - 40 mA/cm², (c) - 200 mA/cm²).

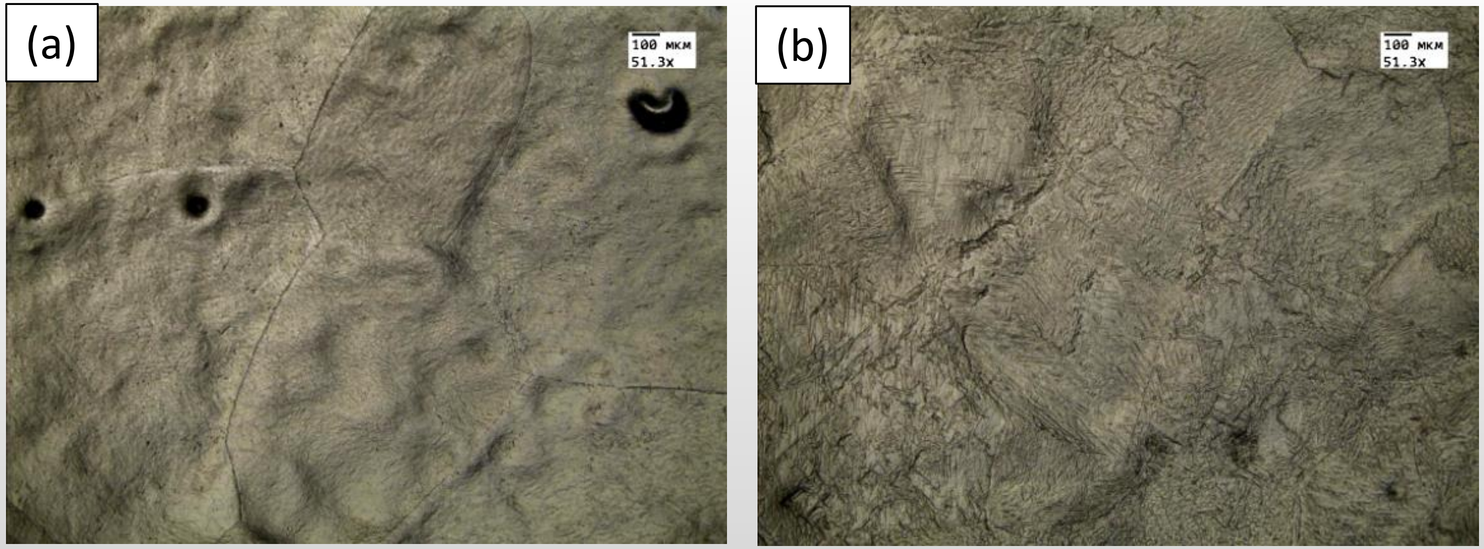

Fig.7. Optical microphotograph of the surface of sample implanted with aluminum ((a) - 40 mA/cm², (b) - 200 mA/cm²) after electron-beam treatment.

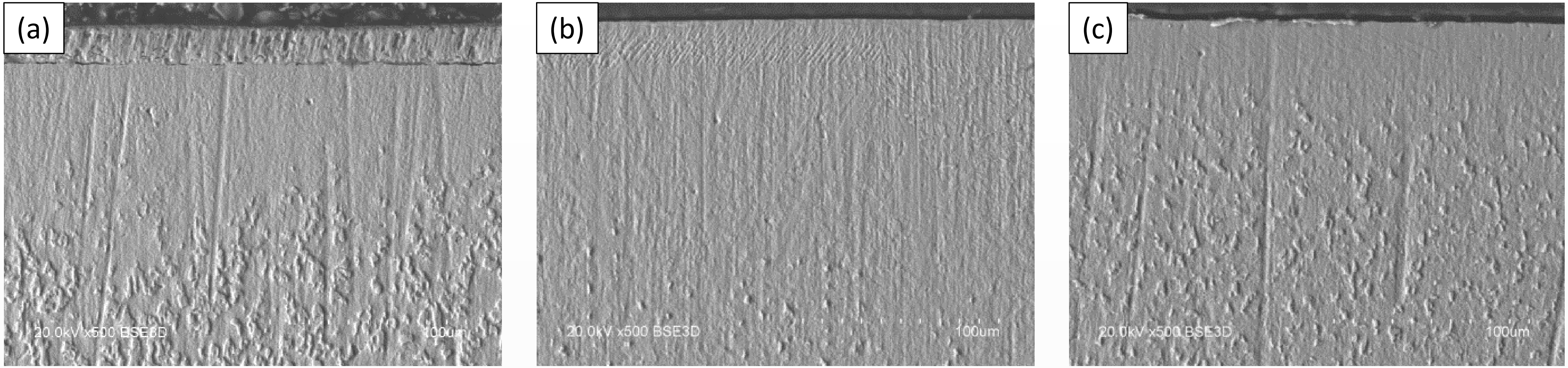

Fig.8. Microphotographs of a samples crossection: (a) - unimplanted titanium after electron-beam treatment; (b) - implanted with aluminum with a current density of 40 mA/cm^2 after electron-beam treatment, (c) - implanted with aluminum with a current density of 200 mA/cm^2 after electron-beam treatment.

Conclusion

High-intensity implantation of sample with an aluminum ion beam in a system with ballistic focusing leads to the formation of an ion-doped layer with a thickness exceeding 30 μm.

High-temperature irradiation regime leads to the formation of a grain structure on the surface of the sample. The aluminum concentration in the surface layer after 1 hour of implantation can reach ≈ 14%.

In the ion-doped layer, the formation of intermetallic phases TiAl and Ti occurs.

Subsequent processing of the samples by a submillisecond intense low-energy electron beam with a duration of 50 μs and an energy density of 10 J/cm^2 leads to the refinement of subgrain structures over the entire depth of the ion-doped layer and a significant reduction in tensile residual stresses.

Acknowledgment

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