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EFFECT OF PULSED ION BEAM IRRADIATION ON THE STRUCTURAL AND PHASE STATE AND MECHANICAL PROPERTIES OF ZIRCONIUM ZR-2.5NB ALLOY*

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Recently, processing methods associated with the use of charged particle beams are often used to improve the performance of metals and alloys and create protective coatings. In the process of electron and ion beam exposure accumulation of defects, formation of metastable phases and nanocrystalline structure are observed in the subsurface layer of metal polycrystals [1–2]. In this case, the presence of hydrogen in the material can significantly affect the structure formed in the subsurface layer. The surface structure, which has a high defect density and contains metastable phases, can have a considerable effect on the properties of materials.

In this work, the effect of irradiation with a pulsed beam of carbon ions on the structural and phase state and mechanical properties of hydride-forming alloys of the Zr-Nb-H system was studied.

Zirconium Zr-2.5Nb alloy with a hydrogen content of 0.002 and 0.19 wt.% (hereinafter, Zr-2.5Nb and Zr-2.5Nb-0.19H alloys) was used as a material for the study. To assess the effect of irradiation on the structure and properties, the samples were irradiated with a pulsed beam of carbon ions with the TEMP accelerator [3]. The peak energy of carbon ions was 200 keV, the ion current density was 100 A/cm^2, and the duration of the ion current pulse was 200 ns. The ratio of H^+/C^{n+} ions in the beam was 20%/80%.

In the initial state in the Zr-2.5Nb alloy, particles of the Nb_β phase are observed in the bulk and at the grain boundaries. The volume fraction of particles determined by the standard grid method in optical images of the alloy structure is 3–4%. At the same time, according to the data of X-ray diffraction analysis, in the initial state, the alloy contains only the Zr_α phase, which is due to the low volume fraction of the secondary phase and the presence of a crystallographic texture in the Zr_α phase.

Hydrogenation of the alloy to a hydrogen concentration of 0.19 wt.% does not lead to any noticeable structural changes. However, according to the data of X-ray diffraction analysis, the phase composition of the alloy changes as a result of hydrogenation. In addition to the main Zr_α phase, the Nb_β phase appears in the Zr-2.5Nb-0.19H alloy and precipitations of ZrH and ZrH_2 hydrides are also observed. In this case, the texture in the Zr_α phase is preserved.

As a result of irradiation with a pulsed beam of carbon ions, an insignificant number of shallow craters are observed on the surface of Zr-2.5Nb and Zr-2.5Nb-0.19H alloys. In this case, the phase composition of the alloy also changes: in addition to the Zr_α phase with the texture preserved as a result of irradiation, precipitates of the Zr_β phase appear in the alloy. At the same time, in a hydrogenated alloy, irradiation leads to more significant changes in the phase composition. In addition to the main Zr_α phase with an unchanged crystallographic texture, the Zr_β phase also appears in the alloy, the volume fraction of the Nb_β phase decreases, and the ZrH_2 hydride precipitates are completely dissolved.

Microhardness measurements for the samples in various states have shown that hydrogenation, as well as irradiation with a pulsed beam of carbon ions, results in the considerable changes in microhardness. Thus, in the initial state, the microhardness of the Zr-2.5Nb alloy samples is (130±7) HV, and after hydrogenation this value rises by 1.3 times, up to (166±7) HV. After irradiation, the values of microhardness for the Zr-2.5Nb and Zr-2.5Nb-0.19H samples are (145±7) HV and (202±7) HV, respectively.

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