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INFLUENCE OF HELIUM ION IRRADIATION ON THE STRESS EVOLUTION IN NC-ZRN/A-ZRCU MULTILAYERD FILMS

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Nowadays the development of new radiation-resistant materials is a crucial problem that is especially urgent for fission/fusion industry, aerospace application, etc. wherein objects are exposed to strong irradiation with ions, neutrons, electrons. So irradiation with light ions due to nuclear collisions can induce a higher ratio of point defects (e.g. vacancies and interstitials) produced relative to defect clusters (e.g. He bubbles) in metallic crystals [1]. This in turn remarkably degrades the performance of structural materials in advanced fission/fusion reactors, which must be significantly improved to extend the reliability and efficiency [2, 3].

For this, it is necessary to create materials with a large amount of sinks for point defects, such as dislocations, grain boundaries, and interphase boundaries [4]. Multilayer systems are promising for research, since interlayer boundaries can affect the elimination of radiation defects [5]. They have significant interfacial regions that can act as stable defect absorbers.

Multilayer films nc-ZrN/a-ZrCu with different Cu concentration (from 44.6 to 73.8 at.%) and thickness of amorphous layer ZrCu (5 and 10 nm) were formed at 300°C by reactive magnetron sputtering in a high vacuum chamber (base pressure $<10^{-5}$ Pa) equipped with three confocal targets and a cryogenic pump (max. 500 l/s). A constant bias voltage of -60 V was applied to the substrate during deposition, while the substrate was rotated at 15 rpm throughout the whole deposition to ensure an equal deposition rate across the substrate area. nc-ZrN/a-ZrCu multilayer films with different Cu content and thickness of ZrN and ZrCu elementary layers have been investigated. The Cu content in the ZrCu layers was varied by changing the DC power supply of the Cu target, from 40 to 52 W, and the DC power supply of Zr target, from 88 up to 294 W.

Ion implantation of multilayer films was carried out with He^{2+} ions with energy of 40 keV on a DC-60 heavy ion accelerator at fluences from 5.0×10^{16} to 1.1×10^{18} cm^{-2}. The energetic parameters of implantation were chosen so as the implanted He distribution depth did not exceed the film thickness, as calculated using the SRIM-2012 code.

X-ray diffraction and transmission electron microscopy (TEM) studies of multilayer films after deposition have shown that the films consist of alternating layers of nanocrystalline ZrN and amorphous a-ZrCu. The formation of horizontal continuous layers with flat and sharp interfaces was revealed.

Studies of stresses in multilayer films have shown that they are compressive and vary from -2 to -4 GPa depending on the thickness of the ZrCu layer and the Cu concentration in it. It has been found that irradiation with helium ions leads to a decrease in the level of compressive stresses. In this case, for multilayer films with an amorphous layer thickness of 5 nm at a dose of more than 9.0×10^{18} cm^{-2}, the stresses decrease to zero and become tensile. The decrease in the stress level is mainly associated with the effects of radiation erosion of multilayer films. The change in compressive stresses in multilayer films upon irradiation with helium ions is consistent with the TEM data. Microscopic studies revealed curvature of crystalline and amorphous layers in the area of implantation of helium ions.

In the paper discusses the mechanisms of changes in internal stresses after implantation of helium ions, as well as the influence of copper concentration in the amorphous layer, its thickness and radiation dose on the level of these stresses.

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