Effect of irradiation of titanium, zirconium, and hafnium nitrides with high-energy xenon ions

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The purpose of this work is to assess the structural and morphological changes produced in Ti, Zr, and Hf nitrides by irradiation with high-energy xenon ions. The use of xenon ions with this energy, which are not radioactive, makes it possible to simulate the formation of uranium fission fragments. Irradiation produced no changes in the phase composition and lattice parameter of the nitrides. In accordance with SEM images of a free surface of the TiN_x sample before and after irradiation, the radiation-initiated structural relaxation has reached completion. SEM images of a transverse fracture surface of the HfN_x sample after irradiation demonstrate a similar irradiation effect: radiation-induced vacancy generation, vacancy coalescence, and subsequent pore faceting. The surface of open pores has more perfect faceting. The pore size characteristic of HfN_x is an order of magnitude greater than that of TiN_x. The pore density in the irradiated ZrN_x sample is roughly the same as in the unirradiated sample. The pore size characteristic of the irradiated ZrN_x is greater than that in the unirradiated sample. This can be accounted for by the fact that the irradiation-induced vacancies diffuse to pores already present in the material, without formation of additional pores. In accordance with cross-section TEM image of the ZrN_x sample after irradiation, the selected area electron diffraction pattern indicates that the ⟨110⟩ orientation of the crystallite is perpendicular to the sample surface ((001) plane of the image). The pores are largely concentrated near the free surface of the sample. Bent extinction contours point to a stressed state. In the near-surface region of the sample we observed grain boundaries and linear arrays of dislocations forming subgrain boundaries. In accordance with high-resolution TEM image of the irradiated ZrN_x sample, the observed local translational symmetry distortions seem to result from irradiation. With the sample thickness in the range 5-10 nm, the density of such distortions is on the order of 10^{11} cm^{-2}. The fact that the observed distortions are unrelated to dislocations, in contrast to those observed in unirradiated ZrN_x samples, suggests that they were produced by high-energy xenon ions.

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