Surface orientation dependence of irradiation-induced hardening in Zr-Nb alloys subjected to 3-MeV Zr^{2+} irradiation

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Abstract

The techniques of ion-irradiation, nano-indentation, and electron backscatter diffraction are jointly utilized in this study, in order to investigate the orientation dependence of irradiation-induced hardening in Zr-Nb alloys. Results show that the hardness gradually decreased from (0001) corner to (10-10) and (11-20) corners, and the lowest irradiation-induced hardening was observed at [0001] orientation.

Keywords: Fuel claddings, Irradiation induced hardening, Crystal orientation, Zr-Nb alloys

1. Introduction

Irradiation induced embrittlement is considered one of the most common performance degradations in the materials for nuclear core applications. However, for the components with strong texture in microstructure, special attention has to be paid to the anisotropic properties when concerning the environmental degradation behaviours. For example, the Zr-based nuclear fuel cladding tube has long been known to grow mainly along the axial direction rather than the circumferential direction when being irradiated in-pile, because the basal planes of α-Zr crystal are preferential to be parallel to the tube's axial direction. Similarly, a question is then raised: is the irradiation-induced hardening isotropy or anisotropy in the textured Zr-based cladding tubes. The aim of this study is therefore to investigate the crystal orientation dependence of the irradiation hardening occurred in Zr-Nb alloys.

2. Experimental procedure

Zr-Nb alloys prepared by arc-melting were used as experimental materials. Disc specimens were prepared and subjected to 3-MeV Zr^{2+} irradiation at 573 K up to ~0.2 dpa using 1.7 MV tandem accelerator at High Fluence Irradiation Facility, The University of Tokyo. After irradiation, nano-indentation tests were firstly conducted to evaluate the irradiation-induced hardening, followed by EBSD analysis performed onto the hardness-tested region to record the corresponding crystallographic information.

3. Conclusion

Results showed that the hardness near (0001) pole corner was the highest and gradually decreased as the orientation deviated to (10-10) and (11-20) poles. After irradiation, it is found that the hardness increased quickly at doses <0.1 dpa, however much milder when the dose >0.1 dpa. Moreover, it is noted the lowest irradiation-induced hardening was observed at [0001] orientation.

References

[1] Huilong Yang, et al. Surface orientation dependence of irradiation-induced hardening in a polycrystalline zirconium alloy, Scr. Mater. 162 (2019) 209-213.