Hardening and Microstructural Evolution of Zr-Fe alloys under Ion Irradiation

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Zirconium-iron model alloys are irradiated with heavy ions to investigate effects of iron contents, irradiation dose, irradiation temperature on surface hardening. Hardening are measured with constant indentor-depth tests. Iron atoms in zirconium enhance loop formation, and loops grow larger in high purity zirconium.

1. Introduction

Zirconium has good high temperature properties and shows almost no swelling under irradiation. In this study, we investigate effects of Fe contents and irradiation temperature on mechanical properties and microstructual evolution in zirconium alloys under irradiation.

2. Experimental

4 kinds of Zr-Fe model alloys (Zr-60wt.ppmFe, Zr-210wt.ppmFe, Zr-440wt.ppmFe, Zr-1450wt.ppmFe) were prepared. They were annealed at 993K for 2 hours, 850K for 1hour and 823K for 5 hours to get homogeneous alpha phase. They were bombarded with 4MeV Ni^{3+} ions in the HIT Facility Tandertron Accelarator to doses of 1 dpa <10dpa and <20dpa at the peak damage depth of 1350 nm from the surface at 300, 400 and 500°C.

Micro-Vickers tests were carried out to measure surface hardening with the use of Shimadzu DUH-201. Considering the damage peak depth and anisotropical surface hardness of zirconium based alloys, tests with constant indentor-depth (700nm) were carried out. Microstructure of the irradiated specimens were also observed by TEM.

3. Results and Discussion

Fig.1 shows Fe content dependence of averaged surface hardening in the specimens irradiated to a dose level of 4.7-8.1dpa. Higher Fe content increases hardening and hardening in basal-planes is larger than that in prism-planes, especially at 300°C. Microstructural observation shows that high density of loops are formed in Zr-1450wt.ppm Fe. These indicate that higher Fe contents increase hardening by high density loop formation, and Fe atoms enhance loop formation on basal-planes at lower irradiation temperature. Pure zirconium shows higher hardening and large loops are

observed only in high purity zirconium. Loop growth is found to be enhanced in pure zirconium.

Fig. 2 shows dose dependence of averaged hardening in Zr-1450wt.ppmFe At 300°C, hardening increases with $(dpa)^{1/2}$. Microstructual observation shows that diameter of loops does not increase with irradiation dose, but density of loops increases linearly with irradiation dose at 300°C. At 400 and 500°C, on the other hand, hardening increases linearly with dpa . Density and diameter of loops increase with irradiation dose at 400 and 500°C.

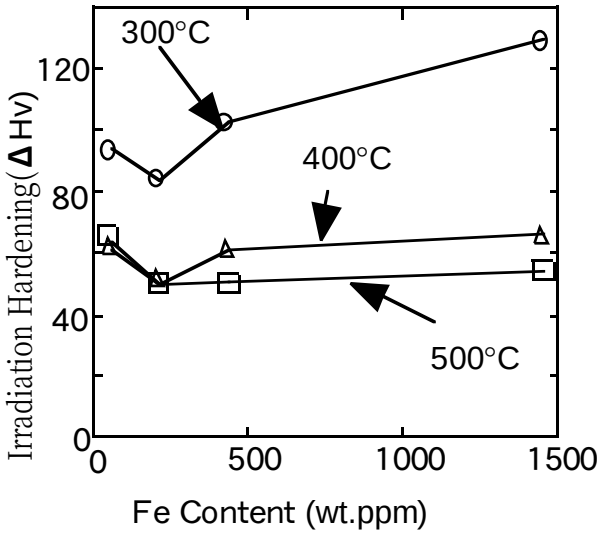

Fig.1 Fe contents dependence of hardedning irradiated with 4MeV Ni^{3+} ions to 4.7-8.1dpa.

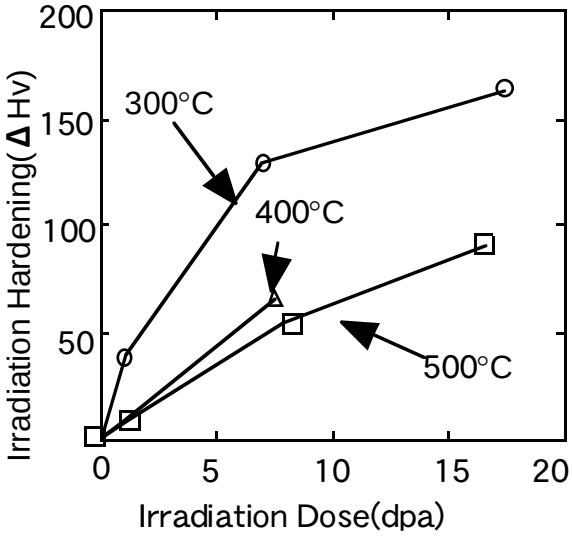

Fig.2 Irradiation dose dependence of Hardening in Zr-1450wt.ppmFe irradiated with 4 MeV Ni^{3+} ions.