§1. Microstructural Evolution of V-4Cr-4Ti by Heavy-ion Bombardment at Relatively Low Temperature

Muroga, T., Miyazawa, T., Nagasaka, T.,
Watanabe, H. (Kyushu Univ.)

Vanadium alloys are promising candidate low activation structural materials for fusion blankets. According to large amount of researches, V-4Cr-4Ti was selected as a leading candidate. For this material, it is known that the factor determining its low temperature operation limit is hardening and loss of elongation by irradiation.

Previous studies showed that addition of Y (and Si, Al) can improve the elongation after irradiation at temperature ranging from 573 to 673K. In the temperature range, Ti-CON precipitates are formed in initial stage of irradiation causing hardening. Thus the addition of Y, which can scavenge interstitial impurities of C, O and N, would suppress the precipitate formation retarding hardening and loss of elongation. However, at temperature lower than 573K, effects of the minor element addition is small because initial defects formed by irradiation are interstitial dislocation loops, on which the impurities are thought to have only small effects.

Thus, for the purpose of predicting radiation hardening at temperature below 573K, dislocation loop evolution kinetics needs to be investigated.

The kinetics of dislocation loop evolution have been investigated extensively for many metals and alloys by High Voltage Electron Microscopy (HVEM) including some vanadium alloys [1]. However V-4Cr-4Ti was not investigated. The objectives of this study are to investigate the dislocation loop kinetics of V-4Cr-4Ti by ion and neutron irradiations comparing with past HVEM irradiations on vanadium alloys. Efforts are being made to extract fusion relevant effects such as cascade damage effects and damage rate effects.

The ion irradiations were carried out with 2.4 MeV Cu^{2+} ions at 403-413K (varied during irradiation), 473K and 573K to 1 dpa and at 4.5×10^{-3} dpa/s at the damage peak depth (800nm from surface) using Tandem accelerator of Kyushu University. Microstructure at the damage peak was observed by TEM following electropolishing.

Table 1. Irradiation conditions

Irradiation	Temperature	dpa	dpa/s
2.4MeV Cu^{2+} ions	403-413K	1.0	4.5×10^{-3}
	473K	1.0	4.5×10^{-3}
	573K	1.0	4.5×10^{-3}
Fission Neutrons (BR2)	363K	0.20	1.10×10^{-7}
	563K	0.20	1.10×10^{-7}
Fission Neutrons (JMTR)	563K	0.08	4.4×10^{-8}

Hardness change by the ion irradiation at 473K at 1, 2 and 8 dpa were reported in the previous paper [2], which showed hardening to ~2 dpa followed by saturation.

Neutron irradiations were carried out at BR2 reactor at 363K and 563K to 0.2 dpa and at JMTR at 563K to 0.08 dpa. The irradiation conditions are listed in Table 1. Some of the data obtained by JMTR irradiation was published elsewhere[3].

Figure 1 shows microstructure by ion irradiations. High density dislocation loops are observed. At 403-413K and 473K, very small defect clusters which are clearly visible only by Weak-Beam Dark-Field (WBDF) conditions were formed. Such very small clusters were not formed at 573K.

Figure 2 shows microstructure after neutron irradiation at BR2 at 363K and 563K. Similar to ion irradiations, high density of dislocation loops were observed. Very small defect cluster which are clearly visible only WBDF conditions were formed only at 363K.

The dislocation loop density is comparable to that of electron irradiations for V-20Ti and V-3Ti-1Si. Quantitative comparison taking the temperature and the damage rate effects are in progress.

[1] T. Muroga et al., ASTM STP 1047 (1990) 199-209.
[2] T. Miyazawa et al., J. Nucl. Mater. 455 (2014) 440-444.
[3] T. Nagasaka et al., Mat. Trans. 46 (2005) 498-502

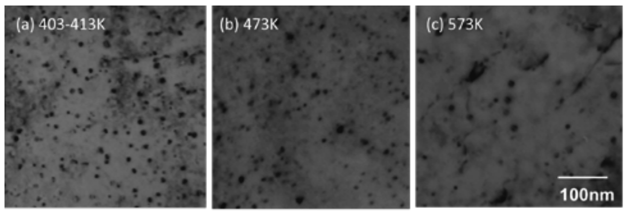

Fig. 1 Microstructure by heavy ion irradiation.

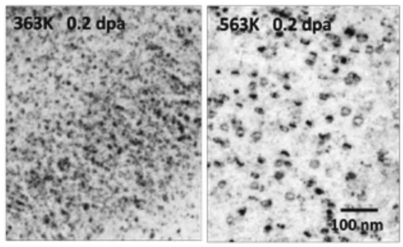

Fig. 2 Microstructure by neutron irradiation at BR2.