§3. Correlation of Microstructural Evolution in V-4Cr-4Ti by Heavy Ion and Neutron Irradiations

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Defect clusters formed in V-4Cr-4Ti by irradiation were identified to be dislocation loops, Ti-rich precipitates and their complexes, whose fraction is dependent on temperature. Extensive researches on dislocation loop evolution have been carried out using electron beams in HVEM (High Voltage Electron Microscope) for vanadium alloys [1,2]. However, electrons cannot cause displacement cascade which is the characteristic of fusion neutron irradiation effects.

The purpose of this study is to investigate dislocation loop evolution processes of V-4Cr-4Ti under heavy ion and neutron irradiations, which produce cascade damage, and correlate with those obtained by the past studies using HVEM. The understanding on the kinetics of microstructural evolution under irradiation with various species is expected to enhance predictability of radiation induced mechanical property change of V-4Cr-4Ti in fusion conditions.

The details of the experimental conditions were reported elsewhere [3]. Figure 1 summarizes microstructural parameters as a function of dose for heavy ion irradiations. The loop number density is highest at 1 dpa, showing that the loop nucleation was completed before 1 dpa. Loops grow and coalesce and tangles with dose, decreasing their number density. The dislocation density, which is defined as a total dislocation length per volume, continues to increase because of formation and evolution of tangled dislocation network. The change shown in Fig. 1 is a typical initial microstructural evolution in irradiated metallic materials.

Figures 2 summarize loop number density as a function of temperature. The data by electron irradiations [1,2] were also indicated for comparison. Fig. 2 shows that the temperature dependence of the loop number density is very weak to ~473 K for electron irradiation and to ~573 K for ion irradiation, both followed by significant negative temperature dependence. A datum for neutron irradiation at 363 K, is close to those for electron and ion irradiations in the similar temperature range.

Figure 2 shows that all the loop number density data within the temperature range of 363 K to 473 K lie between 0.3 to 3 x10^{23} m^{-3}, showing weak temperature and irradiation species dependence. On the other hand, data at the temperature higher than 523 K have clear negative temperature dependence. However the loop number density by ion irradiation is significantly higher than that of electrons in this temperature range in spite of similar damage rate, probably due to the cascade-enhanced dislocation loop nucleation. The low loop number density by neutrons at 563 K can be explained by its very low dose rate.

The mechanistic understanding on the difference of the irradiation effects by fission-neutron, ion and electron irradiations will enhance accuracy of the prediction of D-T fusion neutron irradiation effects to be established based on the surrogate irradiation means. In this case, the validation of the prediction is foreseen by the irradiation facilities of neutrons whose spectrum closely resembles that of D-T fusion neutrons, such as IFMIF (International Fusion Materials Irradiation Facility).

[1] T. Muroga et al., ASTM STP 1047 (1990) 199-209.
[2] Q. Xu, T. Yoshiie and H. Mori, J. Nucl. Mater. 307-311 (2002) 886-890.
[3] T. Muroga et al., Ann. Rep. NIFS, April 2014-March 2015, 292.

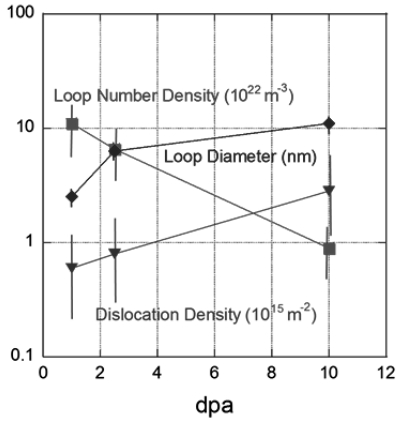

Fig. 1 Microstructural parameters as a function of dose (dpa) by 2.4 MeV Cu^{2+} ion irradiation at 473 K.

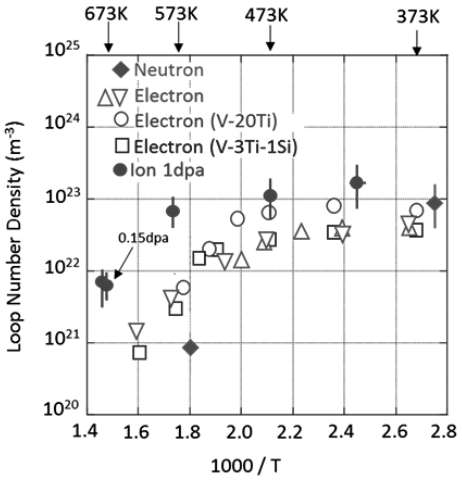

Fig. 2 Temperature dependence of dislocation loop number density. Data by electron irradiation for V-4Cr-4Ti (0.8~1.3 x 10^{-2} dpa/s) [2] and V-20Ti and V-3Ti-1Si (1.6 x 10^{-4} dpa/s) [1] are also shown for comparison.