§98. Synergistic Effects of Neutron (ion) and Plasma on Material in QUEST

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1. Introduction

Low activation V-4Cr-4Ti alloys has an attractive potential use for fusion reactor materials. But the interstitial impurities of carbon, oxygen, and nitrogen (C, O, N) of a V-4Cr-4Ti alloy play an important role in radiation effects such as microstructural changes, irradiation hardening, and embitterment [1-3]. In particular, oxygen is known to influence these alloy properties effectively. The alloy is, however, considered to be used as a fusion blanket structural material that faces a vacuum and helium gas, which may contain a low partial oxygen pressure. To understand the radiation-induced phenomena related to oxygen, such as oxide formation in the matrix, the oxygen level in the vanadium alloy as well as oxygen pick-up from the radiation environment must be considered. The authors showed that in the laser welded V-4Cr-4Ti-0.15Y alloy, manufactured by the National Institute for Fusion Science (NIFS), formation and growth of Ti(C,O,N) precipitates were controlled by Y-addition during ion irradiation. In the case of ion irradiation, oxygen pick-up from a vacuum environment is negligible, especially at higher dose levels. In this study, therefore, to understand the scavenging effect of Y atoms, V-4Cr-4Ti alloys with different Y levels were irradiated under different environment conditions, namely, vacuum (ion irradiation) and He (neutron irradiation) at higher temperatures, where the formation of Ti(C,O,N) precipitates is prominent.

2. Experimental Procedure

High-purity V-4Cr-4Ti alloy (NIFS Heat 2) and Y-doped V-4Cr-4Ti alloys with two different Y levels, i.e., V-4Cr-4Ti-0.1Y and V-4Cr-4Ti-0.2Y, were used. The oxygen and nitrogen concentration in NIFS HEAT 2 were 129 and 139 wppm, respectively. On the other hand, the oxygen concentrations of the V-4Cr-4Ti-0.1Y and V-4Cr-4Ti-0.2Y alloys were 108 and 92 wppm, respectively. Disk specimens (diameter; 3mm) for microscopy were wrapped with pure zirconium as a getter of oxygen and solution treated (annealed) for 2 h at 1273 K in a vacuum (~5.0 x 10^{-5} Pa). Neutron irradiation in a high-purity He atmosphere was conducted in JMTR in a 03M-69U irradiation capsule at 673 K and 873 K. The neutron fluence was $5.18 \times 10^{24}/m^2$ (E > 1.0 MeV), which corresponds to 0.45 dpa for V alloys. In this study, the microstructure was observed by a conventional electron microscope (JEOL 2000EX), and Ti(C,O,N) precipitates formed in the fission-neutron irradiated samples were analyzed by a spherical aberration (Cs)-corrected high-resolution analytical electron microscope (JEOL ARM 200FC) located in a radiation controlled area at the Kyushu University.

3. Results

Fig. 1 shows the microstructure of NIFS HEAT2 and Y-doped V alloys irradiated at 673 K and 873 K during neutron irradiation at the JMTR. Estimated oxygen levels from the measured density and size of Ti(C,O,N) precipitates and results of the Vickers hardness test of the alloys are also shown in the figure. EDS elemental distribution maps for the different elements are shown in Figs. 2 (b) to (f) for C, O, N, Ti, and Y, respectively. In the figure, an STEM-bright field image (Fig. 2(a)) is also shown for comparison. The center part of the precipitates was mainly enriched in Ti and N atoms. C and O atoms were strongly segregated around the precipitates, but segregation of Y atoms was weak. In this study, Ti(C,O,N) precipitates were assumed to be TiO for the estimation of O concentration in the samples. Further investigations are needed to discover the detailed mechanisms of the formation of Ti(C,O,N) precipitates during irradiation

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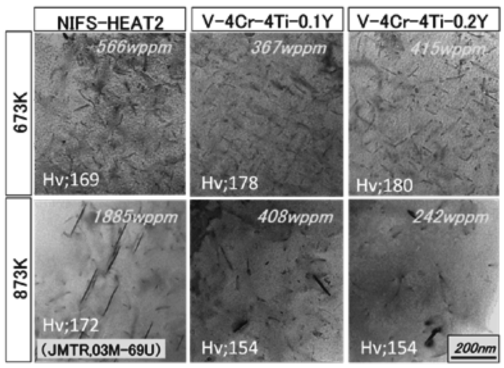

Fig.1 Microstructure of NIFS-HEAT 2, V-4Cr-4Ti-0.1Y, and V-4Cr-4Ti-0.2Y alloys irradiated at 673 K and 873 K in JMTR (03M-69U). The neutron fluence is $5.18 \times 10^{24}/m^2$ (E > 1.0 MeV), which corresponds to 0.45 dpa for V alloys.

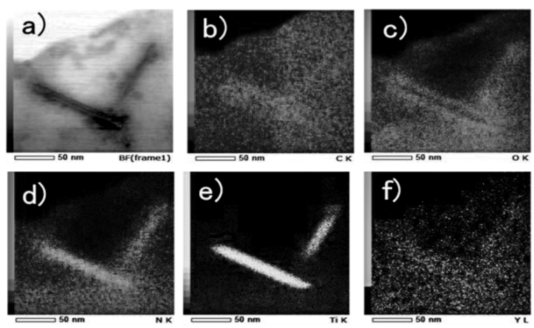

Fig. 2 Elemental EDS mapping images of Ti(C,O,N) precipitate formed in V-4Cr-4Ti-0.2Y alloys irradiated at 873 K for 0.45 dpa.