§17. The Effects of PWHT on Y-Doped and Laser-Welded V-4Cr-4Ti Alloys after Ion Irradiation

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1. Introduction

The welding procedure is one of the key technologies for use of V-4Cr-4Ti alloys as a large component [1]. Our previous studies [2] on neutron irradiated V-4Cr-4Ti alloy (NIFS-HEAT2) revealed that tiny Ti(CON) precipitates were homogenously formed in the weld metal at 673K and the formation was prominent in comparison with base metal. The effects of post-weld heat treatment (PHWT) on weld metal, effectively improving the CVN impact properties for unirradiated material and for material irradiated at lower temperatures, are not effective or have a very limited effect at higher irradiation temperatures where the growth of Ti(CON) precipitates were prominent. On the other hand, Y addition on V-4Cr-4Ti alloys is expected to reduce the Ti(CON) formation, because oxygen is scavenged by Y. The present paper summarized, therefore, the microstructural of laser welded Y doped V-4Cr-4Ti alloy during ion irradiation.

2. Experimental Procedure

Welded joints used in this study were prepared from V-4Cr-4Ti-0.15Y alloy. Before the YAG laser welding (bead-on-plate welding) in a high purity argon atmosphere, the samples were annealed in a vacuum at 1273K for 2hr. The detailed welding procedure was described elsewhere. A 2.4MeV copper ion irradiation was carried out with the tandem accelerator at Kyushu University. The TEM samples were sliced from welded materials and irradiated at 873K up to the dose of 12 dpa. After the irradiation, the specimen was electro-polished by a back thinning method, and the area near the peak damage region (at about 700 nm) was observed by TEM. The damage rate and the implanted copper concentration in this region were 1.7 x 10^{-4} dpa/s and 10^{-2} at. % (at 1 dpa), respectively.

3. Results

After the irradiation at 873K, in NIFS-HEAT2, fine titanium oxides with {100} habit planes were observed even at the dose of 0.75 dpa. The number density of Ti(CON) decreased with increasing dose and the growth of Ti(CON) precipitates was prominent at higher dose levels above 4 dpa. For the case of NIFS-HEAT2, the estimated oxygen levels from the microstructure increased with dose and the value of the sample irradiated at 12 dpa is about 20 times higher than that of unirradiated sample. In this estimation, Ti(CON) precipitates are assumed to be TiO (NaCl type crystal structure). In V-4Cr-4Ti-0.15Y alloy, on the other hand, Ti(CON) precipitates were observed in all dose levels but smaller Ti(CON) precipitates were observed, in comparison with NIFS-HEAT2. The estimated oxygen levels of the base were almost half of NIFS-HEAT2. But, in the higher dose level above 7.5 dpa, the growth of Ti(CON) became prominent. The same oxygen pick-up from vacuum environment during ion irradiation is also reported in ref [3]. Therefore, in higher dose levels, oxygen pick-up from irradiation environment is essential, and thus further studies are needed on Ti(CON) formation (oxidation kinetic) during irradiation.

The formation of Ti(CON) precipitates is detected in the joint of V-4Cr-4Ti-0.15Y alloy. In the case of NIFS-HEAT2, it is known that the irradiation hardening of weld metal was effectively reduced by PWHT at 1073K. The PWHT on NIFS-HEAT2 is very effective for relatively lower temperature irradiation (below 573K). Because a highly segregated distribution of Ti(CON) precipitates were formed during the PWHT at 1073K. Namely, after the annealing, microstructure of the weld metal was divided into two regimes, precipitates-segregation (PS) and precipitates-free (PF) areas. The formation of PS and PF areas is very important to reduce the formation of Ti(CON) precipitate during irradiation, because oxygen impurities are segregated in PS areas, and the PF areas were purified by PWHT. Fig. 1 shows the microstructure, of V-4Cr-4Ti-0.15Y joint after the annealing at the temperature range of 873-1073K for 1 hr. In the figure, Vicker's hardness of each samples were inserted in the figure. As shown in the figure, after the annealing at 1073K for 1hr, PS and PF areas were formed and hardness of the weld metal was reduced to about 250. It was also shown that PWHT at 1073K is contribute to reduce the hardness after the irradiation at all dose levels up to 12 dpa. Neutron irradiation studies using JOYO is in progress to confirm the effective of PWHT on Y doped V-4Cr-4Ti joints.

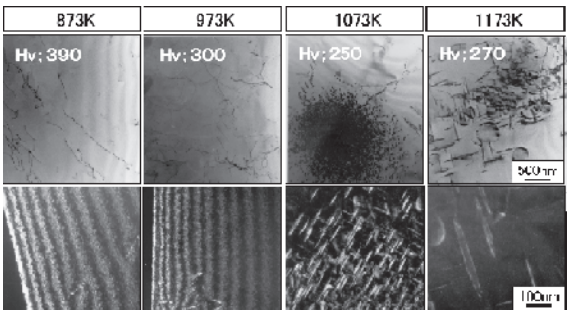

Fig.1
Annealing temperature dependence of V-4Cr-4Ti-0.15Y (weld metal, annealing time;1hr). Upper and lower photos show the images taken by lower and higher magnification, respectively.

[1] T. Muroga, T. Nagasaka, K. Abe, V. M. Chernov, H. Matsui D. L. Smith, Z. -Y. Xu and S. J. Zinklel, J. Nucl. Mater. 307-311(2002)547.
[2] H. Watanabe, K. Yamasaki, A. Higashijima, N. Yoshida. T. Nagasaka and T. Muroga, J. Nucl. Mater. 367-370 (2007)749.
[3] M. Hatakeyama, H. Watanabe, T. Muroga and N. Yoshida, J. Nucl. Mater. 329−333 (2004)420.