§1. Ion Irradiation Experiments on YAG Laser Welded V-4Cr-4Ti Alloy (NIFS HEAT-2)

Watanabe, H., Yamasaki, K., Yoshida, N. (RIAM Kyushu U)
Nagasaka, T., Muroga, T.

1. Introduction

Recently, laser welding technology for V-4Cr-4Ti alloy was developed by NIFS (National Institute for Fusion Science) by controlling the flow rate of high purity argon gas[1]. Because of flexible, in-field, automated and remote operation, and small weldment and heat affected zone (HAS), laser welding is an attractive welding technology. However, quite little is knows as to the irradiation effect on the weldment. The present paper summarized the microstructural evolution of laser welded V-4Cr-4Ti alloy during ion irradiation.

2. Experimental Procedure

Welded joints used in this study were prepared from high purity V-4Cr-4Ti alloy, which was designated as NIFS HEAT2[2]. 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. Oxygen concentrations of the sample before welding, and weld metal are 139 and 158 wt ppm, respectively. 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 573 and 873K up to the dose of 12 dpa. The damage rate and the implanted copper concentration in this region were 1.7×10^{-4} dpa/s and 10^{-2} at. % (at 1 dpa), respectively.

3. Results

Microstructural evolution of samples at several distances from the bead center, which were irradiated at 573K, is shown in Fig.1. Upper and lower bright field images show the microstructure of lower dose (0.75 dpa) and higher dose (7.5 dpa) irradiation, respectively. In Fig.1, dark field images of the microstructure are also inserted. Measured number density of defect clusters (mainly dislocation loops) for each sample is also inserted in the images. As shown in the figure, cluster density of the weld metal (bead center) is slightly higher than that of the base metal and the number density increased with dose from 0.75 dpa to 7.5 dpa. Additional electron irradiation at room temperature using a high voltage electron microscope (HVEM) revealed that about 10 % of dislocation loops formed at 573K(0.75dpa) were vacancy type clusters. Besides dislocation loops, very small precipitates of about 1-2 nm were also observed by high resolution transmission electron microscopy (HRTEM). In Fig.2, the HRTEM image of the sample irradiated at 573K(7.5 dpa) and an image of that annealed at 873K for 100hr are shown. From previous results, long platelet precipitates formed by annealing at above 873K are titanium enriched precipitates (namely, Ti(CON)) on {100} habit planes and have an orientation relationship of [001]bcc//[110]fcc. The precipitates formed at 573K irradiation, as shown by arrows in the upper images of Fig.3, have same orientation relationship of [001]bcc//[110]fcc. Therefore, it is concluded that small Ti(CON) precipitates of about 1-2 nm were also formed besides dislocation loops.

At 873K, fine titanium oxides with {100} habit planes were observed even at the dose of 0.75 dpa. The number density of these Ti(CON) precipitates formed in weld metal is about one order higher than that of base metal. The number density of Ti(CON) decreased with increasing dose and well grown Ti(CON) precipitates were observed at higher dose levels above 7 dpa. Almost same size and density of Ti(CON) precipitates were observed at 12 dpa. The estimated oxygen levels from the microstructure increased with dose and about 20 times higher than that of before irradiation at 12 dpa. The same oxygen pick-up from vacuum environment during ion irradiation is also reported. Therefore, in higher dose levels, effects of oxygen from irradiation environment are essential, and thus further studies are needed on oxygen pick-up and oxidation kinetic during irradiation

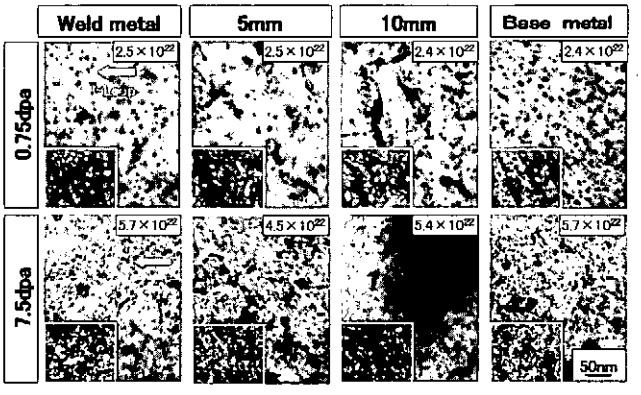

Fig.1 Dislocation loop formation at 573K

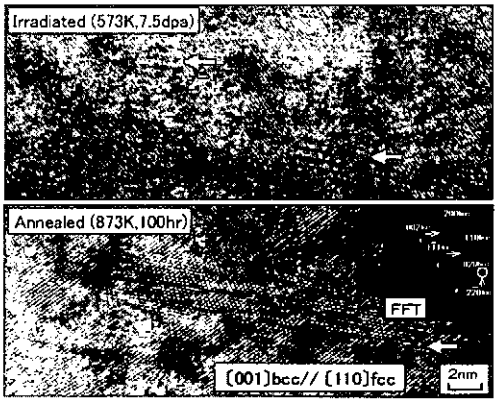

Fig. 2 HRTEM images of samples (weld metal)

References

1) Nam-Jin Heo, T. Nagasaka, T. Muroga, A. Nishimura, K. Sinozaki and H. Watanabe, Fusion Science and Technology, 44(2003)470.
2) T. Muroga, T. Nagasaka, A. Iyoshi, A. Kawabata, S. Sakurai and M. Sakata, J. Nucl. Mater. 283-287(2000)711.