§14. Environmental Effects on Radiation Effects in V-4Cr-4Ti Alloys

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1. Introduction

In the V-4Cr-4Ti alloy, it is well established that interstitial impurities such as oxygen and nitrogen play an important role in radiation effects such as microstructure change, irradiation hardening and embitterment. Among them, oxygen is regarded as the most effective atom in the alloy. Furthermore, the alloy is considered to be used as a fusion blanket structural material that face to a vacuum and helium gas, which may contain a low partial pressure of oxygen. Recently, our ion irradiation experiments on V-4Cr-4Ti alloys at 473-973K revealed that oxygen pick-up from irradiation environment (namely, vacuum) is very minor up to the levels of 1 dpa [1,2]. But at higher dose levels, the effects might cause degradation of mechanical properties due to enhanced formation of titanium oxide precipitates during irradiation. To understand the radiation induced phenomena related with oxygen, such as oxide formation in the matrix, not only oxygen level in the alloy but also oxygen pick-up from radiation environment must be considered. The objective of the present study is, therefore, to understand the detailed mechanisms of oxygen pick-up from irradiation environment which related with titanium oxide.

2. Experimental Procedure

For ion irradiation, welded joint samples by YAG laser were used in this study. These samples were prepared from a high purity V-4Cr-4Ti alloy, which was designated as NIFS HEAT2. Before the 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. The samples were irradiated with 2.4MeV copper ion irradiation with a tandem accelerator at Kyushu University. The TEM specimens were sliced from welded materials and irradiated at 573 and 873K up to the dose of 12 dpa. After 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.

3. Results

Microstructural evolution of laser welded samples at several distances from the bead center, which were irradiated at 873K, is shown in Fig.1. At 873K, fine titanium oxides were observed even at the dose of 0.75 dpa. These precipitates were identified to be Ti(C,O,N) with {100} habit planes. Dose dependence of the measured number density and size of Ti(C,O,N) in several specimens sliced from different positions are shown in Fig.2. The number density of these Ti(C,O,N) precipitates formed in weld metal is about one order higher than that of base metal. The number density of Ti(C,O,N) decreased with increasing dose (region ① in Fig.2) and well grown Ti(C,O,N) precipitates were observed at higher dose levels above 7 dpa (region ② in Fig.2). On the other hand, almost same size and density of Ti(C,O,N) precipitates were observed at 12 dpa. Estimated oxygen levels from the measured density and size of Ti(C,O,N) precipitates were also shown in Fig. 1 . In this estimation, Ti(C,O,N) precipitates are assumed to be TiO (NaCl type crystal structure). 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 using different levels of nitrogen and oxygen samples is also reported in ref [3]. Therefore, in higher dose levels, effects of oxygen from irradiation environment are essential, and thus further studies are needed to avoid oxygen pick-up during ion irradiation.

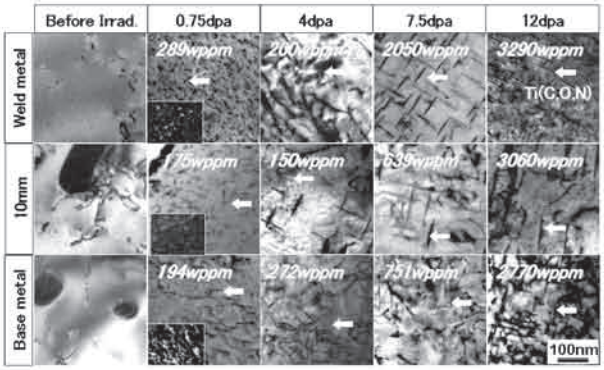

Fig.1 Dislocation loop formation at 873K

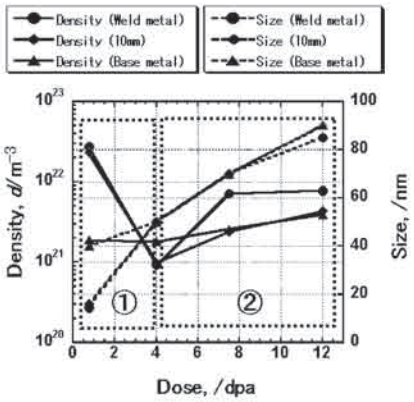

Fig. 2 Dose dependence of measured density and size of Ti(C,O,N) precipitates at 873K.

References

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