Observation of radiation induced defect in austenitic stainless steel after ion irradiation

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1. Introduction

Structural materials in in-vessel will experience time-dependent material degradation in the radiation environments. To understand the degradation of structural material (austenitic stainless steel) used for internals in light water nuclear reactor (LWR), we have to characterize exactly radiation induced microstructural changes because they have been known to be sources for acceleration of the material degradation. Recent researches on radiation induced microstructural changes using advanced analytical systems show the formation of nanometer-sized Ni-Si clusters as well as Frank loop in austenitic stainless steel exposed in LWR environment [1-3].

In this present work, we investigated characterization of radiation induced defects in austenitic stainless steel after ion irradiation to have a better knowledge of radiation induced microstrucutral changes in the structural material.

2. Experimental

2.1 Preparation of Material

The experimental material in this study was typical austenitic stainless steel (316L) having the chemical composition shown in Table 1. The specimens were prepared by mechanical-polishing with diamond suspensions for ion irradiation experiments. To reduce surface damage introduced by the mechanical polishing, we carried out fine polishing with a vibratory polisher using a very fine colloidal silica suspension (0.02 ㎛).

Table 1 Chemical composition (wt%) of material used in the present study

Ni	Cr	Mo	Mn	Si	P	C	S
10.8	16.7	2.0	1.3	0.6	0.05	0.047	0.001

2.2 Ion irradiation

Heavy ion irradiation was performed with a Tandemn ion accelerator. Iron ions used for the ion irradiation has energy of 8MeV. Dose is approximately 5.6E13 ion/cm^2. Irradiation temperature was set as 473 K, 573 K and 673 K. Fig. 1 shows radiation damage profile calculated by a computer program named as the “Stopping Range of Ions and Matter (SRIM)” [4]. The radiation induced damage was expected to be formed below 2 ㎛. At a depth of 1 ㎛, the radiation damage was calculated as 4 dpa.

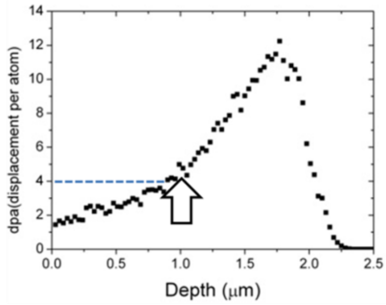

Fig. 1. SRIM calculation for ion irradiation

2.3 TEM analysis method

We prepared TEM sample for the analysis of radiation induced defect in ion-irradiated austenitic stainless steel. An ion milling system with a focused ion beam (FIB) was used for the fabrication of TEM sample. After the FIB milling, we carried out low energy Ar ion milling to reduce surface damage generated by high energy Ga ions milling. A JEOL 2100F located at Korea Atomic Energy Research Institute (KAREI) was used to perform characterization of radiation induced defect for all TEM samples.

3. Result

Figure 2 shows the TEM images of austenitic stainless steels (SS316) irradiated at 473 K, 573 K and 673 K, which were taken at a depth of 1 ㎛. It was found that significant radiation induced damages were clearly visible in the TEM images. Black dots and Frank loops were observed in all ion-irradiated TEM samples.

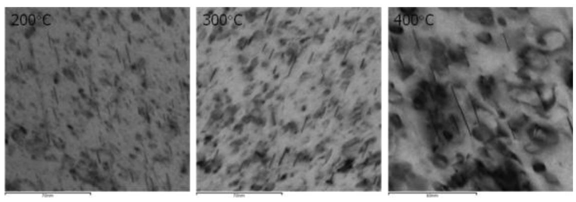

Fig.2 TEM images of Frank loops observed in ion irradiated austenitic stainless steel irradiated at 473 K , 573 K and 673 K.

We measured a number density and an average size of Frank loop which is visible as sharp line contrast in these TEM images. Its number density and size are presented in Figure 3. As irradiation temperature increases, the size of the Frank loop is increased and its number density is decreased. We compared the experimental data of the ion-irradiated stainless steel with data on neutron irradiated austenitic stainless steel published by several researchers [5-9]. As shown in Figure 4, evolution behavior of Frank loops in austenitic stainless steel irradiated at 473 K and 573 K is similar with that of neutron irradiated steel.

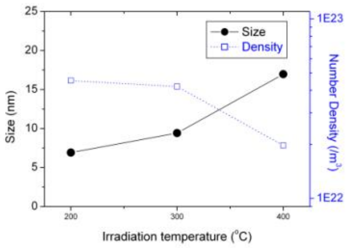

Fig. 3 The average size and density of Frank loops in ion irradiated austenitic stainless steel.

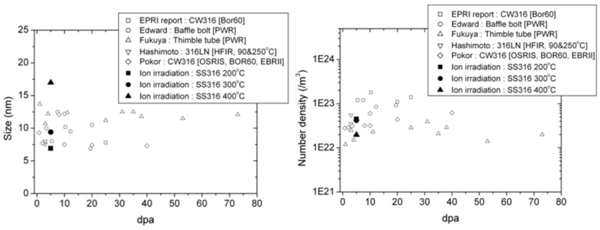

Fig. 4 The average size and density of Frank loops in ion irradiated austenitic stainless steel irradiated by Fe ions and neutrons.

4. Conclusions

A TEM observation was performed to investigate radiation induced microstructural changes in ion-irradiated austenitic stainless steel. Under Fe ion irradiation, Frank loops were formed in the ion-irradiated stainless steel irradiated at all irradiation temperatures. The characteristic of Frank loops in ion-irradiated stainless steel at 473 and 573 K is similar with that of neutron-irradiated stainless steel.

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