Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Analysis of RIS at grain boundary in austenitic stainless steel irradiated at different temperature

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1. Introduction

As a part of a research regarding material degradation under reactor operation, we are investigating radiation induced segregation phenomena in austenitic stainless steels used for internals in nuclear reactors. To have a better knowledge of the RIS phenomenon, we have been prepared simulated material using ion accelerator. Basically, ion irradiation has higher does rate compared with neutron irradiation. Was and Allen indicated that decreasing the dose rate will shift the temperature dependence of RIS to lower temperatures [1]. Therefore, we measured RIS at grain boundary with simulated material irradiated by Fe ions at various temperatures. Also we compared the RIS data with experimental data of neutron irradiated material.

2. Experimental

2.1 Preparation of Material

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

	Ni	Cr	Mo	Mn	Si	P	C	S
SA316_2	10.8	16.7	2.0	1.3	0.6	0.05	0.047	0.001

The material used in this study was an austenitic stainless steel (316L) having the chemical composition given in Table 1. The specimens were mechanical-polished for ion irradiation experiment. Final polishing was carried out with a vibratory polisher using very fine colloidal silica suspension for the reduction of surface damage formed during the rough polishing.

2.2 Ion irradiation

Irradiations were performed using 8MeV Fe^{4+} up to a peak does of about 10dpa. Irradiation temperature was 400℃. Matrix damage for depth from surface was calculated with SRIM [2] assuming 40 eV of average displacement threshold energy. According to SRIM calculation, peak damage was expected to be formed at 1.7 ㎛ due to the Fe ion irradiation. At a depth of 0.5, 1 and 1.5 ㎛, radiation damage was calculated as 2, 4 and 8 dpa respectively.

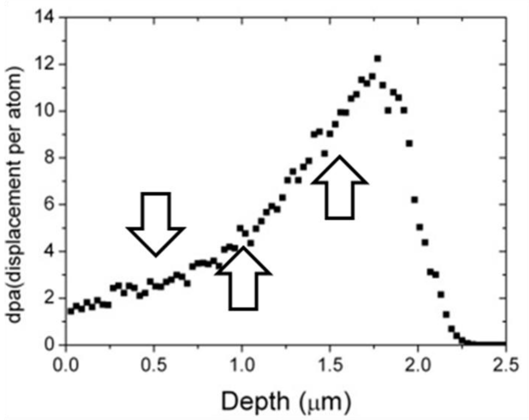

Fig. 1. SRIM calculation for ion irradiation

2.3 TEM-EDS measurement

For chemical analysis at grain boundary, we titled the TEM sample in order to set the GB plane parallel to beam direction. When GB plane is parallel to beam direction, interface fringes was disappeared and sharp contrast must be visible in vicinity of GB. INCA system by Oxford Inc. was used for identification of the chemical compositions at GB using EDS. In quantitative analysis, Cr, Ni, Mo, Si, P and Fe were only considered.

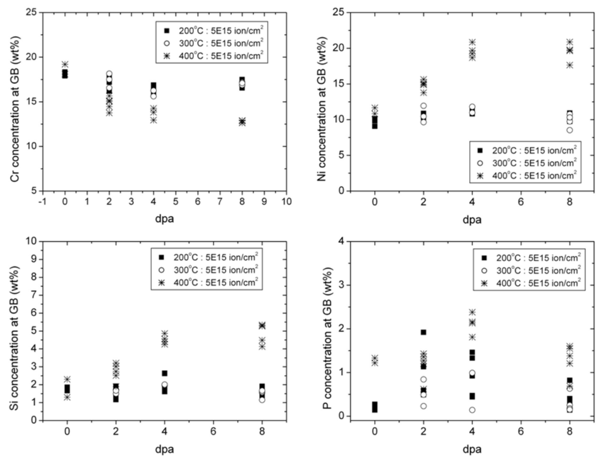

Fig. 2 Cr, Ni, Si and P concentration at grain boundary in austenitic stainless steels irradiated at 200, 300, 400℃.

3. Result

Figure 2 shows EDS results measured at grain boundaries in SS316 steels irradiated at 200,300 and 400℃. In the cases of irradiated SS316 steel at 200℃ and 300℃, there are weak radiation induced segregation and depletion. On the other hands, the Cr element at GB in ion irradiated SS316 steel at 400℃ was depleted significantly. Also the Ni, P and Si elements at GB was enriched considerably. We compare experimental data of the ion-irradiated stainless steel at 400℃ with that of neutron irradiated austenitic stainless steels published by several researchers[4-8]. As shown in Figure 3, RIS of Cr and Ni in the ion-irradiated stainless steel irradiated at 400℃ is similar with that of neutron irradiated steels. On the other hands, it is found that the RIS of P and Si in the ion-irradiated stainless steel irradiated at 400℃ is activated at lower does compared with that in neutron irradiated stainless steels.

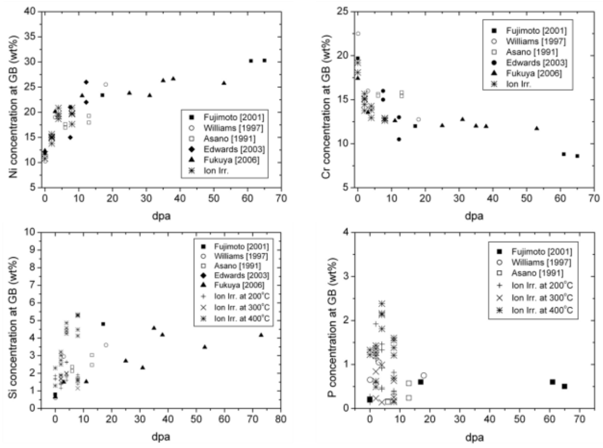

Fig. 2. Cr, Ni, Si and P concentration at grain boundary in austenitic stainless steels irradiated by Fe ions and neutrons.

4. Conclusions

TEM observation was performed to investigate radiation induced segregation and depletion at grain boundary in austenitic stainless steel. Under an Fe ion irradiation, RIS was only detected in the ion-irradiated stainless steel irradiated at 400℃. The tendency of RIS of Cr and Ni in the ion-irradiated stainless steel irradiated at 400℃ is very similar with that of neutron-irradiated stainless steel.

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