Interaction of defects with hydrogen and helium in SUS316L

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Deuterium and Helium retention in ion irradiated SUS316L was investigated by thermal desorption spectroscopy. Deuterium retention was not significantly affected by Fe pre-irradiation and deuterium atoms were trapped in the oxide film rather than trapped inside the sample. Helium atoms were trapped in interstitial type dislocation loops, single vacancies, and vacancy clusters, and the amount retained in single vacancies and vacancy clusters was increased by Fe pre-irradiation.

1. Introduction

To solve the problem of long-lived radioactive waste in nuclear reactors, spallation neutron sources using large accelerators are being studied. In a spallation neutron source, a proton beam hits the long-lived radioactive waste through a window made by stainless steel to destroy long-lived nuclides generates and shorten their lifetime. In the spallation reaction, a large amount of neutrons are generated. These high-energy neutrons further undergo a nuclear reaction with surrounding materials to generate hydrogen and helium. Since the vicinity of the window of the target container is exposed to a strong radiation field due to protons and neutrons as well as high temperature conditions, the life of the target container is determined by the irradiation data [1]. However, in the vicinity of the window of the target container, not only the damage caused by the irradiation of protons and neutrons but also the hydrogen and helium caused by the reaction are trapped in the damaged portion of the irradiation, resulting in embrittlement [2]. The research data of interaction between hydrogen, helium, and the irradiation defects in SUS316L are still inadequate. Therefore, in this study, the irradiation-induced defects of SUS316L and the retention of deuterium and helium were evaluated by thermal desorption spectroscopy (TDS).

2. Experimental procedure

In this study, commercially available SUS316L was used as a sample and rolled to 0.1mm. SUS316L samples were polished and irradiated with 1.0 MeV Fe ions up to the damage peaks of 0.07, 0.3, and 0.7 dpa using an ion accelerator at the Quantum Science and Engineering Center, Kyoto University. Both Fe-irradiated and Fe-unirradiated samples were injected deuterium up to 1.0×10^{20} and 1.0×10^{21} D^+/m^2 and helium up to 1.0×10^{19} and 1.0×10^{20} He/m^2 using an Omegatron gun with 5 keV. TDS was performed by heating the samples at 1 K/s to 1473 K using infrared irradiation. By using a quadrupole mass analyzer, the deuterium and helium release was monitored. The pressure within the TDS chamber was kept to below 1.0×10^{-5} Pa by vacuum pump before heating the samples.

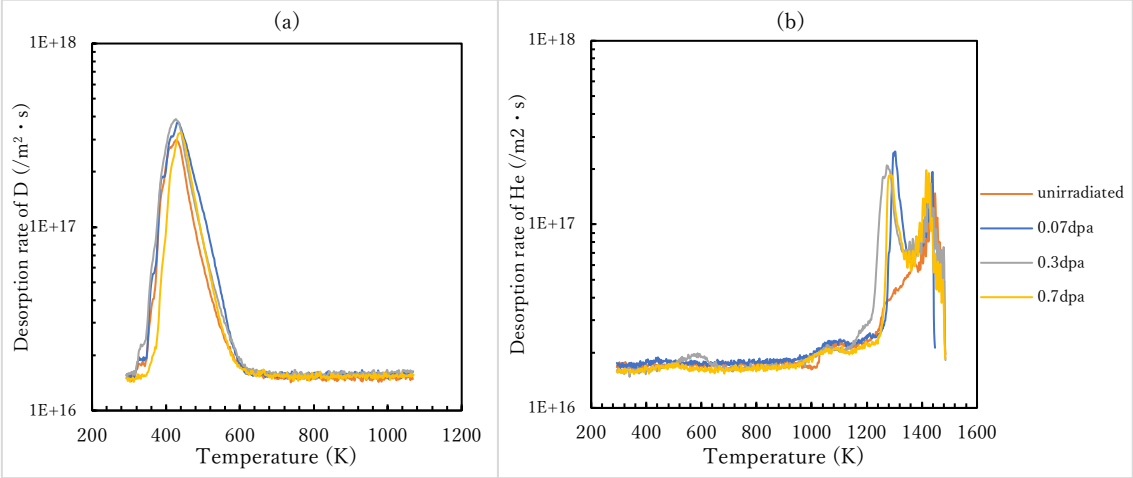

Fig.1 TDS spectra of deuterium (1.0×10^{21} D^+/m^2) (a) and helium (1.0×10^{20} He/m^2) (b).

3. Results and discussion

Figure 1 shows the TDS spectra of deuterium (1.0×10^{21} D^+/m^2) (a) and helium (1.0×10^{20} He/m^2) (b). In the deuterium irradiation, only one peak was observed around 500 K regardless of the presence or absence of Fe pre-irradiation. Considering that the binding energy of single vacancies and hydrogen in SUS316L is about 0.6 eV [3], it is considered that the peak around 500 K is not a trap in a defect but in the oxide film. In other words, for SUS316L, deuterium is not trapped inside the sample, therefore, the effect of Fe pre-irradiation is small. With helium irradiation, three peaks were observed around 1100 K, 1250 K, and 1400 K. It is considered that the peak at 1100 K corresponds to the interstitial type dislocation loop, the peak near 1250 K corresponds to a single vacancy, and the peak at 1400K corresponds to a vacancy cluster. Comparing the peak heights around 1250 K and around 1400K, vacancies are introduced by Fe pre-irradiation and helium is trapped in the vacancies.

4. Conclusion

Deuterium and helium retention in SUS316L were investigated by TDS. The results showed that defects were formed by He and Fe ion irradiation. Deuterium was not significantly affected by Fe pre-irradiation and was trapped in the oxide film rather than trapped inside the sample. Helium was trapped in interstitial type dislocation loops, single vacancies, and vacancy clusters, and retention in single vacancies and vacancy clusters was increased by Fe pre-irradiation.

References

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