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Tritium Retention in Stainless Steel Pre-irradiated with Helium
ヘリウム照射されたステンレス鋼におけるトリチウム保持

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Effects of helium pre-irradiation for tritium retention in stainless steel have been studied by applying β-ray-induced X-ray spectrometry. The amount of tritium retained in surface layers was dependent on energy of tritium ions, and it increased proportionally with the fluence of helium pre-irradiation under the same irradiation dose of tritium ions. However, different retention behavior was observed when the fluence of tritium ions was changed under the same fluence of helium pre-irradiation.

1. Introduction

It is of a great importance to reduce the amount of tritium retained in fusion reactor materials from viewpoint of precise controlling of fuel particles. This is true for safe waste management of the tritium-contaminated materials. It is known that tritium retention depends on flux and fluence of tritium ions impinged into a material and more increase in tritium retention is caused by the increase in radiation damage in the material. In particular, helium irradiation effects are important for plasma-facing materials. From this viewpoint, effects of helium pre-irradiation on tritium retention have been studied in detail by using stainless steel as a model material

2. Experimental

2.1 *Materials*

Helium and tritium gases were used for ion irradiation. Purity of the former gas was above 99.99%, and tritium concentration of the latter one was 0.47%, which was diluted with deuterium gas.

Small plates of stainless steel type 316 (SS316) were used for ion irradiation tests as a model sample, which were mechanically polished with a buff and then rinsed with acetone before set on a sample stage. Size of the sample was 10x10x0.5 mm.

2.2 *Irradiation device*

Irradiation of helium and tritium ions was carried out using a specially designed tritium handling system, which consists of an ion gun, source of helium and tritium gases, vacuum gauges and vacuum pumps such as ion pump and turbo molecular pump. The present ion gun is applicable to irradiation of helium and tritium in the range of ion energy from 0.5 to 3.0 keV. Size of irradiation spot was 5 mmϕ in diameter. Two samples can be set simultaneously on the sample stage, which is made of ceramic. The heater and thermocouple was also inserted into the sample stage.

2.3 *Procedures*

After two samples of SS316 were fixed on the sample stage, it was set in the irradiation chamber. Vacuum pumping was started at room temperature. Temperature of samples was elevated stepwise up to 673 K in vacuum. Final vacuum pressure was below $1x10^{-5}$ Pa.

After heating treatment of samples in vacuum, they were supplied to irradiation of helium and/or tritium ions. Three kinds of irradiation experiments were carried out at room temperature: namely, (1) irradiation of tritium ions only, (2) irradiation of tritium ions for 30 min after helium pre-irradiation for a given time from 10 to 60 min with energy of 1.0 keV, and (3) irradiation of tritium ions for 15 to 75 min after pre-irradiation of helium for 30 min with energy of 1.0 keV. After tritium irradiation, samples were kept in vacuum for one night to avoid the contamination by tritium release from the chamber wall when they were taken out.

2.4 *Evaluation of tritium retention*

The amount of tritium retained in surface layers of SS316 after irradiation was evaluated by the β-ray-induced X-ray spectrometry (BIXS) and the imaging plate (IP) technique. The former is effective for a quantitative measurement of tritium trapped in surface layers, while the latter is useful for two dimensional distribution of tritium. Details of the former technique are described elsewhere[1, 2].

3. Results and discussion

3.1 *Irradiation of tritium ions only*

Figure 1 shows an example of X-ray spectra observed by BIXS for tritium irradiated samples. Characteristic X-ray peak of Ar(Kα) was observed, which was induced by β-rays emitted from tritium atoms trapped in surface layers. Argon was used as a working gas of BIXS. It is known that the intensity of Ar(Kα) peak is proportional to the amount of tritium retained in surface layers[2].

The irradiated molecular tritium ions dissociate on the surface. These tritium and deuterium atoms partly diffuse into the bulk and a part was reemitted from the surface by recombination of these atoms. If most of the tritium atoms do not trapped in surface layers, they easily diffuse into the bulk. As the escape depth of β-rays is considerably shorter than 1 μm in SS316, one can observe a broad X-ray peak (bremsstrahlung peak), when tritium atoms diffuse into a deeper region than the escape depth of β-rays. However, we can't find bremsstrahlung X-ray peak in the observed spectra. This indicates that the irradiated tritium ions are mostly retained in surface layers.

Figure 2 shows dependence of ion energy on tritium retention. It is seen from the figure that the retained amount of tritium changed in U-shape. This indicates that surface reaction of the low energy ions is different from that of the high energy ions. Namely, it is considered that the low energy ions reacts with surface oxygen and carbon atoms, but the high energy ions is basically trapped by radiation damages.

Figure 3 shows dependence of the fluence of pre-irradiated helium ions on tritium retention. As clearly seen from the figure, the amount of tritium retained in surface layers was proportional to the fluence of helium ions. It is suggested that increase in the radiation damages due to helium pre-irradiation causes the increase in tritium retention.

Figure 4 shows dependence of the fluence of tritium ions on tritium retention after helium pre-irradiation. The retained amount of tritium initially decreased with the increase in the fluence of tritium ions, but contrary it increase with the fluence of tritium ions. This indicates that different effects for tritium retention were caused by helium pre-irradiation.

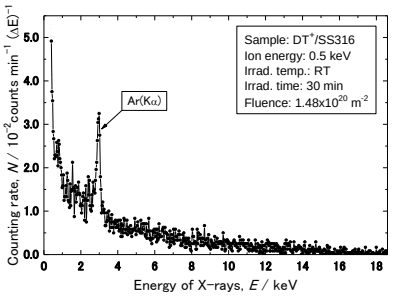

Fig. 1. An example of X-ray spectra observed by BIXS.

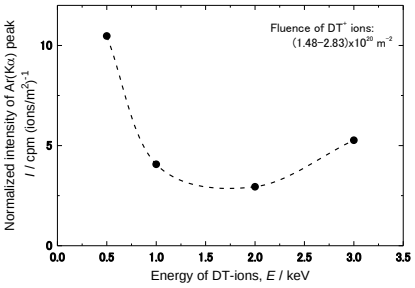

Fig. 2. Energy dependence of the amount of tritium retained in surface layers of SS316 samples.

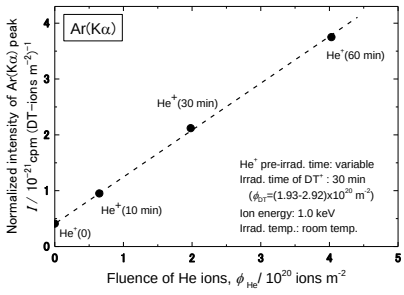

Fig. 3. Dependence of the helium ion fluence on tritium retention. Energy of DT^+ was kept constant as 1.0 keV.

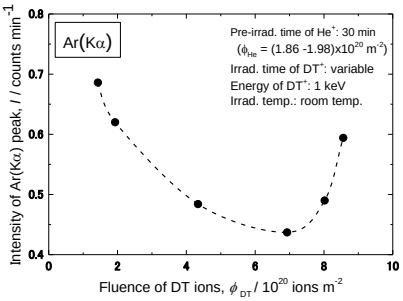

Fig. 4. Tritium retention vs fluence of DT^+ ions. The broken line is an eye guide.

Acknowledgments

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References

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