Research on oxidation resistance of tritium barrier tubes in a fusion reactor heat exchanger
核融合炉熱交換器におけるトリチウム回収管の耐酸化性に関する研究

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In a fusion reactor, tritium is used as fusion fuel. Control of tritium diffusion and leakage due to diffusion is therefore necessary to prevent contamination of the coolant in the second loop and leakage to environment. We proposed a tritium barrier with double tubes for the heat exchanger. The double tube has small tubes with oxidizer and carrier gas for the tritium recovery. In this experiment, we focused on oxidation of tritium barrier tubes and investigated the growth of the oxidation on the inner surfaces of the tubes.

1. Introduction

In laser fusion reactor, tritium, a radioactive material, is used as fusion fuel. So there is a risk that tritium melt in the thermal cycle is saturated and passes through the furnace. To solve this problem, some coating methods have been researched. [1] We proposed a tritium barrier with double tubes for the heat exchanger. The double tube has small tubes filled with oxidizer and a carrier gas for the tritium recovery. By setting these tubes in a heat exchanger, tritium permeation flux is supposed to reduce to 10^{-4}-fond by ANSYS analysis. In addition, this method can be used in combination with other permeation methods such as ZrO or Er_2O_3 coating. The concept of the double tubes, however, has some matters such as oxidation of the inner surface of the small tube. It is assumed that oxidation of the inner surface somehow influences hydrogen permeation. In this experiment, we simulated a tritium barrier tube in a heat exchanger by using light hydrogen instead of tritium and focused on oxidation resistance of the tube. (SS 316 stainless tube)

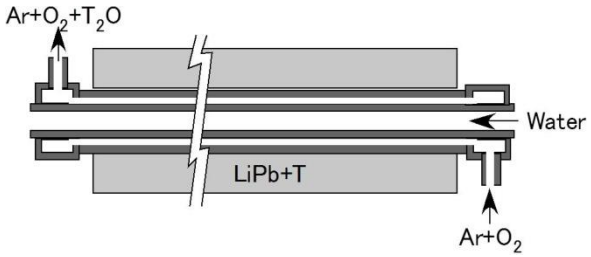

Fig.1 Tritium barrier tube

2. Experimental apparatus

We made the experimental apparatus as shown in Fig.2. Hydrogen is filled in the outer chamber and, an oxygen/argon mixed gas flows through the inner tube.

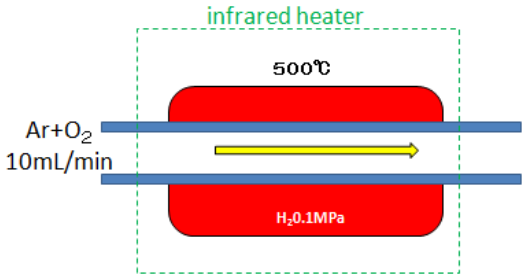

Fig.2 Experimental apparatus

The rate of Oxygen in the mixed gas is 20%, which is the same as that in the air. Then we observed the inner surface of the sample with a digital microscope and SEM and measured mass percentage of oxygen by fluorescent X-ray analysis. For comparison, the experiment without hydrogen (vacuum) was performed as well.

We experienced at various heating duration time; 1 hour, 3 hours, 5 hours and 10 hours.

The amount of hydrogen is passing through stainless steel is given by the following equation.

$$J = 4 \times 10^{-3}(\sqrt{P_{out}} - \sqrt{P_{in}}) \quad (1)$$

J: hydrogen permeation (ml)

P: hydrogen pressure of the outer chamber and the inner tube (atm)

In this experiment, the amount of hydrogen is assumed 62 ml (standard pressure) per hour.

3. Digital microscope and SEM images

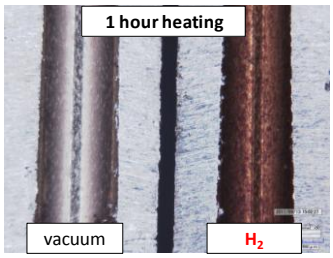

Fig.3 digital microscope images

With digital microscope, we could find difference of degree of oxidation process between hydrogen-filled and vacuumed at even 1 hour of duration time. The inner surface of the tube with hydrogen atmosphere was darker and it seemed more oxidized, both of them, however, ware enable to measure oxygen by fluorescent X-ray analysis because of extremely small amount.

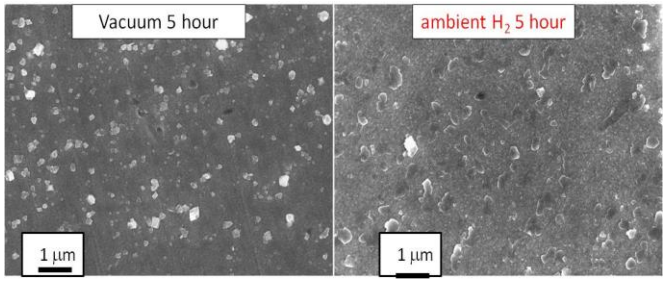

Fig.4 SEM images at 5 hours duration

By SEM observation, clear difference of the surface figure appeared after 5 hour-heating. This result shows that hydrogen permeation strongly influences oxidation of the surface. The oxidation particles in hydrogen atmosphere looked bigger and more coarse-grained, but they disappeared at 10-hour-heating and the surface was similar to vacuumed one.

4. Rate of oxygen in hydrogen atmosphere

The amount of oxygen on the inner surface was measured with fluorescent X-ray analysis, but only long-heating-time samples were measurable; 5-hour-duration in hydrogen atmosphere and both of 10 hours. The other unmeasurable samples, the concentration of oxygen on them were supposed to be less than 2 %. The longer heating time, the higher rate of oxygen was measured. It was assumed that the 5-hour-duration sample of hydrogen atmosphere had more oxygen than vacuumed one because it was measurable. It was not clear whether it is come from the difference of degree of oxygen or reduction by hydrogen.

But, from the amount of oxygen in Figure.5, 10-hour-heating sample of vacuum was more oxidized. At this duration time, the inner surface of both was similar while there was clear difference at 5-hour-duration.

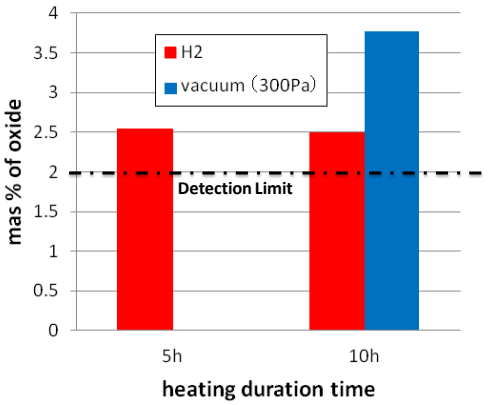

Fig.5 amount of oxygen

It is also clear from Figure.5 that oxidation was suppressed in hydrogen atmosphere compared 5 hours with 10 hours.

5. Conclusion

We experimentaly simulated a tritium barrier tube in a heat exchanger and investigated the growth of the oxidation on the inner surfaces of the tube. From Fig.5, it was cleared that the inner surface of the long-time-heating sample in hydrogen atmosphere was less oxidized than that heated in vacuum while the opposite result came out in short-heating experiment. In long heating time, oxidation seemed to be suppressed because of reduction by hydrogen. In short heating time, however, it is not cleared why the samples in hydrogen atmosphere had more oxide than vacuum ones.

It is necessary to measure the amount of permeation hydrogen at each heating time and the surface composition change of the tube.

References

[1] HATANO Yuji, TORIKAI Yuji, OYA Yasuhisa, ODA Takuji, TANAKA Satoru et al. : *Tritium Permeation, Contamination and Decontamination* J. Plasma Fusion Research Vol.85, No.10 (2009) 726-235

[2] T. Norimatsu et al., Presented at Tritium 2010, Oct.24-29, 2010, Nara, Japan