

An Investigation on Thermal Desorption Behavior of Deuterium in Beryllium for ITER Tritium Removal System

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1. Introduction

Intermediate level and long lived radioactive waste (type B radwaste), will be generated from the vacuum vessel of ITER Tokamak building when its structural components are replaced for maintenance. Because nuclear fusion reactor uses deuterium-tritium fuel, plasma facing materials include some tritium on its inside. ITER is considering tritium removal system (TRS), which eliminates tritium in type B radwaste by heating. Although tritium removal efficiency is expected to be enhanced with increasing heating temperature, the facility capacity and economic aspect should be considered together. In the present study, the thermal desorption behavior of hydrogen isotope in Beryllium (Be) was investigated to determine the condition of TRS.

2. Methods and Results

In the present study, deuterium (D) was substituted for tritium due to its ease of handling. Be, which is a candidate material for in-vessel component of ITER, was subjected to pressurized D ambient in high temperature for D-loading. After that, D-loaded Be sample was heated in thermal desorption spectroscopy (TDS) chamber up to 800°C. During continuous heating, D desorption was detected by residual gas analyzer (RGA) of TDS.

2.1 Deuterium Loading

The sample was cylindrical and the dimension was $\Phi 20 \times 5$ mm. D loading was performed in 25 bar D₂ ambient at three temperatures of 120, 240, and 350°C for 24 h. (D-loaded samples were prepared and provided by Hanyang University.)

2.2 TDS

Because TDS is equipment for investigating thermal desorption behavior of material during continuous heating, it was utilized to investigate the behavior of D desorption in terms of temperature. The pressure of TDS chamber was initially about 10^{-8} torr. Maximum heating temperature for investigating D₂ desorption behavior was 800°C and the ramp rate of TDS heater was set to 0.5 °C/s. To calculate D concentration in the sample, D₂ calibrated leak was installed at TDS to

convert partial pressure to mol or wppm. Before the TDS test, the leak was opened to flow regular D₂ and conversion factor was calculated from calibration leak rate and detected partial pressure of D₂ by RGA of TDS. Using the conversion factor, detected RGA data was converted to quantitative data. Then, the area of TDS curve of D₂ desorption was integrated to calculate the D₂ concentration in each samples.

2.3 D₂ desorption behavior

TDS analysis was performed to investigate the desorption behavior of D in D-loaded Be samples. Fig. 1 shows the concentration of desorbed D₂ from Be loaded at 120 °C. D₂ was not observed all over the temperature. Fig. 2 shows the thermal desorption behavior of D₂ in Be loaded at 240 °C. D₂ desorption started near at 400 °C. The maximum temperature was 544 °C, and the intensity of D₂ desorption at this point was 9.9×10^{-8} mol/m². In case of Be loaded at 240°C, there was a second peak at the temperature of 727 °C. Fig. 3 shows the thermal desorption behavior of D₂ in Be loaded at 350 °C. D₂ desorption started near at 600 °C. The maximum temperature was 787 °C, and the intensity of D₂ desorption at this point was 3.7×10^{-8} mol/m².

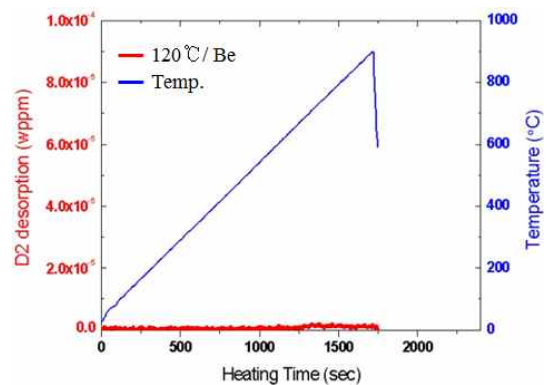


Fig. 1. Desorbed D₂ concentration as a function of heating time (120 °C loaded Be)

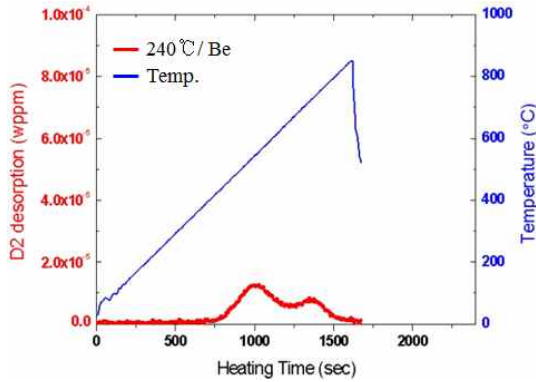


Fig. 2. Desorbed D₂ concentration as a function of heating time (240 °C loaded Be)

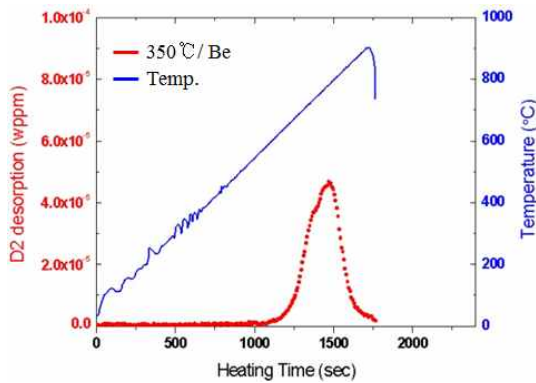


Fig. 3. Desorbed D₂ concentration as a function of heating time (350 °C loaded Be)

The comparison of D₂ desorption as a function of temperature in Be samples loaded at 120, 240 and 350 °C is shown in Fig. 4. The peak temperature and the maximum intensity at this point increased with increasing loading temperature. In case of 120 °C-loaded Be, the D₂ desorption was not observed all over the temperature range. On the other hand, in 240 and 350 °C-loaded Be, D₂ desorption finished at 600 and 856 °C respectively.

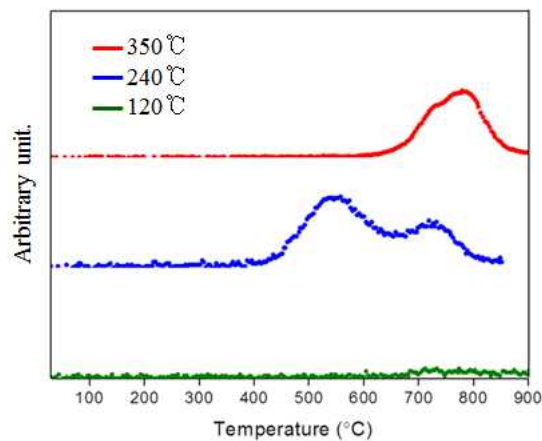


Fig. 4. Comparison of D₂ thermal desorption curves in Be loaded at 120, 240 and 350 °C

Table 1 shows D₂ concentration of Be loaded at 120, 240 and 350 °C measured by KAERI and HYU. The measured data of KAERI for Be loaded at 120, 240 and 350 °C was 0, 6x10⁻³ and 1.2x10⁻² wppm. That of HYU for Be loaded at 120, 240 and 350 °C was 5.8x10⁻⁴, 4.7x10⁻³ and 6.2x10⁻³ wppm. Because both data shows similar value, it was considered that there was reliability in measurement method between KAERI and HYU. Because D₂ amount in Be was very little, it can be considered that the data difference of Be loaded at 350°C between KAERI and HYU is negligible.

Table 1. D₂ concentration of Be measured by KAERI and HYU

Loading Temp. (°C)	Desorption Completion Temp. (°C)	D ₂ amount (wppm) KAERI	D ₂ amount (wppm) HYU
120	N/A	0	5.8x10 ⁻⁴
240	600	6x10 ⁻³	4.7x10 ⁻³
350	856	1.2x10 ⁻²	6.15x10 ⁻³

2.4 Trap activation energy

According to the previous study [1], it has known that peak temperature of desorption decreased with decreasing ramp rate. Using the peak shift, trap activation energy of absorbed element in the material can be calculated. When we remove D in the samples, measuring trap activation energy can be helpful to compare the removal behavior with other materials. In here, three ramp rates of 0.166, 0.332, and 0.5 °C/sec were used. The shift of peak temperature as various ramp rates was measured, and then trap activation energy of D was calculated by peak shift method.

In TDS test results with the ramp rates of 0.166, 0.332, and 0.5 °C/sec, the peak temperatures were 684, 766, and 787 °C, respectively. The graph for trap activation energy of D Be was drawn using the given ramp rates and peak temperatures obtained from each test, as shown in Fig. 5. In here, T_c means peak temperature and Φ represents ramp rate. When draw a linear line for each points, the slope was calculated to -8,089. The slope multiplied by gas constant R=8.314 kJ/mol and the trap activation energy was calculated to 67 kJ/mol. The slope can be changed considerably with little shift of the point. If more exact energy value is needed, TDS test with slower ramp rate will be more proper. However, in the present study, the energy driven from the ramp rates around 0.5 °C/sec was considered to be helpful to compare the removal behavior of D₂ in other ITER candidate materials approximately.

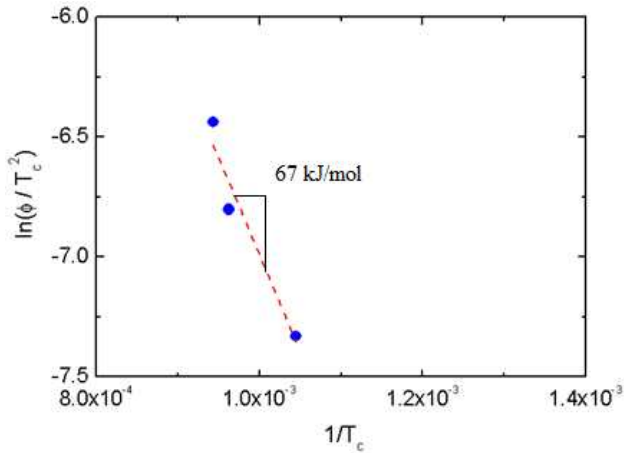


Fig. 5. Trap activation energy of D in Be loaded at 350 °C

3. Conclusions

TDS analysis was performed in Be at 120, 240 and 350 °C. D₂ concentration and the desorption peak temperature increased with increasing loading temperature. Using peak shift method with three ramp rates of 0.166, 0.332, and 0.5 °C/sec, trap activation energy of D in Be loaded at 350 °C was 67 kJ/mol.

REFERENCE

- [1] W. Y. Choo and J. Y. Lee, J. Mater. Sci., 17 (1982)