8. Bilateral Collaboration Research Program

University of Toyama

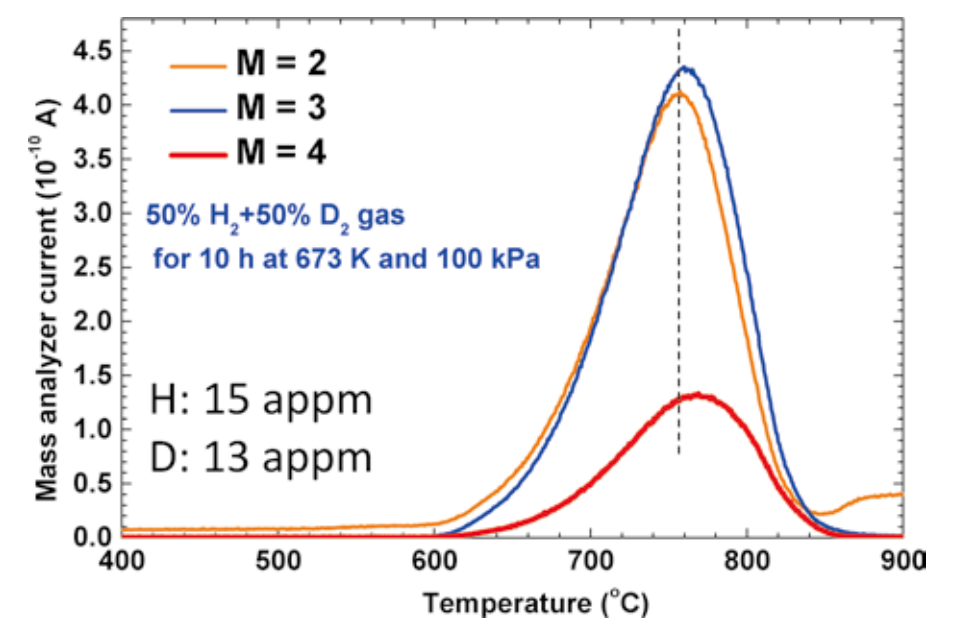

Fig. 1 Thermal desorption spectra of hydrogen isotopes from CuCrZr alloy after exposure to mixture gas of 50 kPa H_2 and 50 kPa D_2 at 673 K.

Highlight

Significant isotope effects were observed in thermal desorption of hydrogen isotopes from CuCrZr alloy recognized as a candidate of heat sink material of future fusion reactors. After exposure to 50% H_2-50%D_2 mixture gas at 673 K for 10 hours, thermal desorption of H_2, HD and D_2 was examined at various temperature ramp rates from 5–30 K min^{-1}. The desorption peak of H_2 appeared first and it was followed by the peak of HD and then that of D_2. Similar isotope effects were observed also for CuCr alloy.

The titles and principal investigators of research projects performed in U. Toyama in 2016 are listed below.

1. Isotope effects on trapping and release of hydrogen isotopes in fusion reactor materials. Y. Hatano, U. Toyama
2. Hydrogen isotope behavior for W with controlled damage profile. Y. Oya, Shizuoka U.
3. Influence of radiogenic He on tritium retention in electron-irradiated. W A. Spitsyn, NRC Kurchatov institute
4. Effect of helium and carbon on tritium permeation and retention behavior for plasma facing tungsten. T. Chikada, Suizuoka U.
5. Effects of plasma exposure on hydrogen isotope retention by plasma-facing materials. K. Tokunaga, Kyushu U.
6. Hydrogen isotope transport through plasma modified fusion reactor materials. H. T. Lee, Osaka, U.
7. Removal of tritium trapped in tungsten by baking in hydrogen atmosphere. Y. Nobuta, Hokkaido U.
8. Tritium removal on the surface of plasma facing materials. N. Ashikawa, NIFS
9. Development of measurement (analysis) method of hydrogen isotopes in dusts. T. Otsuka, Kindai U.
10. Evaluation of tritium doping using ultraviolet irradiation for laser fusion target. K. Yamanoi, Osaka U.
11. Hydrogen isotopes compatibility test of SiC/SiC composite materials. H. Kishimoto, Muroran Inst. Tech.
12. Tritium adsorption properties on helium irradiated tungsten. M. Yajima, NIFS
13. Evaluation of diffusion, retention and desorption of hydrogen isotopes implanted in LHD protection tiles by means of GD-OES. N. Yoshida, Kyushu U.
14. Development of alkaline polymer electrolyte membrane-based water electrolysis system for the volume reduction/concentration of low-concentration tritium-contaminated water. T. Abe, U. Toyama

Many of the projects are related to material-hydrogen interactions. One of the main accomplishments in this year is finding of clear isotope effects in hydrogen isotope desorption from Cu alloys. CuCrZr alloys are candidates for heat sink materials in future fusion reactors including ITER. Detailed understanding of retention and transport of hydrogen isotopes is a key issue for safety and fuel circulation control. Several researchers performed deuterium permeation experiments and reported far larger solubility in CuCrZr alloy than pure Cu. However, the mechanisms underlying such high hydrogen isotope solubility and isotope effects have not been fully clarified. In this study, deuterium retention and desorption were studied for pure Cu, Cu-1.0Cr and Cu-1.0Cr-0.1Zr alloys using thermal desorption spectroscopy (TDS). The disc-type samples of the alloys were exposed to pure H_2 gas and pure D_2 gas at 100 kPa, and the mixture gas of 50 KPa H_2 and 50 KPa D_2 at 673–773K. TDS spectra were obtained using a vacuum device shown in Fig. 2 at temperature ramp rate of 0.5 K/s. The D retention in pure Cu was below the detection limit of the device, while clear desorption peaks were observed for Cu-1.0Cr and Cu-1.0Cr-0.1Zr alloys. The D concentration in Cu-1.0Cr-0.1Zr alloy was above 30 appm and larger than that in Cu-1.0Cr alloy by a factor of 10. These observations suggest that hydrogen isotopes in CuCrZr alloy were trapped in both Cr-rich and Cr,Zr-rich precipitates and trapping effects of Cr,Zr-rich precipitates were far larger than those of Cr-rich precipitates. Clear isotope effects were observed in the TDS spectra from Cu-1.0Cr and Cu-1.0Cr-0.1Zr alloys. The desorption peak of H_2 appeared at the lowest temperature, and it was followed by the peak of HD and then that of D_2.

Clear acceleration of tritium removal from tungsten by isotope exchange reactions was also found. In the study performed by Y. Nobuta *et al*., tungsten samples were first irradiated by 5 keV helium ions in order to create trap sites for tritium. After the irradiation, the samples were exposed to tritium gas at tritium partial pressure of 85 Pa and 573 K for 3 h to load the traps with tritium. Then the samples were subjected to baking treatments in a vacuum and deuterium atmosphere at temperatures varying from 373 K to 573 K. After each treatment, tritium retention was measured with an imaging plate technique to examine the change in tritium retention. After baking in a vacuum and deuterium atmosphere at 373 K and 473 K, no significant change in tritium retention was observed, while tritium retention clearly decreased after baking at 573 K. Tritium retention after baking in deuterium atmosphere was smaller than that after baking in a vacuum. The larger extent of reduction in tritium retention in deuterium atmosphere suggested that baking in deuterium atmosphere was more effective to remove tritium retained in tungsten due to isotope exchange of tritium with deuterium.

T. Chikada and his colleagues have also performed hydrogen isotope exchange experiments by gas exposure for W samples with C-W mixed material layers deposited by plasma-enhanced chemical vapor deposition (PECVD). The samples were exposed to hydrogen gas which contains tritium at 573 K for several hours. Then, deuterium gas exposure for various duration was performed at different temperatures and pressures. TDS measurement was carried out from room temperature to 1173 K to evaluate the retention of all the hydrogen isotopes simultaneously. The desorption spectra of H_2, HD and D_2 were evaluated by quadrupole mass spectrometer and those of tritium were detected by a proportional counters. The experimental results indicated that hydrogen isotope exchange reaction was accelerated under high temperatures. In addition, tritium retention exponentially decreased with increasing exposure duration.

(Y. Hatano)

Fig. 2 Thermal desorption device installed in Hydrogen Isotope Research Center, Organization for Promotion of Research, University of Toyama for measurements of H, D and T.