§17. Analysis of Tritium Transfer Dynamics for Helical Prototype Nuclear Reactor System Design

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i) Introduction

Many studies were devoted to elucidate Plasma Surface Interaction (PSI) and hydrogen isotope transportation and purification understanding for tritium transfer dynamics in fuel cycle for fusion nuclear system. However, it is quite difficult to apply these data derived under well-controlled condition to actual and larger scale plasma devices or fusion devices due to lots of uncertainties. Therefore, the key parameters should be elucidated for the extrapolation of laboratory data (well-controlled condition data) to actual reactor design and it is necessary to treat deuterium and tritium cycle control and tritium recycle to introduce as one system. In our previous work,[1)] Plasma experimental device, namely EXPRESS (Effluence and Exchange Probe for Recycling Estimation at NIFS and Shizuoka University) was established to study plasma-surface-interaction (PSI) and tritium recovery & storage behavior. In this study, the fuel circulation system has been established and exhaust hydrogen gas obtained from PSI part was recovered, purified, stored and finally, re-introduced into PSI part. The key parameters correlated with hydrogen behavior in these parts such as hydrogen concentrations or throughput speeds were evaluated.

ii) Establishment of purification system

The schematic view of experimental apparatus was shown in Fig. 1. The deuterium (D_2) gas with the flow rate of 2 sccm was introduced into PSI part and the plasma experiment was done. The exhaust gas was stored in the preserver tank. Thereafter, it was primarily purified using the zirconium cobalt (ZrCo) bed at 973 K. After the primary purification, the secondary purification process was performed using permeation technique through palladium membrane manufactured by Nihon pionics to recover higher purified hydrogen isotope gas. The obtained gas was stored in ZrCo bed. The gas was re-introduced to PSI part to continue the plasma experiment. The gas composition after the primary and secondary purifications were measured by a quadrupole mass spectrometer (QMS) and the D_2 concentration and throughput speed were calculated. Fig. 2 shows the typical experimental results after the primary purification. The concentration of hydrogen isotope was also shown in the top of Fig. 2. The D_2 concentration in the recover gas was 98.37% and the major impurity of nitrogen was detected before purification. As the purification was proceeded, the D concentration in exhaust gas was reached to be 99.98%, which was much higher than the requirement (99.50%) of secondary purification by Pd membrane with the flow rate of 4.4 sccm. By the secondary purification, 99.98% of hydrogen isotope was derived. It is thought that 0.02% of impurities was contaminated from the wall of tubing. At the palladium membrane, hydrogen gas can be purified with the maximum of 1500 sccm and ZrCo can absorb hydrogen gas with maximum of 250 sccm.

In the initial test, the isotope ratio of supply gas from ZrCo bed was consisted of 50% of D_2 and 50% of the others, HD and H_2. However, in the second test, highly purified D_2 gas can be supplied to PSI part. In addition, recovery ratio of D_2 gas by ZrCo bed was 0.5% in the initial test, but it was improved until 50% in the second test. It was found that primary purification process would be the determining step in the EXPRESS system.

1) Miura. R. .et al.:JPFR-S **10** (2013) 85.

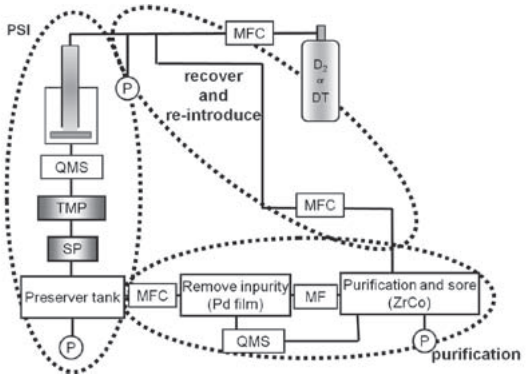

Fig.1 Schematic view of EXPRESS

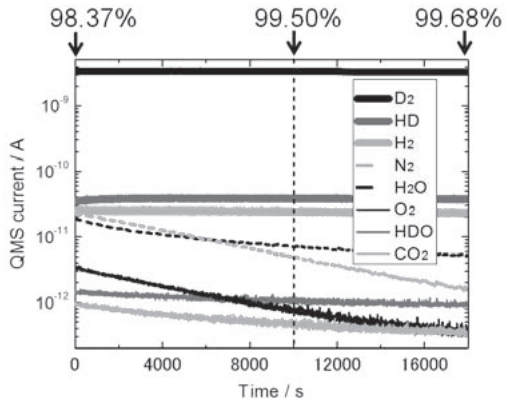

Fig.2 The gas concentration after primary purification