Behavior of hydrogen isotopes loaded into neutron-irradiated tungsten by TPE plasma exposure

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Plasma-facing components in fusion reactor are exposed to high flux deuterium/tritium plasma. Tritium retention in the plasma-facing components affects the design, operation, and lifetime of fusion reactors. In order to achieve reliable prediction of the tritium retention, the behavior of hydrogen isotopes loaded into tungsten, a candidate material of ITER divertor, has been extensively studied using hydrogen/deuterium ion irradiation experiment or plasma exposure experiment. However, the trapping effect of radiation damage induced by fusion neutrons remains uncertain, which is a research subject of Japan-US joint research project TITAN (Task 2-1).

In the present paper, we conducted both experiment and computational simulation in order to study the behavior of hydrogen isotopes loaded into neutron-irradiated tungsten. In the experiment, the neutron irradiation was performed to 0.025 dpa at 50°C in High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL). Subsequently the neutron-irradiated tungsten samples were exposed to high flux deuterium plasma (ion flux: 10^{21}-10^{22} $m^{-2}s^{-1}$, ion fluence: 10^{25}-10^{26} m^{-2}) in Tritium Plasma Experiment (TPE) at Idaho National Laboratory (INL). After the plasma exposure, thermal desorption spectroscopy (TDS) was performed to investigate retention and release temperature of the deuterium. In addition, the distribution of loaded deuterium was measured by nuclear reaction analysis (NRA). In the computational simulation, Monte Carlo technique was utilized in order to model interaction of hydrogen isotopes with radiation defects and migration and desorption behaviors of hydrogen isotopes. The interaction energy, diffusion barrier and desorption energy were determined from previous studies using quantum mechanical calculation of density-functional theory. The deuterium behavior observed in the experiment was analyzed by comparing the release temperature, inventory and distribution of deuterium between the experiment and the simulation. Expected differences between the deuterium and tritium behaviors were also discussed based on isotope effects estimated in the simulation.