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Evaluation study of fuel retention in plasma-facing walls of JA DEMO reactor

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1. Background and purpose

Design studies for demonstration fusion power plant (DEMO) are now in progress. Hydrogen isotopes (deuterium (D) and tritium (T)) are fuel in the plant and they will be retained in the plasma-facing walls (PFWs). The fuel retention in the PFWs is one of critical issues. The retention leads to degrade economic efficiency of fuel cycle system [1] in the plant. In addition, the retention strongly influences particle balance in plasma under the steady-state operation [2].

In order to evaluate the fuel retention in PFWs of DEMO reactor, various factors should be considered. (1) plasma irradiation condition; particle flux and heat load are largely different among the positions in the PFWs. (2) PFW temperature; the temperature influences kinetics on hydrogen isotope behaviors in the wall materials. (3) neutron and helium (He) irradiation effects; they have acute effects on the fuel retention [3].

In this study, we attempted to evaluate the fuel retention in PFWs of JA DEMO (conceptually designed in Japan), considering the above factors.

2. Simulation method

Tungsten (W)-coated first wall in blanket and W-monoblock in divertor are used for the PFWs of JA DEMO. Therefore, we developed simulation code on one-dimensional D diffusion in W [4]. The diffusion code includes D irradiation and kinetic processes in W (trapping, detrapping and recombination emission at the surface). We used this code to evaluate D retention, considering the below factors.

(1) **Plasma irradiation conditions**; D irradiation fluxes and heat fluxes were calculated by integrated edge plasma code SONIC [5] (The fusion power was assumed to 1.5 GW). The poloidal distributions of theses fluxes were represented by the values at 138 grid edges.

(2) **PFW temperature**; the surface temperature and the temperature gradients in PFWs are determined by the heat flux and PFW structure (including cooling pipe and water).

(3) **Neutron and He irradiation effects**; Neutron irradiation produces strong trapping sites for D and, therefore, D retention was dominated by the trapping sites [6]. In this study, we used typical values for the concentration C_T = 0.2 at.% and the de- trapping energy E_T = 2.0 eV (assuming ~0.1 dpa). On the other hands, He irradiation produces bubbles near the surface and enhances recombination emission of D. In this study, we represented the He effects by changing "effective" recombination rate coefficient. The surface barriers (ΔE_{surf}) of the recombination were estimated by comparing D+He simultaneous irradiation experiments [7] with our diffusion simulation.

3. Simulation results and discussion

Figure 1 shows the total amount of D retention in PFWs. Due to neutron irradiation effect, the retained amount was much greater than that in unirradiated case (C_T = 0.13 at.% and E_T = 0.85 eV [6]). The estimate was ~10^{24} D-atoms after the operation time of 10^4 s, which was comparable to that in ITER [8].

By adding the He irradiation effect (assuming D+He plasma irradiation to neutron-irradiated W), D retention was reduced to be 10 – 20 %. This was due to the enhanced recombination emission. In all cases, D retention increased approximately in proportional to the square root of operation time (except for the early stage).

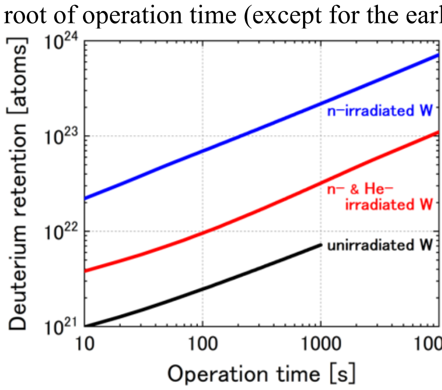

Figure 1: Time evolution of D retention in neutron (n) and helium (He) irradiated PFWs of JA DEMO, along with that for unirradiated case.

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