§4. Global Helium Particle Balance Analysis in LHD

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Global helium particle balance in long-pulse discharges is analyzed for the first time in the Large Helical Device (LHD) with the plasma-facing components of the first wall and the divertor tiles composed of stainless steel and carbon, respectively. During the 2-min. discharge by ion cyclotron resonance heating (ICRH) and electron cyclotron heating (ECH), helium is observed to be highly retained in the wall (regarded as both the first wall and the divertor tiles). Almost all (about 96%) puffed helium particles (1.3×10^{22} He) are absorbed in the wall near the end of the discharge. Even though a dynamic retention is eliminated, 56% is still absorbed. The analysis is also applied to longer pulse discharges over 40 min. by ICRH and ECH, indicating that the helium wall retention is dynamically changed in time.

Helium absorption/desorption in the wall is important to identify for efficient removal. "The wall retention analysis" is generally evaluated by two complementary methods: global gas balance and postmortem analysis using a material probe. In this study, we focus on the global gas balance analysis of helium plasmas by ICRH and ECH in long-pulses in LHD. The first wall and divertor tiles in LHD are made of stainless steel (SUS-316L) and carbon, respectively. In this study, we regard the "wall" as both the first wall and the divertor tiles. The postmortem analysis in LHD reveals that the mixed-material deposition layer composed of dominant carbon (~98%) and a slight amount of iron (~2%) is formed. We have recently found that this mixed-material deposition layer is a possible contributed factor of helium retention.

Analysis of global helium particle balance is conducted in ICRH and ECH discharge with only turbo pumps. The aim of the use of only turbo pumps is to fix the pumping speed for the exhaust condition. The electron density is kept constant with ~1 $\times10^{19}$ m^{-3} and averaged heating power is 1.6 MW. During the discharge for 2 min., the high wall retention is observed. The total number of puffed helium particles is 48 Pam^3 ($=1.3\times10^{22}$ He). Most of the puffed particles are absorbed in the wall. Almost all (about 96%) puffed helium particles (46 $Pam^3=1.2\times10^{22}$ He) are absorbed in the wall just after the discharge. Here, the neutral helium in the vacuum vessel and the plasma particles are negligibly small. The exhausted amount is also small because only turbo pumps with the moderate pumping speed are utilized. It is noted that the retained particles include the temporal short-term retention, the so-called "dynamic retention". To distinguish the total wall inventory from the dynamic retention, the global particle balance analysis has been extended until after the discharge. The extended particle balance analysis until 800 sec. It is assumed that helium particles adsorbed by dynamic retention must be partially released as outgassing from the wall after the discharge. The inventory of helium excluding the dynamic retention is evaluated as ~27 Pam^3 ($=0.7\times10^{22}$ He), which is 56% of the integrated puffed particles.

Analysis of the global helium particle balance is conducted in the long-pulse discharges over 40 min. In the discharge, the cryosorption pumps are used for the main pumping, whose pumping speed of helium is temporally changed. Therefore, the pumping test of helium was carefully conducted after the experimental campaign. Figure 1 shows the temporal evolution of the wall retention in the long-pulse. The dynamic change of the helium wall retention is observed. The inventory can be mainly separated into three phases. In the first phase, defined from 0 to ~300 sec., quite high wall inventory occurs. In this phase, more than 80% of the puffed helium is retained in the wall, as shown in Figure 1(c). After the first phase, the wall inventory shows modest declination. Namely, in the time range between ~300 and ~1,500 sec., the wall retained the particles in the first phase rather releases some particles. However, the high wall inventory appears again in the third phase from ~1,500 sec. to the end of the discharge. In these discharges, the wall inventory including the dynamic retention is 85±30 Pam^3 (60±20% of injected amount). The mechanism of the dynamic and temporal change of the wall inventory is still unclear, but the postmortem analysis indicates that the accumulation of the mixed-material deposition layer might take an important role of wall inventory of helium. As a next step, the comparison between the global particle balance and the postmortem analysis should be conducted for the understanding of the dynamic change of the wall retention.

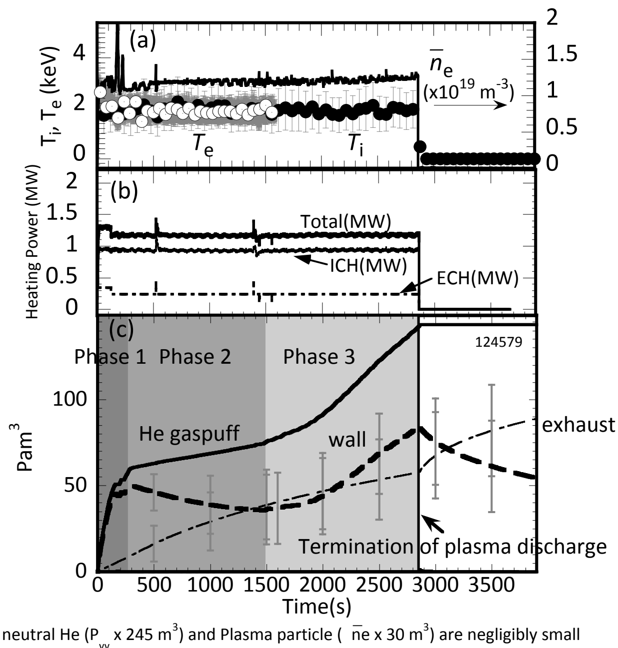

Fig. 1. Temporal evolution of (a) typical plasma parameters, (b) heating power and (c) global particle balance.