§11. Impurity Behavior in a Multi-Species Plasma Mixed with H and He on LHD

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Long pulse operation has been so far carried out in LHD, making use of steady-state toroidal magnetic field, which is produced by superconducting magnets. In this operation, helium dominant plasmas are produced and maintained by ICRF minority heating. Then no impurity accumulation phenomenon is observed unlike hydrogen long pulse discharges with NBI heating. Therefore, we investigate impurity behavior in multi-species plasmas mixed with H and He in order to clarify the effect of background plasma ions on impurity transport. This is also very important in estimating the influence of He ash on impurity transport in burning plasmas.

Figure 1 shows typical long pulse discharges with H and He rich plasmas. In these discharges, the NBI heating power of 7~8 MW is injected into the plasma and the average plasma density is controlled so as to keep around 4.5 x 10^{20} m^{-3} by a feedback control loop, using particle fueling with H or He gas puffing. The ratio of H and (H+He) is obtained from spectroscopic measurements at plasma edge. Impurity behavior can be observed in the time evolution of radiated power (S_{rad}) and impurity line intensity (Fe XXIII) in the core plasma. In the discharge with H rich plasma (solid line), the core radiation increases with time and the intrinsic metal impurity accumulates in the plasma core. However, no impurity accumulation is observed for the discharge with He rich plasma (dotted line). Density scan in long pulse discharges shows more clear difference of impurity behavior in between H and He rich plasmas, as indicated in Fig. 2, where a large number of discharges are plotted on the two dimensional space of the electron density and temperature at the last closed flux surface. The light gray symbols (solid or open) indicate the discharges with H rich plasma and the black circles indicate the discharges with He rich plasma. In H rich discharges, we can find the specific domain where impurity accumulation is observed (impurity accumulation window). The two different types of impurity shielding effects are essential for preventing intrinsic impurities from entering the core plasma. While intrinsic impurities do not accumulate into the core plasma in density scan with He rich plasmas. The impurity retention at the plasma edge on the high collisionality side is caused by friction force in the ergodic layer. The empirical scaling on impurity screening criterion depends on the mass and charge of background plasma ions and the impurity retention area expands to low collisionality side for He plasmas. However, the impurity retention is not effective in all impurity accumulation area, in particular, on the low collisionality side. Therefore, we investigate another impurity shielding effect due to positive radial electric field at the plasma edge on the low collisionality side. Figure 3 shows the dependence of radial electric field (E_r) on background ion collisionality for H and He rich plasmas. The radial electric field depends on the ion collisionality and it has a negative value less than -3.5 kV/m in the low collisionality region ($n > 0.014$) for H plasmas. On the other hand, it is hard to enter the ion root in helium plasmas and the radial electric field does not go down to less than -3.5 kV/m even in the high collisionality region. This suggests that impurity behavior in He plasmas is mainly determined by the impurity shielding effect due to radial electric field.

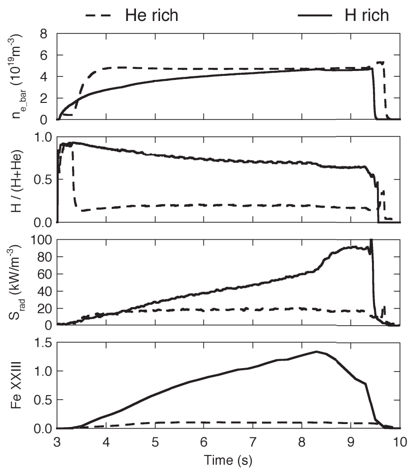

Fig. 1. Typical discharges with H and He rich plasmas

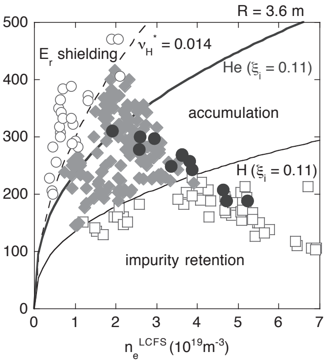

Fig. 2. n-T diagram at plasma edge for impurity behavior

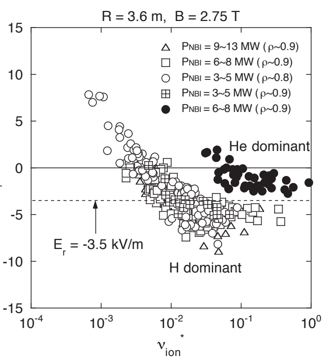

Fig. 3. Dependence of E_r at plasma edge region on ion collisionality for H and He rich plasmas