§10. Core Impurity Transport in Qusai-Steady State Plasmas on LHD

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Impurity behavior in steady-state hydrogen discharges has been so far intensively investigated and we found impurity accumulation window in a specific collisionality regime [1]. However, recently, it is found that such an impurity accumulative behavior is dramatically suppressed with higher NBI heating power (P_{nbi} > 10 MW). In the previous study, two different physical mechanisms (impurity screening due to positive radial electric field in the edge region and impurity retention due to friction force in the ergodic layer) were of importance to prevent intrinsic impurities from penetrating into the plasma core. Here, we investigate the core impurity transport for the discharges with different heating powers and also report the parameter dependence of impurity behavior on directional NBI heating power and toroidal velocity.

First of all, in order to investigate impurity transport in the core plasma region, the metal impurity (Ti) different from the main intrinsic metal impurity (Fe) in LHD is externally injected into the plasma core. Figure 1 shows impurity behavior in steady-state NBI discharges with the heating power of 7 and 11 MW. The plasma collisionality for both discharges is almost the same in the initial stage and the plasma parameters (n, T) are in the impurity accumulation domain. In the case of low power heating (P_{nbi} = 7 MW: thin line), remarkable increase in the core radiation (AXUVD) is observed and the plasma temperature extremely decreases with time. The impurity line intensity (Ti XIX) increases with time and it suggests that the core impurity transport is accumulative. In contrast, the plasma temperature and the core radiation are maintained almost constant in the high power discharge (P_{nbi} = 11 MW: thick line) until about 6.5 s when the heating power goes down. The externally injected impurity (Ti) is pumped out and it is found that the impurity accumulative behavior is strongly suppressed in the plasma core. Next, we investigate parameter dependence of impurity behavior in the steady-state plasmas with the same collisionality. Figure 2 shows the dependence of carbon density increasing rate on the directional NBI power (P_t) and the toroidal velocity in the center. The directional NBI power is defined by $P_t = P_{NBI}(Co) - P_{NBI}(Ctr)$ and closely related to momentum input. The toroidal velocity is proportional to the directional NBI power and we obtain the similar dependence. From these figures, one can see that high co-directional momentum input or toroidal flow prevents to penetrate carbon into the core region. However, impurity behavior strongly depends on the total heating power. Therefore, we investigate the parameter dependence of impurity behavior in the discharges with the same heating power. Figure 3 shows the time evolution of line-integrated radiation for discharges with different external momentum input (P_t). Here, although we can see different impurity behavior, it is still difficult to find a clear dependence of impurity transport on momentum input (toroidal velocity). Further investigation on the influence of momentum input, toroidal flow and turbulence will be needed to understand the physical mechanism.

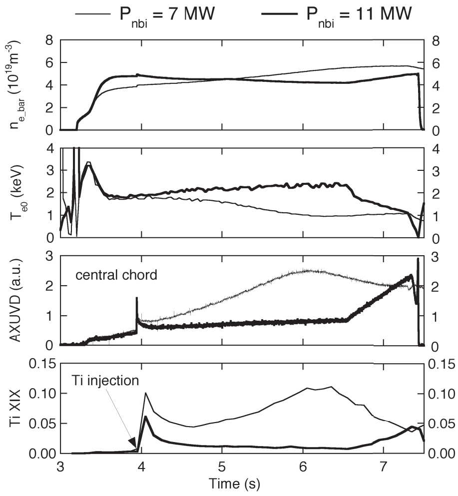

Fig. 1. Core impurity transport in NBI discharges with external impurity (Ti) injection

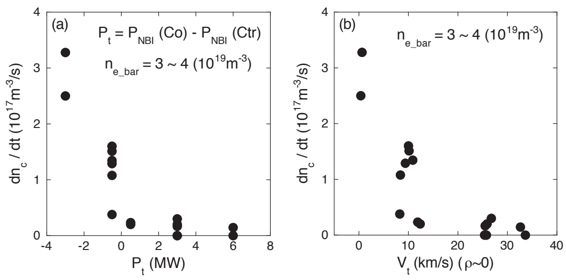

Fig. 2. Dependence of carbon density increasing rate on (a) directional NBI power and (b) toroidal velocity

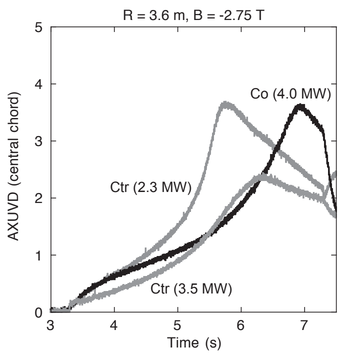

Fig. 3. Time evolution of line-integrated radiation for discharges with different external momentum input

1) Nakamura, Y., et al., PPCF **56** (2014) 075014