§21. Suppression of Impurity Accumulative Behavior in Steady-State Discharges with High Power Heating

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In LHD steady-state hydrogen discharges, we always found impurity accumulation window in a specific collisionality regime [1]. Such an impurity accumulative behavior has been observed in the discharges with the NBI heating power less than 10 MW. Recently, higher NBI heating powers ($P_{nbi} > 10$ MW, $t_d \sim 5$ s) are available for steady-state discharges and it enables us to study impurity behavior in high temperature plasmas. In these discharges, it is found that the impurity accumulative behavior is dramatically suppressed with higher NBI heating power ($P_{nbi} \sim 13$ MW). Here, we report the experimental results in steady-state discharges with high NBI heating power.

Figure 1 shows typical steady-state discharges with high NBI heating power (P_{nbi} = 9.5 and 13 MW). The average plasma density is controlled so as to keep constant (~ 3.5×10^{19} m^{-3}) during the discharge. In the case of low power heating (P_{nbi} = 9.5 MW), remarkable increases in impurity line intensity (Fe XXIII) and core carbon density are observed and the plasma temperature extremely decreases with time in the last stage of the discharge. In contrast, all the plasma parameters are maintained almost constant in the high power discharge (P_{nbi} = 13 MW). The impurity accumulative behavior is strongly suppressed with high power heating. The measurements of carbon density with a charge exchange spectroscopy (CXS) show a peaked profile in the low power heating case (P_{nbi} = 6.7 MW) and a flat profile in the high power heating case (P_{nbi} = 13 MW), as shown in Fig. 2. One can see that high power heating prevents to penetrate carbon into the core region. Figure 3 shows the dependence of the increasing rate of core carbon density on line-averaged electron density. The vertical axis indicates the average increasing rate of carbon density in the core region ($\rho \sim 0.2$) during the discharge. In the case of low power heating (P_{nbi} = 7.5 MW), the density window for impurity accumulation is also found in the carbon density measurement, as observed before in the core radiation. However, the impurity accumulation window almost disappears in the discharges with high power heating (P_{nbi} = 13 MW). This suggests that there exists no impurity accumulation in high performance plasmas with high power heating ($P_{nbi} > 10$ MW).

Recently, impurity shielding criteria for steady-state hydrogen discharges are discussed with two different types of impurity screening effects originating from radial electric field in the edge region and friction force in the ergodic layer [2]. These physical pictures enable us to deepen an understanding of impurity accumulation window. However, the impact of high power heating on impurity accumulative behavior might be related to not impurity shielding in the edge region but impurity transport in the core region. Further investigation on the influence of momentum input, toroidal flow and turbulence will be needed to understand the physical mechanism.

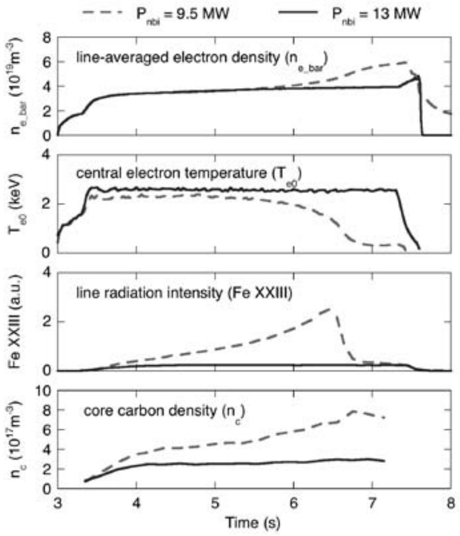

Fig. 1. NBI discharges with 9.5 MW and 13 MW

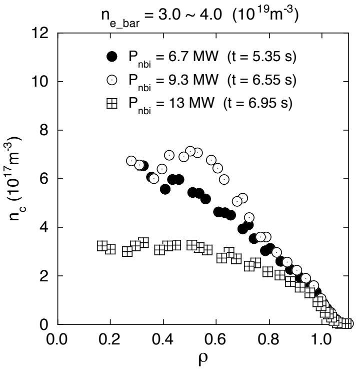

Fig. 2. Dependence of carbon density profile on NBI heating power

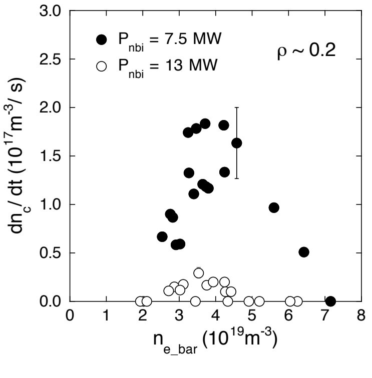

Fig. 3. Dependence of the increasing rate of core carbon density on plasma density (n_{e_bar})

1) Nakamura, Y., et al., Nuclear Fusion **43** (2003) 219.
2) Nakamura, Y., et al., PPCF **56** (2014) 075014