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Strong suppression of impurity accumulation in steady-state hydrogen discharges with high power NBI heating on LHD

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Impurity behavior in normal long pulse hydrogen discharges with a flat density profile is investigated in a wide operational range and steady state operational regimes providing stationary radiation loss conditions at an acceptable level are explored in LHD. As reported before, impurity transport studies in long pulse discharges provide two different physical pictures based on neoclassical impurity transport in the core plasma and on classical theory in the SOL region. For helical plasmas, impurity behavior is generally dominated by the radial electric field (positive in the electron root and negative in the ion root) and impurity accumulation is always observed in the ion root with a large negative radial electric field. On the other hand, intrinsic impurities are shielded by friction force at high edge collisionality in the ergodic layer. Density scans with the same heating power reveal some impurity accumulation window. Recently, high NBI heating power of more than 10 MW is available to long pulse operation and strong suppression of impurity accumulative behavior is observed. Density scan experiments show that there is no impurity accumulation even in a specific collisionality range (impurity accumulation window), where the intrinsic impurities (Fe, C) are always accumulated into the plasma core in the previous discharges. A new excellent operational regime without impurity accumulation is found in steady state hydrogen discharges. The high power heating plasmas in impurity accumulation window have a large negative radial electric field as well as that in low power discharges. A new contribution to impurity transport is required to explain the strong suppression of impurity accumulation. Studies on parameter dependence of carbon density profile show that core carbon density gradient decreases with increasing ion temperature gradient and carbon Mach number (toroidal rotation velocity). These similar correlations are also observed in the ASDEX upgraded tokamak plasmas and explained by the modeling as due to a combination of the turbulent regime and an impurity flux driven by rotation gradient, both of which are indirectly determined by the auxiliary heating power. Thus, the large outward contribution to impurity transport will be discussed with turbulent transport and toroidal rotation effect.

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