Integration of Ion ITB and Electron ITB in the Large Helical Device

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Helical plasma experiments have been confirmed good confinement properties in high-density regimes and a significant advantage in steady-state operation. In contrast to tokamak ITB plasmas, the ion ITB and electron ITB have been observed in the helical plasmas independently, indicating no coupling with each other. Therefore, the ion ITB and electron ITB have been studied separately so far. Recently, an integration of ion ITB and electron ITB was successfully realized due to superposition of centrally focused electron cyclotron resonance heating (ECH) to ion ITB plasmas. The temperature regime of helical plasmas was significantly extended in the $T_i \sim T_e$ regime.

The electron ITB/CERC (core electron root confinement) in helical plasmas had been formed in ECH plasmas in low density regime (n_e is the order of 10^{18} m^{-3}) and characterized by suppression of anomalous transport as well as neoclassical transport due to transition of radial electric field. On the other hand, the ion ITB is formed in neutral beam injection (NBI) heated plasmas with the density regime of 1×10^{19} m^{-3} and characterized by the significant suppression of anomalous transport without transition of the radial electric field (negative E_r). In the 16th campaign of LHD experiment in 2012, the ECH power capability was extended up to 4.6 MW and the density regime of electron ITB formation increased to the same regime with ion ITB, which has enabled the integration of ion and electron ITBs in the 17th campaign in 2013. The simultaneous formation of ion and electron ITBs was successfully demonstrated and $T_{i0} \sim T_{e0} \sim 6$ keV were achieved with intense wall conditioning and superposition of centrally focused ECH. It was observed that the positive radial electric field is formed and the width of ion ITB is larger than that of electron ITB. The ion temperature gradient at the barrier was also observed to decrease with the temperature ratio (T_e/T_i) at the barrier. This experiment indicates that the profile control to keep $T_e/T_i < 1$ is a key of the integration of ion and electron ITBs in helical plasmas. In this talk, the characteristics of the plasmas with ion and electron ITBs and the role of wall conditioning on ITB formation will be also discussed.