§5. Formation of Electron Internal Transport Barrier by Combination of NBI and ECH

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When the centrally focused intense ECRH microwave was superimposed on the NB-heated plasma, the electron temperature shows a centrally peaked profile with a steep gradient inside ρ=0.3 – 0.4. An example of this electron ITB (internal transport barrier) profile is shown in Fig. 1. There exist various kinds of threshold for the electron ITB formation, such as the ECRH power, the NBI power, and the density. Figure 1 shows the density threshold for the electron ITB formation. Reduction of the density by $0.06\mathrm{x}10^{19}\mathrm{m}^{-3}$ leads to an increase in the central T_e from 3 to 7 keV. The electron transport is much improved in a region of the ITB formation. Figure 2 shows the electron thermal diffusivity χ_e as a function of the collisionality in the case of the ITB formation with an ECRH power threshold at $n_e=0.3\mathrm{x}10^{19}\mathrm{m}^{-3}$. When a small ECRH power (180kW) is added to the NBI plasma, the T_e at ρ=0.2 is increased a little and the χ_e is much increased. With a larger ECRH power (280kW) the electron ITB profile is formed and the T_e at ρ=0.2 is raised, and then the χ_e is much reduced. The reduction of the χ_e at the threshold suggests the transition of neoclassical ion root to electron root. However, the χ_e in the ITB profile is one-order of magnitude larger than the theoretical neoclassical one, as shown in Fig. 2. The experimentally observed χ_e reduction in the ITB formation could be attributed to the suppression of the anomalous transport due to the electric field shear at a boundary of the ITB formed by the transition of the electric field.

Figure 3 shows a T_e – n_e diagram for both ITB and no-ITB profiles at ρ=0.2. In the figure, the local ITB formation at ρ=0.2 is judged by the gradient of T_e, $dT_e/d\rho$, at ρ=0.2, i.e., no ITB formation for $dT_e/d\rho<1$, ITB formation for $dT_e/d\rho>5$, and marginal ITB formation for $1< dT_e/d\rho<5$. In the figure, the theoretical transition boundary to the electron root from the ion root is also indicated. The temperature threshold for the ITB formation is dependent on $n_e^{0.4}$, which coincides with the theoretical prediction. The electron ITB profile is also observed in relatively high-density plasmas of $>1\mathrm{x}10^{19}\mathrm{m}^{-3}$ with a higher ECRH power and a higher NBI power. Although an apparent increase in the ion temperature has not been recognized, a high electron temperature in the ITB formation would enhance the ion heating ratio in high-power NBI heating, leading to increase in the ion temperature. Moreover, the neoclassical electron root in the ITB formation would reduce the ion transport in the collisionless regime, which would realize a higher ion temperature.

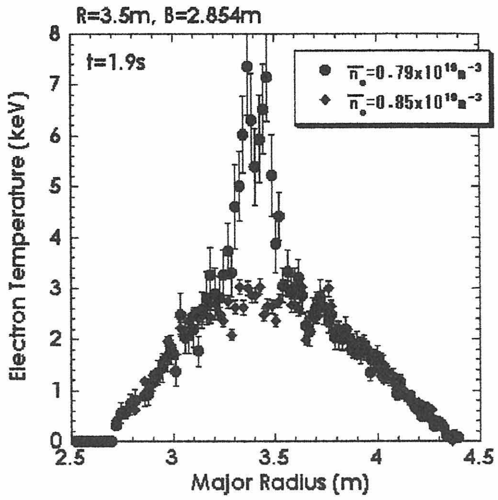

Fig. 1 Electron temperature profiles with and without ITB.

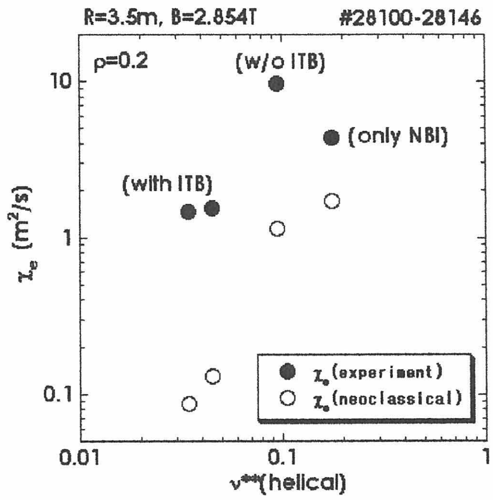

Fig. 2 Electron thermal diffusivity as a function of the collisionality.

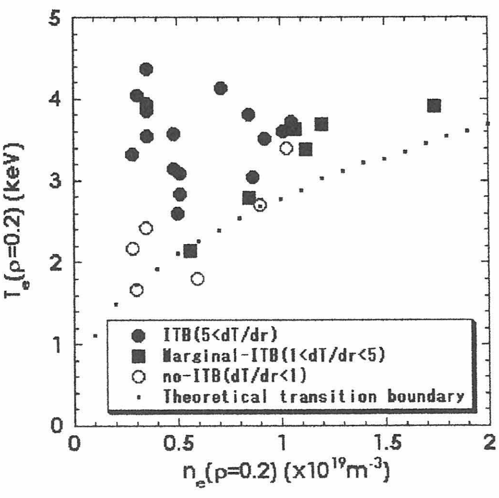

Fig. 3 $T_e - n_e$ diagram for both ITB and no-ITB profiles at ρ=0.2.