§11. Power Balance Analysis in the Hydrogen and Helium Plasma of LHD High Ti Discharge

Tanaka, K., Nagaoka, K., Osakabe, M., Takahashi, H., Yokoyama, M., Murakami, S. (Kyoto Univ.)

The improvement of ion energy confinement was found in He rich plasma of ITB discharge in LHD[1]. Figure 1 shows the comparison of the achieved T_e, T_i in the central region ($\rho < 0.3$) and the deposition power per particle for the different H and He ratio. The set of the plasmas were heated by a 20 – 23 MW hydrogen neutral beam. The line averaged density was $1.35 \times 10^{19} m^{-3}$ and B_t was 2.75T. The fueling ratio of H and He ($R = n_H/(n_H + n_{He})$) were controlled by the discharge cleaning and external gas fueling. As shown in Fig.1, T_i in the central region increases with the increase of He concentration, while T_e almost stays constant. However, the deposition power per particle was almost constant. Figure 2 shows a comparison of profiles in the lowest and the highest achieved T_i in Fig.1. Due to the larger concentration of He^{2+} in He rich plasma, the total ion density becomes lower than that of H rich plasma. However, as shown in Fig.1, P_i/n_i is almost constant, thus, the increase of T_i is not due to the difference of P_i/n_i. As shown in Fig.2 (d), the L_{Ti}^{-1} are almost identical at $\rho < 0.9$ in both cases. This suggests the L_{Ti}^{-1} are limited by the ITG threshold [2] in both cases, while T_i in the edge pedestal region is clearly higher in He rich plasma. Higher T_i in the core region of He rich plasma is due to the higher T_i at $\rho > 0.9$ and is due to the relative improvement of thermal diffusivity in the plasma edge region as shown as follows.

Figure 3 (a) shows a comparison of the ion deposition power. With lower R, deposition becomes lower. Figure 3 (b) shows the spatial profile of effective ion thermal diffusivity ($\chi_{i\,eff}$). $\chi_{i\,eff}$ is defined as Q_i/n_i grad T_i, where Q_i is the sum of ion heat flux of H^+, He^{2+} and C^{6+} ions. T_i was measured by CXRS from C^{6+} Doppler broadening and assumed to be same for these three ion species. Thus, $\chi_{i\,eff}$ was defined as a representative values of ion thermal diffusivity. According to the gyro-kinetic non linear simulation, non linear heat fluxes follow gyro-Bohm diffusivity[3], which is proportional to $m^{0.5}T^{1.5}/(aq^2B_t^2)$, where m_i is mass, T is temperature, q is the charge of each charged particle, a is minor radius, B_t is the magnetic field. The discrepancy from the gyro-Bohm parameter dependence is an indicator of improvement or deterioration of confinement. It should be noted that dependence on q is usually not considered in the conventional scaling, however, q shows strong effects in the gyro-Bohm diffusivity and is necessary to be taken into account in He plasma. Here, we defined the gyro-Bohm factor as $F_{GB} = m_{ieff}^{0.5} T_i^{1.5}/(q_{ieff}^2)$, where m_{ieff} is effective ion mass, q_{ieff} is effective ion charge. m_{ieff} and q_{ieff} were estimated from the ratio of the ions. Figure 3 (d) shows $\chi_{i\,eff}$ profile normalized by F_{GB}. As shown in Fig.3 (d), the difference of the $\chi_{i\,eff}/F_{GB}$ becomes smaller. In particular, for R = 0.34 - 0.73, $\chi_{i\,eff}/F_{GB}$ are almost identical at $\rho < 0.8$, while the difference is still large at $\rho > 0.8$. This result causes the higher edge pedestal T_i as shown in Fig.2 (d).

1) Nagaoka, K., submitted Plasma Fusion Res.
2) Murakami, A., et al., Nucl. Fusion 46, S425 (2006).
3) M. Nunami et al, Plasma Fusion Res. 6, 1403001 (2011)
4) Pusztai, I., et al, Phys. Plasma 18, 122501(2011)

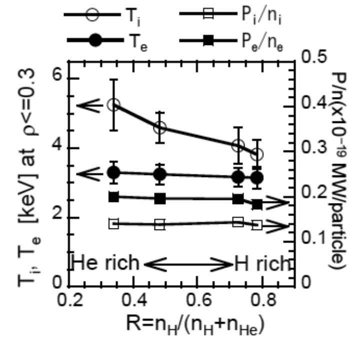

Fig.1 Comparison of T_e, T_i at $\rho<0.3$ and deposition power per particle for different He and H ratio. Deposition power is calculate by GNET[2]

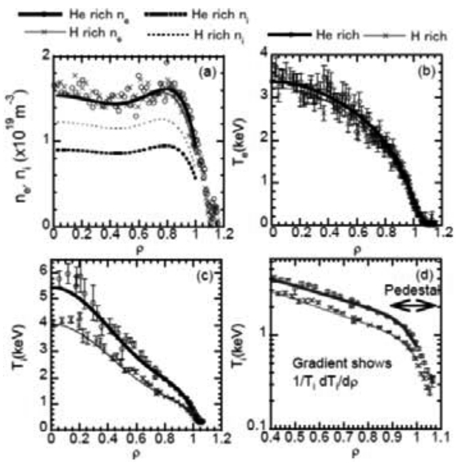

Fig.2 (a) n_e (plain lines), n_i (dashed lines), (b) T_e, (c), T_i, (d) expanded view of T_i profiles (vertical axis is logarithmic scale) in He rich (R=0.34 and the highest T_i plasma) and H rich (R=0.78 and the lowest T_i discharge) plasmas.

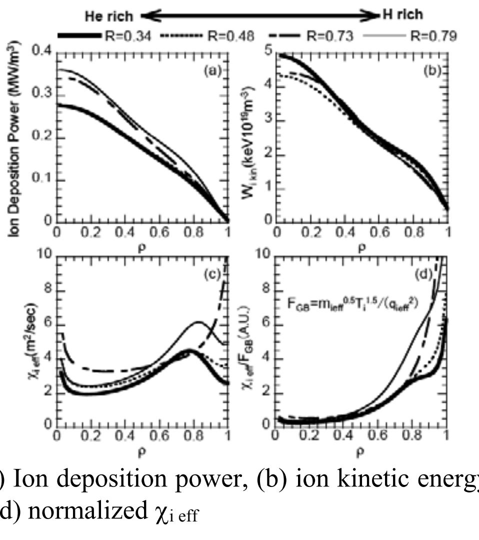

Fig.3 (a) Ion deposition power, (b) ion kinetic energy, (c) $\chi_{i\,eff}$, and (d) normalized $\chi_{i\,eff}$