§8. Evaluation of Z_{eff} Profile in Low-density and High-Ti Discharges with Carbon Pellet Injection in LHD

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Time evolution of the NBI port-through power P_{NBI}, n_e, T_e, T_i, the plasma stored energy W_p and the radiation power P_{rad} in the high-Ti discharge are shown in Fig.1. The Z_{eff} profile evaluated from EUV bremsstrahlung emission is obtained at six time frames [1], denoted as F1-F6 in Fig.1. A carbon pellet is injected at t=4.5 s. The line-integrated density n_e increases from 1.0×10^{13} cm^{-3} to 2.2×10^{13} cm^{-3} after the pellet injection and then gradually decays to 1.4×10^{13} cm^{-3}. The T_e is not significantly affected by the pellet injection. The T_i increases from 3.1 keV to 4.2 keV and becomes higher than T_e after the injection (F2). The value of T_i is maintained at around 4.0 keV for 200 ms (F3). The decrease in T_i starts from t = 5.0s and becomes lower than T_e after t=5.25 s

The radial profiles of Z_{eff}, $n_{C^{5+}}/n_e$, T_i and T_e in the above-mentioned time frames F1-F6 are shown in Fig.2. The Z_{eff} profile in Fig.2 (a) is basically flat before the pellet injection. In the frame just after the injection (F2), the line-averaged Z_{eff} value increases by approximately 0.8 and a centrally peaked Z_{eff} profile occurs. At the same time, the T_i profile is increased as a whole and becomes higher than T_e in the central region ($\rho < 0.6$). All three profiles are maintained in the next time frame when the central T_i stays at 4.0 keV (F3). The normalized C^{5+} density ($n_{C^{5+}}/n_e$) profile derived from CVI 28.5 Å is shown in Fig.2 (b). The radial profile of C^{5+} density in the plasma core shows a good agreement with the Z_{eff} profiles in F2 and F3. The C^{6+} ion density is estimated to be roughly three to four times as high as the C^{5+} density just after the pellet injection by referring a result from similar discharges with carbon pellet injection. The central Z_{eff} is thus around 3.5. Taken into account the presence of other impurities, the Z_{eff} value should be slightly higher. Therefore, the present Z_{eff} value of 3.6 is quite reasonable in F2. When the T_i starts to decrease at t = 5.0s, the Z_{eff} profile gradually returns to the original shape before the injection. Here, it is noted that the C^{5+} density profile measurement in the plasma core is not easy except for the period just after the pellet injection due to the low signal-to-noise ratio. The T_i profile tends to exhibit a similar behavior to the Z_{eff} profile. The T_e profile remains basically unchanged in all time frames.

Comparison between the Z_{eff} and T_i profiles strongly indicates that there is a positive relation between Z_{eff} and T_i. Possible explanations are an enhancement of the absorption efficiency of NBI power and ion heating power per ion with increasing Z_{eff}. It has been also identified that the plasma confinement is improved in such high T_i discharges with carbon pellet injection. A recent study shows there is a strong relation between the density of the carbon impurity and the thermal diffusivity [2]. The time behavior of the Z_{eff} and T_i profiles also suggests that Z_{eff} plays an important role in the confinement improvement.

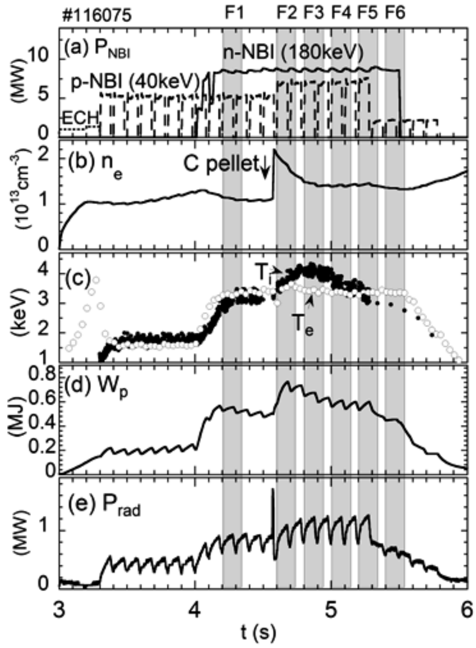

Fig.1 Time evolution of (a) NBI port-through power, (b) n_e, (c) T_e and T_i, (d) plasma stored energy W_p and (e) radiation power P_{rad}. Dashed areas indicate six time frames of F1-F6.

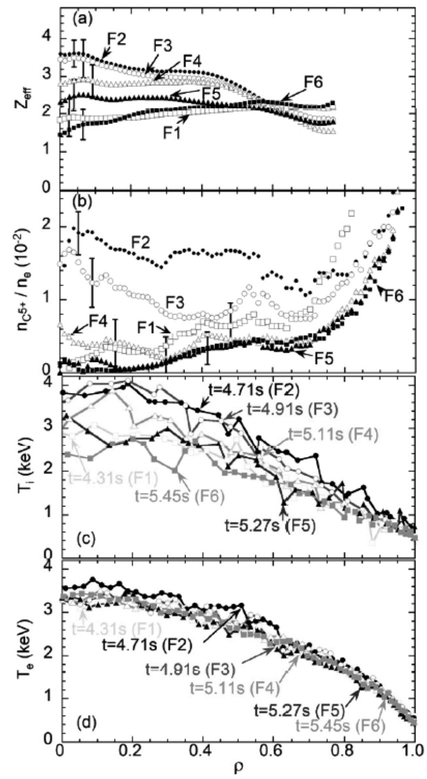

Fig.2 Profiles of (a) Z_{eff}, (b) n_C^{5+}/n_e, (c) T_i and (d) T_e in the six time frames of F1-F6.

1) Huang, X.L. et al.: PFR **10** (2015) 3402036.
2) Osakabe, M. et al.: PPCF **56** (2014) 095011.