§10. Ablation Behavior and Density Redistribution after Pellet Injection in the LHD Plasmas

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Neutral gas shielding (NGS) model, which is the most widely adopted pellet ablation model. If one assumes pellet injection normal to the plasma from the outside midplane and linear profiles for electron temperature and density, the penetration depth scaling of the NGS models is expressed as follows,

$$\lambda/a = C\, T_e^{-5/9}\, n_e^{-1/9}\, m_p^{5/27}\, v_p^{1/3}$$

where T_e, n_e, m_p and V_p are the central electron temperature, the central electron density, the pellet mass and the pellet velocity, respectively. The scaling suggests that the penetration depth depends mainly on the electron temperature. Measured penetration depth, which estimated by duration of Hα emission from ablating pellet, is compared with the NGS scaling. The trend of the measured penetration depth agrees approximately with NGS scaling, but the measured penetration depth is systematically shallower than NGS scaling. This systematical difference can be explained by effect of fast ions on the ablation, because LHD employ very high-energy neutral beam comparison with plasma temperature (150 keV versus 2 keV). Fig. 1 (a) shows the typical electron temperature profile, the density profile and calculated beam component density profile just before a sequence of pellet injection. Since beam component density is comparable to electron density in such a low density plasma, effect of fast ions on the ablation can not be ignored. Fig. 1 (b) shows deposition profiles that are calculated from the NGS model with fast ions on the ablation, and the Hα emission from ablating pellet mapped onto the normalized minor radius is also shown. Calculated deposited density profile with fast ion ablation indicates a good agreement with Hα emission measurement. On the other hand, deposition profile, which is obtained by density profile change, is shallower than Hα emission measurement. Fig. 2 (a) and (b) show electron density and temperature profiles before and after pellet injection into 3.1 MW NBI heated plasma. The measured deposition profile, which is obtained by the density profile change before and 10 ms after pellet injection, is shown in fig. 2 (c). The Hα emission measurement and the calculated deposition profile are also shown. Measured deposition peak is shifted outward as compared with Hα emission peak, and majority of pellet mass was deposited outside of ρ= 0.8. As a result, a net fueling efficiency is 46 %. This profile shift suggest redistribution of pellet mass on the fast time scale. Similar phenomena has been observed in DIII-D[1]. Fig. 8 shows high time resolution waveform at the timing of pellet ablation. Line averaged electron density is divided into two part, core density $\bar{n}_e^{core}$ (ρ<0.7) and boundary density $\bar{n}_e^{boundary}$ (ρ>0.7), using multi-chord interferometer data. Ablation starts at 0.511 s. About the same time boundary density starts to increase, then core density start to increase. Core density increase is stopped and then starts to decrease at the same time the ablation is finished (0.5114 s). Contrary to this, boundary density increases further. The core density decrease and boundary density increase stop at 0.5118 s (400 μs after ablation). These phenomena can be explained as follows: Though pellet penetrates into a certain depth that is well predicted by the NGS with fast ion ablation, a noticeable part of pellet mass are spewed out from the core region, pellet mass redistribute in a short time (~ 400 μs). Hα emission from boundary region grows in the core density decay phase, and divertor flux also increases at the same time. Because a same phenomenon is observed in tokamak, it is consider that there is a general physical mechanics on density redistribution.

[1] L.R. Baylor, et al., Fusion Technology, 34 (1998) 425.

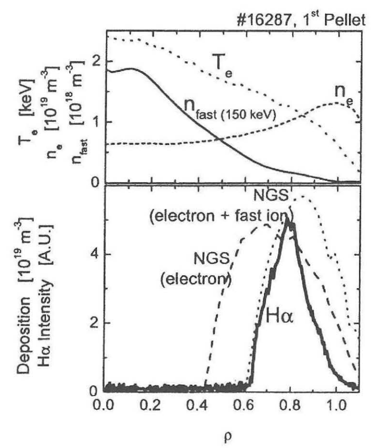

Fig. 1. Typical profiles just before pellet injection and predicted deposition profiles.

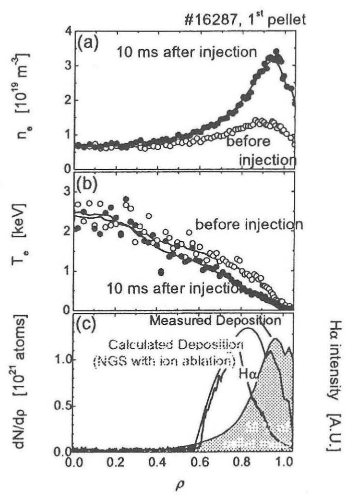

Fig. 2. Profile change caused by pellet injection.

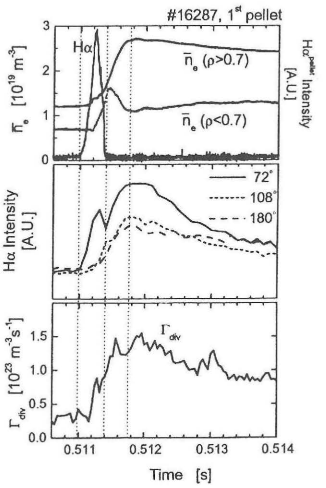

Fig. 3. Plasma behavior during and after pellet ablation.