§17. Observation of an Impurity Hole in a Plasma with an Ion Internal Transport Barrier in the LHD

Ida, K., Yoshinuma, M., Osakabe, M.

Extremely hollow profiles of impurities (denoted as "impurity hole") is observed in the plasma with a steep gradient of the ion temperature after the formation of an internal transport barrier (ITB) in the ion temperature transport in LHD. The radial profile of carbon becomes hollow during the ITB phase and the central carbon density keeps dropping and reaches 0.1 - 0.3% of plasma density at the end of the ion ITB phase[1)].

The details of the time evolution of electron and ion temperature and electron and impurity density profiles are plotted in Fig.1. The changes in profiles after the transition from the L-mode phase to the ITB phase are indicated by arrows. The electron temperature increases after the onset of N-NBIs ($t = 1.9$s) but it saturates in the time scale on the order of the global energy confinement time of $\sim$ 40ms. The ion temperature profiles measured with a 50 spatial channel CXS system are as broad as electron temperature profiles in the L-mode phase and they become peaked at the plasma center along with the increase of the central ion temperature in the ITB phase($t > 2.06$s). The central ion temperature exceeds the central electron temperature and reaches 4 keV. In the ion ITB phase, the ion temperature gradient at half of the plasma minor radius ($\rho = 0.5$) is 5 -6 keV/m, which is twice the electron temperature gradient. The significant differences in the profiles between the electron temperature and ion temperature indicates that there are clear differences in the heat transport between the electron and ion channels and the heat transport improvement appears only in the ion transport not in the electron transport. The electron density profiles are flat in the L-mode phase and in the ITB phase, while the profile becomes slightly peaked during the transient phase from the L-mode phase to the ITB phase. The carbon density profile is slightly hollow in the L-mode phase and it becomes extremely hollow in the ITB phase and the central carbon density keeps decreasing and reaches 0.2 - 0.3% of the electron density at the plasma center. The central carbon concentration is one order of magnitude lower than the carbon concentration near the plasma periphery.

The relation between the ion temperature gradient at half of the plasma minor radius of $\rho = 0.6$ and the central carbon density is plotted in Fig.2. In the L-mode discharge with low N-NBI power, the ion temperature gradient is below 3 keV/m and central carbon density is $\sim 1 \times 10^{17}\mathrm{m}^{-3}$ which is 1 % of the electron density. In the discharge with an ion ITB, the ion temperature gradient increases to 5 keV/m after the formation of the ion ITB and the impurity hole formation starts. Associated with the further increase of the ion temperature gradient up to 6 keV/m, the central carbon density drops to $\sim 3 \times 10^{16}\mathrm{m}^{-3}$ which is only 0.3 % of the electron density. It should be noted that the trajectory of the data points indicates the ion ITB formation precedes the impurity hole formation.

1) K.Ida el., Phys. Plasmas, **16** 056111 (2009).

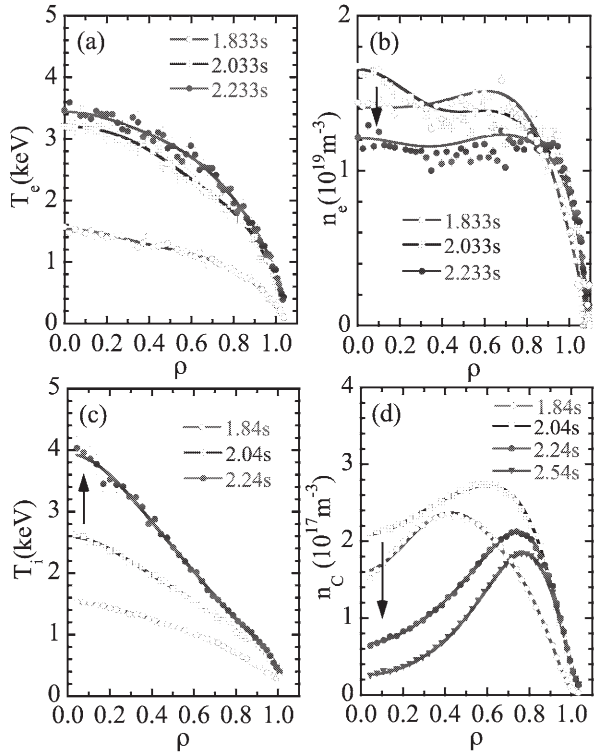

Fig. 1: (Color online) Radial profiles of (a) electron temperature, (b) electron density, (c) ion temperature and (d) carbon density at the L-mode phase (t=1.84s), just before the transition from the L-mode to the ITB phase (t=2.04s) and at the ITB phase (t=2.24s and t=2.54s).

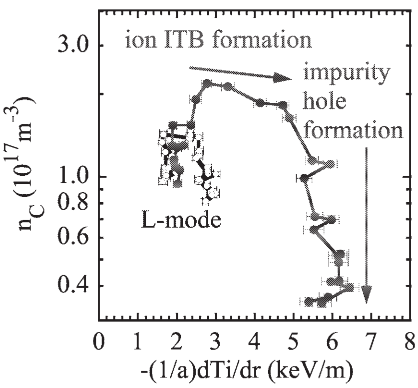

Fig. 2: (Color online) Relation between central carbon density and temperature gradient at $\rho = 0.6$ for the L-mode discharge and ITB discharge. The data is plotted every 20ms.