§5. Observation of Low He/H Density Ratio in the Edge Stochastic Layer in LHD

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Transport of helium is one of the crucial issues in fusion plasma and has been studied by using charge exchange spectroscopy. Charge exchange spectroscopy has been widely used as a powerful tool to measure radial profiles of ion temperature and toroidal rotations using the charge exchange lines of impurities. Compared with the charge exchange spectroscopy using impurities such as oxygen, carbon and helium, the cold component emitted from plasma periphery due to the charge exchange reaction with thermal neutral is relatively large in hydrogen. Recently the charge exchange spectroscopy was applied to the bulk plasmas by subtracting the emission from plasma periphery by beam modulation. By using beam modulation, radial profiles of helium and hydrogen can be measured with charge exchange spectroscopy.

Radial profiles of density ratio of helium to hydrogen ions are measured using charge exchange spectroscopy technique with two-wavelength spectrometer in the wide range of the density ratio of 0.05 - 5 in the Large Helical Device. The method of relative calibration of density ratio of helium to hydrogen is discussed. The density ratio of helium to hydrogen can be measured with passive spectroscopy in the recombining phase at the termination of the plasma, where the temperature decreases rapidly. In this case the assumption of helium transport is not necessary, because all the ions in the plasma experience recombining phase during the termination period using H_α (n=2-3: 656.3 nm) and HeII (n=4-6: 656.0nm)[1]. The charge exchange spectroscopy system is calibrated just before the termination in the discharge where the density ratio of helium to hydrogen is constant in space (flat profile).

Figure 1 shows the radial profiles and time evolution of density ratio of helium to hydrogen in the discharge with helium puff. The density ratio of helium to hydrogen increases after the He gas puff and reaches to 2.0. It should be noted that the $n_{\rm He}/n_{\rm H}$ value outside LCFS stays at a low level of 0.3. This result shows that the helium density outside LCFS (X-point region) does not increase even if helium gas is puffed. The time evolution of $n_{\rm He}/n_{\rm H}$ and the ratio of influx are plotted in Fig. 1(b). The He gas puff is applied at t = 3.4 s and the gas flow exceeds 10 Pa m^3/s and decreases to zero at = 3.8 s. Because the recycling rate of helium is higher than that of hydrogen, the $n_{\rm He}/n_{\rm H}$ value continue to increase after the turning-off of the He gas puff and reaches the maximum value of 2.0 at t = 4.1 s. The $n_{\rm He}/n_{\rm H}$ value inside LCFS is higher than the influx ratio, while that outside the LCFS is lower than the influx ratio. This result clearly shows that the density ratio in the plasma is not identical to the influx ratio because of the difference in penetration and transport between helium and hydrogen.

The decrease of $n_{\rm He}/n_{\rm H}$ value outside LCFS is not due to the low temperature. The electron density and temperature are high enough to make the helium become fully ionized. The electron density and temperature measured with YAG Thomson scattering at the LCFS is 1.5-4.0$\times 10^{19}$m^{-3} and 0.3-0.4 keV. Therefore the significant drop of $n_{\rm He}/n_{\rm H}$ ratio at the LCFS is an interesting observation, In this experiment, the $n_{\rm He}/n_{\rm H}$ ratio is measured at the mid plane where the helical X-point and stochastic layer locates just outside the LCFS. These observations demonstrates that the helium impurity is efficiently exhausted in the stochastic layer near the X-point.

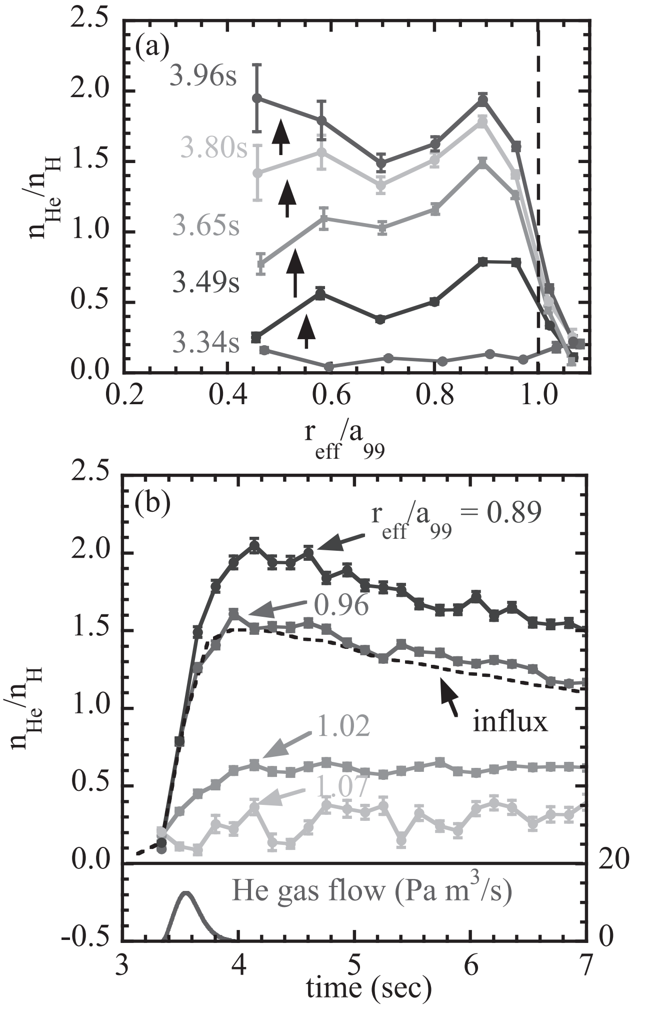

Fig. 1: (a)Radial profiles and (b)time evolution of density ratio of helium to hydrogen in the discharge with helium puff.

1) M.Goto, S.Morita, K.Sawada, T.Fujimoto, S.Yamamoto, J.Miyazawa, H.Yamada, K.Toi, Phys. Plasmas **10** (2003) 1402.