§18. Z Dependence of Impurity Hole in High Ion Temperature Plasma on LHD

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Impurities tend to accumulate in the plasma with an improved confinement mode. The impurity transport is eagerly studied to avoid the impurity accumulation in the high confinement plasma in various magnetic confinement devices. In non-axisymmetric systems, contribution to the neoclassical impurity transport by radial electric field is more dominant than the contribution by the temperature screening effect. Inward convection of impurities is expected from neoclassical theory in the plasma with a high ion temperature gradient because of the negative radial electric field. The negative electric field is observed with heaby-ion-beam-probe in the core region in the high ion temperature plasmas on LHD and inward convection of carbon impurities are predicted by the neoclassical theory. Furthermore, extremely hollow profiles of impurity have been observed in the high ion temperature plasma with a steep gradient of the ion temperature (ion ITB). Transport analysis shows the outward convection of carbon impurity increases associated with the increase of ion temperature gradient and the outward convection is opposite to the convection velocity predicted by the neoclassical theory [1]. We have described the hollow profile of impurities as "Impurity Hole".

It is expected that the impurity hole depends on the charge number, Z, by assuming that the radial electric field connects to the outward convection of impurity transport which produces the impurity hole. Impurity hole develops in a few 100ms from the time when the plasma with ion ITB is produced. Figure 1 shows the radial density-profiles of the electron, helium ($Z = 2$, $\lambda = 468.6$nm), carbon ($Z = 6$, $\lambda = 529.05$nm), and neon ($Z = 10$, $\lambda = 524.9$nm) after the impurity hole developed in the plasma with ion ITB. The density of these impurities are measured with charge exchange spectroscopy. The radial position of the magnetic axis is 3.6m. The ion temperature and the gradient are achieved 4keV and 6keV/m at $R = 4.1$m, respectively. The profiles of the impurities is hollow while the electron density profile is almost flat. To indicate the hollowness of these profiles, the normalized gradient of density of helium , carbon, and neon after the impurity hole developed in the ion ITB plasma are plotted in Fig.2. The normalized gradient of the helium density before the impurity hole developed is also plotted in Fig.2. The normalized gradient for the helium are about 2 at $Reff = 0.3$. This profile is similar to the profiles for carbon and neon. The normalized gradient of the carbon and neon profile is increased up to 4m^{-1} and 8m^{-1}, respectively, by developing the impurity hole within three hundred-milliseconds, while there is no significant change in the gradient of the helium profile. The result shows that the profile of higher Z ion species becomes more hollowed. Although the development of the hollow profile is not observed in the helium profile, no accumulation of helium is observed in the ion ITB discharges. This result can not be explained with the neoclassical transport which predicts that the inward convection becomes stronger for higher Z impurity due to the negative radial electric field in the plasma core.

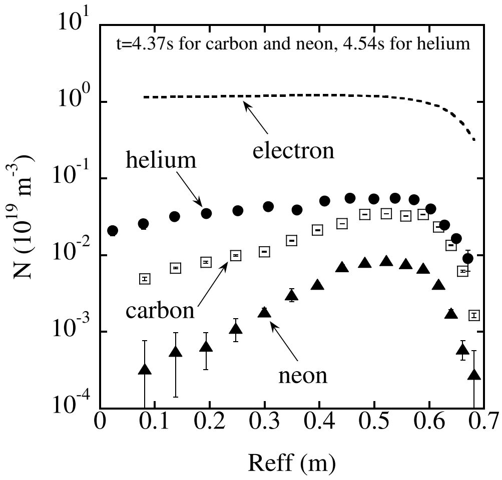

Fig. 1: Radial density profile of the electron (dotted line), helium (circle), carbon (square), and neon (triangle) after the impurity hole developed.

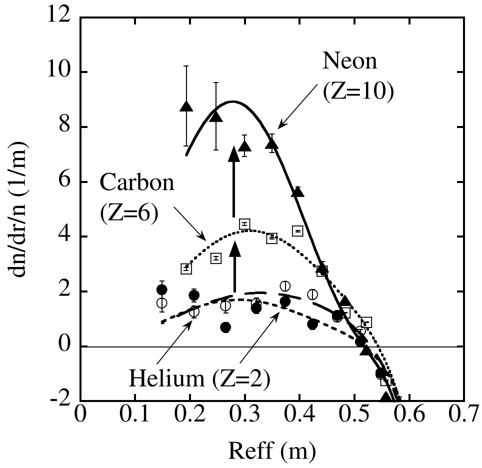

Fig. 2: Radial profile of normalized density gradient of helium (closed circle), carbon (square), and neon (triangle) after the impurity hole developed. The gradient of helium before the impurity hole developed is also plotted (open circle).

1) M. Yoshinuma et al., "Observation of an impurity hole in the Large Helical Device" Nucl. Fusion (2009) vol.49 062002.