§14. Estimation of Diffusion and Convection in Plasma with Impurity Hole in LHD

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It is desirable for the fusion plasma that the hot plasma core is produced with less an impurity, because the impurity causes reduction of the fusion power density through an enhancement the cooling of the plasma by radiation and a dilution of the hydrogen fuel. Profiles of the impurities have been watched with a keen interest while the transport and behaviors of impurities strongly affect on the characteristics of the plasma in magnetically confined fusion experiments. In the large helical device (LHD), an extreme hollow profile of carbon impurity has been observed in the high ion temperature plasma.

An impurity hole which is the extremely hollow profiles of carbon is clearly observed in a discharge with injection of a single carbon pellet, which is intended to increase the deposition of the high-energy neutral beam and to increase the ion temperature in the plasma with the magnetic field strength B_0=-2.676T, the position of magnetic axis R_{ax}=3.6m, the pitch parameter γ=1.254, and the cancelling rate of the quadrupole field B_q=100%. The electron density rapidly increases just after the injection of the carbon pellet at 0.8s in the discharge, which is targeted for the estimation, and then decreases on a time scale of a few hundred milliseconds. The ion temperature increases during the decay phase of the electron density.

Figure 1(a) shows profiles of the ratio of the carbon density to the total density of ion on the time of growing up the hollow profile of the carbon. The ratio is over 10 percent before the time of 1.25s at which the growing of the impurity hole start. Then the density of the carbon decreases associated with increasing of the ion temperature and its gradient, especially in the plasma core. The ratio, at last, decreases down to smaller than 0.3 percent at the time of 1.65s in the plasma core, while the carbon density still remains a few percent at the plasma edge, and the extreme hollow profile of the carbon impurity formed.

We have estimated the diffusion and convection of both the carbon and hydrogen by using the carbon and the electron density profiles which measured with the CXS and the YAG Thomson scattering, respectively. The source of the hydrogen injected with NBI estimated by FIT code calculations. Source of the carbon is only the pellet in the estimation, and we neglect the fuelling of the carbon from the peripheral.

Figure 1(b) and (c) shows the diffusion coefficient D and the convection velocity V, respectively, of the carbon and the hydrogen. The diffusion coefficient of hydrogen is larger than that of carbon while the shapes of the profile are almost same as shown in Fig. 1 (b). The convection velocity of the carbon is positive, which shows outward flow, while the convection velocity of the hydrogen is almost zero in the mid-radius of the plasma as shown in Fig. 1 (c). The outward flow is considered to be a key for the formation of the hollow profile of the carbon, and the hollow profile is not observed in the profiles of the hydrogen. The impurity hole is grew up and sustained with the small diffusion and the outward convection.

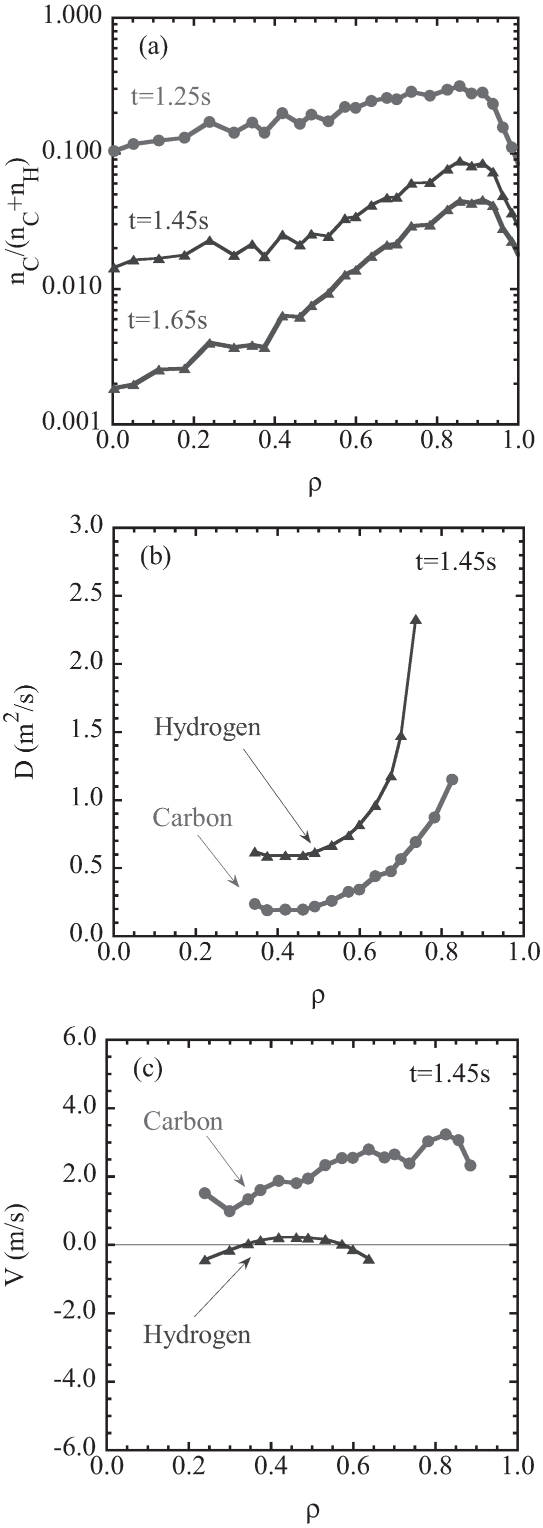

Fig. 1. (a) The profiles of ratio of the carbon density to the total density of ion with in growing of the impurity hole. (b) The profiles of diffusion coefficient of the carbon (circle) and hydrogen (triangle). (c) The profiles of convection velocity of the carbon (circle) and hydrogen (triangle).