§55. A Study of Charge Dependence of Impurity Transport on LHD

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Impurity transport study is one of the critical issues for magnetically confined toroidal plasmas. For the purpose, a new method combined impurity pellet injection[1] with absolutely calibrated high-spatial resolution bremsstrahlung measurement[2] has been applied to hydrogen plasmas on LHD. The bremsstrahlung diagnostic is a powerful tool to be capable of monitoring particle behaviors from the plasma center to the edge.

Carbon, aluminum and titanium pellets were injected into a stationary phase of NBI heated plasmas (R_{ax}=3.6m) in order to investigate particle transports from the transient response. The particle transports were analyzed using a diffusive/convective model [Eq. (1)], and these impurities existed in collisional regime on this experimental condition. The transport coefficients (diffusion coefficient D and convective velocity V) were determined by minimizing the residual error between the measured and calculated bremsstrahlung intensities taking into account the recycling coefficient.

$$\Gamma_q = -D_q(r)\frac{\partial n_q}{\partial r} + V_q(r)n_q, \qquad (1)$$

where Γ_q and n_q are the particle flux and the ion density of the q^{th} charge state, respectively.

The impurity transport was calculated using a one-dimensional impurity transport code, assuming that the D was independent of the impurity ion charge state and the V depended linearly on it. As the result, the D had a spatially constant profile. On the other hand, an inward convection appeared at $\rho>0.6$ where the electron density gradient was significant, and no convection was required at $\rho<0.6$[3] (see Fig.1.).

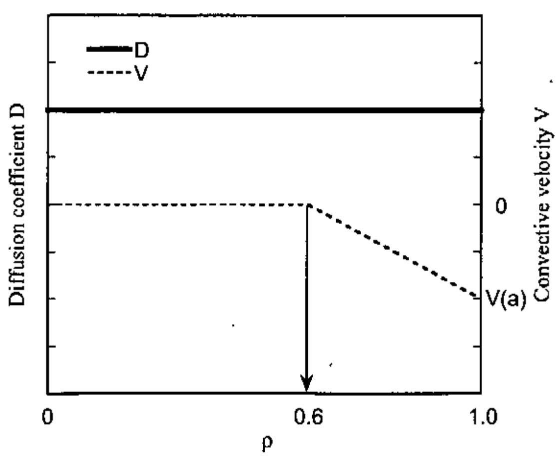

Fig.1. Spatial structure of transport coefficients D and V. The V(a) indicates the inward convective velocity at $\rho=1$.

Thus, it is concluded that the obtained inward V depends on the electron density profile rather than the electron temperature profile. Since it is predicted that an impurity inward V exists in the region with the bulk ion (proton) density gradient in collisional regime on neoclassical theory, the estimated spatial structure of the inward V is consistent with the theory on the assumption that $n_e(\rho)=n_i(\rho)$.

Figure 2 shows dependences of D and V at $\rho=0.8$ on the line-averaged electron density. Dependence of the D on the electron density, the impurity species and its charge state is weak [typically D=0.15-0.25m^2/s in the range of $n_e=1.4\text{-}5.2\times10^{19}m^{-3}$], whereas the inward convection has a strong dependence not only on the electron density but also the impurity ion charge state. Since it is also expected on neoclassical theory that the inward V is proportional to the impurity ion charge state, the charge dependence of the inward V is in good agreement with the theory (see Fig.2). Furthermore, aluminum and titanium were explained as a non-recycling particle. Recycling coefficient of carbon had a finite value from 0.5 to 0.65.

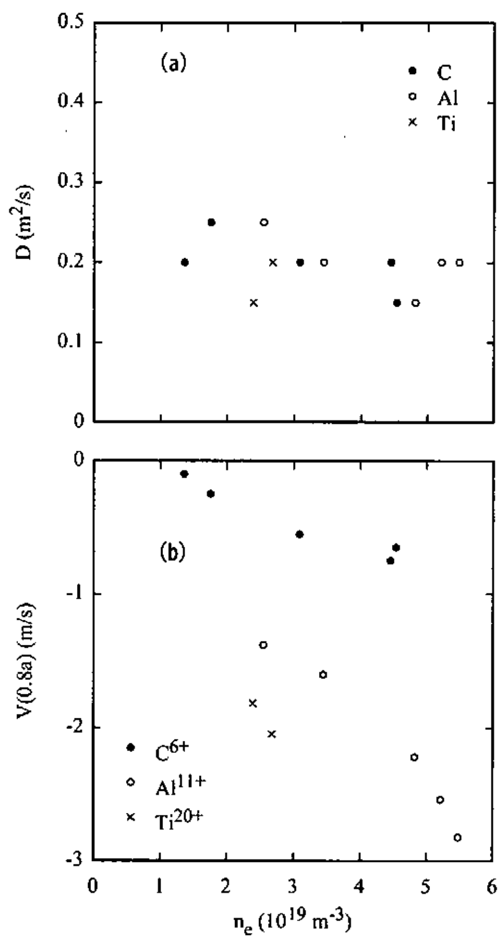

Fig.2. (a) Diffusion coefficient and (b) convective velocity at $\rho=0.8$ as a function of line-averaged electron density.

References

1)Nozato, H., Rev. Sci. Instrum. **74**, 2032 (2003).
2)Nozato, H., J. Plasma Fusion Res. Series **5**, 442 (2002).
3)Nozato, H., Phys. Plasmas **11**, 1920 (2004).