§5. Edge Impurity Transport Study in Stochastic Layer of LHD and Scrape-off Layer of HL-2A

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Understanding of edge impurity transport is one of the most critical issues in magnetically confined fusion devices, in order to keep a purity of core plasma by reducing the impurity influx through LCFS (last closed flux surface), to identify material migration process and to control the impurity radiation pattern/intensity for achieving stable radiative/detached divertor operation. While the tokamak X-point poloidal divertor is being optimized in various aspects in the 2D axi-symmetric geometry, there is also another approach by exploring a possibility of the 3D magnetic field geometry with symmetry breaking, which naturally occurs in the helical devices due to the coil configuration or in the non-axisymmetric tokamaks with the externally applied resonant magnetic perturbation field. The 3D configuration usually introduces stochasticity of magnetic field structure in the edge region, where one expects substantial difference in the transport properties compared to those in the axi-symmetric tokamak scrape-off layer, in terms of coupling between transport components of parallel and perpendicular to magnetic field lines. An attempt is made to analyze the effects of the different magnetic field geometries on the edge impurity transport by comparing the stochastic layer of LHD (Large Helical Device) and the scrape-off layer (SOL) of HL-2A. The analyses are based on the 3D edge transport code simulations implemented in the both devices.

As a measure of degree of the screening, the ratio, $n_{LCFS}^{imp}/n_{dowm}^{imp}$, is plotted in Fig.1 as a function of ν_{SOL}^{*ion}, where n_{LCFS}^{imp} and n_{dowm}^{imp} are the impurity density at LCFS and near divertor plates, respectively, summed up over all charge states. In HL-2A, n^{imp} is obtained by averaging over all flux tubes in the outer and inner divertor legs. ν_{SOL}^{*ion} is evaluated at LCFS. In LHD, the variation of ν_{SOL}^{*ion} in the stochastic layers is indicated with the error bars. The high and low end values correspond to those at around LCFS and the edge surface layers, respectively. When the ratio $n_{LCFS}^{imp}/n_{dowm}^{imp}$ becomes below unity, it can be considered that the screening starts. The impurity source is distributed not only at the divertor plate but also at the first wall uniformly for the both devices to see the effect of source location. In HL-2A, the ratio decreases rapidly above $\nu_{SOL}^{*ion}\sim1$, down to 0.1 showing strong screening against the divertor source. On the other hand, there is almost no screening effect against the first wall source. This is due to the residual thermal force at the upstream, i.e. around X-point even at the high density case, which can not be removed throughout the whole density operation range.

In the case of LHD, at the lowest $\nu_{SOL}^{*ion}\sim1$ with the thermal force dominant regime, there is impurity build up at the upstream but the ratio is relatively small $n_{LCFS}^{imp}/n_{dowm}^{imp}$ compared with HL-2A. With increasing ν_{SOL}^{*ion}, the ratio decreases down to ~0.3 and saturates. The screening is effective also for the first wall source as shown in Fig.1, and the behavior is similar between the divertor and first wall source, in contrast to HL-2A. This is due to the almost uniform distribution of the friction dominant region in the poloidal direction, which then provides effective screening against the impurity coming from any direction. The difference is attributed to the ionization source distribution, i.e. the flow acceleration, between the two devices. The ionization source is limited below the X-point in HL-2A. In LHD, on the other hand, the divertor plates are situated along the divertor legs which rotate in poloidal direction according to the helical coils. Therefore, there exists substantial amount of the recycling neutrals from the divertor plates in all poloidal direction. This gives rise to the poloidally distributed flow acceleration through the ionization source, resulting in the poloidally distributed friction dominant region.

It is also found that the reduction of $n_{LCFS}^{imp}/n_{dowm}^{imp}$, i.e. screening, at the highest ν_{SOL}^{*ion} is stronger in HL-2A. This is considered due to the contribution of perpendicular transport, which alters the coupling between divertor plasma parameter and the upstream density: For HL-2A, $T_{down}\propto n_{up}^{-2}$, $n_{down}\propto n_{up}^{3}$, while for LHD, $T_{down}\propto n_{up}^{-1\sim-2/3}$, $n_{down}\propto n_{up}^{1\sim1.5}$ [1]. One expects that increasing (upstream) density leads to different downstream plasma parameter change between the two devices, which then results in the distinct feature of the impurity transport.

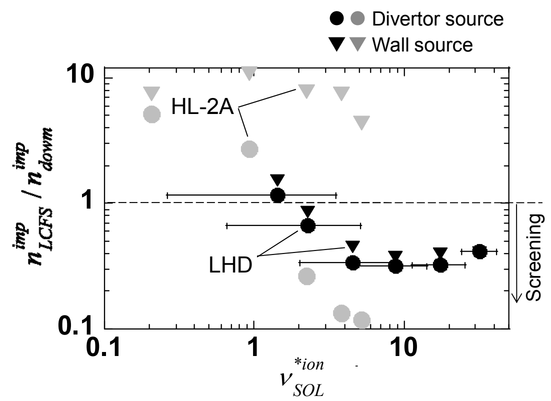

Fig. 1. The ratio $n_{LCFS}^{imp}/n_{dowm}^{imp}$ as a function of collisionality. Circles: impurity released at the divertor plate, triangles: impurity released at the first wall, for LHD (black symbols) and HL-2A (grey symbols).

1) Kobayashi, M. et al. : Fusion Sci. Technol. **58** (2010) 220.