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Divertor characteristics and control on the W-shaped divertor with pump of JT-60U

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In JT-60U, the previous open divertor was modified to a W-shaped divertor with pump last year(Fig. 1) [1]. The W-shaped divertor is characterized by a dome in the private flux region and pumping from the inboard side in the private flux region, which has never been found in other tokamaks. This paper will discuss divertor characteristics such as particle recycling, impurity reduction etc. from viewpoints of divertor geometrical effects and divertor pumping effects.

Geometrical effects of W-shaped divertor on pumping and particle recycling

As shown in Fig. 1, particle pumping in the W-shaped divertor is done from the inboard side of the private flux region divided by the dome(inner pumping). The measured pumping speed is 13 m3/s in molecular flow at the pumping slot in the divertor. A good feature of inner pumping is that high pumping efficiency is expected even with relatively small pumping speed, because the neutral pressure at the inner divertor region is enhanced compared with the outer divertor region due to in-out asymmetry of particle recycling in the usual discharges with ion grad_B drift toward the divertor. In fact, the pumping probability for the particle flux to the divertor in discharges with ion grad_B drift toward and away from the divertor are about 0.6-2% and about 0.2% respectively, showing the importance of pumping location. Figure 2 shows a plot of divertor pumping slot pressure(P1 in Fig. 1), mid-plane pressure in the main chamber(P0) and pressure ratio(P1/P0) as a function of main electron density in L-mode discharges. The different trajectories of pressure show that by adjusting the gap between the plasma surface and the outer baffle (δ_{out}) and the gap between the inner separatrix and the inner wing of the dome (δ_{pump}), the mid-plane pressure and the divertor pumping slot pressure are controlled, respectively. As a result, in the outer X-point configuration with narrow δ_{out} and δ_{pump}, the divertor pumping slot pressure increases up to about 0.5 Pa with the mid-plane pressure kept at about 0.2 mPa. In contrast to this, in the inner X-point configuration, the mid-plane pressure rises twice due to the leak of neutral particles through the large gap δ_{out}. After the MARFE onset shown by shadow in Fig. 2, the increasing rate in divertor pumping slot pressure becomes small and neutral pressure at the outer divertor region(P2 in Fig. 1) begins to increase. In this case, the dome plays a role of separating the inner and outer divertor region in the private flux region.

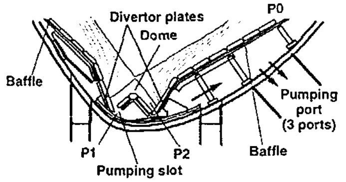

Fig. 1 Structure of W-shaped divertor

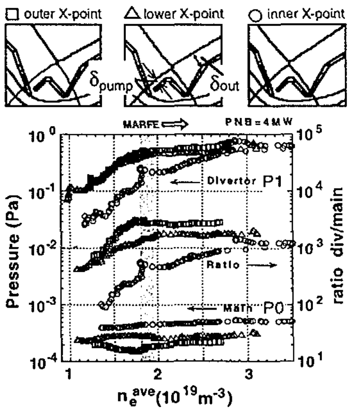

Fig. 2 Dependence of the divertor pumping slot pressure, the mid-plane pressure and pressure ratio on divertor geometry and plsama configurations.

Geometrical effects of dome on reduction of hydrocarbon generated by chemical sputtering

According to the simulation analysis of impurity transport in the W-shaped divertor[2], it is expected that the existence of the dome impedes free upstream motion of hydrocarbon gas produced by chemical sputtering in the private flux region, resulting in reduction of direct penetration of carbon impurities to the X-point vicinity. To confirm this effect, spatial profiles of spectrum band of CD which comes from methane were measured in the L-mode discharges (PNBI=4.7 MW, Ip=1.2 MA), and were compared between the W-shaped divertor and the previous open divertor. As clearly seen in Figs. 3(a) and (b), in the case of W-shaped divertor, CD band intensity near the X-point remains low when the density is increased to the density just below the MARFE onset($2x10^{19}$ m^{-3}). In contrast, in the case of open divertor, CD band intensity near the X-point is found to increase with the increase in electron density. This difference qualitatively agrees with the simulation analysis, suggesting the dome effect on impurity reduction.

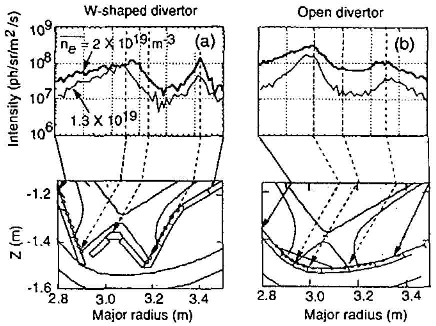

Fig. 3 Comparison of CD band intensity profiles between W-shaped divertor and open divertor

Effects of gas puff and pump on reduction of carbon impurities

A SOL flow generated by a combination of gas puff and pumping is expected to drag impurities to the divertor by frictional force, and is potentially an effective method of impurity shielding[3]. In JT-60U, the effectiveness of this method for carbon impurities was investigated with detailed spectroscopic measurements for attached divertor states. Fig. 4 shows spatial profiles of CII and CIV lines at the divertor region measured in two ELMy H-mode discharges with gas puff only from the main chamber and only from the divertor chamber . Since the SOL effect is expected in the inner divertor region with the pumping slot, CII and CIV intensities at the inner divertor are important. For comparison, carbon impurity generation at the divertor tiles shown by CII intensities in Fig. 4(a) as well as main electron densities were controlled at almost the same value. Therefore, the difference in CIV intensity shown in Fig. 4(b) is considered to show that carbon impurities are dragged to the divertor in the case of main gas puff. Corresponding to the this difference, carbon density in the main plasma was also found to be smaller by about 20%. This suggests that SOL flow generated by main gas puff and divertor pumping was effective in impurity shielding.

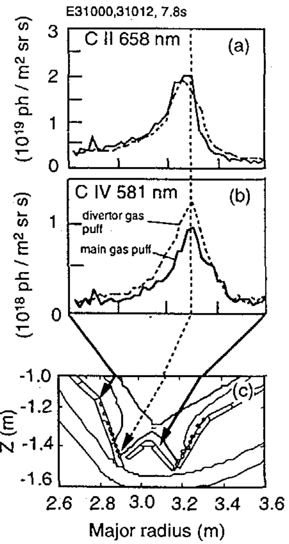

Fig. 4 Comparison of CII and CIV intensity profiles in the divertor obtained in the discharges with divertor gas puff only and main gas puff only.

[1] N. Hosogane et al., in Fusion Energy 1996 (Proc. 16th Int. Conf. Montreal, 1996), Vol. 3, IAEA, Vienna (1996) 555.
[2] K. Shimizu et al., J. Nucl. Mater., 241-243(1997)167
[3] M. A. Mahdavi et al., in Fusion Energy 1996 (Proc. 16th Int. Conf. Montreal, 1996), Vol. 1, IAEA, Vienna (1996) 397.