*34th EPS Conference on Plasma Phys. Warsaw, 2 - 6 July 2007 ECA Vol.**31F**, P-1.024 (2007)*

Deposition and Transport of ^{13}C from Methane Injection into Outer Divertor Plasma in JT-60U

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1. Introduction

Carbon material is a candidate for the divertor target plate of ITER because of its low atomic number and good thermal properties, while its high erosion yield reducing the lifetime of the divertor target plate and redeposition incorporating a large amount of tritium are concerned. Therefore the carbon transport in tokamaks has been extensively studied. In most tokamaks, the inner divertor is deposition dominated, while the outer divertor erosion dominated [1-5]. The mass balance between the two, however, is missing; the deposited mass on the inner divertor exceeds the eroded mass at the outer divertor. Hence it is critically important to understand the mechanisms of carbon transport and deposition in tokamaks.

^{13}C tracer experimtens, i.e. $^{13}CH_4$ puffing into plasmas, have been conducted to investigate the carbon transport. In previous experiments, $^{13}CH_4$ has been injected mostly from the top of plasma or the outer midplane to simulate carbon impurities originated from the first walls (main chamber) [6-8]. In JT-60U, to investigate the transport of carbon impurities originated at the outer divertor tiles, $^{13}CH_4$ was puffed into the outer divertor SOL plasmas. After the $^{13}CH_4$ puffed discharges, the poloidal and toroidal distributions of ^{13}C deposition on dome-wing tiles and divertor tiles have been investigated [9]. In this paper, we have focused on the toroidal distribution of ^{13}C deposition on the divertor tiles and side surfaces of the dome-wing tiles.

2. Experimental

The $^{13}CH_4$ puff experiment was conducted at the last day of the 2004 experimental campaign, and no plasma discharge experiment was performed afterwards. Figure 1 shows the poloidal position of a $^{13}CH_4$ puffing nozzle located between the outer divertor tiles in P-8 toroidal section. In order to introduce $^{13}CH_4$ into the outer divertor SOL plasma, the outer divertor leg was positioned at a little inboard side from the nozzle position. L-mode plasmas were used for the $^{13}CH_4$ puff experiment in order to avoid ELM. The total of ~2 x 10^{23} $^{13}CH_4$ molecules were puffed into the L-mode plasmas of I_p = 1.0 MA and B_T=2.5 T. The duration of NBI heating in a discharge was about 30 seconds and 13 consecutive plasma discharges were repeated under the similar condition. After the $^{13}CH_4$ puff experiment, a total of 30 tiles in P-8 and P-5 (toroidaly 60^o apart from P-8) toroidal sections were extracted. Depth profiles of $^{13}C^-$ deposited on the tiles were obtained by using a quadrupole secondary ion mass spectrometer (ADEPT-1010, Ulvac-Phi). The ^{13}C areal density was evaluated by integrating the intensity ratio ^{13}C and ^{12}C, assuming the bulk density of the deposition layers to be 0.91 g/cm^3 [10].

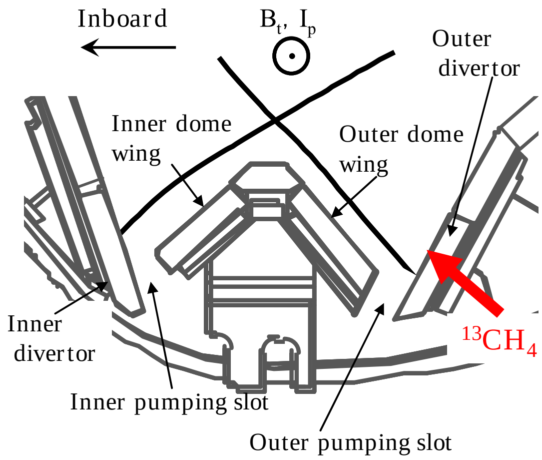

Fig.1 Poloidal cross section of the divertor region of JT-60U with location of $^{13}CH_4$ puffing nozzle.

3. Results and Discussion

The poloidal distribution of ^{13}C deposition areal density on the outer divertor tiles peaked at the strike point. Figure 2 shows the toroidal distribution of ^{13}C deposition areal density at the strike point on the outer divertor tiles. One can clearly see the areal density peaked near the $^{13}CH_4$ puffing nozzle with the density of ~10^{21} cm^{-2} and large asymmetry between the upstream and downstream sides. As indicated in an arrow in Fig.2, we can conclude that ionized ^{13}C particles are transported to the downstream direction by SOL plasma flow in the outer divertor region.

Figure 3 shows the poloidal distribution of ^{13}C deposition areal density on the inner divertor tiles and the frequency of strike point for comparison. Different from the outer divertor, the poloidal distribution of ^{13}C areal density

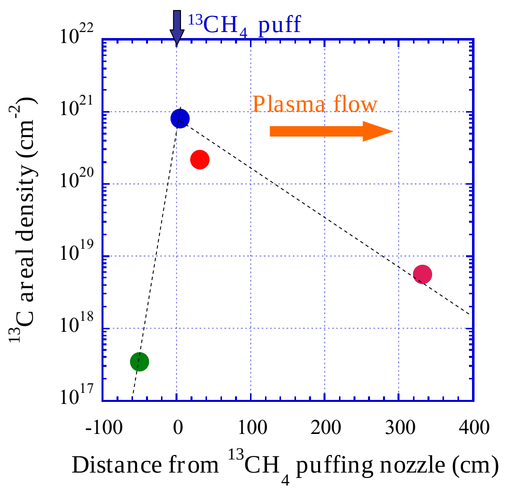

Fig.2 Toroidal distribution of ^{13}C areal density at the strike point on the outer divertor tiles.

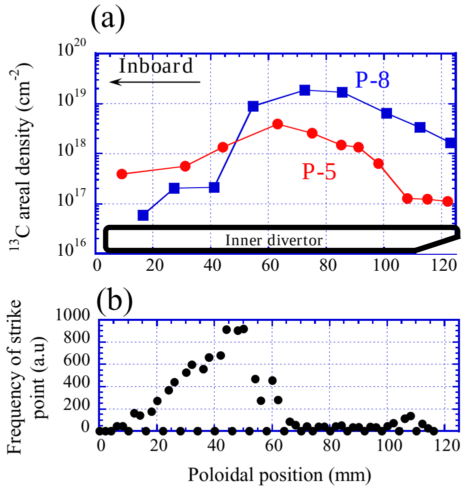

Fig.3 Poloidal distribution of ^{13}C areal density on the inner divertor tiles in P-5 and P-8 toroidal sections (a) and the frequency of strike point (b).

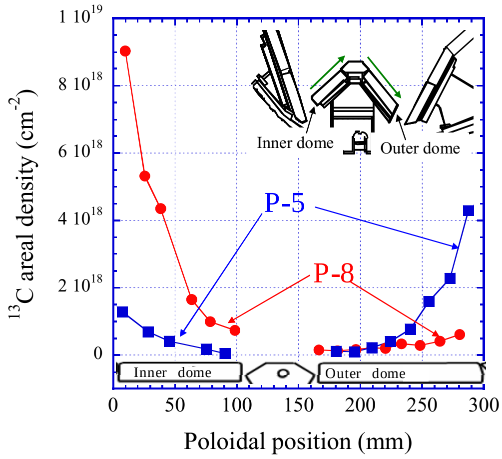

Fig.4 Poloidal distribution of ^{13}C areal density on the outer dome-wing and the inner dome-wing tiles in P-5 and P-8 toroidal sections.

on the inner divertor tiles in both P-5 and P-8 toroidal sections peaked at a little outboard side from the strike point. This result might be caused by ^{13}C transport through the private flux region.

Figure 4 shows the poloidal distribution of ^{13}C deposition areal density on the inner and outer dome-wing tiles in P-5 and P-8 toroidal sections. The poloidal distribution of ^{13}C areal density on both the inner and the outer dome-wing tiles had a profile rapidly decreasing toward the dome top. This distribution is very similar to the carbon deposition distribution on the outer dome-wing tile which was already measured by Gotoh et al [3], indicating that ^{13}C influx on the lower side of the dome-wing tiles was larger than that on the dome top. ^{13}C was also deposited on the poloidal side surfaces facing pumping slot on which ionized particles couldn’t reach. These results suggest that significant amount of neutral particles was transported through private flux region without ionization.

Figure 5 compares ^{13}C deposition areal density on the toroidal side surfaces of the dome tiles in P-8 toroidal section. Analyzed positions indicated by arrows in Fig.5 were located at 3 mm down from the plasma-facing surface. Note that the direction of the SOL plasma flow is inverse between the inner and the outer divertor regions [11]. Little amount of ^{13}C was deposited on the toroidal side surfaces near the dome top. In contrast, on the bottom of the tile ^{13}C deposition was clearly seen at the toroidal side surfaces facing to the upstream side. This result indicates ^{13}C deposited on the dome tiles was transported from the upstream direction.

4. Conclusion

Transport of carbon impurities generated on the outer divertor has been simulated by ^{13}C tracer experiment in JT-60U with $^{13}CH_4$ puffing at the outer divertor. On the outer divertor tile surfaces, the poloidal distribution of ^{13}C deposition areal density peaked at the strike point and ^{13}C was mostly deposited in the downstream side from the $^{13}CH_4$ puffing nozzle. This result indicates that ionized ^{13}C particles were transported to downstream direction by SOL plasma flow. On the inner and the outer dome-wing tiles, ^{13}C was locally deposited on the lower side surface and also on the toroidal side surfaces facing to upstream direction. The poloidal distribution of ^{13}C deposition areal density on the inner divertor tiles had a peak at a little outboard side from the inner strike point suggesting ^{13}C transport through the private flux region.

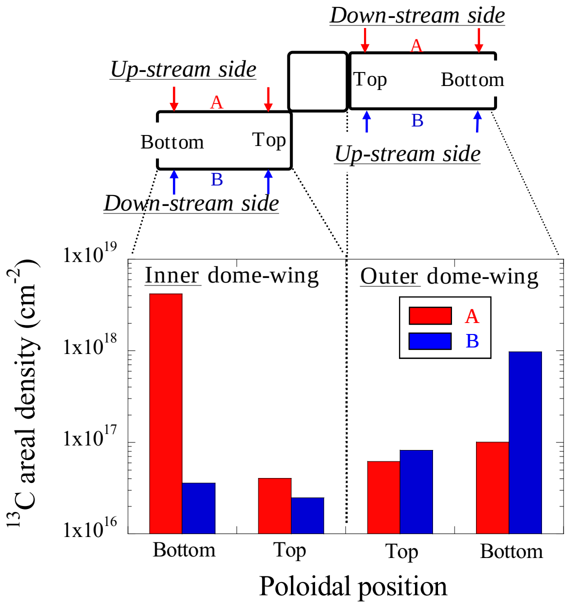

Fig.5 Top view of the dome-wing tiles in P-8 toroidal section (upper) and ^{13}C areal density on the toroidal side surfaces of the dome-wing tiles (lower). Arrows indicate the analyzed positions.

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