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Migration of ^{13}C and deposition at ASDEX Upgrade

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Abstract

To investigate material transport in scrape-off layer plasma and long term deposition in divertor, $^{13}CH_4$ was puffed at the end of 2004 and 2005 experimental campaigns into ASDEX Upgrade from the outer mid-plane. Ex situ analyses of the tiles were performed by secondary ion mass spectrometry. The peaks of ^{13}C were detected below the bottom inner strike point and at the horizontal tile at the outer lower divertor. It was detected ∼21% of the total puffed ^{13}C amount. The deposition rate for carbon by plasma was also calculated in long term experiment. It was obtained to be 22×10^{-3} and 8.7×10^{-3} g/s for the upper (campaign 2004) and lower (campaign 2003) divertors, respectively.

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1. Introduction

Understanding the balance of erosion and redeposition in a divertor with an ITER-like plasma facing component arrangement (metallic first wall and carbon divertor) is very important in order to predict material migration from the main wall to the divertor, and vice versa. Moreover, because carbon is known to trap hydrogen isotopes and form co-deposited hydrocarbon layers [1,2], study of material transport in the scrape-off layer (SOL) plasma helps to estimate the expected size and localisation of the retained tritium in ITER.

Some experiments using ^{13}C as a tracing element for carbon redeposition were performed at JET [3] and DIII-D [4]. Different puffing locations and plasma operation regimes were utilized. To complete our earlier study performed on ASDEX Upgrade [5], we present in this paper results on ^{13}C transport in SOL and deposition on upper and low divertors obtained by measuring the deposition pattern of carbon on plasma facing components under controlled source conditions.

2. Experimental Setup

For post mortem erosion/deposition analyses a full poloidal set of marker tiles (stripes of 3 μm thick

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carbon layer on a 100 nm Re interlayer and 0.5 μm thick *W* layer, prepared by arc discharge method) was installed in the upper divertor (see Fig. 1) during the shutdown in 2003.

At the end of 2004 experimental campaign $^{13}CH_4$ was puffed into the torus from the outer mid-plane during 5 identical top single null H-mode (ELM type I) discharges in hydrogen. The puff was localized only in the sense that one gas valve was used. However, the valve is quite remote in the port. Therefore effectively the whole port acts as a source, which means it has the size of about 0.5 m^2. The molecules will penetrate the SOL to quite different depths which, combined with the large shear in the SOL, will lead to a very rapid distribution of the particles and therefore to a quite symmetric toroidal distribution [6]. The main plasma parameters were $I_p = 0.8$ MA, $B_t = -2.0$ T, $n_e = 9.0 \times 10^{19}$ m^{-2} and $P_{aux} = 5.1$ MW.

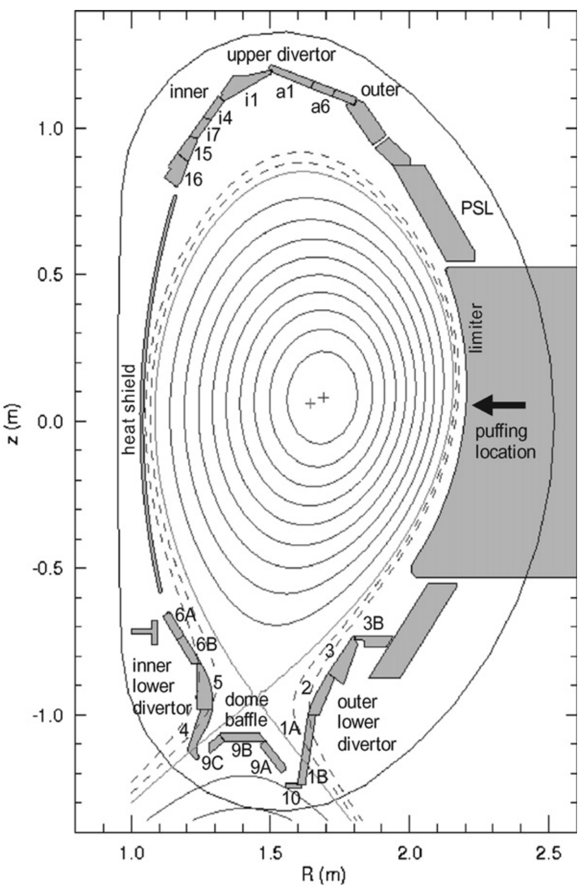

Fig. 1. Cross-section of the ASDEX Upgrade vacuum vessel together with the magnetic surfaces. Numbers correspond to the divertor tile numbers.

The total amount of ^{13}C injected during the experiment was 1.48×10^{22} atoms. ^{13}C serves as a marker because it can be distinguished from the ^{12}C isotope with surface analytical methods. A set of samples of 10 mm in diameter was cut from the divertor tiles on IPP site.

$^{13}CH_4$ was also puffed at the end of the 2005 experimental campaign into the torus from the outer mid-plane at one toroidal location during 13 identical bottom single null L-mode discharges (#20646–20659) in hydrogen. The main plasma parameters were $I_p = 0.8$ MA, $B_t = -2.5$ T, $n_e = 6 \times 10^{19}$ m^{-3} and $P_{aux} = 2.9$ MW. The total amount of ^{13}C injected during the experiment was 1.72×10^{22} atoms.

For ^{13}C profiling secondary ion mass spectrometry (SIMS) was utilised. A set of samples of 17 mm in diameter was cut from the tiles exposed in 2005 using a coring technique [3,7]. The number of the samples (1–3 samples from each tile depending on the tile size) was chosen to provide as many measurement points as possible along the marker stripes. SIMS analysis was made with a double focusing magnetic sector instrument (VG Ionex IX-70S) at VTT. The current of the 5 keV O_2^+ primary ions was typically 500 nA during depth profiling and the ion beam was raster-scanned over an area of 300×430 μm^2. Crater wall effects were avoided by using a 10% electronic gate and 1 mm optical gate. ^{13}C was profiled using a high mass resolution of 2000 ($m/\Delta m$ at m/z 28) to separate the element peak from the interfering isobar $^{12}CH^+$. The pressure inside the analysis chamber was 5×10^{-8} Pa during the analysis. The depth of the craters was measured by a profilometer (Dektak 3030ST) after SIMS analysis. The uncertainty of the crater depth was estimated to be 5%.

3. Results and discussion

3.1. $^{13}CH_4$ puffing experiment

Fig. 2 shows ^{13}C depth profiles for lower outer divertor tiles exposed in 2005 1B and 2 corresponding to *v*-coordinate of 0.27 and 0.62 m, respectively. *v*-coordinate represents the distance from the private flux region along the tiles surface and describes poloidal positions ($v = 0$ corresponds to the top edge of the dome baffle tile 9 A). ^{13}C signal was normalised with ^{12}C level and natural ^{13}C background was subtracted. Data indicate presence of ^{13}C at the surface region with following decrease