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INTRODUCTION

The large-scale use of beryllium [1] and tritium [2] at JET has limited the possibility of performing frequent and regular inspection of the modification of plasma facing components. Relatively sparse information exists on impurity transport and flows in the Scrape-Off Layer (SOL) plasma although this determines largely the migration of material and thus global erosion and re-deposition patterns. Therefore, the application of short-term plasma-inserted probes of various types is helpful as it permits the combination of *in-situ* electrical measurements with *ex-situ* surface analysis of the probe morphology. Results obtained with various electrical probes show a strong flow of the deuterium background plasma directed towards the inner divertor leg. The flow is believed to drive also impurities released from the walls. As a result, the formation of thick co-deposits containing vast quantities of fuel species (D and T) occurs in the inner divertor [3]. This is exemplified in Fig.1 showing the distribution of D and Be on the MKII-A divertor tiles.

Our report focuses on surface studies of co-deposits on fast reciprocating probe heads. The aim was to determine qualitatively and quantitatively species transported in the SOL, to recognise their radial and angular distribution on the probes and thus to conclude on the preferential direction of material transport (flows).

1. EXPERIMENTAL

JET is equipped with two fast reciprocating probe drives operated from the top of the vessel. During a single discharge the probes can be inserted three times with each cycle requiring 400ms. The study was carried out with two probes schematically shown in Fig.2: a retarding field analyser (RFA) and a turbulent transport (fluctuation) probe. The first one was exposed 72 times (including 16 cycles passing the separatrix) during the C1 experimental campaign, whereas the second probe was exposed to helium plasmas [4] and then to a series of discharges in deuterium with silane (SiH_4) and C-13 methane ($^{13}\text{CH}_4$) puffed to the SOL as transport markers (in C4 campaign). Afterwards, the probe heads were dismantled from the drives and transported to a surface analysis station. Nuclear reaction analysis (NRA) was used to determine the amount and distribution of deuterium [$\text{d}(^3\text{He}, \text{p})^4\text{He}$], carbon [$^{12}\text{C}(^3\text{He}, \text{p})^{14}\text{N}$], beryllium [$^9\text{Be}(^3\text{He}, \text{p})^{11}\text{B}$] and boron [$^{11}\text{B}(\text{p}, \alpha)^9\text{B}$].

2. RESULTS AND DISCUSSION

Fig. 3 presents an angular distribution of species measured around the circumference of the carbon cap of the RFA probe. The results obtained for the inconel slit plates of this probe are inserted into Table 1, whereas the data in Table 2 show the comparison of deposition efficiency given in terms of a concentration ratio for respective elements detected on the surface. The distribution of species transported in the SOL and then deposited on the two probes is clearly not uniform. On the ion drift side it is by a factor between 2 and 3 greater than the other side. Moreover, this result is in agreement with the Mach measurements (data from the same experimental campaign are shown in Fig. 4)

detecting the preferential flow direction of the deuterium background plasma towards the inner divertor leg. Accumulation of deuterium on plasma facing surfaces is predominantly associated with its co-deposition together with impurity atoms [5]. The analysis of the RFA slit plates reveals carbon as the major impurity species deposited the SOL. This result together with the determined preferential flow direction strongly contributes to the clarification of the origin of thick carbon deposits in the inner divertor.

Table 1: Deposition on the inconel slit plates of the RFA probe head.

| Element | i-side | e-side |
|---------------------------------|-----------|-----------|
| C (10^{17} cm^{-2}) | 3.5-4.4 | 1.5-2.2 |
| D (10^{17} cm^{-2}) | 1.2-1.4 | 0.3-0.4 |
| B (10^{17} cm^{-2}) | 0.07-0.12 | 0.04-0.06 |

The other impurity element found on the analysed surface is boron. Its presence is most probably associated with erosion of the boron nitride part of the probe itself (for details see Fig. 2), followed by the local re-deposition of sputtered species. The statement is partly supported by images of a CCD camera proving the release of a particle cloud from the fluctuation probe during its insertion in the plasma.

No beryllium was found on the probes indicating that the amount of this element was below the detection limit of the NRA technique ($\sim 1 \times 10^{17}$ at cm^{-2}). Taking into account the total exposure time of the RFA probe ($\sim 28\text{s}$), the upper limit of the B_e flux can at this radial position be estimated to not exceed $4 \times 10^{15} \text{ cm}^{-2} \text{ s}^{-1}$.

Table 2: Comparison of deposition efficiency of various species from the ion and electron drift directions.

| Probe | Areas Analysed | D | B | C |
|---------------------|----------------------------------|-----|------|-----|
| RFA | Cap/Slit _(ion) | 2.5 | 12.1 | - |
| | Cap/Slit _(electron) | 2.5 | 12.0 | - |
| | Cap _{(ion)/(electron)} | 2.5 | 2.0 | - |
| | Slit _{(ion)/(electron)} | 3.0 | 2.1 | 2.2 |
| Turbulent Transport | Ion Side/Electron Side | 2.3 | - | - |

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SUMMARY AND CONCLUSIONS.

Deuterium is incorporated in the deposited films on the probes and its analysis shows that the impurity (mainly carbon) ion flux densities from the ion drift direction are by a factor 2 – 3 greater than those measured on the electron side. The result obtained by means of surface analysis of the both probes is in line with the flow of deuterium determined by the Mach measurements. Boron detected on the carbon fibre cap of the RFA probe most probably originates from erosion of the BN part of the probe. The contribution of boron from the second probe (i.e. turbulent transport made of BN) operated in parallel with the RFA is less probable because there is no direct magnetic connection between the probes.

In conclusion, it is stressed that this study allowed the identification of major impurities in the SOL and the preferential direction of material transport. Further measurements are under way in order to quantify fluxes of impurities (C and other species) injected to the torus as transport markers.

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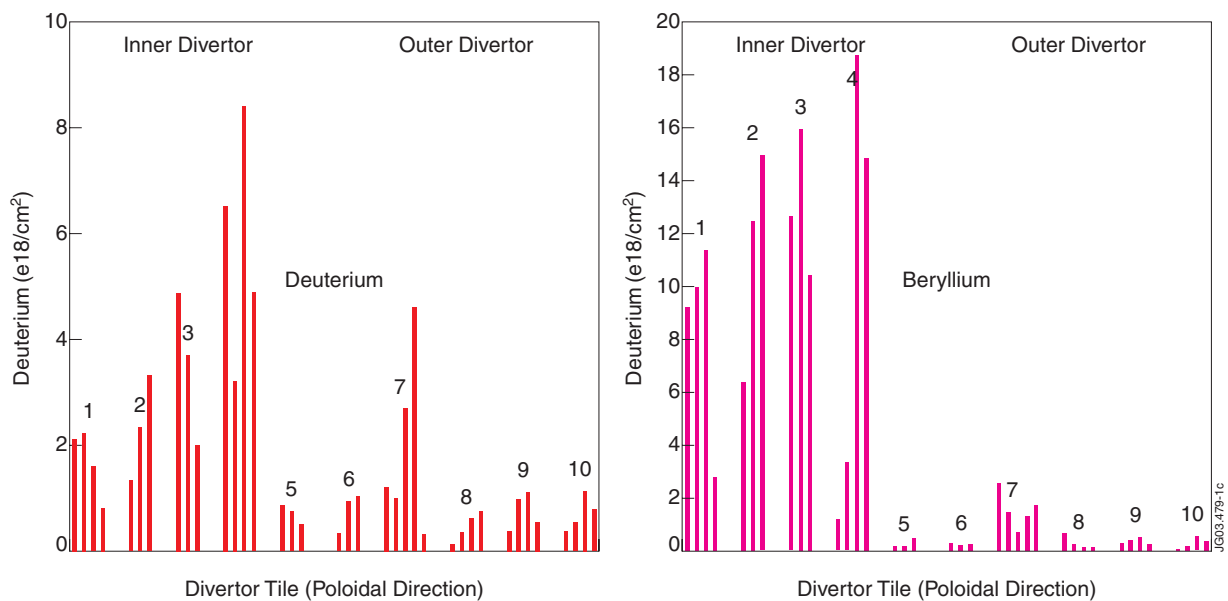


Figure 1: Deposition pattern of deuterium and beryllium on the MkII-A divertor tiles.

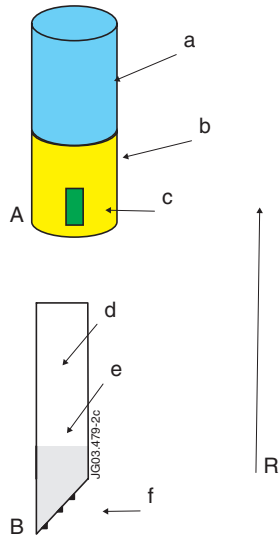


Figure 2: Schematic view of the probe heads: (A) RFA and (B) turbulent transport.
 a: Boron nitride assembly.
 b: Carbon fibre cap.
 c: Entrance diaphragms and RFA slit plates (inconel) on both sides of the probe, i.e. facing the ion and electron drift directions.
 d: Boron nitride body.
 e: Carbonized end of the probe.
 f: Three sets of electrical probes.

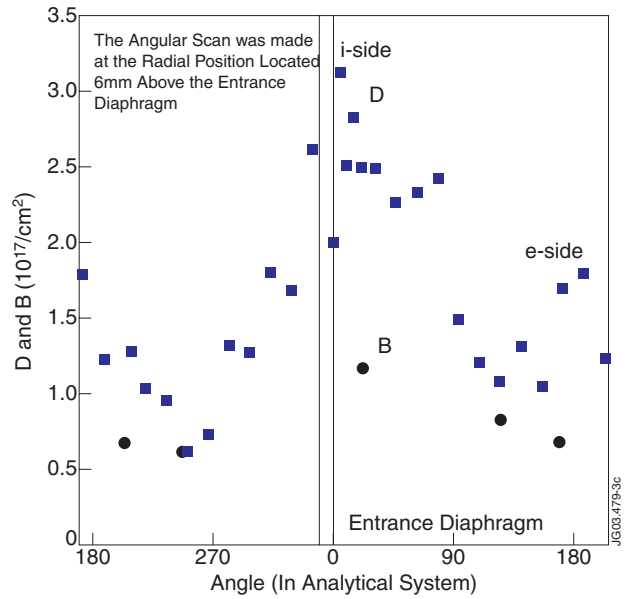


Figure 3: Distribution of deuterium and boron on the cap of the RFA probe.

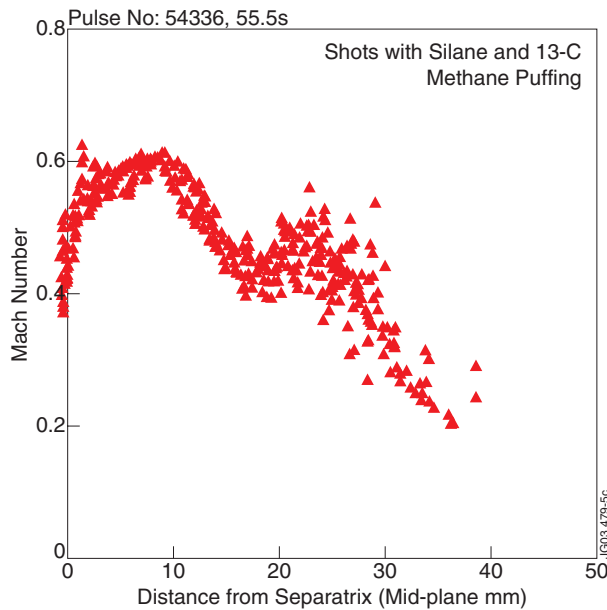


Figure 4: Mach profiles measured with the RFA probe.