EROSION-REDEPOSITION PROCESSES ON THE FT LIMITER STUDIED BY PROBES OF DIFFERENT MATERIAL

G. Maddaluno

Associazione EURATOM-ENEA sulla Fusione, C. R. E. Frascati,
C.P. 65 - 00044 - Frascati, Rome, Italy

A.P. Martinelli

Max-Planck-Institut für Plasmaphysik, Euratom Association,
D-8046 Garching (F.R.G.)

INTRODUCTION

The erosion-redeposition processes occurring on the limiter of a high field, high density tokamak like FT [1] play a great part in the global behaviour of the discharge. In fact in these machines the limiter is by far the major source of impurities.

A knowledge of the extent of the erosion-redeposition phenomena as well as of their poloidal and directional (electron versus ion side) asymmetries can give useful information about the limiter geometry and material to be used on the future devices. Following previous measurements [2,3], efforts have been made in this work for a better understanding of the erosion-deposition processes occurring on the FT limiter.

EXPERIMENT

A set of long-term deposition probes was mounted on the lateral sides of the full poloidal stainless steel limiter support (Fig. 1), between 10 and 25 mm from the plasma edge (the part of the limiter closest to the plasma consisted of mushroom-shaped Inconel pieces). The set included: four couples of graphite (Ringsdorff EK 98) and titanium targets close together, distributed on both the electron and the ion side of the limiter support at about 70° above and below the outer equatorial plane; four graphite targets mounted at about 30° above and below the inner equatorial plane, on both the ion and electron sides; a further couple of graphite and titanium targets (henceforth named CØ and Ti 45) mounted on the electron side at about 30° above the outer equatorial plane. Unlike the other targets, which had their collecting surfaces perpendicular to the toroidal direction, the titanium target of this couple was inclined at 45 degrees and collected only particles travelling between 20 and 25 mm from the plasma edge. In turn, the graphite target was able to collect only the particles reflected or emitted by the titanium surface.

In the summer 1987 experimental period, the targets were exposed to ohmically and rf heated deuterium discharges, with the toroidal magnetic field B_T antiparallel to the plasma current I_p. About 30% of the discharges ended with a disruption. The total time of exposure was 415 s. After removal from the limiter, the targets were surface analyzed by PIXE. Before and after the plasma exposure, the weight of the targets was carefully measured.

RESULTS

Large metal concentrations (Ni, Fe, Cr) were found on all the targets directly exposed to the plasma, the Ti 45 included. Radially averaged values range between $1\cdot10^{18}$ and $5.5\cdot10^{18}$ atoms cm^{-2}, depending on the poloidal as well as on the directional

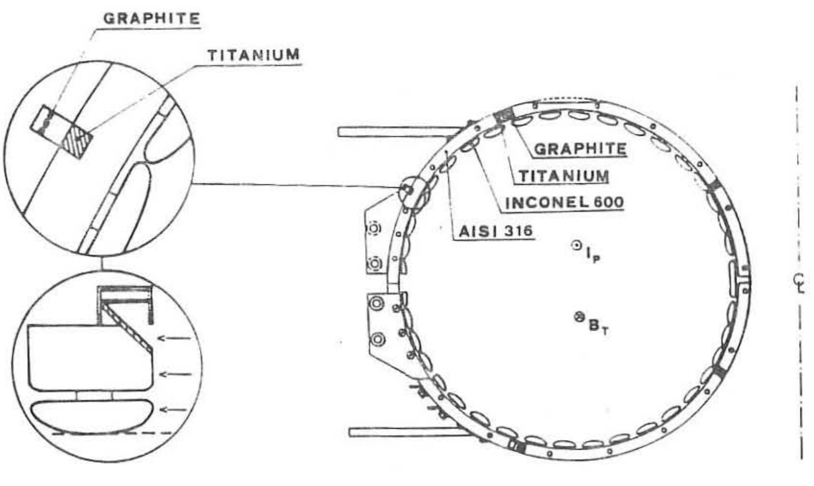

Fig. 1 - Schematic view of the full poloidal FT limiter with the long-term target positions

position (Fig. 2). Much lower amounts (~3.8·10^{16} atoms cm^{-2}) were found on the graphite target CØ.

The elemental composition of the metal deposit resembles Inconel 600, as nickel is by far the major component. Above the equatorial plane, the largest amounts of metallic impurities are on the graphite targets facing the ion side, while in the bottom half of the limiter, the pattern is reversed. The radial profile of the metal deposition shows a composite asymmetric pattern too. Short lengths (0.4÷1.4 cm) are observed on the electron upper side and the ion lower side, whereas the deposits on the lower electron and upper ion side are rather flat. A similar trend is observed on the titanium targets, but the differences in the amount of metal between the electron and the ion side are much smaller.

The weight changes of the closely mounted graphite and titanium targets are reported in Table I. The net erosion of three of the graphite targets as well as the weight increase of all the titanium targets is evident. A weight loss was also measured on the other graphite targets.

Very low titanium concentrations (maximum one monolayer) were found on the graphite targets mounted on the support sides, and nothing at all on the target CØ.

DISCUSSION

The erosion and deposition processes occurring at the limiter during an experimental period can be conveniently investigated with long-term targets by simultaneously performing weight change and impurity concentration measurements. Further information about erosion and its mechanisms can also be obtained from the combination of an erosion target and a collector, as well as from the use of two different materials as erosion target. In this respect the most striking result is the net erosion of the graphite targets (except one) in comparison with the weight increase of the titanium ones (the amount of the metal deposit being the same). This result could be justified by assuming that physical sputtering is the main cause of the graphite erosion, at least in the observed radial range. As a matter of the fact, at the energy the ions

Table I

MATERIAL	POLOIDAL POSITION*	SIDE	WEIGHT CHANGE (mg)
C	110°	e-	+ 0.34
Ti	110°	e-	+ 0.30
C	110°	i+	-10
Ti	110°	i+	+ 5.5
C	250°	e-	-10
Ti	250°	e-	+ 0.78
C	250°	i+	-0.26
Ti	250°	i+	+ 0.55

** 0° on the inner equator, counterclockwise rotation*

are expected to impinge with ($E \sim 5k\,T_e \sim 75$ eV; $T_e \sim 15$ eV [4]) the sputtering yield by deuterium is ten times higher for carbon than for titanium. Chemical sputtering of carbon probably plays a minor role because the temperature of the targets, as inferred from subsequent thermocouple measurements in the same radial position, seldom reached the value which the hydrocarbon production is enhanced at [5].

The negligible erosion of medium-z materials beyond 1 cm from the plasma edge is confirmed both by the low (Ni, Fe, Cr) or no (Ti) metal deposit on the graphite target CØ and by the elemental composition of the metal coverage of the targets, which resembles Inconel rather than stainless steel.

With regard to the asymmetries in the impurity deposition, from a comparison with a previous set of graphite targets exposed to discharges with B_T parallel to I_p [3], a dependence on the B_T direction of these poloidal and directional asymmetries can be inferred (Fig. 3). With $B_T \uparrow \uparrow I_p$ the largest metal concentrations are found on the electron side above, and on the ion side under, the equatorial plane. The opposite is true for $B_T \downarrow \uparrow I_p$. The macroscopic damages on previous FT limiters showed the same dependence on the toroidal field direction.

The composite top-bottom electron-ion side asymmetry of the impurity radial profiles is reversed too, by changing the B_T direction.

The pattern of the radial profiles of the metal deposit in the present experiment is reminescent of the poloidal asymmetries in electron density e-folding lengths, as found on Alcator-C using Langmuir probes [6]. In effect, by adding up the electron and ion side contributions, the poloidal asymmetries of the impurity radial profiles are in qualitative agreement with the trend of the density decay lengths (longer at the outside than at the inside). Nevertheless, in this case, the most evident feature is the existence of a directional asymmetry, which Langmuir probes were not able to discern.

CONCLUSION

Long-term targets of different material (graphite and titanium) have been used on the FT limiter to get information about the erosion and deposition processes.

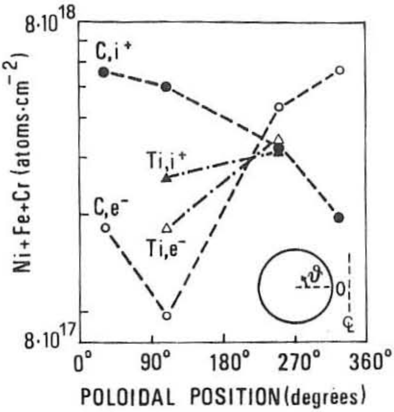

Fig. 2 - Radially averaged poloidal distribution of the metal impurities on the graphite and titanium targets

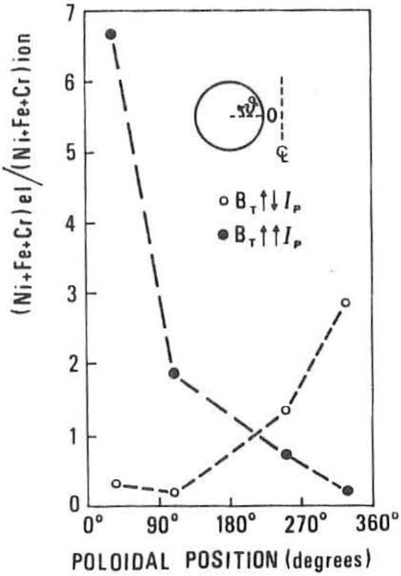

Fig. 3 - Electron to ion side ratio of the metal coverage for both the B_T directions

From impurity concentration and weight change measurements, graphite targets were found to be more eroded than titanium ones beyond 1 cm from the plasma edge, probably as a result of the different sputtering yield. A poloidally and directionally asymmetric pattern of the metal deposit was found too; the pattern depends on the B_T direction. The low erosion of medium-z material on the limiter support could mean a tolerable metal contamination of the graphite mushrooms in the metal-graphite limiter envisaged for FT [7].

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