DEPOSITION AND EROSION AT THE OPEN AND CLOSED ICRH ANTENNAE OF ASDEX

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1. INTRODUCTION

In the ASDEX tokamak ICRH has been applied with two antennae and a total RF generator power of 3 MW for about one and a half years between 1984 and April 1986. Second harmonic and minority heating modes in Deuterium and Deuterium-hydrogen mixture plasmas have been investigated /1/. In April 1986 the antennae were dismanteled to be exchanged by watercooled ones. This gave the possibility to investigate the surface composition of the internal and external surfaces of antenna elements and of the carbon tiles of the antenna protection limiters using ion beam techniques as RBS, PIXE and Nuclear Reactions /4/ as well as SIMS and Auger Electron Spectroscopy. These surface compositions are the time integrated result of deposition and erosion processes during the different operation modes of ASDEX as glow discharge conditioning, carbonization and decarbonization processes as well as tokamak discharges in the L and H mode with NI, ICRH and LH heating and pellet injection.

2. GEOMETRY AND MATERIAL OF THE ANTENNA ELEMENTS

Two low field side loop antennae with Faraday screens and protecting limiters have been installed in ASDEX (Fig. 1, lower part). Central and return conductors of the loops and the antenna side wall elements were silver coated. The limiters were made of graphite mushrooms brazed into copper blocks, the copper being protected against particle bombardment by stainless steel plates at the side seen by the plasma. The Faraday screen was composed of TiC coated rods with different cross sections: the screen of one antenna consisted of T-shaped rods and was almost opaque while at the other antenna circular rods formed an optically open array /2,3/.

3. EXPERIMENTAL RESULTS

The surfaces of the dismanteled limiter elements and Faraday rods showed almost no visible modifications due to the plasma operation, while all parts below the Faraday screen of the optically open antenna - mainly the central conductor - showed a remarkable pattern of dark and bright stripes correlated with the position of the Faraday rods.

The distribution of metals and deuterium found on the TiC-coated Faraday rods and on the center conductor of the optically open antenna are shown in Fig. 2. In contrary to initial expectations carbon due to carbonization processes is almost homogeneously distributed and the dark stripes located in the shadow regions of the Faraday rods on the central conductor show a deposition of Fe and O. The bright stripes show clear maxima of D-implantation.

The distribution of wall material (Fe + Cr + Ni) and of Deuterium on the different Faraday rods is shown in Fig. 3. The concentration of both is clearly larger in front of the plasma than behind. The maxima of metals

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are found at the sides or at half-shadowed surface parts of the rods while Deuterium shows a more homogeneous distribution with maxima rather in front of the plasma.
The deposition of silver on the inner surface of the opaque screen is much smaller than in the case of the optically open one (Fig.3) indicating that silver from the Ag-plated inner antenna surfaces is only eroded by particles coming from outside and not by arcing in the antenna. This is in agreement with the result, that the electrical strength in the open antenna is not worse compared to the closed one up to the tested level /2/.
The small content of tantalum and tungsten is possibly an impurity originating from the TiC coating process.
Figure 1 (upper side) shows the toroidal variation of the surface composition of the Faraday screen elements and of the protection limiters facing the plasma. While the D-concentration is similar for screen and limiter elements, the concentration of wall material (Fe + Cr + Ni) on the screen is considerably smaller than on the limiters.
The amount of Ti, Cu and Ag, measured on the carbon limiter blocks is much larger than at other areas of the torus, thus indicating sources in the direct neighbourhood: the TiC-coated Faraday screen, copper blocks of the limiter elements and the antenna side walls (Fig. 1).

4. POSSIBLE INTERPRETATIONS

The measured surface composition is the integrated result of deposition and erosion processes during tokamak operation and conditioning glow dicharges. Figure 4 shows schematically the relevant particle fluxes for both cases. During tokamak operation electrons and ions follow predominantly the mgnetic field lines, superposed by drift and plasma rotation movements. In addition, there are runaway electrons, energetic ions on drift orbits and charge exchange (D) neutrals moving in random directions. During the glow discharge the plasma (D^+) ions are accelerated in the sheath potential and move perpendicularly towards the wall and antenna structure. Their energy is of the order of a few 100 eV and thus sufficient to cause sputtering. Shadowing is only possible for charged particles.
The stripes inside the open antenna (Fig. 2) can be explained as being the result of random deposition of sputtered, not ionized wall material (Fe+Ni+Cr), possibly predominantly during glow discharges, and erosion at the unshadowed areas below the slits between Faraday rods by D-ions during the glow discharges. The profiles shown in Fig. 3 can also be explained by this shadow effect.
In order to explain the surface composition shown in Fig. 1, glow and tokamak discharges have to be taken into account. Since D-ions at plasma operations would be shadowed from the screen by the limiters, the almost homogeneous D content, implanted with energies below about 1 keV, is obviously the result of glow discharge ions and/or CX-neutrals in tokamak discharges. The small maxima at the ion side of the limiters can be due to an additional ion implantation in tokamak discharges.

The small Fe + Cr + Ni content on the screen situated more than 5 mm behind the first unshadowed magnetic surface could in principle be the result of an ion deposition during tokamak discharges, which is largely reduced due to the shadowing limiters. But the maxima at the sides of the screen rods (Fig. 3) and limiter elements (Fig. 1, mainly at the left one) may rather indicate a homogeneous deposition and a subsequent erosion during tokamak discharges (the erosion during glow discharges should be similar at Faraday rods and limiters). In this case a special ion accelerating process by ICRH just in front of the active antenna area would have to be assumed to explain the erosion. This would be in agreement with the increase of antenna material impurity observed at ICRH operation in JET /5/. The Fe+Cr+Ni maxima at the outer limiter sides are comparable with the deposition on carbon limiters previously used in ASDEX /6/. They may be enlarged by the direct neighbourhood of the stainless steel plate protecting the copper blocks, while Cu and Ag may originate from the Cu blocks and the Ag coating of the Faraday screen support.

SUMMARY

The measured surface composition of the ICRH antenna and protecting limiter elements, dismanteled after an operation time of one and a half year, showed an implanted Deuterium and metal content which can only be explained by combined deposition and erosion processes during tokamak operation and glow discharge conditioning. Some results also indicate a special ion accelerating process during ICRH just in front of the active part of the antenna.

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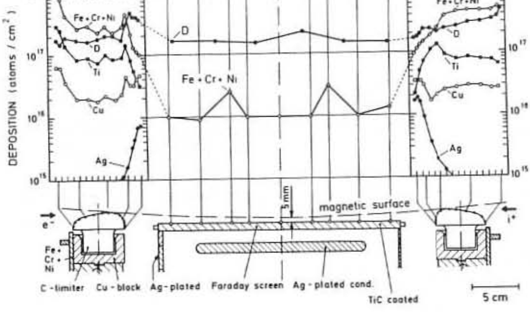


Fig. 1:
Cross section of the antenna and protection limiters (lower part), and distribution of deuterium and metal depositions in toroidal direction.

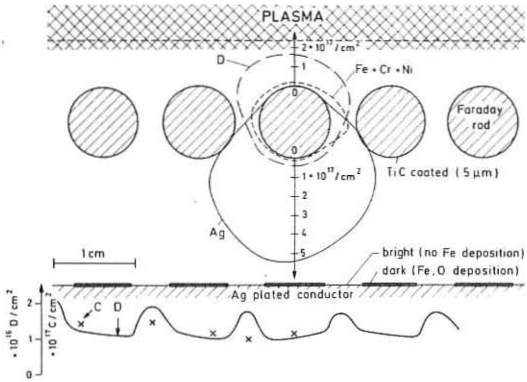
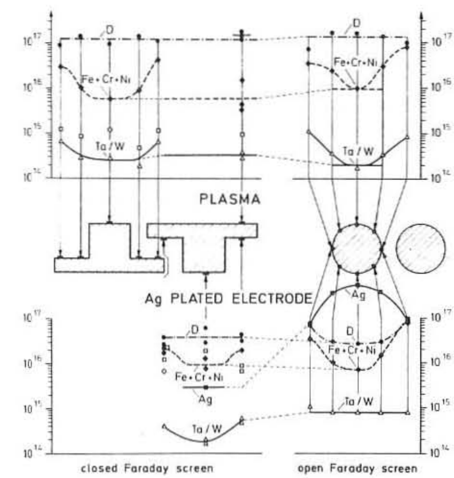


Fig. 2

Stripe pattern on the central conductor and surface composition on central conductor and on the rods of an open Faraday screen.

Fig. 3

Surface composition on the rods of the opaque and the optically open Faraday screen. The maxima at the sides and at shadowed parts can be explained by the lower density of eroding particles. Silver is found at the central conductor of the open antenna only.



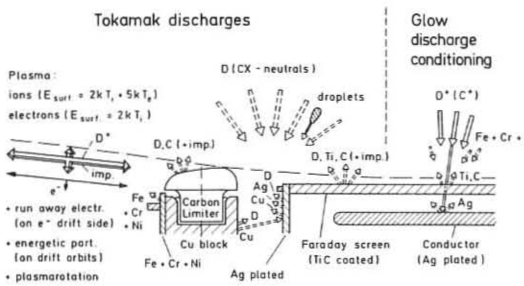


Fig. 4

Fluxes of neutrals (dotted lines) and charged particles in tokamak and glow discharges.