Current distribution at the target of Magnum-PSI

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The ion-to-electron flux ratio in the cross section of the plasma column that bombards the target of the linear magnetized plasma generator Magnum-PSI can be controlled by biasing the target. The plasma column can be tuned from ion dominated to electron dominated flux on its entire cross section. Between these two limit cases there are multiple intermediate combinations which can be obtained: the plasma column can bombard the target mainly with electrons in the central region and with ions in the remaining part of its cross section.

1. Introduction

Obtaining a source of energy based on fusion reactions requires solutions for a large number of physical and engineering problems and involves very complex reactors [1]. For their optimal operation, it is crucial to study and understand the plasma-wall interactions in fusion reactors. Magnum-PSI is a facility designed to allow such studies under relevant conditions [2]. It is a linear plasma generator producing a magnetized plasma column which interacts with a target. The versatility of the plasma column is an important factor for the experimental value of such a device. By this we mean the ability to control the energy deposited on the target by the fluxes of charged particles, ions and/or electrons. Consequently, knowledge of the spatial distribution of the fluxes over the cross section of the plasma column versus different experimental conditions is of particular interest.

The present work reports on recent experiments that revealed the possibility of tailoring the plasma column properties in Magnum-PSI. The cross sectional composition (electron *vs*. ion flux) of the beam at plasma-target interface can be smoothly controlled by target biasing. The measurements were made with a 2D multi-probe system installed as target.

2. Experimental set-up

The experimental device, consisting of Magnum-PSI [2] and the multi-probe system [3], as well as the diagnostic method were previously described in detail. Briefly, the 2D multi-probe system (Fig. 1) was installed at the target location in Magnum-PSI. The 64 probes were arranged in a square matrix of 8×8 and flush-mounted with a tungsten plate which is electrically isolated from the probes. Consequently, the system composed of probes and plate were used to map either the local floating potential or the local current across the plasma column. Each probe had its own biasing/measuring circuit, composed of resistors and capacitors [3]. The linear resolution of the multi-probe system was 4 mm in each of the two directions. The signals collected from all 64 probes were simultaneously registered with a National Instruments data acquisition system.

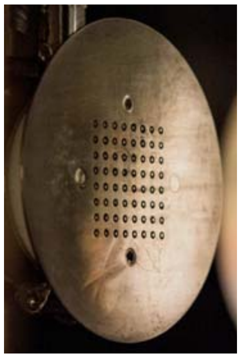

Fig.1. The 2D multi-probe system.

3. Spatial distribution of the current arriving to the target

In order to investigate the cross sectional distribution of the charged particles flux that bombards the target, all the probes were simultaneously biased at the same voltage with respect to the ground. The tungsten plate which faces the plasma column was kept floating. The radial distribution of the probe current measured in a hydrogen discharge of 125 A confined by a magnetic field of 0.95 T is given in Fig. 2, for different biasing voltage on the probes. The total current arriving to each probe is the sum of two currents carried by the charged particles: ions (positive current) and electrons (negative current). It can be noticed that, biasing the probes from -80 to

-30 V, the current intensities measured by the probes change from positive values (ion dominated) to negative values (electron dominated), passing successively through different radial distribution types: (i) ion current, Gaussian profile (V_{probes} = -80 V); (ii) ion current, flat distribution in the centre of the plasma column (V_{probes} = -65 V); (iii) ion current, lower value in the centre than on the sides (V_{probes} = -55 V); (iv) electron current in the centre and ion current on the sides (V_{probes} = -45, -35 V); (iv) electron current, Gaussian profile (V_{probes} = -33, -30 V). Consequently, biasing the target at different potentials with respect to ground it is possible to change the cross sectional distribution of ion and electron fluxes to the target.

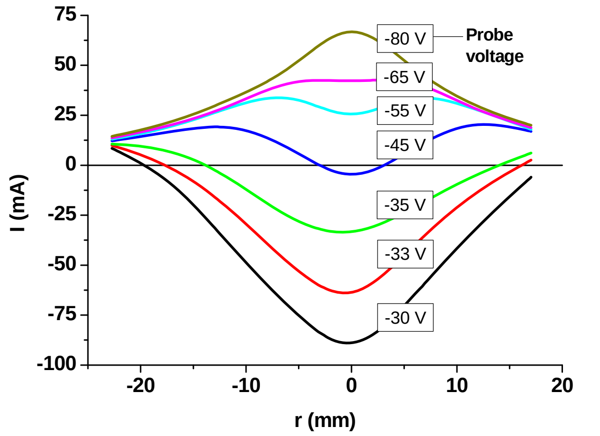

Fig.2. Radial distribution of the probe current (H_2 gas; 0.95 T magnetic field strength; 125 A discharge current; probe voltage as parameter).

The sign (positive or negative) of the local current, measured on each probe, is an indication of the dominant species (ions or electrons) that reach the target in that particular place. Depending on the probe biasing voltage with respect to the local plasma potential, the contribution to the local current of both electrons and ions can be obtained. In order to get more information on the subject, the radial distribution of the local floating potential is plotted in Fig. 3, for the same discharge conditions as in Fig. 2. For comparison, the floating potential of the tungsten plate is also indicated in Fig. 3.

According to electrical probe's theory [4], when a probe is biased negatively with respect to plasma potential, the two components of the probe current are: the ion saturation current and a certain fraction of electron current. If the probe is biased sufficiently negative than the floating potential, so that all the electrons coming from the plasma could be repelled, the probe will collect only the ion saturation current.

Since the minimum local floating potential across the plasma column is -50 V (in the centre of the plasma column according to Fig. 3), and the electron temperature is below 4 eV [3], we can assume that the local probe current measured with the probes biased at -80 V (Fig. 2) is, exclusively, the local ion saturation current. Thus, the contribution of the electron current to other current curves (probe bias of -65, -55 and -45 V) can be obtained by subtracting the local ion saturation current from the local probe current. The electron current intensities obtained as result of this correction are plotted in Fig. 4. The electron current was not calculated for the probe bias of -35, -33 and -30 V because these values can be more positive than the local plasma potential for some of the probes and in this case the ion current that has to be extracted from the probe current is not known (it might be different from the local ion saturation current).

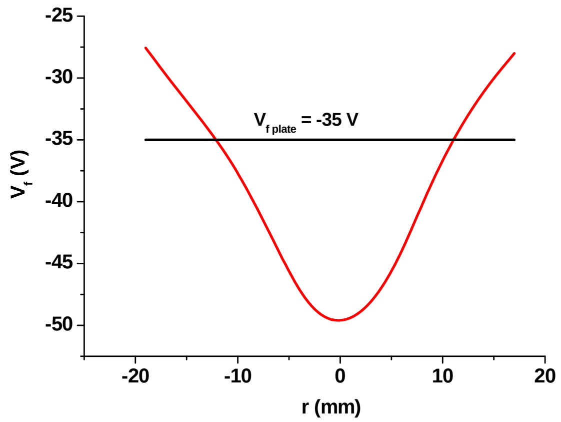

Fig.3. Radial distribution of the local floating potential; $V_{f\,plate}$ = -35 V (H_2 gas; 0.95 T magnetic field strength; 125 A discharge current).

According to Fig. 3, the floating potential of the tungsten plate (which can be assimilated to the target) is -35 V. This means that the current curve in Fig. 2 which was obtained whit the probes biased at -35 V corresponds to the radial distribution of the current arriving to the floating target. Even if the target is floating and, consequently, the total current arriving to it is zero, the target receives non-zero local currents due to the radial inhomogeneity of the plasma column. The central zone of the target (r < 13 mm) collects electron dominated current while the outer zone (r > 13 mm) collects ion dominated currents. The two zones are also evidenced in Fig. 3: in the central zone the local floating potential is more negative with respect to the floating potential of the target while in the outer zone the situation is reversed. This result suggests the presence of a current flow within the floating target, in order to obtain the neutralization of the opposite charges to the target surface and to preserve the equipotential feature of the conductive target.

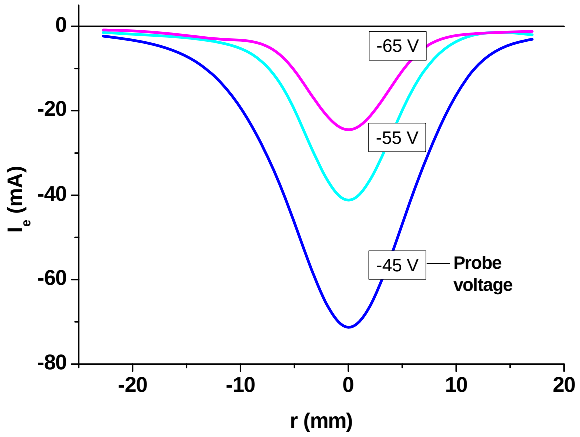

Fig.4. Radial distribution of the electron current (H_2 gas; 0.95 T magnetic field strength; 125 A discharge current; probe voltage as parameter).

4. Conclusion

Local ion-to-electron flux ratio in the cross section of the plasma column that bombards the target of Magnum-PSI can be controlled by biasing the target. This results confirms the versatility of the machine for plasma-surface interaction studies. Due to the radial inhomogeneity of the plasma column, the floating target is subjected to internal currents flow.

5. Acknowledgement

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6. References

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