26th EPS Conf. on Contr. Fusion and Plasma Physics, Maastricht, 14 - 18 June 1999 ECA Vol.23J (1999) 1533 - 1536

Studies of erosion and redeposition in the main chamber wall of the ASDEX Upgrade Tokamak

A. Tabasso, J. Roth, H. Maier, K. Krieger, and
the ASDEX Upgrade Team

Max-Planck-Institut für Plasmaphysik
Boltzmannstraße 2, D-85748 Garching bei München, Germany

Introduction

A critical issue for the choice of main chamber first wall materials in future fusion devices such as ITER is the erosion rate due to bombardment by charge-exchange (CX) neutrals. Because of the relatively small flux density of impacting particles, respective measurements are only possible using long term samples exposed for a full experimental campaign. In ASDEX Upgrade CX-erosion has been studied extensively for tungsten, which is envisaged to replace carbon at the inner heat shield of ASDEX Upgrade in future campaigns. Silicon (also of interest because of its use as wall conditioning material in current machines) was used as medium *Z* alternative.

Experimental Set-up and Results

Graphite samples were covered with thin *W* and *Si* layers by vapour deposition. To study the toroidal and poloidal variation of erosion one toroidal and two poloidal sets of samples were employed. The toroidal set consisted of *8* probes located at the outer midplane wall of ASDEX. Figure 1 represents the arrangement of the poloidal sets of probes. Probes exposed in previous experimental campaigns showed a strong deposition of material by wall conditioning procedures such as boronisation and siliconisation. To separate this effect from the erosion by plasma particles, a great number of probes were equipped with magnetic field operated shutters, which protected the samples from the glow discharges. Figure 2 is a drawing of the probe holder, which demonstrates the principle of operation. The shutter is completely passive and if no magnetic field is applied, it will stay in the closed position. During glow discharge cleaning and wall conditioning no magnetic field is applied and therefore the shutter will protect the probes. However when plasma is started and the magnetic field is switched on, the shutter will align itself with the *B* field therefore leaving the probe exposed to the neutral flux. The samples were exposed for a full experimental campaign. Four months after the beginning of operation, they were removed, analysed and reinserted. It was therefore possible to analyse two sets of data. Especially important is the fact that during the first period no siliconisation of the vessel took place and therefore clearer

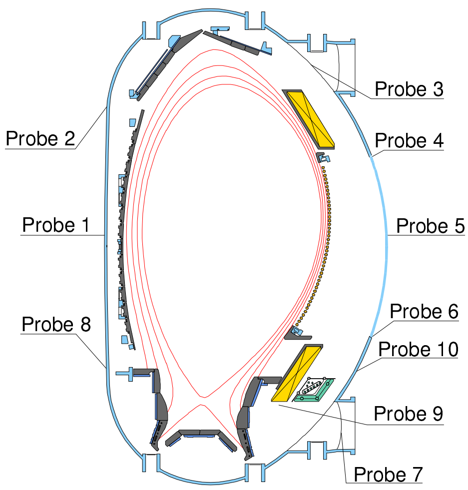

Figure 1: *Cross section of the ASDEX Upgrade vacuum vessel indicating the location of the long term samples*

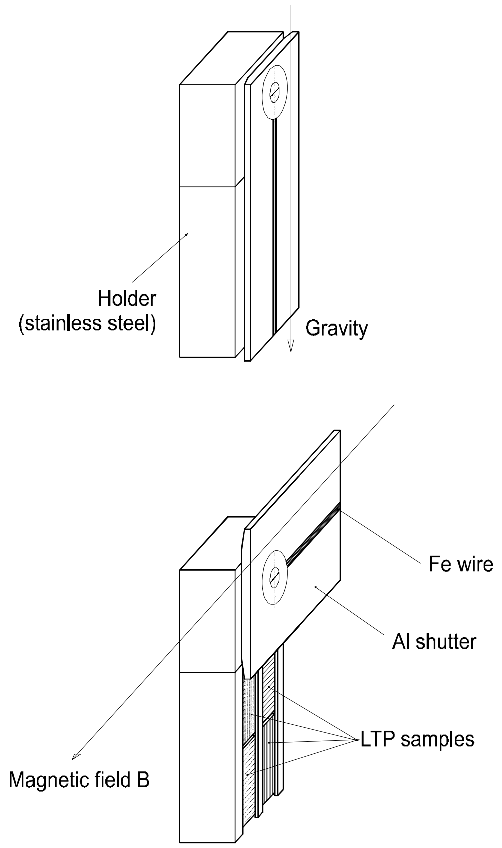

Figure 2: *Drawing of the probe shutters in both open and closed position demonstrating its operation*

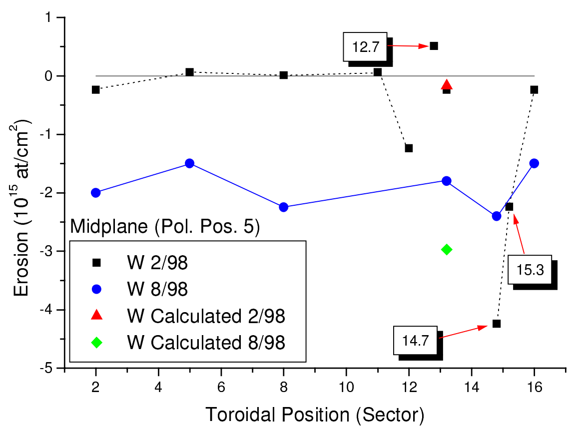

Figure 3: *Erosion of W during two periods of the same experimental campaign. The data are compared with erosion calculated upon the particle fluxes measured by the diagnostic LENA*

results are available also for the silicon samples. The probe erosion was determined by measuring the layer thickness before and after the respective exposure period. The thickness was measured using Rutherford backscattering analysis.

Figure 3 shows the erosion from the *W* coated probes for the different sectors of ASDEX at the same poloidal position (midplane). The probes were initially analysed in February 1998 after *4* months of operation and then at the end of the campaign (August 1998). The results show a toroidal asymmetry in the erosion profile, which could be due either to locally enhanced particle fluxes or to local variations of the CX-particles energy distribution. The results in the second part of the campaign show greater erosion than in the first part and this is due to the fact that the discharge time is almost four times greater in the latter part of the campaign. In sector *15*, two probes were employed, one with (~ *14.7*) and one without (~ *15.3*) shutter. This allows the study of the influence of the shutter under otherwise identical conditions. It is easy to see how the erosion in the probe with the shutter is larger, indicating that the coating during boronisation does somewhat reduce the effective erosion of *W*. The data in position *12.7* (2/98) show a non realistic *W* deposition, giving an indication of the experimental error bars. It appears that the experimental error is ~ 10^{15} *atoms/cm*^{2}. A low energy particle analyser (LENA) is employed in sector *13*. The energy resolved measurement of neutral particle flux was integrated over the experimental periods of the campaign, and the expected *W* erosion calculated using the sputtering yield of [1]. Figure 3 compares the calculation with the data and shows that the effective *W* erosion is somewhat smaller than expected.

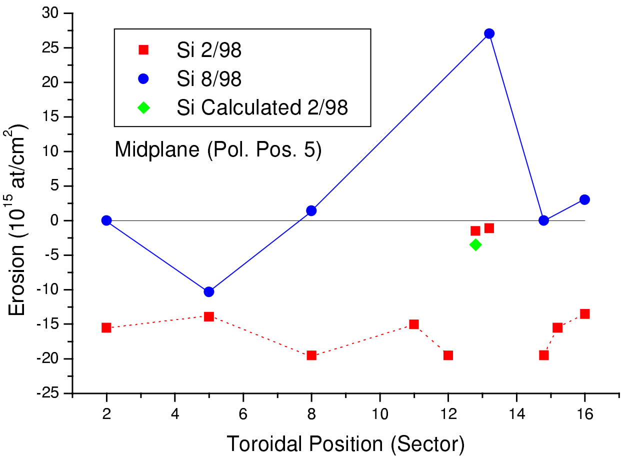

Figure 4: *Erosion of Si during two periods of the same experimental campaign. The data are compared with erosion calculated upon the particle fluxes measured by the diagnostic LENA*

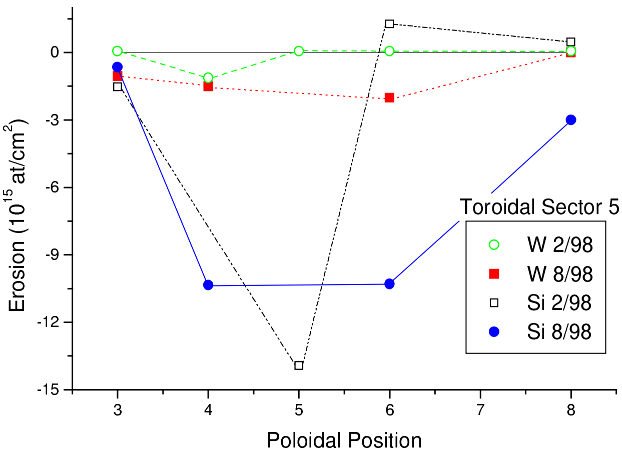

Figure 5: *Poloidal distribution of W and Si erosion for two different periods of the same operational campaign. The asymmetries in the erosion are attributed to an asymmetric particle flux distribution*

Figure 4 is equivalent to figure 3 and shows the erosion of *Si* during the same operational periods. During the second operational period, the vessel walls were conditioned by means of siliconisation, which affects the results to an unknown extend. Still the observed *Si* erosion is at least a factor of *10* larger than the *W* one. The same calculation using LENA data was carried out for the first period of operation and it is possible to see that experimental and calculated results are comparable.

Figure 5 reproduces the poloidal distribution of erosion for both *W* and *Si* during the two operational periods. A poloidal asymmetry of erosion is evident and comparable between the two materials during the same operational period. This can be explained by considering different erosion due to poloidal asymmetries in the neutral particle flux.

Figure 6 shows for the first operational period of the campaign the poloidal distribution of *W* erosion for several toroidal sectors of ASDEX Upgrade. In the figure it is also possible to compare the experimental results with the calculated erosion. For the calculation, particle fluxes deduced from the measurement at the LENA position were used [2]. A homogeneous angular distribution of the impacting particle flux with a solid angle of 2π was employed. In the case of figures 3 and 4 a factor of ~ *10* smaller solid angle was assumed, because of the restriction imposed by the LENA diagnostic aperture.

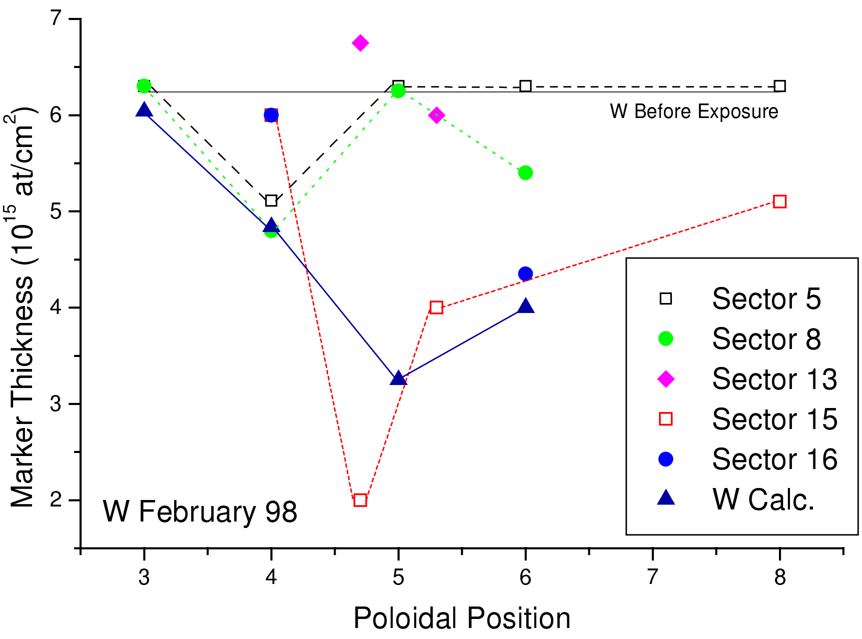

Figure 6: *Poloidal distribution of W erosion for different toroidal sectors during the first period of the operational campaign. The experimental results are compared with the results calculated from a neutral flux derived by [2]*

Conclusions

- Exposure of long term sample with a passively operated shutter avoids the contamination of the samples during wall conditioning.
- The long term samples analysed in two different periods of the same operational campaign show that the *W* erosion by CX neutral particles is around a factor of *10* smaller than the *Si* one. From these results we conclude that the former is more adequate to be a first wall material for future fusion devices.
- The measured erosion is comparable to the calculated (using LENA data) results for *Si* while it is considerably smaller in the case of *W*. This allows optimism with respect to the predictions for CX-particles sputtering of wall erosion of future machines.
- The results show pronounced toroidal and poloidal asymmetries of the erosion profile. The poloidal asymmetries can be explained as a result of the asymmetric poloidal distribution of the CX particle flux. The toroidal asymmetries can be attributed either to locally enhanced particle fluxes or to local variation of the CX energy distribution.

References

[1] W. Eckstein, C. Garcia-Rosales, J. Roth, W. Ottenberger, *IPP Report*, IPP 9/82

[2] H. Verbeek, J. Stober, D. Coster, W. Eckstein, R. Schneider, *Nuclear Fusion*, **38**, 12 (98)