ACCELERATOR-BASED QUANTIFICATION AND DEPTH PROFILING OF HYDROGEN ISOTOPES AND IMPURITY ATOMS IN WALL MATERIALS FROM CONTROLLED FUSION DEVICES

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The fusion reactor ITER, which is under construction in France, will be a milestone on the way towards fusion energy, generating (as currently planned) for the first time conditions in which 10 times more fusion power output is expected than power input for plasma heating. Currently, the largest device is the Joint European Torus (JET), located in Great Britain. Since August 2011 it has been operated with a full metal first wall with beryllium (Be) limiters in the main chamber and tungsten (W, coatings and bulk metal) in the so-called divertor [1]; JET with the ITER-like wall (JET-ILW). Plasma-material interactions constitute an important part of the research programme. The understanding of fuel retention and material migration belong to the top missions of JET-ILW.

This work is focused on the determination of erosion, re-deposition/co-deposition of eroded species with fuel atoms and, on resultant retention of hydrogen isotopes on the JET-ILW wall components. Samples of the components retrieved from the torus after the three consecutive ILW campaigns (ILW-1, ILW-2 and ILW-3) were examined with accelerator-based ion beam analysis (IBA) techniques. This powerful set of methods is one of the crucial tools for surface/sub-surface studies of wall materials from controlled fusion devices [2].

The JET-ILW samples were analysed by the 5 MV NEC Pelletron accelerator at Uppsala University: By means of ^{3}He-based nuclear reaction analysis (NRA) using a standard and micro-beam and, by time-of-flight heavy ion elastic recoil detection analysis (HI-ERDA) with a gas detector [3] using bromine (32 MeV $^{82}Br^{7+}$) and iodine (36 MeV $^{127}I^{8+}$ and 44 MeV $^{127}I^{10+}$) beams. Additionally, microscopy techniques were applied. The major objectives were to determine: (i) Hydrogen (H, D) content and distribution on Be and W after experimental campaigns with different fuelling; (ii) co-deposition of Be, C, O, W and seeded gases on plasma-facing surfaces (PFS) and, in shadowed regions, e.g. gaps between the tiles and grooves of the castellation. The main results are summarized below.

(a) The ratio of H-to-D on surfaces depends on plasma fuelling in the last phase of campaigns. The sum of isotopes contents (H+D) on W lamellae remains similar thus indicating isotope exchange, see Fig. 1.

(b) The content of impurities on Be limiter tiles changes with the position. On the surface of the inner wall guard limiter wings, the impurities amount to 20 atomic %, mainly O (10%), C, N, H isotopes and Inconel components. Inside the castellation C could be determined with HI- ERDA to be around 1%.

(c) Deposits on sides of the bulk W tiles contain Be and C of a ratio around 1, as measured

by μ-NRA. Their content decreases with depth. The D concentration varies strongly: the maximum at 6×10^{17} cm^{-2}.

(d) On the PFS of the bulk W module the Be content reaches the level of 11.2×10^{17} cm^{-2}, C at 8.7×10^{17} cm^{-2}, and D at 4.8×10^{15} cm^{-2}, as measured by μ-NRA.

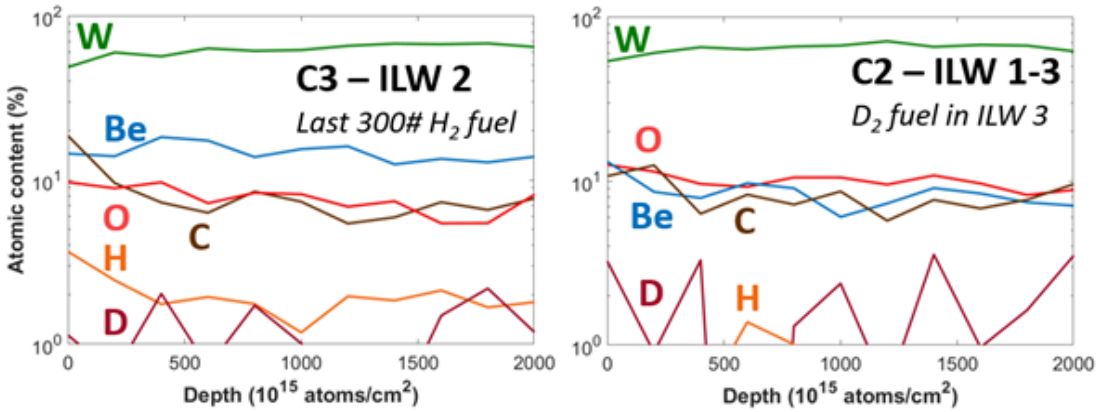

FIG. 1. HI-ERDA depth profiles of elemental composition on W samples from neighbouring positions C3 and C2, retrieved after ILW-2, which finished off with 300 shots of H2, and ILW-3, which finished with D2 fuelling. The total hydrogen isotope retention is 6.7×10^{16} and 5.3×10^{16} cm^{-2}, respectively.

Critical assessment of accelerator-based analysis methods and results will be presented.

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