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Impact of the trapping model on Tritium retention and permeation in DEMO Tungsten/Eurofer First Wall

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In future fusion devices, the tritium retention and permeation in plasma facing components (PFCs) are important safety concerns. In order to predict the tritium retention and permeation during operation of a reactor, numerical modelling of tritium transport and trapping at defects can be done. This allows to know how much tritium atoms are retained in the wall and how much permeate to the cooling system of the PFCs.
In this work, we want to focus on the Water Cooled Lithium Lead design (WCLL), a specific part of the wall of DEMO which is the First Wall (FW) facing the plasma on one side and the breeding material on the other side. One element of the first wall (125x27x255 mm) is composed of a 2 mm thick tungsten (W) on top of a few cm of Eurofer actively cooled by 4 square channels. We want to investigate the impact of the different available trapping models for these 2 materials on the tritium transport and permeation. For W, we use 2 models: the first one includes only the native traps at low detrapping energies [1]. The second adds high detrapping energies that simulates the formation of vacancy clusters due to neutron impact [2]. For Eurofer, we also use 2 models: the first one contains only one low detrapping energy trapping site, as observed in several permeations studies [3, 4] and the second one adds trapping sites with high detrapping energies observed with thermal desorption spectrometry [4]. The calculation are done with FESTIM [5] in a 2D geometry (125x27 mm).
On one hand, the addition of trapping sites with high detrapping energies, whether in W or Eurofer is very similar. It makes increase the breakthrough time for the tritium permeation flux to increase by orders of magnitude going from few minutes to days (or even hundreds of days). On the other hand, it drastically increases the tritium retention in a single FW element: the retention goes from below 1 μg/m-1 to few mg/m-1.

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[2] J. Dark et al, Nucl. Fusion 64 (2024) 086026
[3] G. Esteban et al, J. Nucl. Materials 367-370 (2007) 473-477
[4] F. Montupet-Leblond et al, Nucl. Mater. Energ. 29 (2021) 101062
[5] R. Delaporte-Mathurin et al, Inter. J. Hydrogen Energ. (2024) 786-802

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