Modelling of deuterium trapping, diffusion and permeation in tokamak plasma facing components

ID #976

E. A. Hodille[1], R. Delaporte-Mathurin[1,2], J. Denis[3], M. Pecovnik[4], E. Bernard[1], Y. Ferro[3], R. Sakamoto[5], Y. Charles[2], J. Mougenot[2], A. De Backer[2], C. S. Becquart[6], S. Markelj[4], C. Grisolia[1]

[1] CEA, IRFM, F-13108 Saint Paul Lez Durance, France
[2] LSPM, CNRS, Paris 13, UPR 3407, F-93430 Villetaneuse, France
[3] Aix Marseille Univ., CNRS, PIIM, Marseille, France
[4] Jozef Stefan Institute, Jamova cesta 39, 1000, Ljubljana, Slovenia
[5] NINS, National Institute for Fusion Science, Toki, Gifu 509-5292, Japan
[6] Univ. Lille, CNRS, INRAE, Centrale Lille, UMPR 8207 UMET F-59000 Lille, France

etienne.hodille@cea.fr

Centre de Calcul Intensif d'Aix-Marseille is acknowledged for granting access to its high performance computing resources. This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the EURATOM research and training program 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission. The project leading to this publication has received funding from the French National Research Agency (Grant No. ANR-18-CEO5-0012).

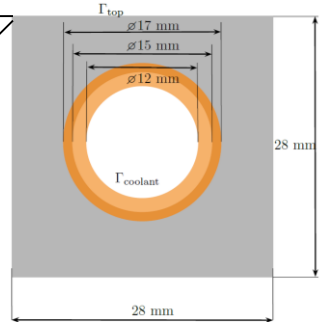
ABSTRACT

- Simulations of H migration in W/Cu/CuCrZr divertor
- Sub-surface with supersaturated layer (0-10 µm): 1D simulation - MHIMS
- Bulk of the monoblock: 2D simulation – FESTIM
- Retention in super-saturated layer: 10^{19} D/m^2
- Permeation to cooling : 1.35×10^{14} D per monoblock
- Release → poloidal gaps: ≈10^{14} D/s per monoblock

Divertor monoblock: modelling strategy

0-10 µm: 1D MHIMS only W

Bulk domain: 2D FESTIM W/Cu/CuCrZr With interface [6]



SIMULATION PARAMETERS

10,000 s of continuous Deuterium (D) plasma

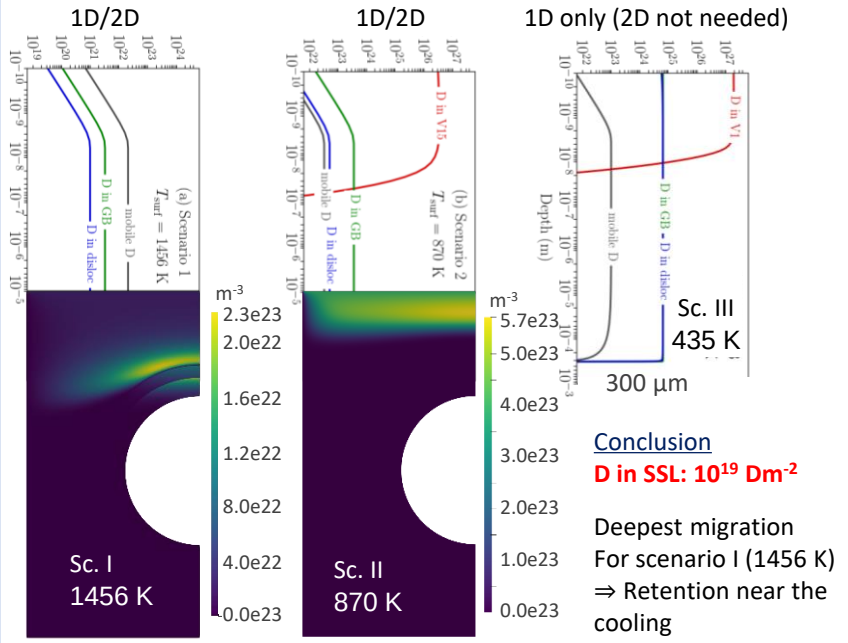
Scenario	ϕ_{heat}	ϕ_{ion} (m^{-2}s^{-1})	E_{ion}	T_{surf}
Sc I	10 MW/m^2	5.0×10^{24}	115 eV	1456 K
Sc II	5 MW/m^2	3.5×10^{24}	75 eV	870 K
Sc III	1 MW/m^2	1.0×10^{24}	50 eV	435 K

TRAPPING PARAMETERS

- **Subsurface W**: Supersaturated layer (SSL) [1,2]
  - Sc. III (435 K): **SSL with V1** (1.5 eV – 0.86 eV) [3]
    - Concentration: 5×10^{-3} at.fr. 0 – 7 nm
  - Sc. II (870 K): **SSL with V15** (1.84 eV -0.90 eV) [4]
    - Concentration: 10^{-3} at.fr. 0 – 10 nm
  - Sc. I (1456 K): No SSL [5] due to annealing of V_n
- **Bulk W**: 2 traps [7]
  - **Grain Boundaries** (1.00 eV) [8]
    - Concentration: 10^{-4} at.fr. homogeneous
  - **Dislocations** (0.85 eV) [9]
    - Concentration: 10^{-4} at.fr. homogeneous
- **Cu and CuCrZr**: Same as in [6]

[1] Gao et al, Nuc Fusion 57 (2017)
[2] Hodille et al, PRMat 2 (2018)
[3] Fernandez et al, Acta Materialia 94 (2015)
[4] Hou et al, Nature Materials 18 (2019)
[5] Zibrov et al, JNM 531 (2020)
[6] R. Delaporte-Mathurin et al, NF 61 (2021)
[7] Hodille JNM 467 (2015)
[8] Zhou et al, Nuc. Fusion
[9] De Backer et al, Ph. Scr. T170 (2017)

RESULTS: D Fields

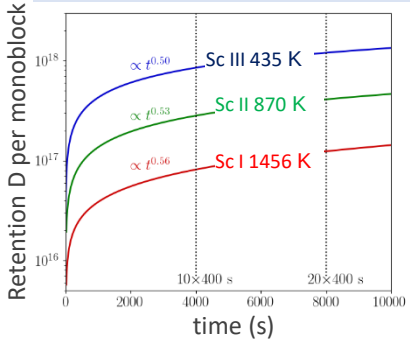


[Conclusion](#)

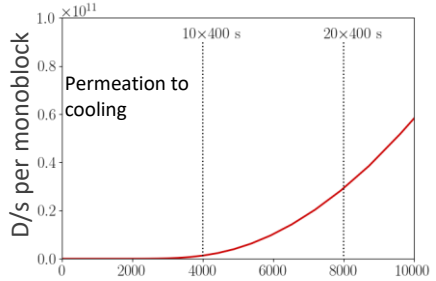
D in SSL: 10^{19} Dm^{-2}

Deepest migration For scenario I (1456 K) ⇒ Retention near the cooling

RESULTS: Macroscopic data



Retention $(R_D = t^{\alpha})$
Sc III > Sc II > Sc I
α = 0.50 < 0.53 < 0.56



Permeation only Sc I after 10,000 s
1.35×10^{14} D per monoblock
⇒ 2.8×10^{17} D for ITER div

Release to Poloidal gaps
10^{14} D/s (I) and 0.5×10^{14} D/s (II)
54 cassettes× 16 In - 22 Out div
⇒ 3.2×10^{17} D/s