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Deuterium retention in tungsten-tantalum alloys

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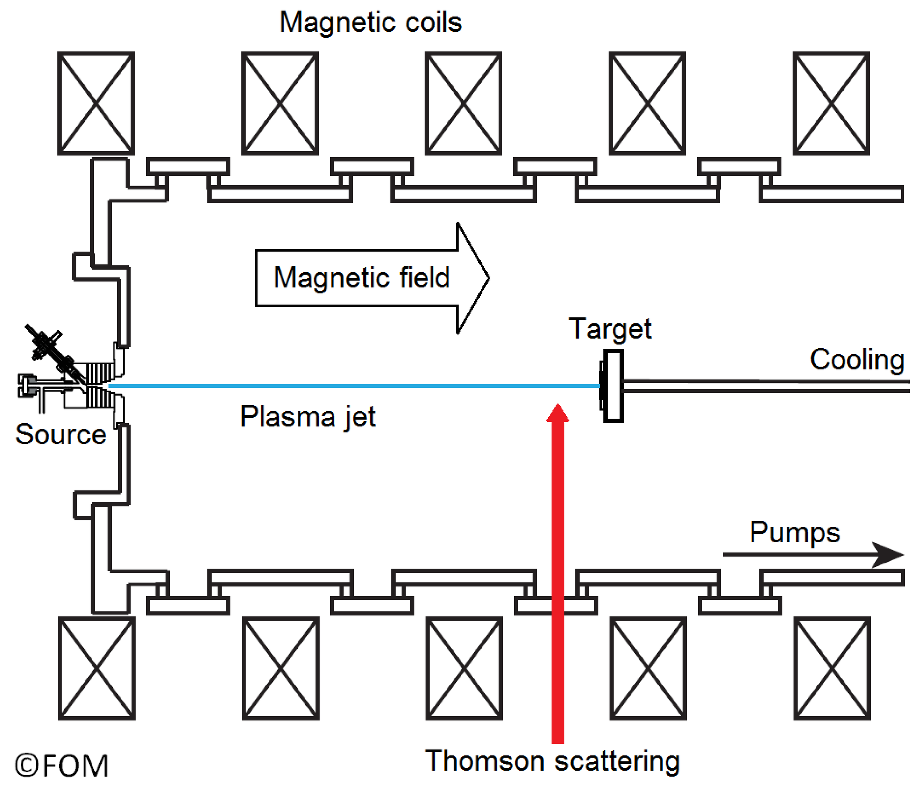
Experiment



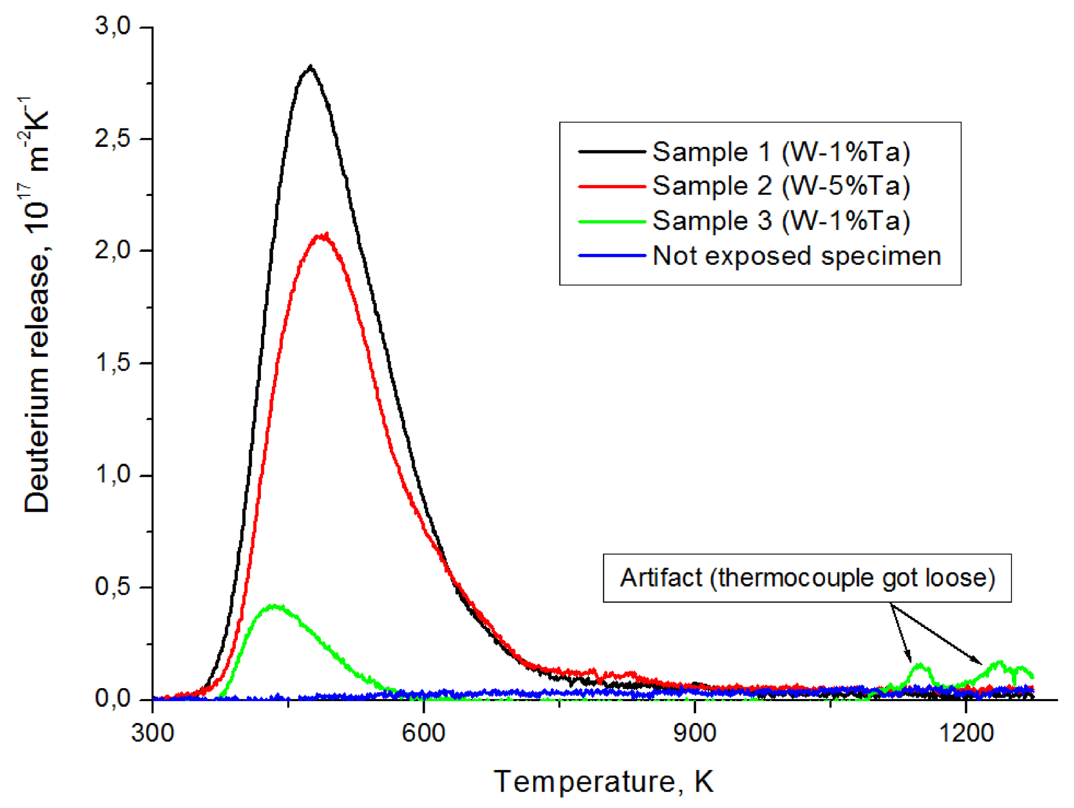
Pilot-PSI (FOM Rijnhuizen, Netherlands)

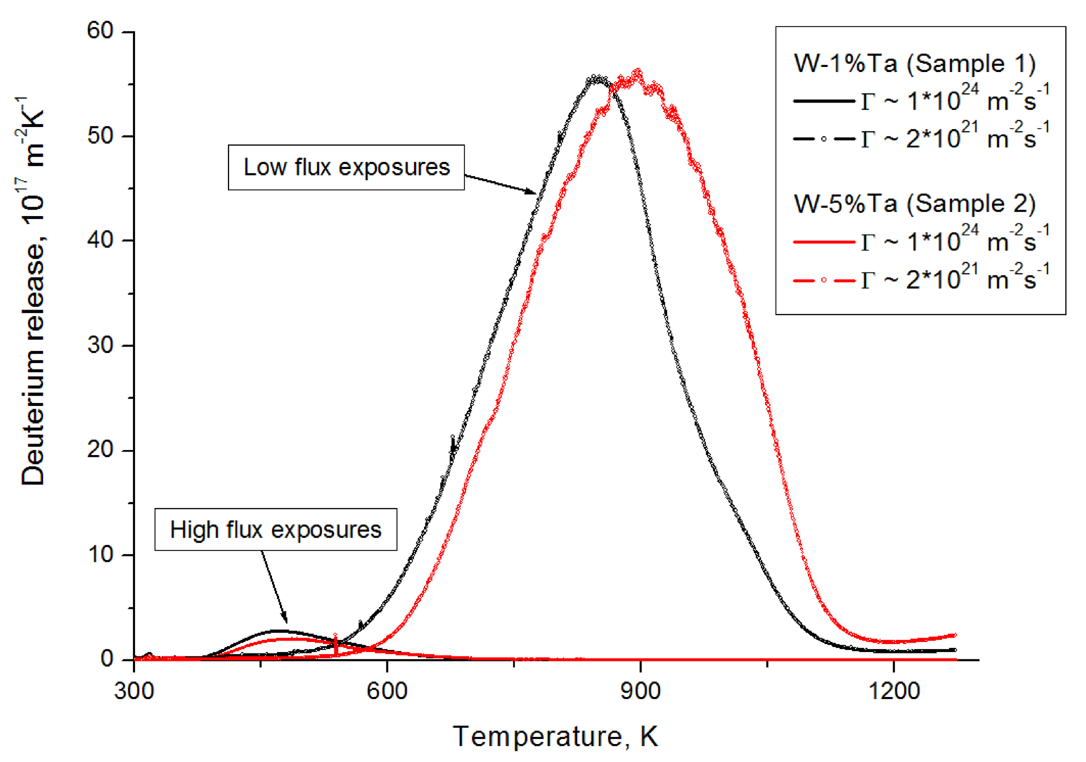
	Sample 1 W-1%Ta	Sample 2 W-5%Ta	Sample 3 W-1%Ta
Ion flux, $m^{-2}s^{-1}$	$1.2*10^{24}$	$1.2*10^{24}$	$3.4*10^{24}$
Total fluence, m^{-2}	$5*10^{25}$	$5.28*10^{25}$	$5.22*10^{25}$
Ion energy, eV	50	50	float (~5)
Temperature, K	430	450	<510
Total retention, m^{-2}	$5.67*10^{19}$	$4.46*10^{19}$	$4.8*10^{18}$

Thermal desorption spectroscopy

Temperature ramp – 0.5 K/s
QMS detects signal of mass 3 (HD) and 4 (D_2)

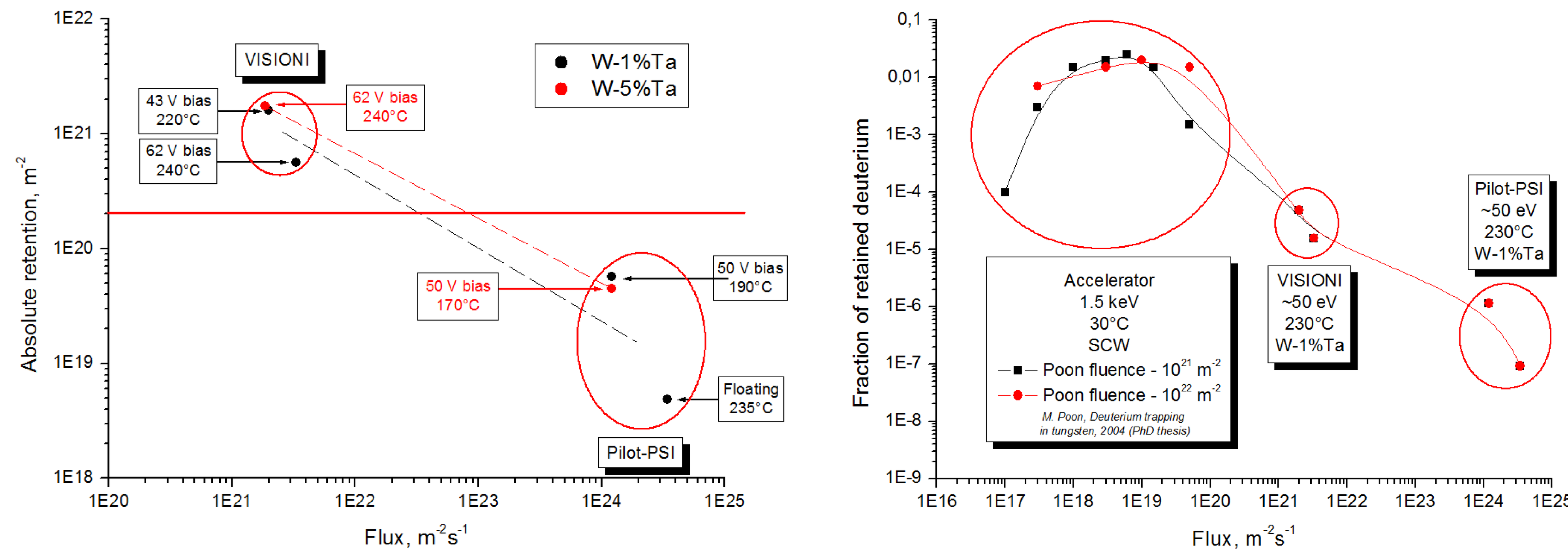
$$\Gamma_D = \Gamma_{HD} + 2\Gamma_{D_2}$$





Low-flux exposures - from *Y. Zayachuk, et al., Fusion Eng. Des. (2011), doi:10.1016/j.fusengdes.2011.03.094*

Fluence dependence of retention



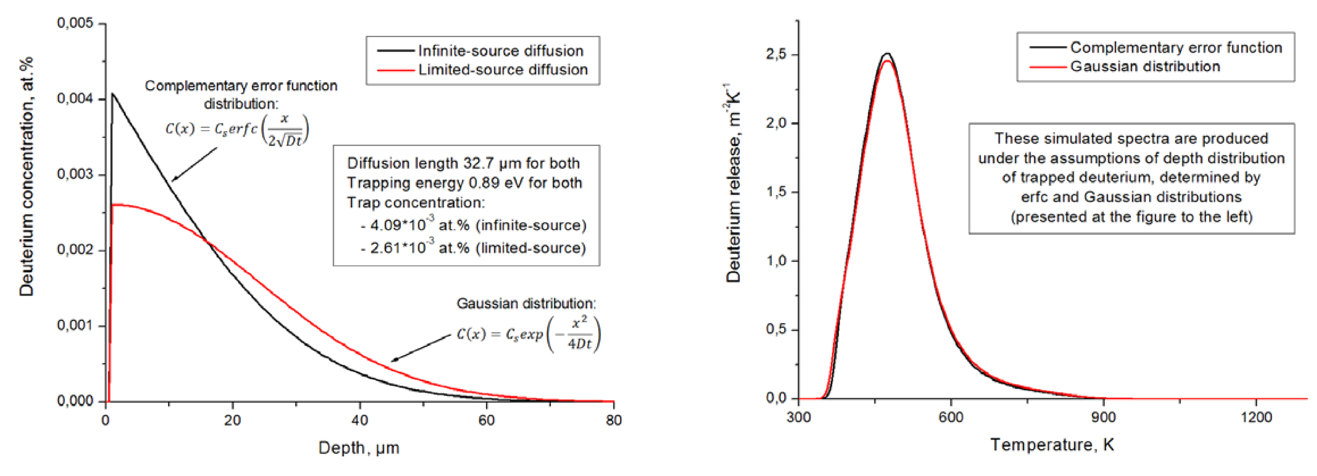
Low-flux exposures - from *Y. Zayachuk, et al., Fusion Eng. Des. (2011), doi:10.1016/j.fusengdes.2011.03.094*

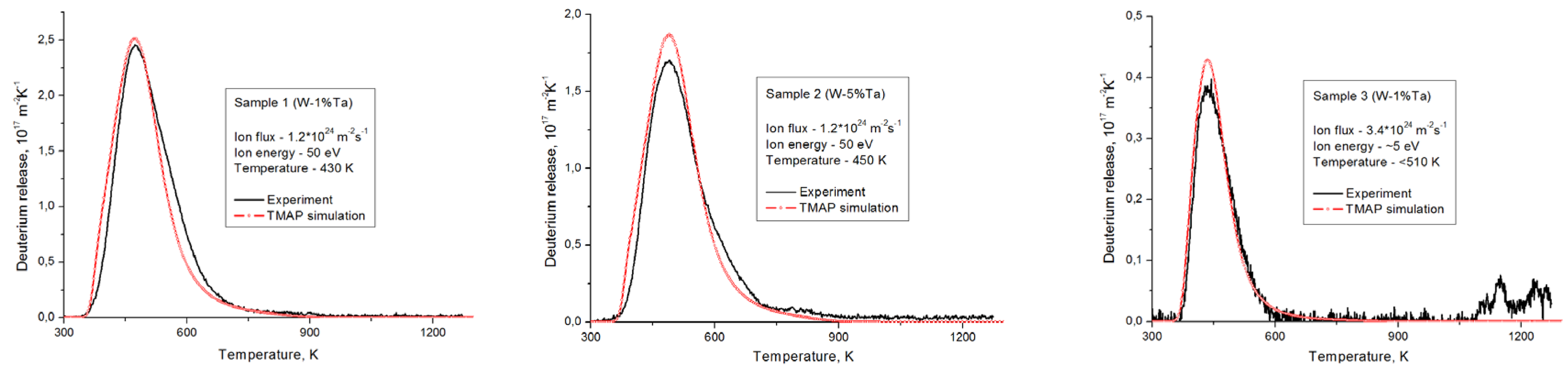
Simulations of desorption spectra

Diffusion code TMAP7
(G. Longhurst, INL, 2008)

Model parameters:

Single trap
Trapping energy 0.9 ± 0.02 eV
Diffusion length $2\sqrt{Dt}$
Frauenfelder diffusivity:
$D = 2.9*10^{-7}\left[\frac{m}{s^2}\right]\exp\left(-\frac{0.39eV}{kT}\right)$
Deuterium-free 1 μm space in sub-surface
Infinite-source diffusion
Modelling of D_2 release only





Diffusion length – 32.7 μm
Trapping energy – 0.89 eV
Concentration of traps – $4.09*10^{-3}$ at. %
Maximum filled fraction – 1.0

Diffusion length – 40.6 μm
Trapping energy – 0.92 eV
Concentration of traps – $2.79*10^{-3}$ at. %
Maximum filled fraction – 1.0

Diffusion length – 9.6 μm
Trapping energy – 0.89 eV
Concentration of traps – $4.09*10^{-3}$ at. %
Maximum filled fraction – 0.37

Conclusion

(1) Ion-driven deuterium retention in tungsten-tantalum alloys (grades, containing 1% and 5% of Ta) was studied by means of thermal desorption spectroscopy (TDS), accompanied by simulations using diffusion code TMAP7. For the first time, flux dependence of retention in the range of more than three orders of magnitude, was determined.

(2) Increase of ion flux leads to the decrease of the amount of retained deuterium under condition of constant incident fluence.

(3) Only single desorption peaks were observed in the TDS spectra for all the investigated samples, suggesting the presence of only one type of traps. Trapping energy was found to be 0.90±0.02 eV, which is somewhat smaller than trapping energy of D on vacancies in pure W (0.95 eV (M. Poon et al., J. Nucl. Mat. 374 (2008) 390-402)). Thus, major trapping mechanism of D in W-Ta alloy is likely trapping on vacancies.

(4) No peak corresponding to the trapping energy in the range of ~1.72 eV, in pure W attributed to D retention on the inner walls of voids and blisters, was observed, suggesting absence of surface blistering. No blistering was observed on SEM images either.

(5) Preliminary conclusion – incorporation of Ta in W decreases somewhat the trapping energy of D by vacancies and enhances material's resistance to the formation of surface blisters.

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