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Correlation of surface chemical states with hydrogen isotope retention in divertor tiles of JET with ITER-Like Wall

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Correlation of surface chemical states with hydrogen isotope retention in divertor tiles of JET with ITER-Like Wall

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JET



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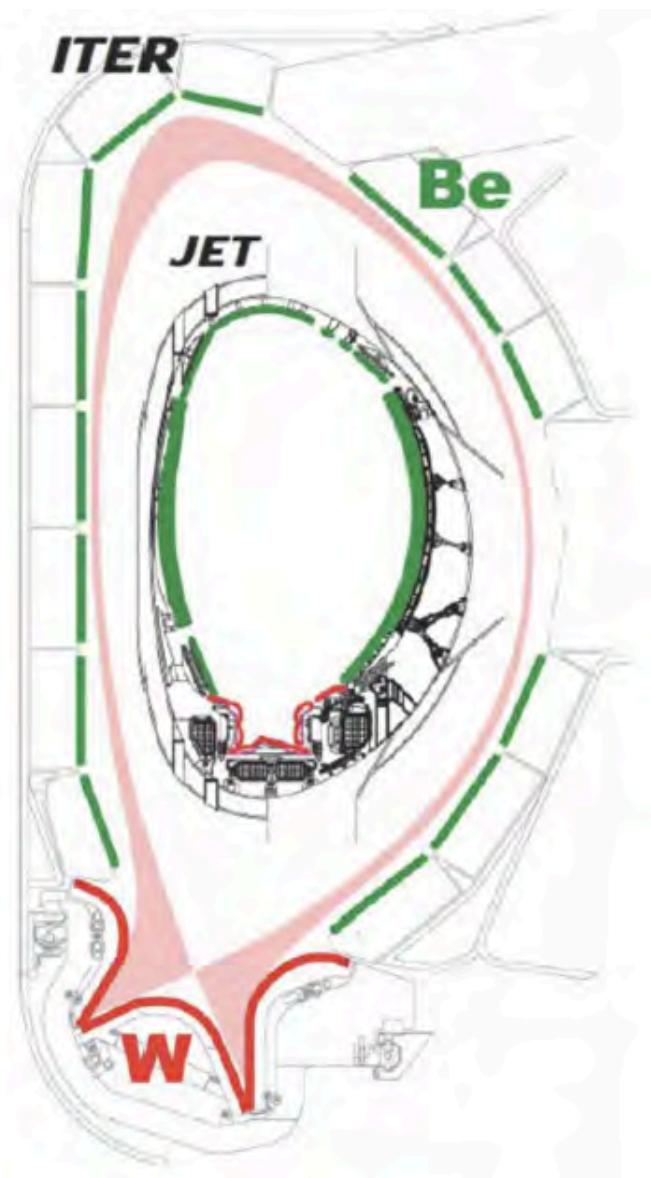
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**See the author list at “Overview of the JET results in support to ITER”, X. Litaudon et al., in press Nuclear Fusion, 26th Fusion Energy Conference (Kyoto, Japan, October 2016)

Introduction - JET ITER-Like Wall Experiment



The objective of JET ITER-Like Wall experiment is to understand the influences of the ITER like Plasma Facing materials on

- ✓ Plasma confinement
- ✓ Impurity behavior
- ✓ **Plasma Wall interaction**
 - ✓ Fuel retention
 - ✓ Materials migration (Erosion/Deposition)
 - ✓ Dust

for the prediction of plasma performance and PWI in ITER

This study was focused on the tiles used for 1st campaign 2011-2012.

Puffed amount of D : $\sim 1.6 \times 10^{26}$ atoms

Total input energy : 150.6 GJ

Predominant strike point : Tile 3 (Inner) & 5 (Outer)

Objective



Discuss the correlation of surface chemical states with hydrogen isotope retention in ILW-1 divertor tiles

XPS (X-ray photoelectron Spectroscopy)

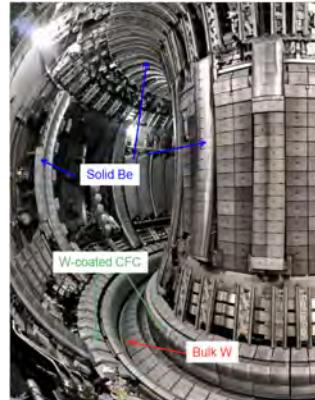
- Atomic concentration
- Chemical states for constituent elements

TDS (Thermal Desorption Spectroscopy)

- H & D desorption temperature
- H & D retentions



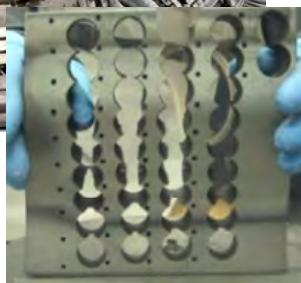
Experimental



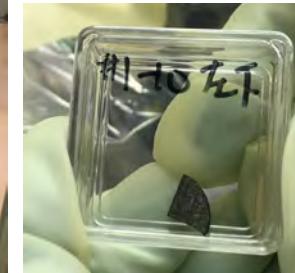
Transport



IFERC, QST



Cut



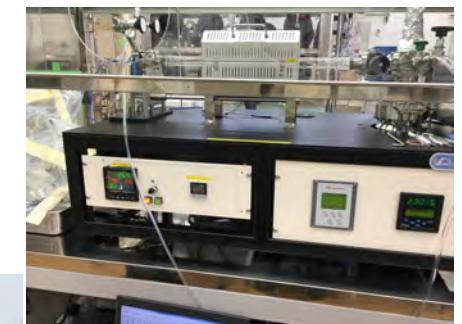
Chemical states

XPS

Analyses

Fuel retention

TDS

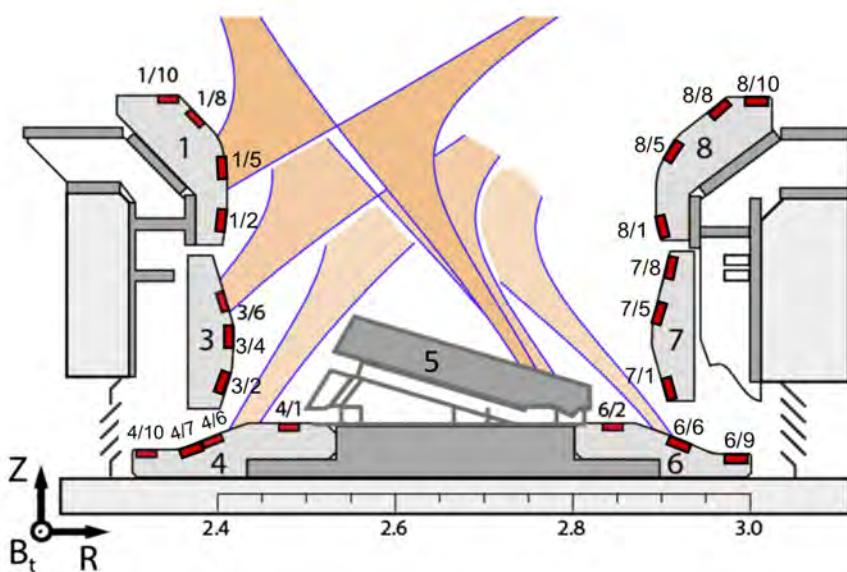


ULVAC PHI
Versa Pro
Source : Al – $k\alpha$
Ar⁺ sputtering
3 keV max 20 min.

RT-1000 °C
0.5 °C s⁻¹
QMS : MKS
Microvision
Calibration :
 D_2 standard leak

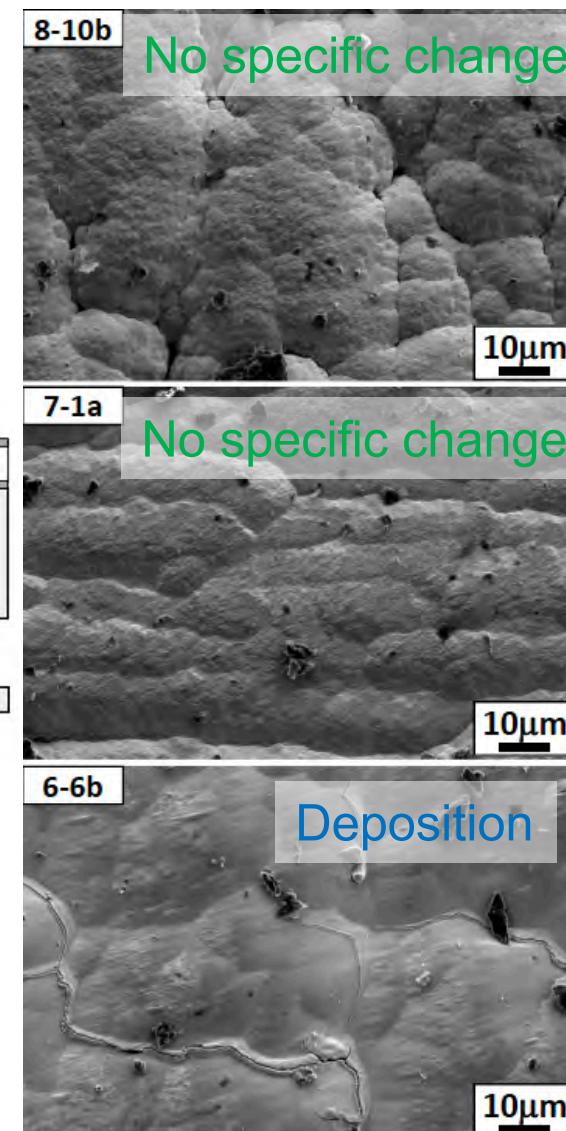
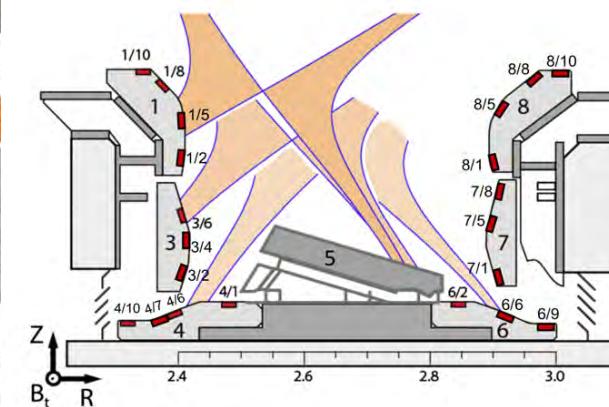
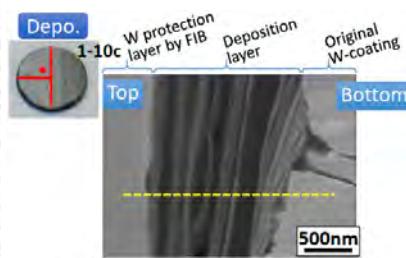
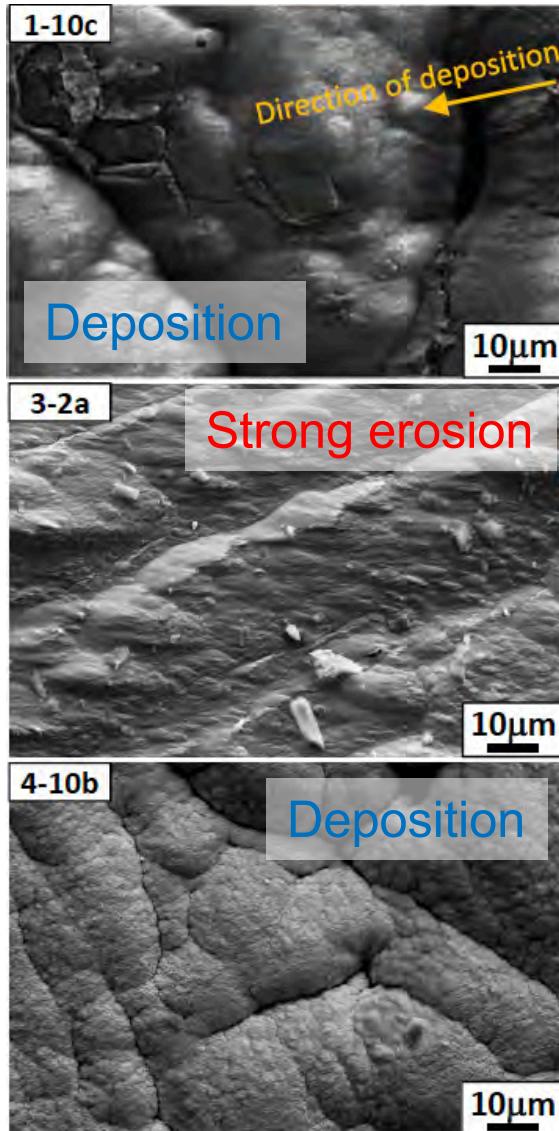
JET

Sample positions



Tile	Sample	Position (s-coordinate, mm)	XPS	TDS
1	1/10	Apron part (217.5)	✓	✓
	1/8	Upper part (261.8)	✓	✓
	1/5	Intermediate part (331)		✓
	1/2	Lower part (392)		✓
3	3/6	Inner strike point (484.7)	✓	✓
	3/4	Inner strike point (526.5)		✓
	3/2	Inner strike point (565)	✓	✓
4	4/10	Shadowed part (734.5)	✓	✓
	4/7	Slope part (796.7)		
	4/6	Slope part (818)	✓	✓
	4/1	Shadow of Tile 5 (917)		✓
6	6/2	Shadow of Tile 5 (1351.2)		✓
	6/6	Slope part (1437)	✓	✓
	6/9	Shadowed part (1492)	✓	✓
7	7/1	Outer Strike point (1642)	✓	✓
	7/5	(1734)		
	7/8	(1796)		
8	8/1	Lower part (1828.6)		
	8/5	Intermediate part (1912)		
	8/8	Upper part (1967)		
	8/10	Apron part (2023)	✓	✓

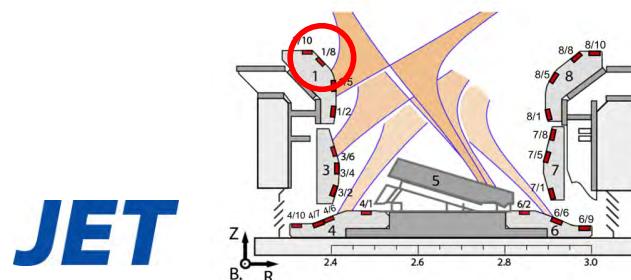
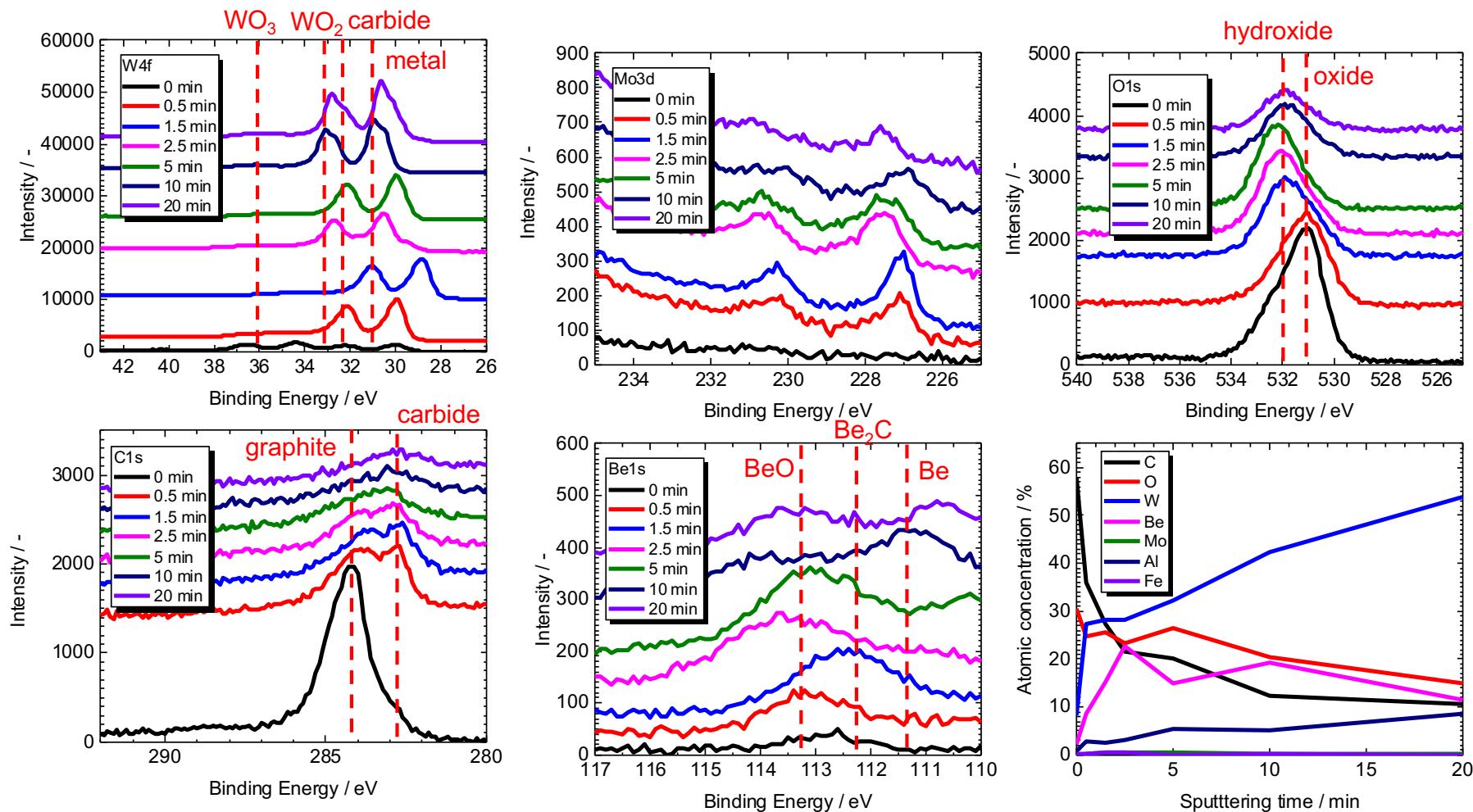
Overview of tile surface morphologies



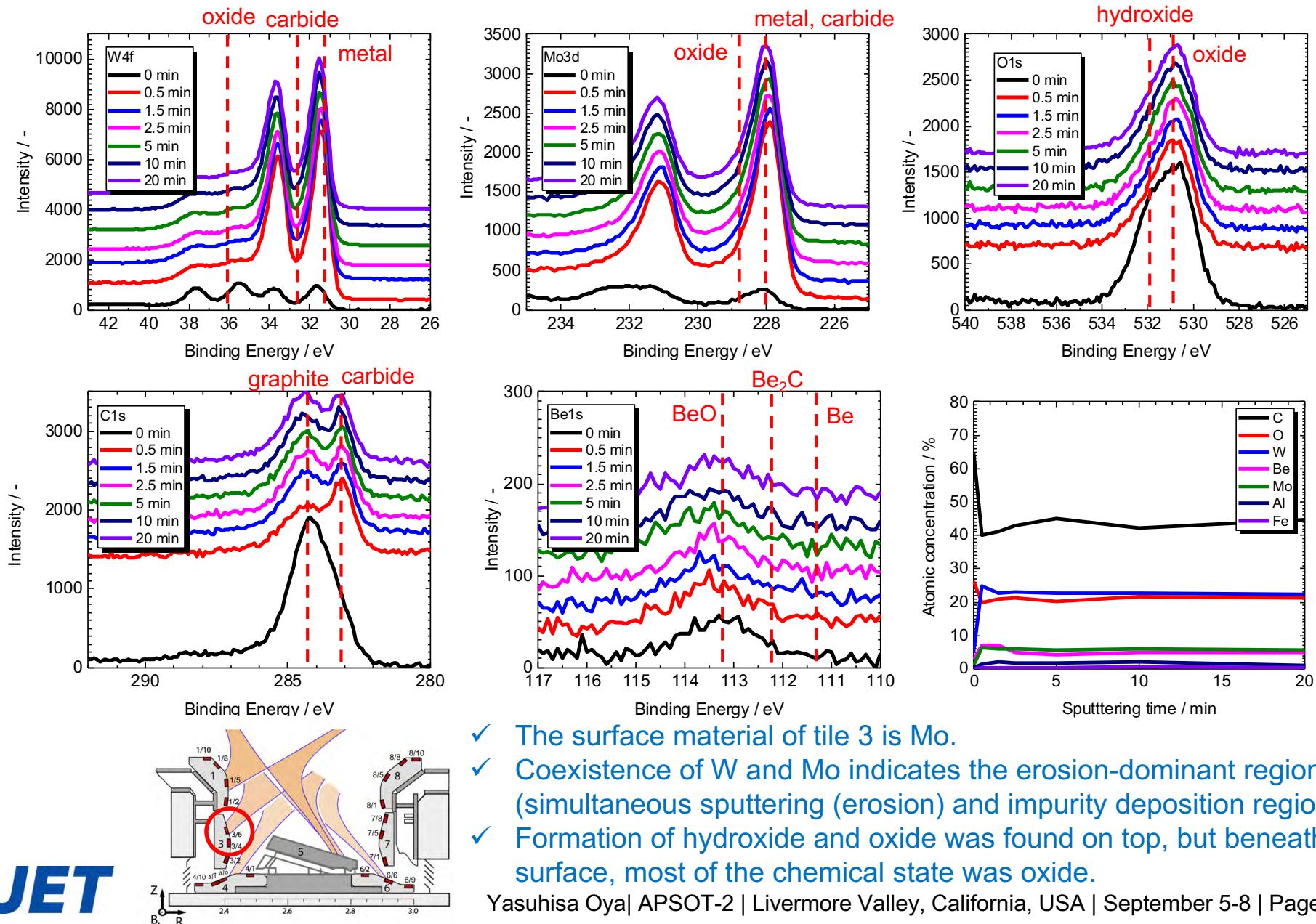
M. Tokitani et al., Fusion Eng. Des. 116 (2017) 1-4.

M. Tokitani et al., Fusion Eng. Des. to be submitted.

XPS analysis for Tile 1, inboard upper part (1/8)

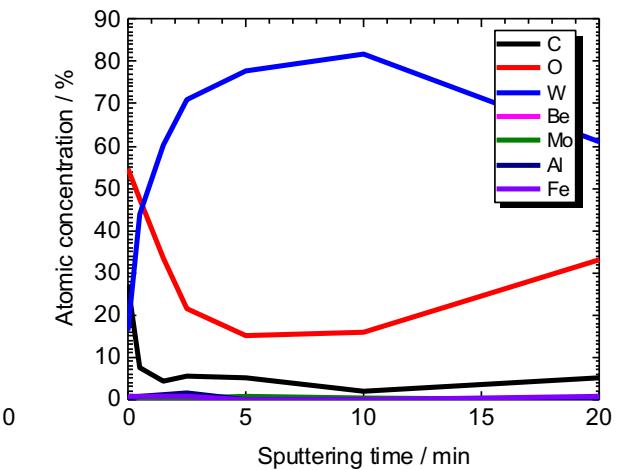
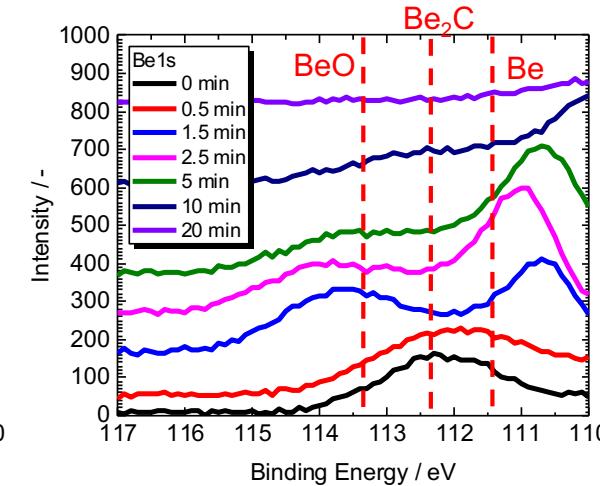
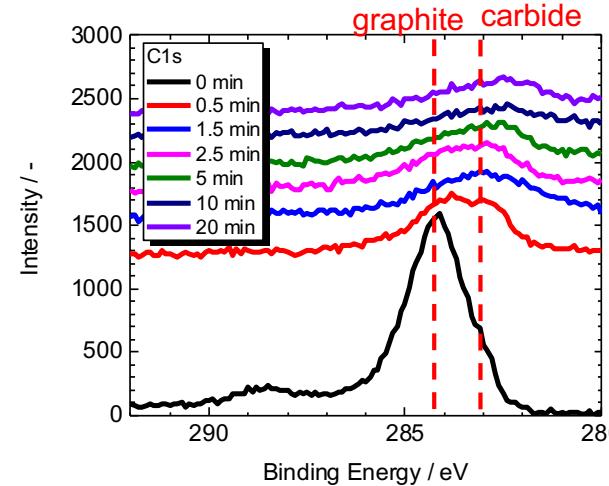
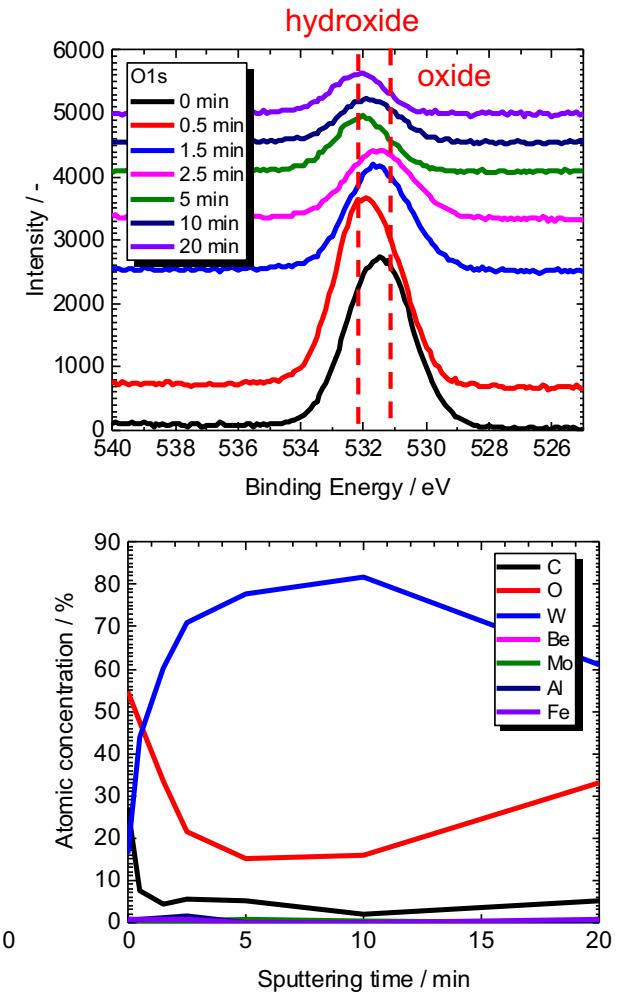
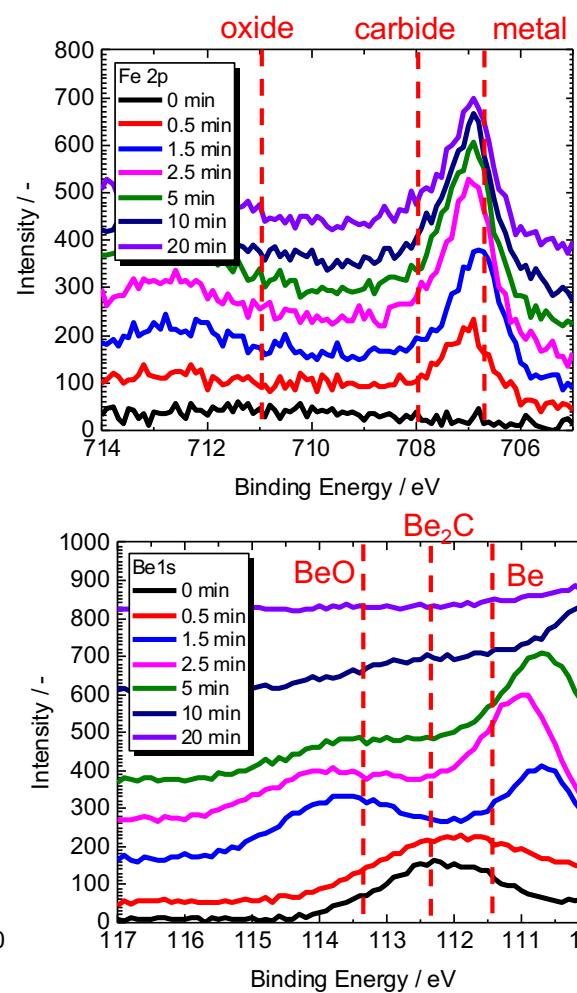
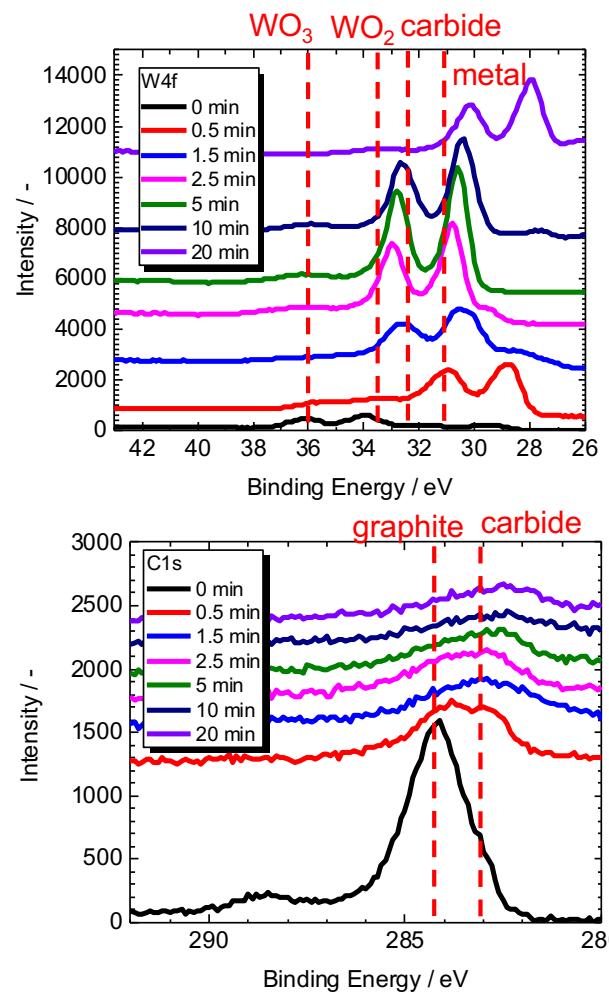


XPS spectra for Tile 3, inner strike point (3/6)



- ✓ The surface material of tile 3 is Mo.
- ✓ Coexistence of W and Mo indicates the erosion-dominant region (simultaneous sputtering (erosion) and impurity deposition region).
- ✓ Formation of hydroxide and oxide was found on top, but beneath the surface, most of the chemical state was oxide.

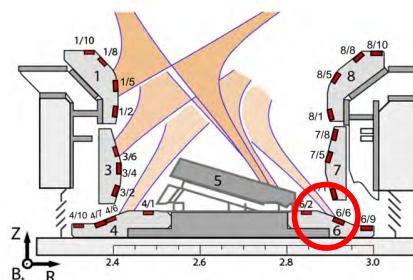
XPS spectra for Tile 6, slope part (6/6)



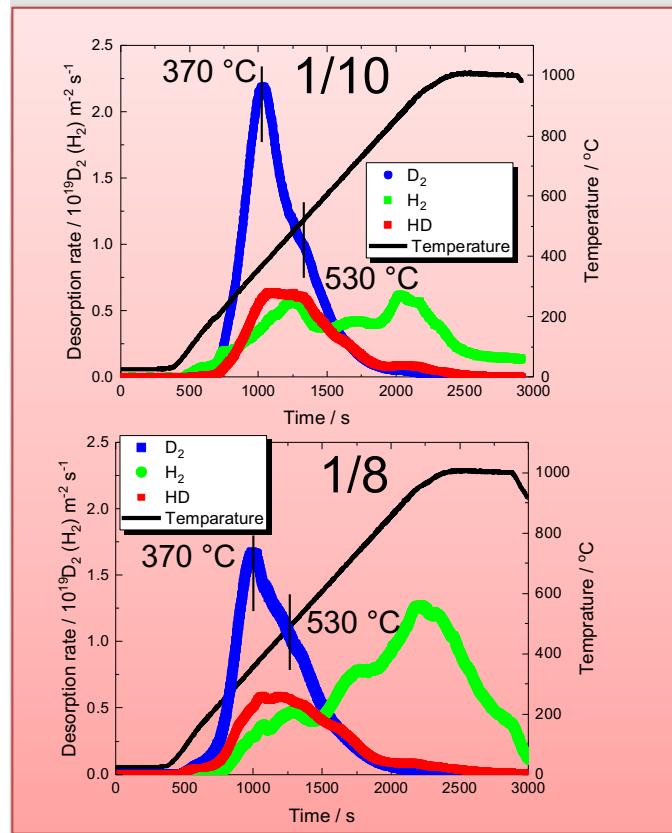
- ✓ Mixed material deposition layer was formed on the surface by TEM, which enhanced the negative peak shift of W 4f and Be 1s.
- ✓ Large chemical shift of W 4f and existence of Fe was observed.
- ✓ Formation of hydroxide and oxide was found.

M. Tokitani et al., Fusion Eng. Des. to be submitted.

Yasuhsia Oya | APSOT-2 | Livermore Valley, California, USA | September 5-8 | Page 10

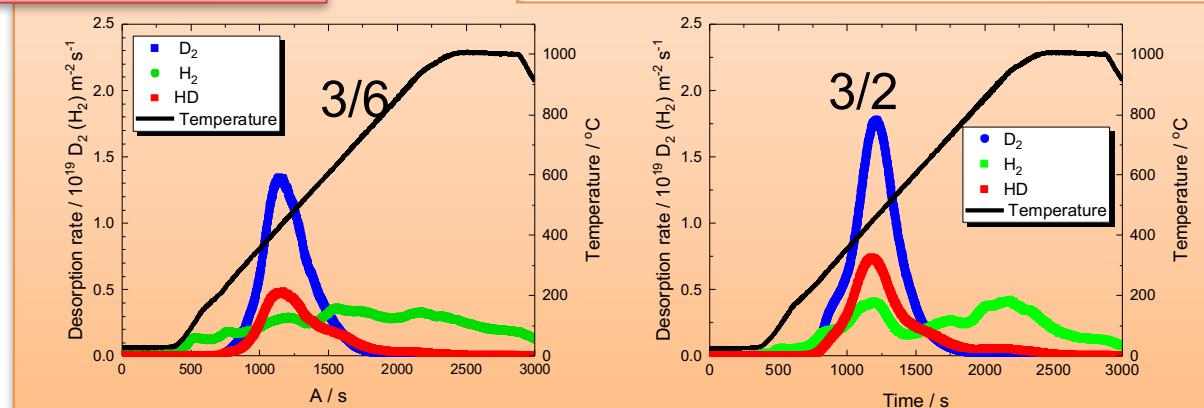
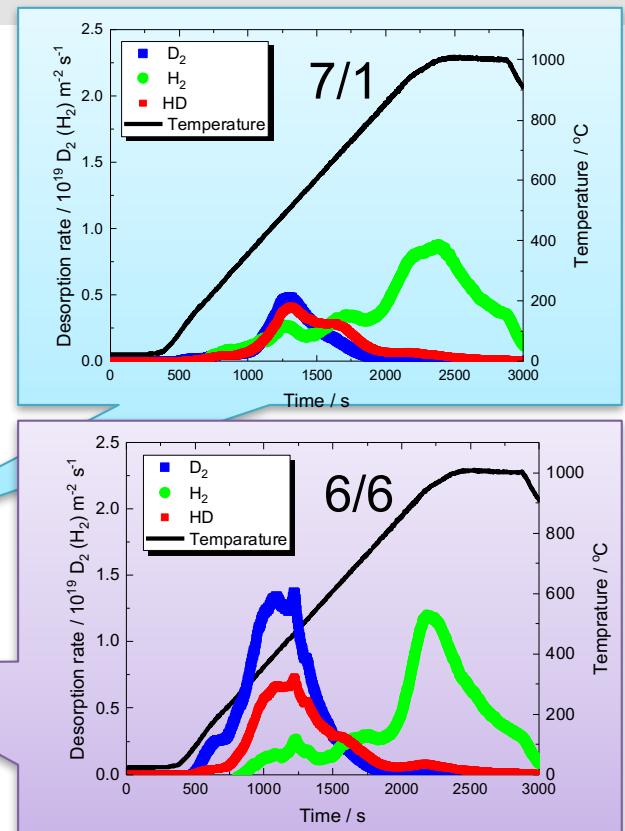
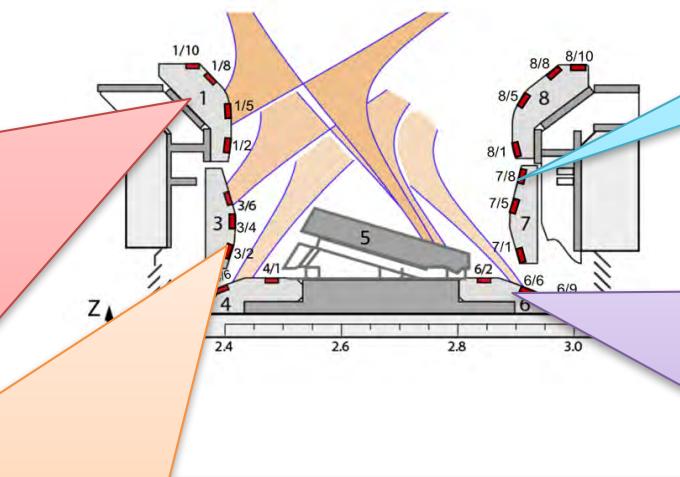


H and D desorption behavior by TDS

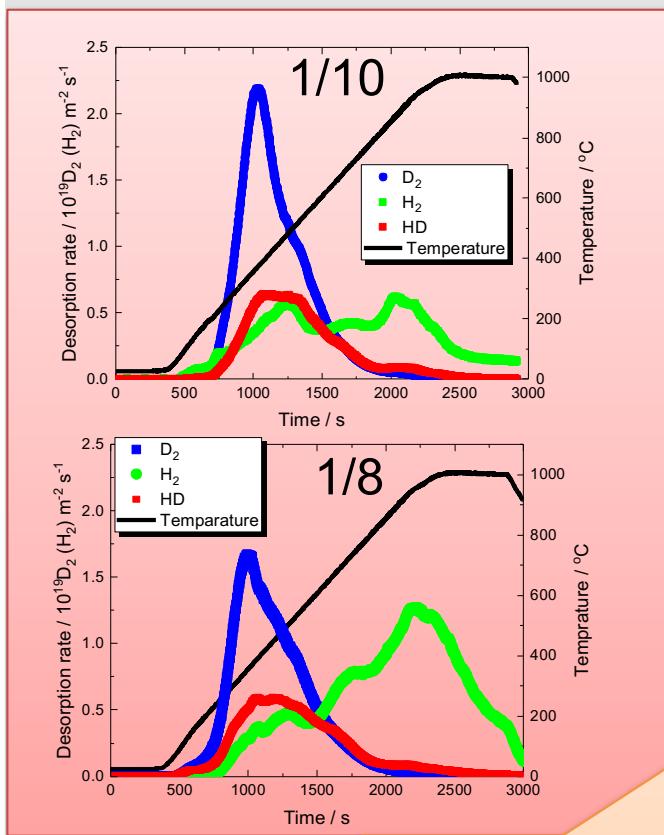


Inner Upper part

- ✓ Highest D and H retention due to thicker deposition
- ✓ H with lower trapping energy was clearly replaced by D

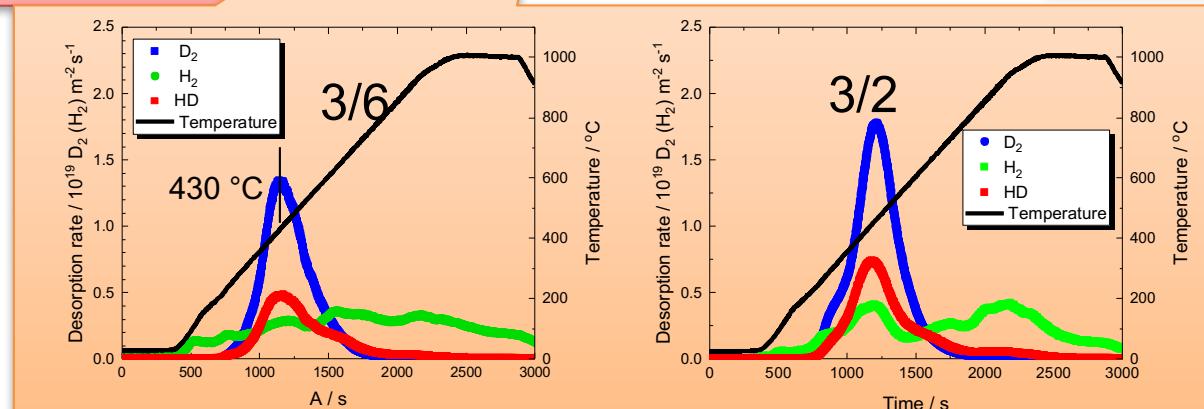
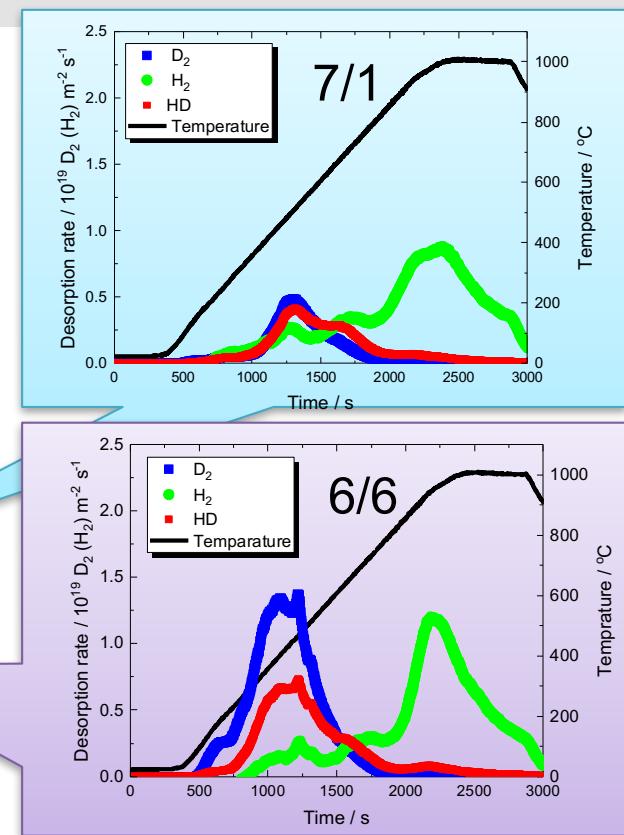
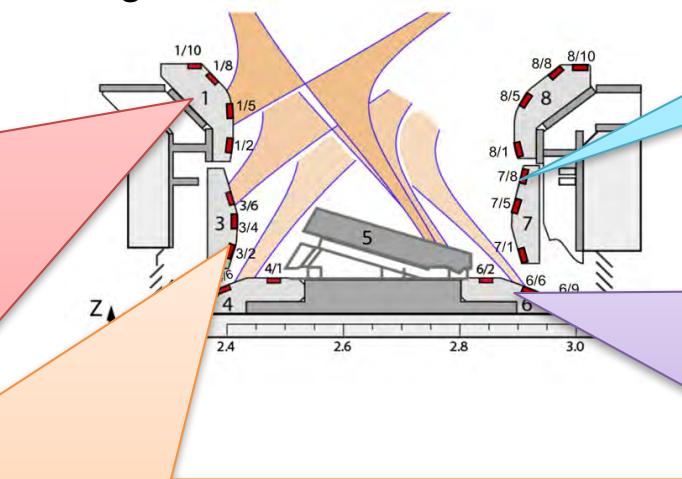


H and D desorption behavior by TDS

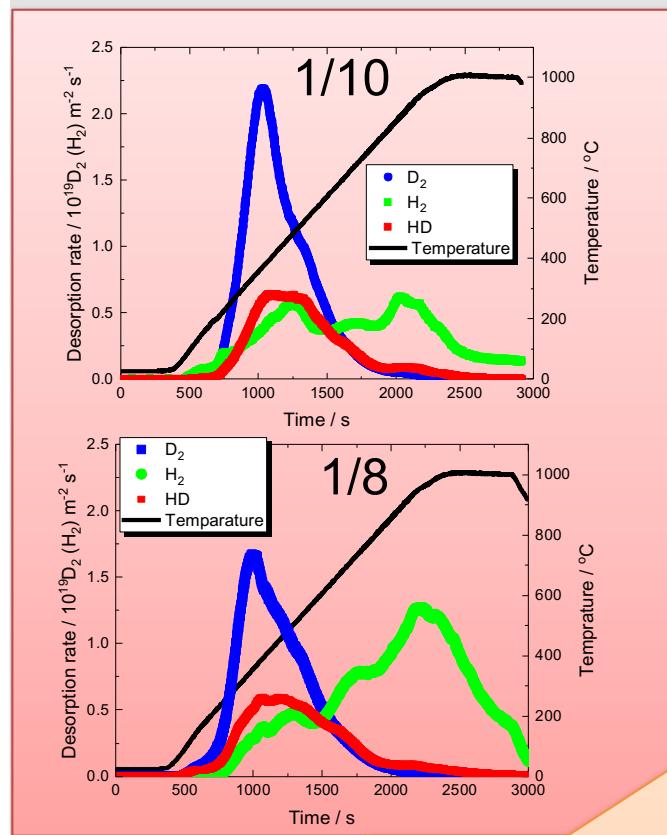


Inner strike point

- ✓ D desorption temperature was shifted toward higher temperature side and H retention was reduced due to higher heat load.

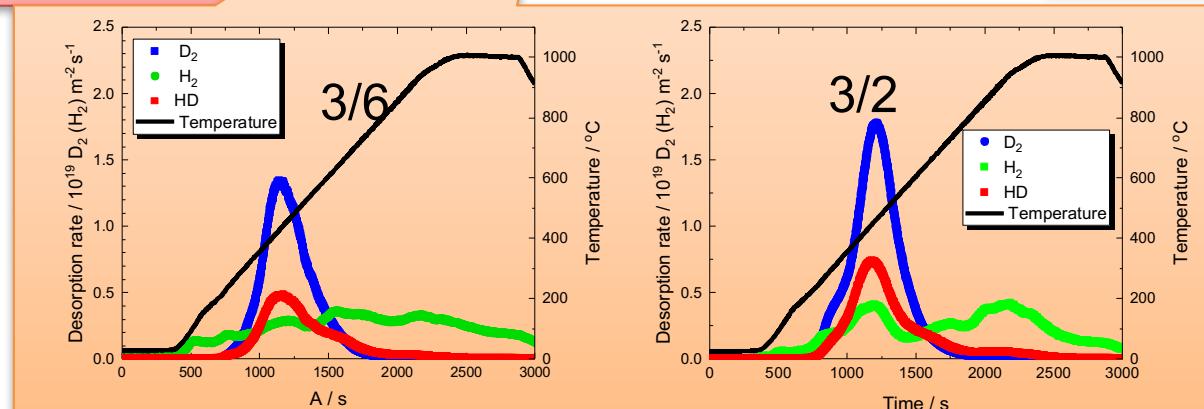
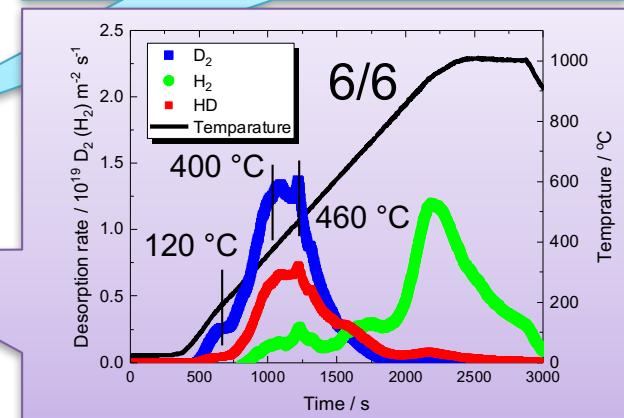
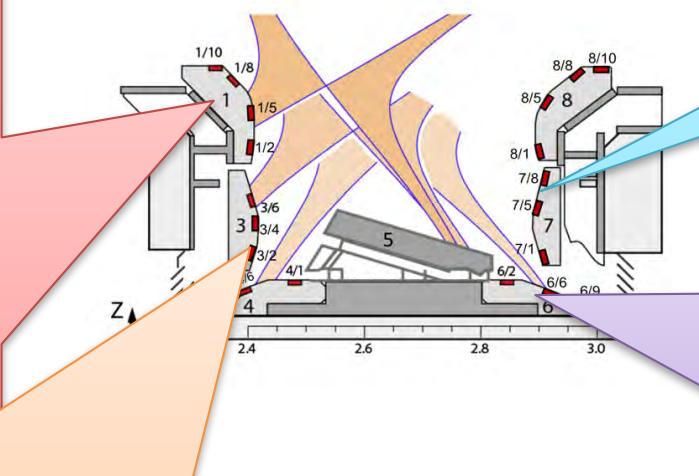
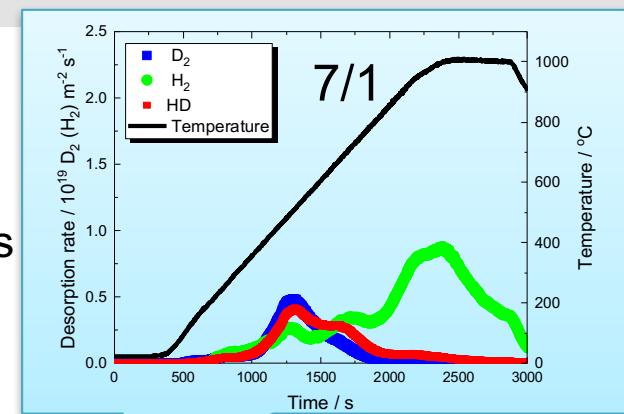


H and D desorption behavior by TDS

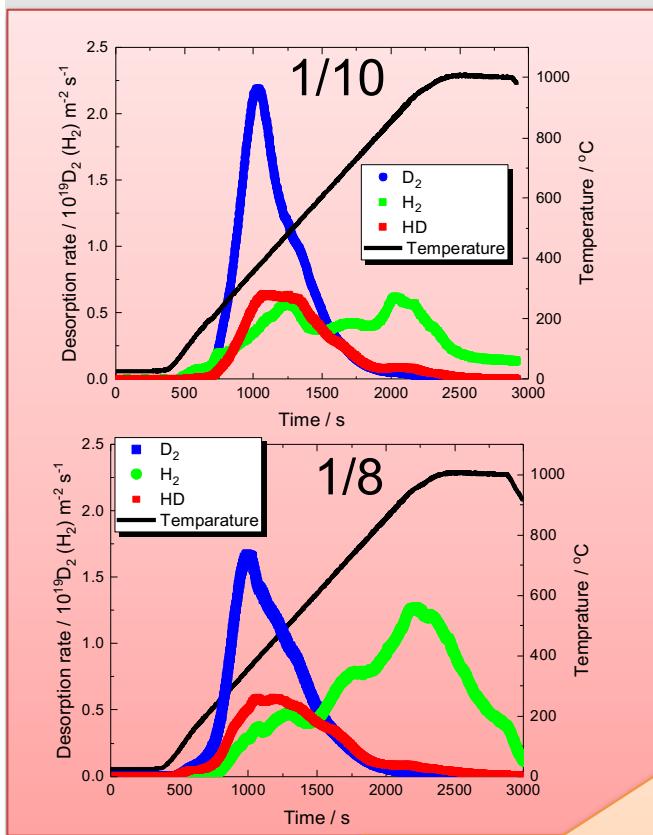


Slope part

- ✓ The D desorption was initiated at lower temperature of 120 °C and two large D desorption was located at 400 °C and 460 °C.

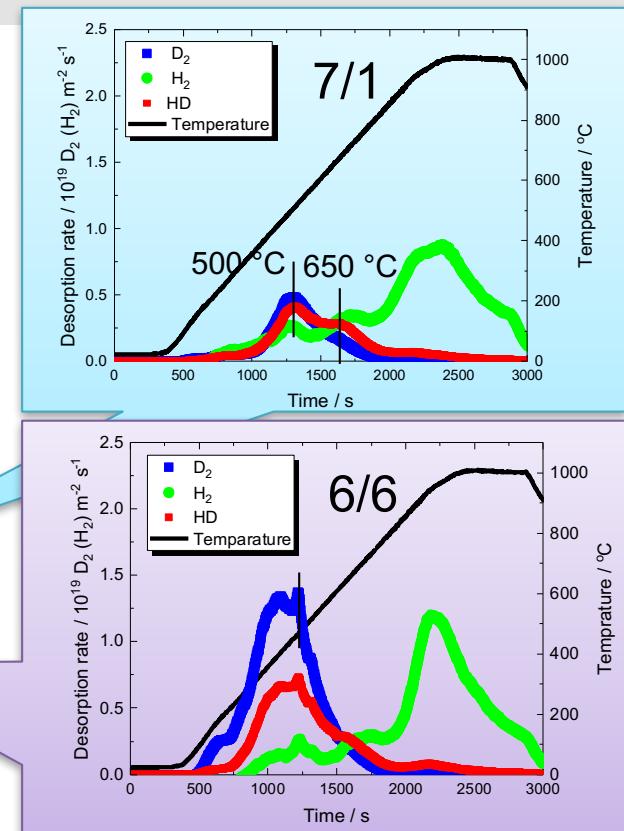
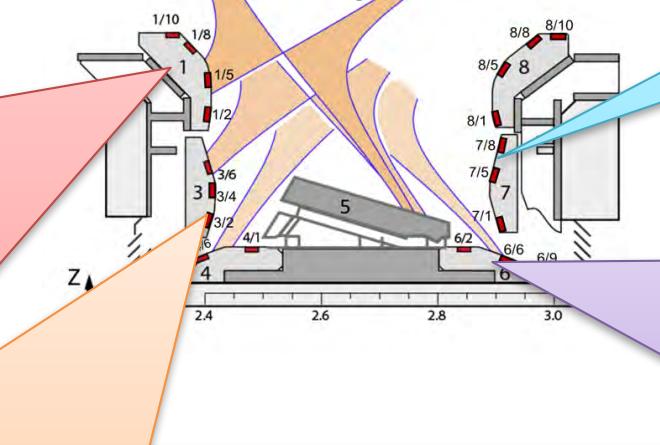


H and D desorption behavior by TDS

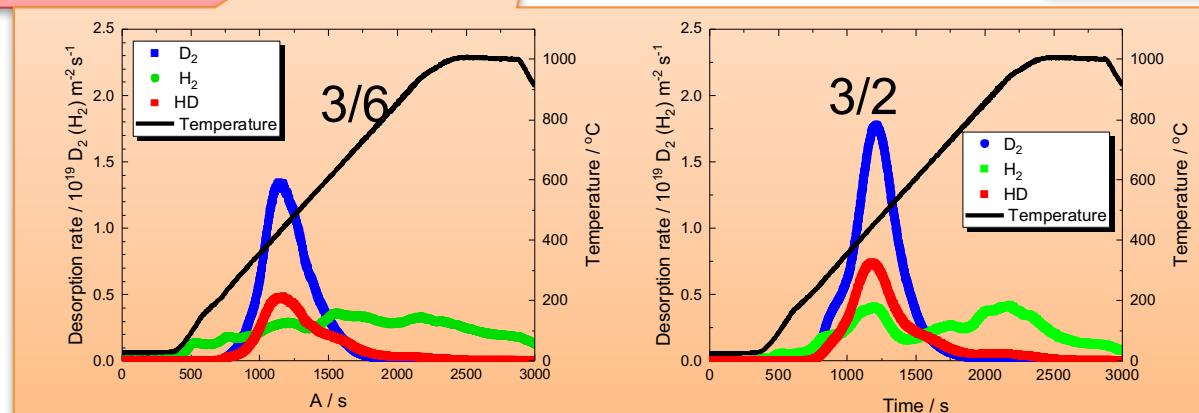


Outer divertor tile

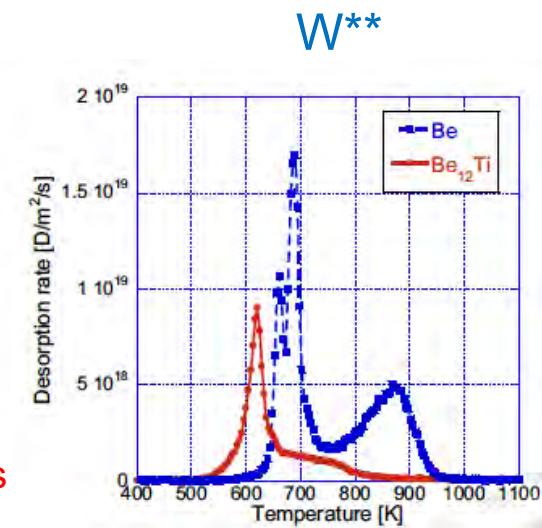
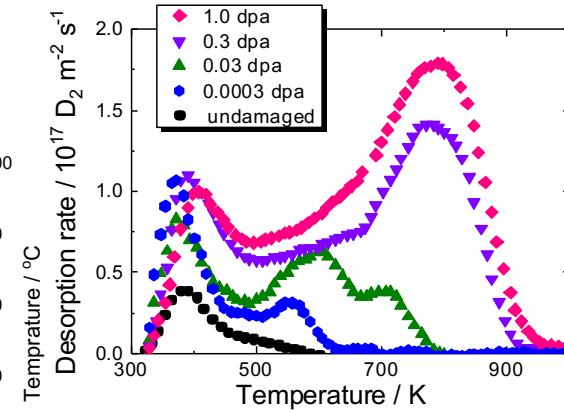
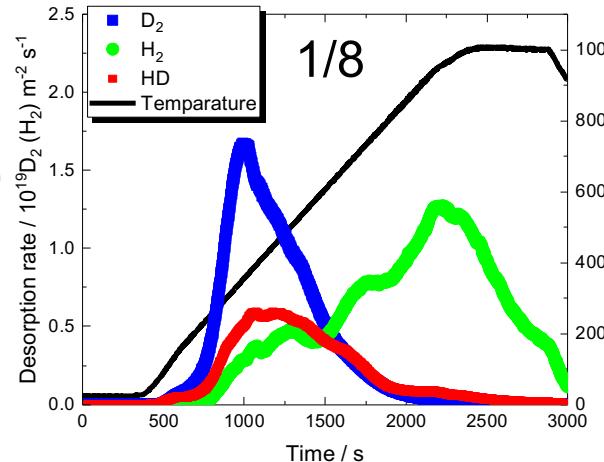
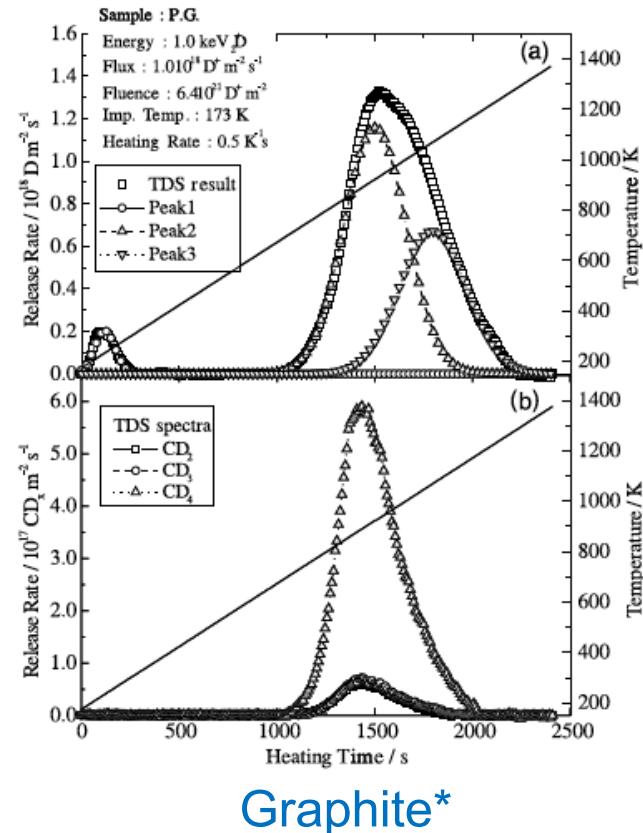
- ✓ The D desorption was quite small compared with that for inner samples, being low-deposition areas*, hence there are no major fuel co-deposition processes taking place.



*K. Heinola, et al, Phys Scr., T167 (2016) 014075.



Comparison of TDS with standard samples



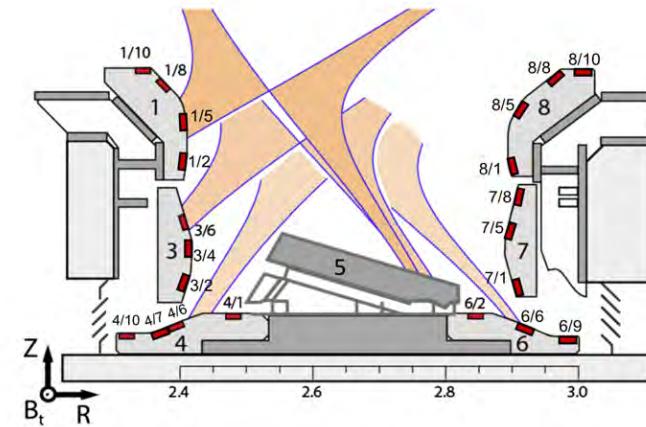
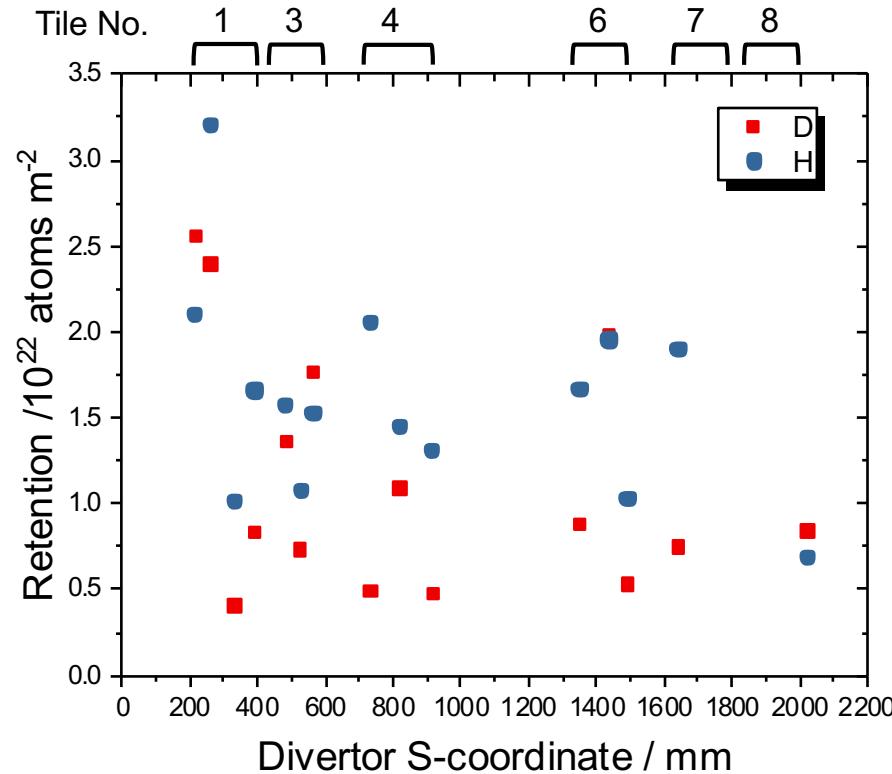
Be***

*Y. Morimoto and K. Okuno, JNM 313-316 (2003) 595-598.

**Y. Oya et al., JNM 461 (2015) 336–340.

***Y. Fujii et al., Nucl. Mater. Energy 9 (2016) 233-236.

Summary of H and D total retentions



- ✓ Higher D and H retentions were found for inner upper divertor region (Tile 1).
- ✓ As moving to outer divertor region, their retention was clearly reduced.
- ✓ For the strike point region (Tile 3), slightly higher retention was found compared with the erosion-dominated area like outer divertor. It can be said that the deposition and formation of mixed material layer would work as hydrogen isotope trapping sites in the divertor of JET ITER-like wall.



Conclusions

- Hydrogen isotope retention and chemical state of the divertor tiles for JET ITER-Like Wall were evaluated by TDS and XPS at QST IFERC Rokkasho site under the framework of BA activities.
- The deposition layer was found in the inner upper divertor area (Tile 1).
- At the inner strike point region (Tile 3), the existence of W and Mo was found, indicating for erosion-dominated region, but the impurity deposition was also found. Higher heat load would induce the formation of metal carbide.
- In the case of outer horizontal tile (Tile 6), mixed material layer was formed and iron impurity was seen clearly being deposited.
- TDS showed the H and D desorption behavior and major D desorption temperature for Tile 1 was located at 370 °C and 530 °C. At the strike point region, the D desorption temperature was clearly shifted toward higher temperature side, indicating of emptying the low-energy traps by higher heat load.
- The deposition and formation of mixed material layer would work as hydrogen isotope trapping sites in the divertor of JET ITER-Like Wall.