TRITIUM RETENTION IN DUST PERTICLES AND DIVERTOR TILES OF JET OPERATED WITH THE ITER-LIKE WALL

ID: TECH/P8-14

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Abstract

- It was present systematic and quantitative study of tritium retention in dust and divertor tiles of ILW by means of tritium imaging plate technique and a full combustion method.
- The amount of tritium in the dust and tiles was also measured.

Background

- The Joint European Torus (JET) is operated with the ITER-Like Wall (JET-ILW) in order to replicate materials for ITER.
- JA-EU Broader Approach collaborative research on JET-ILW tiles and dust analysis has been conducted since 2014.
- A significant number of samples from wall tiles and dust (both from ILW-1 and ILW-3) as well as dust from with the carbon wall (JET-C, campaign 2007-2009) were shipped from JET to QST.
- In this study, remained tritium (T) amount in ILW-1 and ILW-3 tiles were measured.
- Also, remained tritium amount in ILW-1 and ILW-3 tiles were measured and compared with remained amount in JET-C dust. The morphology of dust was examined.

Experimental

JET dusts and tiles

- Dust particles in JET have been studied: (i) JET-C operation in 2007-2009, (ii) the first ILW-1 operation in 2011-2012 and (iii) ILW-3 in 2015-2016.
- The cross-section of the JET-ILW divertor is shown in Fig. 1. Figure 2 (a-d) show respectively: Tile 4 as retrieved after ILW-1, the same tile after preparation of specimens by coring, the cored disk and, a triangular sample (2 mm long edges and 2 mm thickness) cut-out from that disk.

Enhanced Full Combustion Method

- Specific tritium activities in JET dust and tiles were measured by FCM enhanced by the heat of Sn oxidation. At the temperature of 1100–1200 K, Sn reacts chemically with oxygen and its temperature rises to about 2,100 K. The experimental set-up is shown in Fig. 3. It was confirmed that all T in the specimens could be effectively measured by the enhanced FCM shown in Fig.4.

Composition and tritium retention of dust particles

- A tiny amount of dust was placed on the surface of an indium disk (In).
- The intensity of tritium retained on the dust particles was evaluated by TIPT. Electron Probe Micro Analyzer (EPMA) was conducted to determine morphology of the dust particles on the same surface area.
- The obtained maps (images) of the tritium distribution and elemental compositions were super-imposed.

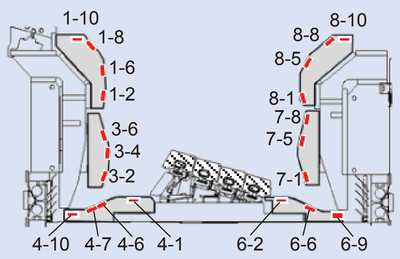

FIG.1. Cross-section of the JET-ILW divertor with marked position of specimen. Red marks indicate specimen position and letters indicate the specimen number.

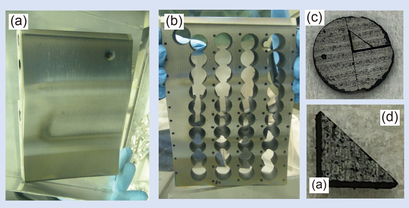

FIG.2. Photos of ILW-1divertor Tile 4 and specimen for FCM: (a) divertor tile, (b) cored tile, (c) cored specimens and (d) cut-out specimen for tritium analysis by FCM.

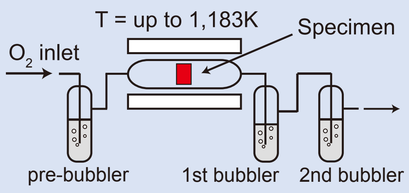

FIG. 3. Experimental set-up for tritium measurement using the full combustion method.

Specimens were wrapped Sn file and introduced into reactor tube. The specimens were heated up to 1,200K under O_2 gas flow. The released tritium in the form of HTO was trapped in two water-filled bubblers

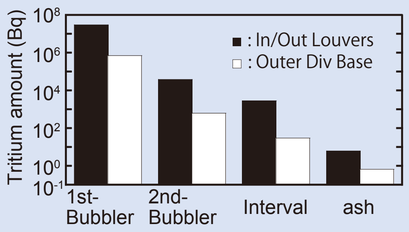

FIG.4. Quantitative measurement of tritium in dusts of In/Out Louvers and Outer Divertor Base at JET-C as measured by full combustion method.

More than 99 % of tritium removed by combustion was captured in the 1st bubbler. It was confirmed that all T in the specimens could be effectively measured by the enhanced FCM.

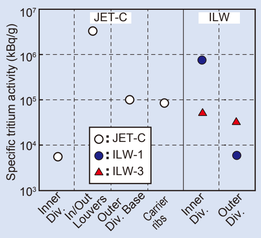

FIG.5 Specific tritium activities in dust particles after operated with JET-C, ILW-1 and ILW-3 as measured by FCM.

The specific tritium activities for ILW dust were within the same range for JET-C.

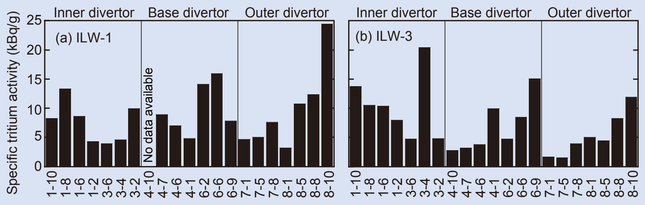

FIG.6. Specific tritium activities in tiles after operated with ILW-1 and ILW-3 as measured by FCM.

The specific tritium activities from FCM are in a similar range for both outer and inner divertor tiles.

Results and Discussions

Specific tritium activities in JET dusts and tiles

- The specific tritium activities of dusts are in the range 5 – 2,600 MBq/g and 6 - 750 MBq/g, respectively for JET-C and ILW, as shown in Fig.5.
- The specific tritium activities of tiles are in the range 3 - 25 kBq/g and 3 - 21 kBq/g, respectively for ILW-1 and ILW-3, as shown in Fig.6.
- The specific tritium activities in the ILW dusts were 3 to 5 orders of magnitude greater than that in the ILW tiles. The dust may originate from the JET-C operation.

Tritium amount in dusts

- The amounts of dust particle of ILW-1 and ILW-3 are over 2 orders of magnitude smaller than that from JET-C. The total activities were quite different: 270 GBq after JET-C, 0.2 GBq after ILW-1 and 0.04 GBq after ILW-3. This difference is a consequence of the much lower quantities of dust generated with a metallic first wall.
- The JET ITER-Like Wall has demonstrated a reduction in dust generation and has been effective in reducing the activity of tritiated dust in the fusion reactor.

Tritium amount in tiles

- The tritium concentration in the tiles is distributed both in the surface and depth directions.
- The amount of tritium in ILW tiles were about 1 MB in most tiles, and less than 3 MBq at most.
- The total tritium amounts of ILW-1 and ILW-3 divertor tile in the vacuum vessel were 713 MBq and 646 MBq, respectively.

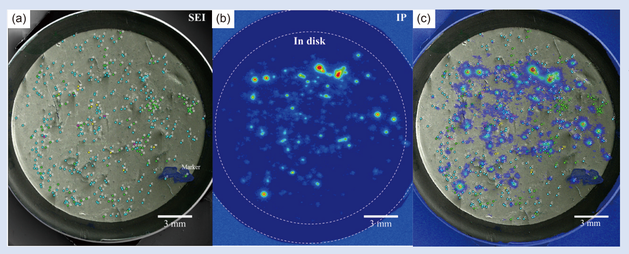

FIG.7. EPMA image showing composition of dust particles (a). Small circles with superscript labels indicate the location and composition (C, O, Be and W) of dust particles. IP image showing tritium distribution on the indium disk (b) and super-imposed image of (a) with (b) - (c).

More than 85 % of the total dust particles retaining tritium were the C-dominated ones.

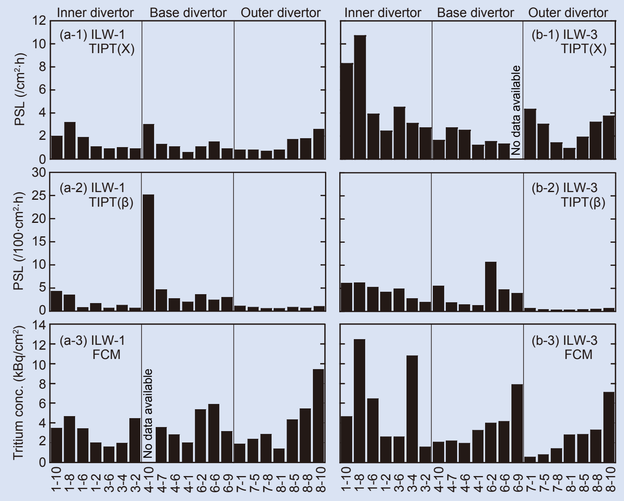

FIG.8. Tritium concentrations as measured by FCM and PSL intensities as measured by TIPT at ILW divertor tiles.

The distribution of the tritium amounts measured by the FCM is slightly different from that measured by TIPT.

- β-rays TIPT : the tritium is measured only on the surface (up to 0.7μm in depth).
- X-rays TIPT : the tritium is measured a little deeper in the tile (up to 35μm in depth).
- FCM : the tritium is measured at the thickness of 2 mm.

TABLE 1 Remained tritium in dust particle at JET-C, ILW-1 and ILW-3 as measured by FCM

		Specific T activity (MBq/g)	Collected amounts (g)	Total activity of T (MBq)
JET-C	Inner divertor	5	110.1	550
	Inner and Outer louvers	2,633	99.4	261,720
	Outer divertor tiles and base carrier	106	51.4	5,448
	Carrier ribs	70	19.3	1,351
	Total		280.2	269,069
ILW-1	Inner Divertor tiles	748	0.27	202.0
	Outer divertor tiles	6	0.77	4.6
	Total		1.04	206.6
ILW-3	Inner Divertor tiles	55	0.50	27.5
	Outer divertor tiles	36	0.36	13.0
	Total		0.86	40.5

The total tritium amounts JET-C : 269 GBq
ILW-1 : 207 MBq
ILW-3 : 41 MBq

TABLE 2 Total tritium amount in ILW-1 and ILW-3

	Tile Number	Average T conc. (Bq/cm²)	Surface area (cm²)	T amount (MBq)	Total number of tiles in vessel (block)	Total T (MBq)
ILW-1	1	3,395	270	0.92	96	88
	3	2,671	540	1.44	48	69
	4	2,803	320	0.90	96	86
	6	4,809	340	1.64	96	157
	7	2,373	640	1.52	48	73
	8	5,140	350	1.80	96	173
	Total			8.22		646
ILW-3	1	6,549	270	1.77	96	170
	3	5,008	540	2.70	48	130
	4	2,381	320	0.76	96	73
	6	5,355	340	1.82	96	175
	7	928	640	0.59	48	29
	8	4,033	350	1.41	96	136
	Total			9.06		713

The total tritium amounts ILW-1 : 646 MBq
ILW-3 : 713 MBq

Summary

- Tritium amount in JET dusts and divertor tiles were measured by the TIPT and the enhanced FCM using the heat of high temperature Sn oxidation.
- Using these two different techniques, it was found that the poloidal distributions of the surface and bulk trapped tritium are quite different.
- The tritium retention of dusts has been drastically decreased in the operation with ILW.
- The amount of tritium in the dust and tiles was measured.

Acknowledgements

- This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 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.
- This work has been supported by the ITER Broader Approach Activity.