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Tritium retention in dust particles and divertor tiles of JET operated with the ITER-Like Wall

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The Joint European Torus (JET) is operated with the ITER-Like Wall (JET-ILW): beryllium in the main chamber and tungsten in the divertor in order to replicate materials for ITER. We present the first systematic and quantitative study of tritium retention in dust and divertor tiles of JET-ILW by means of tritium imaging plate technique (TIPT) and a full combustion method (FCM). (i)The total tritium amount in tiles and dusts can be measured by the new FCM. (ii) Using these two different techniques, we found that the poloidal distributions of the surface and bulk trapped tritium are quite different. (iii) The total tritium activities show significant differences between the JET operation with ILW and the earlier operation with the carbon wall (JET-C) indicating that tritium retention may drastically decrease in the operation with ILW.
Operation of JET-ILW facilitates detailed studies of fuel retention, erosion- deposition processes and dust generation under conditions simulating future machine, i.e. ITER. Until year 2016 three JET-ILW campaigns have been fully completed: ILW-1 (2011-2012), ILW-2 (2013-2014) and ILW-3 (2015-2016) [1]. A significant number of samples from wall tiles (ILW-1 and ILW-3) and dust from ILW-1 as well as dust from JET-C (2007-2009) were shipped from JET to the R&D Building at Fusion Research Center in Rokkasho.
The materials have been examined using TIPT and FCM for the content and spatial distribution of tritium. While TIPT [2] provides the amount and spatial distribution of tritium on the surface of specimens obtained from tiles, FCM [3] provides details on tritium inventories in dust and tiles. In TIPT measurements photostimulated luminescence (PSL) delivers information on the signal intensity. In the case of FCM, a tin (Sn) foil cup serves to wrap and immobilize specimens for combustion. Wrapped specimens placed on an alumina boat in a quartz tube enclosed by a tubular furnace are heated up to 1150 K in the stream of oxygen. Under these conditions, Sn reacts with oxygen causing the temperature to rise up to about 2100 K. As a result, the foil and the enclosed specimen are burnt completely and converted to ash. Oxygen transports the released T to the downstream placed water bubblers from where it is determined by liquid scintillation counting (LSC). The same technique is used to determine tritium remaining in the ash.
Figure 1 shows the poloidal cross- section of the JET divertor and marked positions of the measured specimens. The first number denotes the tile, while the second corresponds to the sample number from a given tile. Figure 2 shows the tritium retention in tiles measured by TIPT and FCM. Evidently, concentrations of tritium on the inner divertor surface obtained by TIPT are higher than those on the outer one. Sample 6-2 (near the divertor strike point) shows the highest concentration on the surface. On the other hand, the bulk tritium retentions (in 2 mm thick samples cut from the tiles measured by FCM) show particularly high retention in 3-4, 6-9 and 1-10. Tritium retention in the outer divertor measured by TIPT is low, while that by FCM is not. Thus, most of the tritium in 8-10 is considered to remain in deeper region than the escape depth of β-rays from tritium decay. Tritium might be deposited in the outer divertor by high energy triton from D-D reaction. On Tiles 1, 3 and 4 mixed co-deposited layers were formed on the surface. The surface modifications have not been detected on Tiles 7 and 8, where sputter erosion and deposition might have been balanced. We found the difference in the amount of tritium present on the surface layer and in the bulk, indicating different factors determining the tritium retention, such as divertor configuration, origin of tritium.
The amount of dust particles collected from divertor modules of ILW-1 (0.77 g from the inner and 0.27 g from the outer) was over two orders of magnitude smaller than that from JET-C (200 g). Figure 3 displays tritium retention (MB/g) in dust particles collected from ILW-1 and JET-C. The tritium retention for JET-C and ILW-1 were similar, but the total activities were quite different: 270 GBq after JET-C down to 0.6 GBq after ILW-1, i.e. a factor of 450. This difference is a consequence of the much lower quantities of dust generated with a metallic first wall. In addition, it has been clearly shown [4] that tritium in the ILW dust samples has been associated with remaining carbon particles, not with beryllium and tungsten.

[1] M. Rubel et al., Fusion Eng. Design 136 (2018) 579-568.
[2] Y. Hatano et al., Nucl. Mat. Energy 18 (2019) 258-261.
[3] N. Ashikawa, et al., Nucl. Mat. Energy 22 (2020)100673.
[4] T. Otsuka et al., Nucl. Mat. Energy 17 (2018) 279-283.

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