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Distribution of Remaining Tritium in the LHD Vacuum Vessel

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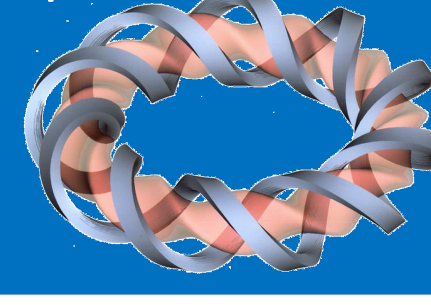


Abstract

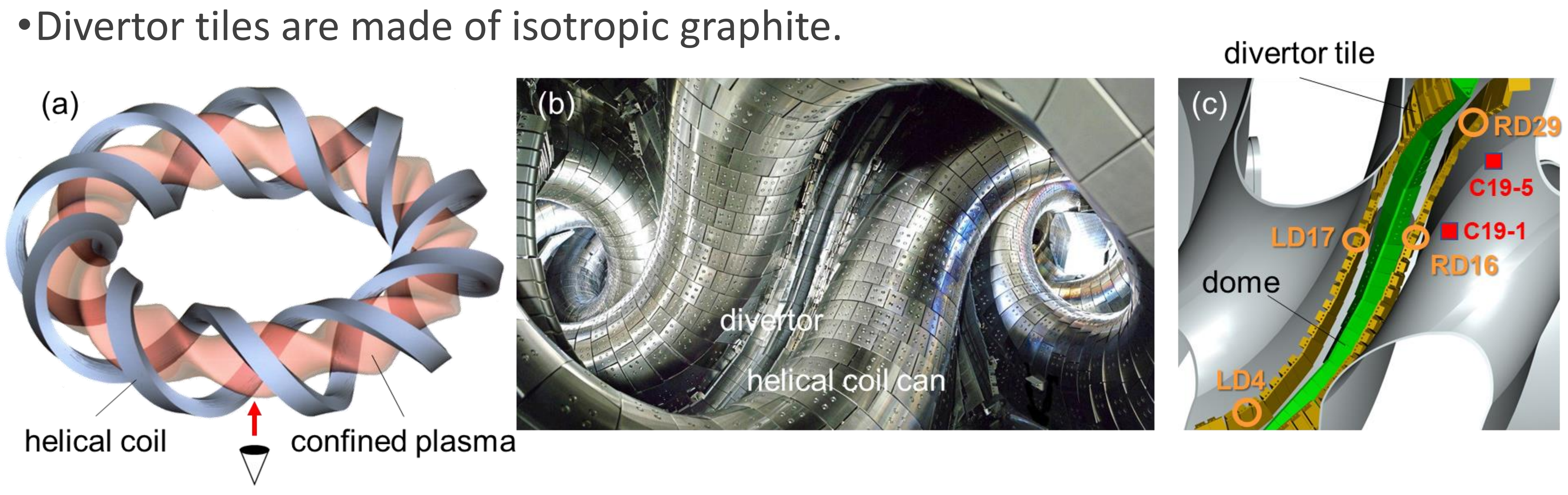
- Distribution of remaining tritium in the vacuum vessel of the Large Helical Device (LHD) has been investigated.
- After the first deuterium plasma experimental campaign, material probes installed on the first wall and some divertor tiles were retrieved to measure remaining tritium in them by using various methods.
- Tracing of orbits of energetic triton was carried out to find the distribution of lost points of them on plasma facing components.
- Results of measurements show that tritium remain densely in divertor tiles and sparsely in the first wall in general, and the evaluated distribution of remaining tritium qualitatively agree with the distribution of lost points of energetic triton.

Background

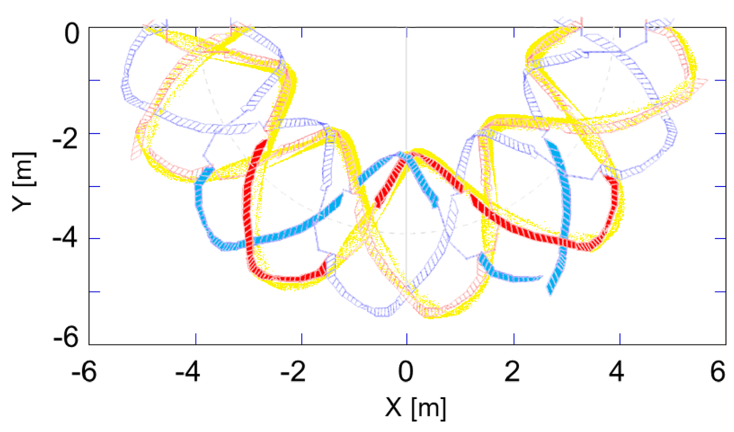
- Deuterium plasma experiment has been started in LHD since 2017. This is the first opportunity of tritium related studies in stellarator/heliotron devices in which three-dimensional magnetic configurations and vacuum vessel structures.
- Analyses of remaining tritium in plasma facing components are important from viewpoints of the studies of triton transport in plasma and tritium migration, and safety of in-vessel works.
- In tokamaks such as JT-60U, TFTR, JET, TEXTOR, analyses of tritium have been conducted. In the case of deuterium plasma experiment, the distribution of remaining tritium depends on the distribution of lost points of energetic triton on plasma facing components.
- In this study, analyses of remaining tritium in material probes and divertor tiles were carried out. Tracing of orbits of energetic triton was also conducted to reveal the relationship between the two distributions.

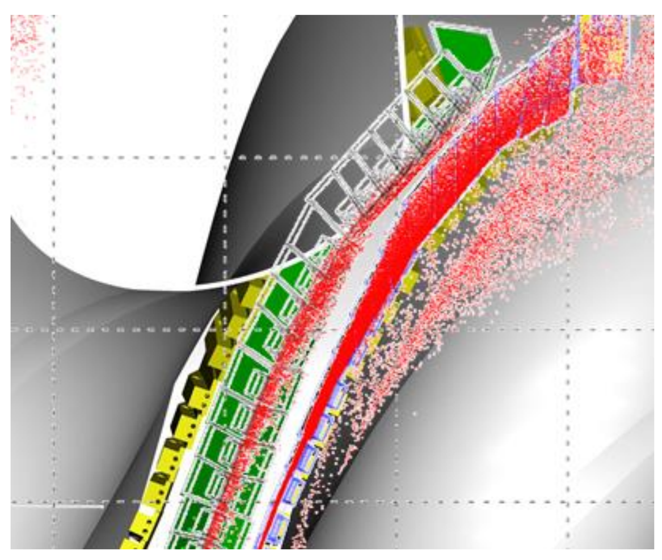
Plasma facing components (PFCs) in LHD

- The LHD vacuum vessel wall is covered by first wall panels made of stainless-steel Type 316L.
- Divertor tiles are made of isotropic graphite.



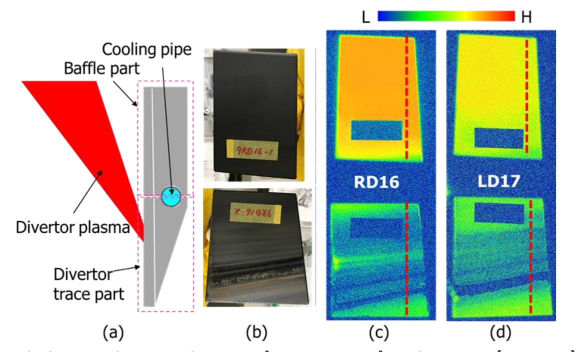
Tracing of orbits of energetic triton



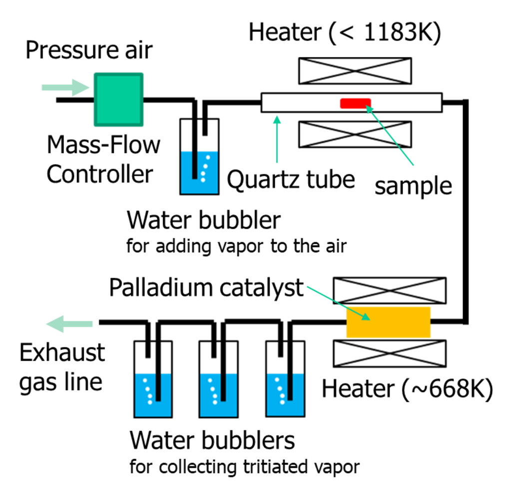


- Lost points of energetic triton with kinetic energy of 1.01 MeV on PFCs were calculated by using a Lorentz orbit following code (LORBIT), and the result is shown in left figures.
- In the top figure, four divertor tiles arrays in the half of LHD vacuum vessel are shown by blue and red. Hatched tiles correspond to divertor tiles arrays shown in the figure in the next part. Yellow dots show calculated lost points of energetic triton for the case of the toroidal magnetic field of the counter-clockwise direction.
- Lost points are along the red colored divertor tiles array.
- In the bottom figure, red dots show lost points of energetic triton in a top part of an inner divertor. Lost points are mainly on divertor tiles but also on the first wall beside divertor tiles.

Methods for analyses

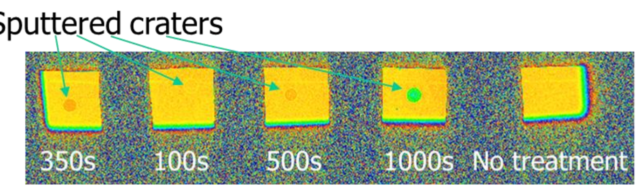


Tritium imaging plate technique (TIPT)



Thermal desorption, full combustion method

- **TIPT**: two-dimensional imaging of remaining tritium near surface
- **Thermal desorption, Full combustion method**: amount of remaining tritium
- **Hydrothermal treatment**: amount of remaining tritium
- **Sputtering treatment + TIPT**: depth profile of remaining tritium
- **BIXS (Beta rays induced X rays Spectroscopy)**: depth profile of remaining tritium
- **SEM, TEM**: surface morphology, microstructure
- **EDX, GDOES**: composition



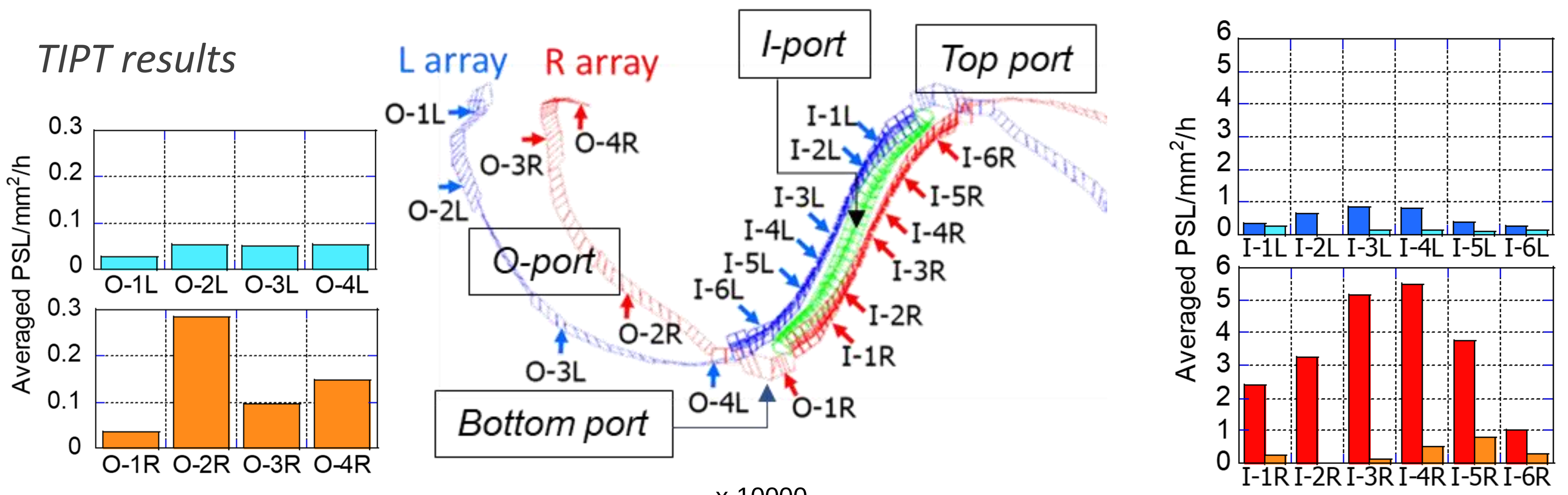
Sputtering treatment + imaging plate technique

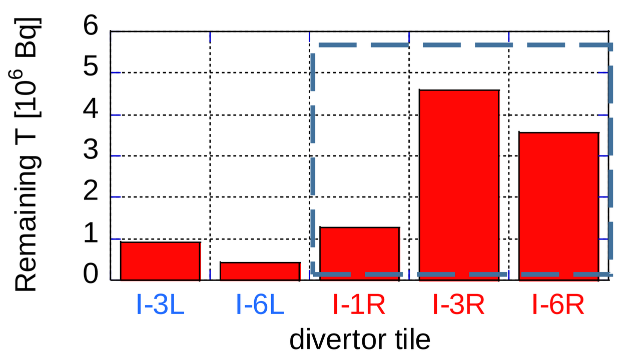
Results of analyses

Divertor tiles

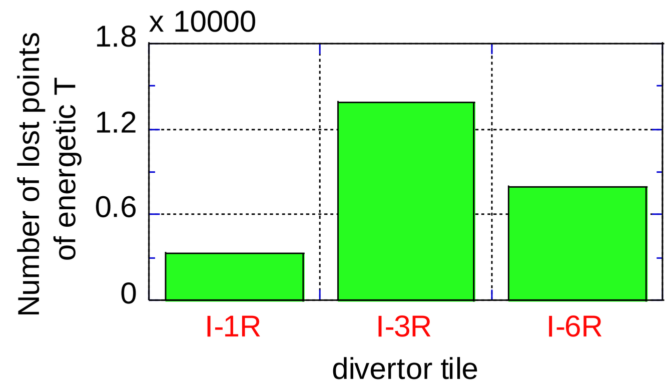
- Asymmetry of remaining tritium in divertor tiles at symmetric positions, and the difference of remaining tritium amount in outer and inner divertor can be caused by the asymmetry of the distribution of lost points of energetic triton.

TIPT results



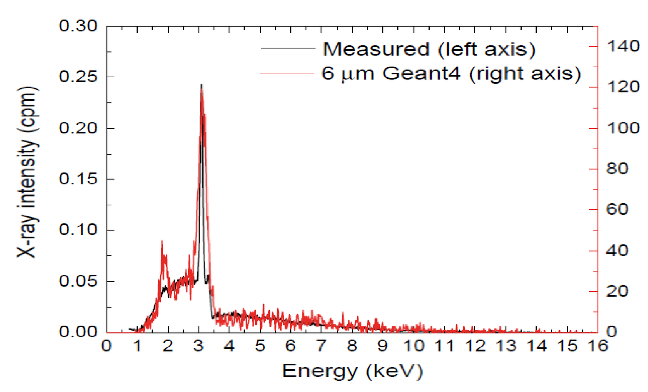


Full combustion method results

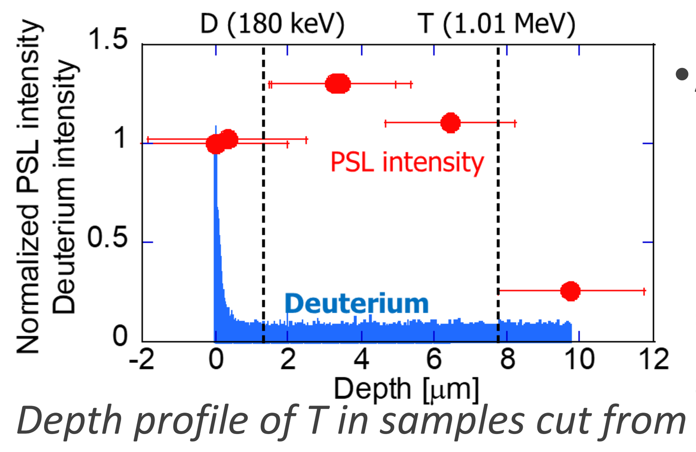


LORBIT calculation result

- Remaining tritium distribution in divertor is similar to the distribution of lost points of energetic triton.



Comparison of BIXS btw. Measured and simulated with assuming the uniform T distribution from the surface to 6 μm.

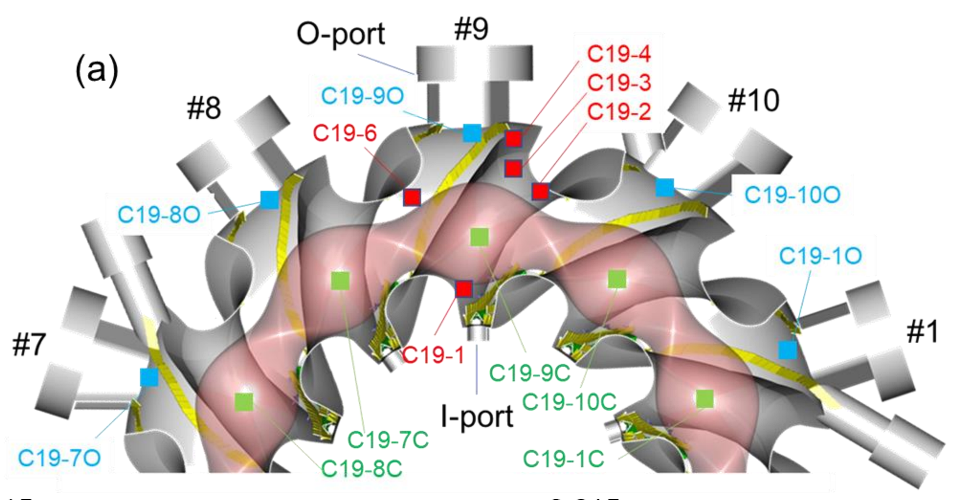


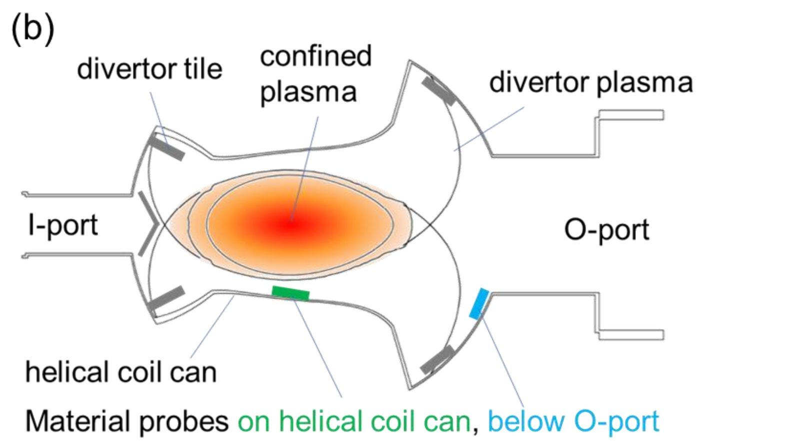
Depth profile of T in samples cut from the I-3R tile obtained by using the sputtering treatment and TIPT

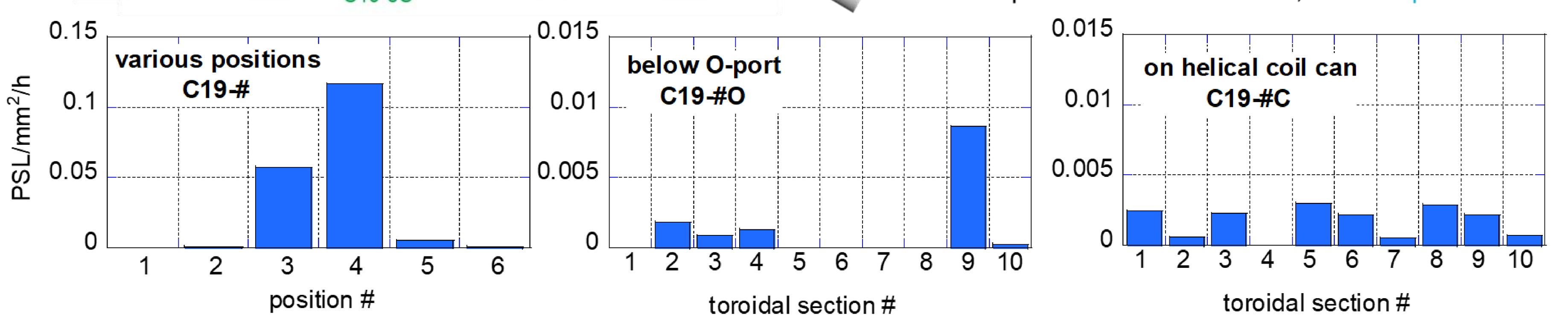
- A depth profile of remaining T in the I-3R tile shows the peak position is ~ 6μm from the surface, and that is consistent with the BIXS result.

Material probes on the first wall

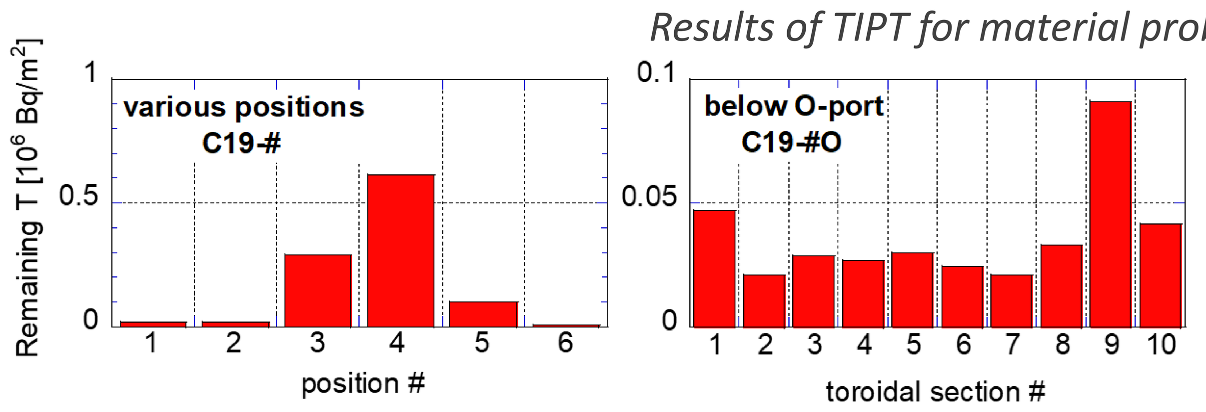
- Areal density of remaining tritium in material probes is relatively large at deposition-dominant area, and the density is similar to that on outer divertor tiles.
- At other area, the density in probes is much smaller than that in divertor tiles.



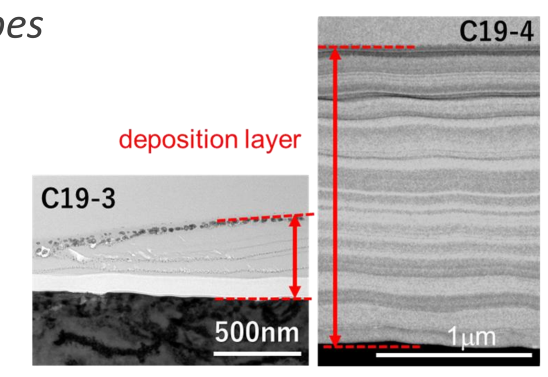




Results of TIPT for material probes



Remaining amount of T in material probes measured by using thermal desorption method



Deposition layers formed on C19-3 and C19-4

Summary

- It has been revealed that tritium are densely and sparsely remaining in divertor tiles and the first wall, respectively. Even the surface area of the first wall is approximately one order of magnitude larger than that of divertor tiles, evaluated remaining amount of tritium in divertor is larger than that in the first wall.
- Similarity of distributions of remaining tritium and lost points of energetic triton, and the depth profile of tritium in the divertor tile suggest that lost energetic triton on divertor tiles are the main source of remaining tritium.
- The relatively large remaining tritium on material probes at deposition-dominant area suggests that the main source of remaining tritium on the first wall is deposition of tritiated hydrocarbon from divertor tiles and/or co-deposition of tritium.
- The evaluated total amount of tritium in the vacuum vessel from the measured results is smaller than that evaluated from the gas-balance analysis. Toroidal asymmetry can be a cause of this result.