S4-1

Subjects of Plasma-Carbon Material Interactions in Fusion Devices

核融合プラズマ装置のプラズマ・炭素系物質相互作用に関する諸課題

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The scope of this symposium it to review the recent investigation on plasma-wall interaction in fusion plasma devices. In this presentation, important subjects in recent studies of the plasma-material interaction will be briefly reviewed in order to make the scope of this symposium clear.

Plasma-wall interaction in magnetically confined fusion devices regulates performance of core plasma and lifetime of the plasma-facing components. Carbon materials are widely used as plasma-facing material in present fusion devices because of its good material properties. In the next fusion devices like ITER (International Thermonuclear Experimental Reactor) intended to have D-T burning plasma in long or steady state operation, it is one of the critical issues to make the precise estimation of the lifetime of plasma-facing components and tritium inventory. For this purpose, comprehensive study of erosion process of the plasma-facing materials, transport of the eroded materials and re-deposition process should be required because the net erosion of the plasma-facing material is determined by the balance between erosion and deposition processes. Moreover, hydrogen isotopes (D, T) could be also co-deposited with the deposited material, which is related to tritium inventory and fueling/pumping efficiency. Figure 1 shows the schematic diagram representing important topics of plasma-wall interaction in fusion devices reviewed and discussed in this symposium.

(a) Erosion process of carbon

Plasma-facing materials are usually eroded by physical sputtering. However, the sputtering process due to chemical reaction between hydrogen and carbon, so called, chemical sputtering is considered to be a dominating erosion process of carbon wall in the present fusion devices. Precise evaluation of the chemical erosion yield is very

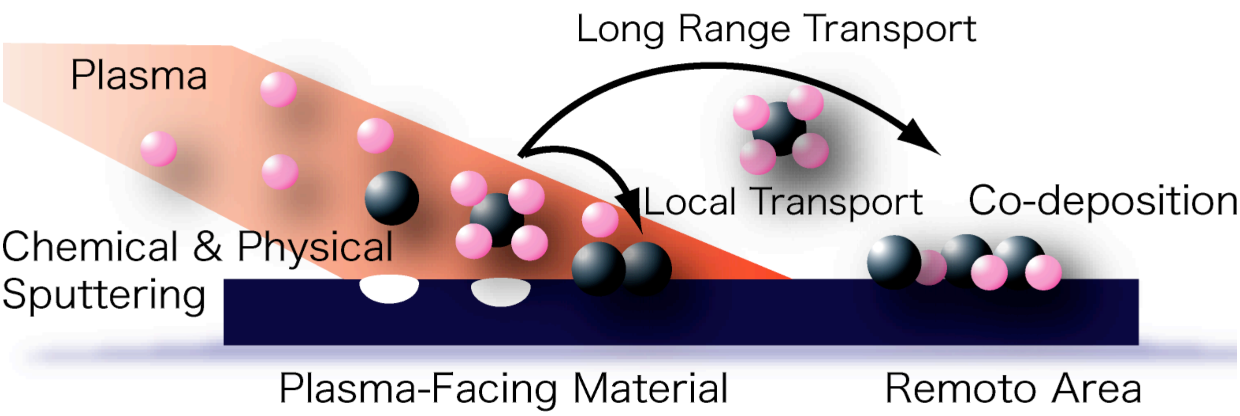

Fig.1 Schematic diagram of plasma-wall interaction in fusion devices reviewed and discussed in this symposium.

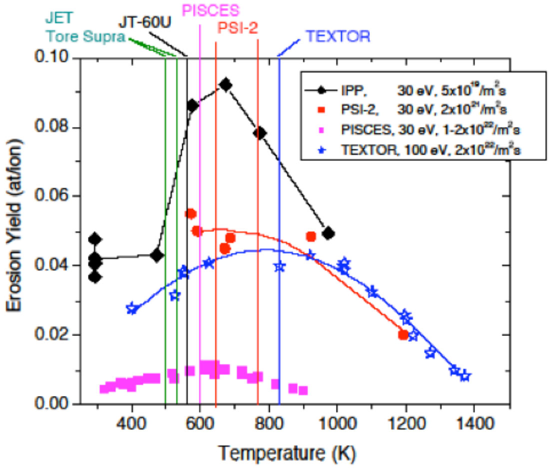

Fig. 2 Dependence of chemical erosion yield on carbon surface temperature as parameter of ion flux in several plasma devices in Ref. [1].

important to estimate the lifetime of the carbon wall. Then, there are many studies of the chemical sputtering in edge plasma condition of fusion devices. However, the physical mechanism of the chemical sputtering has not been fully understood yet. Figure 2 show dependence of chemical erosion yield on the surface temperature in several devices. These data are so scattered depending on the incident ion flux. Understanding of the fundamental physical mechanism of the chemical sputtering is one of the most important subjects, which will be discussed based on molecular dynamic simulation in S4-2.

(b) Transport of carbon impurity

Hydrocarbon species, C_xH_y, which could be generated as a result of erosion of carbon materials, are transported as impurity in the fusion device. The impurity transport in fusion devices is very complicated strongly depending on plasma parameters such as electron density and temperature and plasma flow, and geometry of the devices. There could be two different type of impurity transport (local and long range transport) as shown in Fig. 1. In the local transport, the hydrocarbon species are deposited near the eroded area because hydrocarbon species ionized in plasma are transported to the surface near the eroded area due to strong friction force by streaming plasma or Lorenz force in strongly inclined magnetic field (so called prompt re-deposition). On the other hand, hydrocarbon species can be transported to remote area. Carbon dust, which is a key issue for safety concern, is considered to be generated from re-deposited carbon layers formed on cold remote

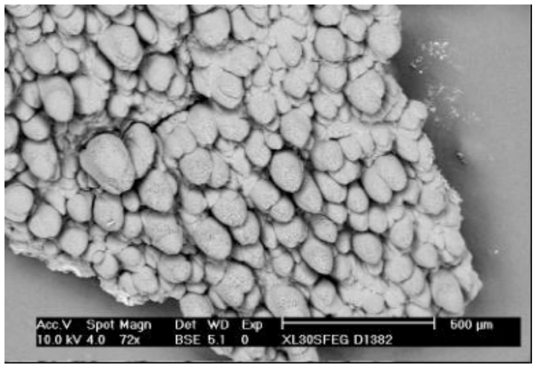

Fig .3 Re-deposited carbon layer observed in the Tore Supra tokamak[3].

material surfaces. In the JET tokamak, thick re-deposited carbon layers were observed at the cold remote region near the pumping area [2]. Similar re-deposited carbon layers were also observed at the target plate located below the toroidal pump limiter in the Tore Supra tokamak [3] as shown in Fig. 3. Carbon dust particles or flakes could be generated by erosion of these re-deposited carbon layers. The production, transport and deposition processes of carbon impurities in the JT-60U tokamak are reviewed in S4-3.

(c) Co-deposition process with hydrogen isotopes

Hydrogen isotopes (D, T) could be co-deposited with the deposited material, shown in Fig. 1 Hydrogen retention in co-deposited layer has a great influence on fueling and pumping in long and/or steady state operation, which is also one of the critical issues in the next generation fusion devices. In the TRIAM-1M, the wall role for sink(pumping) and source(fueling) is changed in time, critically depending on the wall temperature, which is discussed in S4-4. Moreover, Co-deposited layer with hydrogen isotopes like C-H layer is considered to have different material property from pure one, such as for chemical and physical sputtering yield. It is also necessary to make a quantitative characterization of the co-deposited layer.

References

[1] J. Roth, *et al*. Nucl. Fusion, **44**(2001) L21.
[2] M. Rubel *et al*. Nucl. Fusion, **41**(2001) 1087.
[3] E. Delchambre *et al*., Proc of 30th EPS Conf. on Contr. Fusion and Plasma Phys., St. Petersburg, 7-11 July 2003 ECA Vol. 27A, P-3.169