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Impact of Formation of Codeposition Layer on Global Wall Pumping in the Fusion Experimental Device

核融合プラズマ装置における共堆積層の形成と グローバルな壁排気への効果

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A global wall pumping is important from the viewpoint of the density control and the tritium inventory in the steady state operation of fusion plasma. The wall pumping rate was estimated by using a particle balance model. A transition of the wall role from the particle sink to the source was observed. It seems to depend on the wall temperature. When the increase in the wall temperature was suppressed, the net wall pumping rate was enhanced to about 3.6 times higher than that of higher wall temperature. The continuous wall pumping is attributed to the co-deposition of hydrogen with the sputtered metal. The codeposited metal layer is very important similarly to the codeposition of hydrogen with carbon.

1. Introduction

Steady state operation (SSO) is one of the most important issues for the future fusion reactor. As a discharge duration grows longer, phenomena with long characteristic time such as current diffusion and plasma-wall equilibrium times play more important role for the SSO. The particle balance in the main chamber is one of those and it is important from the viewpoint of the density control. The wall plays both roles of the particle sink and the source. The wall temperature is a key for the particle source and the co-deposition is a key for the particle sink. It should be noticed that the formation of the co-deposition layer changes the wall surface properties such as particle absorption.

In Tore Supra, an uncontrolled density increase due to outgassing from uncooled and poorly conditioned in-vessel components had been observed in the high power and long duration discharge, but it has not been observed and continuous wall pumping has been observed after upgrading the plasma facing components (PFCs) [1-3]. Also in TRIAM-1M, the importance of the wall temperature and the codeposition for the global particle balance has been reported [4-7].

2. Particle Balance Model in the Main Chamber

A particle balance equation in the main chamber is written by the following equation:

$$\frac{dN_H^0}{dt} + \frac{dN_H^p}{dt} = \Gamma_{fuel} - \Gamma_{pump} - \Gamma_{wall}, \qquad (1)$$

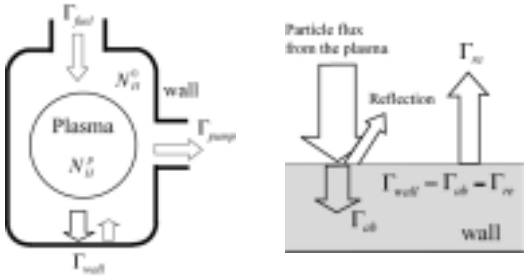

Fig. 1 Schematic diagram illustrating the particle balance flow.

where N_H^0 is the total number of hydrogen neutral atoms in the main chamber, N_H^p the total number of hydrogen ions in the plasma, Γ_{fuel} the fueling rate, Γ_{pump} the pumping rate of the external pump-unit and Γ_{wall} the net wall pumping rate. A schematic diagram illustrating the particle balance flow is shown in Fig.1. The net wall pumping rate means the balance between the hydrogen absorption rate Γ_{ab} and hydrogen release rate Γ_{re}.

3. Transition of Wall Role from Sink to Source

Figure 2(a) shows the time evolution of the wall inventory in the ultra-long discharge in TRIAM-1M (stainless steel wall and molybdenum limiters and divertor plates). The horizontal axis indicates the time from the plasma initiation. In the first 30 min, the wall pumped the hydrogen, i.e. it played a role of the particle sink. The averaged wall pumping rate is evaluated to be 2.4 x 10^{16} atoms m^{-2} s^{-1} from the equation (1). At t~30 min, the role of the wall

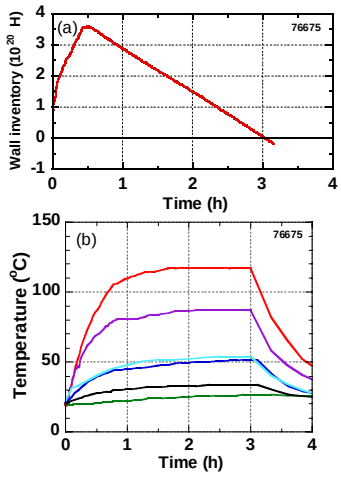

Fig.2 Time evolution of (a) wall inventory and (b) wall temperature.

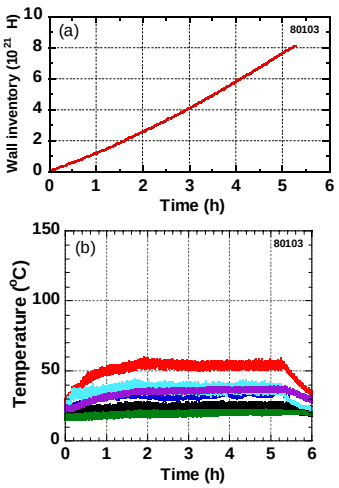

Fig.3 Time evolution of (a) wall inventory and (b) wall temperature. The wall temperature is suppressed by the insert of the movable limiter.

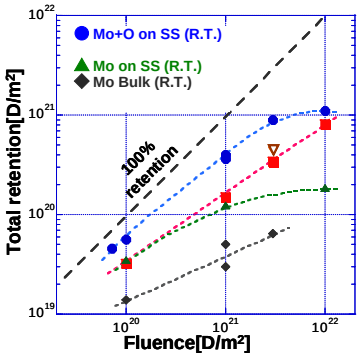

Fig.4 Fluence dependence of the deuterium retention for Mo-deposit in oxygen atmosphere. Deuterium retention in bulk Mo, Mo-deposit in high vacuum and SUS304 are also plotted [9].

transited to the particle source. After that, the wall released the hydrogen until the end of the discharge. During the discharge, the wall temperature increased due to the heat load from the plasma as shown in Fig. 2(b). It is considered that the temperature rise in the wall is attributed to the transition of the wall role from the particle sink to the source.

On the other hand, when the increase in the wall temperature is suppressed by the insert of the movable limiter, the wall inventory continue to increase until the end of the discharge (t ~ 5 h 16 min) as shown in Fig.3. In this discharge, the net wall pumping rate is ~8.6 x 10^{16} atoms m^{-2} s^{-1} and it is 3.6 times higher than that of Fig.2. It means that Γ_{re} is suppressed due to the less temperature increase and Γ_{ab} does not saturate.

4. Impact of Codeposition on the Wall Pumping

As shown in Fig.3, the wall continues to absorb the hydrogen during the ultra-long discharge. One possible candidate for this continuous wall pumping is codeposition of hydrogen with Mo, which is sputtered by high energy neutrals. The co-deposition layer is expected to be always formed on the wall surface during the discharge. Namely, the wall surface can be refreshed and keep up the wall pumping capability due to the codeposition.

In practice, the deposition layer was observed on specimens which were inserted in the scrape off layer of the plasma and was exposed to the ultra-long discharge. Moreover, a reasonable amount of hydrogen was also observed in the deposition layer of Mo [8].

Figure 4 shows the fluence dependence of the deuterium for Mo deposit in the laboratory experiment [9]. The Mo-deposit in oxygen atmosphere has a capability of one order of magnitude stronger retention than that of Mo bulk. The structure of Mo-deposit observed in TRIAM-1M is similar to that in oxygen atmosphere. It is a fine fcc-like grain structure. It suggests that oxygen impurity in the plasma affects on the formation of codeposition layer of Mo.

Codeposition of hydrogen with metal makes a substantial wall pumping. Codeposited metal layer is important similarly to codeposition of hydrogen with carbon.

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References

[1] Equipe Tore Supra (presented by F. Saint-Laurent), Nucl. Fusion **40** (2000) 1047.
[2] J. Jacquinot, et al., Nucl. Fusion **43** (2003) 1583.
[3] D. van Houtte, et al., Nucl. Fusion **44** (2004) L11.
[4] M. Sakamoto, et al., Nucl. Fusion **42** (2002) 165.
[5] M. Sakamoto, et al., J. Nucl. Mater. **313-316** (2003) 519.
[6] Y. Hirooka, et al., J. Nucl. Mater. **313-316** (2003) 588.
[7] M. Sakamoto, et al., Nucl. Fusion **44** (2004) 693.
[8] M. Miyamoto, et al., J. Nucl. Mater. (to be published)
[9] M. Miyamoto and N. Yoshida, J. Plasma Fusion Research **77** No.9 (2001) 888.