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Impact of a movable limiter on the global wall recycling in TRIAM-1M

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1. Introduction

Understanding of the global wall recycling is one of the most critical issues from the viewpoint of density control and tritium inventory for the steady state operation of the fusion plasma. In TRIAM-1M (stainless steel wall, Mo poloidal limiters and Mo divertor plates), studies of the global wall recycling have been promoted in the ultra-long tokamak discharges[1-3]. Moreover, material probe experiments have demonstrated that the hydrogen retention of the Mo deposits on the material probe which was exposed to an ultra-long discharge is consistent with the global wall pumping rate [4]. The co-deposition is a key for the global wall recycling. The comprehensive understanding from the microscopic phenomena such as the co-deposition (i.e. nanoscale) to the macroscopic ones such as global particle balance is important. As part of it, the influence of the local structure of the first wall on the global wall recycling has been studied using a movable limiter with good cooling capability in TRIAM-1M.

2. Experimental setup

For the study presented, we usually used limiter configuration discharges with Ip = 15~20 kA and $\overline{n}_e$ = 1~2 x 10^{18} m^{-3}, which are sustained by 2.45GHz lower hybrid current drive (LHCD). The movable limiter (ML) of which front edge is made of Mo has been installed at the same section as the fixed poloidal limiter (PL) and the pumping port. It is thermally insulated from the main chamber and has good cooling capability. The ML can be approached from above to

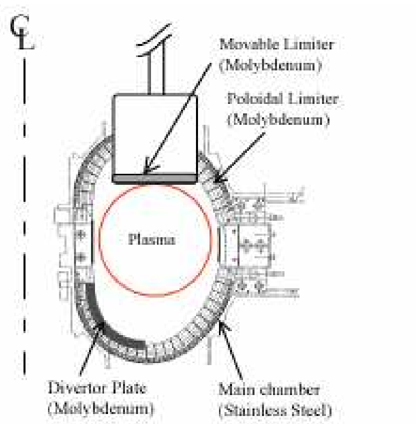

Fig.1 Cross-sectional view of the main chamber at the section of the movable limiter.

the plasma by remote control as shown in Fig.1.

3. Results and Discussion

Figure 2(a) shows the time evolution of the wall inventory in the ultra-long discharge without the ML in TRIAM-1M. 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 global particle balance inside the vacuum chamber. At t~30 min, the role of the wall 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.

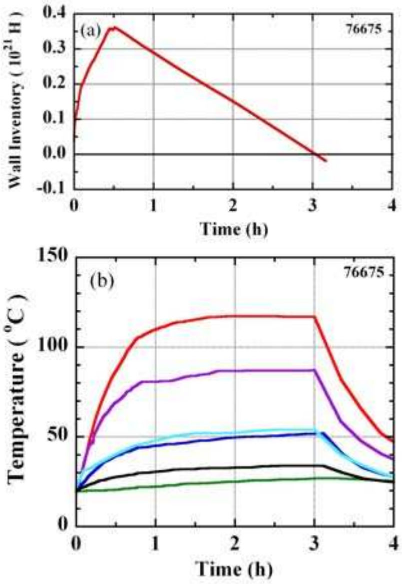

Fig.2 Time evolution of (a) wall inventory and (b) wall temperature.

On the other hand, when the movable limiter is inserted to the plasma edge, the wall inventory continues to increase until the end of the discharge (t ~ 5 h 16 min) as shown in Fig.3 (a). 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. The ML reduces the heat load to other plasma facing components (PFCs). The heat loads to each PFC of the discharge with and without the ML are the following; the main chamber 56% and 70%, the fixed limiters 10% and 30%, the movable limiter 34% and 0%, which are estimated using the calorimetry. As shown in Fig.3 (b), the increase in the wall temperature can be suppressed by ~30% of that of Fig.2 (b). It means that the particle re-emission from the wall is suppressed due to the less temperature increase and the global wall pumping does not saturate. This continuous wall

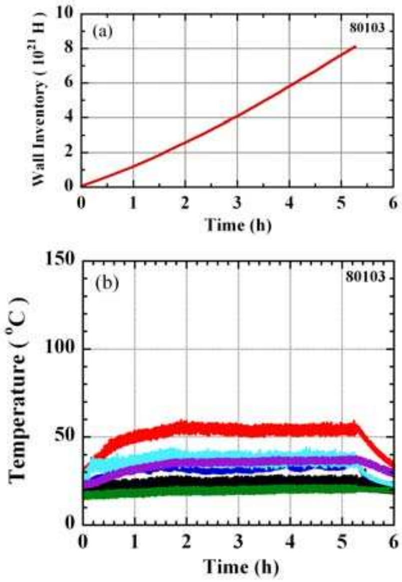

Fig.3 Time evolution of (a) wall inventory and (b) wall temperature. The wall temperature is suppressed by the insert of the movable limiter.

pumping would be attributed to the co-deposition of hydrogen with Mo. In practice, continuous deposition was observed on the viewing window of sapphire located at ~75 mm from the limiter surface during the ultra-long discharge [4].

Figure 4 shows the growth of the deposition layer of Mo on the sapphire window during the discharges with and without the ML. The vertical axis indicates the thickness of the deposition which is made after t = 10 s. The real-time thickness was measured with a technique based on the interference of light on Mo deposits on the sapphire window [6]. In both cases with and without the ML, the average growth rate of the deposition layer is usually from ~2 x 10^{-4} nm/s to ~8 x 10^{-4} nm/s. We cannot see a clear difference of the growth rate with and without the ML as shown in Fig.4. The growth rate is a balance between erosion and redeposition. It depends on the local plasma parameter, the transport of Mo in the SOL and so on. Although the detail analysis is a future work, the hydrogen absorption of the wall due to the co-deposition in the discharges with and without the ML seems to be expected equally likely.

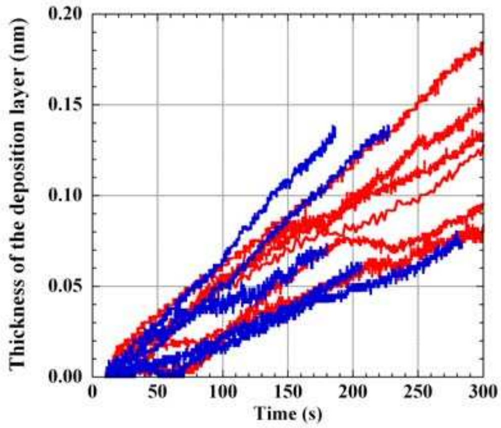

Fig.4 Growth of the deposition layer of Mo on the viewing window of sapphire during the long duration discharges. Red and blue lines indicate the discharges with and without the ML, respectively.

Figure 5 shows toroidal profiles of the H_α intensity at the central chord before and after drawing up of the ML. The origin of the horizontal axis means the position of the ML and the toroidal length is the circumferential length along the plasma center. The right end of the figure means a full circle. The ML was drawn up from the plasma edge at t ~ 2300 s so that the recycling coefficient approached to unity and the effect of the gas fueling on the profile was reduced. The profile is reproduced according to the following fitting function;

$$I_{H\alpha}(x) = P_{mc} + \sum_{i=1}^{3} P_i \exp\left[\frac{-|x - x_i|}{\lambda_{LIM}}\right] + P_{gf} \exp\left[\frac{-|x - x_{gf}|}{\lambda_{gf}}\right], \qquad (1)$$

where x is the toroidal length. P_{mc} is contribution of the main chamber recycling and is assumed to be homogeneous in the toroidal direction. The second and third terms of the right-hand side mean the contributions of the limiters and gas fueling, respectively. After the drawing up of the ML, the gas fueling automatically terminated, since the density increased due to the enhanced recycling. As shown in Fig.5, both of measured profiles can be reproduced when $\lambda_{LIM} = \lambda_{gf} =$

0.3m, of which length is almost consistent with the result of a simple model of DEGAS simulation. The contribution ratio of the main chamber, the ML section, other PLs and gas fueling to the hydrogen recycling is the following; 38%, 45%, 16% and 0.7% before the drawing up of the ML and 54%, 22%, 24% and 0% after the drawing up of the ML, respectively. Integration of H_α intensity with and without the ML over the whole toroidal length is about the same within 3%, which is less than the error, i.e. 15%.

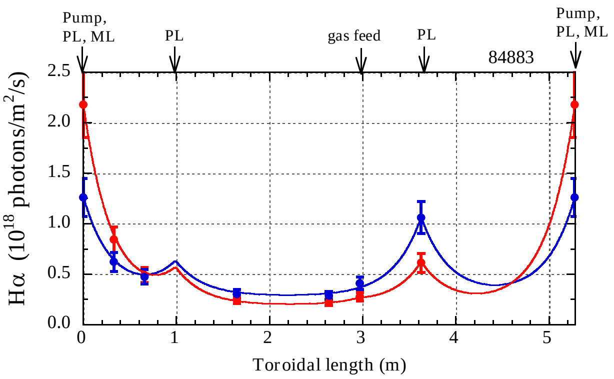

Fig.5 Toroidal profiles of the H_α intensity before (red) and after (blue) the drawing up of the ML.

Summary

In TRIAM-1M, the influence of the local structure of the first wall on the global wall recycling has been studied using the ML with good cooling capability. No wall saturation was observed in the 5 h 16 min discharge with the ML, since particle release was suppressed by less temperature rise of the main chamber. The global wall pumping rate without the ML, ~8.6 x 10^{16} atoms m^{-2} s^{-1}, is 3.6 times higher than that of the long duration discharge without the ML. The temperature rise in the wall is attributed to the transition of the wall role from the particle sink to the source. The co-deposition of hydrogen with Mo is a key for the wall role of the particle sink. No clear difference of the growth rate of Mo deposits on the viewing window located from the limiter surface between with and without the ML. The growth rate is from ~2 x 10^{-4} nm/s to ~8 x 10^{-4} nm/s. The toroidal structure of hydrogen recycling changes significantly near at the ML. However, integration of H_α intensity with and without the ML over the whole toroidal length is about the same within 3% , which is less than the error, i.e. 15%.

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