7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Simulation of Cs layer on plasma grid in ITER-scaled negative ion source for long-term operation

Masafumi Yoshida[1,2], Shunsuke Hayashi[2],
[1] Department of Electrical Engineering, National Institute of Technology, Ube College,
[2] Advanced Course of Production Systems Engineering, National Institute of Technology, Ube
e-mail (speaker): yoshida-m@ube-k.ac.jp

Negative ion based neutral beam injection (N-NBI) is a powerful application for heating and current driving of fusion plasma. For ITER, a beam operation for up to 3600 seconds is required in N-NBI. [1] Up to now, 500 keV, 154 A/m^2 for 118 s beam production was achieved in QST. [2] One of the key issues for an achievement of the requirements in ITER is stabilization of the current of the negative ion beam. Negative hydrogen ions (H^-) are mainly produced on the plasma facing grid (PG) covered by cesium (Cs), which lowers work function to increase a production yield of negative ions, namely surface production process. In this work, we focus on the Cs transport and Cs layer at the PG for 3600 s in ITER scale negative ion source. Time trends of Cs layer at the PG with plasma operation is discussed by using Cs transportation code. [3, 4]

In this model, the temperatures of the chamber wall and PG are set to 30 °C and 180 °C, respectively. The plasma length simulated in this study is 3600 s. The temperatures of the chamber wall and PG rises to 60 °C and 220 °C, respectively, due to heat of plasma. At the beginning of the calculation, Cs is initially input. During the plasma operation, Cs is kept seeding in the negatice ion source. Cs input in the source is neutralized before the plasma operation (vacuum phase). In the plasma operation (plasma phase). a part of Cs is the ionized. They are transported in the source, and is finally reached to 4 regions; chamber wall, plasma grid, loss from the beam apertures and flowing in the source. The amount of Cs at the PG correlates with the thickness of Cs layer, which is depended on the production yield of the negative hydrogen ions.

Figure 1 shows time trends of Cs monolayer at the PG. During the plasma operation (t > 0 s), Cs monolayer is gradually increased without the saturation of the thickness. In addition, with increasing the amount of the initial Cs input mass (N_0), the Cs monolayer at 3600 s was increased and the layer became above 0.5 monolayer, which was an optimal layer for higher production yield of negative hydrogen ions. Figure 2 summarized the Cs layer at the PG at 3600 s under various conditions such as N_0 and maximum temperature in the PG (T_{PG}^{max}). It was found that as Cs accumulated in the negative ion source, T_{PG}^{max} was needed to raise to stabilize the thickness of 0.5 monolayer of Cs layer at the PG. This is to prevent over pilling-up of Cs due to a large amount of Cs incoming to the PG. Therefore, it is suggested that the PG maximum temperature and the initial Cs input mass is also one of key parameter for keeping the optimal thickness of Cs layer on the PG in ITER.

References

[1] Progress in the ITER physics basis, Nucl. Fusion, **47** S18 (2007).
[2] J. Hiratsuka, et al., Rev. Sci. Instrum. 91, 023506 (2020)
[3] M. Yoshida, *et al*., Rev. Sci. Instrum. **87** 02B144 (2016).
[4] M. Yoshida, *et al*., AIP Conf. Proc. **2052** 040008 (2018).

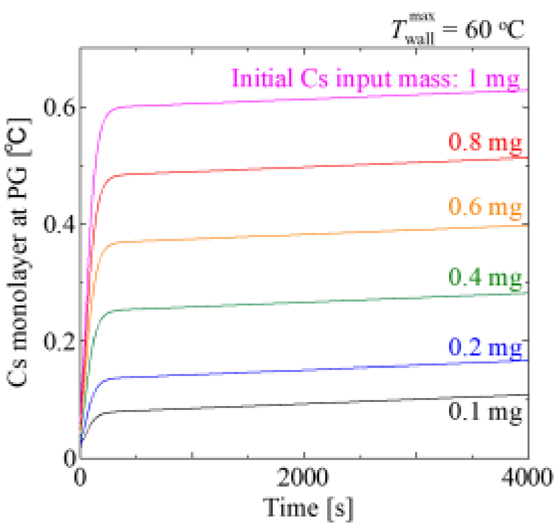

Figure 1. Time trends of cesium monolayer at the PG for 3600 s (T_{wall}^{max} = 60 °C).

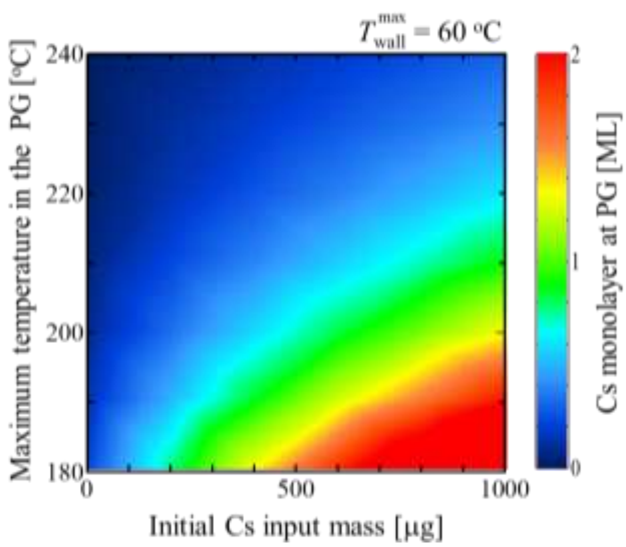

Figure 2. Contour map of Cs monolayer at PG at 3600 s (T_{wall}^{max} = 60 °C).