Miniaturization for practical application of plasma window

Y. Sunada[1], O. Yanagi[1], H. Ohiro, R. Shigesada[1], M. Sumino[1], K. Hatta[1], K. Kurosaki[1], Md Anwarul ISLAM[1], N. Ohno[2], M. Takagi[2] N. Tamura[3], H. Okuno[4], S. Namba[1], K. Yamasaki[1]
[1]Graduate School of Advanced Science and Engineering, Hiroshima University, [2]Graduate School of Engineering, Nagoya University [3]National Institute for Fusion Science, [4]Nishina Center for Accelerator-Based Science, RIKEN
e-mail: m213939@hiroshima-u.ac.jp:

The plasma window is an innovative plasma application technology that separates the atmospheric pressure (100 kPa) and vacuum (1 Pa) using plasma.[1] The atmospheric pressure arc discharge produces a high-density plasma inside the hole (channel), whose inner diameter is 8 mm, at the center of each electrode. The very high temperature and high-density plasma inside the channel heats the neutral gas flowing from the atmospheric pressure side, thus separating the atmospheric pressure side from the vacuum by increasing its viscosity. A feature of the plasma window is that it can transmit electron and ion beams that cannot pass through a glass window. This feature is gathering attention as the application for the differential pumping system of the helium gas stripper in the heavy ion accelerator operated at RIKEN. To realize the above-mentioned application, it is necessary to realize the plasma window that can separate 7 kPa and 1 Pa using a channel with an inner diameter of 8 mm.

The apparatus we used is called the TPD arc plasma source. This apparatus is composed of three types of electrodes: cathode, intermediate electrode, and anode. In addition, a pair of solenoid coils is installed to generate high-density plasma stably. Using this apparatus with an inner diameter of 8mm, our group has succeeded in separating 2.2 kPa and 50 Pa using helium as working gas. However, the applicable situation of the plasma window may be limited due to the large size of the electrodes. In addition, it will be required to apply more electric power for the arc discharge to improve the pressure ratio, which may lead to higher heat load on the electrodes. Thus, in this study, we develop a simplified intermediate electrode and improve its heat removal capacity.

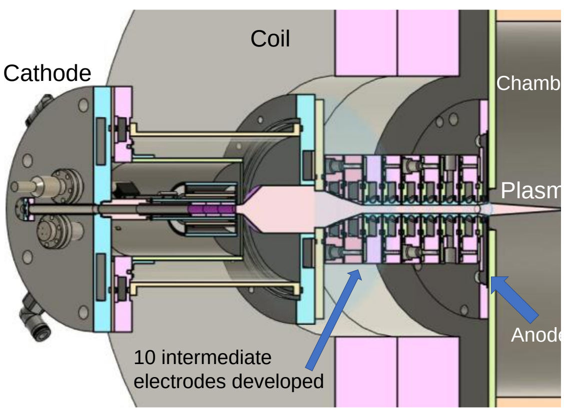

FIG 1. Cross-sectional view of the experiment using the intermediate electrodes developed

Figure 1 shows a schematic view of the newly developed intermediate electrodes and the detail of them are shown in figure 2. The outer diameter of the electrode was changed from 178 mm to 100 mm. This resulted in a 39% reduction in the weight of each electrode, which enabled to install and remove the system easier. Due to the reduction in the outer diameter of the intermediate electrode, the diameter of the coil can be reduced, leading to the miniaturization of the plasma window. Also, the structure of the cooling water channel was changed to improve the heat removal capacity and to make the construction easier. To improve the heat removal capacity, it is necessary to increase the flow rate of the cooling water passing through the electrode. In addition, sufficient amount of volumetric capacity must be left for water inside the electrode to stabilize the heat removal capacity. Therefore, we removed the fins, which is designed to control the flow direction of the cooling water inside the electrode, in order to improve the conductance and secure the cooling water capacity inside the electrodes. The electrode developed enabled to increase the minimum cross-sectional area of the flow path from 19.6 mm^2 to 38 mm^2. Furthermore, despite the 44% reduction in electrode diameter, the volume of water in the electrode was only reduced by 10%. In addition, the removal of the fins made assembly easier than before.

In this presentation, we introduce the details of the structure of the newly designed intermediate electrode and the result of the thermal analysis simulation.

References
[1] A. Hershcovitch, Phys. Plasmas **5**, 2130 (1998)

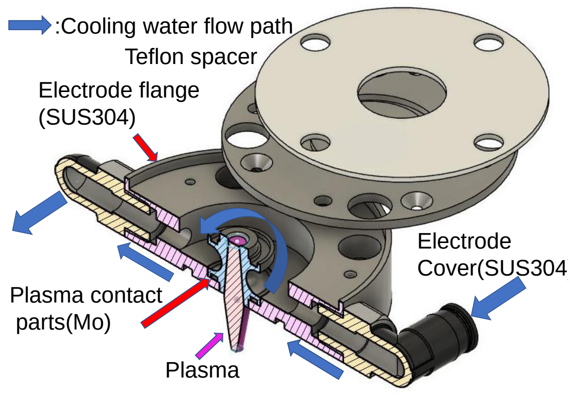

FIG 2. Each component of the intermediate electrode developed and the flow of cooling water