Test of differential pumping system with plasma window using gas cell

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A differential pumping system with a plasma window (PW)[1)] has been developed for application to charge strippers using high-density hydrogen or helium (He) gases, which have a small atomic number. We tested the system with a PW operation using a gas cell where argon (Ar) or He gases were confined up to 100 kPa (1 atm). Figure 1 shows a schematic of the system. The system consists of a gas cell, a PW, and two chambers. The PW has a central bore of 2 mm diameter, which isolates the gas cell from the first chamber. Gas was injected to the gas cell and flowed into the first chamber through the PW. As stated in the previous report,[2)] the two chambers were differentially pumped. The first chamber was mainly evacuated by two mechanical booster pumps with a total pumping rate of approximately 730 $m^3{\cdot}h^{-1}$. The second chamber was evacuated by a turbomolecular pump (TMP) with a pumping rate of 792 $m^3{\cdot}h^{-1}$. The first and second chambers were connected via a flow constrictor with an inner diameter of 6 mm and length of 15 cm.

At first, the plasma was ignited by Ar gas injection. Next, gas flow rates were increased so that a pressure of 100 kPa was attained at the gas cell (P_0). The typical flow rate for Ar was maintained at 2.3 SLM to keep P_0 at 100 kPa at an arc current of 15 A per cathode. Subsequently, we replaced the injected Ar gas with He gas. We successfully operated the PW with He gas maintaining P_0 at 100 kPa. The flow rate of He for keeping $P_0 = 100$ kPa was 4.5 SLM at an arc current of 26 A. The differential pumping efficiency was evaluated by the pressures at the first (P_1) and second chambers (P_2). The pressures P_1 and P_2 in the cases of Ar and He are plotted as functions of arc currents in Figs. 2 (a) and (b), respectively. The solid circles and triangles denote Ar and He data, respectively. The plotted data were adequately corrected depending on the gas species. The maximum pressures of P_0 in the absence of the PW operation were 15 and 9 kPa, maintaining P_1 at 20 and 40 Pa in the cases of Ar and He, respectively. The maximum P_0 values were increased by 6.7 times for Ar and 11.5 times for He when the PW operation occurred. We found that the lowest arc currents per cathode for keeping P_0 at 100 kPa were 11 and 26 A for Ar and He, respectively.

The gas flow rates for keeping P_0 at 100 kPa are also dependent on the arc currents, as shown in Fig. 2 (c). It is noteworthy that the flow rate of He can be reduced by more than one order of magnitude as compared to the conventional differential pumping system without a PW, as estimated in advance.[3)] Also, P_0 reached 130 kPa, which is the maximum value of the gauge. The P_1 and P_2 values were 30 and $4.5{\times}10^{-2}$ Pa for Ar and 36 and $1.4{\times}10^{-1}$ Pa for He, respectively. Further tests using a PW with an enlarged orifice of 4 mm diameter are planned in the near future.

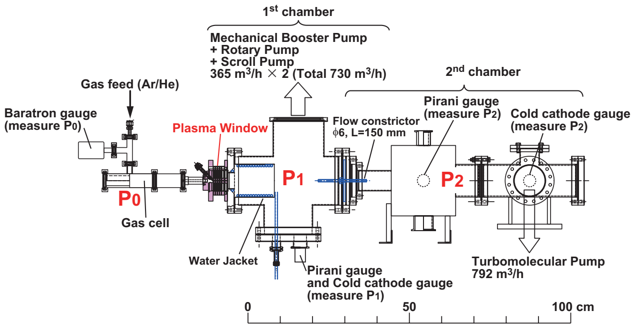

Fig. 1. Differential pumping system with PW.

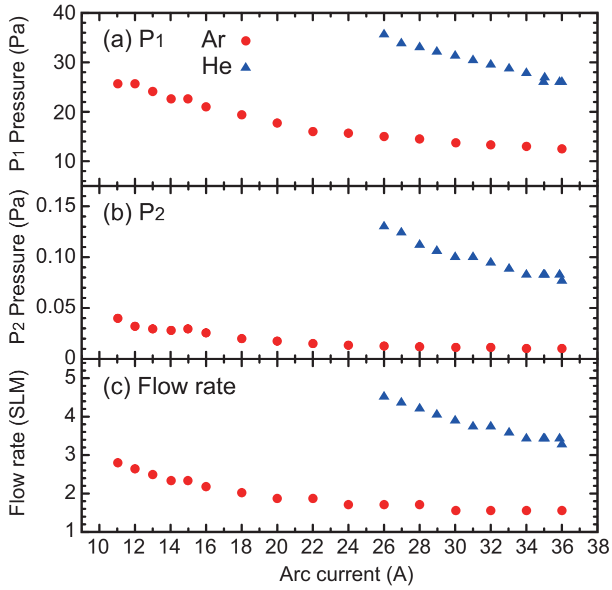

Fig. 2. Pressures (a) P_1 and (b) P_2, and (c) flow rates in cases of Ar and He are plotted as functions of arc current. Please see the text for details.

References
1) A. Hershcovitch: J. Appl. Phys. **78** 5283 (1995).
2) H. Kuboki et al.: J. Rad. Ana. Nucl. Chem. **297** (2013).
3) H. Okuno et al.: Phys. Rev. ST Accel. Beams **14** 033503 (2011).

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