High-Density Sheet Plasma for Versatile Applications of Plasma Window

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Plasma Window (PW) is one of the plasma application apparatuses that can separate a vacuum from an atmosphere (high-gas pressure) without solid substances such as metal or glass. TPD (Test Plasma by Direct current discharge) developed at NIFS or cascaded arc plasma generator can realize such a particular condition. Generally, the PW utilizes cylindrical high-density plasma (T_e > 1 eV, n_e > 10^{16} cm^{-3}) in a channel with a bore diameter of 3~8 mm and the PW device has some intermediate electrodes between a cathode and an anode to generate hot dense plasma (see FIG.1). Two important effects enable us to realize to separate the vacuum from the atmosphere, that is, high-gas temperature and associated high-gas viscosity in the plasma [1]. The PW has been demonstrated up to 1000 times pressure gradient as of this moment (<100 Pa and >100 kPa) [2].

Although the PW works as a pressure separation without a large pumping system, a typical plasma diameter, through which charged particles or x-ray is transmitted, is as small as 3~20 mm in diameter. Thus, the conventional PW is not well known as an innovative and versatile vacuum interface. In this study, therefore, we have developed sheet-type PW (Sheet PW). If one can generate high-density and high-temperature sheet-shaped plasma such as a partition plate between a vacuum and an atmosphere, various applications as a virtual vacuum interface will be expected.

The objections for a first trial are as follows: (1) creation of 100 mm×100 mm squared sheet plasma, (2) investigation of the experimental conditions (discharge current, gas flow, magnetic strength of permanent magnets and solenoid coils) on which sheet plasma can be generated, (3) understanding how to generate required squared sheet plasma and its physical mechanism, and (4) measurements of the plasma parameters of the sheet plasma by emission spectroscopy.

In order to transform initial cylindrical plasma to sheet plasma, a pair of permanent magnets (rectangular NdFeB, 25 mm×100 mm×60 mm) placed perpendicular to the solenoid coil field was used.

In the experiment, first, high-density (~10^{16} cm^{-3}) and high-temperature (~5 eV) TPD plasma (6 mm in diameter) was created in the conventional manner. The TPD discharge current and voltage were <100 A and ~200 V, respectively, the gas flow rate: 0~5.0 L/min. The permanent magnets were up to 1.0 T. In addition, the axial solenoid field of 0~0.2 T was applied. After that, the argon gas was introduced into the vacuum chamber, and then high-viscosity plasma/gas with ~10^{18} cm^{-3}, ~1 eV was produced between the permanent magnets, as shown in FIG.1. For plasma parameter measurements, visible emission spectroscopy was made. In addition, the thickness and the width of sheet plasma were measured on various experimental conditions. As a simple estimation in 0.5 T magnetic field, the aspect ratio of the width to the height is expected to be 25:1.

In this presentation, we will talk about the details of the Sheet PW device and discuss the characteristics of the sheet plasma obtained by visible emission spectroscopy.

References

[1] A. Hershcovitch, J. App. Phys. **78 (9)**, pp5283-5284 (1995).
[2] T. Yamaguchi, master thesis, Hiroshima University, (2021).

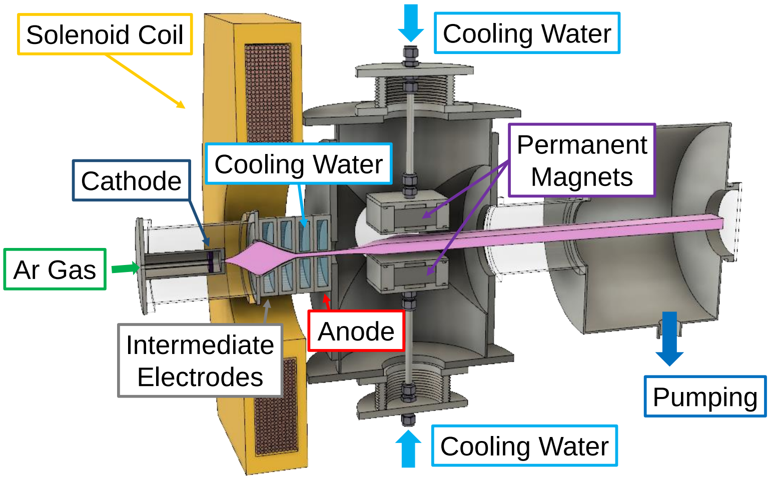

FIG. 1. Schematic diagram of the Sheet PW device.