§18. Generation of High-Density Helicon Plasma using Supersonic Gas Puffing

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Most practical electric thrusters have a lifetime problem coming from a damage of electrodes directly contacting with a dense plasma. A helicon plasma thruster has been proposed as a long lifetime thruster, because it works without any contact electrodes. Therefore, it has a potential to become a main thruster for a deep space explorer, which requires high-thrust and high-specific impulse. Authors have been promoting the Helicon Electrodeless Advanced Thruster (HEAT) project[1] that uses the helicon plasma for generating the dense plasma, and electromagnetic forces for accelerating the source plasma to gain the enough thrust and specific impulse.

In thruster studies, a neutral particle, e.g., Ar and Xe works as a fuel gas. In most cases, these gases are supplied to a discharge tube with a simple nozzle, and a supplying pressure is low. Therefore, the neutral particle fills a discharge tube homogenous. However, there are two problems in this configuration. First, there is a limitation of an electron density increase, due to a neutral particle depletion in the center axis of the high-density helicon plasma. This limitation reduces the thrust performance directly. Second, the high-density plasma causes an erosion of discharge tube wall. For the future MW class thruster, such as a main thruster of a human mars explorer, this problem becomes serious because the particle and heat fluxes of the plasma will increase drastically.

Here, in a field of magnetically confined fusion plasma science, there is an advanced neutral particle fueling method named a supersonic gas puffing (SSGP)[2]. This method uses a concentrated sharp gas beam by injecting a high pressure gas via the Laval nozzle, in order to achieve a deep penetration length in the fusion plasma compared to the conventional gas puffing.

To solve above-mentioned problems, we have proposed a supersonic gas puffing system for the high-density helicon plasma. By the use of the SSGP along the center axis of the helicon plasma, the depletion of neutral particles in the central region will improve. In addition, a number of neutral particles near the wall of the discharge tube will be clearly decreased, causing an electron density decrease, which suppresses the wall damage.

This study aims to carry out preliminary studies of the helicon plasma generation using SSGP. First, we have to estimate and compare behaviors of the neutral particle using the SSGP with those with the conventional gas puffing. We have developed a Schultz type ionization gauge which can measure a pressure even in the high pressure range (~100 Pa). Since the size of this gauge is quite small, three dimensional distribution of the neutral particle density can be measured by scanning of its position. Figure 1 indicates a nozzle which is developed in this study. The nozzle is installed in a vacuum chamber of Large Mirror Device, an inner diameter of 445 mm and an axial length of 1,700 mm. This chamber is evacuated by two turbomolecular pumps, and the background pressure of the chamber is ~ 5×10^{-4} Pa. The injection of a neutral gas is controlled by an electromagnetic valve, and an opening time was around 0.5 ~ 100 ms.

Figure 2 shows preliminary results of the SSGP experiment. These contour maps indicate the pressure distributions of T = 10, 20 and 30 ms. The nozzle is located on the axial and radial positions of 0 mm, The supplied pressure of the Ar gas is 4 MPa, and the opening time of the valve is 30 ms. In this configuration, the profile of the exhausted gas is concentrated near the center. Note that in a low pressure area located in front of the nozzle, there is an error signal. It is considered as the cooling effect of the filament of the ionization gauge.

In the next fiscal year, we plan to develop a new nozzle that can supply an appropriate gas pressure, and carry out plasma experiments using the SSGP.

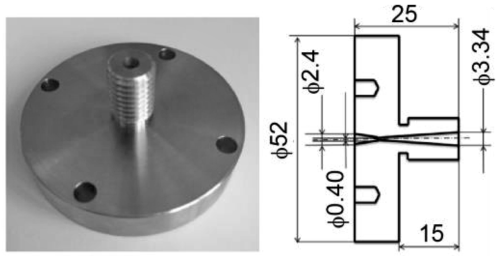

Fig. 1. Developed nozzle.

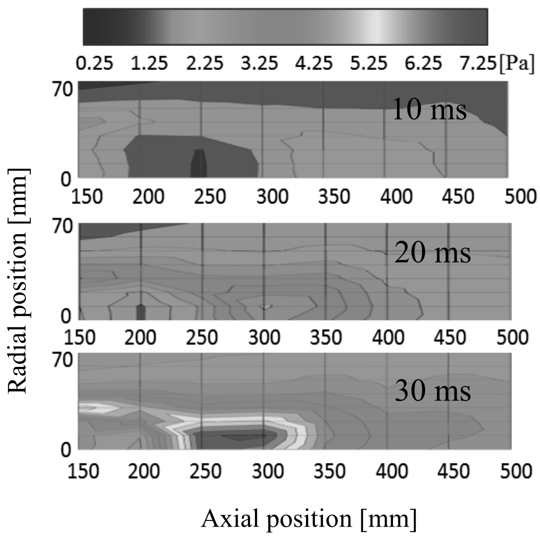

Fig. 2. Pressure distributions.

1) Shinohara, S. et al.: IEEE Trans. Plasma Sci. **42** (2014) 1245.
2) Murakami, A. et al.: Plasma Fusion Res. **5** (2010) S1032.