§25. Photodetachment Diagnostics of H⁻ Ion Sources and Improvement in H⁻ Production Efficiency

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High current H⁺ sources without filaments are desired for the next NBI system of thermonuclear fusion reactors. The most important thing for the efficient H⁺ production is to realize the three requirements: (1) efficient production of the excited molecules in a high electron temperature (Tₑ) region, (2) enhanced dissociative attachment to them in a low-Tₑ region and (3) production of a high electron density (nₑ) plasma.

For the purpose of the efficient H⁺ production, we have produced a high-nₑ hydrogen sheet plasma by helicon wave discharge. A high-Tₑ region and a low-Tₑ region were formed by the spatial control of applied magnetic field. A helicon plasma was produced in a linear machine with a uniform magnetic field of 220 G. The cusp field was superposed on the longitudinal field and a sheet plasma was formed [1]. The spatial profiles of H⁺ density (nₑ) was measured by laser photodetachment. The nₑ, Tₑ and space potential (Vₛ) were measured by a Langmuir probe. This probe was also used to detect photodetached electrons from H⁻. In this report, the correlation between the H⁻ production and the plasma parameters was discussed.

Figure 1 shows the spatial distributions of nₑ and Tₑ. The electron density nₑ was 8x10¹¹ cm⁻³ at the center. A high-nₑ plasma was produced. The electron temperature Tₑ was 7eV at the center and decreased to 1 eV at X=10 mm. The Tₑ profile was sharp, while the nₑ profile was broad. A high-Tₑ region and a low-Tₑ region were formed in a high-nₑ hydrogen plasma. Favorable condition for H⁻ production was attained. Figure 2 shows the spatial profile of nₑ. The H⁻ density nₑ was peaked at X=30 mm where the low-Tₑ and high-nₑ region was formed. The peak value of nₑ was 5x10¹⁰ cm⁻³. The spatial distribution of Vₛ was shown in Fig.3. The plasma chamber was grounded. The space potential Vₛ was -40 V at the center and increased to 0 at X=40 mm. The hollow Vₛ profile was formed.

This may be due to higher-nₑ than the positive ion density in the center region. It is considered, therefore, that a high-energy electron component or an electron beam component exists in the high-Tₑ region, as can be seen in linear DC machine such as TPD. It is favorable for the production of the excited molecules which are produced by impact excitation of energetic electrons.

In conclusion, we have produced the high-nₑ hydrogen sheet plasma. The spatial profiles of nₑ, nₑ, Tₑ and Vₛ were measured. By the spatial control of the Tₑ profile, the high-Tₑ region and the low-Tₑ region were realized in the high-nₑ plasma. In the high-Tₑ region, the excited molecules are greatly produced by energetic electrons. The H⁺ ions were efficiently produced in the low-Tₑ region.

Fig. 1. Spatial distributions of nₑ and Tₑ.

Fig. 2. Spatial distribution of nₑ.

Fig. 3. Spatial Distribution of Vₛ.

Reference