§14. Production of Ions and Radicals in H_2 ECR Plasma with Controlled Electron Temperature

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1. Introduction

Hydrogen (H_2) plasma is widely used for scientific and industrial field. For instance, negative ions in H_2 plasma are used as a negative ion source for the NBI heating of fusion plasma. On the other hand, atomic hydrogen in the silane and methane plasma with a large amount of hydrogen dilution plays an important role for the thin film growth of silicon and carbon, respectively. In these applications, there are strong requirements for selective production, spatial profile control of the species in H_2 plasma.

In this paper, we focused on the negative ion H^- and investigated the high production efficiency via 915 MHz microwave heating. Especially the relationships among the microwave propagation, electron temperature and H^- production were examined experimentally.

2. Experimental

As is well known, the volume production and annihilation of H^- mainly occur in the following reactions [1].

$$H_2 + e_{fast} \rightarrow H_2^* + e_{fast} \quad (1)$$
$$H_2(v \geqq 5\text{-}6) + e_{slow} \rightarrow H + H^- \quad (2)$$
$$H^- + e_{fast} \rightarrow H + e_{fast} + e \quad (3)$$

They indicate that two regions of electron temperature are necessary in the plasma in order to produce H^- efficiently. In this study, 915 MHz ECR plasma were applied because the electron temperature can be controlled in a wide range. In addition, it is advantageous for long-time operation without filament. Using this system, we investigated the effect of microwave propagation on the electron temperature, continuously, relationship between the distribution of the electron temperature and production efficiency of H^-. Experimental condition is the gas pressure of 10 mTorr, the microwave with TM_{01} mode of 1-2 kW and almost uniform magnetic field of about 300 G. The electron temperature was separately measured as the component of parallel ($T_{e//}$) and perpendicular ($T_{e\perp}$) to the magnetic field using Langmuir probe. Simultaneously, the microwave trace was measured by interferometry. In addition, the production efficiency of H^- was estimated from the ratio of the electron saturation current to the ion saturation current.

3. Experimental results and discussion

Figure 1 and 2 show the axial distributions of the electron temperature and positive ion density, respectively. Then, the microwaves propagated until the ECR region (z ≅350 mm) and were absorbed completely. As seen in Fig. 1, the electron temperature was about 8-10 eV where the

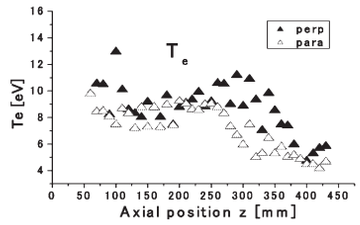

Fig. 1. The axial distribution of the electron temperature.

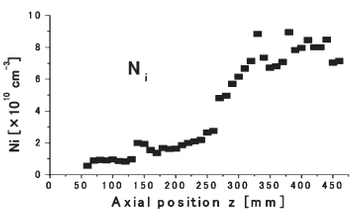

Fig. 2. The axial distribution of the positive ion density.

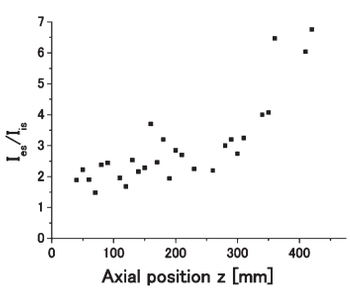

Fig. 3. The axial distribution of the saturation current ratio.

microwaves propagated. After the ECR region, the electron temperature was about 4 eV. Namely, two regions of electron temperature were successfully established. Figure 3 show the axial distribution of ratios of the electron saturation current to the ion saturation current. The ratio in the region of the high electron temperature was about a quarter of that of the low electron temperature. It seems that the negative ions produced much more in the region of the high electron temperature. In general, it is said that the optimal electron temperature for the high efficiency of H^- production was below 1 eV. This experiment, however, shows the high production of H^- at considerably high electron temperature. As one of the reasons, it is considered that reaction (1) and (2) were much promoted in comparison with reaction (3). These results should be confirmed using more precise measurement such as laser photo detachment method.

Reference

1) Fukumasa, O. et. al., Contrib. Plasma Phys. **44**, No. 5-6, 516 – 522 (2004) / **DOI** 10.1002/ctpp.200410073.