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Production Property of Hydrogen Negative Ions in Multiaperture Magnetron Source
多孔マグネトロン方式の水素負イオン生成特性

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A honeycomb-structure negative-ion source with new concept consisting of many coaxial magnetron plasma sources and a negative-ion production section using a plasma-assisted catalytic ionization method is developed. One component of the negative-ion source can produce negative ions even though the production current is not high.

1. Introduction

The research and development of negative-ion sources have been extensively performed in connection with neutral beam injection (NBI) heating for fusion-oriented plasmas. A small admixture of cesium vapor in a hydrogen discharge significantly improves negative-ion production and decreases the current of coextracted electrons [1]. However, the use of cesium complicates the ion source operation and requires the careful stabilization of cesium injection and discharge parameters. There have been many attempts to develop negative-ion sources with acceptable negative-ion beam emittance but without a cesium admixture.

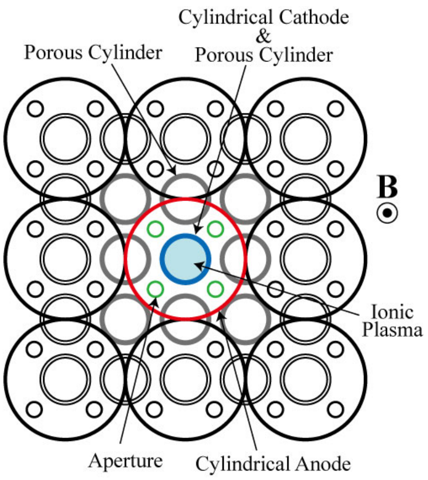

Fig. 1. Cross-sectional position relation among coaxial magnetron sources, apertures, and porous cylinders.

We have proposed a plasma-assisted catalytic ionization method for production of H^+ and H^- ions [2,3]. Hydrogen positive ions produced by discharge are irradiated to a porous catalyst, positive and negative ions are produced from the back of the irradiation plane. In this work, the porous catalyst is cylindrical, not tabular. A tabular porous plate is suitable for fundamental investigation of the plasma-assisted catalytic ionization [3]. Backstreaming positive ions, accelerated in the opposite direction, enter the negative-ion sources for the NBI systems. If the tabular porous plate is used for negative-ion production, the backstreaming strike and cause damage to the porous plate. Therefore, the porous catalyst should be cylindrical so that the backstreaming can pass through it. A honeycomb structure plasma tied many small-volume plasmas in bunch is used for large area irradiation. A small volume plasma is produced for irradiation under conditions of filament free.

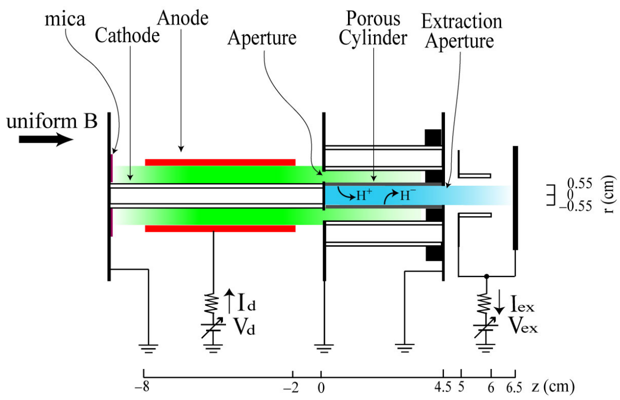

Fig. 2. Schematic diagram of experimental apparatus. The negative ion source consists of a magnetron source and an ion production section.

2. Experimental Apparatus

The negative ion source consists of double-step process, a magnetron source and an ion production section. The magnetron source is a honeycomb structure of cylindrical anodes of 3.6 cm diameter and coaxial cylindrical cathodes of 1.5 cm diameter. The ion production section consisting of many porous cylinders is connected with the magnetron source through apertures in a separate plate. A cross-sectional position relation among the coaxial magnetron sources, the apertures, and the porous cylinders is shown in Fig. 1. Hydrogen plasma generated by magnetron discharge is supplied through four apertures of 0.45 cm diameter to around the porous cylinder. Positive and negative ions are produced inside the porous cylinder by the plasma-assisted catalytic ionization process. The porous cylinders of 1.5 cm diameter are positioned at center-to-center spacing of 1.8 cm.

In this work, production property of negative ions for a set of the coaxial magnetron source and the porous cylinder is investigated, because the total current of negative ions increases proportionally to number of the set. Eight dummy cylinders of 1.5 cm diameter made of SUS304 are set around the porous cylinder as alternatives to the other porous cylinders. The experimental apparatus is illustrated in Fig. 2. Currents of positive and negative ions extracted by an extraction electrode of 1.5 cm inner diameter are measured using a collector at z = 6.5 cm separated 0.5 cm from the extraction electrode. The extraction electrode and the collector are biased at V_{ex}. The anode is positively biased at V_d and the other electrodes are grounded. The porous cylinder of 3 cm length is made of a porous nickel plate rolled with a porous body of a pore size of 0.45 mm, a thickness of 1.4 mm, a specific surface area of 5,800 m^2/m^3, and a porosity of 96.6 %. The hydrogen pressure in the source during operation is about 0.2 Pa. A uniform magnetic field is applied to the apparatus by solenoid coils.

3. Results

A hydrogen plasma generated by magnetron discharge is supplied through four apertures to around the porous cylinder grounded. Positive and negative ions are produced inside the porous cylinder. The ion current extracted I_{ex} is measured using the extraction electrode and the collector biased at V_{ex}, and the current (I_{ex})-voltage (V_{ex}) characteristics are shown in Fig. 3, where the discharge voltage V_d is changed, the discharge current I_d (the discharge power P_d) is maximized by adjusting the magnetic field B. The positive current is much higher than the negative current, indicating the property of ionic plasmas. The currents increase with V_d (P_d), corresponding the irradiation current of positive ions. In the other works relevant to the plasma-assisted catalytic ionization, the positive current becomes higher than the negative current in the case of using a porous plate and the positive-ion irradiation in a direction perpendicular to the porous surface. Then transmitted positive ions through the porous plate are detected. Therefore, positive ions irradiated appear to be partially transmitted through the porous cylinder.

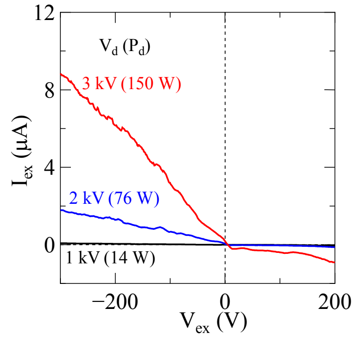

Fig. 3. Current-voltage characteristics of extraction electrode and collector.

The electric field drift of the guiding center in magnitude E/B is independent of charge, mass, and velocity of electrons. Electrons gain energy from the electric field and produce positive ions in the magnetron discharge. Dependences of positive- and negative-saturation currents of I_{ex}, I_+ and I_-, on E/B normalized are shown in Fig. 4, where I_+ and I_- are obtained at V_{ex} = −200 V and +200 V, respectively. I_d (P_d) is maximized by adjusting B in the same as Fig. 3. I_+ and I_- increase with E/B, depending on the property of magnetron discharge.

One component of the honeycomb-structure negative-ion source can produce negative ions even through the produced current is not high. It is necessary for the future that the discharge section is improved and the irradiation current to the porous cylinder is increased more.

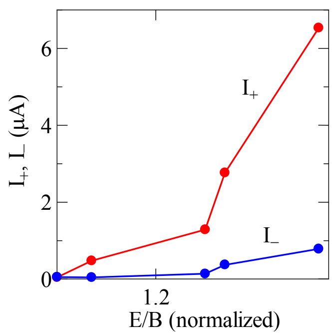

Fig. 4. Dependences of the positive- and negative- saturation currents of I_{ex} on E/B normalized.

References

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