§7. Development of Cesium-free Deuterium/ hydrogen Negative-ion Source Based on Catalytic Ionization Method

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Development of deuterium/hydrogen negative-ion source without cesium admixture is performed. Hydrogen atomic pair ions are produced by plasma-assisted catalytic ionization using a porous nickel plate. When positive ions in a hydrogen plasma discharged are irradiated to the porous plate, the pair ions are produced from the back surface of the plate.[1)-3)] Figure 1 (a) shows a schematic diagram of the experimental setup. A hydrogen plasma is generated by a dc arc discharge in a cuboidal chamber with a cross section of 25 cm×25 cm, i.e., a bucket plasma source. A commercially available Ni porous plate with a porous body of 22-24 cells/cm, 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% is used as a catalyst. The porous catalyst is negatively biased at dc voltage of V_{pc} with respect to grounded chamber wall, and the irradiation current I_{ir} of positive ions can be obtained. Plasma parameters are measured by Langmuir probes at $z = -7$ cm and 3 cm. The hydrogen pressure during operation is about 0.2 Pa.

The plasma potential ϕ_s in the discharge region $z <$ 0 cm remains approximately constant at +10 V, when V_{pc} is changed between −1000 V and −20 V. The irradiation energy of positive ions is $e(\phi_s - V_{pc})$ and proportional to V_{pc}. The probe characteristics are measured at $z = 3$ cm, shown in Fig. 1 (b). The plasma potential in the region $z > 0$ cm is close to 0 V even though the porous plate is negatively biased at V_{pc}. The positive current of the characteristics is higher than the negative current. Thus the production quantity of positive ions from the catalyst surface is greater than that of negative ions.

The positive- and negative-saturation currents of the probe, I_+ and I_-, are obtained at probe bias voltages of −120 V and +120 V, respectively. The dependences of I_+, I_-, and I_{ir} on the irradiation energy at the discharge power of 500 W are shown in Fig. 2 (a). When $e(\phi_s - V_{pc}) > 100$ eV, I_- increases proportionally with the irradiation energy under only positive-ion irradiation; that is, the production quantity of negative ions increases. However I_- increases when $e(\phi_s - V_{pc}) < 100$ eV, because part of the irradiated electrons can pass through the porous plate without termination on the plate surface. I_+ also tends to increase with the irradiation energy, but there are some peaks at various irradiation energies. These peaks only appear when the catalyst surface is in a state of activation. Both I_+ and I_- increase proportionally with I_{ir} which can be varied by adjusting the discharge power. The dependence of the peak energies on the discharge power is shown in Fig. 2 (b). There are at least two peaks at a given discharge power. The peak energies increase with the discharge power. The peaks are a distinctive production property of positive ions and do not appear in the production of negative ions.

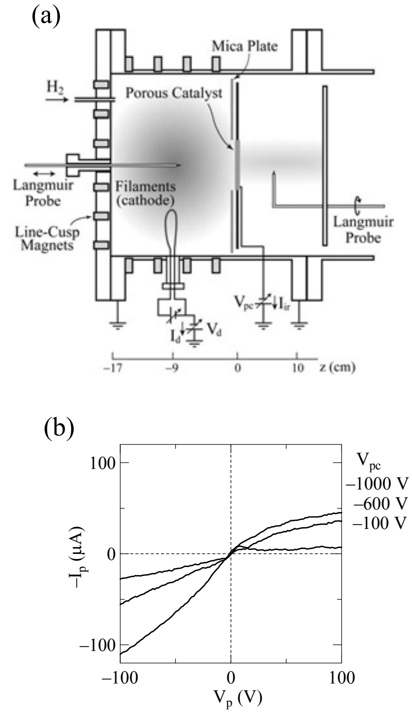

Fig. 1. (a) Experimental setup. Hydrogen plasma is generated by dc arc discharge and irradiated to porous nickel catalyst. Hydrogen atomic ions are produced from the back side of the irradiation plane. (b) I-V characteristics of Langmuir probe at $z = 3$ cm.

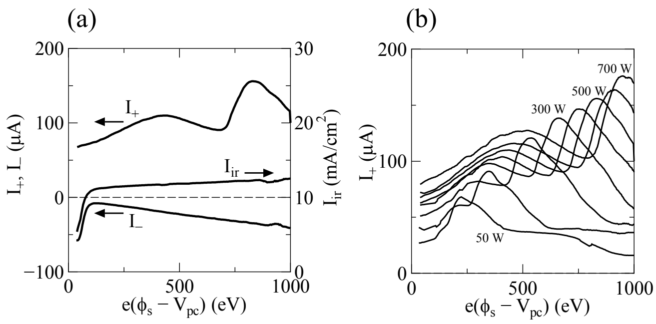

Fig. 2. (a) Probe saturation currents of positive and negative ions and the irradiation current as functions of the irradiation energy. (b) Dependence of peak energies appearing in positive-ion production on the discharge power.

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