§15. Development of Cesium-free Hydrogen Negative-ion Source Based on Plasma-assisted Catalytic Ionization

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A plasma-assisted catalytic ionization method for the production of positive and negative hydrogen ions has been proposed for generating a hydrogen pair-ion plasma and developing a highly efficient hydrogen negative-ion source without a Cs admixture.[1-3] A hydrogen plasma is generated by a dc arc discharge between filament cathodes and a wall anode in a cuboidal chamber with a cross section of 25 cm×25 cm, i.e., a bucket plasma source. The ionization method involves the following steps: positive ions in discharge plasmas are irradiated to a porous catalyst, and positive and negative ions are produced from the back of the irradiation plane. Figure 1 shows a schematic diagram of the experimental setup. The porous catalyst is a commercially available Ni porous plate with a pore size of 0.45 mm, a thickness of 1.4 mm, a specific surface area of 5800 m^2/m^3, and a porosity of 96.6%. The porous plate is negatively biased at a dc voltage of V_{pc} and then irradiated with positive ions. Since the circular irradiation area is 6.1 cm^2 (diameter of 2.8 cm) and the other electrode is covered with a mica limiter plate, the irradiation current density J_{ir} applied to the porous plate can be obtained.

The properties of the extraction current densities of positive and negative ions from the catalyst surface are measured when an electric field is directly applied to the catalyst surface. Typical extraction current density (J_{ex})-voltage (V_{ex}) characteristics are shown in Fig. 2 (a). The positive current is much higher than the negative current. The J_{ex}–V_{ex} characteristics have two inflection points. One is at $V_{ex} \sim V_{pc}$ and the other is at $V_{ex} \sim 0$ V. The kinetic-energy distributions are calculated by differentiating the J_{ex}–V_{ex} characteristics, where the reference potential in the region $z > 0$ cm is the porous-plate potential (V_{pc}) because all the ions are emitted from the porous surface. The energy distributions in the case of a constant irradiation current density (J_{ir} = 15 mA/cm^2) are shown in Fig. 2 (b). There are two components of the ions in the energy distributions determined by taking the reference potential into consideration. The kinetic energy of the high-energy component increases with the irradiation energy. Thus, the high-energy component at about $e(\phi_s - V_{pc})$ (eV) consists of transmitted positive ions that are part of the irradiated positive ions passing through the porous plate that reacted with the porous surface, because the energy is slightly lower than the irradiation energy. The low-energy component at around 0 eV consists of positive and negative ions produced by desorption ionization with a kinetic energy less than 10 eV. The quantity of the low-energy component increases proportionally with the irradiation current density. The extraction current densities of the positive and negative ions can be separately obtained by utilizing their energy difference. It was found that the produced fluxes of positive and negative ions and the flux balance between them are controlled by the irradiation current density and the irradiation energy, respectively.

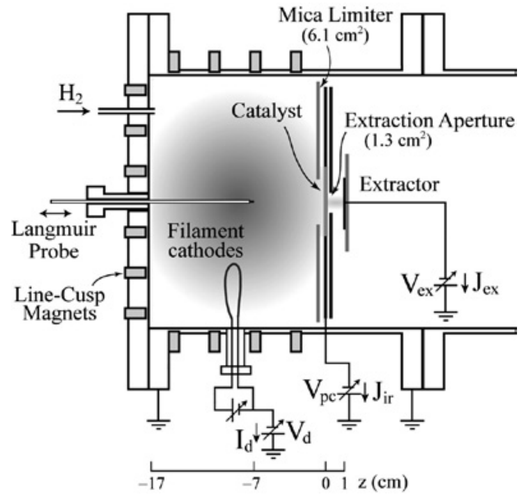

Fig. 1. Experimental setup. The hydrogen plasma generated in bucket source is irradiated to the Ni porous catalyst. The extraction current density of ions J_{ex}, which are produced from the back of the irradiation plane by plasma-assisted catalytic ionization, is analyzed.

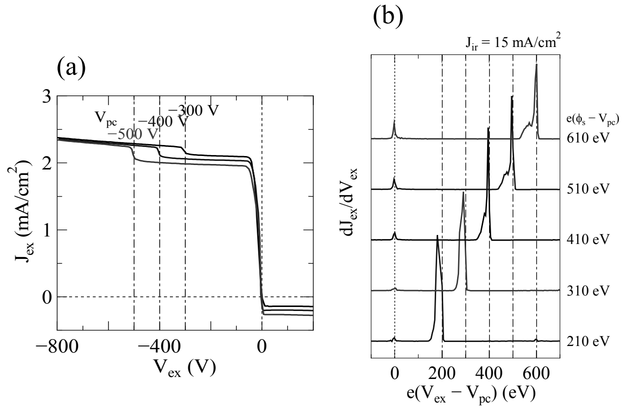

Fig. 2. (a) Extraction current density J_{ex} – voltage V_{ex} characteristics obtained from extractor. (b) Dependence of ion energy distribution calculated from the characteristics on irradiation energy.

1) Oohara, W., Maeda, T., Higuchi, T.: AIP Conf. Proc. **1390** (2011) 430
2) Oohara, W., Maeda, T., Higuchi, T.: Rev. Sci. Instrum. **82** (2011) 093503-1
3) Hibino, T., Higuchi, T., Oohara, W.: Proc. Plasma Conf. 2011 (2011) 22P163