Development of Hydrogen Pair-Ion Source on the Basis of Catalytic Ionization

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Pair plasmas consisting of only positively and negatively charged particles of equal mass have garnered attention because they maintain space-time symmetry [1]. A fullerene pair-ion plasma, consisting of positive and negative ions of equal mass ($C_{60}^+$ and $C_{60}^-$), has been generated, and its collective phenomena have been investigated experimentally [2]. To extensively investigate the physical properties of pair plasmas, particularly their wave-propagation characteristics at higher frequencies, a hydrogen pair-ion plasma source is being developed, because hydrogen atomic pair ions, i.e., $H^+$ and $H^-$ ions, are the lightest ions and have high response frequencies to electromagnetic fields. Several difficulties must be overcome to develop this plasma source. The pivotal problem is the efficient production of $H^-$ ions. The research and development of negative-ion sources [3] have been extensively performed for more than 20 years in connection with neutral beam injection (NBI) heating for fusion-oriented plasmas and ion guns for proton accelerators. The production methods of $H^-$ ions are classified into volume production and surface production due to contact ionization. The generation of a pair-ion plasma requires the production of equal quantities of $H^+$ and $H^-$ ions and the absence of impurities such as electrons and other ions. It is difficult to satisfy these conditions if contact ionization or volume production is adopted. In this study, an atomic ion production process is considered in which atomic hydrogen is produced in the first stage, and ionized in the second stage [4,5].

A dc arc-discharge hydrogen plasma is generated in a rectangular chamber with line cusp magnetic fields. A commercially available porous plate made of Ni is set at an external magnetic filter composed of a pair of permanent magnets, and a parallel magnetic field along the porous surface is applied. The porous plate acts a catalyst and can be biased at dc voltage. The positive ions are irradiated to the porous catalyst, pair ions are produced from the back side of the irradiation plane. Increases in the irradiation flux and energy affect the number of pair ions produced. We suggest the production mechanism as catalytic ionization comprised of dissociative adsorption, surface migration, and desorption ionization. The catalytic activity for hydrogen is important here, whereas the work function does not affect the ionization.