Study on Upgrades of the Magnetron Ion Source for High Current Operation of the Low Pressure Driven IEC Device

Taiju Kajiwara*, Yoko Kamiya, Kai Masuda, Yu Yamagaki,
Genki Hashimoto and Kazunobu Nagasaki

Inst. Advanced Energy, Kyoto University, Kyoto, Japan
* Corresponding Author. Tel: +81-774-38-3443, Fax: +81-774-38-3449
k-taiju@iae.kyoto-u.ac.jp

An IEC device at Kyoto University aims at an operation under a D_2 gas pressure of units of mPa with the aid of a ring-shaped magnetron ion source. This device employs the negatively biased ring-shaped array of permanent magnets between the IEC cathode and the anode, to produce ions in the vicinity of the anode by a magnetron discharge [1]. In this ring-shaped ion-source driven IEC (referred to as a RIS-IEC), the experimental neutron yield was found to be proportional to the square of the IEC cathode current, unlike the linear dependence in any experimental IEC devices so far. One possible explanation for this newly observed phenomenon might be fusion reactions between energetic ions, which are expected to increase the neutron output drastically, thanks to the current-square dependence.

Through a comparison between the neutron yields by the RIS-IEC mode and the glow-driven mode in the present device, it is found that the neutron yield in the new RIS-IEC mode would exceed that of the conventional glow-driven mode if the IEC cathode current would increase to 4 mA. The IEC cathode current in the RIS-IEC mode is, however, limited to 1 mA in the present device. In this study, we discuss an upgrade of the RIS-IEC device for high current operation.

In the present magnetron discharge, the chain-reaction ionization by the electrons, and the secondary electron emission by the ion collision to the magnets balance, to lead to a specific steady-state IEC cathode current dependent on the applied bias voltage and the gas pressure. We plan to place a thermionic electron emitter attached to the magnet array to provide a much higher electron current, e.g. 100 mA, than in the present self-sustained magnetron discharge. Numerical simulations are carried out to see if this system can lead to an enhanced IEC cathode current.

We carried out trajectory simulations of ions and electrons in the present magnetron discharge in a cylindrically symmetric system, by use of a 2-dimendional code [2]. This code handles atomic and molecular collisions among electrons, ions and background neutrals, and takes into account the space-charge effect. In this study we gave constant electron currents of 0.1, 0.3, 1.0 and 120 mA from the magnetron cathode surface as the input conditions of the simulations, which is regarded as the sum of thermal and secondary electron emission currents, neglecting the secondary electron emission from the magnet array. We fixed the gas pressure and the applied bias to the magnet array to 5 mPa He and -10 kV.

As the simulation results, it is found that the ratio of the incident electron currents from the magnet array and the resultant He^+ ion current to the magnetron cathode is roughly 3:10 independent of the incident electron current. An important suggestion from the simulation results is that a linear increase of the ion supply is expected up to an incident thermal electron current of 120 mA with little space-charge effect. The expected IEC cathode current turns out to be ~150 mA, according to the experimental ratio of the magnetron discharge current and the extracted IEC cathode current.

As a candidate emitter attached to the RIS-IEC, a directly heated tungsten dispenser cathode is under consideration, which is commercially available and can provide a thermal electron current of ~20 A in a vacuum. The fundamental electron emission characteristics will be presented in the conference.

[1] K. Masuda, et al., Plasma Phys. Control. Fusion **52** (2010) 095010.
[2] K. Masuda and K. Yoshikawa, Fusion Science and Tech. **52** (2007).