§26. Performance Improvement of a Spherically Converging Ion Beam Colliding Fusion Neutron Source by Use of External Ion Sources

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An inertial electrostatic confinement fusion (IECF, see Fig. 1) neutron source is a device injecting ions and electrons towards the spherical center through a transparent hollow cathode, trapping both species in the electrostatic self-field and making fusion reactions in the dense core. An IECF device can be promising for a portable neutron source. At present, D-D fusion neutrons of about ten millions/sec are successfully produced continuously at our research group, and at several institutions, as well. In order to enhance the neutron yield by an IECF source, it is essential to produce sufficient ions, particularly, in the vicinity of the vacuum chamber to provide full energy under a relatively low pressure to prevent accelerating ions from unnecessary charge-exchange with background gases. Furthermore, it is very encouraging that numerical studies so far have predicted nonlinear dependence of neutron yield on discharge current under low gas pressure condition through formation of electrical double well potential within the central hollow cathode.

The objectives of this study are to improve the IECF performance by use of magnetron discharge mechanism as an extremely compact and simple ion source, and also to extend the accessible pressure range in order to verify the aforementioned numerical prediction of nonlinear regime.

For these objectives we have developed a magnetron discharge mechanism with a coaxial inner anode set up in the nozzle (IFC70, inner diameter of 35 mm) surrounded by a Nd-Fe cylindrical permanent magnet, showing experimentally an ample ion current supply even under a low gas pressure of several mTorr successfully[1]. In that configuration, however, the ions produced would be lost onto the facing wall of the grounded spherical chamber without bouncing motions, because of positive potential of the ions' birthplace.

For longer ions' lifetimes, a refined configuration with an inner cathode instead was hence developed. As schematically shown in Fig. 2, a cathode of 25 mm outer diameter was set up in an IFC70 nozzle (inner diameter of 35 mm). A Sm-Co magnet of 19 mm diameter was set up within the inner cathode to provide appropriate magnetic field distribution for the negatively biased magnetron system. This refined system (I-25) was then tested and compared with the previous positively biased one with the magnet set up outside the nozzle (O-25)[1]. The I-25 system was found to run under a low gas pressure of several mTorr as well, while the discharge current was found much lower than that by the O-25 system (see Fig. 3).

The reason for this low discharge current was then studied by use of an electron tracking code. As shown in Fig. 4, confinement of the electrons is obviously found poor in the I-25 configuration owing to a lower magnetic flux density between the cathode and grounded anode. Use of a shorter magnet and/or a water-cooled Nd-Fe one would be effective for a higher magnetic flux density, and accordingly for a higher discharge current.

Fig. 1. The hollow cathode at the center of the spherical vacuum chamber as the anode, and an IECF plasma within the hollow cathode.

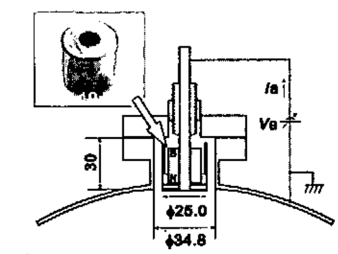

Fig. 2. Schematics of a magnetron-type ion source set up on a spherical chamber of an IECF device.

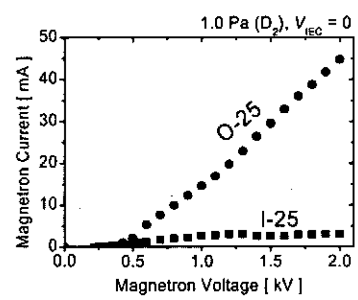

Fig. 3. Magnetron discharge currents comparing positively (O-25) and negatively biased (I-25) systems.

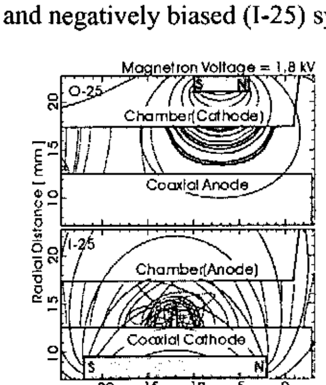

Fig. 4. Calculated electrons' trajectories in the O-25 (upper) and I-25 (lower) magnetron systems.

References

1) Yoshikawa, K. et al. : Ann. Rep. NIFS (2002-2003).