§19. Research and Development of an Extremely Compact Fusion Neutron Source by Spherically Converging Ion Beams

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An inertial electrostatic confinement fusion (IECF) neutron source is a device injecting ions towards the spherical center through a transparent hollow cathode (see Fig. 1), trapping them 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 more than 10^7 sec^{-1} are successfully produced continuously by an IECF device of 340 mm in diameter shown in Fig. 1 at our research group, and at several institutions, as well.

Among current major requirements of compact neutron sources, anti-personnel landmine detection is one of the most urgent issues. For this application in the very near future, further smaller device is required. An extremely compact IECF device of 200 mm in diameter has been thus newly developed. A neutron yield of 10^7 sec^{-1} in DC operation is required for landmine detection through back-scattered neutrons and neutron-captured gamma rays. 4×10^6 sec^{-1} has been achieved so far.

In order to enhance the neutron yield by an IECF source, it is effective 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. For this objective we have been developing a magnetron discharge system[1, 2] which shows in general an ample ion current supply with a compact and simple configuration even under a low gas pressure of several mTorr. Negatively biased inner electrode in the coaxial configuration[2] as shown Fig. 2 is essential, otherwise the produced ions would be lost onto the facing wall of the grounded spherical chamber without bouncing motions.

Recently we have refined the magnetron discharge system with an outer Nd-Fe-B permanent magnet additional to the original inner one. With an optimal configuration, i.e. axial lengths and positions of the two magnets, a more than five times higher magnetron discharge current has been achieved (see Fig. 3). The refined magnetron ion source was then set up on the IECF spherical chamber. Ions supplied by the magnetron ion source were experimentally found essential and effective for maintaining a glow-magnetron hybrid discharge under an envisaged low gas pressure condition. We expected that a higher negative voltage applied to the central gridded cathode would result in a higher extraction ion current from the magnetron source, and accordingly a higher IECF cathode current. It is found however that, as shown in Fig. 4, there is an optimum voltage in terms of a high gridded cathode current. Numerical and experimental studies are being carried out for understanding these phenomena.

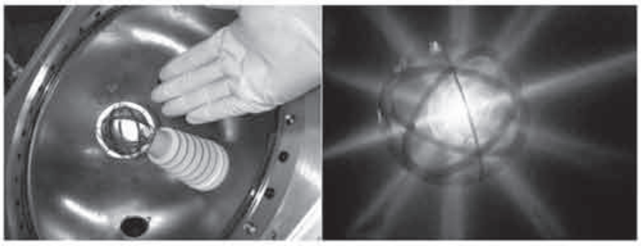

Fig. 1. The hollow cathode at the center of the spherical vacuum chamber as the anode, and an IECF plasma within the hollow cathode.

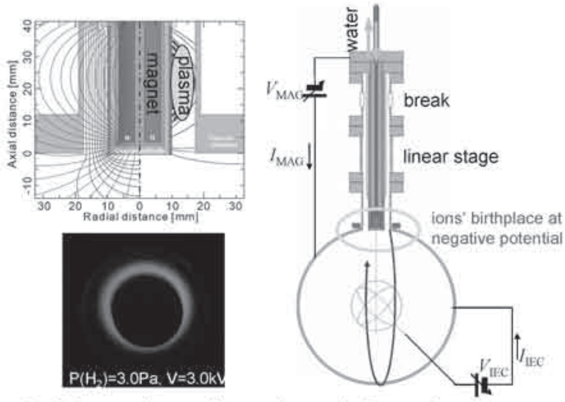

Fig. 2. Schematic configuration of electrodes for magnetron ion source and discharge plasma.

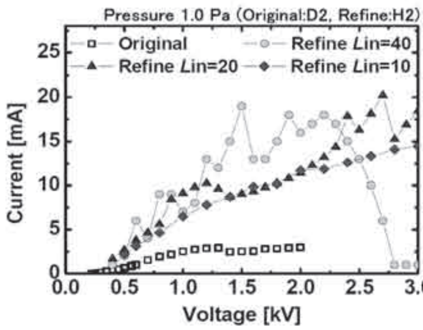

Fig. 3. Magnetron discharge current as the function of magnetron cathode current.

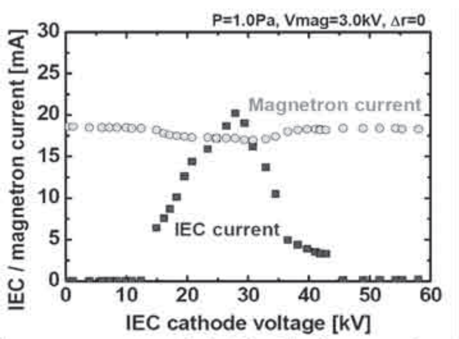

Fig. 4. Glow-magnetron hybrid discharge characteristics under low gas pressure condition of 1.0 Pa.

References

1) Yoshikawa, K. et al.: Ann. Rep. NIFS (2002-2003).
2) Yoshikawa, K. et al.: Ann. Rep. NIFS (2003-2004).