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

Yoshikawa, K., Masuda, K., Yamamoto, Y., Toku, H., Takamatsu, T. (Inst. Advanced Energy, Kyoto Univ.), (Graduate School of Energy Science, Kyoto Univ.), Sudo, S., Tomita, Y.

An inertial electrostatic confinement (IEC) fusion 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. The present IEC devices utilize the dc glow discharge to produce ions in an extremely simple configuration, and steady-state D-D neutron production rates (NPR) of 10^7 - 10^8 sec^{-1} have been obtained at several institutions. This makes the glow-driven IEC suitable for some applications though enhanced neutron yields is desired to extend their application.

However, low fusion efficiencies of the glow discharge based IEC, typically in the range of $Q \sim 10^{-8}$, greatly limits the use of IEC. The main causes for this low fusion efficiency are the rapid loss of ion beam energy by charge exchange collisions with background neutrals and fractional ion energies inherent in glow discharge. In order to sustain the glow discharge, the operating gas pressure of ~ 1 Pa is typically needed. Thus a reduced operating gas pressure could enhance the efficiency on one hand, while on the other hand a higher pressure could result in higher neutron yield since the beam-gas colliding fusion is regarded predominant in the present glow-driven IEC.

Firstly we carried out experiments with different cathode diameters of 50, 58, 65 and 95 mmϕ in an anode of 200 mmϕ. As shown in Fig. 2, pressure multiplied by distance between the electrodes is kept constant as predicted well by numerical simulations, and therefore the ion loss probability through the acceleration is expected independent from the cathode diameter. Thus the neutron yield is found to be enhanced by the larger cathode as seen in Fig. 3, because of the higher target gas pressure.

For further enhancement in the neutron yield, we have developed a magnetron-discharge-based built-in ion source to improve the fusion efficiency of IEC device by reducing the operating pressure [1]. Figure 4 shows comparison

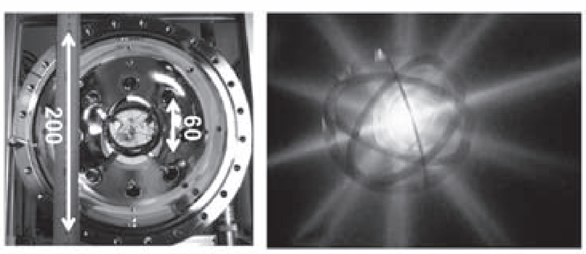

Fig. 1. The hollow cathode at the center of the spherical vacuum chamber as the anode, and an IECF plasma within the hollow cathode.

between the conventional glow-discharge-based IEC (at 1.3 Pa) and the ion source aided IEC, where the operating gas pressure can be controlled independent from the cathode bias voltage. The normalized neutron yield shown in Fig. 4 is the neutron yield divided by the gas pressure and cathode current, which can be used as a figure of merit to compare the IEC operation in different modes since it depends on ion energy and life. In the figure, the normalized neutron yield is seen improved greatly with decreasing pressure. It shows that the ion energy distribution with a lower pressure maintains beam-like characteristics to some extent desired for the efficient fusion generation.

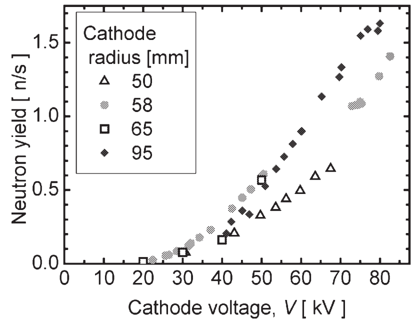

Fig. 2. Neutron yield dependences on cathode bias voltage comparing uses of different cathode diameters

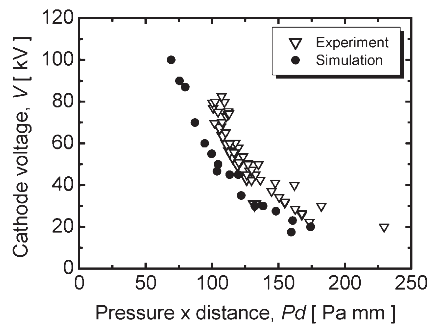

Fig. 3. Pressure – voltage characteristics by experiments and simulations for various cathode diameters ranging from 50 to 95 mm ϕ

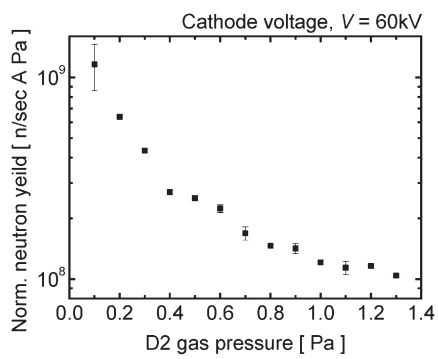

Fig. 4. Normalized neutron yield by magnetron ion source aided IEC as a function of operation gas pressure

References

1) Yoshikawa, K. et al.: Ann. Rep. NIFS (2004-2005).