24P144P

Research on Compact Inertial Electrostatic Confinement Fusion Device
放電型プラズマ中性子源の小型化に関する研究

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Inertial Electrostatic Confinement Fusion (IECF) device is a neutron source which is portable, small and easy-structured. IECF researchers have been studied to get more neutron production rate, using more expensive and powerful power supply and larger vacuum chamber. The research of downsizing about IECF device has not been studied. The discharge characteristic of minimized IECF device is investigated by the particle simulations. As the results, compact IECF device can be operated with much cheaper power supply. The parallel running of small IECF devices with one power supply probably make more neutrons.

1. Introduction

The schematic view of the inertial electrostatic confinement fusion device as a neutron source in Kansai University is shown in Fig.1. It consists of the cylindrical stainless steel vacuum chamber, the spherical mesh anode (300mm in diameter), the hollow cathode of the molybdenum, the power sources of DC and pulse, the gas feeding system, and the pumps. The cathode made of combined six rings to form a spherical shape is set in the center of the anode. The current feed-through terminal made of stainless steel is connected with the cathode. The set of a turbo molecular pump and a rotary pump achieves the gas pressure less than 10^{-3} Pa in the chamber. The deuterium gas is supplied at the steady pressure of 0.6 – 6.0 Pa in the chamber. The D.C. power supply is used for stationary mode operation and applies up to the potential of 80 kV and the maximum current in 50 mA. The glow discharge occurs between the anode and the cathode, and the deuterium ions and the electrons are produced. The electrons move towards the anode and hit the anode surface. On the other hand, the ions are accelerated to the cathode. Some of them collide with the cathode and lost, but most of them go through the cathode and traverse through the cathode many times. During the round-trips, the ions sometimes get the high velocity from the potential energy and make nuclear fusions with the other ions or the background molecules. As the result of the deuterium- deuterium fusion, the neutrons come out through the chamber. The neutrons production rate measured by ^{3}He counter is 10^{7}-10^{8} (1/sec).

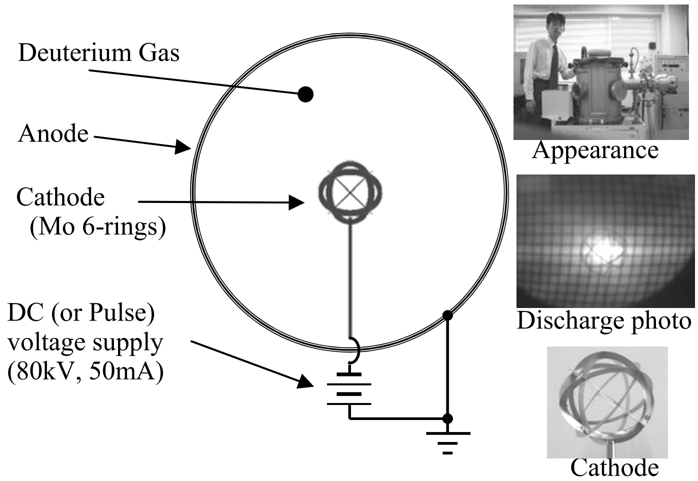

Fig.1. Sketch of Inertial Electrostatic Confinement Fusion Device

2. Characteristics of IECF device

Figure 2 shows the experimental discharge characteristics of IECF device which is comparing the diameters of mesh anodes (150mm and 300mm). It is difficult to discharge with smaller anode because that there is not enough length and pass for the avalanche phenomenon.

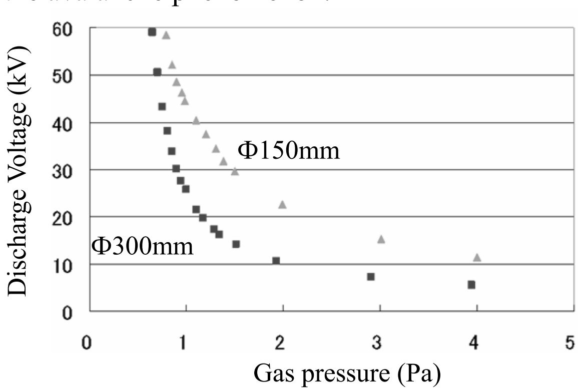

Fig.2. Experimental discharge characteristics of 150mm anode and 300mm anode (Ic=40mA)

Figure 3 shows the neutron production rate v.s. applied voltage characteristics with two different diameters of anodes at 40mA of discharge current. Although there is some difference on the discharge characteristics, almost same neutron production rate is obtained. This is very important characteristic that the operation of the same discharge current produces almost same neutrons.

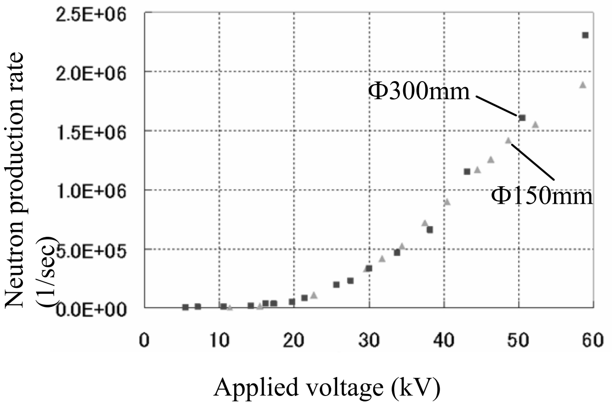

Fig.3. Experimental data of neutron production rate v.s. applied voltage with 150mm anode and 300mm anode (Ic=40mA)

3. Simulation model

The three-dimensional Monte Carlo particle in cell code [1] including the atomic processes is used for investigation of the discharge. The full three dimensional potential are calculated containing the potential effect of the feed-through and the spatial structure of the cathode. The finite difference method with the 1 mm spatial mesh is used for the calculation. Deuterium ions (D^+, D_2^+, D_3^+), fast neutrals (D^0, D_2^0) and electrons (e^-) are taken as tracking particles. The initially 1000 particles of each kind of ion species and 3000 electrons are distributed uniformly between the space of the anode and the cathode. The trajectory of each particle is followed by the Runge-Kutta method. The time step is 10^{-12} sec. After pushing each particle, the atomic and molecular collisions and the elastic collisions are taken into account by Monte Carlo method. When the total number of ions becomes more than 60000, it is recognized that 'discharge' is occurred in this discharge simulation.

4. Simulation Results

Figure 4 shows the calculation results on discharge characteristics compare of device's anode diameters. The anode diameters of 400mm, 300mm, 200mm and 150mm is calculated with the large cathode (70mm in diameter). The anode diameter of 30mm and 15mm with small cathode (7mm in diameter) is used in this particle simulation.

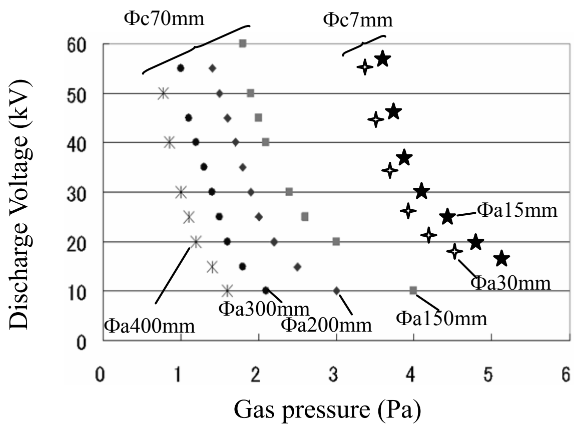

Fig.4. the calculated comparison discharge characteristics of different size of electrodes (400mm, 300mm,200mm and 150mm anodes with 70mm cathode, 30mm and 15mm anodes with 7mm cathode)

These simulation results of discharge characteristics mean that the operation with smaller anode needs more gas pressure, that the 60kV will be applied even in using 15mm anode's device.

4. Conclusions

IECF device is a neutron source with simple structure. The neutron production rate is almost same at same discharge current. The particle simulation shows that the 60kV of discharge probably applied with small 15mm anode.

IECF researchers have been studied for more neutron production rate, using more expensive and powerful power supply (e.g.100kV, 100mA) and larger vacuum chamber (e.g. 600mm anode in diameter). Some researchers are thinking that the beam- beam fusion will occur in low gas pressure. Those attempts' neutron production rates are not much the price of expensive power supplies and equipments.

Smaller IECF device does not need the expensive equipments. It is easy to make the set up of the parallel running of 2 or more small IECF devices. The series connection of the IECF devices with one power supply is possible. It is obvious that 2 IECF devices produce 2 times of neutrons. The stability of the discharge with smaller anode should be investigated in detail.

References

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