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Experimental and Theoretical Study on a Cylindrical Inertial Electrostatic Confinement Fusion Device

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1. Introduction

In a situation where neutron is utilized for various applications, an inertial electrostatic confinement (IEC) fusion device [1] attracts large attention as an alternative neutron generator for its simple configuration and long lifetime of electrode. To maximize the neutron yield in IEC device, it is critical to achieve high voltage and high current at the same time. In this presentation, a simple cylindrical IEC device is developed and its performance is studied. At 6mTorr (130sccm), 54.5kV and 10mA is obtained. To estimate neutron yield in this condition, a particle-in-cell (PIC) simulation is conducted as well, revealing approximately 4.0×10^6 n/s neutron production rates.

2. Methods and Results

In this section, an experimental setup of cylindrical IEC, its result, and PIC simulation are described in detail.

2.1 Experimental Setup

While a conventional IEC of spherical geometry provides a point neutron source, a cylindrical IEC has capability to produce neutrons as a line source. Despite of a loss of charged particles in axial direction, a radially converging type cylindrical IEC has an advantage of uniform neutron production over longer lengths.

Figure 1 shows an experimental setup for the cylindrical IEC device. An anode is made of stainless steel and its size is 282mm in inner diameter and in 200mm height. Two stainless steel cathodes, one in 40mm radius and another in 60mm radius, consist of 16 rods, each in 2mm diameter. Both cathodes have more than 90% transparency. The anode and the inner electrode are at ground while the gridded cathode is biased at negative high voltage. A high-voltage Teflon feedthru is manufactured to prevent electric arc between the cathode and the anode.

Plasma is generated by DC glow discharge between an anode and a gridded cathode. Hydrogen gas, which has similar discharge characteristics to deuterium, is used for discharge. No external resistor is connected; however, an internal circuit in a power supply automatically controls discharge voltage and current.

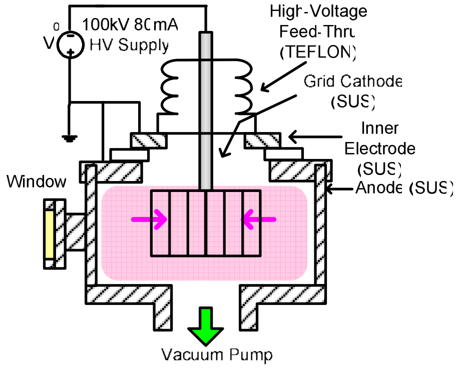

Fig. 1. Experimental setup for cylindrical IEC

2.2 Discharge Characteristics

Figure 2 shows sustaining voltage as a function of gas flow rate. High voltage conditioning is carried out that no problem occurs up to 70kV.

As pressure decreases, higher voltage can be applied. However, maximum has little effect on voltage at fixed pressure due to unique characteristic of normal glow discharge. Therefore, pressure is changed in an alternative way at fixed current to achieve as high voltage as possible.

Pressure is varied from 130sccm (6mTorr) to 230sccm (13mTorr). For the r=60mm cathode, higher voltage can be biased than the r=40mm cathode at the same flow rate, mainly due to shorter distance between electrodes. However, discharge is hard to be sustained below 170sccm. For the r=40mm cathode, 54.5kV is obtained at 10mA fixed current and 51.0kV at 25mA.

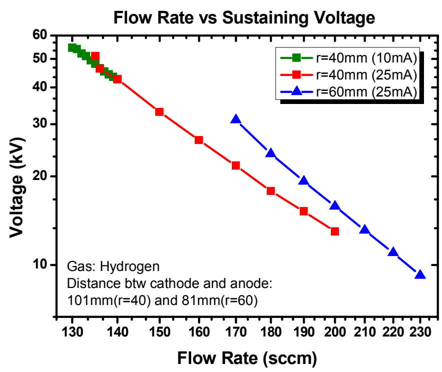

Fig.2. Voltage at the cathode as a function of flow rate

2.3 Particle-in-Cell Simulation Results

Due to complicated discharge situation in IEC and lack of a facility to direct measurement of neutron, PIC simulation [2] is adopted as an indirect method to estimate neutron production rate in this device. As the low pressure and high voltage discharge contains some particular reactions such as heavy-particle collisions and interactions between high energy electrons and surface [3], these reactions are also considered in collision routine for more realistic simulation.

Figure 3 indicates potential and ion distribution (log-scale) in the simulation. As seen in the picture at the right side, the simulation well reveals star mode in the IEC device. The PIC simulation also estimates around 4.0×10^6 neutron production rates, which are reasonable compared to other research results.

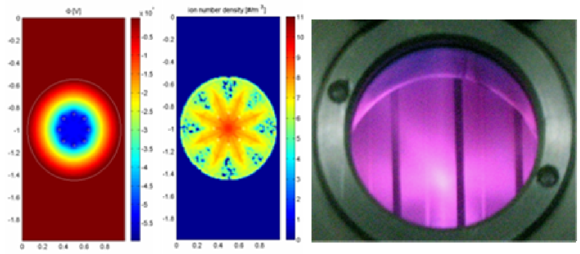

Fig. 3. PIC simulation result at 15mTorr and 60kV. Potential distribution (left), ion distribution (center), star mode in the IEC device (right)

3. Conclusions

A cylindrical IEC device is developed and its performance is experimentally and theoretically investigated through discharge characteristics and PIC simulation. High voltage conditioning test shows no problem occurs up to 70kV. Though the r=60mm cathode shows better result for applying higher voltage at a certain pressure, it is unfavorable to sustain discharge at low pressure. For r=40mm cathode, 54.5kV and 10mA discharge condition at 130sccm (6mTorr) is achieved. The PIC simulation, which includes additional reactions for low pressure and high voltage discharge, results in around 4.0×10^6 n/s for this condition.

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