A small sized electron beam source utilizing hollow cathode plasma for an electron supply source

H. Nakamura[1], M. Watanabe[2]

[1] *Graduate School of Science and Technology, Nihon University, Tokyo, Japan*

[2] *Institute of Quantum Science, Nihon University, Tokyo, Japan*

1. An electron beam source

An electron beam is a flow of electrons, which are accelerated and converged to control their energy and orbit by using an electric or magnetic field. The electron beam belongs to a charged particle beam together with the ion beam. Here, the ion beam is also accelerated ions flow by the electric field. Particle beams source is effective tools for electron microscopes such as transmission electron microscopes (TEM) and scanning electron microscopes (SEM), and for neutralizers of ion thrusters mounted on space machines in recent years. An apparatus for forming this electron beam is called an electron beam source and the development of a small sized electron beam source is the main subject in this research.

Generally used electron beam sources use thermionic emission as a source of electrons. The disadvantage of such electron beam sources has a heat problem of the metal parts of electron supply sources. The part of an electron supply source to generates thermionic electrons are severely-degraded with own heat and their durability is generally low. In order to solve this thermal problem of a general electron beam sources, we are developing an electron beam device source with the electron supply source by using a plasma discharge. The hollow cathode discharge can generate a high-density plasma inside the hollow cathode cavity [1]. To develop a small sized electron beam source with a high current and high durability, the hollow cathode discharge is applied to an electron source for the high current electron beam in this research.

2. Experimental equipment and set up

The schematic diagram of the electrode parts of a newly designed our electron beam source is shown in Fig.1. The maximum diameter of this device is ϕ 36 mm. The diameter and length of the hollow cathode cavity are ϕ 10 and 40 mm respectively. The distance between the hollow cathode and the anode is 5 mm, and the distance between the anode and the extraction electrode is 12 mm. The diameter of electrode holes for the electron beam is ϕ 6 mm. A gas is directly injected into the hollow cathode cavity after the evacuation of inside of the vacuum vessel by using a turbo molecular pump. The length of the electron beam formation part can be changed. The beam current will be measured by using a Faraday cup.

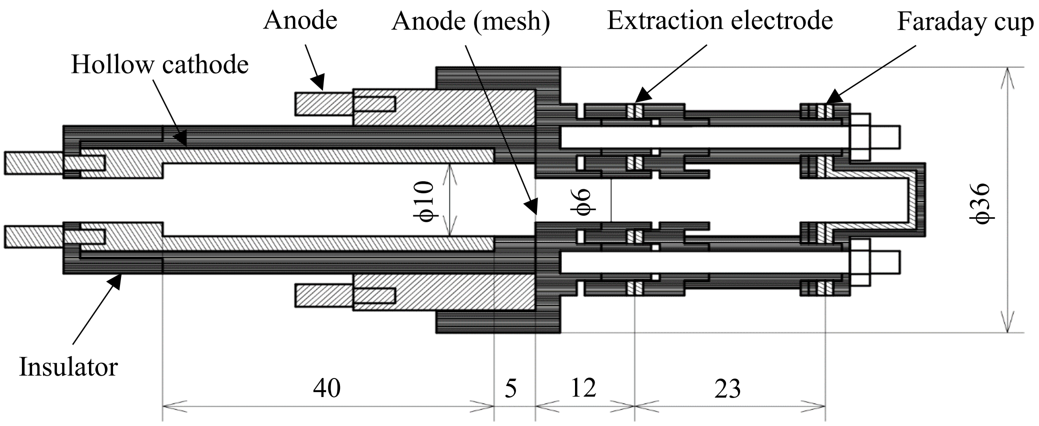

Fig.1 Schematic drawing of a compact electron beam source by using hollow cathode discharge

First of all, to generate hollow cathode plasma, a high voltage is applied to the hollow cathode. Here, the anode was grounded in this experiment. The used gas is air for discharge in this experiment. In our electron beam source, the electric potential of the electron supply source and initial velocity of electrons can be controlled by the discharge voltage, the discharge current and pressure inside the hollow cathode cavity. After the formation of the hollow cathode discharge, an electron beam is generated by the applying the pulsed (AC) or the steady-state (DC) voltage between the extraction electrode and the anode.

3. Experimental result

Figure 2 shows the correlation between the voltage V_d, which is applied between the hollow cathode and the anode, and the discharge current I_d during the hollow cathode discharge. This figure shows the experimental results when the gas pressures inside of the vacuum vessel are 50 Pa and 100 Pa. It can be confirmed that the voltage between the electrodes maintains a constant value as the discharge current increases. Since this is consistent with the characteristics of glow discharge, so it can be considered that the form of hollow cathode discharge is glow discharge.

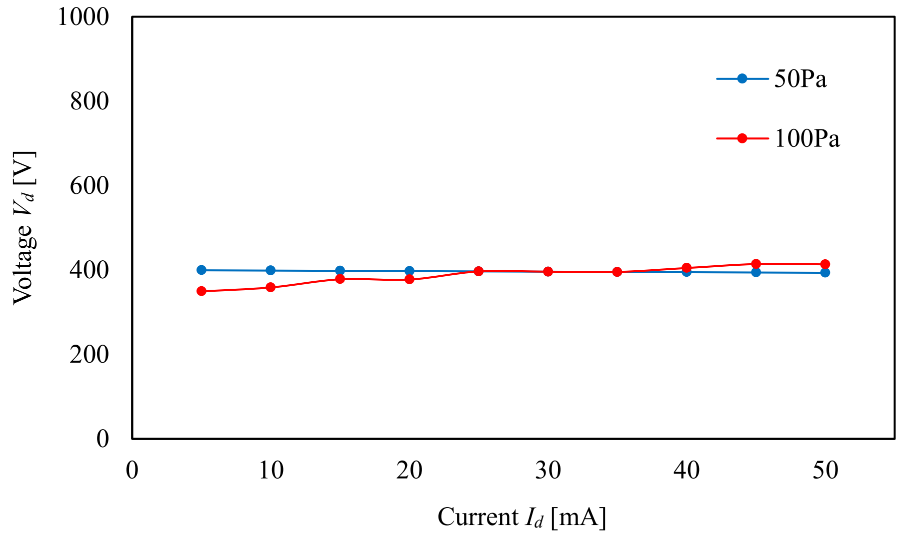

Fig.2 Voltage-current characteristics in this experimental device

Figure 3 shows the correlation diagram between the extraction voltage V_{ex} and the electron beam current I_b when a steady extraction voltage is applied to the extraction electrode. This figure shows the results when the gas pressure inside of the vessel is 50 Pa and the input power to the hollow cathode plasma is 4.0 W and 7.9 W. The input power is estimated by the product of the voltage V_d applied and the discharge current I_d. The electron beam current is 23.5 mA when the input power was 4.0 W, and 31.8 mA when 7.9 W. Assuming that the beam cross-sectional area is the area of the hole of the electrode, the electron beam current density was 83.1 mA/cm^2 at 4.0 W and 112 mA/cm^2 at 7.9 W.

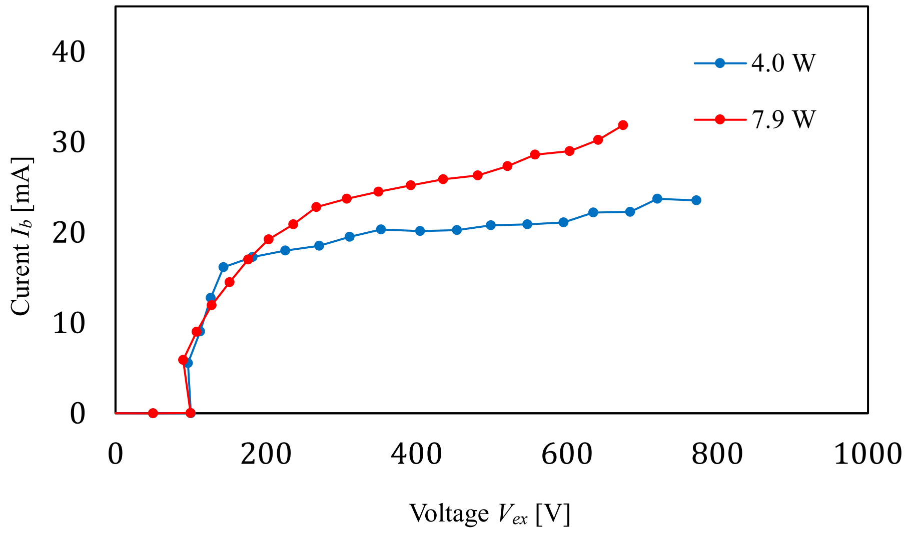

Fig.3 Voltage-current characteristics in this experimental device

4. Conclusion

In order to solve this thermal problem of a general electron beam sources, we are developing an electron beam device source with the electron supply source by using a plasma discharge.

The discharge by the hollow cathode designed in this research is considered to be glow discharge, and it is considered that the durability can also be expected for the electron supply source. In addition, the steady application of the extraction voltage succeeded in the steady formation of the electron beam with the electrons in the plasma as the electron supply source. The maximum electron beam current observed in this experiment was 31.8 mA at an extraction voltage of 675 V, and 112 mA/cm^2 at a current density.

References

[1] R. Mavrodineanu, Hollow Cathode Discharges - Analytical Applications, Journal of Research of the National Bureau of Standards. 89, (1984)

[2] INTRODUCTION TO PLASMA PHYSICS AND CONTROLLED FUSION, Francis F. Chen, 1984

[3] SAEKI Koichi, Hot-Cathode Discharge Plasmas, J. Plasma Fusion Res. Vol.79 1242-1248. No.12, 2003