CONTROL OF ION-ENERGY DISTRIBUTION IN A BACK-DIFFUSION TYPE PLASMA

KAWAI, Yoshinobu
Research Institute for Applied Mechanics, Kyushu University : Associate Professor

https://doi.org/10.5109/7173493

出版情報：Reports of Research Institute for Applied Mechanics. 22 (70), pp.147-153, 1975. 九州大学応用力学研究所
バージョン：

Reports of Research Institute for Applied Mechanics
Vol. XXII, No. 70, 1975

CONTROL OF ION-ENERGY DISTRIBUTION IN A BACK-DIFFUSION TYPE PLASMA

By Yoshinobu KAWAI*

The author studies a new type of plasma, back-diffusion type plasma, in which the energy distribution of the ion beam is controlled experimentally in the temperature as well as in the beam velocity. The dependence of the beam energy and the temperature of ions on grid and anode potentials are described.

1. Introduction

A back-diffusion type plasma source [1] has been developed in order to produce a quiescent and uniform plasma in a steady state. It is well known that the plasma obtained by the back-diffusion type plasma source is essentially a sort of neutralized ion-beam plasma.

The funnel type plasma source [2] has been designed to make the pressure difference between the discharge region and the experimental one in the back-diffusion type plasma source. Parameters of the plasma obtained by the funnel type source have been reported [2,3] in detail except for control of the energy distribution of ion beams. Interesting phenomna in plasma wave experiments depend substantially on the energy distribution function of particles that constitute the plasma.

In this paper is reported the control of ion-energy distributions in the back-diffusion type plasma by the funnel type plasma source in wider pressure ranges than that [2] reported previously. In § 2. and § 3. the experimental arrangement and the experimental results and discussions are given, respectively.

2. Experimental Arrangement

The experimental setup is shown in Fig. 1. Plasma are generated in the funnel-shaped glass chamber and are diffused into the glass tubing of 10 cm in diameter where experiments are made. The plasma source is called the back-diffusion type plasma source [1], which consists of an array of pipelike oxide-coated cathodes (4.4 cm long and 3.6 mm in diameter) and two sheets of mesh grids made of molybdenum wires. The grid and the anode are located at about 5 mm and 5 cm, respectively, from the cathode surface.
In the present experiments, the argon gas is fed from a tip of the funnel

* Associate Professor, Research Institute for Applied Mechanics, Kyushu University

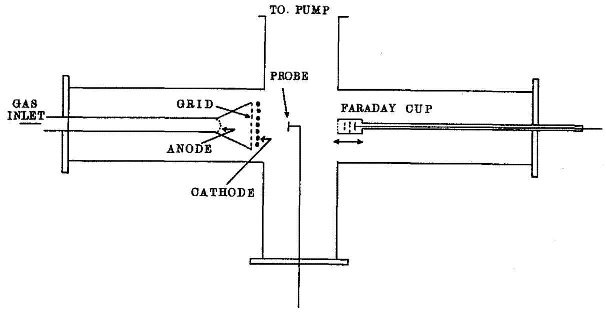

Fig. 1. Schematic diagram of the experimental apparatus.

which has a circular opening 6 cm in diameter at a solid angle $\pi/6$.

In operation the cathode is grounded and the grid is kept at a positive potential with respect to the earth, so that electrons emitted from the cathode surface are accelerated between the cathode and the grid and trapped in an electric potential well between the cathode and the anode untill they collide with gas atoms. So the plasma can be produced in the region between the grid and the anode by these trapped electrons.

On the other hand, a part of ions in the plasma thus produced diffuse through the grid and are accelerated up to the grid voltage or anode one, where the ion is neutralized by thermal electrons pulled from the cathode surface by the force of the space charge. Thus we can obtain a neutralized ion-beam plasma.

Plasma parameters are measured by using the plane Langmuir probe of 10 mm in diameter. In the experimental region, the electron density was controlled over the ranges from 10^7 to 10^8 cm^{-3} under pressures from 10^{-3} to 10^{-4} torr. The electron temperature was observed to be about leV below. The energy distribution function of the ion is measured by means of the Faraday cup (two sheets of grids and a collector of 5 mm in diameter), whose resolution in energy is confirmed[3] to be few % by comparing the half width of the energy distribution function obtained from the Farady cup with that obtained from the 127° type electrostatic energy analyzer with the resolution of 4 % below.

3. Experimental results and discussions

A typical result of the energy distribution function of the ion is shown in Fig. 2, where the grid voltage V_g and the anode voltage V_a are at 40 and 140 V, respectively. The ratio of the half width of the energy distribution to the energy is estimated to be few % from the energy distribution function observed experimentally. Therefore, we can used this plasma source as the low energy ion source. It should be noted that the double-humped distribution function is observed[4)5)]. When the anode voltage is low, a single distri-

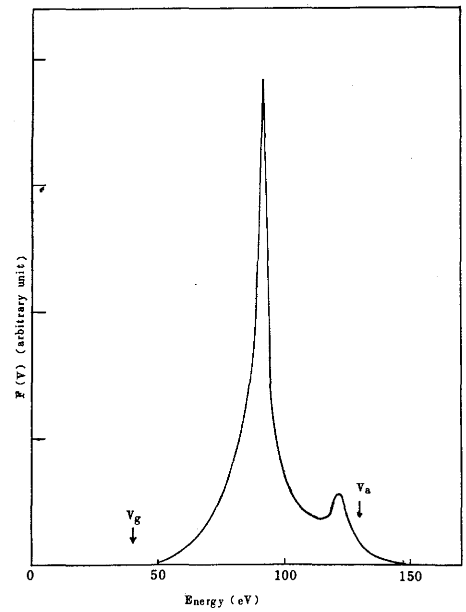

Fig. 2. Typical example of the energy distribution of ions, where V_g=40V and V_a=130V.

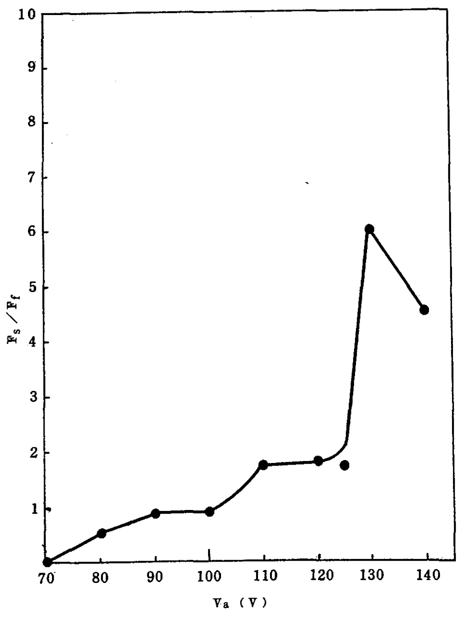

Fig. 3. Intensity ratio of the slow beam to the fast beam as a function of anode potential, where V_g=40V.

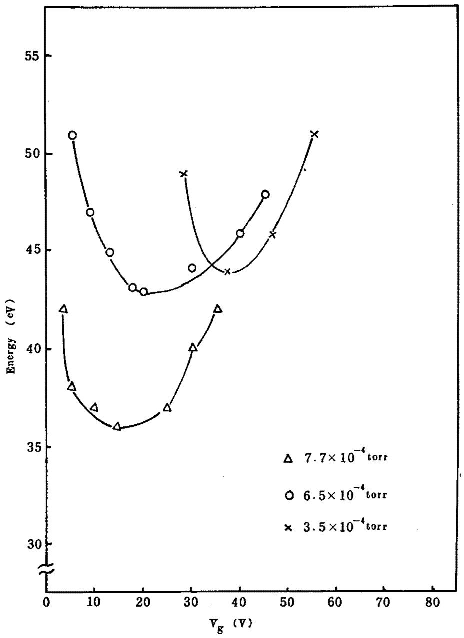

Fig. 4. Beam energy versus grid potential.

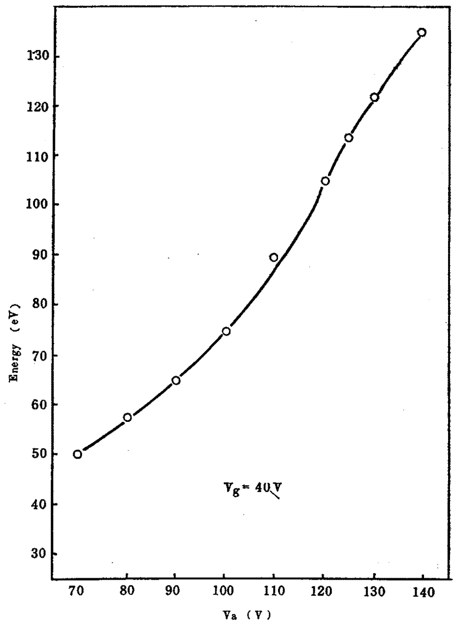

Fig. 5. Beam energy versus anode potential, where V_g=40V at the pressure of 3.5×10^{-4} torr.

bution is observed. However, increasing the anode voltage, another peak appears in a low energy region, its peak value becomes large more and more, and finally exceeds that of the high energy peak, as shown in Fig. 3. The control of the double-humped energy distribution of ions in the normal back -diffusion type plasma also has been reported by HONZAWA[6].

Figure 4 shows values of the beam energy as a function of the grid potential with changing pressures as a parameter. It is found from this figure that when the grid potential is low, the beam energy corresponds to the anode potential rather than the grid one and when the grid potential exceeds some critical value, the beam energy increases with the grid potential.

Keeping the grid potential small with a low pressure, the beam energy increases with the anode potential, as shown in Fig. 5, where V_g=40V and $p=3.5\times10^{-4}$ toor.

The temperature of ions, T_i, is estimated from the decaying slope with increasing energy of their distribution under an assumption that the distribution is drift-Maxwellian. The mean-free path of the charge exchange and the elastic collision of between ions and neutral atoms is about few cm, so

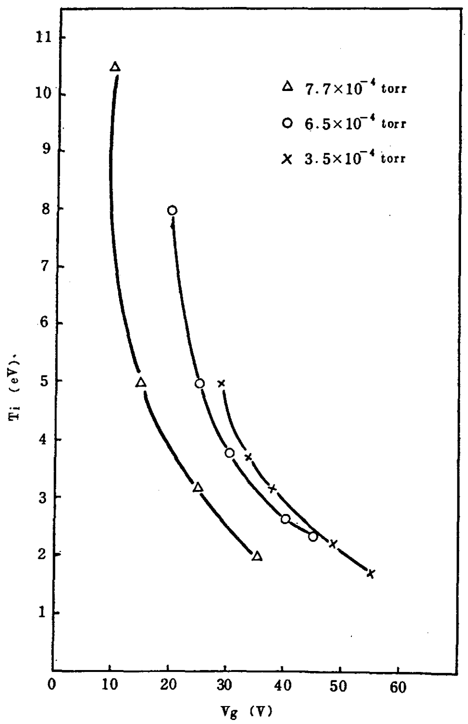

Fig. 6. Ion temperature versus grid potential for different pressures: △ 7.7×10^{-4} torr; ○ 6.5×10^{-4} torr; × 3.5×10^{-4} torr.

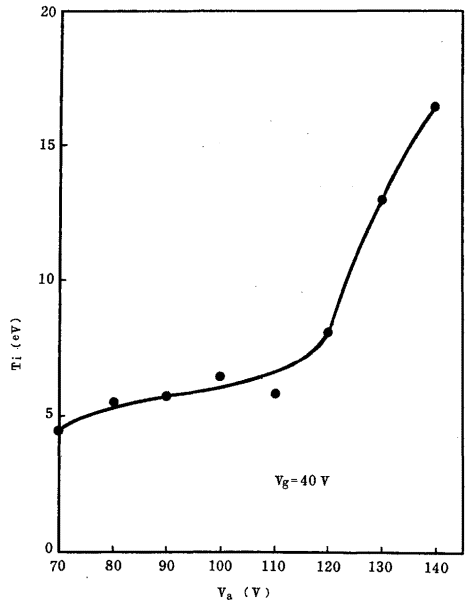

Fig. 7. Ion temperature versus anode potential, where $V_g = 40V$ at the prssure of 3.5×10^{-4} torr.

that the ion will be almost thermalized when it streams from the discharge region to the experimental one. Increasing the grid potential with keeping the anode potential constant, the ion temperature decreases, as shown in Fig. 6. On the other hand, the larger the anode potential becomes, the larger the ion temperature does, as shown in Fig. 7.

The mechanism of controlling the energy and the temperature of ions is understood as follows. In the plasma source, the main potential gap is limited within the region between the grid and the anode, where most of ions is produced. It may be assumed that the energy of ions in the experimental region has been given by the potential where the ionization has taken place, and that the temperature has been determined by the potential difference, ΔV, between the place where the ionization has taken place and the anode.

In the case which ionization takes place mostly between the anode and the grid, the potential is uniform in grid-anode space, the beam energy is approximately equal to the grid potential. When the grid potential is larger than the ionization potential but less than the anode potetial, the bump appears in the high energy region of the energy distribution, as shown in Fig. 2. This bump is considered to be due to the ion ionized near the anode and accelerated by the potential difference with respect to the cathode. For low pressures, electric fields exert also in grid-anode space, and the energy is not simply determined by the grid voltage, as shown in Fig. 4.

Incrasing V_g, ΔV decreases, so that the ion temperature becomes small, as shown in Fig. 6. On the other hand, keeping $V_g=40$ V under the low pressure, ΔV increases with V_a, so that the ion temperature increases with V_a, as shown in Fig. 7.

An ion acoustic wave[7] was excited by a grid in the plasma and its dispersion relation was obtained. Experimental dispersion relation[7] was in good agreement with the theoretical one, indicating the estimation of the ion temperature to be fairly well since the damping rate of the ion acoustic wave in a collisionless plasma is sensitive to the ion temperature[8].

In conclusion, both the ion beam energy and the ion temperature in the back-diffusion type plasma can be controlled easilly by changing the grid potential or the anode one of the funnel type plasma source, suggesting that the funnel type plasma is much more suitable for wave experiments such as wave-particle interactions.

Acknowlegements

The author wishes to acknowledge Professor H. Ikegami for his fruitful discussions. He also thanks Professor K. Takayama for his encouragement.

This work was partially performed under the collaborating research program at the Institute of Plasma Physics, Nagoya University, Nagoya, Japan.

References

1) Takayama K., Ikegami H., and Aihara S., Back-Diffsion Plasma Source, Proc. 8th Intern. Conf. Phenomena in ionized gases, Vinna, (1967) 552.
2) Takamura S., Tanaka Y., and Okuda T., Characteristics of the Plasma Produced by the Funnel Type Plasma, Annual Rev. of IPPJ, Nagoya Univ. 1968-1969, 74.
3) Kawai Y. and Ikegami H., Control of Ion-Energy Distribution In A Back-Diffusion Type Plasma, Phys. Letters, *32A* (1970) 318.
4) Kawai Y., Lampis G., Aihara S., and Kawabe T., Plasma Ion Oscillations in Discharges Produced by Back Diffusion Plasma Sources J. Phys. Soc. Japan *26*, (1969) 578.
5) Andersen S., Jensen V.O., and Michelsen P., Production of Double Humped Ion Velocity Distribution Function In A single-Ended Q-Machine, Phys. Letters *31A* (1970) 395.
6) Honzawa T., Production of Ion Stream Composed of Two Components in Velocity Distribution, Japan J. appl. Phys. *10*, (1971) 139.
7) Kawai Y., and Ikegami H., Nonlinear Effect of Large-Amplitude Ion Acoustic Waves, Plasma Phys., *13* (1971) 463.
8) Jackson J.D., Longitudinal Plasma Oscillations, J. Nucl. Energy, Part C*1* (1960) 171.

(Received November, 30, 1974)