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Characteristics of Power Dissipation in Neon DC Glow Discharge Positive Columns

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Introduction

It is interesting from the physical and the technological viewpoints to clarify how the electric power input is consumed in discharge plasmas. The collision processes are known as the typical power dissipation processes. Among these collision processes, the elastic collisions between electron and molecule heat the neutral gas directly, and also the collision between the molecules leads to the gas heating owing to the relaxation of vibrational energy to translational one (V-T relaxation). Therefore the neutral gas temperature brings us the important information about the power dissipation processes occurred in discharge plasmas, although the experimental investigation on the gas temperature in discharge plasmas has been less performed so far [1-4].

By the way, the electron temperature decreases with the working pressure in dc rare gas positive columns where the V-T relaxation process does not exist. This means that the dissipation process of the power input which is used for the acceleration of electrons first, shifts from the electron inelastic collisions to the elastic one with increasing pressure. In this paper we measure the neutral gas temperature in Ne dc positive columns with varying the discharge current and the pressure, and try to show experimentally the variation of power dissipation process with the pressure at constant electric power input.

Experimental setup

As shown in Fig. 1, the Ne positive columns 700 mm in length are obtained in a Pyrex glass tube with an inner diameter of 60 mm and a length of 1000 mm [1]. A small amount of gas flow is allowed from the anode to the cathode to avoid the accumulation of impurities in the positive column. The experiments are performed for the pressure range of 2-13 torr with varying the discharge current from 10 to 80 mA. In order to obtain the electron temperature and the electron density, we use a couple of spherical single probes 100 mm apart each other along the positive column. The neutral gas temperature T_g in the positive column is measured by the chromel-alumel thermocouples.

Experimental results

Fig. 2 shows the dependence of the axial electric field E_z on the discharge current I_p with the working pressure as a parameter. As seen in this figure, E_z decreases slowly with I_p, and also there exists somewhat a complicated variation due to the ionization waves at 4-6 torr where E_z decreases first and then increases again with the pressure. The broken lines in this figure show the hyperbolas of constant power input I_pE_z = const. and the intersections of those hyperbolas and the characteristics of E_z (interpolated solid lines) are used to obtain I_p and E_z which give the constant power input. In Fig.3 the variation of temperature difference ΔT_g between the plasma center and the peripheral region in the positive column is presented as a function of the pressure with I_pE_z as a parameter. In the case of rare gas discharges, ΔT_g is almost proportional to I_pE_z and η which means the ratio between the power used for the neutral gas heating and the power input [1,5]. Consequently this figure shows that η increases with pressure and then practically reaches the saturated value of about 80 % which is obtained from the relationship between η and ΔT_g. In the present range of pressure the theoretical calculation by Boltzmann analysis based on the two term approximation shows that η approaches 100 % with pressure, and there exists about 20 % difference between the theoretical and the experimental results. At present the cause of this difference between both results is not clear, but that may be due to ionization waves which occur in the extensive region of pressure and discharge current in Ne dc glow discharges.

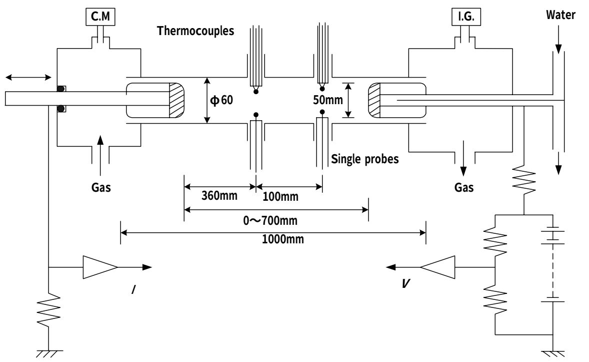

Fig. 1: Schematic view of discharge system. The electrode separation can be varied from 0 to 700 mm and the cathode is water cooled. C.M. and I.G. are the capacitance manometer and the ionization gauge respectively.

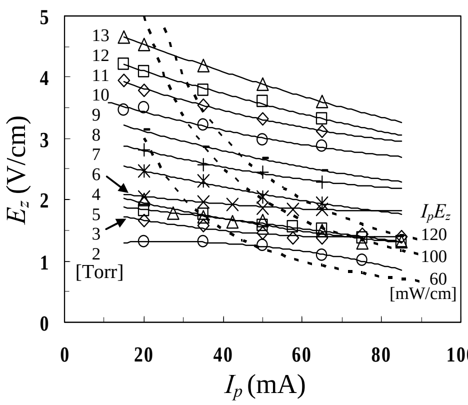

Fig. 2: Dependence of the axial electric field E_z on the discharge current I_p with the pressure as a parameter. The broken lines are hyperbolas of constant power input.

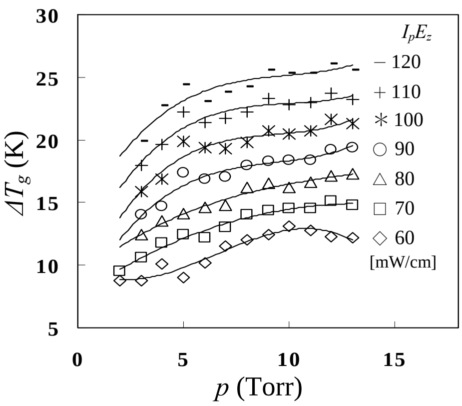

Fig. 3: Dependence of the temperature difference ΔT_g between the plasma center and the peripheral region with the power input I_pE_z as a parameter.

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