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Measurement of Low Pressure Plasma Parameters by the Floating Double Probe Method in Magnetic Field on a Subnormal Glow Discharge Region in Molecular and Rare Gases

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ABSTRACT

In floating double probe technique in equivalent resistance method [1,2] the plasma parameters have been measured in subnormal gas discharge. The electron temperature and electron density have been studied in both the transverse and longitudinal magnetic field in low pressure for air, hydrogen and argon gases. It is observed that in case of transverse magnetic field, the electron temperature increases whereas the radial electron density decreases and in case of longitudinal magnetic field, the electron temperature decreases and the radial electron density increases.

Keywords : *Floating double, Equivalent resistance, Plasma parameters.*

1. Introduction

The Langmuir probe method is one of the standard methods of measuring the plasma parameters such as electron temperature and electron density in gaseous discharge. Johnson and Malter [1] have described and developed Langmuir probe technique and proposed the floating double probe technique by equivalent resistance method to obtain the plasma electron temperature, in which the plasma potential changed with time. Later on further modifications have been made by Yamanto and Okuda [3], Dote [4], Phadke et. al [5], Liberman [6] and Kaneda [7] in floating double probe characteristics for the transitional region. We report here the results of measurement of electron temperature and electron density for molecular and rare gases with magnetic field.

2. Experimental Procedure

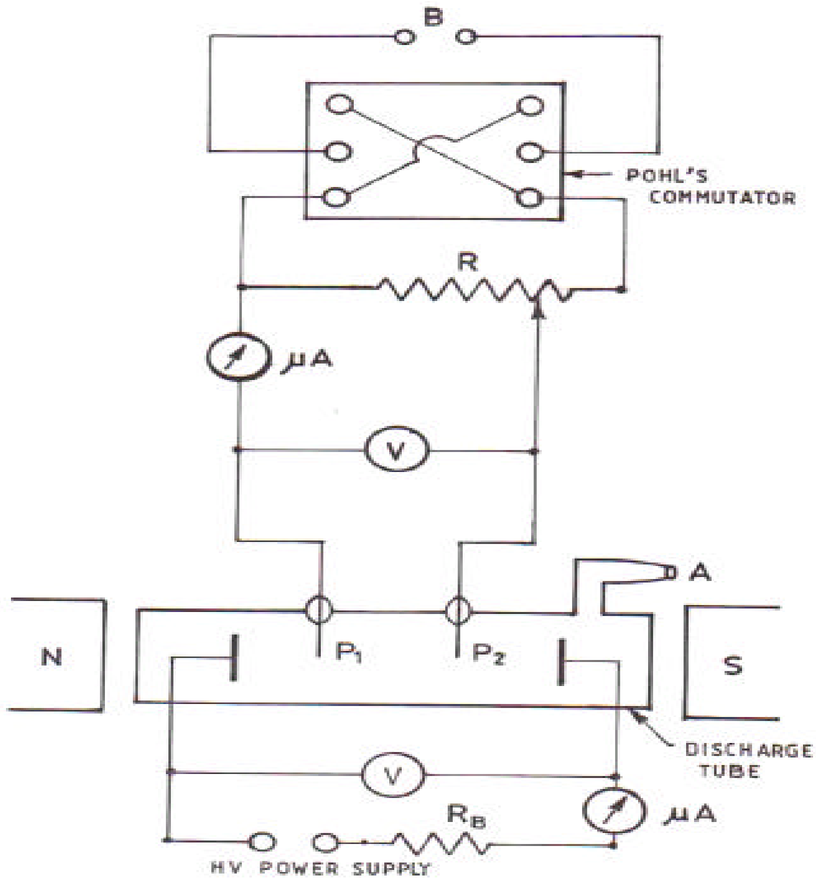

Figure 1. Experimental arrangement

Fig.1 shows the experimental set-up. A d.c source from a 1.5 KV regulated power supply with an insignificant ripple was used to ionize gas. The discharge tube was cylindrical of length 8 cm and diameter 7.2 cm and fitted with two plane parallel copper electrodes of diameter 5.5 cm separated by a distance 2.5 cm. There were two identical cylindrical probes (P_1, P_2) inserted to the discharge tube perpendicular to the axis of the tube. Each of these two was cylindrical tungsten wire of diameter 0.5 mm and inserted in the plasma and was of 3 mm length. They were separated by a distance 6 mm and the probe nearest to anode was at a distance 1.6 mm from it. The gas pressure was measured by Pirani gauge calibrated by a Mc leod gauge. The ballast resistor (R_B) limited the discharge current and kept the HV unit within its current capacity. A current meter (sensitivity: ±0.25μA) was connected to measure the average discharge current. The tube was placed within the pole-pieces of diameter 7.0

cm of an electromagnet. With this same electromagnet both the transverse and longitudinal magnetic field were applied to the gas discharge by rotating the tube. In the figure the setting of longitudinal magnetic field has been shown. The electromagnet is energized by a stabilized power supply and the magnetic field has been measured by an accurately calibrated gaussmeter (sensitivity:±2%). The discharge tube was thoroughly cleaned and properly dried. Pure and dry air and Spectroscopically (XL Grade) pure hydrogen and argon gases supplied by British Oxygen Company Ltd. have been used in the present study. To measure the probe current against probe potential, the probes have been interconnected by d.c voltage source (B) through a Pohl's commutator, inserting a current meter to this circuit.

1. Results and discussion

The electron temperature has been determined from the way in which I_d, the probe current, varies with V_d, the probe voltage, by floating double probe method of Dote [4] which was modified from the equivalent resistance method by Johnson and Malter [1]. The expression for electron temperature (T_e) is given by [4],

$$T_e = \frac{e}{k} \frac{\sum I_{PO}}{4\{ (\frac{dI_d}{dV_d})_0 - 0.82S \}} \tag{1}$$

where, Te = electron temperature,

e = charge of an electron,

k = Boltzmann constant,

$\sum I_{PO} = I_{P_1O} + I_{P_2O}$,

$(\frac{dI_d}{dV_d})_0$ = Slope from the current-voltage characteristics at the inflection,

S = Slope at the positive ion saturation characteristic.

From the same characteristic curve the electron density is determined by the following equation [4,8],

$$n_e = 4.\frac{I_{Sat}}{A\,e\sqrt{\frac{8kT_e}{\pi\,m}}} \tag{2}$$

where, ne = electron density,

I_{Sat} = saturation current,

A= effective electron or ion collection geometrical area of the probe,

e = charge of an electron,

k = Boltzmann constant,

T_e = electron temperature,

m = mass of electron.

A schematic diagram of the double probe characteristics for the measurement of electron temperature for argon, one of the gases in transverse magnetic field is shown in fig.2

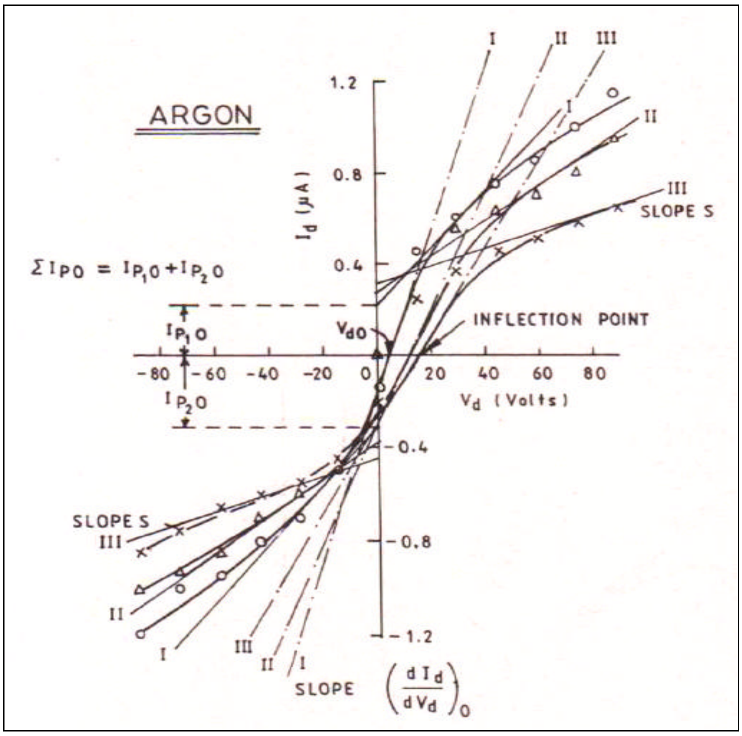

Fig.- 2 Schematic diagram of double probe characteristics .

Pressure (P): 0.6 torr, Discharge Current (I):100µA, Mag. Field (H): I:18 G, II: 76G, III: 116G

For air, hydrogen and argon gases in case of longitudinal magnetic field T_e and n_e have been determined and entered in the Table-1.

It is observed that the electron temperature decreases in longitudinal magnetic field and the electron density increases with the magnetic field.

In case of transverse magnetic field the T_e and n_{e-} values have been determined by the same procedure as done in case of longitudinal magnetic field. The values of T_e and n_e for air, hydrogen and argon gases have been displayed on the Table-2.

From the result it is found that the electron temperature (T_e) increases with the increase of transverse magnetic field and the electro density (n_e) increases with it. Therefore, it is exhibited in the present study the equivalent resistance method can effectively find out the important plasma parameters in magnetic field.

Table 1. For longitudinal magnetic field

Gas	Press-ure(P) in torr	Tube Current (I) in µA	Mag. field (H) in Gauss	T_e in eV	n_e in cm^{-3}
Air	0.7	100	150	2.05	1.131×10^{15}
			224	1.64	1.315×10^{15}
			376	1.03	1.723×10^{15}
Hydro-gen	0.7	100	150	1.95	0.106×10^{15}
			224	1.63	0.142×10^{15}
			376	1.24	0.278×10^{15}
Argon	0.6	100	376	1.76	0.467×10^{15}
			725	1.49	0.520×10^{15}
			1097	0.87	0.530×10^{15}

Table 2. For transverse magnetic field

Gas	Press-ure(P) in torr	Tube current (I) in µA	Mag. field (H) in Gauss	T_e in eV	n_e in cm^{-3}
Air	0.7	100	18	0.698	1.783×10^{15}
			76	1.173	1.325×10^{15}
			150	1.775	1.313×10^{15}
Hydro-gen	0.7	100	18	2.074	0.247×10^{15}
			30	3.567	0.185×10^{15}
			62	4.770	0.157×10^{15}
Argon	0.6	100	18	3.350	0.248×10^{15}
			76	4.791	0.198×10^{15}
			116	7.632	0.140×10^{15}

4. Conclusion

We can conclude that the alignment of the magnetic field with respect to the direction of the discharge current has a decisive effect on the change in plasma parameters. The experimental data from probe measurements thus show that while in a longitudinal magnetic field the electron temperature decreases and radial electron density increases, in transverse magnetic field the electron temperature increases and radial electron density diminishes.

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