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Measurement of Plasma Parameters on Low Density Plasma in a Magnetic field Produced in Air by Double Electric Probe Within a Toroidal Chamber

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ABSTRACT

The measurements of electron temperature and electron density in low density magnetized plasma developed in Air within a toroidal chamber have been carried out by the floating double probe technique in the equivalent resistance method [1,2]. From the variations of probe current with the differential probe voltage, electron temperature and electron number densities can be determined [3]. It has been observed that the electron temperature increases and the radial electron density decreases with the toroidal magnetic field when the double probes are aligned in transverse positions and for axial alignment of the probes with the magnetic field electron temperature decreases where as electron number density increases. The method is also applicable to the continuing discharge where it has the advantage over the single probe of exerting a negligible influence on the discharge [4].

Keywords : *Floating double probe, axial and transverse positions of the probes with toroidal magnetic field, electron temperature and electron number density.*

1. Introduction

The technique of measurement of plasma electron temperature and electron number density by Langmuir probe method is well known.

An equivalent resistance method [1,2,3] was used in double probe method (DPM) to determine plasma parameters. This paper briefly examines the extensions of Langmuir probe to the study of low pressure inductively coupled plasmas (LP-ICP) produced in Air excited by a 13.56 MHz radio frequency power with different filling pressures and different magnetic fields. In the present investigation it is proposed to make an experimental study of the nature of the variation of these parameters by the probe method. A magnetic field H applied to the plasma effectively reduces the free paths of the charge particles perpendicular to H to less than the radius of curvature $\rho = \frac{mv}{eH}$, v being the velocity and m, the mass of the particle and hence for a probe collecting across the magnetic field becomes valid in moderate magnetic field. For this purpose, the magnetic field used in the present experiment has been kept below 100 gauss.

2. Experimental Set Up

The toroidal vacuum chamber used for this work has major radius of 13.18 cm and minor radius of 3.18 cm with an arrangement for pre ionizing sources with quartz window for UV radiation. The block diagram (figure. 1) shows the apparatus used in the experiment. It consists of H type solenoid coil excited by a 13.56 MHz radio frequency power source in presence of a produced magnetic field. A vacuum tube voltmeter (VTVM) circuit has been designed to measure the mean value of the plasma break down voltage. The floating double Probe circuit (figure 2) has been introduced to measure the plasma parameters in transverse and longitudinal positions with the axial magnetic field (figure 3 (a) & (b)). Probe voltage was supplied by a continuously varying chargeable battery and the probe current was measured by a DC micro ammeter (with a minimum measurable current of 0.1 μA). Each probe is made of platinum wire of diameter 0.2 mm, length of 5 mm and a separating distance of 1.5 cm for transverse and of 3.25 cm for axial positions of measurements. The experiment was carried out using dry air in 0.1 Torr to 0.2 torr of filling pressure and magnetic field up to 75 Gauss.

Keeping the filling pressure constant for fixed plasma breakdown voltage; floating probe potential was varied from a high negative value to positive value and the corresponding probe current was noted in the micro ammeter. This procedure is repeated for different magnetic fields whose values has not been allowed to exceed 100 Gauss in conformity with the limitations that should be observed for the validity of the probe theory in magnetic field [5,6]. In the equivalent resistance method, the slope of the current-voltage characteristics and the positive ion current to probes at the inflection point are required.

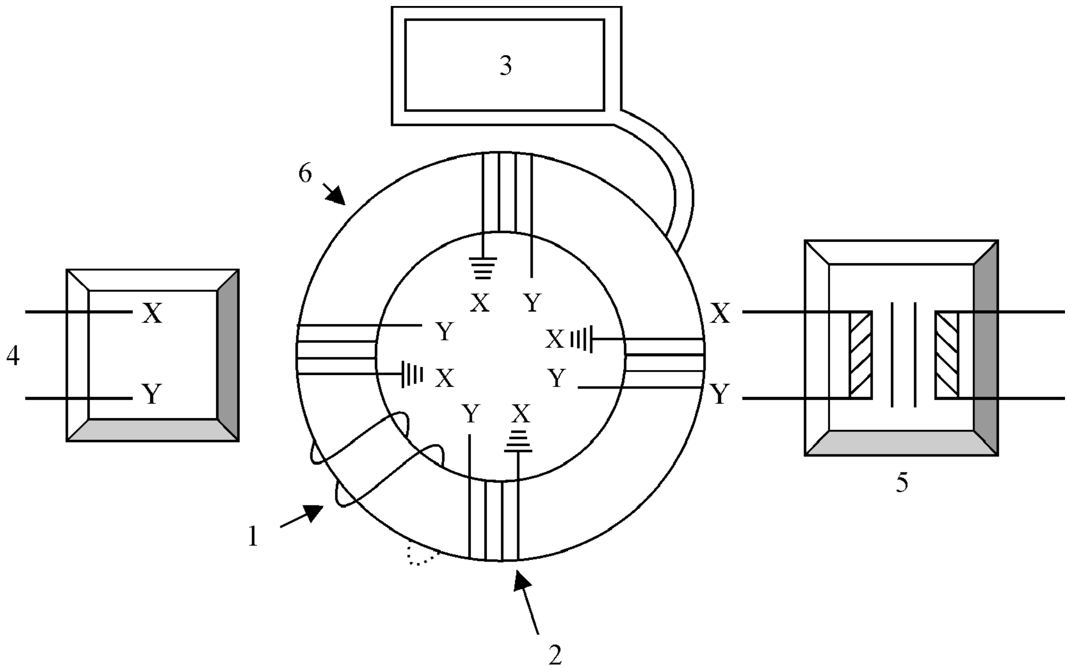


Figure 1

(1) Annular coils for axial magnetic field
(2) Annular H type solenoid coil
(3) Gas inlet with measurement of filling pressure
(4) Radio frequency power source
(5) Tuning coil with Primary and Secondary
(6) The toroidal chamber

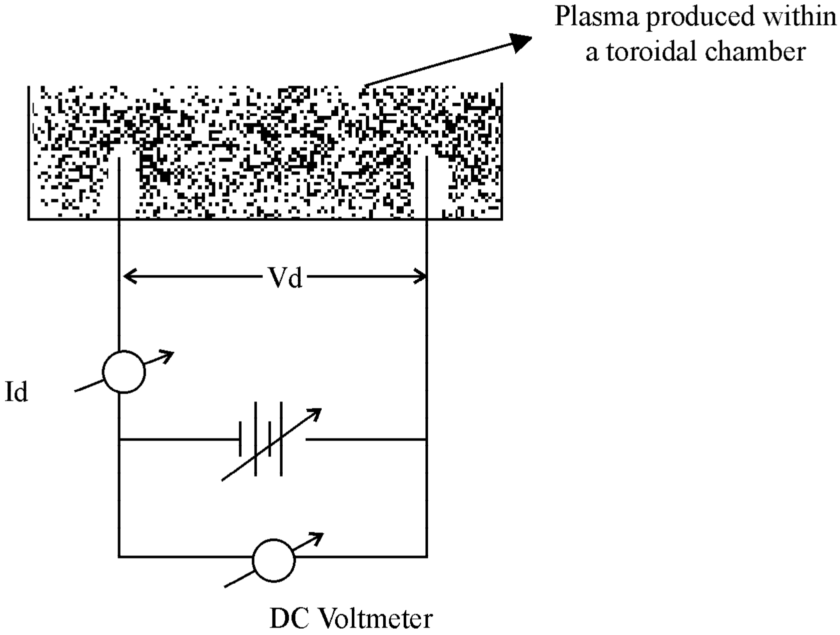


Figure 2 : Set up of the Floating Double Probe

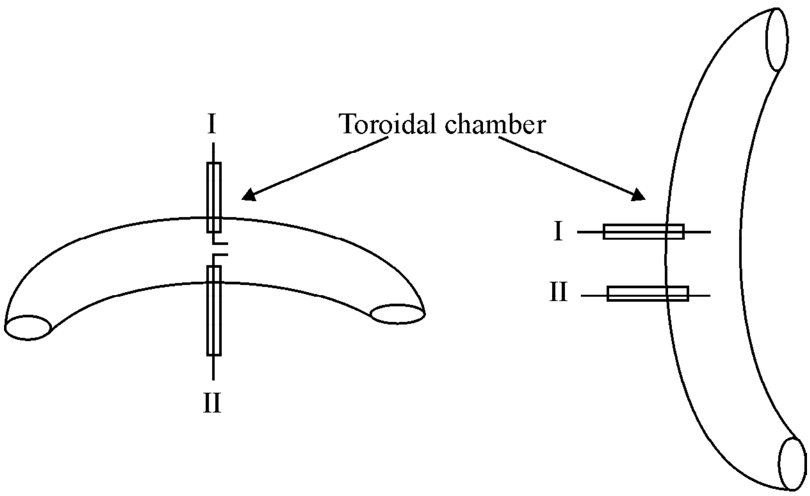


Figure 3(a)
Probe Structure in transverse Positions with magnetic field

Figure 3(b)
Probe Structure in axial positions with magnetic field

I: Probe 1
II: Probe 2

3. Results and Discussions

For a parametric study of the low-pressure inductively coupled plasma, a developed double Langmuir probe was employed in this experiment. The double probe configuration offers several advantages over the single probe technique. The double probe produces a small current drain from the plasma, which leads to less erroneous results; also, a double probe is preferred when a magnetic field is present because the ion current is much less affected by the magnetic field. To study the results accurately in the double probe technique, it is necessary to know the various conditions of the probe.

A typical I – V curve for the determination of the electron temperature and the electron number density are shown in figure 4 & 5 and the expression for electron temperature is given by [3]

$$T_e = \frac{e}{K} \frac{\sum I_{p0}}{4\left\{\left(\frac{dI_d}{dV_d}\right)_0 - 0.82s\right\}} \qquad (1)$$

where

T_e is the electron temperature,

e is the charge of an electron,

K is the Boltzmann constant,

$\sum I_{p0} = I_{p10} + I_{p20}$,

V_d is the probe potential in terms of differential voltage,

I_d is the associated current in the circuit,

$\left(\frac{dI_d}{dV_d}\right)_0$ is the slope of the current-voltage characteristics at the inflection point

To calculate the electron density, the following equation was used [4].

$$n_e = 4\frac{I_{sat}}{A.e.v^{th}} \qquad (2)$$

Where A is the effective electron / ion collection area of the probe,

n_e is the unperturbed electron density,

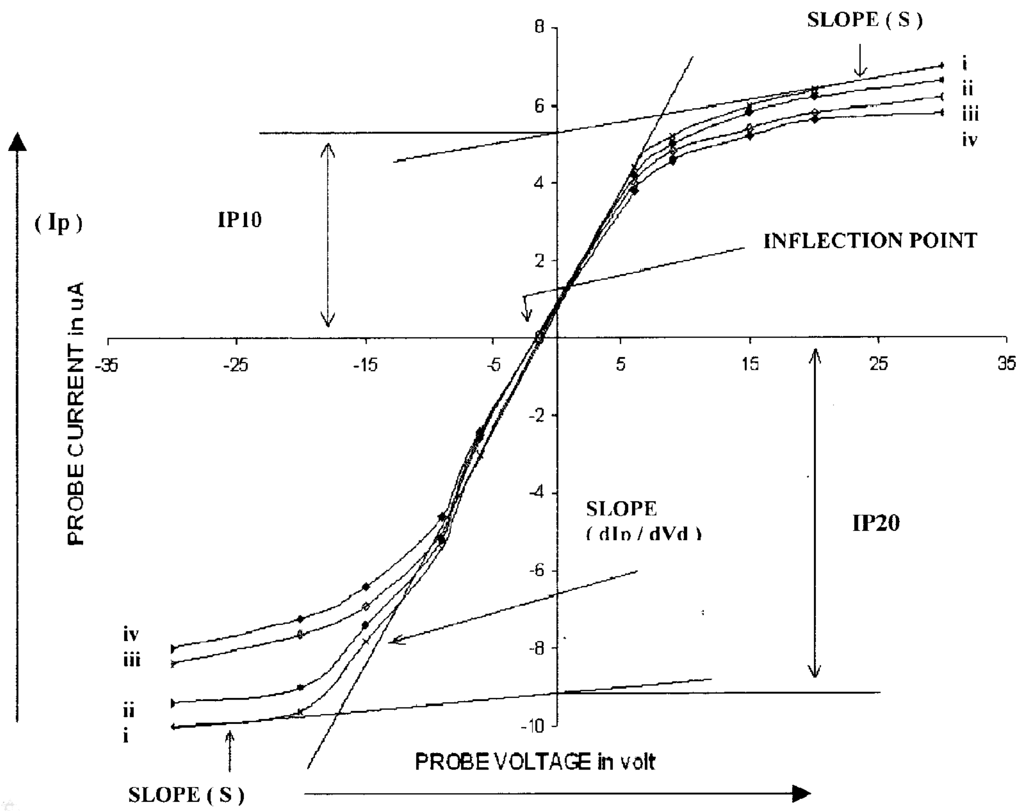
$V^{th} = \sqrt{\left(\frac{8KT_e}{\pi m}\right)}$ is the thermal speed of the electron,

I_{sat} is the ion or electron saturation current obtained from the tangent of volt-ampere characteristics

S is the slope of the positive or negative ion saturation characteristic.

Taking the values of the different factors for with and without magnetic fields in axial and transverse modes by equations (1) and (2) electron temperature (T_e) and electron density (n_e) are determined by inspecting the slopes of volt - ampere characteristics and the results are entered in Table (1) and (2).

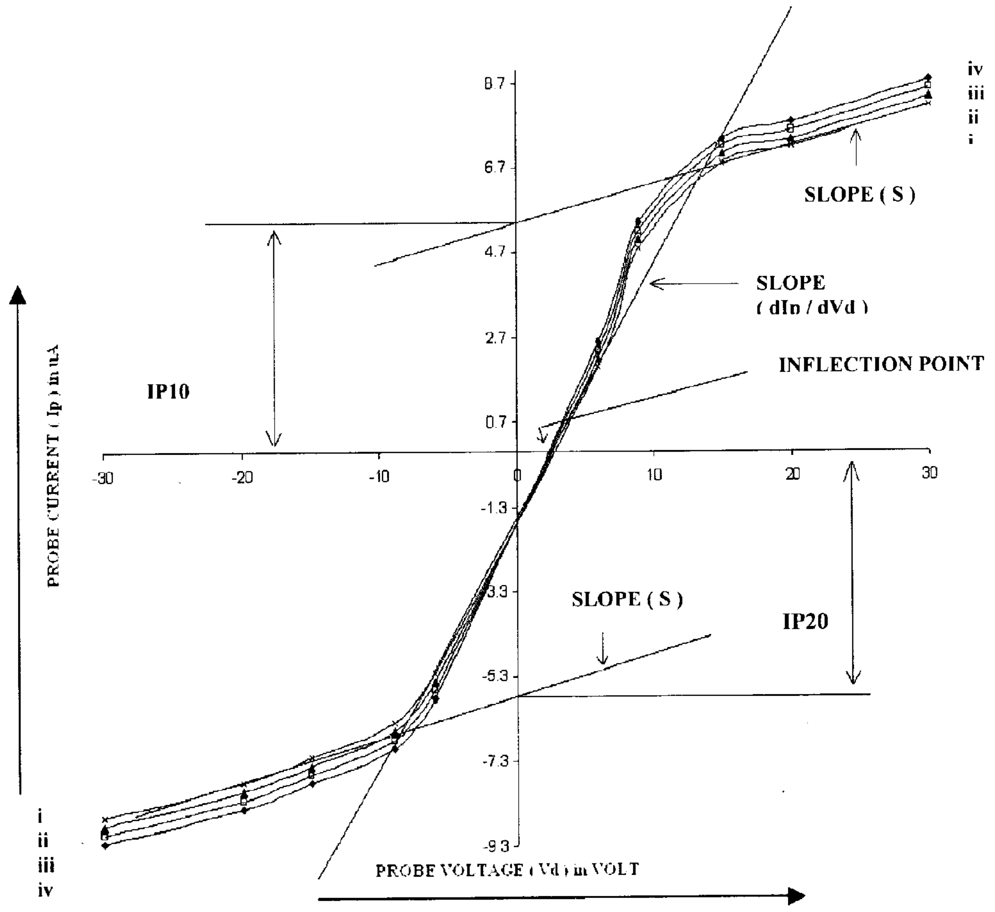
Therefore it is shown in the present study the double probe technique can effectively find out the salient plasma parameters in magnetic field provided a low density plasma is used and the value of the magnetic field is low.



$$\sum I_{P0} = I_{P10} + I_{P20}$$

i : 0 Gauss; ii : 25 Gauss; iii : 50 Gauss; iv : 75 Gauss.

Figure 4 : Schematic diagram of the double probe characteristic in axial position with the toroidal magnetic field



$$\sum I_{P0} = I_{P10} + I_{P20}$$

i : 0 Gauss; ii : 25 Gauss; iii : 50 Gauss; iv : 75 Gauss.

Figure 5 : Schematic diagram of the double probe characteristic in transverse position with the toroidal magnetic field

4. Variation of Electron Temperature and Electron Density for Different Magnetic Fields

Gas used = **AIR**

Table 1 : Longitudinal positions of the probes with the magnetic field

Pressure (Torr)	**Magnetic field** (Gauss)	**Electron Temp.** (ev)	**Electron Density (x10^{15})** (/m^3)
0.15	0	9.50	9.823
	25	8.76	10.772
	50	8.11	11.302
	75	6.87	12.914
0.175	0	10.12	6.299
	25	8.49	7.085
	50	6.74	8.816
	75	4.89	9.885
0.2	0	10.16	7.23
	25	8.80	7.99
	50	7.37	8.95
	75	5.79	10.34

5. Variation of Electron Temperature and Electron Density for Different Magnetic Fields

Gas used = **AIR**

Table 2: Transverse positions of the probes with the magnetic field

Pressure (Torr)	**Magnetic field** (Gauss)	**Electron Temp.** (ev)	**Electron Density** ($\times 10^{15}$) ($/m^3$)
0.1	0	7.72	9.50
	25	7.97	9.10
	50	9.50	8.31
	75	9.88	7.56
0.125	0	7.29	8.67
	25	7.94	8.09
	50	9.77	6.83
	75	10.87	6.18
0.15	0	5.78	9.60
	25	5.79	9.34
	50	6.28	8.48
	75	7.07	7.73

6. Conclusion

The electron temperature and electron density of low-pressure inductively coupled plasma were measured by a double Langmuir probe. As expected, the electron temperatures were higher but the electron number densities were lower than those of with an axial magnetic field. This indicates that a significant amount of electrons had enough energy to excite and ionize almost all elements by a collision energy transfer process. On the other hand, the electron temperature decreases but the electron number density increases for longitudinal mode magnetic field than those of without a magnetic field.

REFERNCES

1. E.O. Johnson and L. Malter: Physical Review 80 (1950) 58
2. K.M. Burrows: Australian Journal of Physics 15 (1962) 162
3. T. Dote : Japanese Journal of Applied Physics 7 (1968) 964
4. S.K. Sadhya, D.C Jana and S.N. Sen :Proc. Indian National Science Academy 45,4 (1979) 309-321
5. H. Aikawa : J. Phys. Soc. Japan 40 (1976) 1741
6. T.Kameda : J.Appl Phys. 16 (1977) 1887
7. Haddelstone, R.A and Leonard, S.L. (1965) Plasma diagnostics technique, Academic Press, New York, P: 374-383