MEASUREMENTS OF ELECTRONIC MEAN FREE PATHS IN ARGON PLASMAS

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ABSTRACT

Electronic mean free paths in an argon discharge were measured using the interaction between the plasma electrons and a slow wave on a helix. The results compare favorably with available data.

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INTRODUCTION

A plasma diagnostic technique developed several years ago[1,2] has been extended to measurements of decay time of plasma and the determination of electronic mean free paths. The method is based on the measurement of the decay of the microwave signal propagating along a helix wrapped around the tube (1.25 cm inside diameter) containing the plasma.

MEASUREMENTS

The experimental arrangement is shown in Figure 1 A, and the oscilloscope display in Figure 1 B. The current pulses were obtained by pulsing the switch (the 7534 tube) at a rate of 200 Hz. The current was on for 10 μsec, and its amplitude was controlled by the impedance of the tube. The microwave signal was 300 μsec wide, and the synchronization between the pulse generators allowed the location of the current pulse anywhere within the microwave pulse. The current decay time was measured and found faster than 5 μsec, indicating that the decay of the microwave signal was related to the plasma decay and not to the net current. Further, the plot of the decay time of the signal vs pressure indicated a limit which was suggestive of the condition at which the electronic mean free paths were comparable to, or greater than, the walls of the vessel.

The initial conditions of the plasma, upon application of the current pulse, are generally expressed as[3]

$$I = I_o \exp(-p_o P_c v t) \qquad (1)$$

where $p_o = (273\, p/T)$ is the "reduced" pressure in Torrs; T is the temperature; P_c, the probability of collision; and v, the electron velocity. Since $I = nev_d$, where n is the electron density; e, the charge; and v_d, the drift velocity,

$$n = n_o \exp(-t/\tau) \quad (2)$$

where $\tau = 1/(p_o P_c v)$. The mean free path[3]

$$L = \frac{1}{p_o P_c} = \frac{v}{\tau} \quad (3)$$

can now be determined from the measurements of τ and n_o, the initial electron density. In order to maintain a reasonably uniform electron density throughout the cross-section within few microseconds after the cessation of the current pulse, low values of current were used.

RESULTS

The measured values of mean free time are shown in Figure 2 for three values of initial currents. The corresponding values of percentage ionization are shown in Figure 3. These were obtained from electron density measurements during the current pulse using the slow wave on the helix.[1,4] The electron temperature was then calculated from Saha's equation[5] using the measured values of electron densities, and used to calculate the values of L in equation 3. The values of L ranged from 5×10^{-3}cm at 1 Torr to 5×10^{-1}cm at 100 mTorr, which was anticipated because of the low electron temperature (less than 10^{-3} electron-volts).

As a check, equation of the asymptote of Figure 2 was determined, i.e.

$$\frac{1}{p} = 1.77 \times 10^{-2} \exp(-.04t) \quad (4)$$

where p is in milliTorr, and t in microseconds. Equating the slope of this line to $p_o P_c v$, the electron temperature was calculated using the actual values of p_o, and values of P_c given in Figure 1.10 of reference 3. The temperature thus obtained was about 30-40% higher than the one obtained from Saha's equation. Because of the necessary extrapolation, this agreement was considered satisfactory. Thus, the slopes of curves on $\frac{1}{p}$ vs t plot, obtained by measurements of the time constant of the decay of the microwave signal, can be used to determine the electronic mean free path or temperature.

CONCLUSIONS

A new method of measurement of electronic mean free paths or temperature has been presented. The results are in reasonable agreement with available data. This method allows the measurements of such paths for very low electronic energies, but further refinement of the technique is necessary for greater accuracy.

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