DETERMINATION OF ELECTRON DRIFT VELOCITY IN GAS DISCHARGE PLASMA BY TRANSIT TIME MEASUREMENTS

V. T. CHIPLONKAR AND V. V. WAGLE

Ion Physics and Electronics Laboratory, Physics Department, Institute of Science, Bombay-32

OBSERVATIONS have been reported on the electron drift velocity in gases based on transit time measurements, in the case of electron swarms[1-3]. The present paper reports the results of similar investigations for a gas discharge plasma where the electron number density is considerably higher (6–33) $\times$ 10^9 per cm^3. A cylindrical plasma (radius = 1·95 cm) is formed in argon (gas pressure = 0·20–0·60 Torr, discharge current = 1·50–5·00 mA) in a discharge tube, provided with aluminium electrodes. The electrodes are made in the form of a central circular sector and an outer concentric ring, insulated from it; only the central region (radius = 1·0 cm) is used for the actual current density measurements, in order to reduce the error due to the radial decrease in the number density of the electrons due to diffusion and other effects[4,5]. The cathode is provided with a central aperture[6] (radius $\approx$ 0·4 mm) through which are supplied electrons from an auxiliary d.c. maintained gas discharge, in argon, at the same pressure. The electron injection has the effect of making the length of the cathode dark space negligibly small so that the plasma column length approximately equals the interelectrode distance D, for the main discharge (which can be varied). It also reduces the maintenance potential V_{co} for the main discharge and generally gives rise to a well-behaved[7] plasma, free from spatial irregularities. The number of electrons injected is time modulated by the superposition of a rectangular voltage pulse (height = 70 V, duration = 150 μs, repetition frequency = 1·6 kHz, rise time < 0·02 μs) from a pulse generator, on the main voltage of the auxiliary discharge. The increased density of the electrons is followed in its course through the plasma, with the help of two insulation encased circular capacitor probes P_1, P_2, positioned on the outside of the discharge tube; probe P_1 is kept fixed at the cathode, the distance of probe P_2 can be varied. The drift velocity of the electrons is determined by measuring the time delay between the signals picked up by the two probes, with the help of a calibrated double beam C.R.O. (Tektronix type 547). The transit time is measured as a function of the distance between P_1 and P_2 and its average value t_d for traversing one cm length of the plasma, is determined graphically in order to eliminate end effects[2] and to ensure that the measurements refer to equilibrium conditions.

It is necessary to verify that the velocity thus determined represents the average drift velocity of the electrons and not the velocity of propagation of a voltage/current perturbation in the plasma. It is known[8] that the velocity with which such a perturbation travels through the plasma is of the same order as the velocity of the acoustic waves, given by

$$\bar{V} = (\gamma k \bar{T}/M)^{1/2} = (\gamma P_0/\rho_0)^{1/2} \qquad (1)$$

where M refers to the mass of the argon. The velocity calculated from this expression comes out to be of the order of (5–9) $\times$ 10^2 cm/sec for our pressure conditions. Donahue and Dieke[9] have reported a velocity for the longitudinal potential waves through the plasma of argon (P_0 = 12 mm) of (5·3–7) $\times$ 10^3 cm/sec; whereas Chiplonkar and Rane[10] have reported a velocity of (12–15) $\times$ 10^3 cm/sec for a self-generated potential wave, in a gas discharge plasma, in hydrogen (P_0 = 0·35–0·10 Torr, I_{oo} = 10–5 μA). All these values are much smaller than the electron drift velocity observed by us from the transit time data. It is clear, therefore, that for our experimental conditions, the perturbation produced in the electron density does not propagate as a wave.

Another important point which requires consideration is whether under the given experimental conditions, the electron conduction current involves an actual transport of the electrons, from one end of the plasma to the other or involves a collective phenomenon as in the case of conduction by free electrons in a metal wire. In the latter case, the velocity determined from the transit time observations will not have the significance of a drift velocity. The current density J_A at the anode, can be expressed as $J_A = N_{eo}\ q_e\ V_{dp}$ where N_{eo} = number density of the electrons in the plasma, V_{dp} = drift velocity of the electrons near the anode region. Measurement of J_A (directly) and of N_{eo} by the Langmuir single probe enables an estimation of V_{dp} to be made. The axial anode current has been measured by means of a milliammeter, connected between the central sector and the earth. It would be reasonable to conclude that the phenomenon involves an actual transport

of the electrons, if V_{dp} calculated in this manner could be shown to be smaller than V_{dT} found directly from the transit time measurement (*vide supra*). This is clearly borne by typical data shown below.

Gas — argon.

P_0 = gas pressure (Torr)

I_{co} = discharge current (mA).

J_A = anode current density (A/cm²).

V_{dT} = electron drift velocity from transit time (10^6 cm/sec).

V_{dp} = electron drift velocity from probe data (10^6 cm/sec).

P_0	I_{co}	J_A	V_{dT}	V_{dp}
			±1%	±5%
0·20	1·5	4·8	1·8	0·19
0·20	5·0	15·9	3·3	0·31
0·30	5·0	15·9	2·3	0·29
0·45	5·0	15·9	1·8	0·39
0·60	5·0	15·9	2·0	0·88

The longitudinal electric field E_0 in the plasma, has been measured from (*i*) the observation of V_{co} the maintenance potential with D, at constant I_{co} and also from direct measurements with the help of static probes provided in the anode. The values by both these methods were found to be in agreement with each other. Figure 1 presents typical data obtained in this manner. The reduced field E_0/P_0 has magnitudes between 30·0–33·3 volts/cm Torr for the conditions used here.

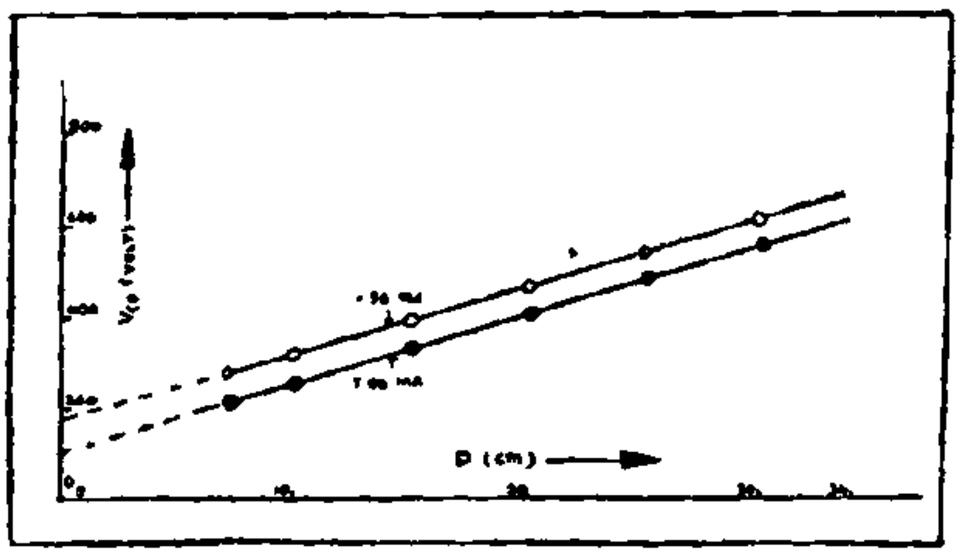

FIG. 1. Variation of maintenance voltage V_{co} for the total discharge with interelectrode distance D. Gas : Argon. P_0 = 0·45 Torr.

Observations on the electron transit time for different travel distances in the plasma are shown in Fig. 2. It will be noted that the graphs are linear, except near the cathode end. The energetic electrons, injected in the main discharge, appear to require to travel some distance in the plasma, before they attain their equilibrium terminal drift velocities, as a result of collisions and of the longitudinal electric field. Values of V_{dT} obtained from these data vary between (1·2–3·3) × 10^6 cm/sec. They appear to be reasonable in comparison with V_d = 1·8 × 10^6 .cm/sec for E_0/P_0 = 4·5 V/cm Torr given in the literature[11]. The electron drift velocity, observed here, appears to show a small increase with increase in I_{co}, at constant P_0. E_0 has been observed to show practically no variation with I_{co}. The probe data, however, show that under these conditions, T_e, the electron temperature has a small decrease with increase in I_{co}.

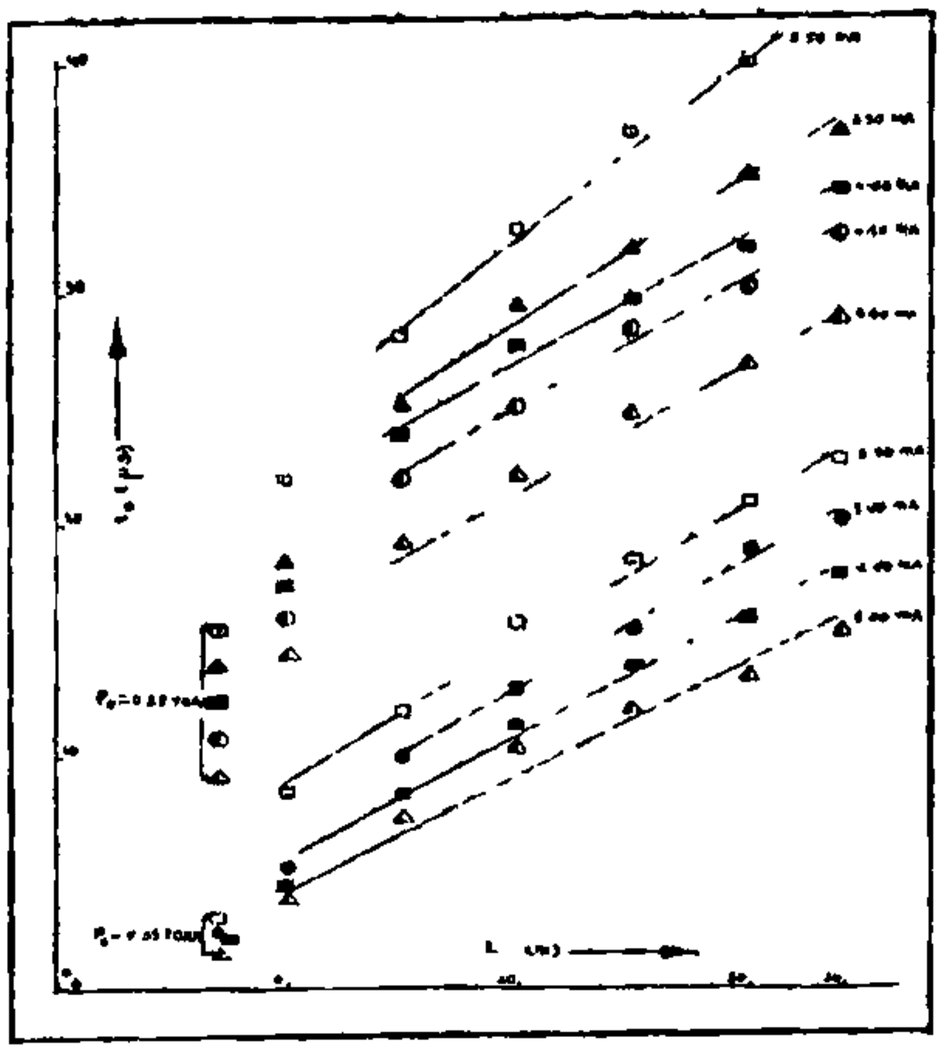

FIG. 2. Variation of electron transit time t_d with L, travel distance in plasma. Gas : Argon.

TABLE I

Gas—Argon	P_0=0·20 Torr
I_{co} in mA	T_e in eV
1·5	3·11
5·0	2·50

The change in V_{dT} with I_{co} may, therefore, have a real physical significance.

The results show that the mobility description for the motion of the electrons in the plasma is sufficiently accurate for E_0/P_0 as high as 30·0 volt/cm Torr. The electron mobility has magnitudes between (0·67–2·44) × 10^5 cm²/volt sec. The method of observation appears to be fairly accurate and can be used in turn to calculate the number density of the electrons in the plasma under certain conditions.

One of the authors (VVW) is thankful to the Ministry of Education, Government of India, for the research training scholarship.

1. Gilardini, A., *Low Energy Electron Collisions in Gases,* Wiley, New York, 1972.
2. Chanin, L. M. and Stein, R. D., *Phys. Rev.,* 1964, 136 A, 138.
3. Hurst, G. S. and Parks, J. E., *J. Chem. Phys.,* 1966, 45, 282.
4. Francis, G., *Handbuch der Physik,* Springer, Berlin, 1956, 22, 120.
5. Chiplonkar, V. T. and Desai, Y. R., *Physica,* 1967, 35, 211.
6. Crompton, R. W. and Jory, R. L., *Australian J. Phys.,* 1962, 15, 451.
7. Persson, K. B., *J. Appl. Phys.,* 1965, 36, 3086.
8. Ingard, U., *Phys. Rev.,* 1967, 158, 166.
9. Donahue, T. and Dieke, G. H., *Ibid.,* 1951, 81, 248.
10. Chiplonkar, V. T. and Rane, S. R., *Journal of Scientific and Industrial Research,* 1962, 21 B, 269.
11. von Engel, A., *Ionized Gases,* Clarendon Press, Oxford, 1965, p. 124.

PARTIAL PURIFICATION AND ANTITUMOUR ACTIVITY OF L-ASPARAGINASE FROM *AZOTOBACTER VINELANDII* *

S. A. GAFFAR AND Y. I. SHETHNA

Microbiology and Cell Biology Laboratory, Indian Institute of Science, Bangalore 560 012

ABSTRACT

Stimulation of L-asparaginase activity in *Azotobacter vinelandii* has been attempted using a variety of carbon and nitrogen sources. Though the tested carbon sources failed to induce the enzyme, nitrogen sources such as ammonium salts, urea, L-aspartic acid and L-glutamic acid were found to be good inducers. The partially purified enzyme preparation possesses antitumour activity against Yoshida ascites sarcoma in rats.

INTRODUCTION

L-ASPARAGINASE from microbial source has been widely used in the chemotherapy of asparagine dependent tumours[1]. Clinical results have shown that L-asparaginase from *Escherichia coli* causes toxicity[2] and immunosuppression[3] in addition to development of resistance[4]. This necessitated studies on L-asparaginases from different sources as a possible chemotherapeutic agent against cancer. In this paper, we report the production, partial purification and antitumour activity of L-asparaginase from *Azotobacter vinelandii,* a nitrogen fixing organism which could be readily cultivated on a large scale in an inexpensive medium.

MATERIALS AND METHODS

Azotobacter vinelandii OP (obtained from Dr. R. H. Burris, University of Wisconsin) was maintained on modified Burk's nitrogen free medium with sucrose as the carbon source[5]. For regular experiments, the organism was routinely cultured in Erlenmeyer flasks, and incubated on a rotary shaker (250 rpm) at 30° C. A 10% inoculum was used throughout the experiments.

Protein was estimated by the method of Lowry *et al.*[6]. Enzyme was assayed essentially as described by Jayaram[7]. One unit is the amount of enzyme required to produce 1 μ mole of ammonia at 37° C for 30 min. at pH 7·4.

RESULTS AND DISCUSSION

Studies on the Production of L-asparaginase

The specific activity of L-asparaginase in different phases of growth of the organism remained almost the same. As the enzyme activity was found to be low (specific activity 2·2) for being exploited for large scale preparative purpose, growth studies were carried out to increase the enzyme yield.

The following carbon sources were tested individually for their ability to stimulate the enzyme activity; glucose, galactose, mannitol, sodium benzoate, lactose, ethanol, and mannose. These carbon sources supported good growth of the organism, but failed to stimulate the synthesis of the enzyme. The nitrogen sources tested were added to the complete growth medium with sucrose as carbon source. Table I summarizes the effects of various nitrogen sources tested for the increased production of the enzyme. Many of the complex nitrogen sources like yeast extract, bacto-tryptone,

* Presented at the annual meeting of the Association of Microbiologists of India in December 1974.