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Electron drift velocities in N_2, CO_2, and (N_2+CO_2) laser mixtures[a)]

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A time-of-flight technique has been used to obtain electron drift velocities in N_2, CO_2, and N_2-CO_2 mixtures covering the E/N range 3–93 Td. In the case of the pure gases, excellent agreement with previous work is obtained over the entire E/N range. The mixtures, which are of laser importance, have not been studied previously.

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The current interest in gas discharge lasers has brought about a need for electron transport studies. The drift velocity of electrons under the influence of an applied field is an important parameter in a gas discharge. Although a multitude of data exists dealing with the drift velocity of electrons in *pure* gases, gas lasers often use mixtures of gases whose characteristics may differ significantly from the pure components. In this letter electron drift velocities are presented for CO_2, N_2, and (CO_2 + N_2) mixtures.

The experimental procedure followed in this work is similar to that used by Nygaard *et al.*[1] Figure 1 shows a diagram of the swarm apparatus. The vacuum chamber is pumped by two 25-l/sec ion pumps, which after a mild bakeout (150 °C), yields a background pressure of 10^{-8} torr. The electrodes are 7.5-cm diam stainless steel plates supported on ceramic stand-offs. The drift space is adjustable by means of a linear motion feedthrough calibrated in 0.0127-cm units.

High-purity samples of CO_2, N_2, (CO_2 + N_2) mixtures are prepared in the chamber at pressures of 50, 100, and 300 Torr. Light from an ArF excimer laser enters through a port at the bottom of the chamber, passes through a screen on the anode, and strikes the photocathode. The short-duration (17 nsec) short-wavelength (193.6 nm) laser pulse produces a burst of electrons which then drift to the anode under the influence of the applied electric field. The resulting current is monitored on an oscilloscope.

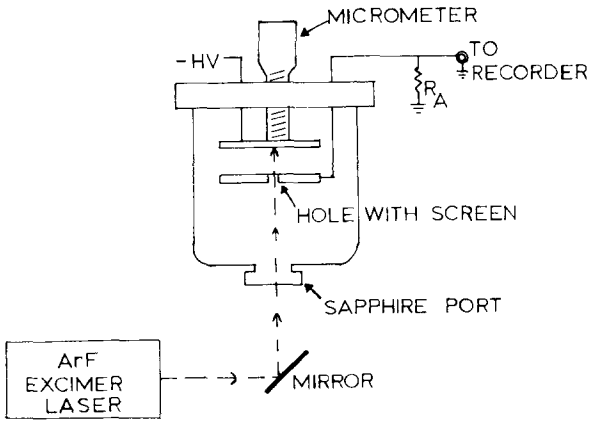

FIG. 1. Diagram of the swarm apparatus. Light from the ArF* excimer laser enters through the sapphire viewport, passes through the screen on the anode, and strikes the photocathode. Photoelectrons drift under the action of the applied field. The resulting voltage drop across R_A is monitored on a transient recorder or a storage oscilloscope.

When the anode resistor R_A is small (50 Ω), the current i_d in the drift space will be equal to the current following in R_A. The average current which flows in the drift space when n_e electrons drift with velocity W is given by

$$i_d = n_e e W/d\,, \tag{1}$$

where d is the interelectrode spacing and e is the electronic charge. The voltage developed across R_A will be

$$V_R(t) = n_e(t) e W R_A/d\,. \tag{2}$$

At a time T_e equal to the electron transit time (assuming negligible diffusion), all electrons reach the anode and $V_R(t)$ goes abruptly to zero. Thus, the electron transit time (and hence the drift velocity) is easily determined. Figure 2(a) shows a typical electron transit recorded in a (20% N_2 + 80% CO_2) mixture at $E/N = 24.6$ Td (1Td = 10^{17} V cm^2).

If R_A is made very large (10^6 Ω) no charge flows through R_A during the electron transit. Under these conditions the anode potential is given by[2]

$$V_R(t) = \frac{n_0 e}{C(\alpha-\eta)d}\{\exp[(\alpha-\eta)Wt] - 1\}\,, \tag{3}$$

where α and η are ionization and attachment probabilities per unit length, C is the interelectrode capacitance, and n_0 is the initial number of photoelectrons. Since the current drops abruptly to zero at $t = T_e$, the slope of $V_R(t)$ has a discontinuity at $t = T_e$. Figure 2(b) shows a typical transient from which the drift velocity is easily obtained.

In the work presented here R_A was usually set at 50 Ω and data such as that of Fig. 2(a) recorded. At times, howev-

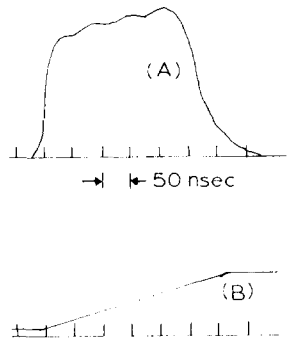

FIG. 2. Two oscilloscope traces showing electron transients in an 80% CO_2 20% N_2 gas mixture. (a) $R_A = 50\,\Omega$, and (b) $R_A = 10^6\,\Omega$.

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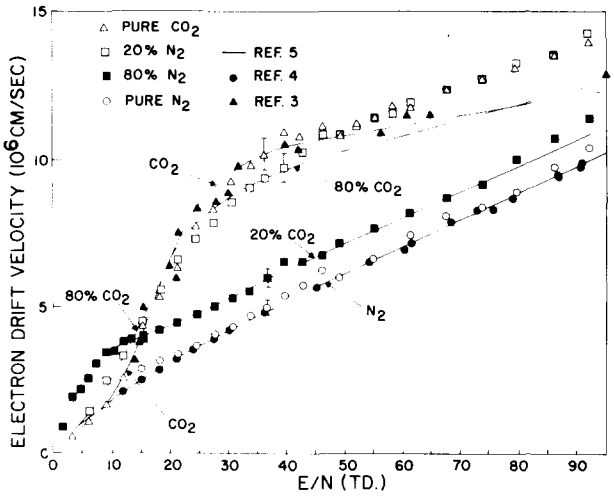

FIG. 3. Electron drift velocity plotted versus E/N. The results from all data is shown. Samples at 50, 100, and 300 Torr were analyzed. Previous experimental values for the drift velocities in CO_2 and N_2 are given as well as theoretical calculations for all the mixtures. The mixtures have not been previously studied.

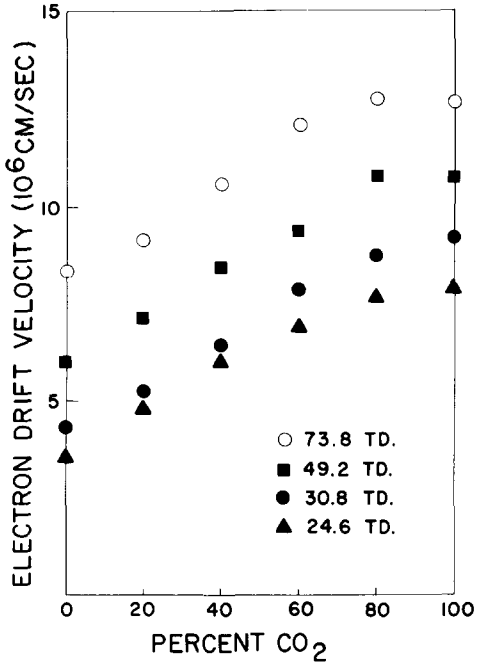

FIG. 4. Effect of adding CO_2 to pure N_2. Total pressure has been maintained at 50 Torr. The left margin corresponds to pure N_2, the right to pure CO_2.

er, when resulting values of V_R became too small to determine T_e accurately, R_A was increased to $10^6\,\Omega$ and the type of transient shown in Fig. 2(b) was used. The two methods agree to within $\pm 2\%$.

As a consistency check on the present work, the electron drift velocity was first measured in pure CO_2 and N_2. The results are shown in Fig. 3 plotted versus E/N. For comparison previous work by other experiments is included. Excellent agreement was obtained in both gases over the entire E/N range. The error bars indicate $\pm$ one standard deviation which was found to be about 5%.

Two different ($CO_2 + N_2$) mixtures were studied over the entire E/N range. Figure 3 shows the electron drift velocities in a 20% N_2 and in an 80% N_2 mixture. Notice that the 20% N_2 mixture differs only slightly from the pure CO_2, while the 80% N_2 mixture differs significantly from either component. Finally, Fig. 4 demonstrates the variation in electron drift velocity at several E/N values and 50 Torr total pressure as the fraction of CO_2 is varied from 0 to 1.

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