THE RATIO OF LATERAL DIFFUSION COEFFICIENT TO MOBILITY FOR ELECTRONS IN CARBON DIOXIDE AT MODERATE E/N*

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In this work the present results of measurements of the ratio of the lateral diffusion coefficient to mobility D/μ in carbon dioxide at moderate values of reduced electric field E/N and obtained with the help of Townsend and Huxley method, have been compared with those based on the other experimental technique. The values of the D/μ coefficient have been determined at an ambient temperature for E/N over the range 184.5–488.7 Td.

The measurements of the D/μ coefficient presented in this work have been performed by means of Townsend and Huxley's technique [1], in which the electrons diffuse through a gas in a homogeneous electric field between a "point" source and an anode. In the described method the fraction of total current falling on the central disc of the divided anode is determined experimentally.

In the presence of the ionization processes the steady state solution of the electron transport equation — electron density n-satisfying the boundary conditions on the cathode and anode is expressed as an infinitive series of dipole solutions

$$n = \sum_{k=-\infty}^{+\infty} r_k^{-3}(z-2kh)(\beta r_k+1)\exp(\lambda_L z-\beta r_k), \tag{1}$$

where

$$r_k = \left[(z-2kh)^2+\frac{D_L}{D}\varrho^2\right]^{1/2}, \quad \beta = \lambda_L\left(1-\frac{2\alpha}{\lambda_L}\right)^{1/2}, \quad \lambda_L = \frac{W}{2D_L}.$$

The quantities h, α, W, D_L and D are the length of diffusion space, the ionization coefficient, the drift velocity, the longitudinal and lateral diffusion coefficients, respectively.

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The variables ϱ and z determine the position of an arbitrary point in a cylindrical coordinate system, where the z-axis is parallel to the electric field.

If $\alpha = 0$, formula (1) is identical with those given for the first time by Warren and Parker [2] for isotropic diffusion and Lowke [3] for anisotropic diffusion.

The integration of the current density over the surface of an anode allows one to obtain an expression for the fraction R of the total electron current falling on the central disc of a divided anode in the form

$$R = \frac{\sum_{k=-\infty}^{+\infty} [\![r_k'^{-3} \exp[\lambda_L h - \beta r_k'] \{(2k-1)^2 h^2 (\beta r_k' + 1) - [1 - \lambda_L h(2k-1)] r_k'^2\} - [\beta + \lambda_L \operatorname{sign}(2k-1)] \exp[h(\lambda_L - \beta|2k-1|)]]\!]}{\sum_{k=-\infty}^{+\infty} [\![r_k''^{-3} \exp[\lambda_L h - \beta r_k''] \{(2k-1)^2 h^2 (\beta r_k'' + 1) - [1 - \lambda_L h(2k-1)] r_k''^2\} - [\beta + \lambda_L \operatorname{sign}(2k-1)] \exp[h(\lambda_L - \beta|2k-1|)]]\!]}, \quad (2)$$

where

$$r_k' = \left[(2k-1)^2 h^2 + \frac{D_L}{D} b^2\right]^{1/2}, \quad r_k'' = \left[(2k-1)^2 h^2 + \frac{D_L}{D} c^2\right]^{1/2}.$$

In the above b and c are the radius of the central disc and the external radius of the anode, respectively.

The values of the ratio of the longitudinal diffusion coefficient to mobility D_L/μ and the ionization coefficient α, necessary for the determination of the D/μ coefficient, have been taken from various sources. The values of the α coefficient have been adopted from the measurements by Bhalla and Craggs [4]. Since the values of the D_L/μ coefficient in carbon dioxide are not available in the examined range of E/N, the estimation of the ratio D_L/D has been made with the help of the classical theory of collisions [5] and the thermodynamic treatment of anisotropic diffusion in an electric field [6]. The value of the maximal error of the procedure applied to find the ratio D_L/D does not exceed approximately 25% [7]. On account of the very slowly changing character of the dependence of D/μ as a function of D_L/μ in expression (2), a change in the value of D_L/μ by $\pm 25\%$ causes nearly $a \pm 2.5\%$ change in the D/μ coefficient. The total error of the measurement of the D/μ coefficient in this experiment is not larger than about 4.5%.

The apparatus constructed to U.H.V. standard has been described previously [8].

The measurements of the gas pressure were made by means of mercury-filled McLeod gauge covering the range of pressure 0.3–9 Torr with an accuracy of 3% for the pressures below 1 Torr and with an accuracy larger than 1% for pressures above 1 Torr.

For the measurements spectrally pure carbon dioxide of purity higher than 99.99% has been used.

The present results have been illustrated in Fig. 1. The data of this work are consistent with those obtained earlier [9] for $E/N \leqslant 183.9$ Td. For $185 \lesssim E/N \lesssim 300$ Td our data points lie lower than those by Lakshminarasimha et al. [10], e.g. for $E/N \approx 200$ Td the difference between these data is about 10% and decreases for higher E/N. Above 300 Td

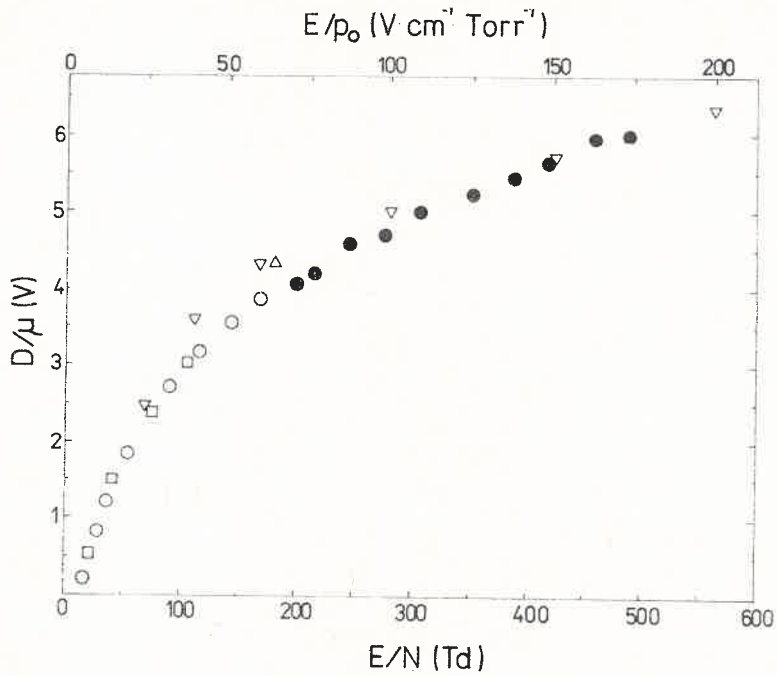

Fig. 1. Ratio of the lateral diffusion coefficient to mobility in carbon dioxide as a function of E/N. ● Present results; ○ Results of work [9]; □ Rees [11]; △ Lowke and Parker [12]; ▽ Lakshminarasimha et al. [10]

the agreement between the results of both works is very good. In the range of $180 \lesssim E/N \lesssim 280$ Td the present results agree well with those obtained by us previously [13].

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