Journal of Physics D: Applied Physics

RAPID COMMUNICATION

The characteristic energy and ratio of longitudinal diffusion coefficient to mobility for electrons in hydrogen and nitrogen

To cite this article: W Roznerski *et al* 1990 *J. Phys. D: Appl. Phys.* **23** 1461

J. Phys. D: Appl. Phys. **23** (1990) 1461–1463. Printed in the UK

RAPID COMMUNICATION

The characteristic energy and ratio of longitudinal diffusion coefficient to mobility for electrons in hydrogen and nitrogen

W Roznerski, J Mechlińska-Drewko and K Leja

Department of Technical Physics and Applied Mathematics, Technical University of Gdańsk, 80-952 Gdańsk, Majakowskiego 11/12, Poland

Received 30 July 1990

Abstract. Using the Townsend–Huxley technique both the characteristic energy (D/μ) and ratio of longitudinal diffusion coefficient to mobility D_L/μ for electrons in hydrogen and nitrogen have been determined, at ambient temperature over ranges of reduced electric field E/N: $70 \leqslant E/N \leqslant 1500$ Td and $40 \leqslant E/N \leqslant 750$ Td for hydrogen and nitrogen respectively. The results of the present work have been compared with some approachable experimental and theoretical data.

Since the Townsend–Huxley method (Huxley and Crompton 1974) yields results of high accuracy (Crompton *et al* 1965), this experimental technique has been applied in this work to determine both the characteristic energy and ratio of longitudinal diffusion coefficient to mobility. In the Townsend–Huxley method, the thermal electrons emitted from a source of a small size diffuse through a gas in a homogeneous electric field and are collected by an anode. Actually, this technique depends on the measurement of the ratios of the currents arriving at the coaxial segments of a divided anode. In the present version of the experiment the following form of the expression for the fraction R of the total current falling onto the central part of an anode has been used (Huxley and Crompton 1974):

$$R = \frac{1 - \left[\frac{b}{r'_b} - \frac{1}{\beta h}\left(1 - \frac{h^2}{r'^2_b}\right)\right]\frac{h}{r'_b}\exp[-\beta(r'_b - h)]}{1 - \left[\frac{b}{r'_c} - \frac{1}{\beta h}\left(1 - \frac{h^2}{r'^2_c}\right)\right]\frac{h}{r'_c}\exp[-\beta(r'_c - h)]} \qquad (1)$$

where

$$r'_b = \left(h^2 + \frac{D_L}{D}b^2\right)^{1/2} \qquad r'_c = \left(h^2 + \frac{D_L}{D}c^2\right)^{1/2}$$

$$\lambda_L = W/2D_L \qquad \beta = \lambda_L(1 - 2\alpha/\lambda_L)^{1/2}.$$

The quantities b, c, h, α, W, D and D_L are the radius of the central disc, the external radius of the anode, the length of diffusion space, the drift velocity, the ionization coefficient and the transverse and longitudinal coefficients, respectively.

A suitable use of the expressions (1) allows us to take into account any other version of anode as well. Measuring the current ratios at various pressures and geometrical variants of the anode, for each E/N reduced electric field value, we form the system of equations (1), and subsequently a suitable numerical procedure gives both the characteristic energy D/μ and the ratio of longitudinal diffusion coefficient to mobility D_L/μ as the solution. Because the quantity R is a very slowly changing function of D_L/μ, generally the use of a considerable number of the equations (1) is necessary.

The results of the present work are illustrated in three figures. Figure 1 shows the results of this work in hydrogen up to 1500 Td. We noticed that our D_L/μ data agree fairly well with those of Blevin *et al* (1976) over the common E/N range. The present D_L/μ results also agree well up to 1000 Td with those of Saelee and Lucas (1977). As to the characteristic energy for hydrogen, our D/μ results are in very good agreement with those of Crompton *et al* (1965). It is worth adding that the difference between the two sets of data

0022-3727/90/111461 + 03 $03.50

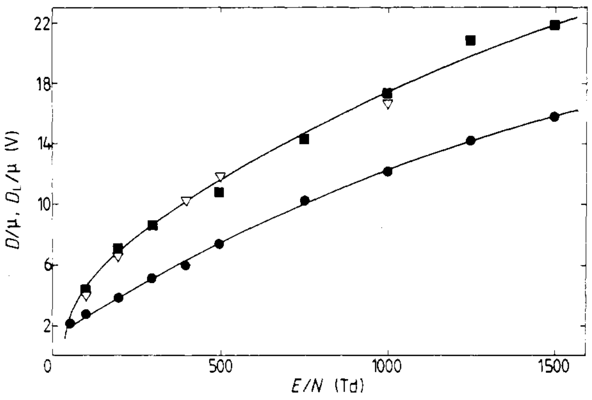

Figure 1. Characteristic energy D/μ and the D_L/μ coefficient as a function of E/N in hydrogen up to 1500 Td. D/μ: ●, present results; D_L/μ: ▽, Saelee and Lucas (1977); ■, present results.

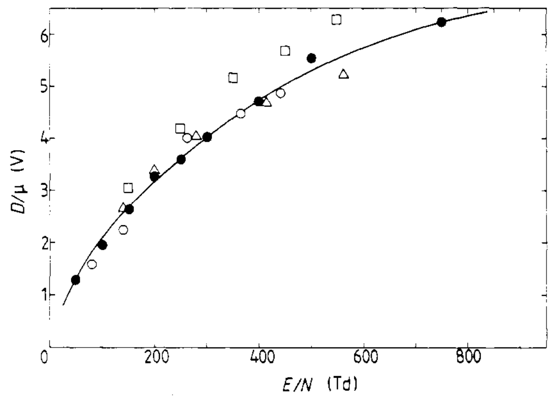

Figure 3. Ratio of transverse diffusion coefficient to mobility (D/μ) as a function of E/N up to 750 Td in nitrogen. △, Kontoleon *et al* (1973); ○, Fletcher and Reid (1980); □, Wedding *et al* (1985); ●, present results.

between 70 and 200 Td does not exceed 3.3%. In figures 2 and 3 the results of the present work for nitrogen are presented. Our D_L/μ results (figure 2) agree very well with those of Wedding *et al* (1985) between 200 and 300 Td, and those of Fletcher and Reid (1980) for E/N between 400 and 500 Td. Although not presented in figure 2, the experimental data of Nakamura (1987) agree with ours within the combined errors of the two data sets.

We observed, however, some discrepancies between our D_L/μ results and those of Saelee *et al* (1977). The points of the latter work lie higher (except one point for 566 Td), and the largest difference between both sets of data reaches about 25% at 266 Td. Figure 3 shows a good agreement of our results with the experimental data of Fletcher and Reid (1980) and Kontoleon *et al* (1973), except for the point at 566 Td in the latter work. The difference between the results of the present work and those of Wedding *et al* (1985) increases up to about 10% for $E/N > 350$ Td.

The present D/μ and D_L/μ data agree fairly well with the Boltzmann and Monte Carlo results of Penetrante and Bardsley (1984) for $E/N = 70$ and 100 Td, and Braglia *et al* (1985) for 150 and 200 Td. For $E/N < 50$ Td our results disagree with the data of the theoretical work quoted above, and discrepancies are larger than the estimated error of the present work while the all-experimental results mentioned earlier agree with each other over the common E/N ranges, at least in the limit of combined errors of the experimental data sets. The fact that all experimental results have been obtained using various measurement techniques raises the degree of their reliability (as a common experimental data set). It seems that the reason for the discrepancies described above is probably the lack of a consistent set of cross sections for nitrogen.

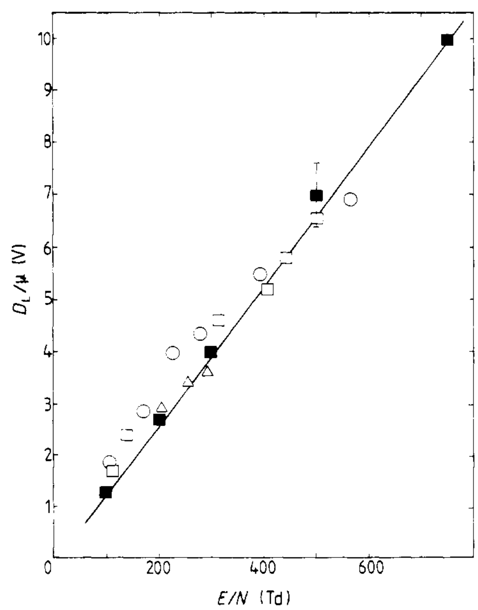

Figure 2. Ratio of longitudinal diffusion coefficient to mobility (D_L/μ) as a function of E/N in nitrogen up to 750 Td. ○, Saelee *et al* (1977); □, Fletcher and Reid (1980); △, Wedding *et al* (1985); ■, present results.

The authors would like to thank Mr R Barczyński for his valuable and willing help in elaborating the numerical part of this work.

The present work was supported in part under project CPBP 01.06.

References

Blevin H A, Fletcher J and Hunter S R 1976 *J. Phys. D: Appl. Phys.* **9** 1671

Braglia G L, Wilhelm J and Winkler R 1985 *Lett. Nuovo Cimento* **44** 257

Crompton R W, Elford M T and Gascoigne J 1965 *Aust. J. Phys.* **18** 409

Crompton R W, Liley B S, McIntosh A I and Hurst C A 1965 *Proc. 7th ICPIG (Beograd)* vol 1 (Beograd: Gradevinsha Knjiga Publishing House) p 86

Fletcher J and Reid I D 1980 *J. Phys. D: Appl. Phys.* **13** 2275

Huxley L G H and Crompton R W 1974 *The Diffusion and Drift of Electrons in Gases* (New York: Wiley)

Kontoleon N, Lucas J and Virr L E 1973 *J. Phys. D: Appl. Phys.* **6** 1237

Nakamura Y 1987 *J. Phys. D: Appl. Phys.* **20** 933

Penetrante B M and Bardsley J N 1984 *J. Phys. D: Appl. Phys.* **17** 1971

Saelee H T and Lucas J 1977 *J. Phys. D: Appl. Phys.* **10** 343

Saelee H T, Lucas J and Limbeek J W 1977 *Solid State Electron. Dev.* **1** 111

Wedding A B, Blevin H A and Fletcher J 1985 *J. Phys. D: Appl. Phys.* **18** 2361