ELECTRON TRANSPORT PARAMETERS OF THE XE-HE MIXTURE GASES IN GAS DISCHARGE

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SUMMARY

The physical characteristics of Xe-He mixture gases in gas discharge are very important to study light source for not only plasma display panels (PDPs) but also other industrial applications. In the present study, authors have calculated and analysed electron transport coefficients of Xe-He mixture gases in gas discharge using a two-term approximation of the Boltzmann equation for energy. These electron transport coefficients in Xe-He mixture gases are electron drift velocity, density-normalized longitudinal diffusion coefficient, transverse diffusion coefficient, and the Townsend first ionization.

Keywords: *gas discharge; mixture gas; Xe-He; electron transport coefficients*

INTRODUCTION

Plasma display panel (PDP) has been widely used to fabricate commercial display, digital display [1-3]. Normally, these DPDs with a size larger than 50 inches and a thickness less than 10 cm include millions small discharge cells [2]. In each cell, a rare gas such as Xe is often used to ignite and extinguish successively. In order to reduce the discharge on set voltage and sustain a uniform glow discharge, He or Ne gas is often added with suitable mixture ratios [2]. Moreover, Xe-He and Xe-Ne mixtures allow the ionization and avalanche effect, which are the most important component material of panel x-ray detectors. Because of above reasons, the physical and chemical data and applications of these mixtures have been reported by many authors. H. Lee *et al.* [2] and ref. therein studied the characteristics of these mixtures with different mixture ratios and suggested the new Xe-He based gas mixture for gas microstrip detector (GMD) structure. Uchida *et al.* [1] have calculated and analysed the electron swarm parameters and related properties in Xe-He and Xe-Ne mixtures using the Boltzmann equation analysis. However, these coefficients are still unavailable over the wide rage of E/N values.

In order to understand and study physical processes and physical characteristics of Xe-Ne gas mixtures in gas discharge, the electron drift velocity, W, density-normalized longitudinal coefficient, ND_L, density-normalized transverse coefficient, ND_T, ratio of longitudinal coefficient (D_L) and electron mobility (μ), and Townsend first ionization coefficient (α/N) in Xe-Ne mixtures were calculated in previously study [4]. With the same purpose, in the present study, these coefficients for Xe-He gas mixtures in gas discharge were also calculated and analysed using the two-term approximation of Boltzmann equation for energy. The results of this study, along with the results in [4] provide the better understanding for these mixtures. These are useful for selecting good choices in many industrial applications using these mixtures.

TWO-TERM APPROXIMATION OF BOLTZMANN EQUATION FOR ENERGY

The following two-term approximation of Boltzmann equation for energy, which was suggested by Tagashira [5] and successfully applied for Xe-Ne [4], BF_3-Ar and BF_3-SiH_4 [6], TEOS-Ar and TEOS-O_2 [7] mixtures, is also briefly represented. The present analysis used the electron swarm method. The electron transport coefficients, which include the

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electron drift velocity, the density-normalized longitudinal diffusion coefficient, the Townsend first ionization coefficient and the electron attachment coefficient are obtained from electron energy distribution function (EEDF). The EEDF can be deduced from solution of Boltzmann's equation. In this study, a backward prolongation technique, along with an initial condition and input data are used for computation. The initial condition and the input data are listed as follows:

The initial conditions are: the gas number density $N = 3.5353\times10^{16}$ cm^{-3}; the partition ratio of the remaining energy after ionization collision is 0.5.

The input data contain electron collision cross sections of objective gases; the temperature of gases; ratio of E/N; ε_{max} and the division number over the range of $0\text{-}\varepsilon_{max}$.

The relationship between the electron transport coefficients with EEDF and electron collision cross sections are given in expressions (1-4).

The electron drift velocity calculated from the solution of electron energy distribution function, f(ε, E/N), of the Boltzmann equation is:

$$W=-\frac{1}{3}\left(\frac{2}{m}\right)^{1/2}\frac{eE}{N}\int_0^{\infty}\frac{\varepsilon}{q_m(\varepsilon)}\frac{df(\varepsilon,E/N)}{d\varepsilon}d\varepsilon. \quad (1)$$

where ε is the electron energy, m is the electron mass, e is the elementary charge and $q_m(\varepsilon)$ is the momentum-transfer cross section.

The density-normalized longitudinal diffusion coefficient is:

$$ND_L=\frac{V_1}{3N}\left(E\int_0^{\infty}\frac{\varepsilon}{q_T}\frac{\partial}{\partial\varepsilon}(F_1\varepsilon^{-1/2})d\varepsilon+\int_0^{\infty}\frac{\varepsilon^{1/2}}{q_T}F_0d\varepsilon\right) \quad (2)$$
$$-(\varpi_0A_2-\varpi_1A_1-\varpi_{02})$$

where V_1 is the speed of the electron, q_T is the total cross section; F_n and ϖ_n $(n = 0, 1, 2)$ are, respectively, the electron energy distributions of various orders and their eigenvalues. V_1, ϖ_n, ϖ_{0n}, and A_n are given by

$$V_1=\left(\frac{2e}{m}\right)^{1/2} \quad (2.1)$$

$$\varpi_0=V_1N\int_0^{\infty}\varepsilon^{1/2}q_1F_0d\varepsilon. \quad (2.2)$$

$$\varpi_1=-\frac{V_1E}{3N}\int_0^{\infty}\frac{\varepsilon}{q_T}\frac{\partial}{\partial\varepsilon}(F_0\varepsilon^{-1/2})d\varepsilon+(\varpi_0A_1-\varpi_{01}). \quad (2.3)$$

$$\varpi_{0n}=V_1N\int_0^{\infty}\varepsilon^{1/2}q_1F_nd\varepsilon. \quad (2.4)$$

$$A_n=\int_0^{\infty}F_nd\varepsilon. \quad (2.5)$$

where q_1 is the ionization cross section.

The Townsend first ionization coefficient is:

$$\alpha/N=\frac{1}{W}\left(\frac{2}{m}\right)^{1/2}\int_I^{\infty}f(\varepsilon,E/N)\varepsilon^{1/2}q_i(\varepsilon)d\varepsilon. \quad (3)$$

where I is the ionization onset energy and $q_i(\varepsilon)$ is the ionization cross section.

The electron attachment coefficient is:

$$\eta/N=\frac{1}{W}\left(\frac{2}{m}\right)^{1/2}\int_0^{\infty}f(\varepsilon,E/N)\varepsilon^{1/2}q_a(\varepsilon)d\varepsilon. \quad (4)$$

where $q_a(\varepsilon)$ is the attachment cross section.

RESULTS AND DISCUSSION

It is necessary to use the consistent electron collision cross section set for both of Xe and He atoms to reproduce the reliable electron transport coefficients in Xe-He mixtures. Therefore, the electron collision cross section for Xe atom determined by Hashimoto and Nakamura [8] and He atom determined by Hayashi [9] were used throughout in this study. The accuracy of the electron collision cross section set for each gas was confirmed to be consistent with all electron transport coefficients in each pure gas. For the sake of comparison and justification the validity of the sets of collision cross sections and that of two-term approximation of the Boltzmann equation, the measured electron transport coefficients in each gas have been showed in Figs. 1-4. The calculated electron transport coefficients in each pure gas are in good agreement with the measurements over the wide E/N range.

Electron drift velocity (W)

The results for the electron drift velocities, W, as functions of E/N for Xe-He mixtures calculated in the E/N range 0.01 < E/N < 800

Td (1 Td = 10^{-17} V.cm^2) by a two-term approximation of the Boltzmann equation are shown in Fig. 1. Slight regions of the NDC (negative differential conductivity) phenomena in 70% and 90% Xe-He mixtures are observed in the E/N range 0.2 < E/N < 3 Td. The NDC is relatively shallow in these cases. The occurrences of these phenomena are due to the Ramsauer-Townsend minimum (RTM) of the elastic momentum transfer cross sections of the Xe atom. In this binary mixtures, the values of W are suggested to be between those of the pure gases over E/N > 1 Td and these values grow linearly over E/N > 10 Td. The increased concentration of Xe atom caused increase of electron drift velocity characteristics of Xe-He mixtures.

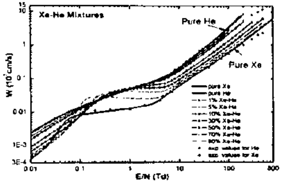

Figure 1. Electron drift velocity, W, as functions of E/N for the Xe-He mixtures with 1%, 5%, 10%, 30%, 50%, 70% and 90% Xe. The solid line and symbols show present W values calculated using a two-term approximation of the Boltzmann equation for the Xe-He mixtures. The symbols show the experimental values for He and Xe from [10].

Density-normalized Longitudinal and Transversal Diffusion Coefficients (ND_L and ND_T)

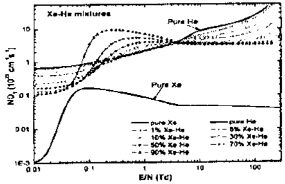

Figure 2. Transverse diffusion coefficient coefficient, ND_T, as functions of E/N for the Xe-He mixtures with 1%, 5%, 10%, 30%, 50%, 70% and 90% Xe. The solid line and symbols show present ND_T values calculated using a two-term approximation of the Boltzmann equation for the Xe-He mixtures.

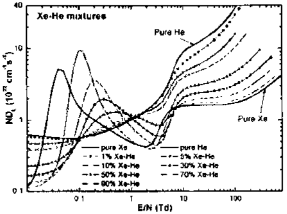

Figure 3. Density-normalized longitudinal diffusion coefficient, ND_L, as functions of E/N for the Xe-He mixtures with 1%, 5%, 10%, 30%, 50%, 70% and 90% Xe. The solid line and symbols show present ND_L values calculated using a two-term approximation of the Boltzmann equation for the Xe-He mixtures.

The results for the density-normalized longitudinal diffusion coefficients, ND_L and transverse diffusion coefficient coefficient, ND_T, as functions of E/N for Xe-He mixtures calculated in the E/N range 0.1 < E/N < 800 Td by a two-term approximation of the Boltzmann equation are shown in Figs. 2 and 3, respectively. In these binary mixtures, the values of ND_L and the ND_T are suggested to be between those of the pure gases over E/N > 8 Td and E/N > 3 Td, respectively. On the other hand, in Fig. 3, the NDC regions are clearly indicated in ND_L curves in Xe-He mixtures and the NDC region moves to the right to higher percentage of Xe.

The Townsend first ionization coefficient

The first Townsend ionization coefficient, α/N, as functions of E/N for Xe-He mixtures calculated by a two-term approximation of the Boltzmann equation are shown in Figs. 4. The