# Electron Drift in mixture of Ar-He in DC glow discharge

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An electron drift in the mixture of Ar/He was studied for a spatially uniform electric field. Functions of the electron energy distribution are found by solving the Boltzmann equation in the two-term approximation and applying the Monte Carlo method. We take into account both elastic and non-elastic collisions of electrons with atoms. Integral characteristics of the electron drift in the gas discharge were calculated, allowing to analyze the drift of electrons on a qualitative level. The results of calculations of the drift characteristics in the mixture of Ar-He are shown at the values of reduced electric field 6<E/N<25 Td. Results of calculations with the Boltzmann equation have a good agreement with calculations by Monte Carlo method.

## 1. Introduction

Diffusion and drift of electrons in gases have been well studied both theoretically and experimentally [1, 2]. But in recent years there has been a great interest in simulation of kinetics of electrons in low-temperature plasma, due to numerous technological applications. It is the numerical simulation that gives accurate and complete information about the characteristics of gas-discharge plasma, which is necessary for understanding and interpreting the properties of dust structures in plasma.

Discharge in a mixture of different gases leads to a very significant change in the characteristics of both the electronic and ionic components of the plasma. Moreover, the characteristics of the gas discharge can be highly in even at very small concentration of impurities. This fact is used in many technical applications of gas discharges, such as gas lasers, plasma display panels, plasma etching reactor and processing of semiconductor materials, light bulbs and flash etc.

## 2. Models

The non-stationary Boltzmann equation in a two-term approximation for isotropic $f_0(u)$ and anisotropic $f_1(u)$ electron energy distribution functions (EEDF) can be written in the following form [3,4]:

$$\frac{\partial}{\partial u}\{\frac{u}{3K}e_0E\frac{\partial f_0}{\partial u}\}+\frac{\partial}{\partial u}(Gf_0)=uHf_0-S_0(u,f_0)-S_w(f_0)$$

$$e_0E\frac{\partial f_0}{\partial u}+Hf_1=0, \qquad (1)$$

where $u = m\mathrm{v}^2/2$ – kinetic energy of electrons, $e_0$ is the charge of an electron.

Here, the coefficients that describe the elastic and inelastic energy losses of electrons in atoms:

$$G(u)=\sum_k 2\xi_k\frac{m}{M_k}u^2Q_k^m(u), \qquad (2)$$

$$H(u)=\sum_{k,l}\xi_kQ_{k,l}^{ex}(u)+\sum_k\xi_kQ_k^{io}(u), \qquad (3)$$

$$K(u)=\sum_k\xi_kQ_k^{io}(u)+H(u), \qquad (4)$$

$$S_0(u)=\sum_{k,l}\xi_k(u+u_{k,l}^{ex})Q_{k,l}^{ex}(u+u_{k,l}^{ex})f_0(u+u_{k,l}^{ex})+ \\ +\sum_k 4\xi_k(2u+u_{k,l}^{io})Q_{k,l}^{io}(2u+u_{k,l}^{io})f_0(2u+u_{k,l}^{io}) \qquad (5)$$

$$S_w(f_0)=f_0/\tau_\alpha \qquad (6)$$

where, $m_e$ is the mass of an electron, $M_k$ is the mass of atom, $\xi_k = N_k/N$ is the partial gas concentration sorts $k = (Ar,He)$, $N=\sum N_k$ - the total density of the gas, $Q_k^m(u)$, $Q_{k,l}^{ex}(u)$ and $Q_k^{io}(u)$ are the momentum, excitation and ionization cross sections of electrons in elastic and inelastic collisions, $S_w(f_0)$ is recombination of electrons on the wall of a discharge tube with radius $R$, $\tau_a = (R/2.405)^2/D_a$ is the characteristic time of electrons losses on the wall, $D_a$ is the coefficient of ambipolar diffusion.

Also EEDF and integral characteristics of the electron drift were calculated by method Monte Carlo [5]. In this method the following conditions were used. For the process of electron drift in the positive column one can assume that total number of births and deaths of electrons are equal. Then the death of electrons on the walls can be taken into account by introducing into the algorithm a rule that for each act of ionization one electron is removed from the whole ensemble. The most logical for the problem of electron drift in the positive column is assumption that only a most energetic electron, which appears in an act of ionization, can leave the ensemble. The average energy of electrons that leave the system can provide a good estimation of the potential of the wall. Thus, the wall potential is determined from the condition that the number of ionization events equal to that of particles' escapes from the system.

For comparison, the distributions of Maxwell, Druyvesteyn and pipe-line model were also obtained. Pipe-line model is the model in which formation of the EEDF is determined by the Joule heating model and non-elastic collisions, while the energy loss of electrons at elastic collisions with atoms are assumed to be negligible [2].

## 3. Results of calculations and discussion

Figure 1 presents electron energy distribution functions for the drift in the mixture and pure of Argon and Helium. It is shown that adding impurities of argon to helium leads to a significant change in the function of the electron distribution.

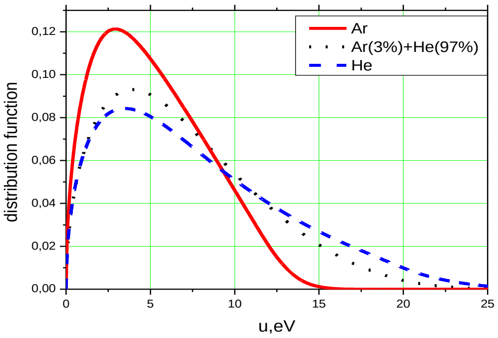

Figure1. Electron energy distribution function by solving the Boltzmann equation at *E/N=24.7 Td*

Figure 2 shows the results of calculations of electron energy distribution functions for the drift at at *E/N=24.7 Td* (first column in Table 1). The figures prove that results of EEDF calculations with the Boltzmann in mixture of Argon (3%) in Helium (97%) at equation have a good agreement with calculations by Monte Carlo method. Monte Carlo simulation took into account the finiteness of wall potential and the loss of electrons on it; when solving the two-term approximation of the Boltzmann equation we used the model of ambipolar diffusion of electrons on the wall. For comparison, the distributions of Maxwell, Druyvesteyn and pipe-line model are also shown.

In Table 1 integral characteristics of the electron drift in a uniform external electric field are shown the drift velocity, average energy, and the rate of input energy for ionization and excitation of atoms. The results of calculations by Monte Carlo method and the two-term approximation of the Boltzmann equation give slightly good agreement.

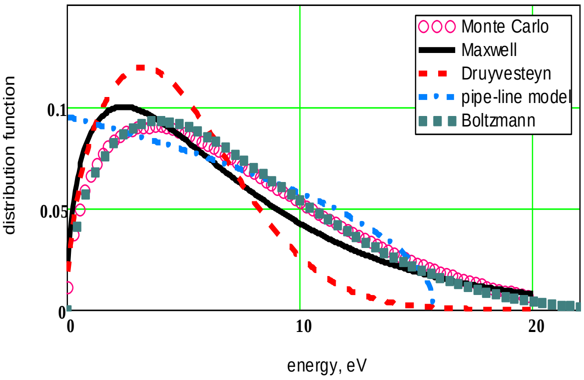

Figure2. Electron energy distribution function in mixture of Argon (3%) and Helium (97%) at *E/N=24.7 Td*

Table 1 - Characteristics of the electron drift in mixture of Argon (3%) and Helium (97%) at different values of electric field.

Surface potential of the tube - $\varphi_{wall}$ , V

Drift velocity - W, km / s

Average Energy - <ε>, eV

The energy factor of Townsend - $eD_\perp / \mu$ , eV

Ionization coefficient of Townsend - $\alpha / N_a$ , $10^{-16}$ cm$^2$

| *E/N, Td* | *24.7* | *12.3* | *6.2* |
|---|---|---|---|
| $\varphi_{wall}$ *, V* | *23.0* | *22.0* | *14.0* |
| *W, km/s , MC* | *49.7* | *26.0* | *13.0* |
| *W, km/s , Boltzmann* | *52.5* | *27.8* | *14.5* |
| $eD_\perp / \mu$ *, eV, MC* | *4.75* | *4.0* | *2.6* |
| $eD_\perp / \mu$ *,eV, Boltzmann* | *5.7* | *4.8* | *2.8* |
| $<\varepsilon>$ *, eV, MC* | *7.3* | *6.7* | *3.6* |
| $<\varepsilon>$ *, eV,Boltzmann* | *6.8* | *6.3* | *3.3* |
| $\alpha / N_a$ *,* $10^{-16}$ *cm*$^2$ | *0.0008* | *0.006* | *0.03* |

## 3. References

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