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THE VALIDITY OF USING THE TRANSPORT PARAMETERS OF THE TOWNSEND DISCHARGE IN THE SIMULATION OF THE RF AND DBD DISCHARGES BY THE FLUID MODEL

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The fluid model has recently been used in several domains like the simulation of the discharges that use the sinusoidal electric field as in the RF and DBD discharges. In this work, the validity of using the transport parameters of the Townsend discharge in the simulation of the ac discharges by the fluid model method is studied. Generally in the ac discharges, the drift velocity of the dc discharge is taken multiplied by $\sin(\omega t)$, and the reaction rates and the diffusion coefficient are taken constant. These suppositions are well tested. It is confirmed that the drift velocity of the dc electric field can be used multiplied by $\sin(\omega t)$ in the simulation of the ac discharges by the fluid model if the first non-equilibrium and the difference on the negative side are neglected. The ionization frequency of the dc field multiplied by $\sin(\omega t)$ should be used with caution in the simulation of the ac discharges and attention should be paid to two main factors: the phase shift and the amplitude. The ionization coefficient of the dc field multiplied by $\sin(\omega t)$ can't be used for several reasons. It is not realistic to take constant reaction rates in the simulation of the ac discharges by the fluid model. The diffusion coefficients of the dc field can be used in the simulation of the ac discharges by the fluid model as constant values only in special conditions.

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1. *Introduction*

There are several methods that simulate dc and ac discharges like the particle-in-cell Monte Carlo collision (PIC/MCC), method based on the solution of the Boltzmann equation and the fluid model. The fluid model is used in different discharges that use the sinusoidal electric field like the capacitively coupled RF discharge (CCP) [1 − 2], the inductively coupled RF discharges (ICP) [3] and the dielectric barrier discharges (DBD) [4 − 6]. These methods need the transport parameters like the drift velocity, the mobility, the ionization frequency and the diffusion coefficients. Application of the fluid model is relatively easy and the plasma of high density can be simulated without much problem. Generally, the transport parameters of the Townsend discharge are used in the simulation by the fluid model since the transport parameters can be determined experimentally only in this type of discharge between parallel plates. The difficulties arise if the geometry of electrodes or the nature of the electric field change.

The aim of this study is to check the validity of using the transport parameters of the Townsend discharge in the simulation of the ac discharges by the fluid model method. This subject is well clarified in the following. The equation used in the different discharges to calculate the densities of the different species of charged particles in the plasma is given by [7]

$$\frac{\partial n_k}{\partial t} + \nabla \cdot \boldsymbol{j}_k = R_{\mathrm{prod},k} - R_{\mathrm{loss},k} \,, \tag{1}$$

where n, $\boldsymbol{j}$ and R denote species number density, flux, and production or loss rate and the index k refers to the different species. The flux equations describe transport based on diffusion and on migration in the electric field (for the charged species) [7]

$$\boldsymbol{j}_k = \mu_k n_k \boldsymbol{E} - D_k \nabla n_k \,, \tag{2}$$

$$v_k = \mu_k E \,, \tag{3}$$

where E is the electric field, μ_k and D_k denote the mobility and diffusion coefficients and v_k is the drift velocity of the different species.

In the case of the RF or DBD discharges, the direction of motion and the oscillatory behavior of the charged species is expressed by the velocity or exactly by electric field (see Eqs. (2) and (3)). The sinusoidal electric field is given by

$$E = E_0 \sin(\omega t) \,, \tag{4}$$

where E_0 is the amplitude of the electric field and ω is the electric field pulsation.

To see if it is correct to use directly the sinusoidal electric field in Eq. (2), a comparison is made between the temporal drift velocity calculated under the ac field and the average drift velocity of the dc field (Townsend discharge) multiplied by $\sin(\omega t)$. The drift velocities in the two cases are calculated by the same code. The amplitude of the sinusoidal electric field used in the simulation equals the electric field used in the calculation of the drift velocity of the dc field. If they are equal, this use is correct. In Eq. (2) the diffusion coefficient is not influenced by the electric field, it is taken to be constant. This coefficient will be calculated under the ac field and it will be seen whether this coefficient is constant in two RF cycles. If it is not, its use must be checked.

In some work, when the ions are supposed to be quasi-static, the ion density is given by [8]

$$\frac{\partial n_i}{\partial t} = v_i n_e \,, \tag{5}$$

where n_i, n_e and ν_i denote the ion density, the electron density and the ionization frequency. For the ionization frequency the comparison is made between the ionization frequency calculated under the ac field and that calculated under the dc field multiplied by $\sin(\omega t)$. If they are equal, the ionization frequency multiplied by $\sin(\omega t)$ can be used directly in the Eqs. (1) and (5) in the case of the sinusoidal electric field.

The spatial density in the case of the Townsend discharge is given by [9]

$$n_e = n_{e0} \exp(\alpha x) \,, \tag{6}$$

where n_e, n_{e0} and α denote the electron density, the initial electron density and the ionization coefficient.

For the ionization coefficient, the comparison is made between the ionization coefficient calculated under the ac field and that calculated under the dc field multiplied by $\sin(\omega t)$. If they are equal, the ionization coefficient multiplied by $\sin(\omega t)$ can be used directly in Eq. (6) in the case of the sinusoidal electric field. Furthermore, in most of the works on the simulation by the fluid model, the reaction rates are taken constant even in the ac field discharges. This supposition is also checked. For more explanation of the comparison see Section 2.4.

Also another condition for the use of the transport parameters in the dc field multiplied by $\sin(\omega t)$ is required. The transport parameters calculated under the ac field must be in steady state since if the transport parameters of the ac field have an increasing or a decreasing behavior, their application is not correct.

The gas used in the simulation is nitrogen. This gas is less frequently used in the CCP RF or DBD discharges, but the aim of this work is not to determine the transport parameters to be used, but only to make the comparison and to show the validity of using the transport parameters of the Townsend discharge in other discharges.

2. *Method of simulation*

The Monte Carlo (MC) method described in Ref. [10] is used in this work. For the treatment of collisions, we use the Monte Carlo collision (MCC) method described in Ref. [11]. In the MCC method, the electrons are treated one after another and the secondary electrons are also taken in account. For each electron, the equations of motion under the electric field are calculated first, then the probability of each collision process is calculated, according to the electron energy. The collision process is selected by producing a random number. As a result, the energy of the test electron decreases according to the nature of the collision process. Each electron makes several collisions. Several parameters, like the energies, the drift velocities and the number of ionizations are registered to be used in the calculations of the transport parameters.

2.1. Equations of motion

The equations of motions in the case of the dc discharge, when the electric field doesn't depend on the time and is anti-parallel to the z-axis ($-E//Oz$), yield new velocities as determined by the Newton's law,

$$\begin{cases} v_{x1} = v_{x0} \\ v_{y1} = v_{y0} \\ v_{z1} = v_{z0} + e\dfrac{E}{m}\Delta t \end{cases} \tag{7}$$

The new positions are determined also by the same law as follows

$$\begin{cases} x_1 = x_0 + v_{x0}\Delta t \\ y_1 = y_0 + v_{y0}\Delta t \\ z_1 = z_0 + v_{z0}\Delta t + e\dfrac{E}{2m}(\Delta t)^2 \end{cases} \tag{8}$$

where e and m are the electron charge and mass, E is the electric field, Δt is the free flight time between two successive collisions calculated as follows [10]

$$t_c = \frac{-1}{\nu_{\mathrm{tot}}}\ln(r_i)\,, \tag{9}$$

where r_i is a random number in the interval $[0-1]$. ν_{tot} is the total collision frequency given in the Eq. (16).

The sinusoidal electric field is given as follows

$$E(t) = E_0 \sin(2\pi f t)\,, \tag{10}$$

where $f = 13.56$ MHz in this work.

In the case of the sinusoidal electric field, Eqs. (7) and (8) are also used, but instead of E, one employs $E(t)$. The electric field changes rapidly and its effect is direct on the motion of electrons. The direct use of $E(t)$ is adopted by making an approximation. The approximation is to assume that the electric field is constant between two successive collisions or it is constant during a small time interval $\mathrm{d}t$.

The new energy under the action of the electric field is given as follows

$$\varepsilon = \frac{1}{2}m_e\big(v_{x1}^2 + v_{y1}^2 + v_{z1}^2\big)\,. \tag{11}$$

Concerning the dispersion of electrons after each collision, a completely isotropic scattering is supposed (often used in the Monte Carlo method). The direction of electrons changes after each collision. It is between two scattering angles which are chosen by

$$\chi_i = \arccos(1 - 2r_i)\,. \tag{12}$$

The azimuthal angle is chosen by

$$\psi_i = 2\pi r_i \tag{13}$$

where r_i is a random number in the interval $[0-1]$.

2.2. *Treatment of collisions*

Each process of collision occurs after a free flight which is characterized by the relative frequency of collisions [10]

$$\nu_k(\varepsilon) = \left(\frac{2\varepsilon}{m_e}\right)^{1/2} \sigma_k(\varepsilon) n_g \,, \tag{14}$$

where $\sigma_k(\varepsilon)$ is the collision cross section and n_g is the gas density.

After generating a random number r, the collision process selected will be the n^{th}, with n such that [10]

$$\sum_{k=1}^{n-1} \frac{\nu_k}{\nu_{\mathrm{tot}}} < r < \sum_{k=1}^{n} \frac{\nu_k}{\nu_{\mathrm{tot}}} \,. \tag{15}$$

As a result, the total frequency of collision will be in the form [10]

$$\nu_{\mathrm{tot}} = \sum \nu_{\mathrm{reals}}(\varepsilon) + \nu_{\mathrm{fictive}}(\varepsilon) = \left\{ \sum \nu_{\mathrm{reals}}(\varepsilon) \right\}_{\max} \,. \tag{16}$$

The sum is run over the number of the collision processes.

2.3. *Electron collision processes*

There are two classes of electron interactions treated in this work: (i) elastic electron-molecule collisions, (ii) inelastic electron-molecule collisions.

2.3.1. **Elastic electron-molecule (e-M) collisions**

In the case of the elastic collisions, supposing that the target particle is in rest, the ratio of the energy before the collision ε and after the collision ε' is given by [10]

$$\frac{\varepsilon'}{\varepsilon} = 1 - 2\frac{m_e}{M}(1 - \cos\chi) \,, \tag{17}$$

where χ is the deviation angle, m_e is the electron mass and M is the molecule mass.

2.3.2. **Inelastic electron-molecule (e-M) interactions**

Three cases of inelastic collision processes are distinguished in this work.

An *excitation* of a molecule to a uniquely defined state (individual rotations, vibrations and electronically excited states) decreases the energy of the test electron instantaneously by the energy required to excite the molecule (the minus sign implies a loss) [11]

$$\Delta\varepsilon = -\varepsilon_{\mathrm{exc}} \tag{18}$$

where $\varepsilon_{\mathrm{exc}}$ is the excitation energy of the molecule.

In the case of *ionization*, the excess energy is shared between the test electron and the electron released from the ionized molecule. The energy change of the test electron becomes [11]

$$\Delta\varepsilon = -\varepsilon_{\mathrm{ion}} - (\varepsilon - \varepsilon_{\mathrm{ion}}) r_i \,, \tag{19}$$

in which r_i is a random number between 0 and 1. The released electron continues with the energy [11]

$$\Delta\varepsilon = (\varepsilon - \varepsilon_{\mathrm{ion}})(1 - r_i) \,. \tag{20}$$

The *attachment* of the test electron leads to the loss of all of its energy [11]

$$\Delta\varepsilon = -\varepsilon \tag{21}$$

2.4. Calculation of the transport parameters

The transport parameters are calculated by averaging the condidered quantities as follows. The drift velocity is given by [12]

$$W_z = \frac{1}{n} \sum_{i=1}^{n} v_{zi} \,, \tag{22}$$

where v_{zi} are the drift velocities of electrons (see Eq. (7)) and n is the number of electrons present at the instant t.

The ionization rate is calculated as follows [10]

$$k = \left(\frac{2}{m_e}\right)^{1/2} \int_0^{\infty} \varepsilon f(\varepsilon) \sigma(\varepsilon) \mathrm{d}\varepsilon \,, \tag{23}$$

where $f(\varepsilon)$ is the electron energy distribution function, σ is the cross section and m_e is the electron mass.

The first Townsend ionization coefficient is calculated as follows

$$\alpha = k / W_z \,. \tag{24}$$

The diffusion coefficients are calculated using the following formula [13]

$$D = \frac{1}{2\,!} \frac{\mathrm{d}}{\mathrm{d}t} \langle r^* r^* \rangle \,. \tag{25}$$

where $r^* = r - \langle r \rangle$. For the comparison between the transport parameters of the dc and the ac discharges, the transport parameters are first calculated in the case of the dc discharge, and the average values are multiplied by $\sin(\omega t)$ as follows

$$W_z(t) = W_{z0} \sin(\omega t) \,, \tag{26}$$

$$f_{\mathrm{ion}}(t) = f_{\mathrm{ion}\,0} |\sin(\omega t)| \,, \tag{27}$$

where W_{z0} and $f_{\mathrm{ion}\,0}$ are the average transport parameters calculated in the case of the dc discharge. The transport parameters calculated using Eqs. (26) and (27) will be compared with the temporal transport parameters calculated under the ac field. The ionization coefficient and the diffusion coefficients are not multiplied by $\sin(\omega t)$ since they do not have the sinusoidal behavior as will be shown.

In Table 1 are presented the different electron-collisions processes of the nitrogen used in the simulation. The reactions considered in this work are: the momentum transfer, 1 molecule rotation, 9 molecule vibrations, 2 vibrational excitations, 11 excitations and total ionization. They are listed in Table 1.

TABLE 1. Considered reactions of $\mathrm{N_2}$ *with the levels and energy range [14].*

Reactions	Levels	Energy range (eV)
Momentum transfer		0 – 1000
Molecule rotation		0.03 – 3.6
Molecule vibration	$v = 1$	0.3 – 50
Molecule vibration	$v = 1$	1.65 – 3.6
Molecule vibration	$v = 2$	1.8 – 3.5
Molecule vibration	$v = 3$	2 – 3.3
Molecule vibration	$v = 4$	2.1 – 3.2
Molecule vibration	$v = 5$	2.2 – 3.3
Molecule vibration	$v = 6$	2.3 – 3.1
Molecule vibration	$v = 7$	2.4 – 3.4
Molecule vibration	$v = 8$	2.6 – 3.4
Molecule vibrationnal excitation		7 – 70
Molecule vibrationnal excitation		7.3 – 70
Molecule excitation		8 – 70
Molecule excitation		8 – 100
Molecule excitation		8.1 – 70
Molecule excitation		9 – 70
Molecule excitation		9 – 150
Molecule excitation		9 – 1000
Molecule excitation		9.1 – 50
Molecule excitation		11.5 – 100
Molecule excitation		12.92 – 50
Molecule excitation		13 – 1000
Molecule excitation		14 – 1000
Total ionization		16 – 1500

3. *Results and discussion*

For the comparison of the results with the available results in literature, the drift velocity, the energy and the ionization coefficients are calculated by the code under the dc field in the case of nitrogen and compared in Table 2 with the calculations of Phelps et Pitchford [15] (Boltzmann method).

Figure 1 shows the variation of the applied voltage in two cycles in the case of the ac field of different amplitudes (E_0 = 150, 1000, 1500 Td, where 1Td = 10^{-19} Vm^2).

TABLE 2. Different transport parameters of N_2 *calculated and compared with the calculations of Phelps and Pitchford [15].*

	E/N(Td)	ε (eV)	V_d (m/s)	α m^2
Phelps et al.	150	3.81	1.48×10^5	6.93×10^{-23}
This work	150	3.77	1.46×10^5	9.6×10^{-23}
Phelps et al.	1000	15.72	6.43×10^5	1.58×10^{-20}
This work	1000	16.56	7.26×10^5	1.69×10^{-20}
Phelps et al.	1500	22.4	8.55×10^5	2.54×10^{-20}
This work	1500	24.44	1.01×10^5	2.41×10^{-20}

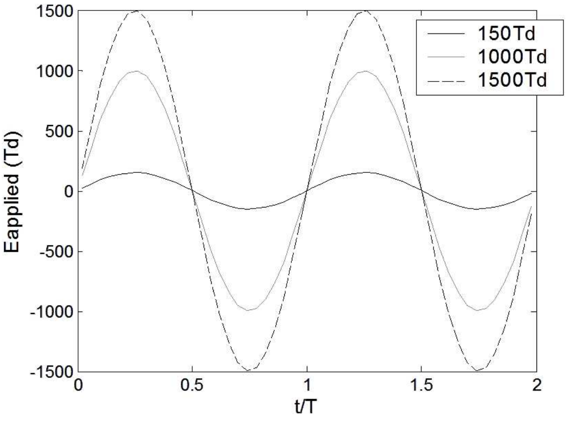


Fig. 1. The applied voltage in the case of the ac field in two cycles with E_0 = 150, 1000 *and* 1500 Td.

3.1. *The validity of using the drift velocity multiplied by* $\sin(\omega t)$

Figure 2 shows the comparison between the drift velocity calculated under the ac field and that calculated under the dc field multiplied by $\sin(\omega t)$ in two cycles in

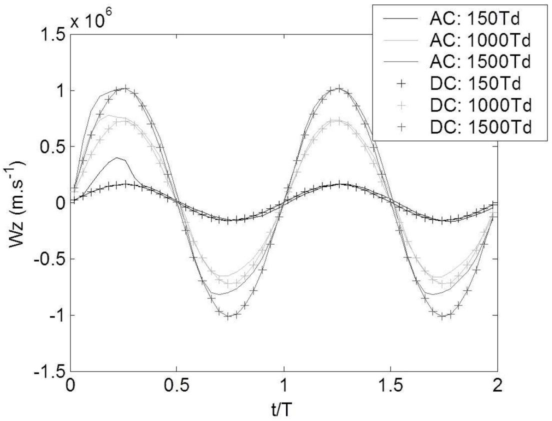


Fig. 2. Drift velocity in two cycles for the nitrogen: solid line for ac field, solid line with plus sign for dc field multiplied by $\sin(\omega t)$*. Black:* 150 Td*, blue:* 1000 Td*, red:* 1500 Td.

the case of nitrogen for different values of the electric field (E_0 = 150, 1000, 1500 Td). The drift velocity is generally used in the calculation of the electron density (see Eqs. (1), (2) and (3)). For the study of the steady state of the drift velocity, one is interested only in the case of the ac field. In the first moments, the drift velocity takes a time to achieve the steady state. In this time, the drift velocity increases but after a few moments, the electric field drives electrons to the steady state and the drift velocity after the region of non-equilibrium has the regular sinusoidal behavior. The region of the non-equilibrium decreases if the amplitude of the electric field increases. That the steady state is sustained means that the condition of using the drift velocity of the dc field multiplied by $\sin(\omega t)$ is good. When the steady state is sustained, the drift velocity of the ac field is fused with that of the dc field multiplied by $\sin(\omega t)$, especially in the case of low values of the electric field (150 Td). For high values of the electric field on the positive side, the drift velocities of the ac and dc fields remain always equal and fused, but on the negative side, the drift velocity of the ac field is lower than that of the dc field. The difference between the two types of the drift velocities on the negative side increases if the electric field increases. As a result, for low values of the electric field the drift velocity of the dc field (of the Townsend discharge) multiplied by $\sin(\omega t)$ can be used (for example in Eq. (1) in the case of the ac fields) without any approximation after the region of non-equilibrium. But for high values of the electric field, it can be used only if the difference on the negative side is neglected. The region of non-equilibrium is generally negligible for very high values of the electric field. The diminution on the negative side influences also the ionization as will be shown.

3.2. The validity of using the ionization frequency multiplied by $\sin(\omega t)$

Figure 3 shows the comparison between the ionization frequency calculated under the ac field and that calculated under the dc field multiplied by $\sin(\omega t)$ in

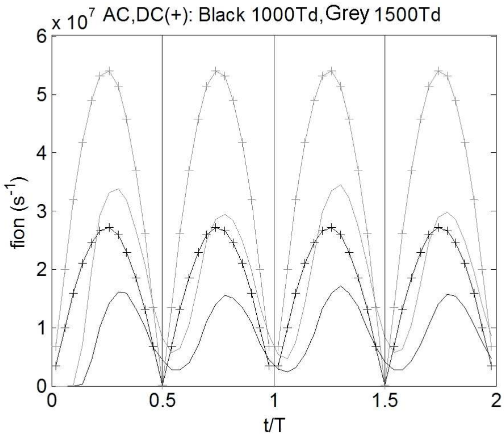


Fig. 3. Ionization frequency in two cycles for the nitrogen: solid line for ac field, solid line with plus sign for dc field multiplied by $\sin(\omega t)$. *Black:* 1000 Td, *blue:* 1500 Td.

two cycles in the case of the nitrogen and different values of the electric field ($E_0 =$ 1000, 1500 Td). Generally, the ionization frequency is used in the calculation of the temporal electron and ion densities (see Eqs. (1) and (5)). In Fig. 3 it appears that the ionization frequency of the dc discharge multiplied by $\sin(\omega t)$ can't be used in the case ac discharges for the following four reasons.

First, the amplitudes of the ionization frequency in the case of the dc field multiplied by $\sin(\omega t)$ are very large compared to those of the ac field (see Table 3). The difference in the case $E/N = 1000$ Td is 41% and in the case of $E/N = 1500$ Td 36%.

TABLE 3. ionization frequency (s^{-1}) *in the ac and dc fields at* $E/N = 1000$ *and* 1500 Td.

E/N (Td)	1000	1500
DC field	2.71×10^7	5.40×10^7
AC field	1.58×10^7	3.45×10^7

The second reason is when the ionization frequency in the case of the ac field is delayed when compared to that of the dc field multiplied by $\sin(\omega t)$. The maxima of the ionization frequency are not at $t/T = 0.25$, 0.75, 1.25 and 1.75, and also the minima are not at $t/T = 0.5$, 1, 1.5 and 2. Therefore, the distributions of ions in the plasma using the two types of the ionization frequency are not the same.

Thirdly, in the case of the ac field at $t/T = 0.5$, 1, 1.5 and 2 the ionization frequency is not zero as opposed to the case of using the transport parameters of the dc field multiplied by $\sin(\omega t)$. The ionization is not zero in these instances only in certain conditions, for relatively low values of the electric field when the ionization is weak.

The fourth reason is that in the case of the ac field the ionization frequency for $t/T = 0.25$ and 1.25 is not equal to the ionization frequency at $t/T = 0.75$ and 1.75.

From the preceding we can conclude that there is a need to improve Eqs. (1) and (5).

3.3. The validity of using the ionization coefficient multiplied by $\sin(\omega t)$

Figure 4 shows the variation of the ionization coefficient calculated under the ac field in two cycles in the case of nitrogen and for different values of the electric field ($E_0 = 1000$, 1500 Td). The ionization coefficient is generally used to determine the spatial electron density (see Eq. 6). The ionization coefficient of the dc field multiplied by $\sin(\omega t)$ can't be used in the case of the ac field as Fig. 4 shows. This physical quantity has not a sinusoidal behavior in the case of the ac field and it is not comparable to that using the dc field. For $E/N = 1000$ Td it is constant. There is only an increase and decrease at $t/T = 1$, for $E/N = 1500$ Td it has constant values except at $t/T = 0.5$, 1, 1.5 and 2 it has a little increase and decrease and it returns to the constant values. This behavior of the ionization coefficient is due to the phase shift between the drift velocity and ionization frequency. Furthermore, the ionization coefficients are approximately equal for different values of the electric field, except at $t/T = 1$. At $E/N = 1000$ Td it has extreme values and reaches approximately $7.38 \times 10^{-19}\mathrm{m}^2$. Furthermore, the reactions rates like the ionization frequency and the ionization coefficient have not constant values. In most of the works that simulate these processes using the fluid model in the ac discharges, the reactions rates are assumed to be constant (see for example Refs. [1], [7] and [16]). However, it is not realistic to take the constant values of the reactions rates.

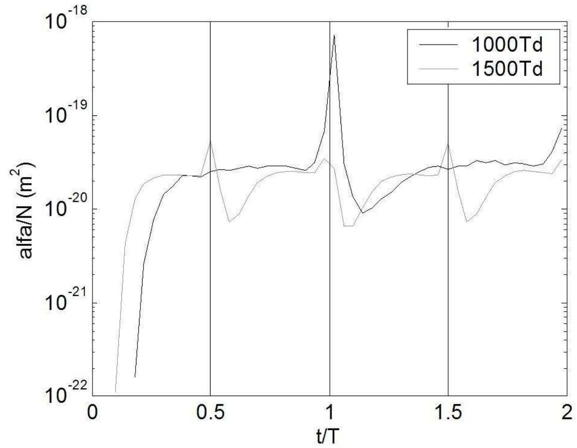
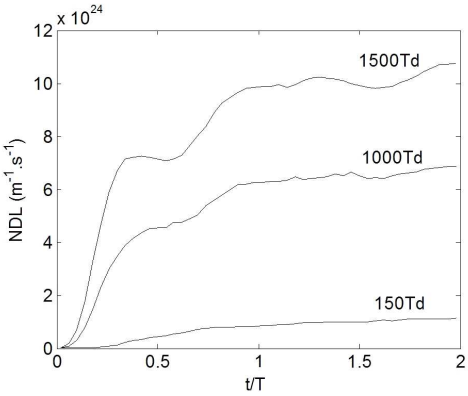


Fig. 4. Ionization coefficient under the ac field in two cycles for the nitrogen at $E_0 = 1000$ *and* 1500 Td.

3.4. The validity of using constant diffusion coefficients in the continuity equation

The diffusion coefficients are very important in the calculation of the electron and the ion densities (see Eq. (1)). In the literature, the diffusion coefficient is used in the continuity equation (Eq. (1)) as a constant value even in the simulation of the ac discharges (like DBD discharges, see for example Ref. [7], and RF discharges, see for example Ref. [16]); this supposition is tested in this work by calculating the diffusion coefficients in the case of the ac field.

Figures 5 and 6 show the variation of the longitudinal diffusion coefficient and the transverse diffusion coefficient, respectively, calculated under the ac field in two cycles in the case of the nitrogen, for different values of the electric field ($E_0 = 150$, 1000, 1500 Td).



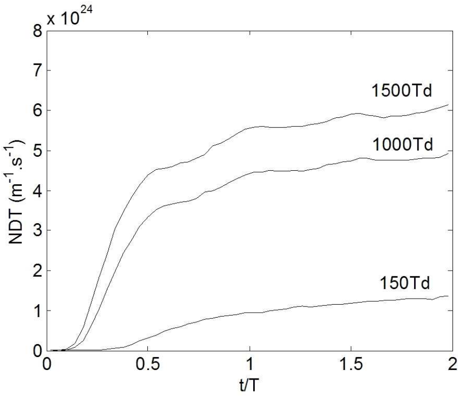


Fig. 5 (left). Longitudinal diffusion coefficient in two cycles under the ac field for the nitrogen at $E_0 = 150$, 1000 *and* 1500 Td.

Fig. 6. Transverse diffusion coefficient in two cycles under the ac field for the nitrogen at $E_0 = 150$, 1000 *and* 1500 Td.

The first remark is that the diffusion coefficients in the case of the ac electric field have not the sinusoidal behavior. Also, depending on the value of the electric field, the coefficients tend toward a steady state, in particular in the second cycle. For low values of the electric field, the steady state is not sustained ($E_0 = 150$ Td) and it needs more time, but for high values of the electric field, an approximately steady state is sustained with small deviations. Also, the diffusion coefficients of the ac field are not equal to the diffusion coefficient calculated in the dc discharge. As examples, this coefficient was averaged over the second cycle and compared with the coefficient calculated in the case of the dc discharge, as shown Tables 4 and 5 for the longitudinal and the transverse diffusion coefficients, respectively, and for three values of the electric field $E/N = 150$, 1000 and 1500 Td.

As it is shown, the diffusion coefficients in the case of the dc electric field are greater than those calculated in the case of the ac field. The difference decreases if the electric field is high when the steady state is sustained. Therefore, the diffusion coefficients of the dc field can be used in the case of the ac field only for high values of the electric field if the difference is neglected, and after the second cycle.

TABLE 4. Longitudinal diffusion coefficient in ac and dc fields at $E/N = 150$, 1000 *and* 1500 Td.

E/N (Td)	150	1000	1500
DC field	1.68×10^{23}	7.38×10^{24}	1.12×10^{25}
AC field	1.00×10^{24}	6.52×10^{24}	1.01×10^{25}

TABLE 5. Transverse diffusion coefficient in ac and dc fields at $E/N = 150$, 1000 *and* 1500 Td.

E/N (Td)	150	1000	1500
DC field	2.22×10^{23}	5.23×10^{24}	6.59×10^{24}
AC field	1.16×10^{24}	4.66×10^{24}	7.58×10^{24}

4. *Conclusion*

The validity of using the transport parameters of the Townsend discharge in the simulation of the ac discharges by the fluid model is studied. It is confirmed that the drift velocity of the dc electric field can be used multiplied by $\sin(\omega t)$ in the simulation of the ac discharges by the fluid model if the first non-equilibrium and the difference in the negative side are neglected.

The ionization frequency of the dc field multiplied by $\sin(\omega t)$ needs more attention when used in the simulation of the ac discharges since there are two main factors to be well studied, the phase shift and the amplitude.

The ionization coefficient of the dc field multiplied by $\sin(\omega t)$ can't be used for several reasons.

It is not real to take constant reaction rates in the simulation of the ac discharges by the fluid model.

The diffusion coefficients of the dc field can be used in the case of the simulation of the ac discharges by the fluid model as constant values only in special conditions.

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PRIMJENLJIVOST TRANSPORTNIH PARAMETARA TOWNSENDOVOG IZBOJA U SIMULACIJAMA RF I DBD IZBOJA U MODELU TEKUĆINE

Model tekućine se u posljednje vrijeme rabi u više područja za simulaciju izboja sa sinusoidalnim električnim poljem, poput RF i DBD izboja. U ovom se radu proučava primjenljivost transportnih parametara Townsendovog izboja u simulaciji izboja izmjeničnom strujom (AC) u modelu tekućine. Općenito se u AC izbojima uzima posmična brzina u izboju stalnom strujom (DC) pomnožena sa $\sin(\omega t)$ a brzine reakcija i difuzijski koeficijent uzimaju se stalnima. Te se pretpostavke pažljivo ispituju. Potvrđuje se da je ispravno uzeti posmičnu brzinu DC polja pomnoženu sa $\sin(\omega t)$ u simulacijama AC izboja u modelu tekućine ako se zanemare prvo neravnotežno stanje i razlike na negativnoj strani. Frekvencija ionizacije DC polja pomnožena sa $\sin(\omega t)$ može se rabiti u simulacijama AC izboja ali s oprezom pazeći na dva faktora: pomak faze i amplitudu. Ionizacijski koeficijent DC izboja pomnožen sa $\sin(\omega t)$ ne može se rabiti u simulacijama AC izboja zbog više razloga. Nije realno pretpostaviti stalne brzine reakcija u simulacijama AC izboja u modelu tekućina. Vrijednosti difuzijskih koeficijenata DC izboja mogu se rabiti kao stalne vrijednosti u AC izbojima u modelu tekućine samo u posebnim uvjetima.