Studying Effect of Temperature on Electron Transport Parameter and Coefficients in CF_3I Mixture with N_2O

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Abstract

In this study, the electron transport coefficients in CF3I gas and their mix with N2O are calculated by using two-term approximation of Boltzmann equation (BEq) in the E / N extent of (100 - 700) Td for the first time. This work also examines the effect of temperature change on these parameters, including the electron mean energy (ϵM), density normalized mobility (μN), longitudinal diffusion coefficient (NDL), ionization (α/N) and attachment coefficients (η/N).To our knowledge, no previous work has studied electron transport parameters and coefficients of these mixtures. The concentration of N2O in the mixture is ranged from 20% to 80% and the gas temperature range is 300-3500 K under 1atm. Our analysis explores that for concentrations below 20%, of electron transport parameters and coefficients be comparatively approaches to pure CF3I values. In contrast, the effect of adding N2O in the mixture increases the ionization coefficients, while the attachment coefficient decreases because CF3I is more electronically than N2O and the properties of CF3I gas dominate the mixture. As it seems clear the dependence of electron transport coefficients on the temperature of mixture.

Key Words: Electron Transport Parameters, Electron Mean Energy, CF3I, CF3I Mixture with N2O, Density Normalized Mobility.

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Introduction

Through the dielectric properties of the gases used in the HV instruments and other applications, the studies and computations of electron transport coefficients are important of these gases [1-3]. Trifluorododethane has recently been employed as a potential high-voltage dielectric [4,5]. It is an "environmentally friendly" gas for their low greenhouse effect because of the weak bond for C-I, and extremely short atmospherically life [6]. As well that Trifluoromethane gas is a nominee alternative to bromotrifluoromethane (CF_3Br), which is utilized in fire-fighting aircraft [7].

It also provides a large amount of CF_3 in the plasma by utilizing the effect of electron separation and the ionization. It has a dielectric strength similar to SF_6,which is most important.

Further, additional merit of it, is, the less mischievous environmental influence compared to SF_6, which was the most widely used insulating gas to date. Nevertheless, the boiling point of CF_3I is aloft as mentioned in the reference [8, 9]. For the sake of reducing the boiling point, the CF_3I gas is mixed with other gases.

That is necessary to use CF_3I in insulation applications. Given the prospective importance of CF_3I and its mixtures as an alternative to SF_6, there are only infrequent studies on Electron Transfer Parameters (ETP) for CF_3I gas mixtures [10, 11], thus so more studies are necessary.

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The purpose of this study to propose CF3I gas and its mixtures with N2O as an alternative to SF6, as an applicable gaseous insulator. In this paper, we studied the effect of changing the temperature of the mixture on transport parameters and coefficients. Also, calculated and analyzed the electron transport parameters and coefficients, which include the electron mean energy ϵ_M, μN, NDL, α/N and η/N of pure CF3I and its mixtures with N2O by using a numerical solution of the BE for a vast range of E/N. The present paper presents possibility to use CF3I-N2O gas mixtures to evaluate the best potential for applications in dielectric gases in power devices.

Theory

In this study, the (ETP) in pure CF_3I and its mixture with N_2O were calculated using the numerical solution of the BE of a two-term approximation. Generally, the (ETP) are functions for the reduced electric field (E/N), which can be calculated by solving BE through the essential collision cross sections data. By integration the term that includes the electron distribution function (EEDF), $f(\epsilon, E/N)$, is normalized by [12].

$$\int_0^\infty f(\epsilon, E/N)d\epsilon \cong 1 \qquad (1)$$

whereϵrepresents electron energyand α is collision factor. So can take The BE equation in the ionization gas the following formula [13-16].

$$\frac{\partial f}{\partial t} + v.\nabla_r f - \frac{eE}{m}.\nabla_v = \alpha(f) \qquad (2)$$

The electron rate coefficients are represented by the following equations, [17, 18].

$$k_i = \sqrt{\frac{2e}{m}} \int_0^\infty \epsilon q_i(\epsilon)d\epsilon \qquad (3)$$

$$k_a = \sqrt{\frac{2e}{m}} \int_0^\infty \epsilon q_a(\epsilon)d\epsilon \qquad (4)$$

In the above equations, k_i gives rate of ionization and k_a the rate of attachment. We can also define k_{ex} that represents the rate of electronic excitation in the following equations,

$$k_{ex} = \sqrt{\frac{2e}{m}} \int_0^\infty \epsilon q_{ex}(\epsilon)d\epsilon \qquad (5)$$

In the equations above, q_i, q_a and q_{ex} represent the cross-sections of ionization, attachment and excitation respectively. It is also possible to calculate additional parameters using the rate coefficients and electron energy, where ionization coefficients (α) and attachment coefficients (η) can be calculated as:

$$\alpha = k_i \; N/v_D \qquad (6)$$

$$\eta = k_a \; N/v_D \qquad (7)$$

The first Townsend is another definition of the ionization coefficient given by the following equation [19]:

$$\alpha/N = \frac{1}{v_D}\sqrt{\frac{2e}{m}} \int_0^\infty \epsilon q_i(\epsilon)d\epsilon \qquad (8)$$

The equation below is defined by the electron attachment coefficient.

$$\eta/N = \frac{1}{v_D}\sqrt{\frac{2e}{m}} \int_0^\infty \epsilon q_a(\epsilon)d\epsilon \qquad (9)$$

v_D represents the drift velocity can be defined by the following equation [20.21]

$$v_D = -\frac{1}{3}\sqrt{\frac{2e}{m}\frac{E}{N}} \int_0^\infty \frac{1}{Q_m(\epsilon)}\frac{\partial f}{\partial \epsilon}\epsilon d\epsilon \qquad (10)$$

The electron mobility, which represents the ability of electrons or charged particles to move in a medium can be written under the influence of an electric field pulling it. [22]

$$\mu_e = -\frac{1}{3N}\sqrt{\frac{2e}{m}} \int_0^\infty \frac{1}{Q_m(\epsilon)}\frac{\partial f}{\partial \epsilon}\epsilon d\epsilon \qquad (11)$$

The electron mean energyϵ_M and diffusion coefficient can be expressed and calculated by the following equations [23,24,25]

$$\epsilon_M = \int_0^\infty \sqrt[2]{\epsilon^3} f(\epsilon)d\epsilon \qquad (12)$$

$$D = \frac{2}{3m}\frac{\epsilon_M}{Q_m}(13)$$

Result and Discussion

In this part we display the results about the behavior of electron transport parameters and coefficients of a pure CF_3I, N_2O and CF_3I- N_2O gas mixture with E/N, which affected by temperature change and the concentrations of gas mixtures.

Electron mean energy

The computed results of electron mean energy (ϵ_M), is presented in Fig. (1) for pure CF_3I gas at various gas temperatures as function of E/N. Generally, it is seen that for the same temperature the electron mean energy increased smoothly with increasing E/N for pure CF_3I gas. As can be seen from the data in Fig. 1, the $\epsilon_M$increases by increasing the temperature at the same E/N, where the lowest ϵ_M value is happening at the temperature 300 K and the highest value is at 3500 K.

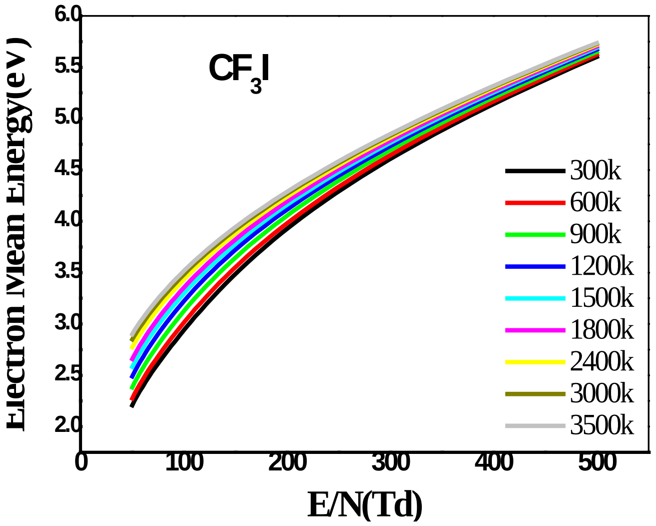

Figure 1: The relationship between ϵ_M and E/N for pure CF_3I gas at different temperatures

The variation of the ϵ_M with E/N of various mixing ratios in CF_3I–N_2O is shown in Fig. (2). Also, it shows the effect of adding CF_3I gas to the mix with N_2O on ϵ_M at values are relatively close to pure CF_3I, that is, at low N_2O concentrations. The ϵ_M decreases as the concentration of CF_3I increases in the mixture for $E/N > 100$ Td. The addition of CF_3I into the admixture increases the peak of the EEDF in the low energy domain, indicating the increase of the numerical value of the low energy of electrons. Therefore, the ϵ_M should reduce with the increase of the CF_3I proportion in the mixture, which is elucidated in the Fig. However, at values of $E/N < 100$ Td the behavior is inversely proportional, indicating that the increase of ϵ_M whenever the concentration of CF_3I increased in the mixture.

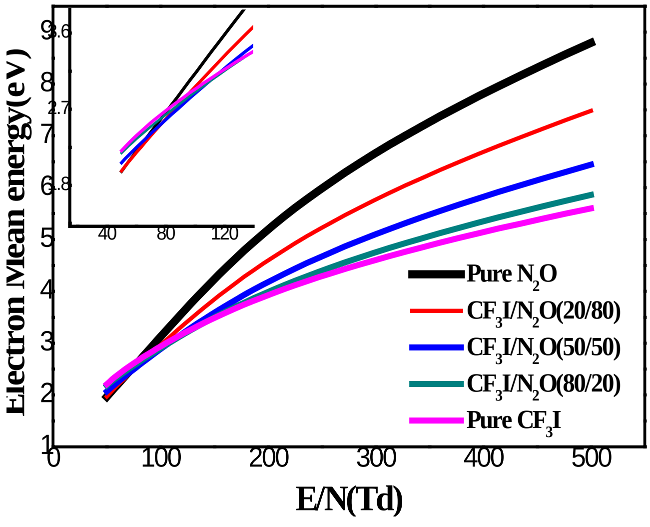

Figure 2: The relation between ϵ_M and E/N for a CF_3I gas mixture with N_2O at different concentrations

The dependence of ϵ_M of CF_3I–N_2O mixtures on the gas temperature for various concentrations of N_2O at 50 Td is shown in Fig. (3). We note that increase the electron mean energy values with increasing the temperature. Furthermore, the mixture curves of ϵ_M vs. temperature lay between the curves of the pure gases. As the CF_3I content decreases in the mixtures the curve is moved down close to pure N_2O.

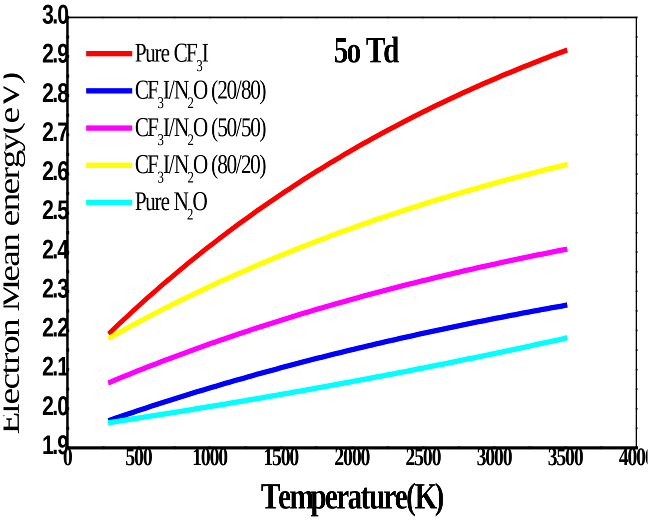

Figure 3: The relation between ϵ_M and the temperature of the CF_3I and N_2O gas mixture with different concentrations

Density Normalized Mobility(μN)

Fig. (4) explains the (μN) dependence on the reduced electric field E/N for several diverse values of temperature. It is observe that the general behavior of the (μN) for pure CF_3I gas is inversely proportional with E/N due to loss of electron energy during collisions. The μN is clearly reduced at $E/N \leq 200$ Td in a manner that $\mu N \propto 1/\sqrt{E/N}$ and then decreases slightly when $E/N > 200$ Td. The figure illuminates that μN decreases with increasing the temperature of the gas at the same E/N.

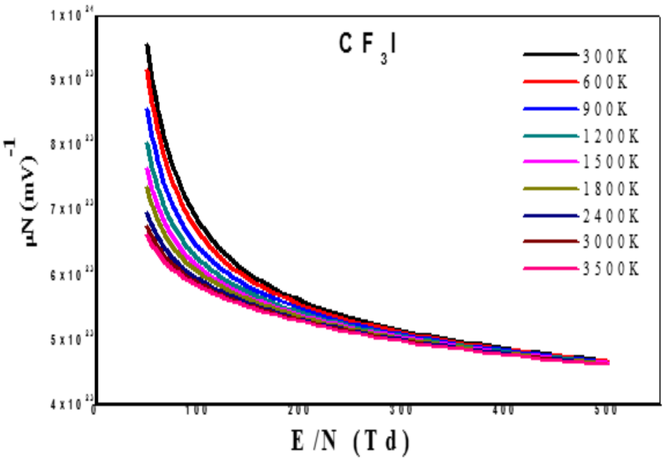

Figure 4: The relationship between μN and E/N for pure CF_3I gas and for different temperatures

The effect of temperature with μN for the mixtures of N_2O gas and CF_3I is shown in Fig. (5). Note that μN increases with increasing N_2O concentrations in the mixture, and is less valuable as pure of the CF_3I.

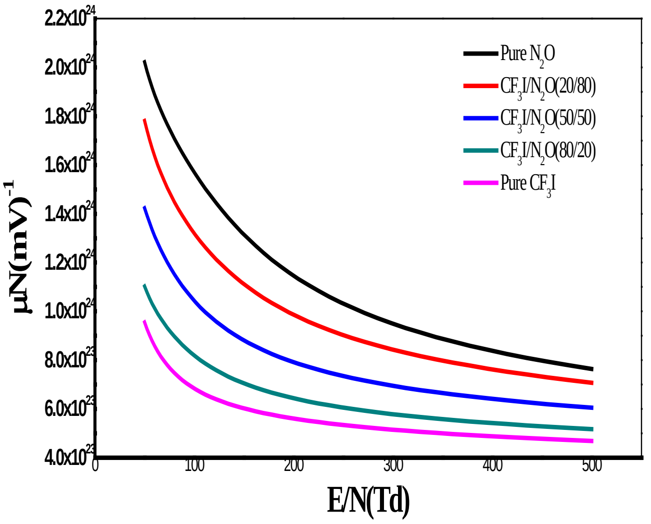

Figure 5: The relationship between μN and E/N for different concentrations of the CF_3I and N_2O mixture

Fig. (6) illustrates similar behavior as in the previous Fig. Nevertheless, here it is shown the relationship between μN and CF_3I concentration with N_2O at different temperatures. As the temperature increased the curve of the relationship move down.

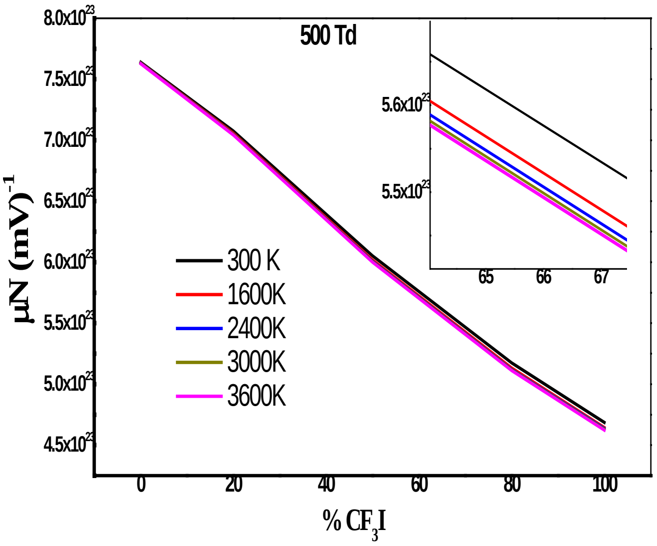

Figure 6: The relationship between μN and CF_3I concentration in the mixture with N_2O at different temperatures

Longitudinal diffusion coefficients (DN_L)

Fig. (7) is a plot of the DN_L dependence on the reduced electric field E/N for CF_3I gas. Obviously, DN_L increases by an increased E/N. The increase is slow at $E/N < 200$ Td, and increases rapidly when $E/N > 200$ Td. For similar E/N and concentration of CF_3I gas note that the DN_L increases by increasing the temperature.

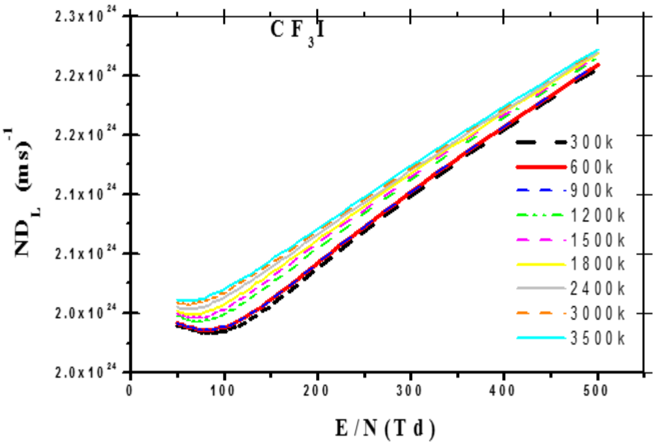

Figure 7: The dependence of DN_L on E / N for CF_3I gas and for different temperatures

Fig. (8) shows the decrease of longitudinal diffusion coefficient DN_L by increasing the concentration of the CF_3I in the mixture of constant reduced electric field and several temperatures. The reason for this behavior is due to the strong electron attachment cross section of CF_3I for the low energy electrons. This is why DN_L is higher for the low CF_3I concentrations. Apparently, the DN_L increases as the temperature increased for the same concentrations of the CF_3I in the mixture.

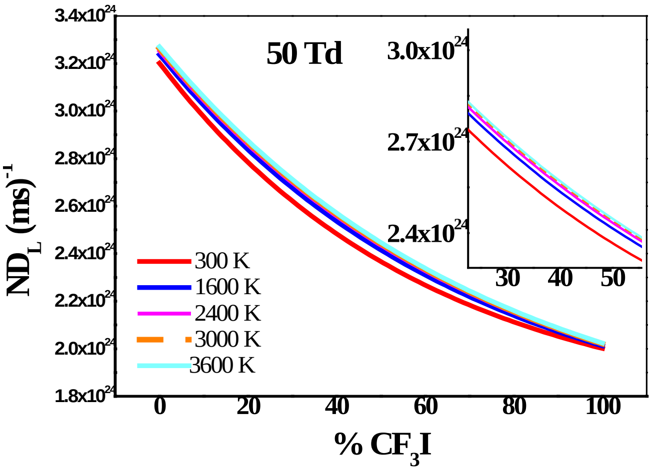

Figure 8: The dependence of DN_L on the CF_3I concentration in the mixture and for different temperatures

Ionization coefficient (α/N)

Fig. (9) shows the dependence of α/N on the reduced electric field for pure CF_3I gas at different temperatures (300–3500 K) and 1 atm. Distinctly, as E/N increases the ionization coefficient will exponentially raise. As well as, the α/N increases as the gas temperature increased for constant E/N. However, the curves of $\alpha/N$are roughly coincide for the 300 and 600 Ksince the dissociation of CF_3I occurs hardly at temperatures below 1000 K. And so with another increase in CF_3I temperature the α/Nalso increased.

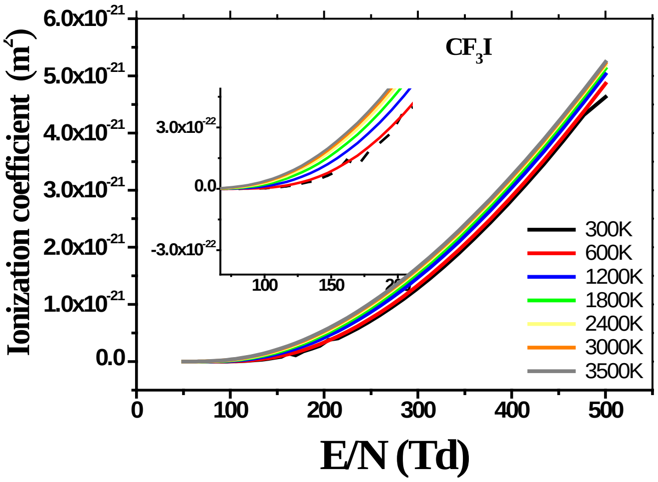

Fig 9: Theα/Ndependence on reduced electric field for pure CF_3I gas at different temperatures

Fig. 10 shows the variations of α/Nat differentratio of CF_3I–N_2O mixtures with E/N at 300 K temperature. The observed increase in E of a low CF_3I ratio in the mixtures can be attributed primarily to two reasons: firstly, the ionization cross section for the CF_3I gas is low and secondly, the high density of electrons at higher energy for the case of the rising N_2O concentrations in mixture.

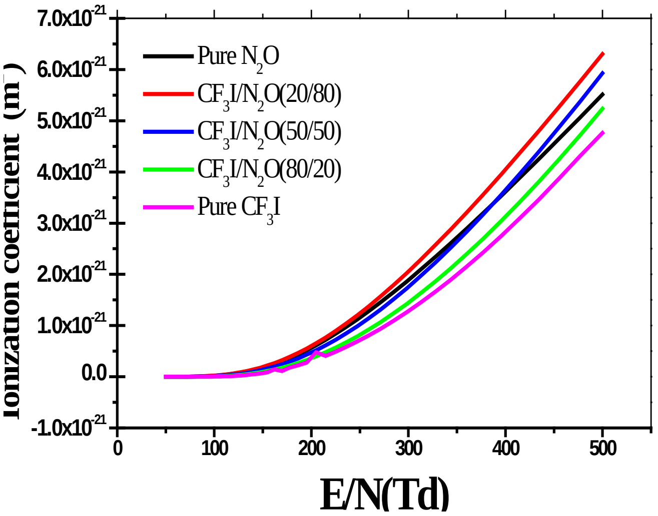

Figure 10: The α/N dependence on the reduced electric field for different ratios of CF_3I–N_2O gas mixture at 300K and 1 atm

Reduced attachment coefficient η/N

Fig. 11 shows the η/N dependence on the reduced electric field at various temperatures (300–3500 K). At temperatures below1000 K, the η/N curves between 300 and 600 K are roughly the same due to the absence of disintegration of CF_3I. It has been observed that separating CF_3I into smaller molecules and atoms take place with increasing the temperature of the CF_3I gas, then the attachment coefficient will be diminishing significantly.

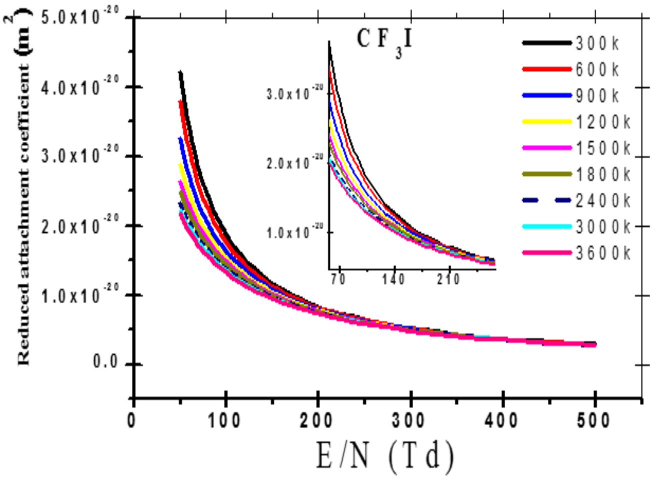

Figure 11: Dependence of reduced attachment coefficient upon the reduced electric field at assorted temperatures for pure CF_3I gas

Fig. 12 shows the η/N for CF_3I–N_2O mixture with E/N at dissimilar ratios. The η/Nhas a different inclination from α/Nbecause of attachment strength of electron of CF_3I, its separate molecules, and $\eta/N$of N_2O is lower than of CF_3I. Even so, the attachment cross sections of CF_3I and its separated particles are comparatively considerable at the low energies because higher the ratio of N_2O will increase the electron density in these energies.

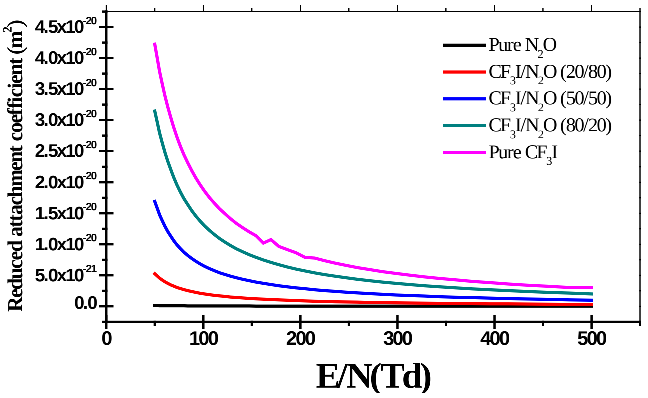

Figure 12: The η/Ndependence on reduced electric field for CF_3I–N_2O gas mixture at different ratios at 300 K and 1 atm.

Conclusion

By applying the two-term approximation of the BEq for CF_3I gas and its mixture with N_2O we outline thecalculation of the ETP and the coefficients (the ϵ_M , μN, ND_L, and ionization and attachment coefficients) at a range of the E/N between (100 to 700) Td for several temperatures. The values of ETP and coefficients are relatively close to pure CF_3I values when the concentration of N_2O in the mixture with CF_3I is less than 20%. The result of adding N_2O appears in the mixture is such that to increase the ionization coefficient, but reduce the attachment coefficient since CF$_3$I is more electronically than N$_2$O. On the other hand, the effect of changing the temperature of the mixture on the electron transport parameters and coefficients is directly proportional to the temperature as it increases. Our use of CF$_3$I–N$_2$O mixture in this study is to provide the best possibility for applications in the gas insulation of power equipment.

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