Calculation of the Characteristic Electron Energy for Mercury -Argon Mixture

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Abstract

Numerical study is applied to the mercury-argon mixture by solving the Boltzman transport equation for different mixture percentage.

The mixture parameters such as electron distribution function, D/μ, excitation rate and ionization coefficient which are plotted as a function of E/N.(Values of the ratio of the electric field, E to the gas number density). The results show a good agreement with available experimental and theoretical data.

Introduction

The electron energy distribution is an important function of E/N (the ratio of the electric field to the gas number density). A theoretical and practical study of the electron swarm kinetics in gases explain how the determination of electron energy distribution and gives the ways how the electron loss it's energy in collisions for electron-gas type [1-8].

The low values of E/N lead to energy loss due to elastic collisions with the gas. Hence the electron energy distribution, and velocity would be found from the change in the collision cross section for momentum transfer Q_m (ε) with energy ε. Using Boltzmann equation, the transport parameters would be determined which is of good agreement with experimental values [15]. These would predict the cross sections for momentum transfer $Q_m(\varepsilon)$ at low values [9]. This contribution is, therefore, important, since these energies are also low for the direct measurements for collision cross sections. When E/N increases the swarm energy increases, and the inelastic scattering becomes important. The cross section values for

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momentum transfer were deduced from scientific data, which would achieve or predict the inelastic cross sections.

High intensity discharge (HID), also known as gas discharge, offers many technique advantages over conventional halogen lamps, such as higher colour temperature heat and considerably longer life [10-11].

Theory

The main objective of Boltzmann transport equation is to predict this distribution which is expressed as f(r,v,t) .The behavior of electron interactions with gas molecules are governed by the distribution in space, energy and time of the electrons in the pure gas and/or in a mixture of gases.

The prediction of this distribution function can be done by solving the electron transport equation which is often called the Boltzmann transport equation. The general form of the Boltzmann transport equation may be written as [12-13].

$((\partial/\partial t(\nabla)+ v.\nabla r + (eE/m).\nabla v)\ f(r,v,t)) = (\partial f/\partial t)$ collisions

or

$$(\partial f/\partial t) + v.\nabla r\ f + a.\ \nabla\ v\ f = \sum_j \int\int [f(v',r,t)\ F_j\ (V_j',r,t) - f(v,r,t)\ F_j\ (V_j,r,t)]^*\ v_{rj}\ \sigma_j\ (\theta, v_{rj})\ d\Omega_j\ dV_j$$

Where:

$a = (eE/m)$ is the acceleration of charged particle.

F_j = The velocity distribution function of the neutral species j.

$v_{rj} = |v - V_j|$ relative velocity of charged particle with respect to the neutral species of gas j.

v = The velocity of charged particles.

V_j = The velocity of neutral species j.

$\sigma_j\ (\theta, v_{rj})$ = The differential microscopic cross section of the interacting charged particles with neutral species j.

$d\Omega_j = \sin\theta\ d\theta\ d\phi$ the element of solid angle, where θ and ϕ are the polar and azimuthal angles, respectively.

The left hand side and the right hand side of the above equation describe how f(r, v, t) changes by virtue of the independent (collisionless) motion and because of binary collisions of charged particles with neutral particles, respectively.

The physical meaning of the individual terms can be explained as follows:

$(\partial f/\partial t)$ = states that f(r,v,t) changes with time at fixed values of v and r.

$v.\nabla r$ f = describes that part of the change due to the free motion of charged particles where some of them leave the vicinity of r and other move in.

$a.\nabla v$ f = describes that part of change due to an external force altering v.

F_j = describes the loss of charged particles having velocities in the vicinity of v by collisions with neutral of velocity V_j.

F_j' = describes the gain of electrons into the velocity region around v by collisions of charged particles of velocity v′ with neutrals of velocity V_j' .

However, the right hand side of the Boltzmann equation attributes all of this change to binary collisions.

The electron distribution function , f(r,v,t) is approximated by f(v) because it is assumed that the electric field is independent of space and time and the problem of electron interactions is spacially uniform. However, the velocity dependence distribution function can be represented by the Legendre series expansion [14].

The Results and Conclusion

The Figures (1-3) Shows the energy distribution function for the mercury-argon mixtures has been computed at E/N values 2.0E-17 V.cm2, 2.0E-16 V.cm2, and 2.0E-15 V.cm2, respectively. The value of the distribution function at the electron energy of 5 eV is larger .This behaviors showed if the mercury concentration decreases in the mixture, the electron distribution function increases [15].

The Figures (4-5) shows the characteristic energy E_k increases with E/N in the elastic region, then starts to become approximately constant at 1 eV and then starts to increase at E/N value 1.0E-15 V.cm2 nearly which are showing increasing in the characteristic energy values when the mercury concentration percentage decreased [16].

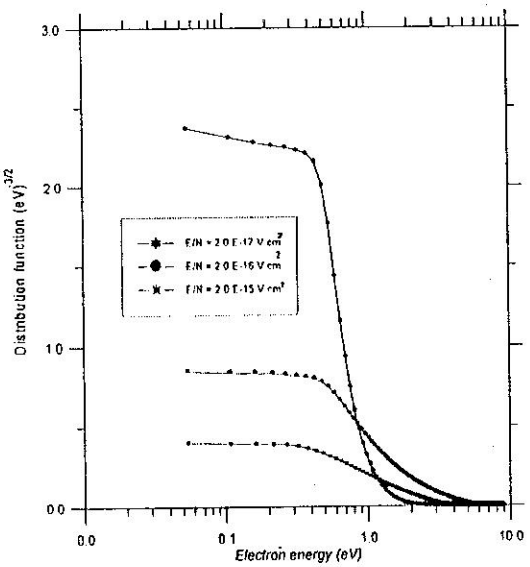
Fig (6-7) shows the fractional partition of total discharge power as a function of E/N (V cm^2). Notice that for E/N= 10^{-16} V cm^2 virtually all of the energy is going into electronic excitation.

Fig (8) shows the excitation rate behavior showed the value of E/N at which the excitation rate starts to increase with the increase of E/N value

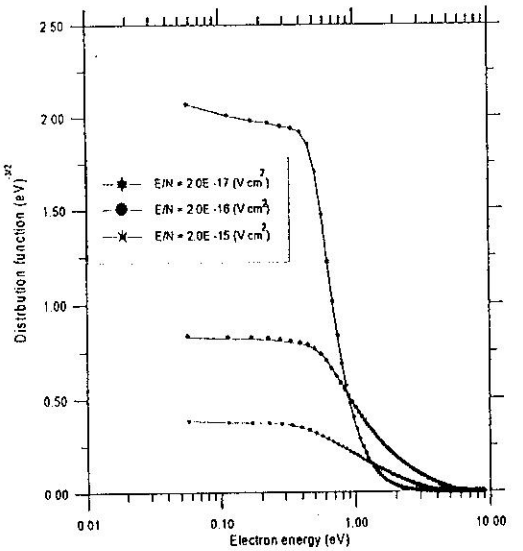
for each electronic level and most the electrons energy transfer to the second electronic level up to a specified E/N value which depends according to the type of mixture. The electronic levels gain their energy according to E/N value such as the case of energy transfer to the 6 $^3p_2$ and 6 $^1p_1$ levels. However, the value of E/N is different and they depend on the type of mixture.

Fig (9) shows the behavior of ionization coefficient as a function of E/N.The value of ionization coefficient increases with the decrease of mercury vapor concentration in the mixture. As E/N value increases, the differences in ionization coefficient values decreases down to the value at which they are approximately meeting at one point. This behavior is due to the increase in the number of electrons that causing the ionization as the mercury vapor concentration decreases in the mixture.

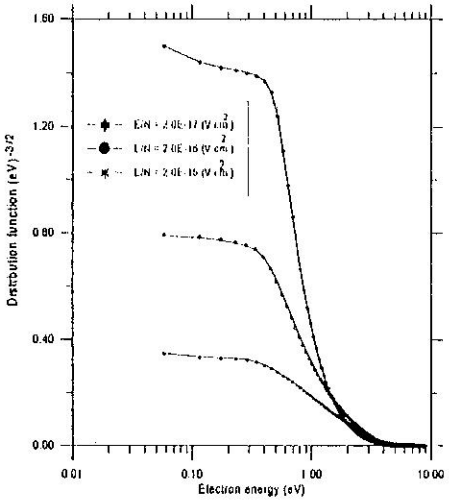
The equations which are using to explain the above figures can be done by solving the electron transport equation numerically.



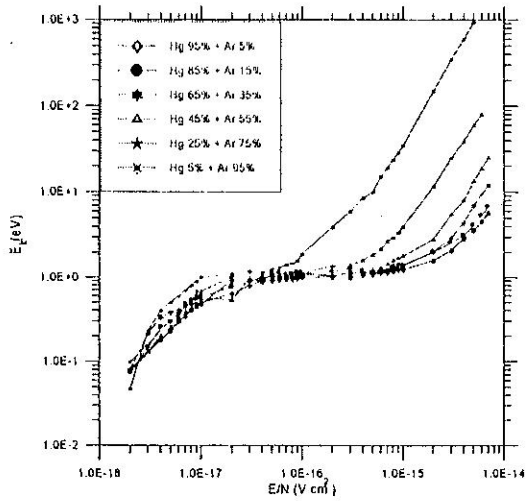
Fig(1): The electron distribution function versus the electron energy in Hg-Ar mixture , (95% Hg , 5% Ar).



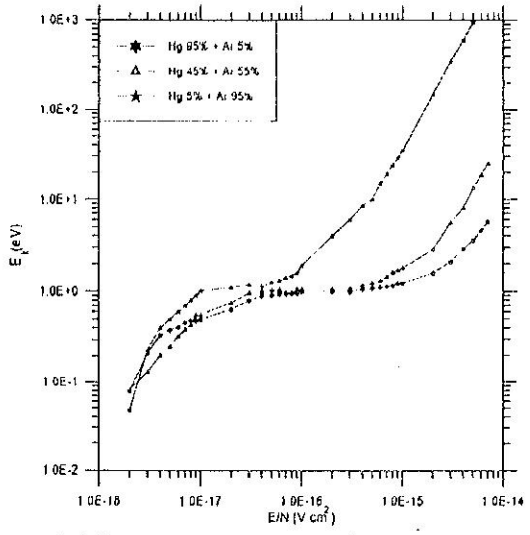
Fig(2) : The electron distribution function versus the electron energy in Hg-Ar mixture ,(85% Hg ,15% Ar).



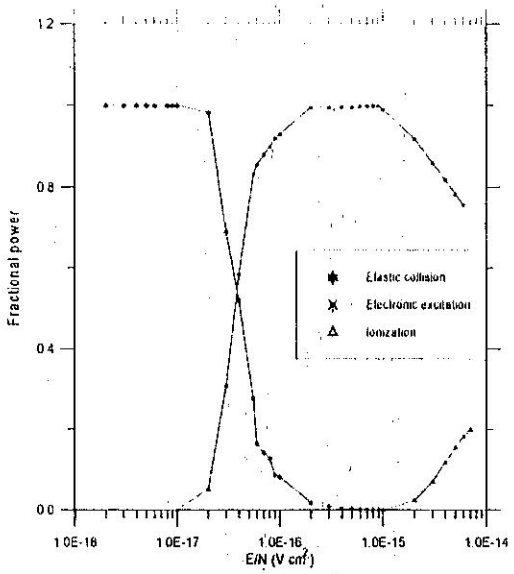
Fig(3) : The electron distribution function versus the electron energy in Hg-Ar mixture ,(65% Hg ,35% Ar).



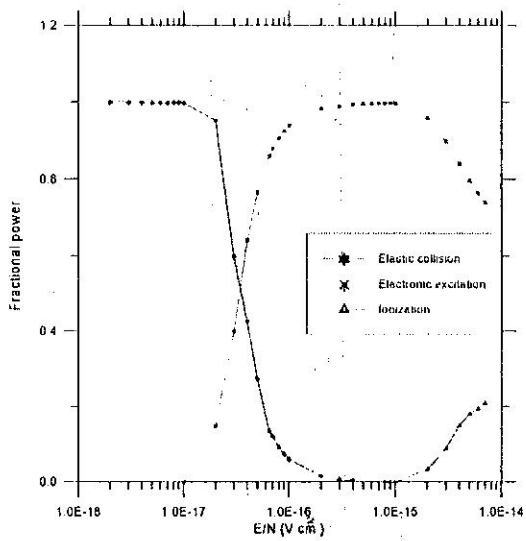
Fig(4) : The electron characteristic energy versus E/N in Hg-Ar mixture .



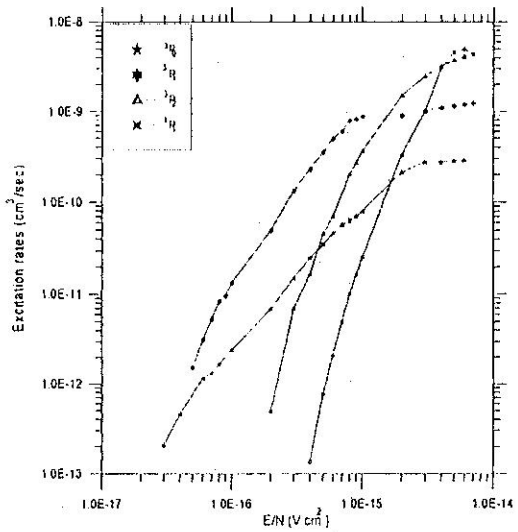
Fig(5) : The electron characteristic energy versus E/N in Hg-Ar mixture .



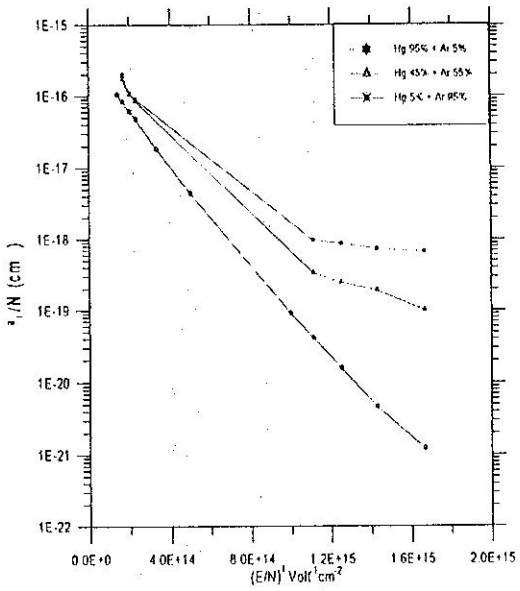
Fig(6) : The fractional partition of total discharge power versus E/N in Hg-Ar mixture ,(95% Hg ,5% Ar)



Fig(7) : The fractional partition of total discharge power versus E/N in Hg-Ar mixture ,(85% Hg ,15% Ar).



Fig(8) :The computed excitation rates to selected excited states versus E/N for Hg in Hg-Ar mixture ,(95% Hg , 5% Ar) .



Fig(9) : The ionization coefficient per molecule versus (E/N) in Hg-Ar mixture.

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10- إبراهيم كيطان فياض ، د.رعد حميد ، (2002) التفريغ الكهربائي في غاز الاركون ،.التربية للبنات ، جامعة بغداد ، المجلد 13 (1) ، ص 99 كلية مجلة

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حساب الطاقه المميزة للألكترونات لمزيج بخار الزئبق و غاز الاركون

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الخلاصة

تم تطبيق دراسة عددية لحل معادلة الانتقال لبولتزمان لمزيج من بخار الزئبق و غاز الاركون ولنسب خلط مختلفة حيث تم حساب معلمات المزيج مثل دالة توزيع الاليكترون، D/μ، معدل تغير التهيج ، معامل التأين ، وتم رسمها كدالة لـ E/N (نسبة شدة المجال الكهربائي E ، الى الكثافة العددية للغاز N). أظهرت النتائج تطابقا جيدا مع المعطيات العملية و النظرية المنشورة.