Calculation of Electron Drift Velocity in Xenon Gas Using Boltzmann Equation Analysis

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Abstract

The momentum transfer cross section for electrons in xenon, has been studied by using a simple two term solution for Boltzmann equation for electron drift velocity in pure xenon over a wider range of E/N from 0.001 Td to 1000 Td (1 Td = 10^{-17}V.cm^2) these results are useful for determining the electron drift velocity which is an important swarm parameter .We found that electron drift velocity in xenon gas are low. Our theoretical calculation results seem in good agreement with the published experimental results.

Keywords: drift velocity, xe uses and application, Boltzmann transport equation

Introduction

The first aim of the present paper is to compute electron drift velocity which is an important swarm parameter because it is useful to control energy and also used to characterize conductivity of gas weakly ionized [1]. Xenon is a rare and inert towards most chemicals, odorless, colorless, tasteless, although xenon is not toxic, its compounds are highly toxic due to their oxidizing characteristics [2]. Xenon has no undesirable ecological effect since it is a naturally occurring gas in Earth's atmosphere [3] and because scarcity and high cost, xenon has relatively little commercial use, also we can obtained by extraction from liquid air [4]. The major use is in the lighting industry, also used in photographic flashes [5] and in medicine as an ideal anesthetic not only because of its beneficial effect but also its lack of toxicity and in medical imaging [3], modern ion thrusters for space travel use inert gases especially xenon for propellant so there is no risk of the explosions associated with chemical propulsion. The inert nature of xenon makes it environmentally friendly and less corrosive to an ion engine than other fuels such as mercury or cesium. Xenon was first used for satellite ion engines during the 1970[6].Xenon compounds are also used commonly in modern laser technology, exciter lasers that are used for photolithography and laser eye surgery contain xenon gas, also used in high energy particle physics research [7] .Xenon gas that possessed a low drift velocity . In this research we calculate electron drift velocity values high and low of the E/N in xenon pure through solving the Boltzmann equation, the range covered in 0.001 Td – 1000 Td (1 Td = 10^{-17} V.cm^2)

Theory

The program calculates the electron energy distribution function; this is done by solving the Boltzmann transport equation. This equation describe the statistical behavior of a thermodynamic system and also can be used to determine how physical quantities change, such as heat energy and momentum [8] .The study of Boltzmann equation is important because to faithfully represent the physical situation and obtain a valuable insight into the features of the solutions of the full Boltzmann equation [9].The general form of the Boltzmann transport equation is [10]

$$\left(\frac{\partial}{\partial t}+\upsilon.\nabla_r+\frac{eE}{m}.\nabla_V\right)f(r,\upsilon,t)=(\frac{\partial f}{\partial t})_{collisions} \qquad (1)$$

Where f (r,υ,t) is the distribution function for at time t and spatial location r with velocity υ,($\frac{e\,E}{m}$) is the acceleration of charged particle ,($\frac{\partial f}{\partial t}$)is states that f(r,v,t) changes with time at fixed values of v and r , (υ.∇_r) is describe that part of change due to an external force altering v.

The resulting solution gives the distribution function of electrons accelerated by dc electric field and in a mixture of atomic or molecular gases .From distribution function the drift velocity and other transport parameters are calculated for comparison with experimental data. In addition rates of energy loss through elastic and inelastic scattering are evaluated and displayed for use in discharge kinetic models.

The electron drift velocity is one of the most important electron swarm parameters to describe the behavior of electrons in gases and the drift velocity had been determined by the kind of gases and the value of E/N where E is the electric field and N is the gas number density[11].

Using the distribution function one can computes the electron drift velocity [10],

$$v_d = -\frac{1}{3}\left(\frac{2e}{m}\right)^{\frac{1}{2}}\left(\frac{E}{N}\right)\int_0^\infty \frac{1}{\sum_s \delta_s \sigma_s(\epsilon)}\frac{df_0}{d\epsilon}\epsilon d\epsilon (cm/sec) \qquad (10)$$

And also can compute the electron mean energy,

$$\bar{\epsilon} = \int_0^\infty f_0\,(\epsilon)\epsilon^{\frac{3}{2}} d\epsilon (eV) \qquad (11)$$

Where ϵ is electron energy in (eV), N is the gas density incm^{-3}, E /N is in (Vcm^2) n_e is electron density in (cm^{-3}),δ_s =(N_s/N),σ_s= momentum transfer cross section for species s.

Results and discussion

I've studied behavior the electron drift velocity as a function of E/N in pure xenon gas, as shown in figure (1) and the results in table (1), it is noted that drift velocity increases linearly with the increasing of E/N except in the range (0.04≤ E/N ≤ 4) Td, the drift velocity become unstable, generally the electron drift velocity is low because electron cloud must drift long distances towards the anode. Our theoretical calculation results seen good agreement with published experimental results (1٢) as shown in figure (2).

Conclusion

It is noted that drift velocity dependence on the electric field, The drift velocity of xenon gas is low to overcome this problem a low percentage of some light molecular gases may be added to improve the drift velocity. In this paper we use the Boltzmann equation to calculate the electron drift velocity in xenon gas for the range of E/N from 0.001 Td to 1000 Td.

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Table (1): Values of the drift velocity of electrons in (cm / s) in xenon gas

E/N (Td)	V_d*10^6(cm/s)	E/N (Td)	V_d*10^6(cm/s)
0.001	0.001	3	0.2
0.003	0.0012	4	0.25
0.005	0.002	5	0.3
0.007	0.0029	6	0.352
0.009	0.0035	7	0.409
0.01	0.004	8	0.453
0.02	0.0085	9	0.475
0.03	0.018	10	0.562
0.04	0.025	20	1.011
0.05	0.05	30	1.39
0.06	0.08	40	2.01
0.08	0.09	50	2.6
0.1	0.1	70	3.5
0.2	0.12	90	4.51
0.3	0.13	100	5.01
0.4	0.135	200	12.02
0.5	0.14	300	17
0.6	0.143	400	24.1
0.7	0.15	500	30
0.8	0.155	600	35.02
0.9	0.16	700	40
1	0.165	800	44.9
2	0.18	900	50.02

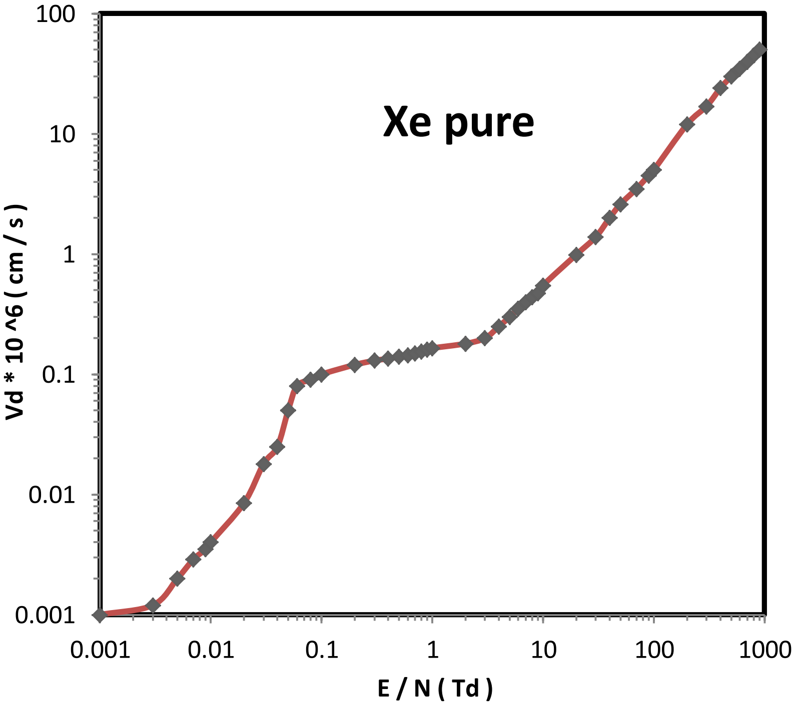

Figure1:Electron drift velocity as a function of E/N for pure Xenon

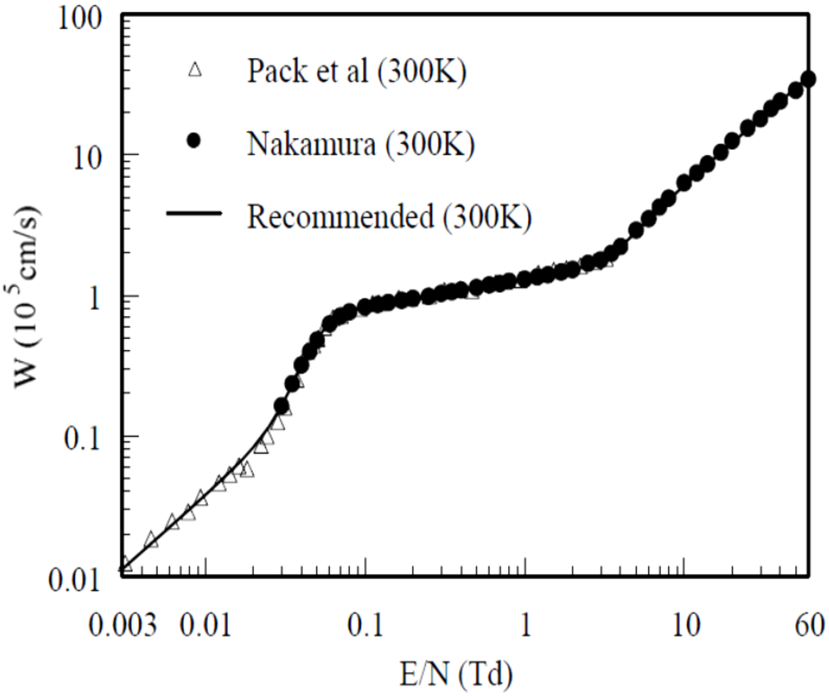

Figure2:Electron drift velocity as a function of E/N for pure Xenon [12]

حساب سرعة انجراف الالكترون في غاز الزينون بإستخدام تحليلات معادلة بولتزمان

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الخلاصة

لقد درسنا المقطع العرضي لأنتقال الزخم للالكترونات في غاز الزينون بإستخدام حل معادلة بولتزمان لغاز الزينون لمدى واسع من قيم (E\N) من (0.001 Td –1000Td) (1 Td = 10^{-17}V.cm). هذه النتائج تكون مفيدة لتحديد سرعة انجراف الالكترون والتي تعتبر من عوامل الانتقال المهمة وقد وجدنا ان سرعة انجراف غاز الزينون تكون واطئة نسبيا .لقد وجدنا اتفاق جيد بين القيم المحسوبة والمقاسة لسرعة الانجراف للالكترون في غاز الزينون النقي.

المفاتيح : سرعة الانجراف ، استعمالات وخصائص الزينون ، معادلة بولتزمان