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ВЛИЯНИЕ ИЗМЕНЕНИЯ ЧАСТОТЫ ЭЛЕКТРИЧЕСКОГО ПОЛЯ НА ФУНКЦИЮ РАСПРЕДЕЛЕНИЯ ЭЛЕКТРОНОВ ПО ЭНЕРГИЯМ (ФРЭЭ) АРГОНОВОЙ ПЛАЗМЫ

Аннотация: *В этой статье было изучено статистическое исследование функции распределения электронов по энергиям (ФРЭЭ) аргоновой плазмы, а коэффициенты переноса электронов были найдены путем решения уравнения Больцмана с использованием двухчленного приближения.*
Функция распределения электронов по энергиям (ФРЭЭ) находится при различных значениях частоты приложенного электрического поля.
В результате мы обнаружили, что значение EEDF уменьшается с увеличением частоты и смещением в сторону более высоких энергий.

Ключевые слова: *ФРЭЭ, уравнение Больцмана, аргоновая плазма.*

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THE INFLUENCE OF ELECTRIC FIELD FREQUENCY VARIATION ON THE ELECTRON ENERGY DISTRIBUTION FUNCTION (EEDF) OF ARGON PLASMA

Abstract: *In this paper, a statistical study of the electron energy distribution function (EEDF) of argon plasma was studied, and the electron transfer coefficients were founded by solving the Boltzmann equation using two-term approximation.*
The electron energy distribution function (EEDF) is found at different values of the applied electric field frequency.
As a result, we found that the EEDF value decreases with increasing frequency and shifting towards higher energies.

Keywords: *EEDF, Boltzmann equation, argon plasma.*

1. Introduction

In practice, plasma can be defined as a gas that fulfills known conditions, including dense plasma and non-dense plasma. Many researches have been published related to the study of dense plasma gas, including the study of the flow and energy of helium ions produced from plasma devices of different densities when gas pressure changes [1]. And to study the properties of the ion beam produced by the NX_2 dense plasma devices with helium and nitrogen gases [2]. Optimal X-ray optimization of nitrogen from NX_2 dense plasma devices [3]. Optimization of X-ray fluorescence from NX_2 dense plasma devices [4].

Or a plasma of variable density as a study of the mutual effect between a relativistic electron beam with a dense, hot, heterogeneous plasma in the presence of a static external magnetic field [5]. And the study of the instabilities of an electron beam in a heterogeneous dense hot plasma [6].

We have, through previous research, studied some important statistical properties of many types of plasmas at different temperatures. The statistical distributions that describe them have been determined in terms of the change of some of their variables with a focus on the local thermal equilibrium state [7].

The statistical method is considered one of the important methods of studying that can be obtained from statistical equations. And since the plasma particles have a high energy that can be transferred to other particles through collisions, the transferred energy can be able to disassemble the excited particles and form new ions and particles, which increases the probability of collisions and increases the complexity of the energy and statistical calculations of the plasma.

For the sake of simplicity, the use of inert gases (single atoms) has become commonplace, as they form the simplest plasma medium that can be studied according to statistical equations. The choice of argon was due to several reasons, the most important of which is its great abundance in the atmosphere (it is considered the third gas in terms of abundance after nitrogen and oxygen), in addition to its low cost of acquisition, and the most important reason is its low ionization energy compared to other gases [8].

2. Experimental:

2.1. Numerical calculations:

The Boltzmann equation was relied upon by the following equation [9]:

$$\frac{\partial f}{\partial t} + v \cdot \nabla f + \frac{e}{m} E \cdot \nabla_v f = \left.\frac{\partial f}{\partial t}\right|_c \qquad (1)$$

The EEDF equation can be written more familiarly and is similar to the static convection propagation equation:

$$\frac{d}{d\epsilon}\left(\widetilde{W}\, F_0 - \widetilde{D}\frac{dF_0}{d\epsilon}\right) = \tilde{S} \qquad (2)$$

We calculated EEDF for argon gas, and showed the effect of both applied field frequency on (EEDF). Here, it is necessary to identify the types of collisions (reactions) that occur in the plasma medium, and some of them are listed in the following table:

Table (1) Particle collisions in argon plasma medium and the rate at each collision occurred

collisions	Collision rate
$Ar^{+} + 2e \rightarrow Ar + e$	$8.75\times10^{-39}(T_e)^{-4.5}$
$Ar^{+} + e + Ar \rightarrow Ar + Ar$	$1.5\times10^{-40}(T_g/300)^{-2.5}$
$Ar^{*}_2 + e \rightarrow 2Ar + e$	1×10^{-15}
$Ar(4s) + Ar(4s) \rightarrow Ar^{+}_2 + e$	$3.15\times10^{-16}(T_g/300)^{-1/2}$
$Ar(4s) + Ar(4s) \rightarrow Ar^{+} + Ar + e$	$1.62\times10^{-16}(T_g)^{1/2}$
$Ar(4s) + Ar(4p) \rightarrow Ar^{+} + Ar + e$	$1.62\times10^{-16}(T_g)^{1/2}$
$Ar(4p) + Ar(4p) \rightarrow Ar^{+} + Ar + e$	$1.62\times10^{-16}(T_g)^{1/2}$
$Ar^{*}_2 + Ar^{*}_2 \rightarrow Ar^{+}_2 + 2Ar + e$	$5\times10^{-16}(T_g/300)^{1/2}$
$Ar^{*}_2 + Ar(4s) \rightarrow Ar^{+}_2 + Ar + e$	$6\times10^{-16}(T_g/300)^{1/2}$
$Ar(4p) \rightarrow Ar(4s) + h\nu$	$4.4x10^{7}$
$Ar^{*}_2 \rightarrow 2Ar + h\nu$	$6x10^{7}$

3. Results and Discussion:

3.1. Effect of electric field frequency on (EEDF):

We calculated (EEDF) for argon plasma after entering the argon gas equations into mathematical programs for studying the statistical properties of the plasma after knowing the rate of collision occurrence mentioned in Table (1) [25-30]. Also, equation

(2) was introduced to find (EEDF), after applying the boundary conditions and entering the appropriate parameters:

Gas temperature: $T_g = 300\ (k)$, Electron density: $n_e = 1E18\ (1/m^3)$

Ionization degree: $\beta = 1E-6$

Also, the initial middle energy of the electron is given by the value $\varepsilon_0 = 2\ (V)$, and the value of the reduced electric field: $E/N = 10\,Td$

After putting these parameters in the programs and performing some calculations, we came to study the effect of the frequency of the electric field applied to the argon plasma within a range between (2-10 Hz) and the graphs of the change of (EEDF) were drawn in terms of the electron energy (ev) and shown in figure 1:

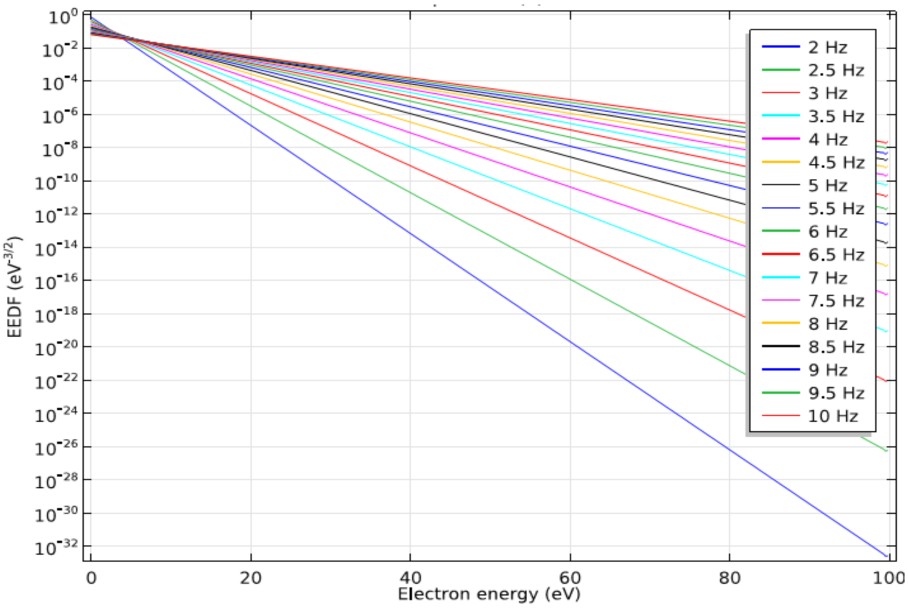

Figure 1: changes in the EEDF at different frequencies

We observed from the figure a decrease in the EEDF values by increasing the electron energy, and the reason for this is due to the increase in the possibility of effective collisions between the electrons and the different particles present in the gaseous medium, which reduces the energy of the electrons after these collisions.

We notice from the previous figure that the energy of the electron increases with the frequency increasing and (EEDF) is shifted to the right (towards the higher energies). This indicates the increase in the number of electrons carrying the higher energies.

The effect of frequency on (EEDF) at low energies is weak, and this is indicated by the convergence of follower lines (EEDF) at low energies for different values of frequencies. While the frequency effect of the EEDF increases with increasing electron energy, especially at lower frequencies.

4. Conclusion:

1- It was observed that when studying the effect of the electric field frequency applied on argon plasma within a range between (2-10 Hz), the electron energy increased with an increase in the frequency value and the EEDF shifted towards the right (i.e. towards higher energies).

2- It was also observed that the frequency effect on (EEDF) at low energies is weak, and this is indicated by the convergence of (EEDF) lines at low energies for different values of the frequencies.

3- At a constant value of the electron energy (60 eV), the value of the EEDF function increases with the increase in the frequency value.

References:

1. Sahyouni W, Nassif A, Zeidan O. Study the Flux and Energy of the Helium Ions Beam Produced by Two Different Dense Plasma Focus Devices When Gas Pressure Changes. Am J Mech Appl. 2020;8(1):16–20.
2. Sahyouni W, Nassif A. Ions Beam Properties Produced by NX2 Plasma Focus Device with Helium and Nitrogen Gas. Am J Mod Phys. 2019;8(1):1–4.
3. Sahyouni W, Nassif A. Nitrogen Soft X-Ray Yield Optimization from UNU / ICTP PFF Plasma Focus Device. Am J Mod Phys. 2020;8(6):86–9.
4. Sahyouni W, Nassif A. Neon Soft X-Ray Yield Optimization from NX2 Dense Plasma Focus Device. Jordan J Phys. 2018;11(3):167–72.
5. Sahyouni W, Abdel-Hafez M. The effect of an electron beam on a hot dense, heterogeneous plasma. Tishreen University Journal. 2015; 37 (15).
6. Sahyouni W, Al-Abd Al-Hafiz M. Instabilities of an electron beam in a hot dense, heterogeneous plasma. Al-Baath University Journal. 2015; 37.

7. Sahyouni W, Alsebaai O. A statistical study of ionization in some plasmas with the sequence of electron concentration and temperature. Al-Baath University Journal. 2017; 39 (19): 71-92.
8. Chen F. Introduction to plasma physics and controlled fusion. New York; 1984.
9. Lieberman MA, Lichtenberg AJ. Principles of Plasma Discharges and Materials Processing. 2th ed. New York: Wiley; 2005.