Journal of Al-Nahrain University Vol.14 (3), September, 2011, pp.73-76 Science

Experimental Study of Glow Discharge Plasma Properties at the middle Distance between Anode and Cathode for Aluminum Electrodes

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Abstract

The plasma parameters which have been studied were electron density, Debye shielding, plasma oscillation and electron temperature. The parameters measured by using single probe in glow discharge at different pressure and different gases (air and Argon). The results show that, the density of free electrons is inversely proportional with the pressure because of the recombination process which increases with pressure increasing. Also Debye length decreases when pressure increases and plasma oscillation inversely proportional with the pressure. Finely, the current density in a positive bias voltage applied on the probe was larger than the current density and vice versa.

Introduction

Plasma resulting from ionization of neutral gases generally contains equal numbers of positive and negative charge carriers. In this situation, the oppositely charge fluids are strongly coupled [1, 2].

Saha equation describes the ratio of different stages of ionization of atoms. In most practical (low gas densities) radiative process will be more important and an explicit detailed equilibrium calculation is necessary in order to determine the distribution of electrons over the various energy levels, Saha equation is given by [3].

$n_i/n_a \sim g_i/g_a\, e^{-(J/T)}$ ....(1)

where n_i= is the number of ions, n_a= number of neutral atoms, J= ionization energy, g_i= statistical weight of ions, g_a= statistical weight of neutral atoms [2].

The shielding of an external electric field from the interior of a plasma can be viewed as a result of high plasma conductivity. The electrons in a plasma are oscillating with a frequency ω_p due to the applied external field, where response typical time for a plasma to an external field [4,5,6].

The DC glow discharge at low pressure is one of the most familiar of gas discharges. There are three basic regions described in Fig.(1). These regions are the cathode region, the glow region and the anode region [7, 8].

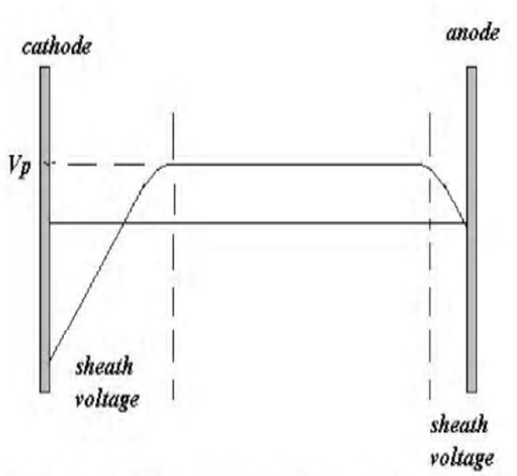

Fig.(1) Voltage distribution in a DC glow discharge process.

The glow at the anode disappears (dark region). There are various other types of glow discharge such as: spry discharge. High pressure glow discharge. And hollow cathode discharge [3].The electron density (n_e) can be calculated using the following equation [2].

$n_e = I_{sat} / eA\,(\sqrt{KT_e/2\pi m_e})$ .... (2)

where A=Area of probe $2\pi rl = 0.0942\ cm^2$,

K =Boltzmann constant (1.38×10^{-23} J/K), me=electron mass (9.1×10^{-31}kg),e=electron charge.

Each electron will be oscillated with frequency (ω_p), this frequency is called plasma frequency is given by.

$\omega_p = 2\pi\times10^4 (n_e)^{1/2}$ .... (3)

The plasma can be produce internal electric field which is opposite to the external electric field, some of charged particles are closed to the electrodes with a certain thickness, this thickness is called Debye shielding (λ_D), which is given by.

$\lambda_D=(\varepsilon_0 KT/n\,e^2)^{1/2}$ ....(4)

ε_0=permittivity of space ($8.85\times10^{-12}\ N^{-1}m^{-1}e^2$) Applying external electric potential the electrons of the plasma will gain energy, this energy is represented by the electron temperature T_e, which is given by.

Te (K)=(1/slope)×11600 ....(5)

where the slope is the relation between probe current and probe voltage[9].

Experimental Part

In this work are used the instrument; Rotary pump($1-1\times10^{-1}$) atm, power supply(500-1500) Volt, voltage probe power supply, mille ameter, voltmeter, two circular Aluminum electrode (with 1mm thickness and 10 cm diameter), Aluminum probe (Langmuir probe with 0.8 mm), Nitrogen gas.

A small metallic probe with variable potential is inserted into a plasma in a steady state. A static shielding sheath is formed there without plasma production or losing. We consider the voltage-current characteristics IV when potential at the probe is externally varied with respect to the wall of the plasma [3]. They are known as probe characteristics in a plasma.

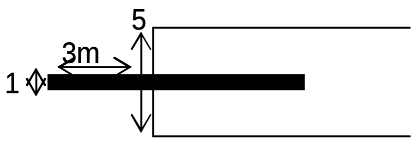

Fig.(2) Diagram of probe.

Furthermore this probe is operating by 8 sweeping mode, which change from 80 Volt to – 80 volt [6].

Results and Discussion:

The glow discharge happens at the initial condition, where pressure ~ (1×10^{-1}) mbar, electrical potential (500-1500) Volt, and current ~(1×10^{-3}) Amper, in this work four parameters are studied [8, 9].

From equations (3, 4, 5, 6) we have determined the parameters of experiment n_e, T_e, ω_p and λ_D.

Table (1)
Shows the basic parameters of the experiment.

P mbar	n_e cm^{-3}	λ_D m	w_p rad/s	Te K	f_p sec^{-1}
2×10^{-1}	9.307×10^{12}	5.5×10^{-6}	19.16×10^{10}	29580	3.05×10^{10}
3×10^{-1}	9.15×10^{12}	5.1×10^{-6}	18.99×10^{10}	33408	3.024×10^{10}
4×10^{-1}	9.088×10^{12}	4.7×10^{-6}	18.92×10^{10}	35960	3.014×10^{10}

Fig.(3) represented the Debye shielding which is inversely proportional with the square root of the density of gas and this is because the sphere of Debye shielding will be closed to the electrodes. Since the density of gas is foreword proportional with the pressure. Then, the Debye shielding is inversely proportional with pressure.

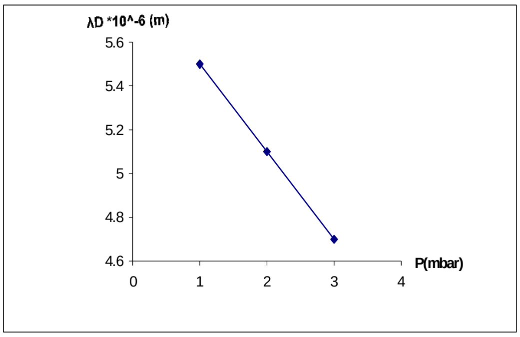

Fig.(3) Relation between Debye shielding and pressure.

Fig.(4) represented the relationship between the electron density which proportion with saturation current, and inversely proportional with the pressure because the ions will be closed to electrons.

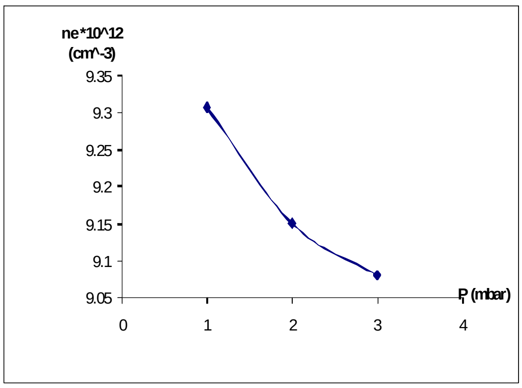

Fig. (4) Relation between electron density and pressure.

The plasma frequency is inversely proportional with the density of gas because the mean free path decrease with pressure and the free electrons decreases because of the recombination process and this is illustrated in Fig. (5).

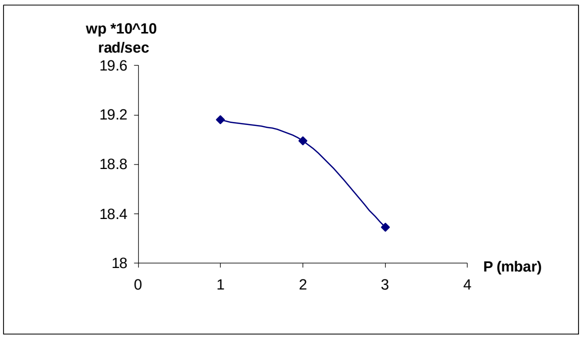

Fig. (5) Relation between plasma oscillation and pressure.

One of One of the properties of the ionized gas is the electron temperature where the electron have a certain temperature in eV unit where it is value about 2-5 eV where the electron energy represented by the temperature and this temperature due to the external potential exerted on the gas and the temperature proportional to the pressure this shows in Fig.(6).

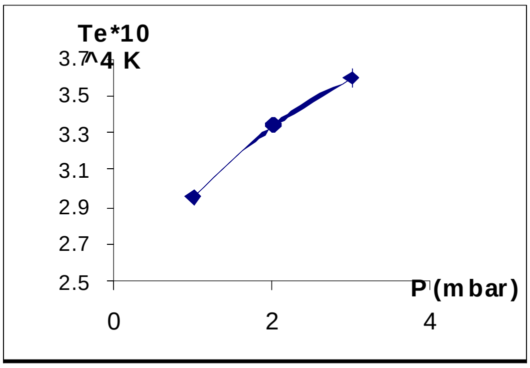

Fig.(6) Relation between electron temperature and pressure.

When the probe supplied by negative the current through the probe was found very small because of the ions is a heavy mass and the velocity of ions is very small, and when we supplied with positive voltage, the probe current is large because of the electrons will attracted to the anode which are causes this current where this is shown in Fig.(7).

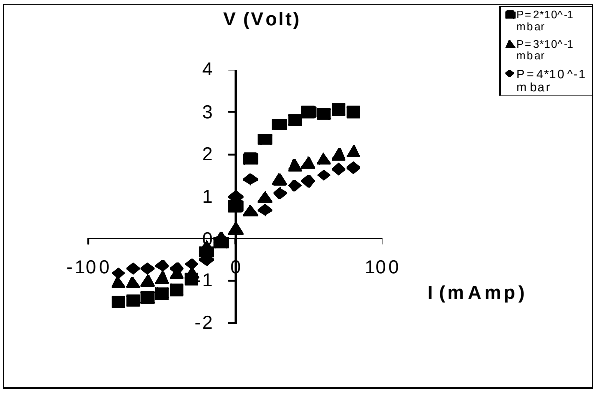

Fig. (7) The relation between I and V.

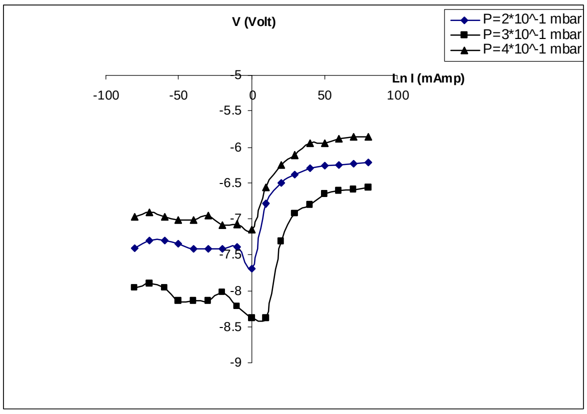

Fig. (8) Shows the relation between Ln I and V.

Conclusions

From the study we can conclude that

1. When a probe voltage applied is appositive the current is larger than that of a negative voltage.
2. The density of free electrons is inversely proportional with the pressure which decays due to the recombination process when pressure increases.
3. Debye length decreases when pressure increases because of the compressing process of the charged particles.
4. Plasma oscillation is inversely proportional with the pressure.
5. Electron temperature depends directly with the pressure under the general gases law.

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الخلاصة

في هذه التجربة تم دراسة بعض معلمات البلازما مثل (كثافة الالكترونات، عمق ديباي, تردد البلازما و درجة حرارة الإلكترون). تم قياس هذه المعلمات باستخدام الحساس المنفرد لعدة ضغوط و غازات مختلفة (الهواء و الاركون). ومن النتائج المستحصلة تم معرفة إن كثافة الالكترونات تقل بزيادة الضغط نتيجة لإعادة الاتحاد و كذلك عمق ديباي، و التيار في حالة الانحياز الموجب يكون اكبر بكثير من حالة الانحياز السالب.