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Plasma Beam Interaction with Negative Glow Discharge

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ABSTRACT

A miniature coaxial gun has been used to study the effect of the energy spectrum of the ejected plasma on the interaction with negative glow region in a normal glow discharge. The peak discharge current flow between the coaxial electrodes was 5.25 KA as a single pulse with pulse duration of 60 μs. Investigations are carried out with Argon gas at pressure 0.4 Torr. The sheath thickness of the ejected plasma from the coaxial discharge was 6 cm with different densities and energies. The spectrum of electron energy varies between 6 eV and 1 eV, while the electron density varies between 5x 10^{12} cm^{-3} and $4x10^{13}$ cm^{-3}. The peak velocity of the ejected plasma was 0. 8 x 10^5 cm sec^{-1} in the neutral Argon atoms. Argon negative glow region used as base plasma has an electron temperature of 2.2 eV and electron density of 6.2 $x10^7$ cm^{-3}. It had been found that the velocity of the ejected plasma decreased when it moves in the negative glow region and its mean electron temperature decreased. The results are compared with the theory of beam interaction with cold plasma.

Key Words: Glow Discharge / Negative Glow / Plasma Beam Interaction.

INTRODUCTION

Since glow discharge became important for industrial applications, such as laser, circuit breakers, material surface treatments, production of pure materials such as ceramics and silicon. The understanding of the physical phenomena of it grow during the last years. Although the glow discharge is simple in construction, it is rich in physical processes, which need more detail and accurate studies.

The DC-low pressure glow discharge consists of three main regions, cathode full, negative glow and positive column. Negative glow discharge region is the brightest region of the normal glow discharge and the electric field is quite low at the boundary between the cathode dark space and the negative glow .The electrons reaching its boundary have been accelerated through the cathode dark

ic electrons are travelling through the negative glow region, they lose their energy through ionization and excitation, and hence the

reduction in electron density. A steady state will be reached such that a balance is maintained between the rate of production by ionization and the rate of electron loss through recombination [1, 2]. The negative glow region is highly collisions region. Glow discharge produces low-density plasma where the ion temperature is of the order of rest gas, while the electron temperature can reach several electron volts. The main interest of this study, is the interaction of ejected plasma from coaxial plasma accelerator with the negative glow plasma.

The coaxial plasma accelerator can produce a plasma sheath propagating in the expansion chamber with velocity 10^7 cm sec^{-1}, with plasma density ~ 10^{15} cm^{-3} and temperature of <10 eV. The pioneer work carried out by Marshall showed that coaxial plasma gun can be used to eject 0.1 mg of plasma with high momentum and energy [3]. The device consists of an inner and outer electrodes separated at the breach by an insulator, a capacitor bank, and gas vacuum system. At the start of the discharge of capacitor bank, the current flows across the surface of the insulator, minimum resistance, forming a plane plasma sheath. Then the plasma sheath is lifted the insulator surface by the effect of Lorentz force (**J** x **B**). The Lorentz force then accelerates the plasma sheath toward the muzzle of the coaxial gun. The electrical discharge has to be matched with the axial motion of the plasma sheath such that the sheath peak velocity at the muzzle coincide with the peak discharge current [4].

EXPERIMENTAL ARRANGEMENTS

The device consists of miniature coaxial plasma gun system and glow discharge system, Fig. (1). The glow discharge system consists of power supply and two copper electrodes, each of 75 mm diameter and with 100 mm separation distance enclosed by a pyrex glass cylinder . The two copper electrodes can be move freely through the glass cylinder. The cylinder is fitted with two Aluminum flanges, the lower flange is connected to the gas inlet through a needle valve and the upper one is connected to the vacuum system. The electric probe and the miniature coaxial plasma gun are fixed through ports at the middle of the discharge vessel surface. The miniature coaxial plasma gun system consists of small capacitor bank and two stainless steel electrodes isolated at the breach by a Teflon disc. The inner electrode is a solid rod with 3 mm diameter and 45 mm length and the outer electrode has 6 mm inside diameter and 45 mm length.

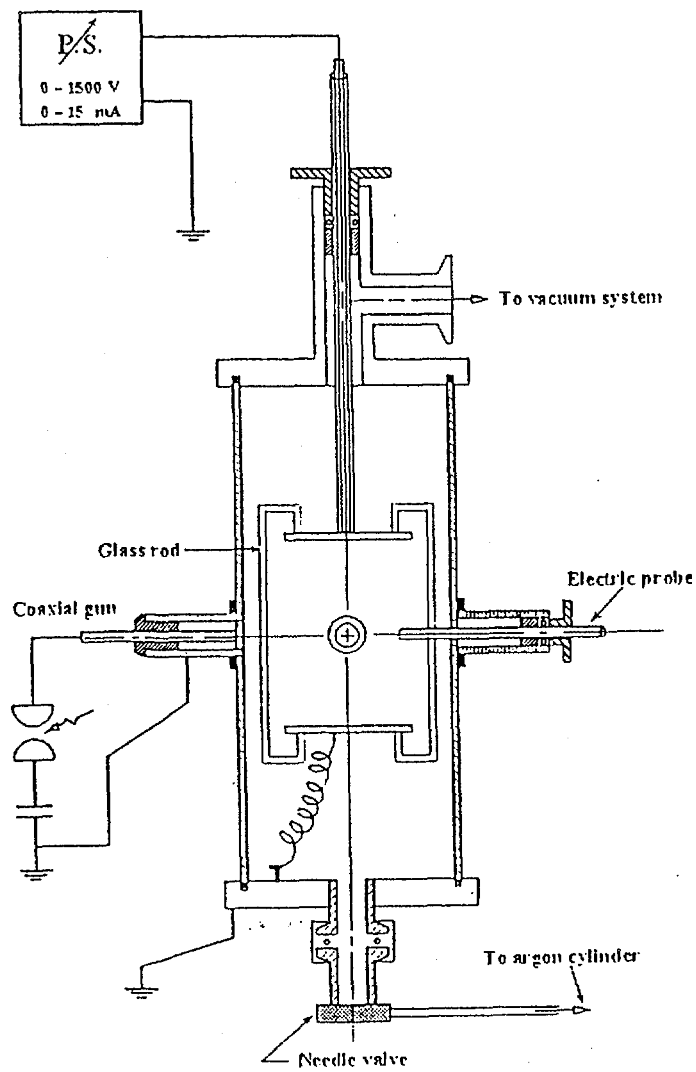


Fig (1) : Schematic diagram of the experimental system

EXPERIMENTAL RESULTS AND DISCUSSION

Argon gas is used with dynamic filling pressure of 0.4 Torr for all the experimental investigation in this work. Electric probes are used to study the negative glow region [5]. The glow discharge is fed by 340 V and 2 mA from a stabilized power supply. From single electric probe characteristics ln I_p versus V_p showed several straight lines represents three different temperature of 1.1, 1.9, and 2.4 eV with densities of 2.5, 4.5, and 6.2 x 10^7 cm^{-3} respectively . More accurate results can be obtained by taking the second derivative of probe current I_p versus the retarding voltage V_r. The retarding voltage is obtained by subtracting the plasma potential from the plasma potential Vp. Since the negative glow is considered highly collision region, the three groups of electron temperature have Maxwellian distribution. When the three distributions are added together, the resultant distribution Fig. (2) is found to be in close agreement with the experimental obtained one. Double electric probe characteristics showed that the mean electron density and temperature in the negative glow region, at r = 0, z = 2 cm (z is measured from the cathode, r = 0 at the Centre of it), are 6.2 x 10^7 cm^{-3} and 2.2 eV respectively.

The coaxial gun is operated in the absence of the glow discharge The discharge showed a single discharge pulse with peak current of 5.25 KA with pulse width of 60 μ s (the discharge current is measured by the Rogovisky coil), Fig. (3). The ejected plasma was in form of a single pulse, Fig. (3), with pulse width of 70 μ s, detected by double electric probe .The calculated inductance of the discharge was 230 nH, while the total resistance varies between 90 m and 240 m . The double electric probe showed that the electron temperature of the ejected plasma varies with time between 1 eV and 6 eV, while the density varies between 5 x 10^{12} and 4 x 10^{13} cm^{-3} Fig. (4) .The velocity of the ejected plasma from the plasma gun has been measured for different discharge current Fig. (5-a). It has been found that the plasma stream velocity increased with the increase of the discharge current (I_d) in a linear form for $I_d > 2$ kA. From the plasma stream velocity and the plasma pulse width, the plasma length is obtained. The plasma thickness found to be increased slightly with the increase of the discharge current Fig. (6).

When the ejected plasma flows through the negative glow region it has been found that the plasma thickness shows no significant variation in the presence of the negative glow, Fig. (6) while the plasma stream velocity slightly decreased Fig. (5-b).

Measurements of the electron density and temperature of the plasma stream after interaction with the negative glow region showed a decrease of temperature by ~ 30 %.

The important kinds of beam interactions are classified into, Cherenkov effect, normal Doppler and anomalous Doppler effect. These interactions do not applied on the cold low-density beam plasma interaction with cold low-density plasma. The interaction, which must be taken into account, is the individual interaction between particles. In our case the plasma is unmagnetized and the plasma beam interacts with cold low-density plasma, hence Bremsstrahlung effect is the only possible interaction. The energy losses of the plasma beam by Bramsstrahlung radiation will be

$$E = 5.35\times10^{31} \int n_e T_e^{-1/2} \sum n_I Z_I \, dt \qquad Joule\ cm^{-3}$$

It has noticed that an excited wave occurs during the interaction, which appears as additional fast moving plasma detected by double electric probe, Fig. (7). The excited wave velocity was ~ 10^6 cm sec^{-1}.

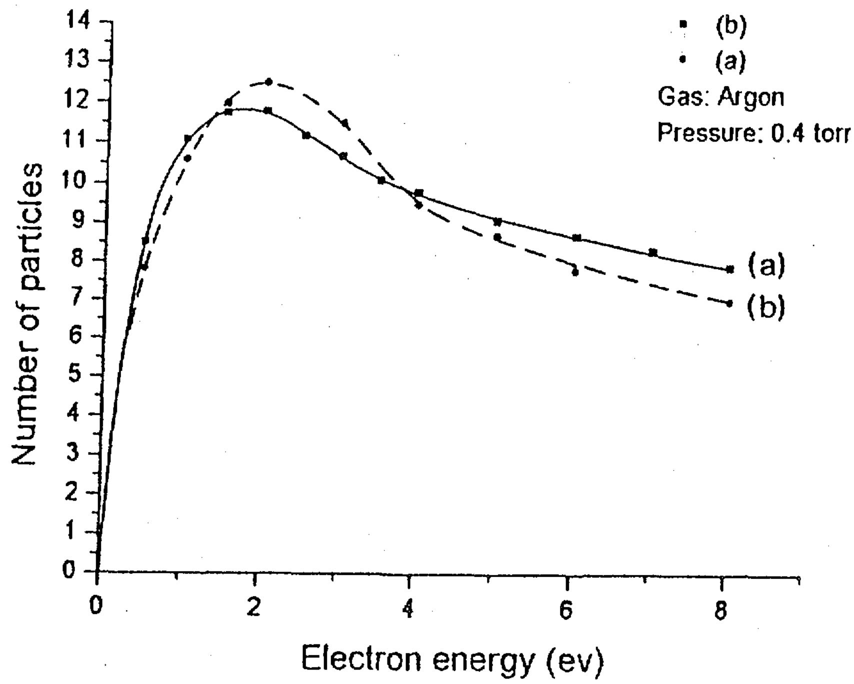
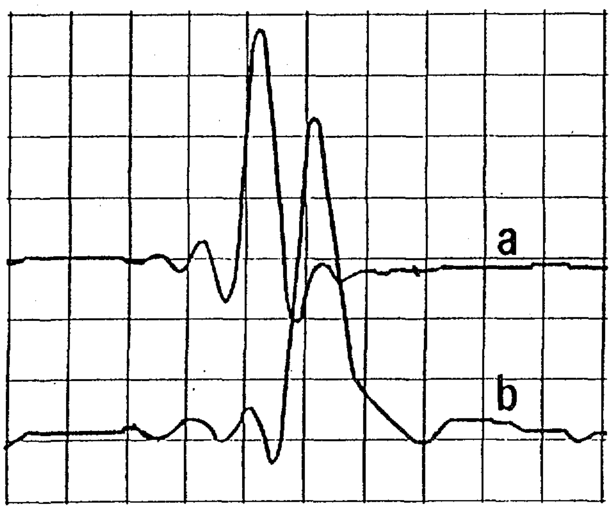


Fig (2) Electron distribution function energy
(a) Experimental derivation .
(b) Theoretical Maxwelliam



100 μs / div

Fig (3) Oscilloscope signal of coaxial gun
(a) Discharge current (1.5 kV/div).
(b) Electric probe signal (50 mV/div).
(Without glow discharge).

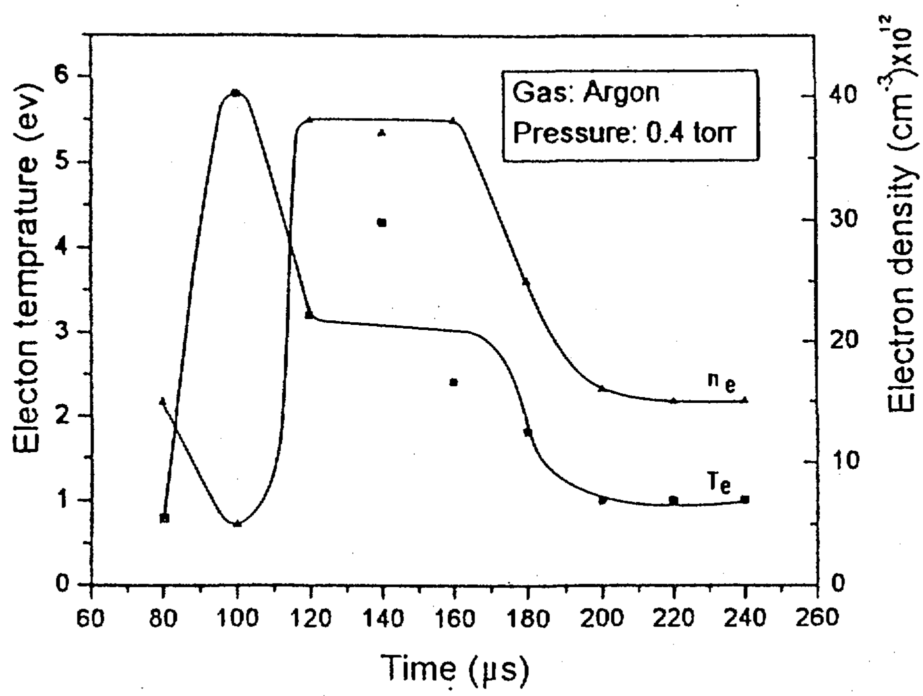


Fig (4) : The variation of the electron temperature And density of the ejected plasma with time .

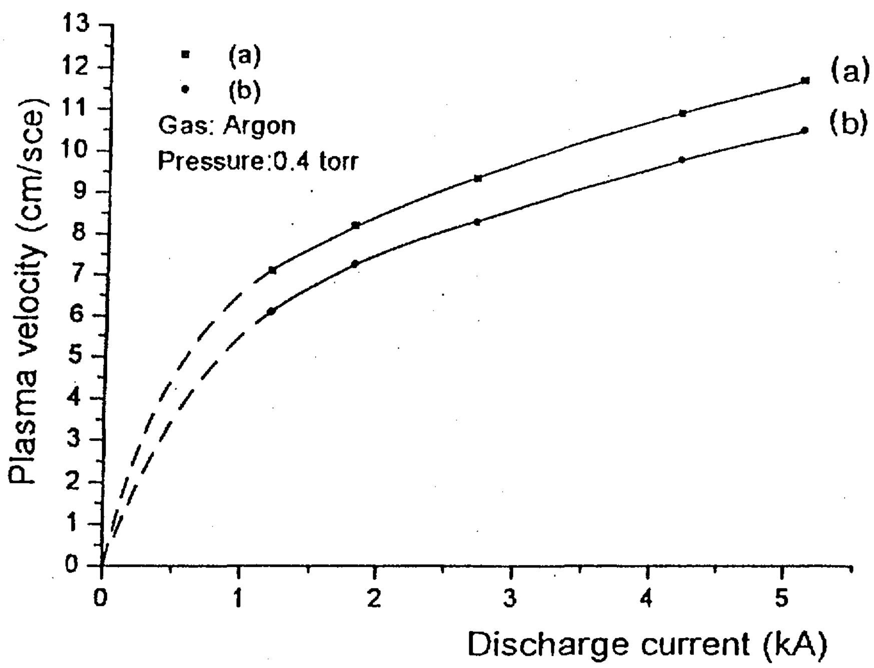


Fig (5) : The variation of ejected plasma sheath velocity Versus discharge current .
(a) In neutral argon gas .
(b) In argon negative glow region .

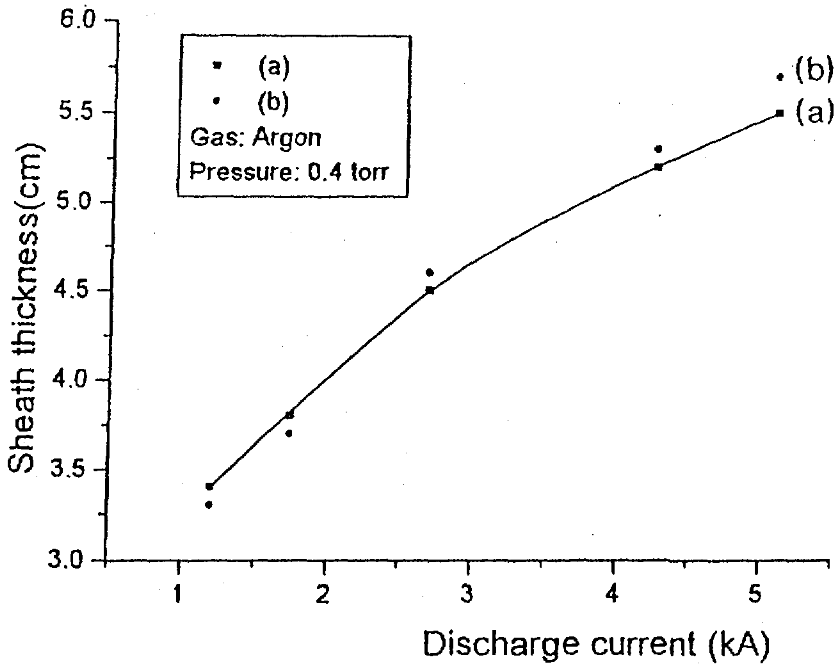
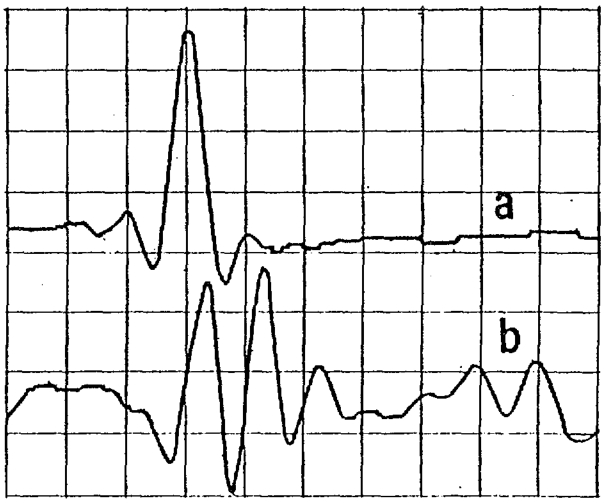


Fig (6) The variation of plasma sheathg thickness versus discharge current, with and without negative glow region.



100 μs / div

Fig (7) Oscilloscope signal of coaxial gun

(a) Discharge current (1.5 kV/div).

(b) Electric probe signal (20 mV/div). (Without glow discharge).

CONCLUSION

It has been found that the negative glow region in a normal glow discharge, which is powered with 340V, 2 mA in an Argon gas, consists of three groups of electrons each has Maxwellian distribution.

A miniature coaxial gun is fed by 200 joule capacitor bank produced a single pulse discharge current with peak value of 5.25 KA. The ejected plasma velocity from the coaxial gun increased with the increase of the discharge current. The electron energy spectrum of the ejected plasma varies with time between 6eV and 1eV.

The interaction of the ejected plasma and the negative glow is only individual particle interaction. A generated pulse due to the interaction has been detected and more studies have to be carried out to understand it. Also the effect of the impurities from the eroded material of the coaxial gun and other must be considered in future investigation.

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