Measurement of Electron Temperature (T_e) in a Positive Column By Using Double Probe Method

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Abstract

In this work the diode planer magnetron sputtering device was designed and fabricated. This device consist from two aluminum disc (8cm) diameter and (5mm) thick. The distance between the two electrodes is (3cm).

Design and construction double probe made from tungsten wire with (0.1mm) diameter and (1.2mm) length, to investigate the electron temperature under different argon gas pressure. The probes was situated in the center of plasma between anode and cathode.

The effect of the argon gas pressure on electron temperature was studied as this distance.

The result of this work shown that, when the argon gas pressure increased, the electron temperature will decreased.

الخلاصة

في هذا العمل تم تصميم وتصنيع منظومة الترذيذ المغناطيسي المستوية المستمر. تحتوي هذه المنظومة على قطبين من الألمنيوم بقطر (8سم) وبسمك (5ملم) والمسافة التي تفصل بينهما هي (3سم).
بالإضافة إلى ذلك تم تصميم وتصنيع مجس ثنائي بقطر (0.1 ملم) وطول (1.2 ملم) مصنوع من مادة التنكستن لتشخيص درجة حرارة الإلكترون وبضغوط مختلفة لغاز الآركون. ويتم وضع المجس في مركز البلازما بين القطبين الموجب والسالب. كذلك تضمن البحث دراسة تأثير ضغط غاز الآركون على درجة حرارة الإلكترون عند المسافة المحددة. إن نتائج هذه الدراسة بينت أنه عند زيادة الضغط فأن درجة حرارة الإلكترون تقل.

Introduction

The glow discharge owes its name to the fact that plasma is luminous. The glow can be produced by applying a potential difference between two electrodes in a gas. The potential drops rapidly close to the cathode, vary slowly in the plasma, and change again close to the anode. The electric fields in the system are restricted to sheaths at each of the electrodes.

The sheath fields are such as to repel electrons trying to reach either electrode. Electrons originating at the cathode will be accelerated, collide, transfer energy, leave by diffusion and recombination, slow by the anode and get transferred into the outside circuit. [1,2]

The luminous glow is produced because the electrons have enough energy to generate visible light by excitation collisions. Since there is a continuous loss of electrons, there must be an equal degree of ionization going on to maintain the study state. The energy is being continuously transferred out of the discharge and hence the energy balance must be satisfied also. Simplistically, the electrons absorb energy from the field, accelerate, ionize some atoms, and the process becomes continuous. Additional electrons are produced by secondary emission from the cathode.

These are very important to maintaining a sustainable discharge. Three basic regions are describe below, the cathode region, the glow regions and the anode region.

Several practically important configurations of glow discharge are shown below. [3,4]

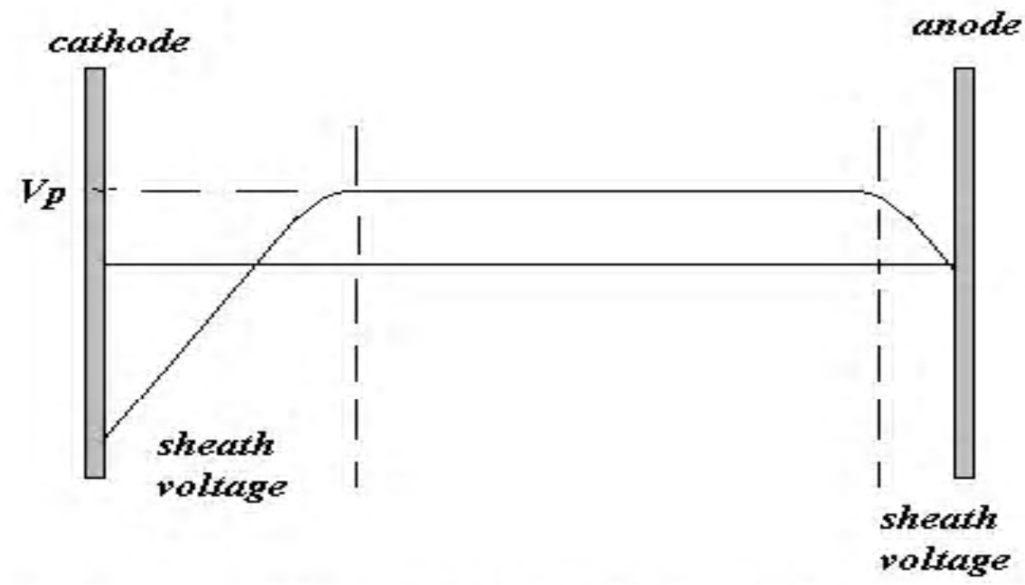

Fig.(1): Voltage distribution in a DC glow discharge process.

The fluorescent light bulb type of an arrangement is an evacuated glass tube with circular disc electrodes at either end, connected to a high voltage DC power supply. Once a sustainable DC glow discharge is established, it has a striking appearance of alternating light and dark spaces.

Double Langmuir Probe Theory

One of the earliest plasma diagnostic techniques was the electrostatic probe, first described and analyzed by Langmuir. Langmuir probes are used for localized measurements of plasma electron densities (n_e), electron temperatures (T_e), floating potential and plasma potential.

In other situations, the plasma potential may change with time, which will create difficulties in maintaining a constant voltage difference between a probe and the plasma potential. In these situations single Langmuir probes are not readily applicable, Johnson & Malter (1950) developed a technique that overcomes some limitations of the single probe [5,6].

It involved the use of two Langmuir probes biased with respect to each other and isolated from ground. This allows the probes to electrically float with regard to the plasma therefore allowing the probes to follow the changes in the plasma potential [11].

Double probe method was widely used to study the plasma properties. Most of the probe theories consider the case of a plasma at rest [7,8,9].

However, in some plasmas the electron drift velocity in the axial direction, which is principally responsible for carrying the discharge current, may reach an appreciable fraction of the thermal velocity, altering the electron drift velocity distribution from maxwellian to drift-maxwellian form. Under these circumstances, it is important to recognize the signature of the drifting electrons in the double probe characteristic [10,11].

A double probe consists of two electrodes that are inserted into a plasma. The spacing between the probes must be small enough that the properties of the plasma can be taken to be constant over that interval. In the case of a cylindrical double probe, the electrodes are nothing more than two exposed lengths of wire [11].

Figure (2) shows the electrical circuit for double probe and the voltage – current characteristic is shown in figure (3).

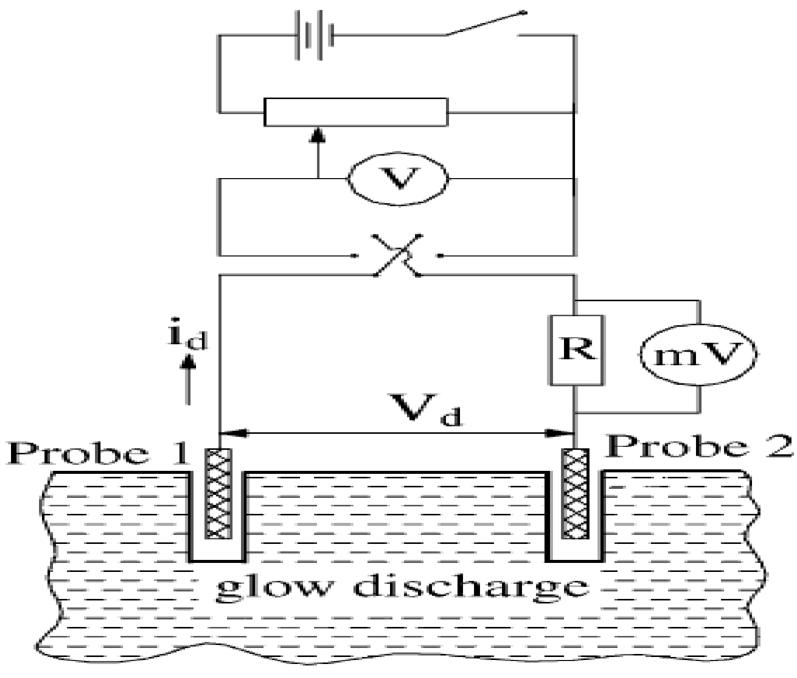

Fig.(2): Basic double probe circuit [12].

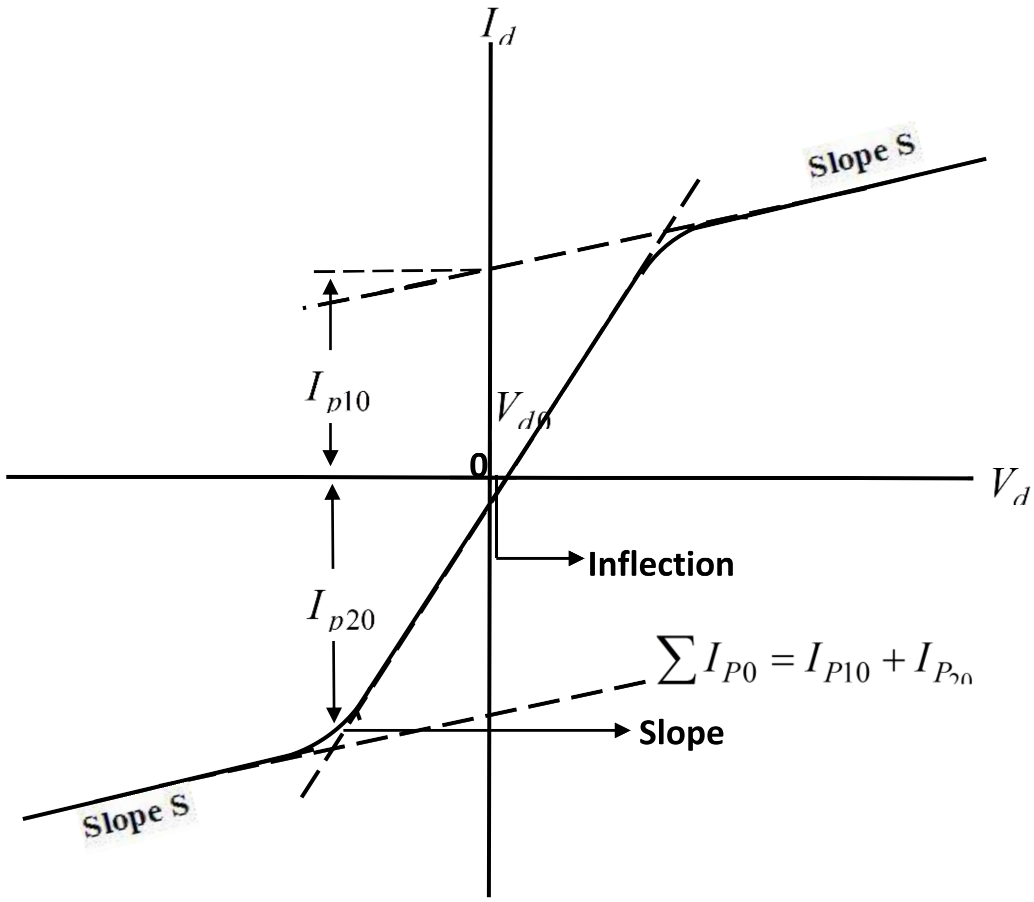

Fig.(3): Schematic diagram of the double probe characteristic [10].

Results and Discussion

The electron temperature has been determined from the way in which I_d (the probe current) varies with V_d (the probe voltage) by floating double probe method of Dote [10] which was modified from the equivalent resistance method by Johnson and Malter [5].

The expression for electron temperature (Te) is given by [10]:

$$T_e = \frac{e}{k}\frac{\sum I_{PO}}{4\left\{\left(\frac{dI_d}{dV_d}\right)_O - 0.82S\right\}} \qquad \text{..................(1)}$$

Where, Te=electron temperature,
e=charge of the electron,
K=Boltzmann constant,

$$\sum I_{PO} = I_{P_1O} + I_{P_2O}$$

$$\left(\frac{dI_d}{dV_d}\right)_O =$$ Slope from the current – voltage characteristics at the inflection.

S=Slope at the positive ion saturation characteristic**.**

The planer magnetron sputtering device was designed and fabricated. This device consist from two alumina disc 8 cm diameter and 5 mm thick. Figure (4) shows photograph of the probes used in this work and figure (5) shows the experimental set – up of this device.

The principle operation of this device is glow discharge. In addition this device is operate in constant mode (where the external constant applied voltage 1 kV).

The distance between the electrodes (3 cm) long, so that, the planer magnetron sputtering in our design can be named (diode planer magnetron sputtering).

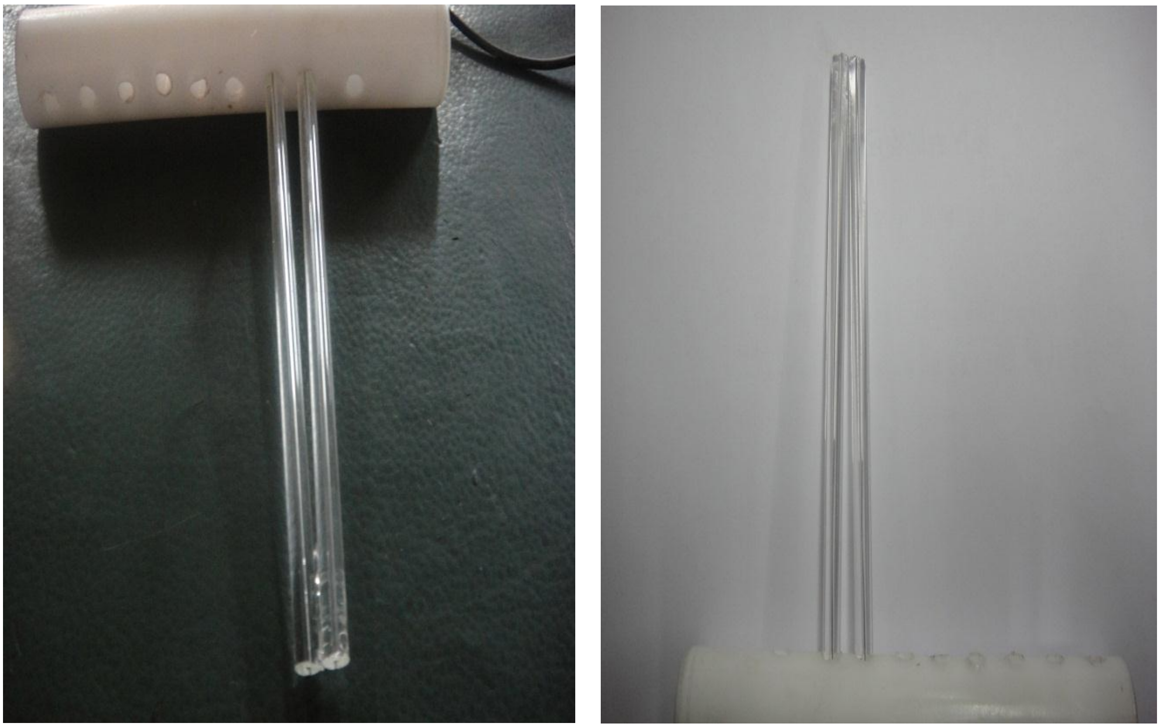

Figure (4): photograph of the probes used in this work.

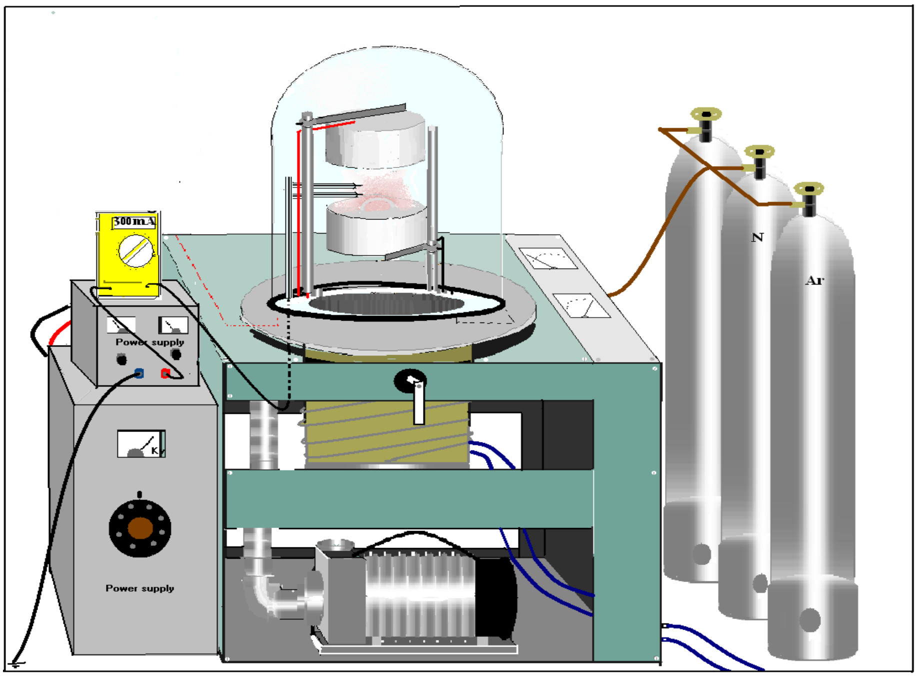

Figure (5): experimental set – up.

To investigate the electron temperature in positive column region, Langmuir double probe was situated in the center of plasma between anode and cathode. Figure (6) illustrated current voltage (I–V) characteristics of double probe in pressure ranges $2\times10^{-1} mbar,\ 3\times10^{-1} mbar\ ,4\times10^{-1} and\, 5\times10^{-1} mbar.$

The electron temperature can be calculated by using equation no.(1) [10]. Figure (7) shows the electron temperature as a function of pressure, this figure illustrated that the electron temperature decrease with the increase of gas pressure.

With the increase of gas pressure, electrons mean free path will become short. This will result in increased electronic inelastic collision and make the electron energy loss.

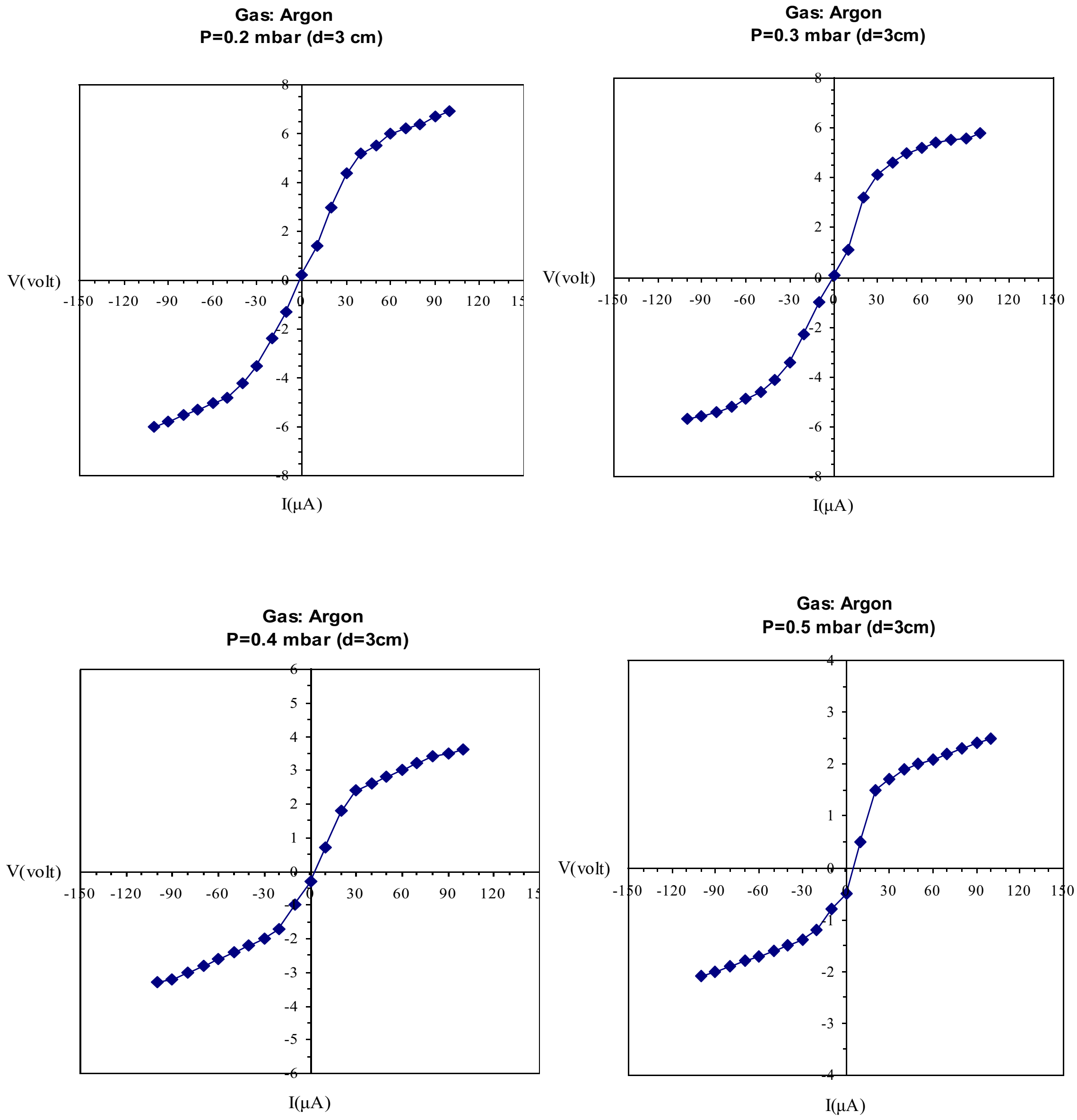

Fig.(6) I – V characteristics of double probe in different pressure ranges.

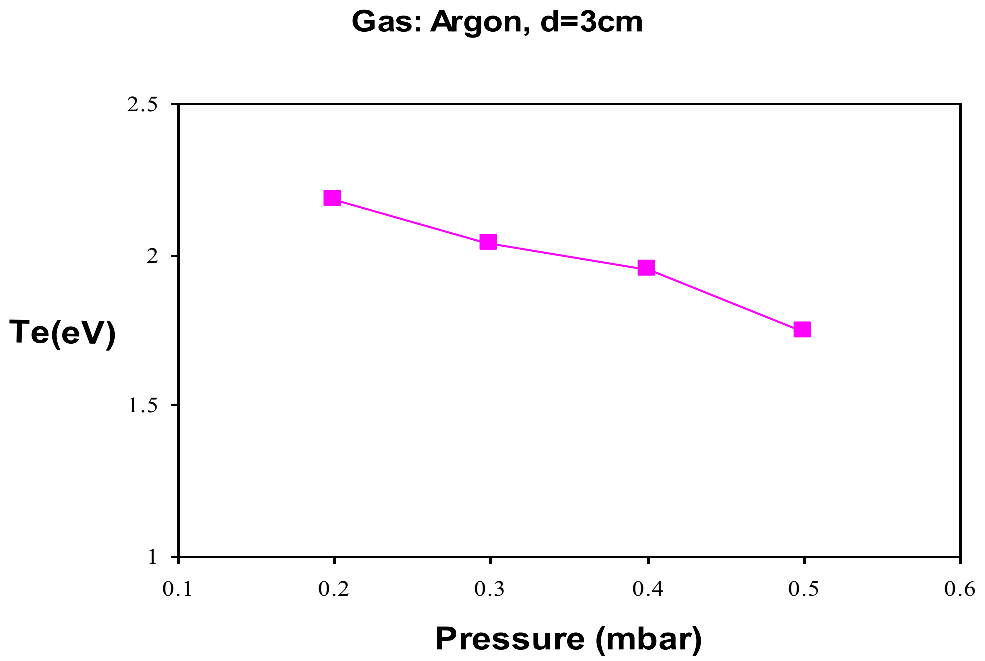

Figure (7): The relation between temperature of electron as a function to the pressure.

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