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website : http:// jsci.utq.edu.iq Email: utjsci@utq.edu.iq

Measurement of Deby length By using single probe technique

Emad A. Salman Alaa J. Ghazai

Department of Physics- College of Science - Thi – Qar University.

Abstract

In this work the planer magnetron sputtering device was used. As well as a 1mm copper diameter and 3 mm length Langmuir probe was used a diagnostic device to investigate electron temperature, electron density and Deby length under different pressure at distance 0.7 cm from the anode surface was measured.The effect of the pressure on plasma parameter was studied at this distance.The result of this work shown that, when the pressure increased the electron temperature and Deby length will decreased while the electron density increased.

قياس طول ديباي باستخدام المجس المنفرد

عماد عبد الرزاق سلمان علاء جبار غزاي

قسم الفيزياء – كلية العلوم – جامعة ذي قار

الخلاصة

في هذا البحث تم استخدام منظومة الترذيذ المغناطيسي المستوية المستمر. بالإضافة إلى ذلك تم تصميم وتصنيع مجس منفرد بقطر (١مم) وطول (٣مم) مصنوع من مادة النحاس لتشخيص درجة حرارة الإلكترون، كثافة الإلكترون وطول ديباي وبضغوط مختلفة وبمسافة تبعد (٠.٧ سم) عن سطح الآنود. إن تأثير الضغط على معلمات البلازما بتلك المسافة تم دراسته أيضا. إن نتائج هذه الدراسة بينت أنه عند زيادة الضغط فأن درجة حرارة الإلكترون وطول ديباي يقلان بينما كثافة الالكترونات تزداد.

Introduction

Cold plasma technologies have found extensive application in material processing for over 30 years and they are now widely used in the manufacture of thin film material, magnetic media, special glasses, and for metal coating, etc. In the last decade, great attention has been devoted to a reactive dc magnetron sputtering. Its technology has covered a vast range of industrial applications [1- 3].The use of plasma for material deposition is widely used in technological and industrial process. Magnetron sputtering is the most popular for thin film deposition [4]. Noble gases are commonly used to generate the plasma because they are almost inert. Generally, plasmas are characterized by external parameters such as direct current (DC) input power, substrate bias, pressure, and gas flow rate. However, knowledge of these external parameters does not provide adequate understanding of the sputtering process. More insight relating to the film composition and growth rate, for example, is provided by investigating the internal plasma parameters. Many diagnostic techniques, such as Langmuir probe [5], Optical emission spectroscopy (OES) [6], and mass spectrometry[7], are used to characterize plasma. Among these techniques, Langmuir probe is widely used to measure plasma parameters such as electron density (ne), ion density (ni), electron temperature (Te), etc.The Langmuir probe consists of an electrode whose potential is varied to obtain an I –V characteristic which is used to calculate different plasma parameters [8].

The interactions between these particles and the process gas molecules result in momentum and energy exchange between the colliding particles and gases may result in excitation, ionization and dissociation of the process gas as well as other neutrals.

Debye Length

Debye length is one of the important parameter of plasma. If an electric field is created in the plasma, the charged particles will react to reduce the effect of the field. The lighter, more mobile, electrons will respond fastest to reduce the electric field. If plasma had an excess of positive or negative particles, this excess would create an electric field and the electrons will move to cancel the charge.The response of charged particles to reduce the effect of local electric fields is called Debye shielding and the shielding gives the plasma its quasi-neutrality characteristic. Let assume that an electric potential is applied between two surfaces immersed in plasma. The surfaces will attract equal amounts of charged particles of opposite sign. The concentration of charged particles near the two surfaces will shield the charged surfaces from the plasma bulk, which will remain neutral. The applied electrical potential will therefore develop mostly near the surfaces, over a distance λ_D, called the Debye length and defined by [9].

$$\lambda_D = 743\sqrt{\frac{T_e}{n_e}} \qquad (1)$$

Where n_e is the density of the electrons (cm^{-3}), T_e electron temperature in eV. The first condition for plasma existence is the Debye length should be very small when compared with the system dimension (L) i.e. $\lambda_D <<< L$.

Langmuir Probe Construction

The Langmuir probe composed with copper wire was inserted into the vacuum chamber. The tip is not covered with glass house for insulation as shown in Fig.(1). Cylindrical probe was used for single probe measurements. The diameter and length of the copper probe out side the glass house are 1 mm and 3 mm, respectively. Further more this probe is operating by sweeping mode, which changes from 80 volt to -80 volt.

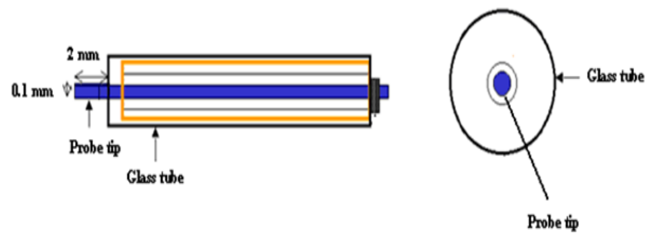

Fig.(1) Shows Langmuir probe design

The electrical circuit is shown in fig.(2). From the plot of probe current versus voltage which is called the I-V characteristic, the plasma parameters can be calculated. The pressure varied within the range of 1x10-1 - 6x10-2mbar by adjusting the pumping speed through the opening control of throttle. The plasma was excited by combination of DC voltage supply working up to 5000 V and maximum DC current of 500 mA. The probe was situated near from the target (distance z =0.7 cm from the target).

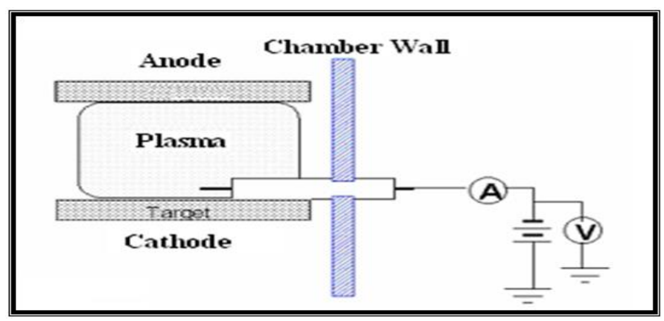

Fig.(2) Electrical circuit for the Langmuir probe

Result and Discussion

This section includes the results and the analysis of the experimental measurements of plasma characteristic by single Langmuir probe and studies the influence of gas pressure on the plasma characterization. The plasma chamber where formed by DC planar magnetron sputtering, as well as the construction and the probe device were used for studying the plasma diagnostic (to obtain electron temperature, electron density and Debye length). To investigation plasma properties in a region near from the anode, Langmuir probe was located at 0.7 cm distance from the anode. Figure (3) illustrated I – V characteristics of probe in pressure ranges

$1\times10^{-1}\,mbar\,, 8\times10^{-2}\,mbar\ and\ 6\times10^{-2}\,mbar$.

From this figure we can show the electron current is grater than ion current because the electron mass is less than ion mass. As well as, the electron saturation current decreases with pressure.

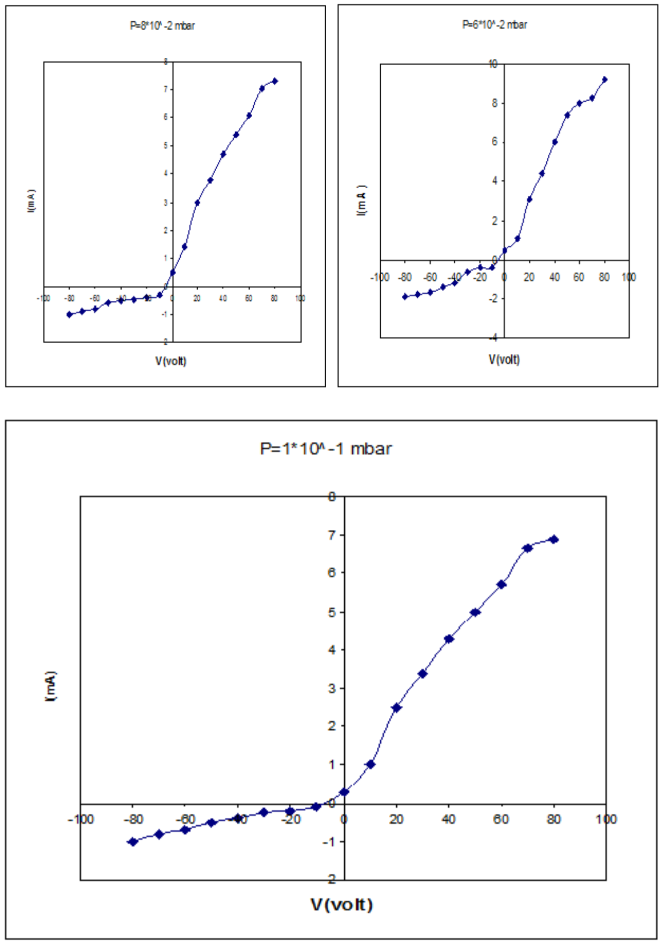

Fig. (3): The relation between current probes as a function to the voltage probe.

The electron temperature can be calculated by take the (Ln I) and drown as a function to probe potential and shown in figure (4). The slope of transport region with give to T in eV [10].

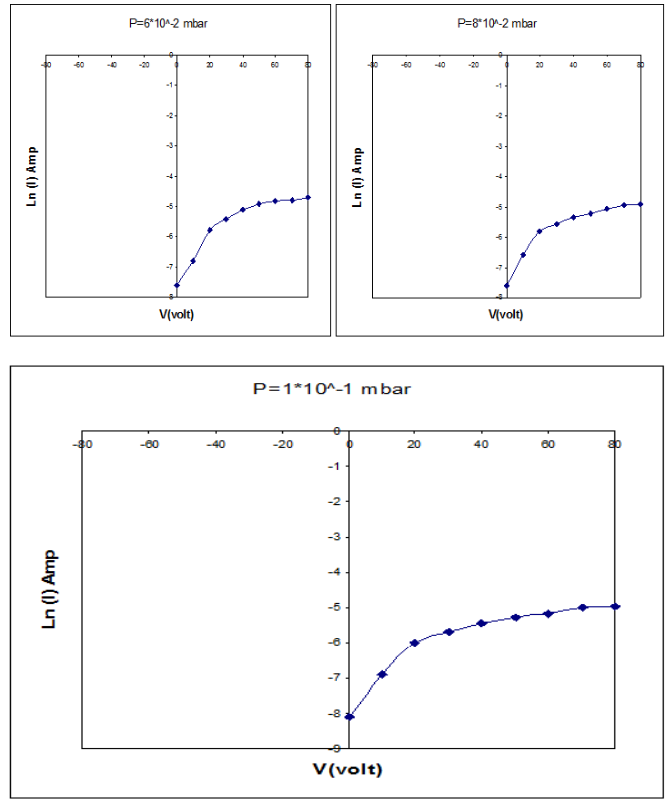

Fig.(4): The relation between Ln (I) as a function to the voltage probe.

Figure (5) shows the electron temperature as a function to pressure, this figure illustrated that the electron temperature decrease with pressure. This decreasing in temperature behavior with pressure because of the Langmuir probe located in the anode sheath which there is no collision in this region and 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 less.

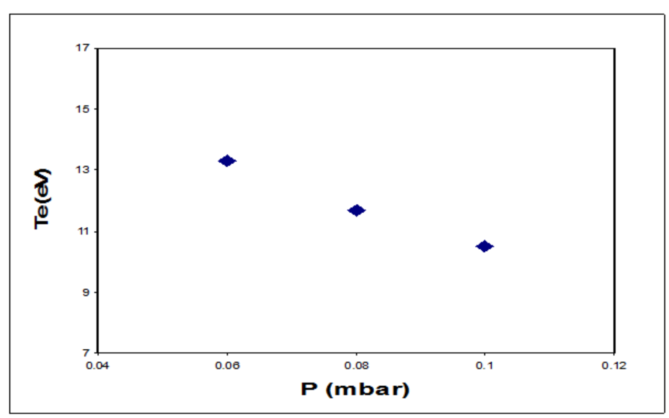

Fig.(5): The relation between temperature of electron as a function to the pressure.

The electron density (n_e) can be calculated by using figure (3) and figure (4) with equation below:

$$n_e = \frac{I_{esat.}}{eA\left(\sqrt{\frac{KT_e}{2\pi m_e}}\right)} \quad \text{..........(2)}$$

Where A is the area of probe $= 2\pi r l = 0.0942\, cm^2$, K Boltzman constant, M_e mass of electron and e charge of electron. The behavior of such densities are shown in figure (6). From this figure, we noted that the electron density will increase with pressure, because of the electron temperature will decrease with pressure. So that, the electron will escape of this region as a results to their temperature decreasing. Consequently the electron current and density will be increased.

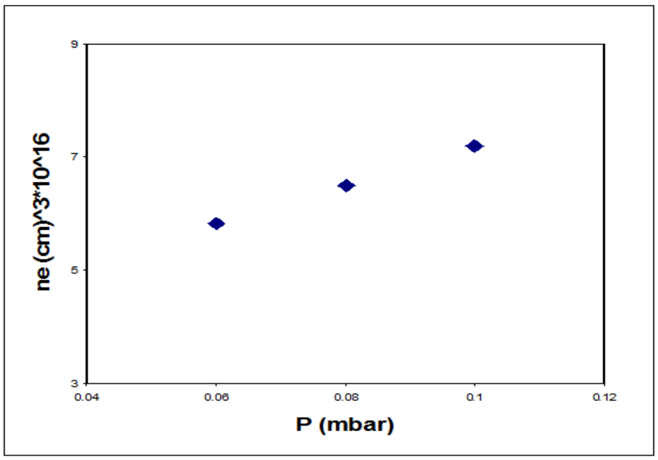

Fig.(6):The relation between the density of electron as a function to the pressure.

We can calculate the values of Debye length for all different pressures by using equation (1) and listed in table below.

Table (1): The values of Deby length at different gas pressure.

Pressure (mbar)	Electron temperature (eV)	Electron density (cm^3)	Deby length (cm)
1×10^{-1}	10.5	7.18×10^{16}	8.9×10^{-6}
8×10^{-2}	11.7	6.49×10^{16}	9.9×10^{-6}
6×10^{-2}	13.3	5.83×10^{16}	1.1×10^{-5}

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