ISSN 1991- 8690 الترقيم الدولي ٨٦٩٠ - ١٩٩١

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Measurement of Plasma Parameters by using Nitrogen gas

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Abstract

In this work the diode planer magnetron sputtering device was used. This device consists from two alumina disc (8cm) diameter and (5mm) thick. The distance between two electrodes is 2cm, 3cm, 4cm and 5cm. Design and construction double probe made from tungsten wire with (0.1mm) diameter and (1.2mm) length, to investigate electron temperature, electron density and ion density under different distance between cathode and anode measured. The probes were situated in the center of plasma between anode and cathode. The result of this work shown that, when the distance between cathode and anode increased, the electron temperature will decreased. The electron density was found to increase with increasing distance between the electrodes. The behavior of ions density is similar to that electron but the value is higher.

قياس معلمات البلازما باستخدام غاز النيتروجين

علي جهاد كاطع

قسم الفيزياء – كلية العلوم – جامعة ذي قار

الخلاصة

في هذا العمل تم استخدام منظومة الترذيذ المغناطيسي المستوية المستمر. تحتوي هذه المنظومة على قطبين من الألمنيوم بقطر (٨سم) وبسمك (٥مم) والمسافة التي تفصل بينهما هي ٢سم، ٣سم، ٤سم و٥سم. بالإضافة إلى ذلك تم تصميم وتصنيع مجس ثنائي بقطر (٠.١مم) وطول (١.٢مم) مصنوع من مادة التنكستن لتشخيص درجة حرارة الإلكترون، كثافة الإلكترونات وكثافة الايونات بمسافات مختلفة بين الكاثود والآنود. إن تأثير المسافة بين الأقطاب على خواص البلازما تم دراسته. إن نتائج هذه الدراسة بينت أنه عند زيادة المسافة بين الكاثود والآنود فأن درجة حرارة الإلكترون تقل. لقد وجد أن كثافة الالكترونات تزداد بزيادة المسافة بين الأقطاب، سلوك كثافة الايونات نفس سلوك الالكترونات ولكن بقيمة أعلى.

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. Because of the complexity of the physical and chemical environment in a process plasma, a large array of process monitors, historically termed "Plasma diagnostics", are required to characterize the plasma, or to properly monitor important control parameters.

Plasma diagnostics are used to deduce information about the state of the plasma from observations of physical processes and their effects. The information is used to verify performance of the experiment and for control of the plasma volume regarding its topology and boundary. It is important to describe the plasma, which is done by comparing theoretical predictions with measurements. This is done in terms of a number of plasma parameters [5]. Plasma diagnostics encompasses all methods and techniques employed for the determination of macroscopic as well as of microscopic properties and parameters of plasmas as a function of space and time. There are many different diagnostic tools that can be used, depending on the type of plasma under investigation and the specific information that is required [5,6]:

1- Electrostatic probes.
2- Surface probes.
3- Microwave interferometry.
4- Impedance analysis.
5- Quantitative plasma mass spectroscopy.
6- Emission and absorption spectroscopy.
7- (Laser) fluorescence spectroscopy.

Parameters that characterize plasmas are the electron (n_e), ion (n_i) and neutral (n_0) densities, the respective temperatures (energies) of these species, and the magnetic (B) and electric (E) fields. Since laboratory plasmas range from small-volume configurations of $10^{-16} m^3$ (e.g. micro pinches) to large-volume system of about 50 m^3 (magnetic fusion device JET), and density and temperature cover a range from 10^{14} to $10^{30} m^{-3}$ and from $10^3 K$ to several times $10^8 K$ (1eV…10eV), respectively, a large variety of different methods is used which originate in a number of fields of physics and applied physics [4,5].

Double Langmuir Probe

In some types of plasma discharges there does not exist an electrode or reference point that is in good contact with the plasma. This reference point is needed when applying a bias voltage to a Langmuir probe. 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 and Johnson and Malter (1950) developed a technique that overcomes some limitations of the single probe [7,8]. 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. Double probe method is widely used for the study of plasmas properties. Most of the probe theories consider the case of a plasma at rest.[9,10] .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.[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. The electrical circuit and voltage – current characteristic of the double probe method is shown in figures (2) and (3) respectively.

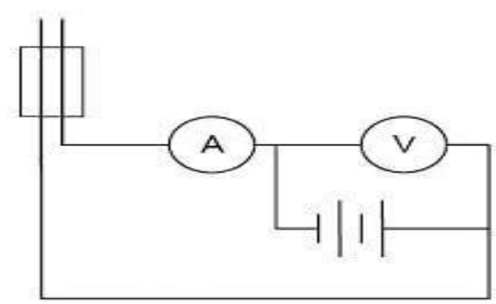


Fig.(2): Basic double probe circuit.

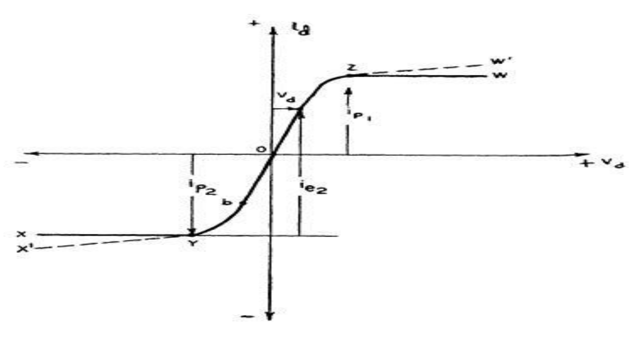


Fig.(3): Schematic diagram of the double probe characteristic.

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 [11] which was modified from the equivalent resistance method by Johnson and Malter [7]. The expression for electron temperature (Te) is given by [11]:

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

Where, Te=electron temperature, $e =$ charge of an 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.

From the same characteristic curve the ion saturation current (I_{sat}) is given by:

$$I_{sat} = \frac{1}{4}Aen_e\bar{v} \qquad (2)$$

Where $A =$ effective electron or ion collection geometrical area of the probe, $n_e =$ electron density and $\bar{v} =$ mean speed. The factor $\frac{1}{4}$ in the above equation is composed of two factors of $\frac{1}{2}$. One accounts for the fact that at the sheath edge the density is half the plasma density. The other is merely the average of the direction cosine over a hemisphere. The velocity distribution of each species can be represented by a Maxwell-Boltzmann distribution and the energy distribution quantified by a temperature. However, often the electron temperature is very considerably higher than the ion and gas temperature, i.e. [6]

$$kT_e >> kT_i \approx kT_g$$

Where T_i is the ion temperature and T_g is the gas temperature. In low pressure (<100Pa) plasmas, the gas and ion temperatures can be 300k while the electron temperatures may be over 20000k. In the literature, the temperature and other energies are often presented in terms of electron volts (eV), where [6]

$$kT = 1eV \equiv 11600\,k$$

The mean speed given by:

$$\bar{v} = \sqrt{\frac{8kT_e}{\pi m_e}} \qquad (3)$$

Where $m_e =$ mass of electron. Therefore, a simple rearrangement of equations (2) and (3) leads to an expression for the electron density:

$$n_e = 4\frac{I_{sat}}{Ae\sqrt{\frac{8kT_e}{\pi m_e}}} \qquad (4)$$

In this work, the planer magnetron sputtering device was used. This device consist from two alumina disc 8 cm diameter and 5 mm thick. 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 planer magnetron sputtering in our design can be named (diode planer magnetron sputtering).To investigation plasma parameters in positive column region, Langmuir double probe was situated in the center of plasma between anode and cathode. Figure (4) illustrated I – V characteristics of double probe in distances 2cm, 3cm, 4cm and 5cm. The electron temperature can be calculated by using equation (1) [11]. Figure (5) shows the electron temperature as a function to the distance between two electrodes, this figure illustrated that the electron temperature decreases with the increase of distance. With the increase of distance between electrodes, electrons mean free path will become short. This will result in increased electronic inelastic collision and make the electron energy loss. The decrease in T_e with increase distances is due to reduces the electron current, energy of electron cause to multiple collisions. Figure (6) (a) and (b) shows the electron and ion densities as a function to the distance between two electrodes, this figures illustrated that the electron density increases with the increase of distance. The behavior of ions density is similar to that electron but the value is higher. When the distance increases, there are more neutrals present, hence the distance between collisions (mean free path) decreases and less energy is gained between collisions and consequently the increase in the number of collisions means the frequency of ionization will increase leading to an increase in the density.

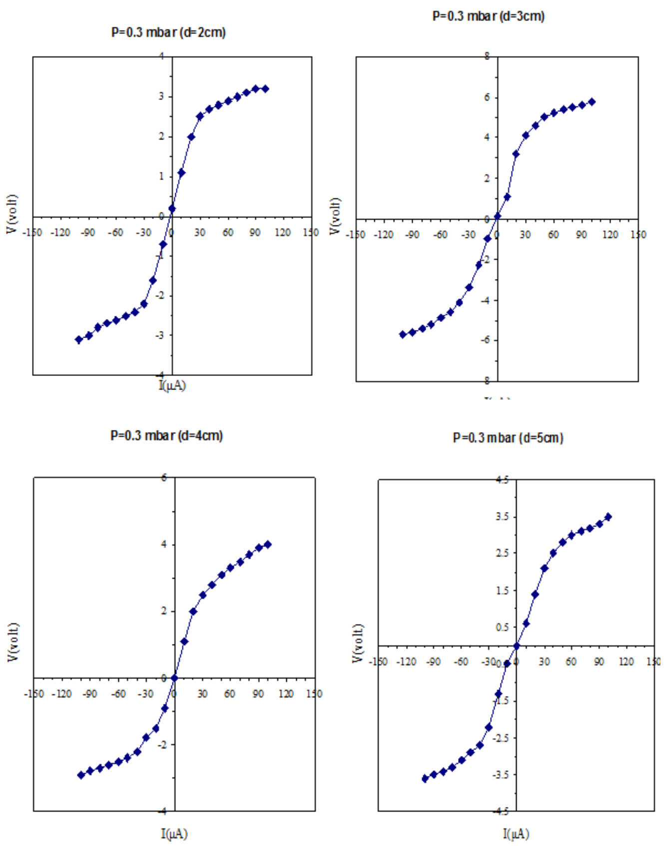


Fig.(4) I – V characteristics of double probe in distances 2cm, 3cm, 4cm and 5cm.

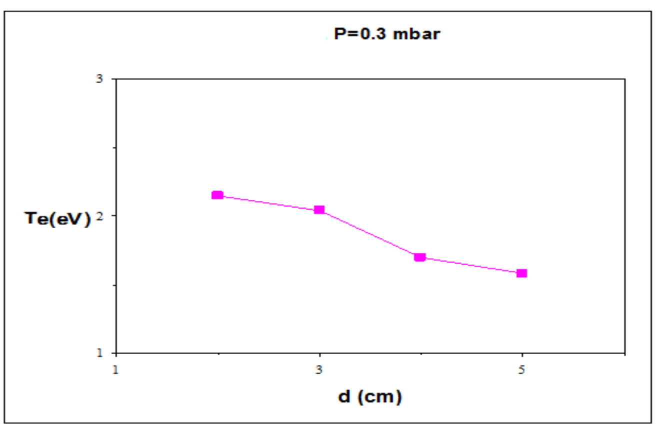
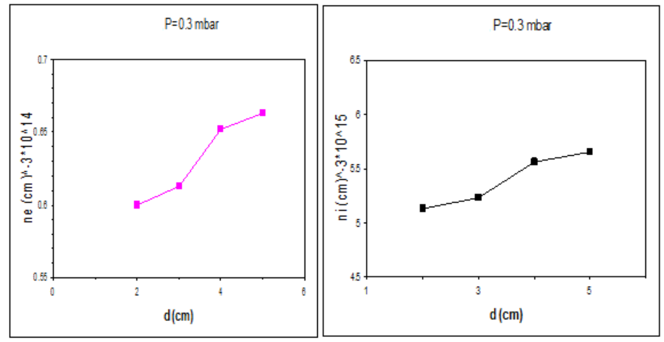


Fig.(5): The relation between temperature of electron as a function to the distance.



a b

Fig.(6): The relation between (a) electron density, (b) ion density, as a function to the distance.

References

1- R.Barni, C. Riccardi, E. Selli,M Massafra, B. Marcandalli, F.Orsini and G.Poletti " Plasma Process Polymer ",Vol. 2, (2005),P.64.

2- A. Belkind, A. Freilich, R.A. Scholl, J. Vac. Sci.Technol, Vol.A 17 (1999),P.1934.

3- P.J. Kelly, R.D. Arnell,“Vacuum”Vol.56 (2000),P.159.

4- J. Kong, H. Shen, B. Chen, Z. Li, W. Shi, W. Yao, Z. Qi, Thin Solid Films,Vol. 207 (1999), P. 51.

5- D. M. Manos and H. F. Dylla, "Diagnostics of plasmas for Materials processing", Academic Press, Inc., 1989.

6- R. Shishoo, "Plasma technologies for textiles", Boca Raton Boston, New York, Washington, 2007.

7- E. O. Johnson and L. Malter, "Physical Review", 80, 58, 1950.

8-F.F.Chen,"Plasma diagnostic Techniques", Academic, NewYork, 1965.

9- S.S.Pradhan and D.C.Jana, Journal of Physical Sciences,10,158, 2006.

10- C. Das, D. C. Jana, A. K. Hui, Journal of Physics, 208, 012127, 2010.

11- Toshihiko Dote, Japan J. Appl. Phys., 7,964,1968.