International Journal of Recent Research and Review, Vol. V, March 2013
ISSN 2277 – 8322

Influence of Discharge Pressure on the Plasma Parameter in a Planar Dc-Sputtering Discharge of Argon

Mohammed K. Khalaf[1], Nathera Abass Ali Al-Tememee[2], Bahaa T. Chaid[2], Fwad T. Ibrahim[2]
[1]*Ministry of Science and Technology, Baghdad, Iraq*
[2]*Department of physics, College of Science, Baghdad University, Iraq*
Email: mohammedkhkh@yahoo.com

Abstract- Plasma parameters in a planar dc-sputtering discharge in argon were measured by cylindrical electrostatic probe (Langmuir probe).Electron density, electron temperature, floating potential, and space potential were monitored as a function of working discharge pressure. Electrostatic probe and supporting circuit were described and used to plot the current – voltage characteristics. Plasma properties were inferred from the current-voltage characteristics of a single probe positioned at the inter-cathode space. Typical values are in the range of (10^{-16} -10^{-17}) m^{-3} and (2.93 – 5.3) eV for the electron density and the electron temperature respectively.

Keywords- Electrical discharges, plasma parameter, dc-sputtering, Electron density, Electron temperature.

I. INTRODUCTION

The use of electrostatic probes is the simplest experimental technique to measure the properties of the plasmas [1-4]. This technique was introduced and developed by Irvin Langmuir about fifty years ago, and contently is sometimes called the method of Langmuir probes. Basically electrostatic probe is merely a small metallic electrode, usually a wire inserted into plasma. The probe is attached to a power supply capable of biasing it at various voltages positive and negative relative to the plasma, and the current collected by the probe then provides information about the conditions in the plasma. Electrostatic Langmuir probes are one of the basic tools of the plasma physicist for measuring electron densities, temperatures, and energy distributions. The technique has been extensively used and in many cases the quantities measured compare very well with those obtained by other techniques [5, 6]. Hence, the plasma parameters; electron temperature, electron density and axial electric field will be changed from one region to another under the same condition. The probe technique is an important one because it can make local measurements. Almost all other techniques, such as spectroscopy or microwave propagation, give information averaged over a large volume of plasma [7, 8].

In the present work, the behavior of space potential, floating potential, electron temperature, and plasma density as functions of discharge pressure were examined. The objective is to demonstrate that electrostatic probes used as plasma diagnostics tools can be used to measure the glow- discharge properties during sputtering.

II. EXPERIMENTAL WORK

The scheme of the plasma reactor used in this investigation is shown in Fig. 1(a). The reactor is made of a stainless steel cylinder (inner diameter *0.3 m*, height *0.34 m*). Also, the electrodes are made of stainless steel; they are *15 mm* in thickness and *100 mm* in diameter. The vacuum chamber was preliminary evacuated using a combination of rotary and diffusion pumps to achieve a residual pressure of 10^{-5}mbar . The gas flows were controlled mass flow meters and the gas pressure was monitored by Pirani vacuum gauge.

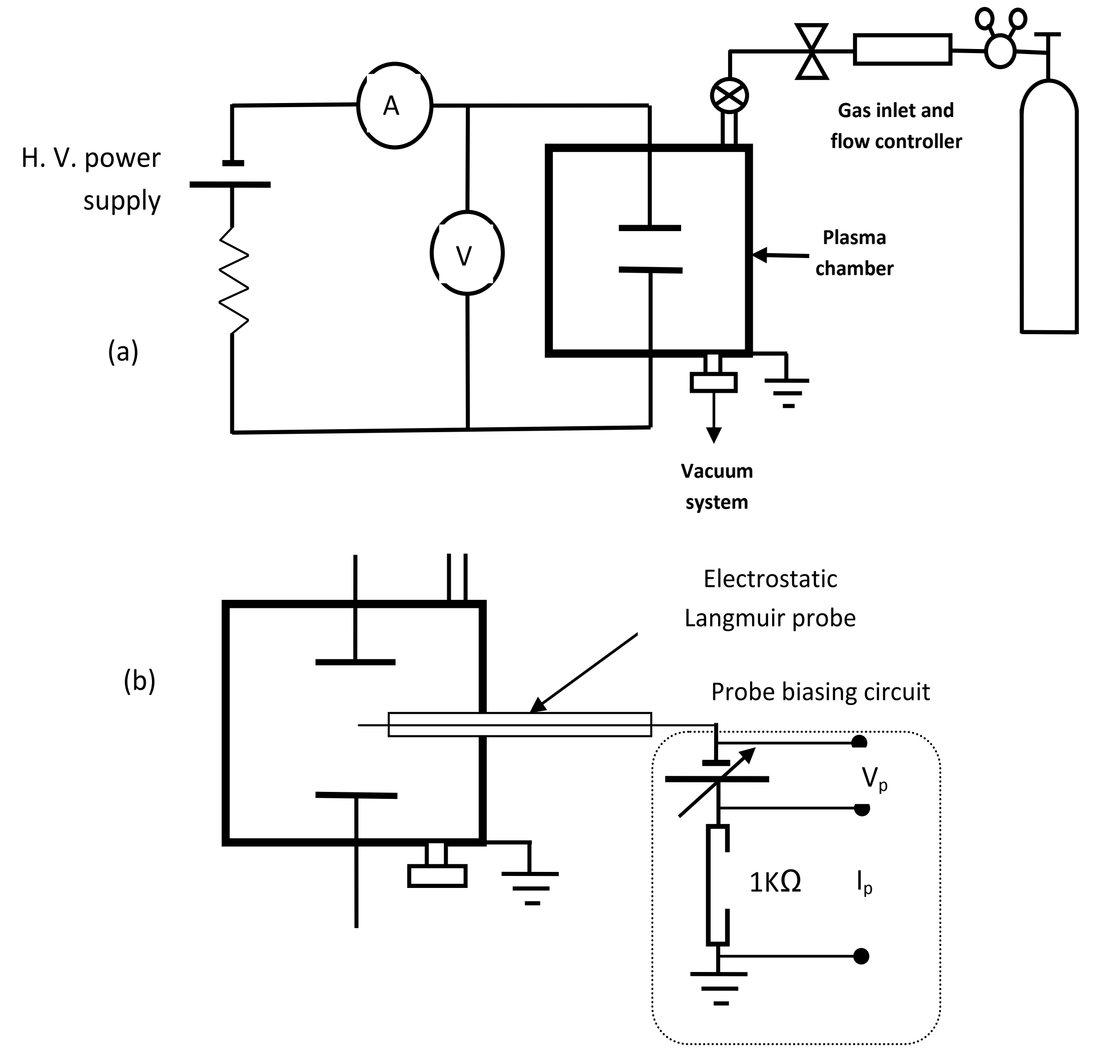

Fig.1 (a) schematic sketch of the experimental system.(b)electrostatic probe biasing circuit

The electrostatic probe measurements have been performed by using the configuration of cylindrical single probe. This probe, positioned inside the cathode region of plasma column and at the axis of the discharge, essentially consists of one tungsten wire of 5 mm in length and 0.2 mm in diameter. The unexposed length of the probe was covered with glass and attached to the base of the probe manipulator. The plasma generated between the two electrodes is characterized by the presence of impurity metal-ions, gas ions and new compounds due to intensive ion sputtering of the cathode, thus promoting the contamination of the chamber walls and of the electrostatic probes. Prior to *I-V* measurements the probe surface is cleaned by polarizing the probe at the cathode potential during a period short enough for the probe to reach incandescence by ion bombardment heating. The probe biasing circuit is show in Fig. 1(b).

III. RESULT AND DISCUSSION

The description of the *I-V* characteristics of an electrostatic probe depends not only on the plasma investigated but also on the geometry of the probe used. In the present investigation a cylindrical probe of radius 0.2 mm and length 5mm was used. Since, in weakly ionized argon plasma, at (0.015-0.15) mbar pressure, mean free path for charge particle-neutral collision is in the order of centimeters, charged particle collection is collisionless. Furthermore, for all the plasmas studied, as we seen in Table I, the condition $r_p<3\lambda_D$ (r_p=probe radius, λ_D=Debye length) was satisfied which means that charged particle collection was orbital-motion limited.

Table 1

The plasma parameters with different discharge pressure

P (mbar)	0.015
T_e (eV)	5.3
I_d (mA)	4.8
n_e*10^{16}electron/m^3	2.476
N_i*10^{14}ion/m^3	2.088
V_f (volt)	-12
V_p (volt)	110
λ_d (cm)	0.018

The experimental setup used to measure the plasma characteristics is shown in fig. 1(b). Variable resistor *R* is used to bias the probe continuously from -200 to +200 and probe current is measured by the voltage drop across R=1kΩ.

Fig.3 shows the variation of the plasma electrons density and, electron temperature as a function of pressure. As in this figure the electron temperature decreased gradually with increased of working pressure, while the electron density increase. The mean free path and acquired energy of electron decrease with increasing working pressure, therefore reducing the ionization process.

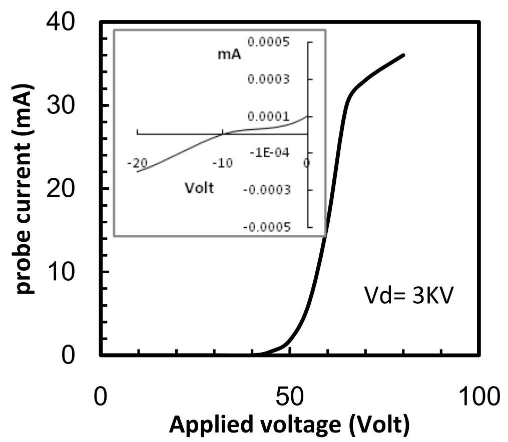

Fig. 2: I-V characteristics curve of Langmuir probe for argon discharge plasma at 3KV discharge voltage and mbar working pressure.

These results can be explained as the working pressure decrease where these means decreasing in number of gas molecule in chamber and the accelerated free electron show fewer molecules for bombard, therefore smaller amount energy to form new free electrons and positive ions.

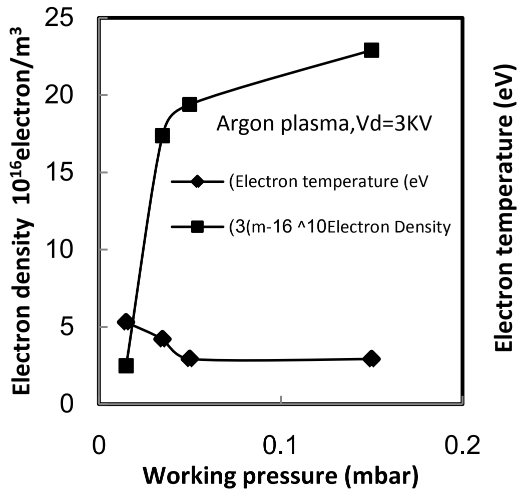

Fig. 3: Variation of the plasma electron density and temperature as a function of working pressure.

The variation of floating potential and space potential as a function of pressure in a dc discharge is shown in fig. 4. These parameters were measured from fig.2, where the floating potential increase, and space potential decrease with increasing working pressure.

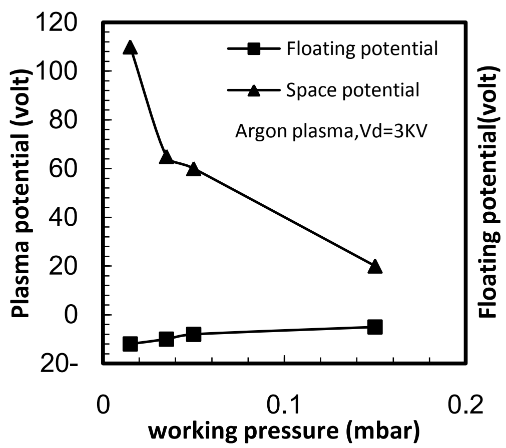

Fig. 4: Floating potential, and space potential as a function of working pressure

The ion current and density in Ar plasma can be calculated corresponding to orbital motion limit (OML) theory. The I_p^2 vs. V, plots for the ion-collection range (V<0) were obtained. The slope of the linear region of these I_p^2 vs. V curves was used to calculate the ion density. The Fig.5 shows the evaluation of ion current and density in Ar plasma as a function working pressures.

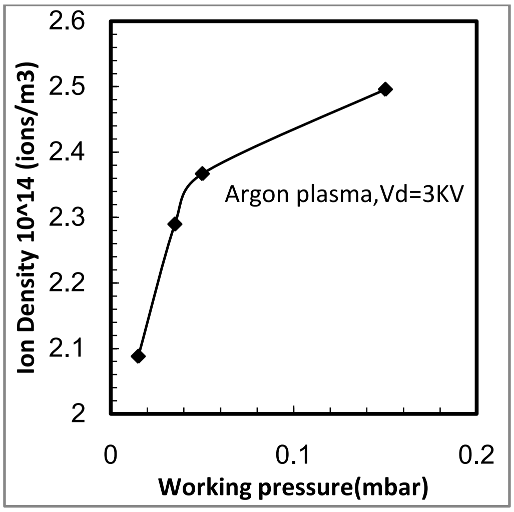

Fig. 5: The Ion density of Ar plasma measured as function of working pressure.

The ion density measured in the Ar plasma was increased with increasing of gas pressure due to the frequency of collisions became higher. Electrons suffer collisions with neutral particles, ionizing them. They lose their energy and are accelerated in electron field gaining again energy to produce ionization. The obtained ion current and density of Ar plasmas are different for the same operating conditions due to the difference in mass and ionization potential.

IV. CONCLUSIONS

A cylindrical Langmuir probe was used to measure the density and temperature of the electrons of argon plasma. The dependence of these plasma parameters on the pressure was experimentally determined. The plasma has electron density of the order of (10^{-16} - 10^{-17}) m^{-3} and electron temperature in the range of (2.93 – 5.3) eV.

The Present investigation shows that electrostatic Langmuir probes can be used effectively to measure the properties of the plasma sputtering. The observed dependence of the plasma parameters and the sputtering variables makes this technique useful not only in controlling the stability of the discharge during sputtering deposition but also in enhancing the repeatability of the sputtering process for a given system.

V. REFERENCES

[1] F. F. Chen, "*Electric Probes," Plasma Diagnostic Techniques*, Ed. by Huddleston and Leonard (Academic Press, 1965).

[2] E. Eser, R. E.Ogilvie, and K. A. Taylor," *Measurement of plasma discharge characteristics for sputtering applications*", J. Vac. Sci. Technol. 15(2), 199-202(1978).

[3] G. Petraconi and H. S. Maciel, "*A New Double Probe System for Studies of Non-Uniform Plasmas*" Brazilian Journal of Physics. 33(4), 782-787(2003).

[4] D. Mascali , N. Gambino, R. Miracoli ,S. Gammino , L. Torrisi , F. Maimone ,L. Tumino ," *Plasma parameters measurements by means of Langmuir probe*", Radiation Effects and Defects in Solids, 163, 4-6, 471 (2008).

[5] H. Andrei, V.V Covlea and E. Barna, "*The Smoothing and the digital processing of Langmuir Probe Characteristics*", Romanian Rep. in Phys., 55, 2, 51(2003).

[6] L.B. Loeb, "*Basic Process of Gaseous Electronics*", 2^{nd} ed. U.C.P., 361(1960).

[7] D. Akbar, and S. Bilikmen "*Effects of non-uniform dc glow discharge system on argon positive column plasma*", 33r Eps; conference on plasma phys. R, 19-23 Jane 2006, ECA vol.301, D-5-010 (2006).

[8] S. B. Singh, N. Chand and D.S. Patil "*Langmuir Probe Diagnostics of Microwave Electron Cyclotron Resonance (ECR)*", J.Vacuum ,10,1016 (2008).