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Langmuir probe Diagnostic for local parameter measurement in Magnetized Plasma using LabVIEW

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ABSTRACT
In recent years, plasma technology is used by Semiconductor, thin film industries for deposit layers, etching process and surface modification. So it is necessary to understanding internal plasma parameter. Langmuir probe is one of the simplest techniques which is used to measure wide range of plasma parameter like plasma potential, floating potential, electron temperature, electron energy distribution function (EEDF) etc. Langmuir current voltage characteristic is obtained by varying bias voltage of the probe. LabVIEW is most powerful Microsoft window compatible software which is used to immediate data acquisition and analysis. In this paper describes analysis of Langmuir data using LabVIEW software which automatically measure I-V Plasma probe Characteristics and obtain EEDF of plasma.

Keywords – EEDF, LabVIEW, Langmuir probe, Plasma Diagnostic, Plasma parameter

I. INTRODUCTION

Plasma can be described as ionized gas consists of equal numbers positive ions and electrons. Plasma is used by semiconductor and thin film deposition industry for etching and material processing. To develop new etch and deposition it is necessary to understanding basic internal plasma parameter. Langmuir probe is used to measure critical plasma parameter helps minimize development time and optimize plasma process for desire application. Langmuir probe is one of the most powerful diagnostic tool which is used to measure the low temp plasma parameter. The ability to measure local plasma parameter using Langmuir probe making them superior than other diagnostic techniques. Electrostatic Langmuir probe consists of small metallic conductor that is inserted into plasma to collect current. The biased voltage applied to probe is varied and collect the current to probe to generate I-V trace. From current voltage characteristics plasma potential, floating potential, electron temperature, electron density and electron energy distribution can be obtained. Langmuir probe is vital diagnostic tool because it can make local measurement. almost all other techniques, such as spectroscopy or microwave propagation, give information averaged over large volume of plasma.[1] This paper present analysis of plasma using LabVIEW software to extract meaningful information from the Langmuir I-V trace.

II. EXPERIMENTAL SETUP

Vacuum chamber used for plasma analysis. An inert background gas (argon) introduced into chamber up to pressure 1.2×10^{-2} mbar. Langmuir probe consists of metal electrode of 1mm area of probe tip was made of SS covered by ceramic tube. The electrical connection is provided by copper wire which comes out through the vacuum compatible BNC connector mounted on SS 304.The SS shaft was introduced into vacuum chamber through the vacuum feedthrough such that the probe could be positioned at the desire locations inside the chamber. Langmuir probe measure the current for the bias voltage range from -80V to 30V. The amount of collected probe current is depends on probe tip area and various plasma parameter. The output current is measured by isolation amplifier and applied voltage measured with Tektronix oscilloscope. This data could be stored in data storage device. This measurement data is used to plot I-V characteristics to determine various plasma parameter.[2] Schematic diagram of probe circuit shown in fig.1

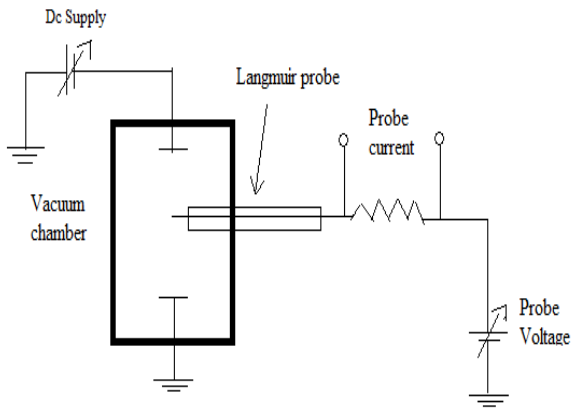

Fig1: Schematic diagram of Probe Circuit

III. RESULTS AND DISCUSSION

A typical Langmuir characteristic shown in fig.2 is used to determine various plasma parameters. LabVIEW is powerful Microsoft compatible software that provides immediate data acquisition and analysis. LabVIEW is programming language of virtual instrument and that allow instrument control, data acquisition and pre/post processing of data analysis. LabVIEW program was written to partially automate to determine various .Fig 3 shows the LabVIEW front panel, which what the user will see. The front panel illustrates all the plasma parameter, all the plot. Floating potential is easiest parameter to determine, the voltage at the probe collect no current. From measured I-V data floating potential is -10.97V.

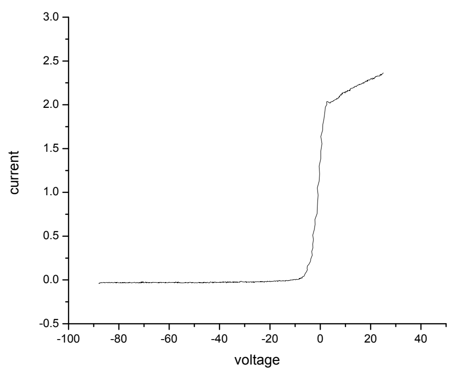

Fig 2:Typical Langmuir probe Characteristics

Ion saturation current is negative so to measure the electron temperature and for the further analysis it is necessary to subtract ion saturation current from the total current .I_{sat} is negative , but I_{probe} - I_{sat} is almost positive.

Plasma potential can be measured by different method and resultant value can be averaged. First method is graphical method. In this method two line, fitted to curve and intersection of two lines indicate the plasma potential. From this tangent method plasma potential is 1.9V. In ideal case plasma potential corresponds to the maximum of the first derivative and zero of the second derivative. By using numerical calculation and differentiation we obtain first and second derivative. In fig 3 first and derivative is examined and plasma potential can be calculated from the maxima in the 1^{st} derivative is 1.68V and from the zero of the second derivative is also 1.68V.

Electron temperature can be obtained from the slope of the logarithmic of electron current and voltage curve in region between V_f and $V_{p.}$ [3] by equation.

$$T_e = \frac{\Delta \mathrm{v}}{\Delta \mathrm{In}} \qquad (1)$$

Where I is electron current.

After obtaining electron temperature from the logarithmic graph of current verses voltage, electron density can be obtained from equation (2)

$$n_e = \frac{I_{es}}{eA_p}\sqrt{\frac{2\pi m_e}{K_B T_e}} \qquad (2)$$

Electron Energy distribution function (EEDF) is one of the most important property for fusion and process plasma. As various properties of plasma depends on different part of EEDF such as diffusion coefficient depend on the bulk of the EEDF and ionization or excitation rates depend on the tail of the EEDF, the determination of the whole distribution is compelling for a comprehensive characterization of a plasma. [4]

Druyvesteyn method was derived specially for EEDF. Particles in gas will have different velocity and velocities of each particle will be changing due to interaction with other particles. Electrons with sufficient velocity component in direction of the probe will be collected.[5]

$$I_e = eA_p \int_{-\infty}^{\infty} dv_x \int_{-\infty}^{\infty} dv_y \int_{V_{min}}^{\infty} dv_z v_z f_e(v) \qquad (3)$$

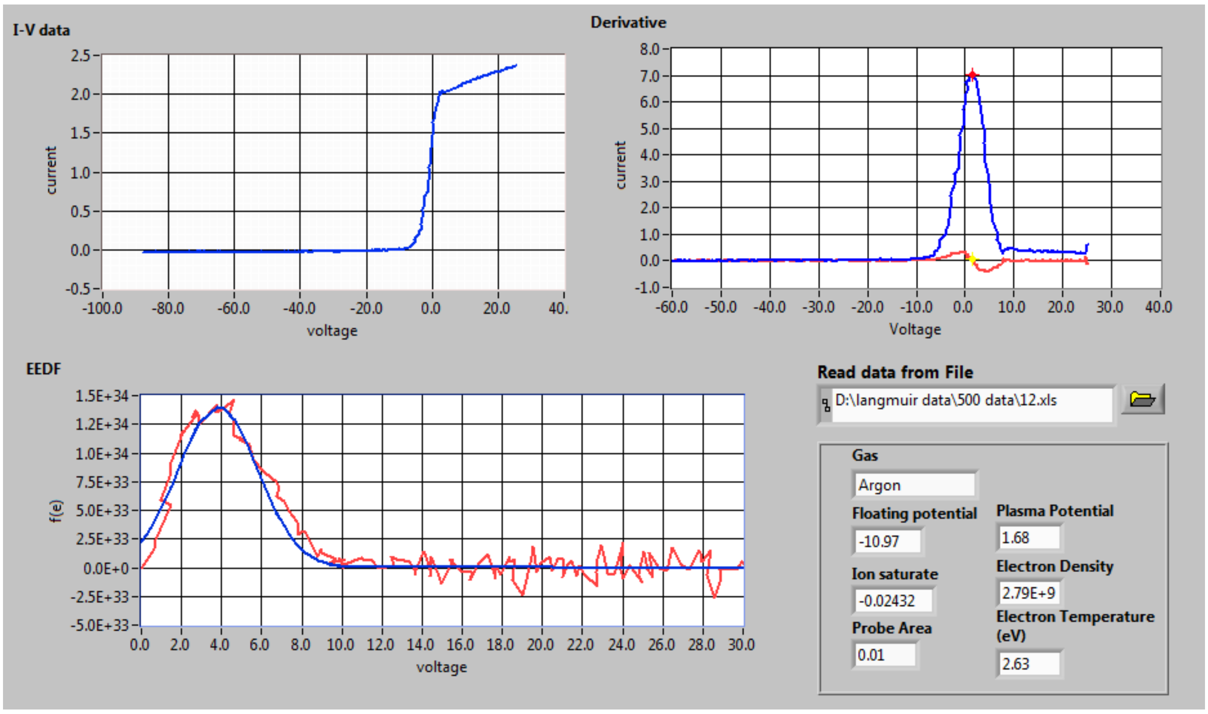

Fig 3. LabVIEW Front Panel

Where,

$$V_{min} = \left(\frac{2e(\emptyset_p - V_p)}{m_e}\right)^{1/2}$$

Probe voltage is measured with respect to ground, plasma is at plasma potential so it necessary to express electron energy distribution with respect to plasma potential. This makes plasma potential reference energy level and the voltage V represents electron energy relative to the plasma potential reference.

EEDF is dependent only on the second derivative of the probe characteristics. (Fig 3)[5]

$$F(\epsilon) = \frac{4}{e^2 A_p}\sqrt{\frac{mV}{2e}}\,\frac{d^2 I}{dV^2} \qquad (4)$$

Where, $V = \emptyset_p - V_p$,

Ap is area of the probe, m is electron mass, e is electron charge, F(ϵ) is Electron energy distribution.

There are various smoothing techniques are applied to simulated data and T_e and n_e are calculated using Druyvesteyn method. Polynomial fitting for smoothing data is less effective and it introduced artificial oscillation. Here Gaussian curve fit method is use for smoothing data. By comparing smoothed data with original is used to determine what information is lost during smoothing process. [5]Electron temperature and electron number density also obtained from Druyvesteyn method. Electron density can be obtained by integral of f(ϵ).

$$n_e = \int_0^\infty f(\epsilon)\, d\epsilon$$

Electron temperature can be obtained from integral of distribution function,[6]

$$T_e = \frac{2}{3}\langle\epsilon\rangle = \frac{2}{3n_e}\int_0^\infty \epsilon\, f(\epsilon)\, d\epsilon$$

Current voltage a characteristic of plasma is obtained using argon gas.

IV. Conclusion

From Langmuir probe I-V data, various plasma parameter like floating potential, plasma potential, electron temperature, electron density and electron energy distribution. Plasma potential is essential for all analysis performed. By applying $v=\Phi_p-V_p$, the plasma potential becomes zero reference point and EEDF is shifted on the horizontal axis. So an error in plasma potential shifts the EEDF and change on electron temperature and number density.

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