Diagnostic of Ion Species in Low Pressure Plasmas

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Objectives

This work proposes a method to measure *I-V* characteristic of a plane probe for each ion specie present in low-pressure plasma by using a mass spectrometer as an ammeter whose probe entrance can be biased at an arbitrary electric potential. From the *I-V* characteristics, the corresponding Ion Energy Distribution Function (IEDF) of each one of the ion species composing the plasma is determined with an accuracy in energy lower than 0.015 eV. Moreover, the plasma potential, and ion density and temperature are obtained.

Introduction

The plasma processing of materials is a very complex task because it involves plasmas with multiple species of ions. In order to control and improve those technological processes, it is necessary to improve plasma diagnostic methods to determine the plasma potential, the electric field distribution in the plasma and the energy distribution function of each charged specie composing the plasma, both electrons and ions, which let us to determine their corresponding densities and temperatures. In this way, systems for ion analysis based in mass spectrometry are often used because they let to study each one of the multiple specie of ions in the plasma separately. In fact, these instruments can determine the IEDF by using energy filters. Nevertheless, there usual accuracy in energy is about 0.1 eV. This value is not enough for low temperature plasmas and should be diminished. Langmuir probes methods are still being widely used to diagnostic plasmas, even in the case of electronegative plasmas or in those where the positive ion temperature should be considered [1,2]. Nevertheless, Langmuir probes methods are not so useful in plasmas constituted by multiple ion species, because, the ion current is very small and difficult to be measured, and furthermore, it is the superposition of the current due to the several ion species in the plasma, so these methods are unable to discriminate what part of the measured current corresponds to each ion specie. Moreover, these measurements are necessary to understand the flow of ions reaching the probe surface in order to understand the interaction between the plasma and a surface immersed in it [3]. So, diagnostic methods of plasmas composed of several ion species must be developed because, even in the case of plasma formed by only one kind of gas, Argon for example, there are always other gases present as impurities due to residual air or sputtering from the walls or electrodes of the discharge. From this point of view, the measure of the *I-V* characteristic of a single ion specie is of great interest because it corresponds to the flow of these ions to the mass spectrometer probe (which play the role of the surface to be processed) as a function of the biasing potential.

Method

We present a method for measuring the *I-V* characteristic of a plane probe for each of the ion species in a low pressure plasma by using a mass spectrometer as an ammeter whose probe can be biased at an arbitrary electric potential. A mass spectrometer, Hyden Analytical Sampling Plasma Mass Spectrometer (PSM), PSM003 model, provided with a Hyden Analytical Driven Electrode Probe Accessory (DEPA), is used. The PSM is tuned for maximum number of counts per second. Once the tuning is done, none of the tuning parameters are modified (extractor, energy, mass, lens, focus…). The DEPA is immersed in the plasma and is biased in potential. It is provided of a 50 μm radius orifice, through which molecules and ions enter to the PSM. This radius is lower than the corresponding Debye length of the plasma, thus, the irregularities in the electric field of the mass spectrometer DEPA due to the orifice are shielded by the sheath surrounding it. Therefore, the mass spectrometer will measure the flow of an ion specie passing through the orifice, which plays the role of a plane probe, for each biasing potential. The *I-V* characteristic of the corresponding ion specie can thus be measured.

In order to use Langmuir probe diagnostic methods we first smooth the *I-V* characteristic. Figure 1 shows the measured and smoothed data of an Ar^+ ion *I-V* characteristic measured in an Argon DC discharge. Then the first and second derivative of the smoothing characteristic are obtained. From the condition $d^2I/dV^2 = 0$, we obtain the plasma potential V_p, and finally the IEDF [4], see Fig 2, with an energy sensitivity closer to 0.015 eV. By integrating the IEDF, Ar^+ ion density and temperature are obtained.

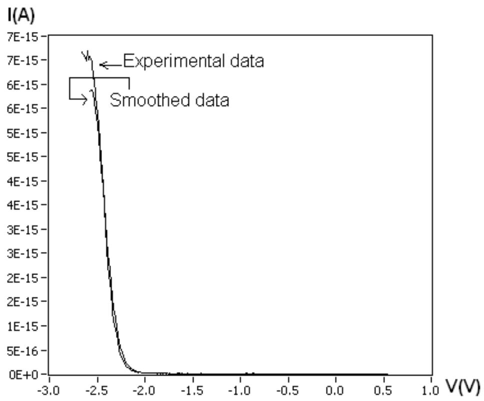

Fig. 1: Measured and smoothed data of an Ar^+ ion *I-V* characteristic

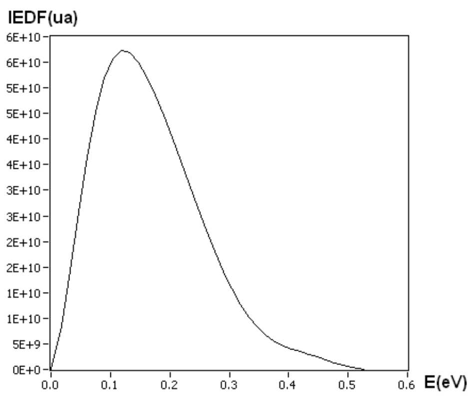

Fig. 2: IEDF: Ar^+ Ion Energy Distribution Function

Contributions and conclusions

We have measured *I-V* characteristics of several ion species in an Ar plasma and the corresponding IEDF is obtained. We conclude that the IEDF can be approximated to a Maxwellian distribution function. The results obtained for the ions from the IEDF, density and temperature, have been compared with those obtained by other classical probe methods, [4]. There is very good agreement between both results.

References

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