Impedans Application Note

Measurement of EEDF tail on a grounded electrode with the Semion™ Ion Energy Analyser System

Overview

The Semion™ Retarding Field Energy Analyser (RFEA) is commonly used to measure ion energy distributions (IED's) impacting grounded or biased surfaces in plasma discharges. The RFEA is less commonly applied to the measurement of the electron energy distribution reaching a surface. In many circumstances, the positive space charged sheath, which necessarily develops adjacent to the surface, repels the low energy electrons and only permits electrons with energy greater than the instantaneous sheath potential to reach the surface for detection.

The RFEA is therefore generally only suited to the measurement of the high energy tail of the EEDF. The temperature of the tail of the EEDF is however an important discharge parameter since the high energy electrons often control ionisation and chemical reaction rates in the discharge.

Experiment

The experiment involves the measurement of the tail of the EEDF using the RFEA mounted on a grounded electrode in an inductively coupled plasma reactor. Figure 1 shows a schematic of the experimental set up.

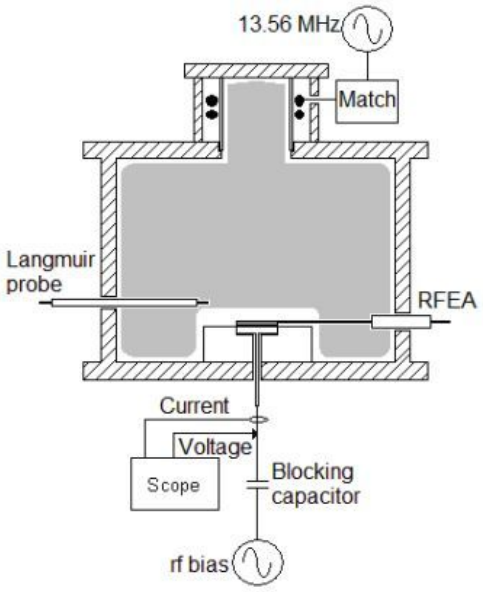


Figure 1. Experimental set up

The inductive source power is set to 300 W at 13.56 MHz and argon gas pressures used are 2.25, 4.5 and 7.5 mTorr. To determine the accuracy of the RFEA results, the data is compared with the results obtained in the same discharge with the ALP™ Automated Langmuir Probe system.

The electron temperature can be extracted from the RFEA current-voltage characteristic from a plot of the natural logarithm of the collector current versus the retarding potential applied to the discriminating grid. The slope of this characteristic is given by

$d(ln\ I_e)/dV=e/kT_e$

where *Ie* is the collected electron current, *V* is the discriminator voltage and *kTe* is the electron temperature.

A comparison between the electron temperature measured with the RFEA and Langmuir probe are given in figure 2. In this type of discharge, at the operating pressures used, it is common to have a two temperature EEDF where the low energy electrons are cooler than the high energy tail. The results in figure 2 confirm this. The Langmuir probe analysis obtains the temperature of the low energy region of the EEDF while (for the reasons stated earlier) the RFEA determines the temperature of the high energy tail. The temperatures are quite different at the lowest pressure. At the highest pressure the temperatures are quite similar as expected since with increasing pressure electron-electron collisions become more frequent and tend to Maxwellianise the entire EEDF.

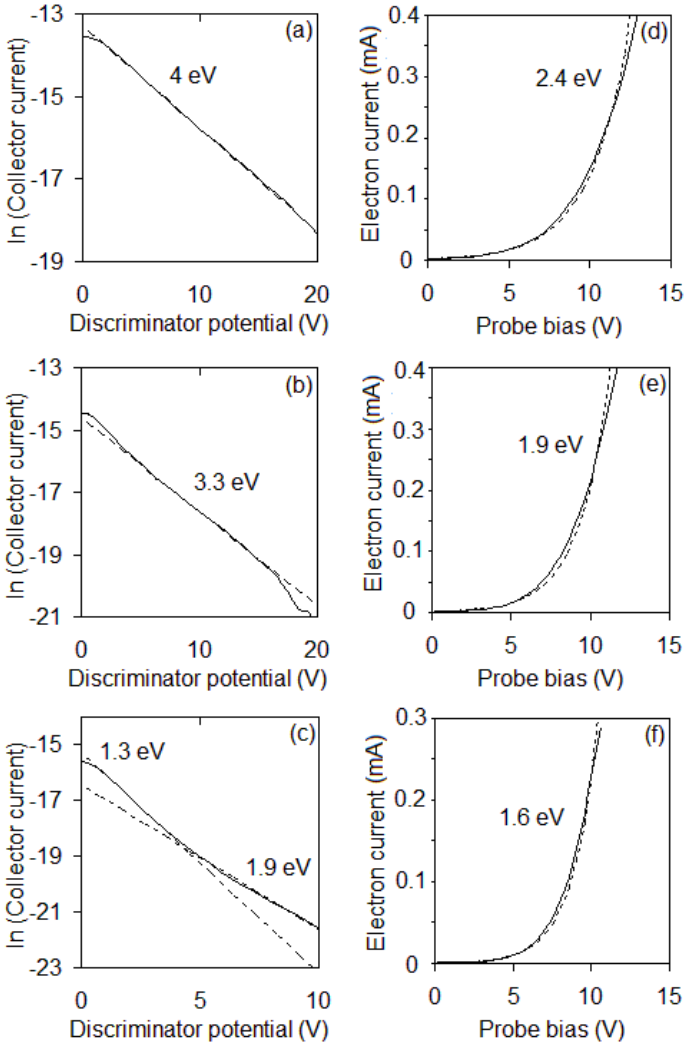


Figure 2. Comparison of electron temperature measured with the Langmuir probe and the RFEA

Electron Energy Distribution Function (EEDF)

The EEDF from the RFEA can be compared with that measured using a Langmuir probe to check the accuracy of the measurement. The Langmuir probe EEDF is calculated using the standard expression

$$\frac{f(\varepsilon)}{\sqrt{\varepsilon}} = \left(\frac{d^2 I_e}{dV^2}\right)\frac{2m_e}{e^2 S}\sqrt{\frac{2e}{m_e}}$$

where the symbols have their usual meanings. It can also be shown that the EEDF for the RFEA can be written in the form

$$\frac{f(\varepsilon)}{\sqrt{\varepsilon}} = \left(\frac{dI_e}{dV}\right)\frac{T}{A}\sqrt{\frac{2m_e}{e^3 \pi k T_e}}$$

where again the symbols have their usual meanings. For a more detailed discussion of this procedure please see reference [1]. It is clearly seen from figure 3 that the Langmuir probe resolves the low energy region of the EEDF while the RFEA resolves the high energy tail. Exceptional agreement is obtained in the overlapping energy region illustrating the accuracy of the RFEA for tail EEDF measurement.

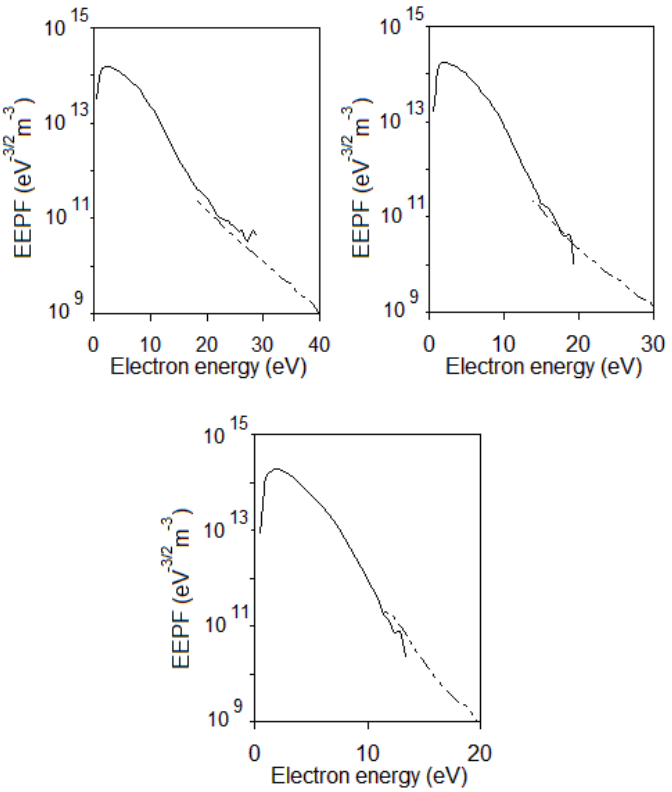
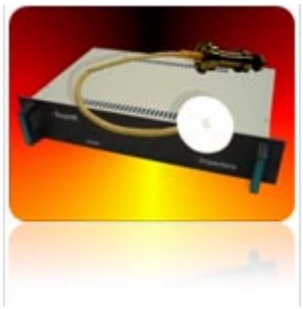


Figure 3. Comparison of EEPF's measured with the Langmuir probe (solid) and RFEA (dashed)

Reference

[1] D. Gahan, B. Dolinaj and M. B. Hopkins, Plasma Sources Sci. Technol. 17 (2008) 035026



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Our products represent the next generation in plasma diagnostics technology, and coupled with our in-depth plasma knowledge and years of experience, our customers can be sure that they can fully characterise, optimise and monitor their plasma process with confidence.