Langmuir Probe Evaluation of the Negative Ion Density in Oxygen Gas Discharge Magnetized Plasma

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Although the Langmuir probe method is as old as plasma physics itself, the potential of the method has not yet been fully exploited. One of the problems in probe measurements in electronegative plasmas (for example oxygen gas discharges) is to separate the signal arising from negative ions from the electron part in second derivative (SD) probe measurements of the electron energy distribution function (EEDF).
The main goal of this work is to use a relatively low magnetic field sufficient to suppress the probe signal from the electron component, but not sufficient to influence the negative ions part of the SD in order to obtain reliable data for the negative ions densities in an oxygen gas discharge.

Among the contact methods of plasma diagnostics, the electric probes are the least expensive and still the fastest and most reliable diagnostic tools allowing one to obtain the values of important plasma parameters - Langmuir probes (LP) allow local measurements of the plasma potential, U_{pl}, the charged particles density and the electron energy distribution function, $f(\varepsilon)$ (EEDF). Although the electric probe method is as old as plasma physics itself, the potential of the method has not yet been fully exploited. New probe theories and designs constantly appear with the results summarized in numerous reviews and monographs. In spite of this, incorrect applications of electric probes are commonly found in the literature. The errors mainly arise from a lack of awareness about the multitude of regimes of probe operation and the limits of validity of theories. On the other hand, in many different contemporary technologies, as plasma chemistry, plasma etching, thin layer dielectric deposition, etc. more complicated types of plasmas are required, such electronegative or magnetized plasmas. Applying Langmuir probes in these adverse conditions is still subject of discussion. One of the problems in probe measurements in electronegative plasma (for example oxygen gas discharges) is to separate the signal arising from negative ions from the electron part in second derivative (SD) probe measurements of the EEDF.

This work reports a continuation of our negative ion density measurements in oxygen, low-pressure, magnetized plasmas [1]. The plasma is produced in a stainless steel discharge tube, whose length/diameter dimensions are 1.5/0.17 m. The wall of the discharge tube is grounded and the cathode is made of hot filaments. An axial magnetic field is created by a solenoid. A platinum cylindrical Langmuir probe, whose radius/length are $5\times10^{-5}/5\times10^{-3}$ m, is placed either axially or radially at the centre of the discharge in order to perform measurements along and across the magnetic field. The electron energy distribution functions in oxygen magnetized discharges are deduced from the second derivatives of the measured $I(V)$ characteristics [2, 3]. The derivatives evaluated numerically [4].

In the measurements of the second derivatives of the $I(V)$ characteristics, when the probe has a parallel orientation to the magnetic field, close to the plasma potential a peak appears due to the collection of negative ions. At the same time, the electron part of the second derivative is substantially suppressed relatively to the case of a probe perpendicularly oriented to the magnetic field. Thus, using an appropriate orientation of the probe and in low magnetic field conditions, so that the electron part of the second derivative is suppressed while the negative ion part is not affected, we can accurately evaluate negative ion density values.

The results of plasma parameters (negative ion densities, plasma potential, electron densities and temperatures) evaluations at different discharge conditions are presented and discussed.

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