Electrical diagnostics for electronegative plasmas

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1. Introduction

Plasmas produced in electronegative gases, such as CF\(_4\), Cl\(_2\), SF\(_6\) and O\(_2\), and not only, are widely used in micro and nano-electronic industry for etching, ashing, oxidation and other surface functionalization processes. H\(_2\) plasmas are also used to produce negative ions for fusion and extensive research is devoted recently to create negative ion sources for neutral beam processing and space propulsion. In a broader perspective most of the reactive gases are also electronegative so that, the role of negative ions in plasma processing cannot be neglected. The continuous decrease of the features size in nano-electronic industry (now below 40 nm) requires a more precise control of plasma parameters including not only pressure, gas flow and temperature profile but also the density of reactive species including the negative ions. Despite of a good progress in plasma diagnostics, yet more is to be done for developing inexpensive but reliable techniques compatible with the strict requirements for device-making setups. Moreover the properties and possibilities to control the electronegative discharges are not completely understood.

The aim of this work is to review the main electrical diagnostics techniques available to investigate electronegative discharges and also to present some of the most recent results on properties of electronegative discharges and plasma sources for negative ion production.

2. Electrical probes

Electrostatic probes have been used to detect negative ions since 70’s. While the use of this technique can give good results for density ratios of negative ion to electron higher than 10 its applicability for lower density ratios is questionable [1]. In this context is was demonstrated that double hump structures observed in the electron energy probability function close to plasma potential cannot be associated with negative ion parameters because those structures are produced by a particular change in the work function over the probe surface as a result of discrete ion focusing [2]. Another way to detect the plasma parameters in the presence of negative ions is to use the sensibility of the test function in the mid and high energy tail of the distribution function [3]. The presence of negative ions is also associated with a lower heat flux to the probe for potentials higher that plasma potential, a fact that led to the development of a thermal probe that allows one to record at the same time not only the current bias, \(I(V)\), but also a temperature bias characteristic, \(T(V)\), so increasing the available information to extract the plasma parameters [4]. The recent discovery of the discrete and modal focusing effects, associated with three-dimensional plasma-sheath-lenses created the possibility to detect even low densities of negative ions using the sheath-lens probe [5]. Alternative electric diagnostics techniques for negative ions can be based on the very sharp transition from a positive sheath to the anodic glow [6].


The positive ion extraction from electropositive plasmas is rather easy as one can control the plasma potential with the bias of a large electrode. However, this is not the case of electronegative discharges. The influence of biased electrodes, of small or large dimensions on plasma parameters in electronegative discharges can give more information about the possibility to control and used these plasmas for processing. Development of negative ion sources for both applications and basic science is rather challenging and some of these efforts will be presented in direct correlation with diagnostic approaches [6-8].

References