A simple optical emission spectroscopy technique for detecting EEDF changes in low-pressure pulsed-RF plasma

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We present a study carried out on a capacitively coupled radiofrequency pulsed plasma with the aim of determining the effectiveness of a simple spectroscopic technique for characterising the evolution of the EEDF in pulsed low-pressure discharges. Two pulsing frequencies (1 kHz & 5 kHz) each operated with two duty cycles (10% & 50%) were used to generate the low pressure radiofrequency discharges. Measurements of light emission from rare-gas atoms were combined with electron density measurements made with a microwave hairpin probe resonator were able to trace the evolution of the EEDF and electron density (n_e) throughout the pulse cycle and in particular during the ignition/re-ignition phase of the pulses.

Pulsed plasmas offer an extra set of parameters (pulse frequency, duty cycle & power modulation) that can be used to control important plasma parameters such as the EEFD and the electron density (n_e) [1, 2]. One feature of pulsed plasma is that higher plasma densities are obtained for pulsed plasmas with an average input power equal to that of continuous plasma which is of particular importance to industrial processes [3]. A second feature is that plasma chemistry kinetics, such as ionization, dissociation and excitation rates, are highly sensitive to the details of the EEDF and the charged particle densities. Therefore, understanding the evolution of these key parameters will provide the ability to fine tune the plasma kinetics either to increase or suppress the production of particular desired species to improve plasma processes such as etching and deposition. In this study we aim to test a simple-Optical Emission Spectroscopy (OES) method in combination with microwave resonator hairpin probe measurements to track the evolution of the EEDF and n_e throughout a pulse cycle, especially during the ignition/re-ignition phase.

In this study, we present a simple-OES technique which, in combination with electron density measurements, allows us to track the evolution of the EEDF and n_e at a high time resolution. Using a mixture of noble gases (Ar, Kr, Xe) and selecting specific emission lines from each gas we can trace the evolution of the high energy tail of the EEDF. Emissions from 6p-6s, 5p-5s, & 4p-4s transitions from Xe, Kr, & Ar respectively were measured, with these transitions chosen as the upper states are populated principally by direct electron excitation [4]. These measurements allow access to an interval of electron energy ranging from 9 eV to 13.5 eV. The electron density in the experiments was measured using a floating microwave resonator hairpin-probe [5].

The study was carried out in a capacitively coupled radiofrequency Gaseous Electronic Conference (GEC) reference chamber at a pressure of 100 mTorr (13.3 Pa). Ignition behavior was investigated for two different pulse frequencies (1 kHz & 5 kHz) and two different duty cycles (10% & 50%) for each case. The results allow us to discuss the effect of the afterglow period on the re-ignition of the discharge.

References

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