Experimental and computational investigations on striations in electronegative capacitively couple rf discharges

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We observed the self-organized striated structures of the plasma emission in capacitively coupled radio-frequency (CCRF) CF_4 plasmas via phase resolved optical emission spectroscopy and their formation was analyzed by PIC/MCC simulations. The striations were found to result from the periodic generation of double layers due to the modulation of the densities of positive and negative ions upon responding to the external RF electric field.

The measured spatio-temporal electronic excitation patterns at various external parameters (driving frequency, pressure, RF voltage) show a good agreement with the simulation results. In the presence of striations, the minimum (CF_3^+, F^-) ion densities in the bulk region exhibit an approximately quadratic increase with the driving frequency, while they are independent of other external parameters.With these densities, the characteristic frequency of the ion-ion plasma is near the driving frequency, indicating that a resonance occurs between the positive and negative ions and the oscillating RF electric field inside the plasma bulk. A discharge mode transition into “striated” mode can occur when increasing the pressure or RF voltage. A phase diagram is established to present the parameter domain for the presence of striations.

The properties of striated structures in electronegative dual-frequency capacitive discharge in CF_4 and the effect of the high-frequency voltage amplitude $?_H$ on the striations were also studied. The electronic excitation patterns measured at different $?_H$ show good agreement with the PIC/MCC simulation results. As $?_H$ increases, the width of striations (defined as the full width at half maximum) increases, while the striation gap (defined as the width of high electric field region in the bulk) remains almost unchanged, leading to a decrease in the number of striations. The striations finally vanish at a higher $?_H$. A hysteresis of plasma parameters (time averaged electron excitation rate, ion density profile, etc.) induced by increasing and decreasing $?_H$ was observed both in experiment and simulation.

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