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Low-Frequency to High-Frequency Transition of an Atmospheric Pressure Helium Dielectric Barrier Discharge

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Dielectric barrier discharge is a well-known device for its diffuse discharge capability at atmospheric pressure. In a plane parallel configuration (2 mm gas width) with solid alumina dielectrics on each electrode, a diffuse discharge will occur under proper conditions. It is the case when the driving voltage is a sinusoidal waveform oscillating at 25 kHz and the feed gas is a Penning mixture of helium with ppms of N_2. These conditions give rise to a glow discharge (APGD) and is typical of the low-frequency range (LF). In the same conditions, when the driving frequency is oscillating at 13.56 MHz, in the high-frequency range (HF), the discharge is no longer pulsed in nature but rather a continuous plasma fluctuating between two oscillating sheaths. This behavior is typical of capacitively coupled radio-frequency discharge (CCRF) in the α mode.

The aim of this paper is to investigate the transition through which the discharge shifts from the LF glow discharge to the HF discharge in the RF-α mode. Phase-locked imaging is used as the main diagnostic. On the one hand, the discharge is no longer in a purely glow discharge mode at frequencies above 100 kHz. On the other hand, above 1 MHz, the plasma is clearly in the RF-α mode when the applied voltage is sufficiently high. In addition, for intermediate frequencies, in the medium frequency range (MF, defined as 0.3-3 MHz), the Ω mode can be sustained at low applied voltage. This mode, where electron heating in the bulk is the main power transfer mechanism, can only be sustained between 100 kHz and 5 MHz. Electrical measurements indicate that this discharge mode is always sustained at a power density of the order of 0.1 W/cm^3.

Optical emission spectroscopy is used to compare the discharge modes. While the LF glow discharge and the HF discharge in the RF-α mode display fairly similar spectra, the spectrum of the Ω mode occurring in the MF range displays strongly different emissions. In fact, the ratio of helium emissions over impurities (mainly OH, N_2 and N_2^+) is much lower in this latter mode than in the formers. This suggests that the ratio of high-energy electrons over metastable atom density (impurities mainly depend on helium metastable atoms density) is higher in both the LF and HF discharges. In other words, the electron temperature is expected to be significantly lower in the Ω mode occurring in the MF range.

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