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Electron power absorption modes at igniting phase in a pulsed capacitively coupled argon plasma

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Compared with a continuous-wave (cw) rf discharge, a pulsed rf discharge has shown its potential in improving the etch profile features and reducing the plasma induced damage, as it can provide high flexibility of controlling important plasma parameters, such as the electronic energy distribution function (EEDF) and the electron density by adjusting the pulse repetition frequency, the duty cycle, etc. Therefore it has attracted increasing academic and industrial interest in recent years.

In a pulse modulated rf capacitive discharge operated in argon, it is well known that the electron temperature or emission intensity exhibits a sharp peak at very beginning of the active glow and then slowly declines to a stable value. This is generally explained like this: at the igniting phase the electron density is very low, the rf power is coupled to these few electrons, leading to high averaged energy obtained by each electron. In this work, the spatio-temporal evolution of electron excitation rate in a pulsed capacitive discharge operated in Ar was measured by phase-resolved optical emission spectroscopy. It is found that the electronic excitation dynamic at the pulse-ignition phase exhibits different behavior from that in stable-state discharge. During the first tens of rf cycles after the pulse ignition, the plasma is found to operate in DA (drift and am bipolar) mode. This is because at the igniting phase the electron density is low, similar to that in electronegative capacitive discharge, a high electric field must be built up inside bulk region to push electrons, sustaining a certain current flowing through the bulk region. With the advance of time, the discharge gradually turns into α mode as the electron density rises. Also, we investigated effects of external parameters (the rf voltage, the working pressure, the duration of after-glow, etc.) on the DA-α mode transition during the active-glow period.