Effect of Secondary Electrons on the Ionization Dynamics and Control of Ion Properties in Electronegative Capacitive Discharges

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The realization of the separate control of the ion flux and ion energy distribution at the substrate in capacitively coupled radio frequency (RF) discharges is an important issue for various applications of plasma processing, ranging from plasma based etching and deposition procedures in the semiconductor industry to plasma assisted surface treatment of medical interest. In order to attain such independent control of the ion properties, the application of non-sinusoidal voltage waveforms (pulse-like, or saw-tooth-type, for instance), known as „tailored“ or „customized“ RF voltage waveforms for the excitation of capacitive RF discharges, has recently been introduced. Such waveforms differ from the conventionally applied sinusoidal voltages by exhibiting different absolute values of their positive and negative extrema. This control method is based on the electrically asymmetric plasma response, known as the Electrical Asymmtery Effect, observed when non-sinusoidal exciting voltage waveforms are applied, leading to the generation of a dc self-bias voltage in a geometrically symmetric discharge cell. The applications of tailored voltage waveforms, generated by using multiple harmonics of a base frequency (multi-frequency excitation), offer new possibilities for controlling plasma properties. Most of the systematic studies on capacitive RF plasmas excited by tailored voltage waveforms have been conducted so far in electropositive capacitive RF discharges. However, the applications usually require complex mixtures of reactive gases. For instance, oxygen is widely used in etching and thin film deposition techniques, CF_4 is also frequently applied to etch silicon and silicon-dioxide in microelectronics.

Secondary electrons generated at the electrodes are known to influence the ionization dynamics and induce transitions of the discharge operation mode from the α-mode to the γ-mode in electropositive discharges at high driving voltage amplitudes and/or pressures. In electropositive discharges these γ-electrons influence the quality of the separate control of ion properties. Here, we report our systematic simulation studies of the effect of secondary electrons on the electron power absorption and ionization dynamics and on the quality of the separate control of ion properties at the electrodes in low-pressure capacitively coupled RF discharges operated in reactive, electronegative gases excited by tailored voltage waveforms.