MODE TRANSITION OF NANOSECOND PULSED DISCHARGES FROM DIFFUSE TO MULTI-STREAMERS AND THE GUIDING EFFECT OF RUNAWAY ELECTRONS*

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Runaway electrons (RAEs) have been widely observed in nanosecond pulsed discharges (NPDs) and it is believed that RAEs have a big impact on the breakdown and propagation of NPDs and the formation of diffuse discharge at atmospheric pressure [1, 2]. Nevertheless, it is still desirable to explore how RAEs function on the pattern and mode of NPDs.

In this work, the role of RAEs on the mode transition of NPDs from diffuse to multi-streamers is investigated. NPD is driven by high-voltage (HV) pulses with a rise time of about 3 ns between blade-to-plate electrodes with a gap of ~ 1 cm, where the blade is the cathode with a width of ~ 4 cm. A beam collector with a rise time of about 50 ps and covered by a titanium foil with a thickness of 1 μm as electron energy filter (higher than 10 keV) is used to detect RAEs. By increasing the HV amplitude, the distribution of RAEs' amplitude also shifts to higher value, i.e., more RAE pulses with a larger amplitude are observed.

With intensified charge coupled device (ICCD) camera, single-shot discharge images are observed. It is observed that with a large HV amplitude (~ 30 kV), the NPD is initially in a diffuse mode near the blade (cathode). Later on, it branches and transfers into multi-streamers, which propagate synchronously toward the plate (anode). However, with a small HV amplitude (~ 10 kV), the NPD forms a short diffuse channel near the blade and cannot penetrate the gap.

Using particle-in-cell Monte-Carlo collision (PIC-MCC) simulation, a similar mode transition of diffuse to multi-streamers can be obtained with RAEs emitted from the cathode, as observed in discharge images. This mode transition cannot be reproduced without RAEs, i.e., the NPD rapidly turns into filamentary mode without RAEs in the PIC-MCC simulation. Furthermore, it is proved that the flux of RAEs controls the pre-ionization degree before the discharge is initiated and dictates the branching and non-uniformity degree of discharge during its propagation. With the distance from the cathode increasing, RAEs are depleted and the non-uniformity of the NPD develops. Assisted with the PIC-MCC simulation, it is proposed that an enhanced RAE emission would produce a large volume diffuse discharge at atmospheric pressure.

REFERENCES

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