Observation of the primary streamer in nanosecond pulsed streamer discharge using the quadruple emICCD camera system

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Abstract: A high-speed gated quadruple emICCD camera system is developed to investigate the propagation characteristics of the primary streamer in a coaxial-cylindrical reactor. In this system, continuous images during single discharge can be captured to clarify the primary streamer propagation process in detail. Moreover, the propagation behaviours, including streamer length, propagation velocity, and streamer width, were analysed with different inner electrode diameter.

Keywords: streamer discharge, the primary streamer, emICCD camera

1.Introduction

Concerning the current global environmental pollution problem, non-thermal plasma (NTP) has been evoking the interest for researchers due to its advantageous performances such as mild operation temperature, short reaction time, and flexible application [1]. Nanosecond pulsed streamer discharge has been studied as a promising method for the generation of NTP. The short pulse rising time and pulse width ensure the high energy efficiency for accelerating the electrons instead of the bulk gas molecule. Typically, the streamer discharge involves the primary streamer and the secondary streamer discharge phases. Compared with the secondary streamer, the primary streamer shows higher electric field and higher energy yield of radical generation [2]. However, the propagation characteristics of the primary streamer, especially the mechanism of the acceleration of the streamer head, are still unclear and difficult to be studied due to the fast propagation of the primary streamer. In this work, we first time developed a quadruple emICCD camera system to catch the discharge process in a coaxial-cylindrical reactor for better observation of the primary streamer process. This system can capture four continuous images in real time for nanosecond pulsed discharge. The propagation characteristics of the primary streamer are further studied by varying the diameter of the inner electrode of the coaxial-cylindrical reactor.

2.Experimental set up

A schematic diagram of the experimental setup is shown in Fig. 1. The coaxial-cylindrical reactor used in this work is composed of a stainless outer electrode with 60 mm diameter and a stainless inner electrode with different diameters. The diameter of the inner electrode varies among 0.2 mm, 1.0 mm, and 2.0 mm. The length of the inner electrode is fixed at 5 mm to avoid the transmission line effect of the long discharge distance. A quadruple emICCD camera system is established to photograph the rapid discharge process. In this system, three half mirrors divide a discharge image into four images and sent to the corresponding emICCD camera. In this way, four emICCD cameras (PI-MAX4:1024EMB, Princeton Instruments, USA) can simultaneously to capture the discharge image in series by setting sequential exposure onset time. The distance between the camera lens and the discharge reactor is 21 cm. To investigate the fast propagation process of the primary streamer, 0.3 ns interval time are adapted by the four emICCD cameras. The system takes pictures in the order of camera A-B-C-D in recycle until the arrival of the primary streamer at the outer electrode. The voltage and current signal are recorded by the oscilloscope (RTO2044, ROADE&SCHWARZ, Germany). During the discharge, the applied voltage is 55 kV with the rising time of 5 ns.

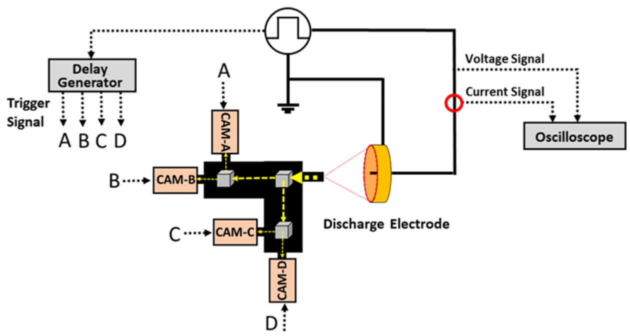


Fig. 1. Schematics of the experiment set-up

3.Results and discussion

3.1 Propagation process of the primary streamer with different inner electrode diameter

Fig. 2 exhibits the time dependence of the streamer head position from the central electrode under different inner electrode diameter (0.2 mm, 1.0 mm, and 2.0 mm). T ns represents the beginning shooting time of the camera A when the inner diameter is 0.2 mm. It can be inferred that many streamers propagate in the coaxial-cylindrical reactor at the same shooting time. Box plot is applied here to better analyze the propagation data of the primary streamer. The thicker diameter of the inner electrode leads for a shorter propagation process of the primary streamer. This is because the increase of the inner electrode diameter can not only decrease the propagation distance of the primary streamer, but also enhance the electric field strength of the streamer head [3]. After extracting the middle value from the box plot in Fig. 2(c), the results are shown in Fig. 3. Fig. 3 manifests that the propagation of the primary streamer linearly depend on the time before the final jump of the primary streamer.

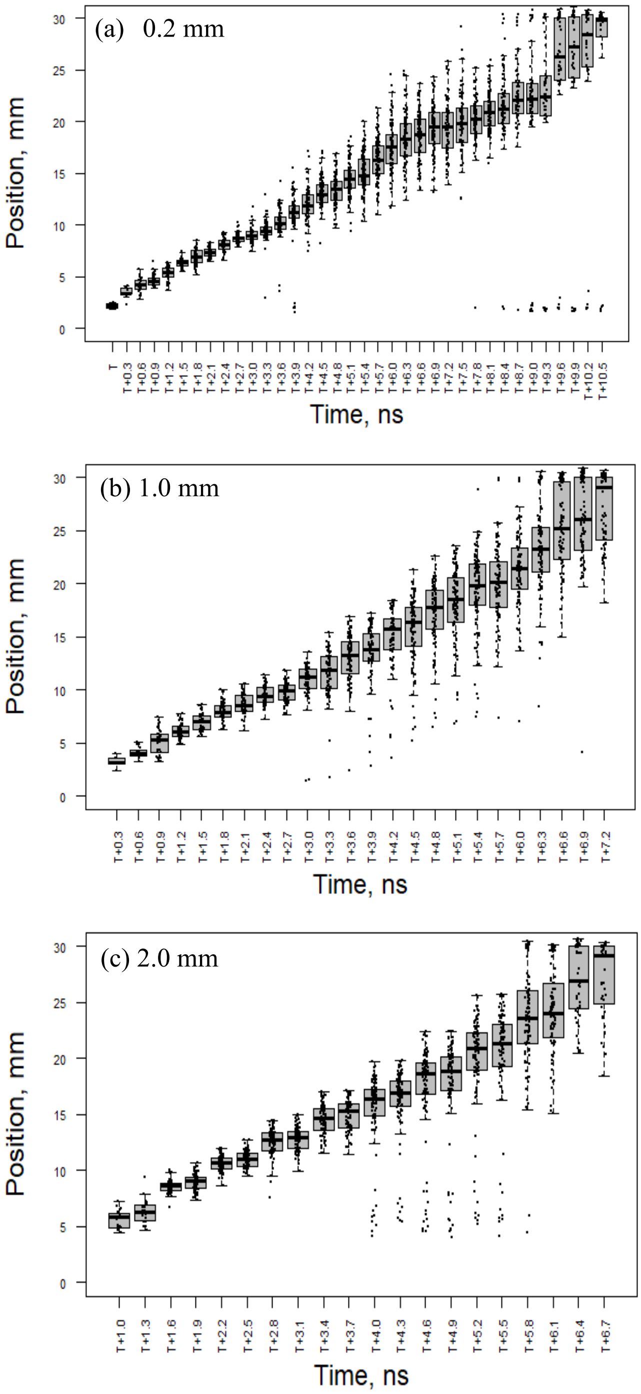


Fig. 2. The streamer head position as a function of time under different inner electrode diameter of (a) 0.2 mm, (b)1.0 mm, and (c) 2.0 mm

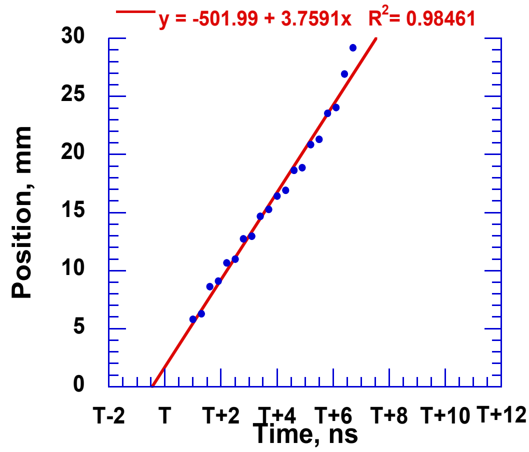
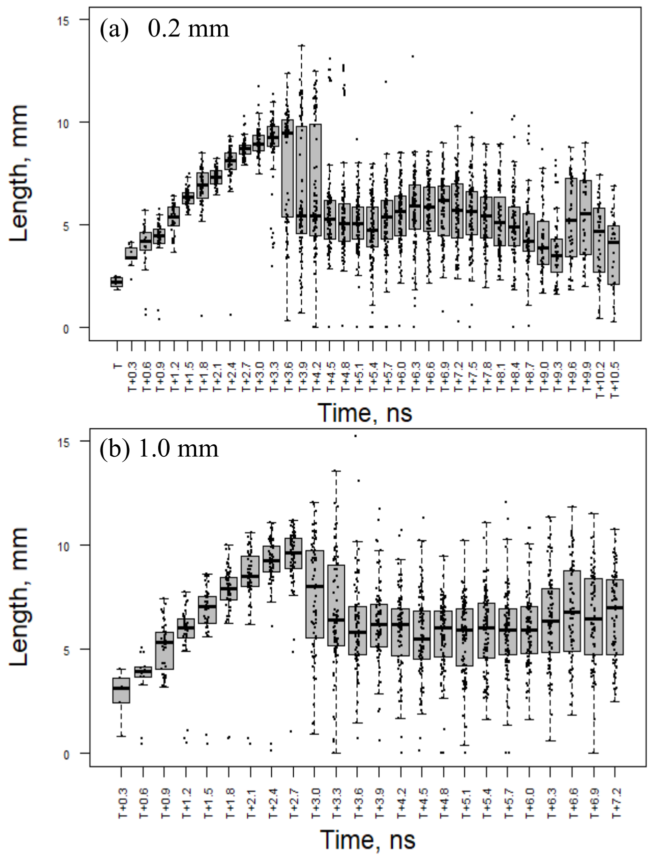


Fig. 3. Linear fitting of the streamer head position with time when the inner electrode diameter is 2.0 mm.

3.2 Streamer length of the primary streamer

Fig. 4 shows the variation of streamer length with time under different inner electrode diameter of 0.2 mm, 1.0 mm, and 2.0 mm. The data reveals that the streamer length of the primary streamer exhibits three phases. The streamer length firstly increases with time, then decreases, and at later stage the streamer length fluctuates. The mechanism behind this phenomenon deserves to be further studied in detail.



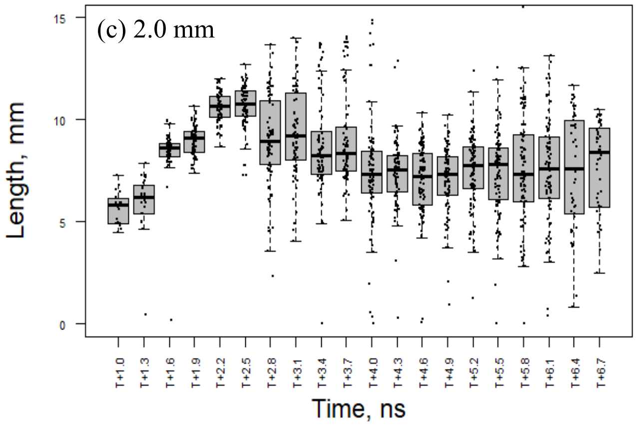


Fig. 4. The streamer length as a function of time under different inner electrode diameter of (a) 0.2 mm, (b)1.0 mm, and (c) 2.0 mm

4.Conclusions

In this work, a quadruple emICCD camera system is built to explore the fast propagation process of the primary streamer. The final jump is clearly captured during the propagation of the primary streamer. The streamer length of the primary streamer shows regular variation as a function of discharge time. The quadruple emICCD camera system provides an advanced way to further reveal the detailed characteristics of the primary streamer in nanosecond pulsed discharge.

5.Acknowledgements

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6.References

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