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Measurement of Electric Field in Pulsed Corona Discharge
パルスコロナ放電進展時の電界計測

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Electric field of streamer is estimated using spectroscopic method. The streamer discharge in atmospheric pressure is ignited by the pulsed high voltage generator supplying ten nanoseconds of pulse rise time. In synthetic air, the intensity and the length of secondary streamer are increased by the applied voltage. The emission intensity of $N_2(C^3\Pi_u)$ and $N_2^+(B^2\Sigma_u^+)$ are measured using monochromator and photomultiplier tube in order to estimate the electric field of streamer.

1. Introduction

Non-thermal plasma driven by pulsed streamer discharge in atmospheric pressure is a promising technology for the decomposition of environmental pollutants and in medical treatment [1-2]. For industrial use, evaluation of the electric field strength in the plasma has been expected. Some workers have evaluated the electric field of the streamer in experiment [3-4]. However, the electric field estimation of streamer is not well understood yet due to the measurement is hard to carry out due to the high spatio-temporal resolution in several hundreds of micrometer and a sub-nanosecond.

In this paper, we observe the monochromic light of nitrogen emission to estimate the electric field of streamer using photomultiplier tube and digital camera with image intensifier. We particularly pay attention to the influence of the voltage waveform with or without generating secondary streamer on the electric field.

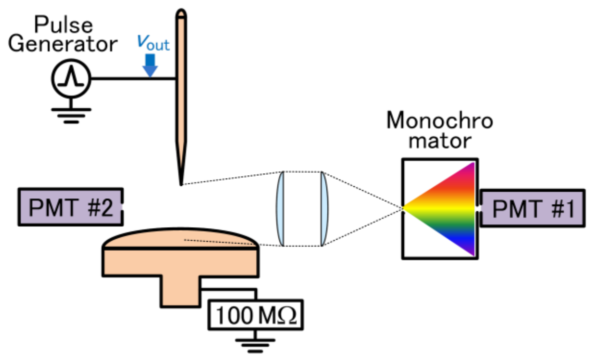

Fig. 1. Sketch of the experimental setup.

2. Methodology

Fig. 1 shows the sketch of experimental set up for time resolved measurements of nitrogen emission in streamer discharge. The needle-to-plate electrodes having gap of 7 mm are employed to generate the discharge in particular location. The electrodes are placed in a cylindrical reactor filled with synthetic air. The applied voltage of 18.5 kV, generated by the pulse power generator, has pulse width (FWHM) of 98.8 ns and pulse rise time (10-90% of maximum voltage) of 10.2 ns.

The emission from the discharge is focused on the input slit of a monochromator (Nikon, P250) with both the slits width of 0.1 mm. A photomultiplier tube PMT1 (0.57 ns in rise time) for detection of monochromatic light as the main signal and PMT2 for the down edge trigger of the oscilloscope as the synchronizing signal are used, since the derivative of this signal is actually used to define the zero-point of the relative time scale. The discharge propagated between the electrodes is observed with digital camera with image intensifier unit.

The data procedure of electric field estimation is that the intensity ratio of nitrogen emission from equation (1) and (2), considered with quenching by neutral particles of oxygen and nitrogen, finds the ratio of rate constant and calculates the electric field using BOLSIG+ software package [5]

$$N_2(C^3\Pi_u)_{v'=0} \rightarrow N_2(B^3\Pi_g)_{v''=0} + h\nu \qquad (1)$$

$$N_2^+(B^2\Sigma_u^+)_{v'=0} \rightarrow N_2^+(X^2\Sigma_g^+)_{v''=0} + h\nu \qquad (2)$$

3. Results

Fig. 2 shows the image of streamer observed between electrodes by digital camera with image intensifier unit. The streamer exhibits branching in both cases. The length of the secondary streamer increases with applied voltage, being and 3mm at 18.5 kV.

Fig. 3 shows that both emissions of I_B and I_C, being I_B and I_C of monochromatic light in the reaction (1) and (2) respectively, begin at 0 ns with applied voltage of approximately 8.6 kV. The maximum intensity of I_B is approximately 100 times smaller than peak intensity of I_C. The emission intensity of I_B decays slower than I_B and has the second peak of emission from secondary streamer (see Fig. 2).

The reduced electric field has the first peak of 800 Td at 3.9 ns after emission beginning and decreases to 372 Td at 9.1 ns. It is considered that the transition from primary to secondary streamer is occurred at the time of approximately 9.1 ns and the secondary streamer maintains the relatively low electric field between 350 to 575 Td for 25.6 ns. It is also considered that the sharp decline of the reduced electric field at 5.1 ns is caused by the electrical reflection in PMT1's circuit. The peak value of electric field on primary streamer seems suitable for the numerical calculations [6]. On the other hand, the value of electric field on secondary streamer after the time at 9.1 ns is 3-5 times higher than the numerical calculation [7]. It is considered that the emission of I_B (equation (2)) is relatively strong at the tip of the needle electrode due to the higher electric field.

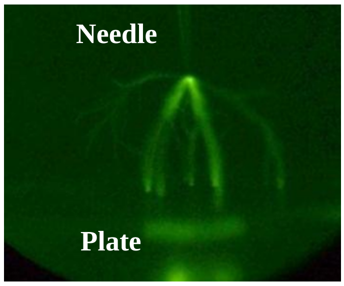

Fig. 2. Streamer channels for applied voltages of 18.5 kV

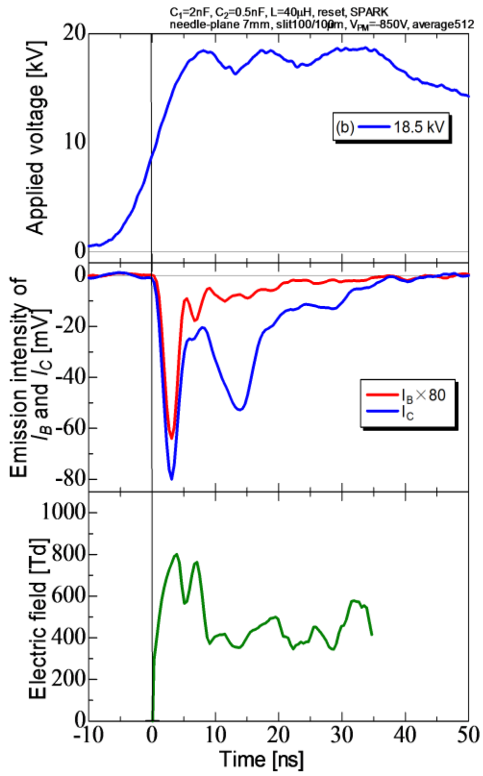

Fig. 3. Waveforms of applied voltage, emission intensity of I_B and I_C, and electric field of streamer.

4. Conclusion

As a conclusion, the emission intensity of primary streamer and the length of secondary streamer increased with applied voltage.

The reduced electric field sharply dropped to the value between 350 and 575 Td after sustaining the peak of 800 Td driven by primary streamer until 9.1 ns. It was shown that the transition from primary to secondary streamer.

Acknowledgment

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Refferences

[1] J. S. Chang, P. A. Lawless, and T. Yamamoto: IEEE Trans. Plasma Sci. **19** (1991) 1152.

[2] G. Fridman, G. Friedman, A. Gutsol, A. B. Shekhter, V. N. Vasilets, A. Fridman: Plasma Process. Polym. **5** (2008) 503.

[3] I. Gallimberti, J. K. Hepworth, and R. C. Klewe: J. Phys. D: Appl. Phys. **7** (1974) 880.

[4] K. Kozlov, H. Wagner, R. Brandenburg, and P. Michel: J. Phys. D: Appl. Phys. **34** (2001) 3164.

[5] CPAT & Kinema Software: http://www.siglo-kinema.com/bolsig.htm.

[6] Z. Bonaventura, A. Bourdon, S. Celestin, and V. P. Pasko: Plasma Sources Sci. Technol. **20** (2011) 035012.

[7] O. Eichwald, O. Ducasse, D. Dubois, A. Abahazem, N. Merbahi, M. Benhenni, and M. Yousfi: J. Phys. D: Appl. Phys. **41** (2008) 234002.