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Synchronized Generation of Positive Surface Streamer Discharge in Atmosphere

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Under certain conditions, streamers are generated simultaneously from two electrodes on the same plane. The synchronization is found to be produced by light emitted from the first streamer. Not only the light of the UV region, but also VUV, is effective.

1. Introduction

Lichtenberg figure method has been used for studies on surface discharge since its development in 1777. With this method, Pedersen [1] described synchronized generation of surface discharges using five electrodes on an insulator surface. After that, studies on surface discharge continued, but it would seem that the synchronization mechanism remains unclear. Recently, Chiba et al. [2] demonstrated that the cause of synchronization between two streamers which started from two different electrodes in parallel connection is attributable to the initial electron emitted from the insulator surface by illumination from the first streamer.

We have also examined the relationship of synchronization mechanisms of streamers and energy of photons radiated from the first streamer. It is considered that the phenomenon includes some important processes as the supply of initial electron: not only surface discharge, but also barrier discharge [3]. In particular, barrier discharge is a frontier of recent discharge plasma technology for development of a practical apparatus.

2. Experimental Procedure

Figure 1 shows a front view of the experimental setup. Standard lightning impulse voltage (1.2/50 μs) which has several tens of kilovolts peak value was applied to the parallel connected electrodes. The two electrodes were placed on an insulator plate made of acrylic resin. It is a square plate of side 300 mm and thickness 10 mm and has an aluminum back electrode. The back electrode is also a square plate of side 350 mm and thickness 10 mm ; it is grounded through a resistor put on the shielded box. Both terminals of the resistor were connected to a digital waveform recording system. Current and applied voltage were recorded by the system simultaneously. Dust figures were obtained on the insulator plate using photocopier toner. Observations were repeated several tens to a hundred times according to demand. It was judged that the streamers were synchronized if only one or two streamers occurred within a 100 ns interval in the current waveform. In that case, the obtained symmetrical dust figures had the same diameter as circles on the insulator plate. Probabilities of synchronization were determined for all experiments. A shading plate or an optical filter indicated by H in the figure was used to intercept discharge light or to limit the short side of wavelength of the light passing through a territory between the parallel electrodes, respectively. Several pieces of shading plate with different length or several optical filters were prepared for the purpose.

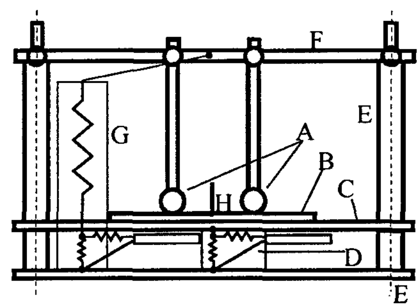

Figure 1 Experimental setup
A: Spherical Gaps, B: Acrylic Resin Insulator, C: Back Electrode, D: Current Measuring System, E: Insulator, F: Metallic Bar, G: Voltage Divider, H: Shading plate or Optical Filter

3. Results and Discussions

Without the shading plate, two streamers originated from both electrodes were synchronized with almost 100 % probability. The result is plotted by the open circle in Fig. 2. We call that synchronization of surface discharge. In contrast, if the shading plate was mounted on the middle point of the two electrodes, the probability of synchronization decreased remarkably to almost zero, as shown by the open triangles in the same figure. As length of the shading plate increased, probabilities decreased, as shown by the open squares in the same figure. Results suggest that the initial electrons emitted from an insulator near another electrode by illumination of the first streamer decrease with increase of the shortest

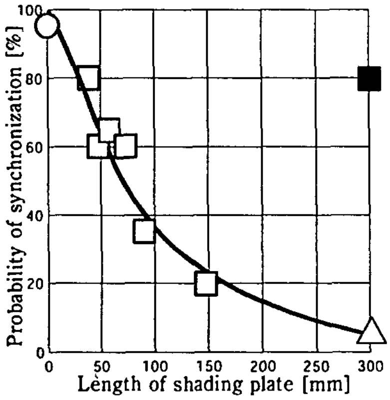

Figure 2
Probability of synchronization as a function of length of shading plate.

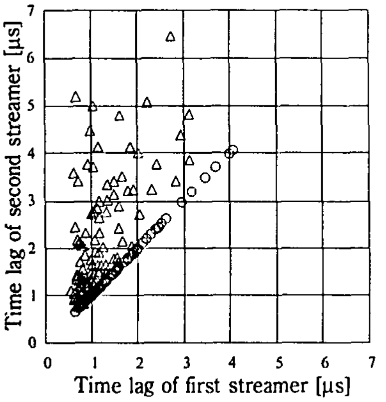

Figure 3
Time lags of first and second streamer.
Open triangle :With shading plate
Open circle :Without shading plate

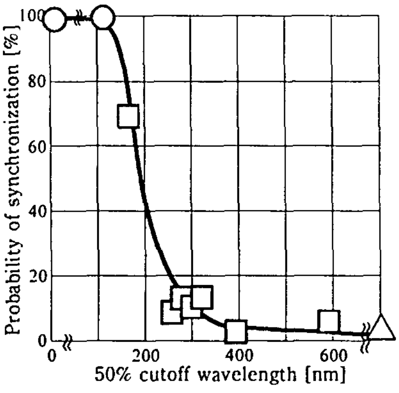

Figure 4
Probability of the synchronization as a function of cutoff wavelength of the filters

light pass along the surface of the insulator plate. Nevertheless, with the shading plate, the probability returned to above 80 %, as plotted by a closed square in the figure, when both electrodes were illuminated by ultraviolet light. UV is emitted from low-pressure mercury lamp that was fixed over the electrode system.

In the case where probability is approximately 100 %, the time lags of the first and second streamer are almost equal, as shown by the open circles in Fig 3. These time lags, which are observed in each current waveform of the one shot experiment, lie on a straight line in the graph. The horizontal axis of T_1 is a time lag of the first streamer; the vertical axis of T_2 is also a time lag of the second (another electrode) streamer from the origin of the applied impulse voltage to the electrodes, respectively. Cases of the open circles on the straight line as shown in the Fig. 3 correspond to plots indicated by the open circle in the Fig. 2. In contrast, the open triangle plots in the Fig. 3, i.e. T_2s become longer than T_1s give low synchronization probabilities, as shown by the open triangle in the Fig. 2.

It is supposed that UV light from the first streamers can introduce synchronization of surface streamers through the initial electron supply by the first streamers. Optical filters were used to investigate wavelength dependency of synchronization probability. Open circles of zero and 112 nm on the horizontal axis in Fig. 4 achieved 100 % probability of synchronization through one hundred times measurements without the shading plate and using an MgF_2 filter, respectively. In cases where filter of 350 nm cutoff or longer were used, probabilities sharply decreased and reached almost zero. The plot indicated by an open triangle in Fig. 4 is the result with shading plate of 300 mm and shows the non-synchronization of streamers.

For cases where distances between electrodes were changed, a similar tendency to that in Fig. 2 was recognized by experiments.

It is considered that the short side of the wavelength against the light required for the generation of synchronization is about 250 nm. This value corresponds almost to 5 eV and is the minimum energy for photoemission from the insulator surface [4], [5]. Our results also satisfied the necessity of photo-ionization near the insulator surface and the photoelectron emission from the insulator surface for interpretation of progression of dust figures experimentally and through computer simulation [6].

4. Conclusions

In order to investigate the relationship between synchronization probability and the wavelength of light radiated from the first streamer, more detailed experiments than the experiments described in previous papers were performed. Results confirmed that UV and VUV from the first streamer induced synchronization between the two streamers. That is not only UV but also VUV, radiated from the first streamer triggers the second one.

References

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