Observation of Two Consecutive Pulsed Discharge Over Water Surface in Argon

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Abstract: Two consecutive pulsed discharges generated over a stationary water surface in argon are observed to understand the post-discharge phenomena. Two ICCD cameras are used to take images of the propagation of the first and the second pulse discharges. A cylindrical vessel filled with argon gas and containing a purified water is used. The pulses with an interval time ranging from 1 to 1000 μs are generated by a pulsed power generator consisting of two MOSFET. When the interval between two pulses is less than approximately 20 μs, the development of the discharge of the second pulse enhanced, and the propagation velocity of the discharge and the charge quantity of the second pulse are higher than those of the first pulse. The maximum discharge velocity estimated from the time change of the discharge length of the first and second pulses are 0.35 and 0.52 × 10^6 m/s, respectively.

Keywords: Discharge over water surface, post-discharge phenomena, propagation velocity

1. Introduction

Pulsed discharge in contact with water has recently been attracting significant attention as a promising technology for various fields such as environmental remediation [1] and agriculture applications, which have been extensively investigated [2]. The discharge enables the instantaneous production of oxidants, with very high oxidation potential, such as hydroxyl radicals, inside the discharge channel at the water surface [3]. However, details of the propagation process of the discharge with a time duration on the order of nanoseconds and its relationship with the chemical reactions occurring at the gas-liquid interface remain open questions.

In this study, the post discharge relaxation phenomena of two consecutive pulsed discharges generated over stationary water surface are observed. Two ICCD cameras are used to take images of the propagation of the first and the second pulse discharges. A cylindrical vessel filled with argon gas and containing a purified water. A pulsed power generator consisting of two MOSFETs is used to generate high voltage pulses with a discharge interval ranging from 1 to 1000 μs.

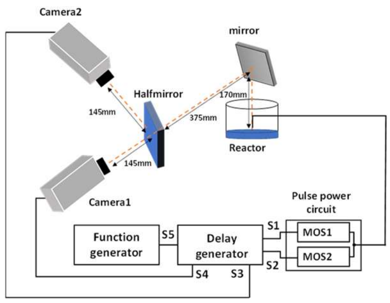

Fig. 1. Schematic diagram of the discharge observation system using ICCD cameras.

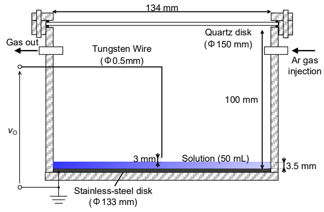

Fig. 2. Schematic diagram of the reactor for the discharge observation

2. Experimental Setup

Figure 1 shows the schematic diagram of the discharge observation system using two ICCD cameras. The system consists of a discharge reactor, a pulsed power generator using a two MOSFET, a function generator, a delay generator (Stanford Research Systems, DG645) and two ICCD cameras (Andor, istar 334T, ICCD cameras 1 and 2). Figure 2 shows the discharge reactor. The reactor consists of a cylindrical acrylic vessel (134 mm in a diameter and 100 mm in a height) covered with a quartz glass disc. The inside of the reactor is filled with an argon gas. A stainless-steel disc is placed on the bottom of the reactor and used as a grounded electrode. A 50 mL of purified water is added to the vessel. A tungsten wire (0.5

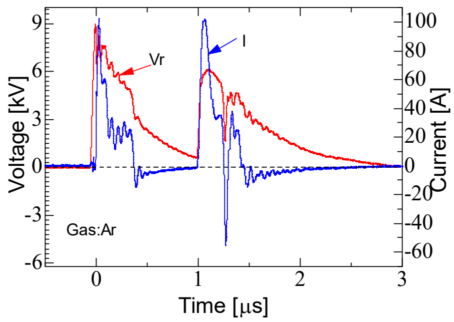

Fig. 3. Typical waveforms of applied voltage and current flows reactor.

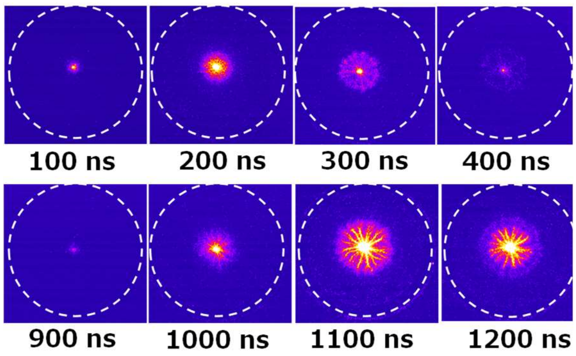

Fig. 4. Framing photographs of the discharge

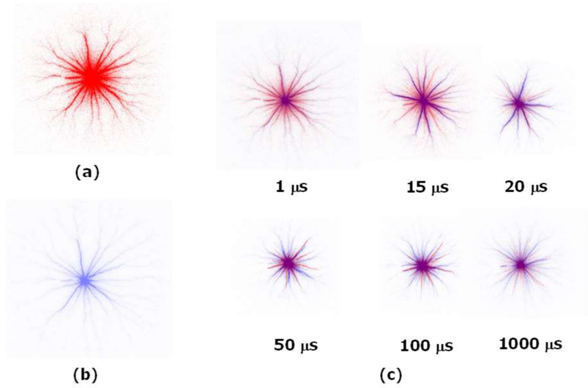

Fig. 5. Photograph of (a) the first pulse discharge and (b) the second pulse discharge. (c) Superimposed images of two images (a) and (b) for various interval times of pulses

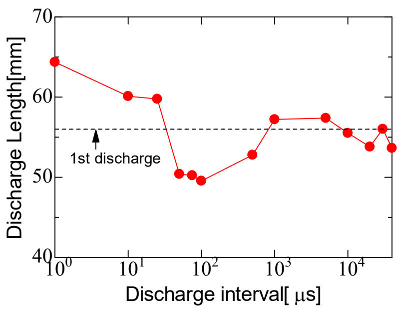

Fig. 6. Discharge length of the second pulse discharge as a function of discharge interval.

mm in a diameter) is placed above the water surface with a gap length of 3 mm and used as a high-voltage electrode. Figure 3 shows the pulse voltage applied to the high voltage electrode, generated by the pulsed power generator. When the MOSFETs 1 and 2 are turned on, the first and second pulses are applied to the electrode. The time interval between turning MOSFET 1 off and turning MOSFET 2 on is adjusted by the delay generator and ranges from 1 us to 1000 µs. The exposure of cameras 1 and 2 is synchronized with the switching of MOSFETs 1 and 2. The exposure time is fixed at 500 ns.

To evaluate the propagation velocity of the discharge inside the bubble, an ICCD camera (Nac Image Technology, Ultra Neo 2 UV), which is capable of taking 12 consecutive images (ICCD camera 3) is used instead of the two ICCD cameras 1 and 2. ICCD camera 3 is placed in front of the quartz window instead of ICCD camera 1. The exposure time is fixed at 100 ns. The 12 images of a discharge are taken continuously with a time step of 100 ns.

3. Results

Figure 4 shows continuous framing photographs of the discharge using the ICCD camera. The first discharge occurs at 100 ns and then, the second discharge occurs at time of 1000 ns, from the tip of the electrode at the centre of the reactor and propagates radially to outwards. The length of the discharge occurring at second pulse is longer than that of the first discharge. Figure 5 (a) and (b) show photographs of the discharge occurring at the first pulse (red) and the second pulse (blue), respectively, taken with two ICCD cameras. Figure 5 (c) shows superimposed images of the discharges occurring at the first and second pulses (a) and (b) for various interval time, with purple indicating the discharge channel occurring at the same position. The two discharges propagate along the same path when the interval time is less than 20 µs, and the correlation of the path decreases as the interval time increases. Figure 6 shows the discharge length of the second pulse as a function of the interval time. The discharge length of the first pulse is approximately 57 mm. When the discharge length is less than 20 µs, the discharge length of the second pulse is longer than that of the first pulse. The maximum discharge velocity estimated from the time change of the discharge length of the first and second pulses are 0.35 and 0.52 × 10^6 m/s, respectively. Figure 7 shows the charge quantity of the second discharge as a function of the pulse interval time. The charge quantity of the second pulse is higher than that of the first pulse of approximately 0.85 µC for an interval time of less than 3 µs. These results show that the second pulse discharge can be enhanced by the effect of the first pulse discharge within the post discharge period of less than several µs to 20 µs. The discharge channel increases the gas temperature and the reduced electric field, leading to an enhancement of the

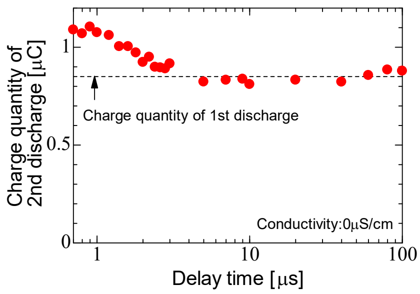

Fig. 7. Charge quantity of the second pulse discharge as a function of discharge interval

ionization. On the other hand, as shown in figure 6, the discharge length of the second pulse is shorter than that of the fist pulse with an interval time from 20 μs to 1 ms. Since the conductivity of the purified water is less than 1 μS/cm and the time constant obtained by the inverse of the product of conductivity and permittivity is long, the water surface can be charged up by the first pulse. The charges on the water surface reduce the electric field, which suppress the development of the second pulse discharge.

4. Conclusion

The propagation of two consecutive pulsed discharges generated over stationary water surface in argon is observed to understand the post discharge phenomena. When the interval between two pulses is less than 20 μs, the development of the second pulse discharge is enhanced, and the discharge propagation velocity and the charge quantity of the second pulse are higher than those of the first pulse. The maximum discharge velocity estimated from the time change of the discharge length of the first and second pulses is 0.35 and 0.52 × 10^6 m/s, respectively.

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6. References

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