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パルスパワーを用いたプラズマの生成と液相応用
Pulsed Power Generated Streamer Discharges and Its Application on Liquids

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1. Introduction

Pulsed power generated discharge plasma enables a large volume, various reactive species, a large amount of high energy electrons, and has sufficient energy efficiency of gas and liquid treatments. This manuscript briefly introduces its characteristics and examples of applications.

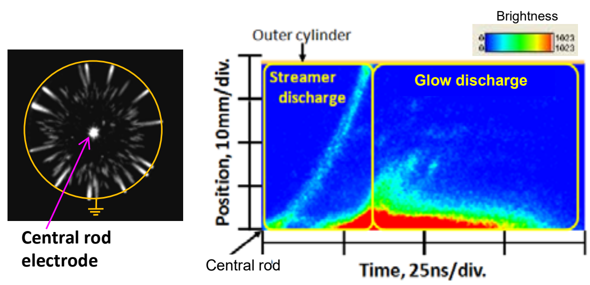
2. Pulsed Discharges Generated by Pulsed Power Technology

To generate discharges by pulsed power, the simplest power supply is the capacitor bank, which consist of a DC power source, a capacitor and a switch. The advantages of this system are the simple circuit structure and available with any kinds of load connection. The disadvantage is that time duration of output voltage varies with time constant based on the circuit and load combination. In general, one of the most important issues of pulsed power technology for non-thermal plasma application is to form a square pulse and the impedance matching between power supply and load. Thus, making a flat top of voltage waveform means it is able to transfer high voltage to load constantly which produces large amount of reactive species. In this point, the advanced pulsed power supply shall be the pulse forming network, PFN. PFN consists with a DC source, a series of LC ladder modulators, and a switch. This also can be substituted by using a coaxial cable, namely pulse forming line, PFL [1].

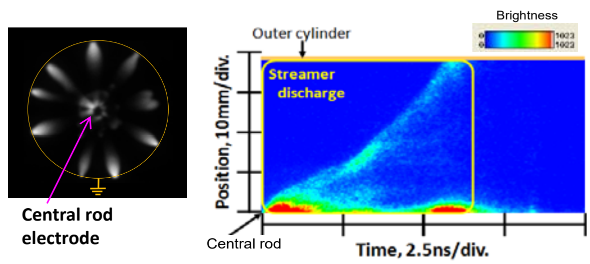
Fig. 1 shows a framing image and a streak image of a 100 ns pulsed discharge in a coaxial electrode generated by a three-stage Blumlein line generator: a kind of PFL [2]. From Fig. 1, two stages of the discharge can be clearly defined during the pulsed discharge. The first one is the “streamer discharge,” which means the phase of streamer head propagation between electrodes. The other one is the “glow discharge” that follows the streamer discharge. The averaged propagation velocity of the streamers was 1.2 mm/ns for 60 kV applied voltage. It was also observed that the gas temperature increased by about 150 K during the glow discharge phase. The temperature rise indicates thermal loss during the plasma reaction process that would lower treatment efficiency in applications.

3. Nanosecond Pulsed Streamer Discharge

In order to make plasma reactions with higher energy efficiency, a pulsed discharge aimed to reduce the glow discharge phase has invested: namely the “nanosecond pulsed streamer discharge”. Fig. 2 shows the images taken with the same method using a nanosecond pulsed power generator which theoretically has 5 ns of pulse duration [2]. From Fig. 2, it is clearly observed that the time duration of the streamer discharge was within 6 ns. At around 5 ns, emission from the central rod electrode was observed, which attributed to the strong electric field at the rod, but finally disappeared at around 7 ns. In this case, the glow discharge phase was not observed. The averaged

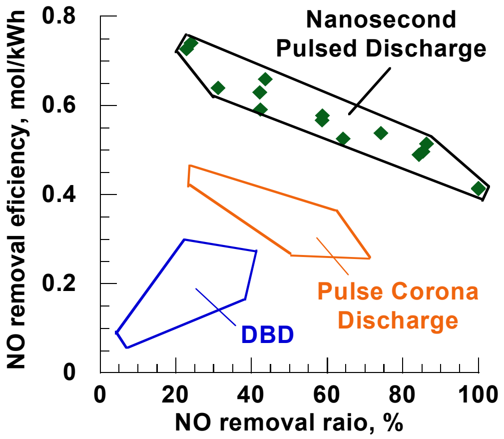


(a) Framing image　　(b) Streak image
Fig.1. Images of a 100 ns pulsed discharge in a coaxial electrode taking from axial direction [2].

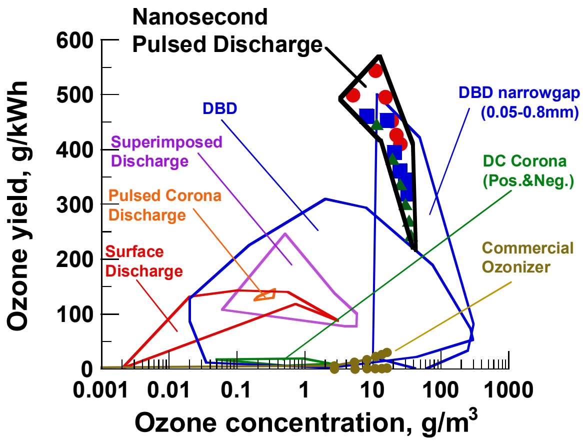


(a) Framing image　　(b) Streak image
Fig.2. Images of a 5 ns pulsed discharge in a coaxial electrode taking from axial direction [2].

propagation velocity of the streamers was 6.1 mm/ns for 67 kV applied voltage, which is about 5 times faster than 100 ns one. Using nanosecond pulsed discharge, its energy efficiency in gas treatment applications shows the better performance than other non-thermal plasma methods. Fig. 3 gives the examples in case of nitric monoxide treatment and ozone generation [3].



(a) NO treatment



(b) Ozone generation

Fig.3. Characteristics map of nitrogen monoxide (NO) treatment (a) and oxygen-fed ozone generation (b) based on different discharge methods [3].

4. Treatment of Liquids Using Nanosecond Pulsed Streamer Discharge

To achieve the higher surface-area-to-volume ratio of plasma-liquid reaction, wastewater was sprayed into the discharge reactor where gas phase plasma was generated. Fig. 4 shows the schematic diagram of water treatment system using nanoseconds pulsed discharge. The spray unit was mounted in the upper inlet of the discharge reactor, and treatment water was circulated at a certain flow rate. Fig. 5 shows the treatment results with different persistent organic pollutants (POPs) that all has different chemical structures. The treatment was fixed at same experimental conditions, and the feeding gas was O_2 to generate discharge plasma. Treatment time was 3 hours. The results shows that TOC are reduced with all samples.

5. Conclusion

Nanosecond pulsed discharge plasma generated by pulsed power has sufficient energy efficiency for plasma processing application, due to its unique physical properties of discharge phenomenon.

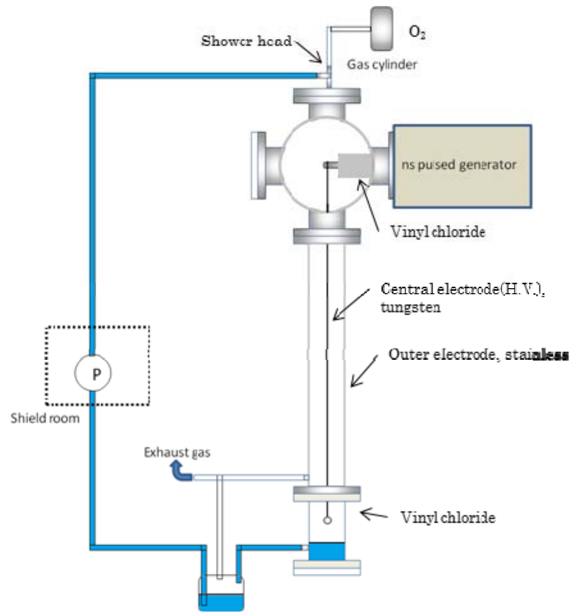


Fig.4 Schematic diagram of water treatment system using nanoseconds pulsed discharges.

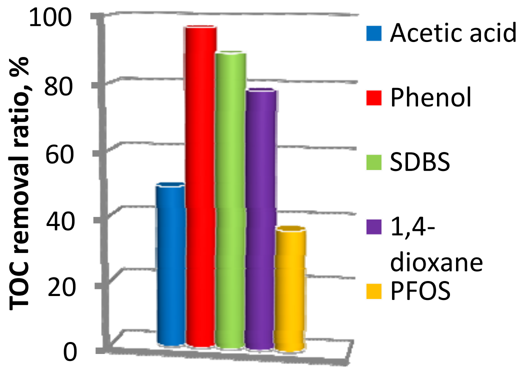


Fig.5 Treatment of different persistent organic pollutants in water using nanoseconds pulsed discharges.

References

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