PRODUCTION OF OZONE USING NANOSECOND SHORT PULSED POWER *

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Abstract

Production of ozone is one of the most typical industrial and commercial applications of electrical discharge. The demand of ozone will be increasing for wholesome and environment-friendly sterilizations. The production of ozone using the pulsed power discharge will apply electron accelerations around the head of streamer discharge. The breakdowns in reactor, however, often limit the efficient production. The pulse shape should be controlled for dimension of the reactor. On the other hand, the narrow reactor is preferable to obtain high energy density in the discharge region. It is clear that a pulse shortening is one of effective approaches.

The nanosecond pulsed power voltage applies for ozone production. The short pulse is generated from a combination of a short pulse forming line and a short gas gap switch with high pressure, and supplies to the reactor with a wire–to–cylinder configuration. The effects of the pulse shape, dimension and configuration of the reactor and flow rate of oxygen gas on ozone production are discussed here. The efficiency, producing ozone, of 350 g/kWh is obtained at present.

I. INTRODUCTION

Production of ozone is one of the most typical industrial and commercial applications of electrical discharge. The demand of ozone will be increasing for wholesome and environment–friendly sterilizations. With an expectation of higher efficiency of production and higher concentration, the production of ozone by pulsed power discharges has been studied [1]-[8].

The production of ozone using the pulsed power discharge will apply electron accelerations around the head of streamer discharge principally; dielectric barriers are superfluous. The breakdowns in reactor, however, often limit the efficient production. The pulse shape should be controlled for dimension of the reactor. On the other hand, the narrow reactor is preferable to obtain high energy density in the discharge region. It is clear that a pulse shortening is one of effective approaches.

Here, pulsed power voltage with ns–width applies for ozone production. The short pulse is generated from a combination of a short pulse forming line and a short gas gap with high pressure, and supplies to the reactor with a wire–to–cylinder configuration. The experimental condition is changed for some reactors with different configuration.

II. EXPERIMENTAL CONFIGURATION

A. *Pulsed Power Generator*

Figure 1 represents the equivalent circuit of pulsed power generator. The generator consists of a capacitor bank, a pulse transformer, a considerable short pulse forming line and a gas gap switch with a short separation. The capacitor bank (25.8 nF) is charged by DC power supply and a gap switch (GS_1) self-breakdowns. The combination of the pulse transformer (1:24) and the capacitors behaves as a tesla transformer, thereby the pulse forming line, whose capacitance is evaluated to be 56 pF, is multiplicatively charged. The gas gap switch with a short separation applies to fast rise of voltage so that the output voltage pulse has sub nanosecond rise and pulse width of ns. The typical waveform of output voltage pulse for 81 Ω load is shown in Figure 2. In the condition that the initial charging voltage of C_1 is 5.2 kV, the peak voltage is 130 kV and the pulse width (FWHM) is approximately 1 ns. The DC power supply is controlled by a personal computer and the repetitive ratio: 500 pps of the generator is possible at present.

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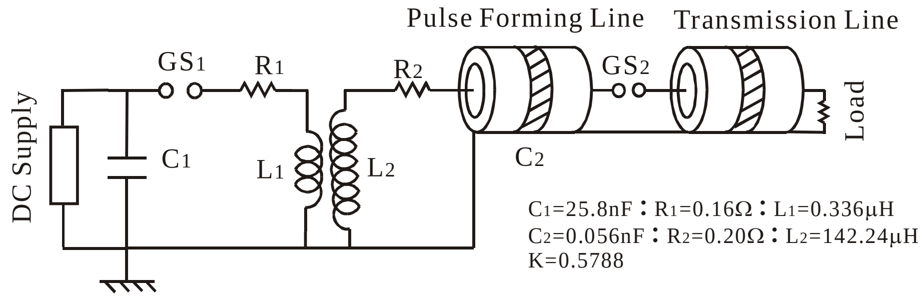


Figure 1. The equivalent circuit of the pulsed power generator.

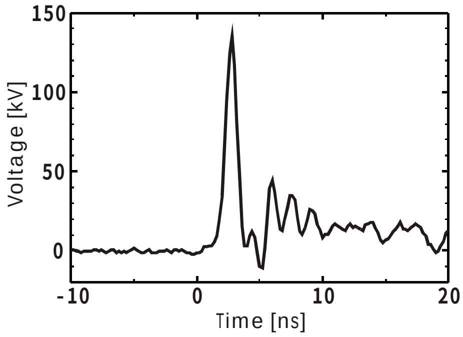


Figure 2. The typical waveform of voltage for 81 load.

B. Experiment of Ozone Production

The experimental configuration is shown in Figure 3. The pulsed power is applied on the inner electrode of a coaxial reactor. The reactor consists of the copper cylindrical outer electrode of 58 mm in diameter and 500 mm or 1000 mm in length and the inner spiral electrode. A copper wire is coaxially wound on a polyvinyl chloride (PVC) cylinder and the winding rate of 2 turns/m or 10 turns/m is adopted. Oxygen gas regulated by a flow controller axially flows in the coaxial reactor and the density of ozone in oxygen is measured with an ozone meter at an end of the reactor. The experiments of 2 L/min in flow rate are focused in this paper. The applied voltage is observed by a resistive voltage divider and a shunt resistor measures the reactor current.

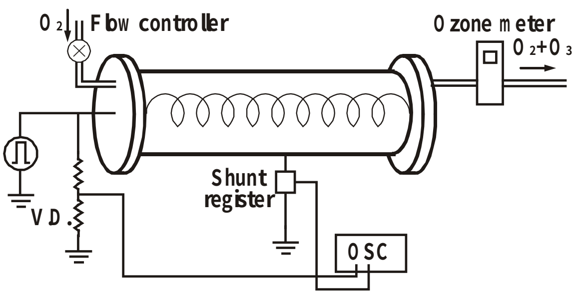
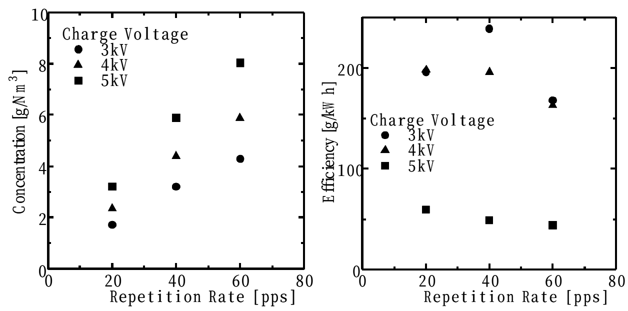


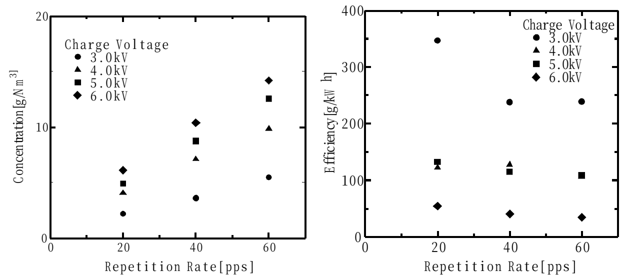
Figure 3. The configuration of equivalent circuit of the pulsed power generator.

III. EXPERIMENTAL RESULTS AND DISSCUSSION

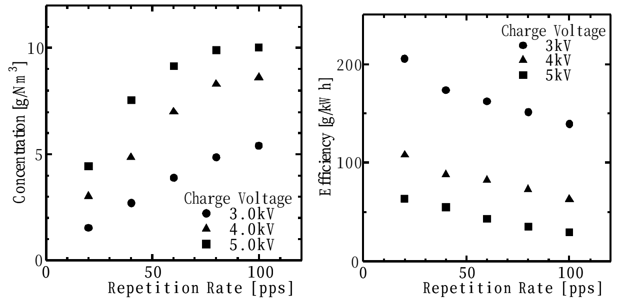
Figures 4 show the concentration of ozone and the efficiency of ozone production in the various experimental conditions. The efficiencies are evaluated



(a) Length=500 mm, Rate=2 turns/m



(b) Length=1000 mm, Rate=10 turns/m



(c) Length=500 mm, Rate=10 turns/m

Figure 4. The concentration and efficiency versus repetitive rate.

from discharge energies that are the integration of product of reactor voltage and reactor current. As the repetitive rate of pulsed power generator increases, the concentration of ozone increases and the efficiency decreases. While the concentration increases with the charged voltage of the capacitor bank, the clear properties of the efficiency are not found. The maximum concentration is about 15 g/Nm^3 in this experimental condition, and higher concentration is obtained for higher repetitive rate or lower flow rate of oxygen. The maximum efficiency of ozone production reaches to 350 g/kWh.

It is difficult to determine and find the good reactor from the data arrangement of Figure 4. Figure 5 and 6 is re-plotted from Figure 4 by using the specific energy. The specific energy is calculated from the deposited energy divided by flow rate to estimate the capability of reactors. Although the slope of plots in Figure 5 seems to represent the capability, the number of plots is not enough to estimate. In Figure 6, the plots are parted into two groups: over 100 and another. The lower group would result from arcing.

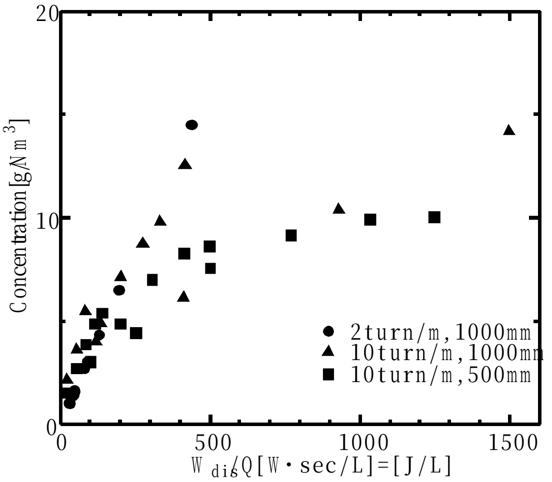


Figure 5. The relationship between the concentration and the specific energy.

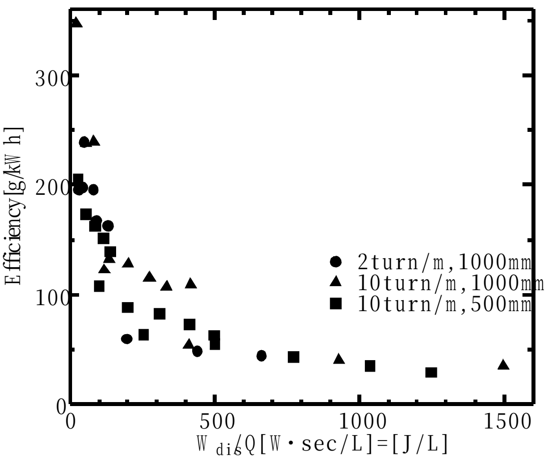


Figure 6. The relationship between the efficiency of ozone production and the specific energy.

In the fast pulsed power as ns width pulse, it is clear that efficiency is significantly affected by the matching between the pulser and load (reactor) as well as the capability of reactor. Figures 7 show the comparison between the efficiency of ozone production and the energy transfer from the capacitor bank to discharge. Since the specific energy is selected as a horizontal value, the correspondence between two graphs can be followed. Generally speaking, the energy transfer ratio is low when the efficiency of ozone production is high, and vice versa. In these reactors, the volume of reactors will be small for initially charged energy. Plenty of consideration is, however, required to design the large volume reactor owing to matching and discharge characteristics. Although the transfer ratios over 100% are obtained, inductive factors are ignored from evaluation of energy deposited in discharge. The efficiency may be, thereby, higher than these data.

IV. SUMMARY

Pulsed power voltage with ns-width applied to ozone production. The efficiency of ozone production reaches 350 g/kWh. At present, the configuration of the reactors is not optimized sufficiently, the design for optimization is difficult because a number of data is not enough and handling fast ns pulse is ticklish. It is, nevertheless, clear that shortening pulse improve the efficiency of ozone production considerably. Further optimization of reactor and developments of diagnostics for ns high voltage pulses are next tasks.

V. REFERENCES

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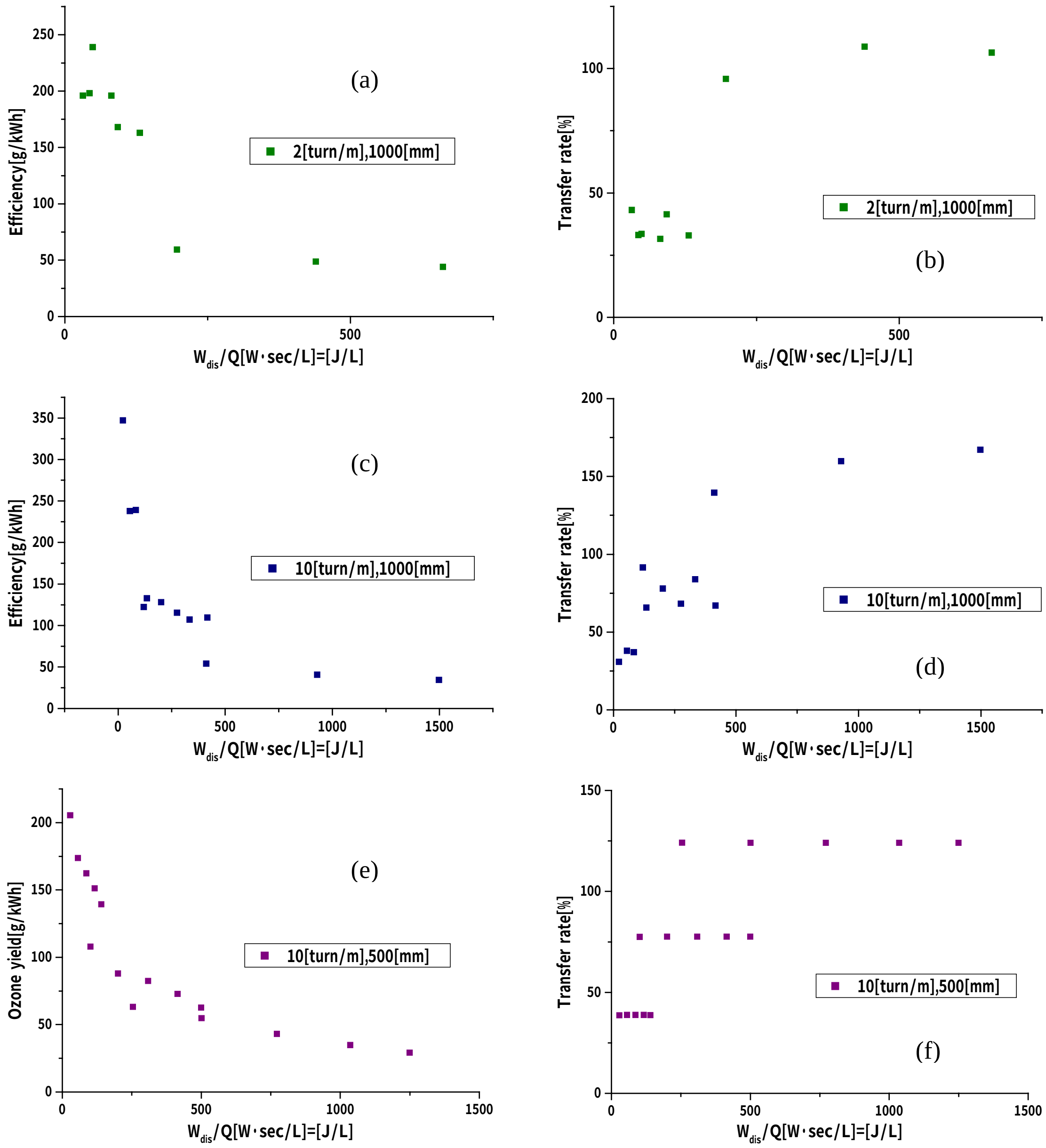

Figure 7. The comparison between the efficiency of ozone production and the energy transfer from the capacitor bank to discharge, versus specific energy.

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