<table>
<thead>
<tr>
<th>Title</th>
<th>Effect of Pulse Width on Ozone Generation in Pulsed Streamer Discharges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Tamaribuchi, Hiroyuki; Wang, Douyan; Namihira, Takao; Katsuki, Sunao; Akiyama, Hidenori</td>
</tr>
<tr>
<td>Citation</td>
<td>Digest of Technical Papers-IEEE International Pulsed Power Conference, 2007: 407-410</td>
</tr>
<tr>
<td>Issue date</td>
<td>2007-06</td>
</tr>
<tr>
<td>Type</td>
<td>Conference Paper</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/2298/10313">http://hdl.handle.net/2298/10313</a></td>
</tr>
<tr>
<td>Rights</td>
<td>©2007 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for purposes other than personal or editorial use requires the written consent of the publisher.</td>
</tr>
</tbody>
</table>

Kumamoto University
EFFECT OF PULSE WIDTH ON GENERATION OF OZONE BY PULSED STREAMER DISCHARGE

H. Tamaribuchi, D. Wang, T. Namihira, S. Katsuki and H. Akiyama
Graduate School of Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, Japan

Abstract
Ozone has been used in treatment of drinking water and waste water (e.g., deodorization, decolorization, and disinfection). Though general ozonizers based on silent discharge or barrier discharge have been used to supply ozone at many industrial situations, there is still some problem, such as improvements of ozone concentration and ozone yield.

In this work, ozone was generated by pulsed power discharge in order to improve the characteristics of ozone generation. High electric field with short pulse width could accelerate electrons to cause chemical reactions for ozone production without accelerating ion. This means pulsed power discharge could generate ozone without gas heating. It is also known that a pulse width gives strong effect to the improvement of energy efficiency in exhaust gas processing.[9] In the conference, the effect of pulse duration on ozone generation by pulsed streamer discharge would be reported.

I. INTRODUCTION
Ozone is a very effective and potent oxidant and, therefore, there is a wide interest currently in an energy efficient production of ozone for numerous and diverse practical applications. These may include, sterilization, deodorization, decolorization, bleaching processes, chemical synthesis, and gas treatment. Ozone has little detrimental effect on the environment, as the natural decay product ozone is oxygen. It has the added advantage of less energy consumption than other alternatives, such as the chlorination process. Because of the hazards of storage, handling, and transportation due to its inherent instability, ozone is usually generated on the site of its application. Generally, ozone is generated with high voltage ac in a corona gas discharge.

The energy efficiency in conventional generators operating either at the power frequency or using thyristor-controlled converters at frequencies up to a few kilohertz is rather low, because a portion of the applied electrical energy is converted into heating the gas and the electrodes and therefore wasted. Ozone production by pulsed streamer non-thermal discharges has been shown to be very effective without significantly raising the gas temperature or inducing arc breakdown between the electrodes at room temperature and atmospheric pressure. It is also known that a pulse width gives strong effect to the improvement of energy efficiency in exhaust gas processing. [8] In this work, the effect of pulse duration on ozone generation by pulsed streamer discharge was investigated. Ozone concentration and ozone production yield (efficiency) are measured at various pulse widths (50ns, 100ns, 200ns) in dry air.

II. EXPERIMENTAL SETUP

A Pulsed Power Generator
Fig.1 shows the schematic diagram of a Blumlein line generator used as a pulsed power source in the present work. The generator consist of two coaxial cables which had a characteristic impedance of 50 Ω (RG-213/U, Mitsubishi Cable Industries, Japan). The total characteristic impedance of the generator was 100 Ω (50 Ω × 2 cables). On the Blumlein line generator, the cable length defines the pulse width that is defined as the full width at half maximum of the output voltage (FWHM). In this study, the generator had pulse widths of about 50, 100 and 200 ns and corresponding cable lengths of 5.0, 10.0 and 20.0 m, respectively.

Figure 1. Pulsed power generator.

B Production of ozone
Fig. 2 shows the experimental set-up for ozone generation in this experiment. In the present work, the air gas flow rate was controlled at 0.1 l/min by mass flow controllers (SEC-E440J, STEC Inc., Japan) at atmospheric pressure and a temperature of 273 K.
A concentric coaxial cylindrical reactor was employed as a discharge electrode. The central rod made of tungsten, 0.1 mm in diameter was placed concentrically in a copper cylinder having 76 mm inner diameter, and the length of 500 mm. A coaxial cylindrical reactor was used as it has been shown to be more effective in producing energetic electrons due to the generation of high electrical fields near the wire [10, 11]. The energetic electrons are necessary to produce active radicals such as N, O and OH by collision with N₂, O₂ and H₂O [10, 11].

In the present work, a positive voltage polarity was chosen for the central electrode of the reactor, the charging voltage to the generator was changed during 12.5-22.5 kV, and a pulse repetition rate of 5-100 pps (pulses per second) was used. The applied voltage from the Blumlein line generator was measured using a resistive divider (1 Ω : 10 kΩ), which was connected between the central electrode of the reactor and the ground. The discharge current through the reactor was measured using a current monitor (Model 2878, Pearson Electronics Inc., USA), which was located on the return current to the ground. A digital oscilloscope (HP54845A, Hewlett Packard, USA) with a maximum bandwidth of 1.5 GHz and a maximum sample rate of 8.0 G samples/s recorded the signal. The concentration of ozone is measured using an ultraviolet (UV) absorption meter (V-550, JASCO, Japan), which is close to the maximum of the Hartley absorption band of ozone. The instrument was calibrated by the manufacturer.

Figure 2. Experimental setup.

III. RESULTS AND DISCUSSION

A. Effect of Pulse Width

Fig. 3 shows typical waveforms (a) voltage across and (b) current through the reactor for varying pulse widths. After the peak the behavior of the pulse for different widths varied due to the varying stored charge with varying capacitance of the Blumlein line generator.

Figure 3. Typical waveforms of (a) voltage across and (b) current through the reactor for varying pulse widths.

Fig. 4 shows the discharge energies per pulse. The input energy (\(\int V I dt\)) to the discharge per pulse for different pulse width was calculated from the voltage and current waveforms and t.

Figure 5 shows production of ozone as a function of charging voltage for various pulse widths. Figure 5 shows that the pulse width does not influence strongly the production of ozone under the same charging voltage condition.

Figure 6 shows ozone production yield as a function of charging voltage for various pulse widths. The production yield of ozone in g/kWh is determined from

\[ Y = \frac{C \times G \times 60[\text{min}/\text{h}]}{E \times f} \]  

where G is the gas flow rate in l/min, C is the concentration of ozone in g/m³, f the pulse repetition rate (pulse/s) and E the input energy to the reactor per pulse (J). Figure 6 shows that ozone production yield was higher for shorter pulse widths at a fixed charging voltage. This is because the input energy to the reactor decreased
with decreasing pulse width while the change in ozone concentration was relatively small.

In this experiment, the pulse width of the Blumlein line generator was fixed at 50 ns.

Figure 7 shows a dependence of discharge energies per pulse on pulse repetition rate at various charging voltage. The discharge energies per pulse decreased with increasing the pulse repetition rate.

Figure 8 shows production of ozone as a function of pulse repetition rate for various charging voltage. The ozone production increased with increasing the pulse repetition rate.

Figure 9 shows ozone production yield as a function of pulse repetition rate for various charging voltage. The ozone production yield decreased with increasing the pulse repetition rate.

Figure 10 shows all experimental results in this work. Figure 10 shows ozone production yield as a function of production of ozone for various pulse widths. It will be observed from figure 10 that the production yield decreases with increasing production of ozone at same pulse width.

**B. Effect of Pulse repetition rate**

**Figure 4.** Input energy into discharge reactor per pulse.

**Figure 5.** Dependence of ozone concentration on charging voltage.

**Figure 6.** Dependence of ozone production yield on charging voltage.

**Figure 7.** Input energy into discharge reactor per pulse.

**Figure 8.** Dependence of ozone concentration on pulse repetition rate.

**Figure 10.** Ozone production yield as a function of production of ozone for various pulse widths.
**IV. CONCLUSIONS**

Pulsed power at short durations (50-200 ns) has been used to generation of ozone in air. The following conclusions have been deduced.

1. The ozone concentration increased with increasing applied voltage.
2. The input energy to the discharge per pulse decreased with increasing ozone concentration in reactor.
3. The ozone production yield decreased with increasing ozone concentration at fixed pulse rate.
4. The energy required to generation of ozone decreased with decreasing pulse width.

In this work, it showed that a pulse width gives effect to the improvement of energy efficiency in generation of ozone by pulsed streamer discharge.

**V. REFERENCES**