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Performances of Nanosecond Pulsed Discharge

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The conventional methods such as selective catalytic reduction method, electron beam method and lime--gypsum method could not treat exhaust gases completely. In addition, the energy efficiency and the cost of the conventional ways are still unfavourable. In recent years, the pollution control techniques using electric discharge plasmas which attract attention as the low cost and high energy efficient exhaust gas treatment methods, have been widely studied. In our laboratory, pulsed streamer discharge plasmas which are one of the non-thermal plasmas have been used to treat exhaust gases. Since a pulse width of applied voltage has a strong influence on the energy efficiency of the removal of pollutants, the development of a short pulse generator is of paramount importance for practical applications. In this work, nanosecond pulse generator which can output the 5 ns pulsed voltage is developed. In addition, the exhaust gas treatment and the ozone production by nanosecond pulse generator were demonstrated.

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1. Introduction

Pulsed streamer discharges in atmospheric pressure gases have been studied for many years since it is one of the promising technologies for the removal of the hazardous environmental pollutants. In this decade, especially, some researchers reported that the shorter pulsed power gives the improvement of the energy efficiency to treat pollutant gases. Therefore, the development of a nanosecond (ns) pulse generator is paramount important for practical applications. In the present work, a pulse generator which can output the 5 ns pulsed voltage is presented. Additionally, the exhaust gas treatment and ozone production by ns pulse generator were demonstrated.

2. Experimental apparatus and procedure

Figure 1 shows the schematic diagram of the nanosecond pulse generator (NS-PG) [1]. The output voltage to

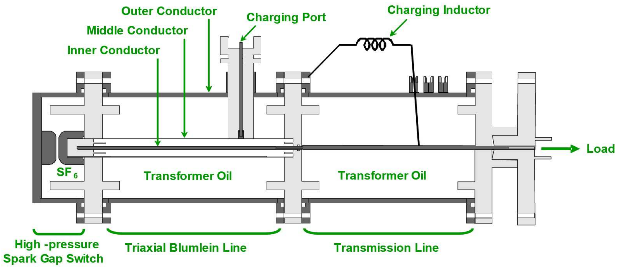

Fig. 1. Schematic diagram of the ns pulse generator (NS-PG).

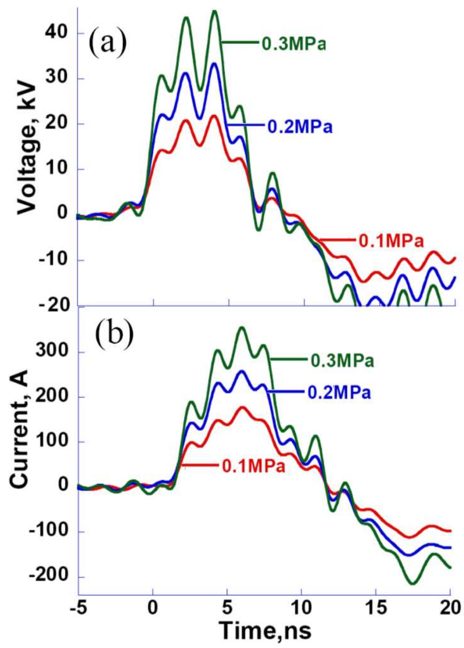

Fig. 2. Typical output waveform from ns pulse generator. (a) Applied voltage. (b) Discharge current.

the electrode was varied by regulating the gas pressure of SF_6 in spark gap switch. The voltage was applied to the rod electrode and measured by the capacitive voltage divider, and the discharge current through the electrode was measured using a current monitor (Pearson current monitor, Model 6585, Pearson Electronics Inc., USA), which was located on the inner rod of the transmission line. Figure 2 shows typical output waveform from ns pulse generator. It can be observed in Fig. 2 that the pulse width is approximately 5 ns.

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3. Experimental results and discussion

3.1. Nitric oxide removal experiment result

In this experiment, the reactor having 76 mm in internal diameter and a length of 810 mm was used and SF_6 gas pressure was fixed at 0.3 MPa (peak voltage = 53 kV, injection energy for one pulse = 50 mJ). The simulated exhaust gas composition was assumed to be nitric oxide (NO) density 200 ppm to the nitrogen atmosphere. The content of O_2 in the gas stream was adjusted to 5% and water fed by bubbling. The gas mass flow is 2.0 L/min. Figure 3 shows NO removal ratio and Fig. 4 shows NO removal efficiency. We see from Fig. 3 that the NO removal ratio increased with the presence of O_2 and water fed by bubbling into gas stream. This result demonstrated that the presence of O_2 and water fed by bubbling in the gas stream was more effective for NO removal. This is because OH radicals or O radicals are effective for the NO removal. As a result, 5 ns pulse generator with the reactor having 76 mm in internal diameter and a length of 810 mm and gas condition $N_2/NO/O_2$ (5%) and water fed by bubbling could obtain the NO removal ratio almost 100%, and in Fig. 4 at 60 ppm NO removal ratio (60 ppm is smog emission standard in Japan [Air Pollution Control Law]) it is very high NO removal energy efficiency of 2.2 mol/kWh. Additionally with the past experiments, characteristics of NO removal using the ns pulse streamer discharge was experimentally investigated [2]. The following results have been deduced.

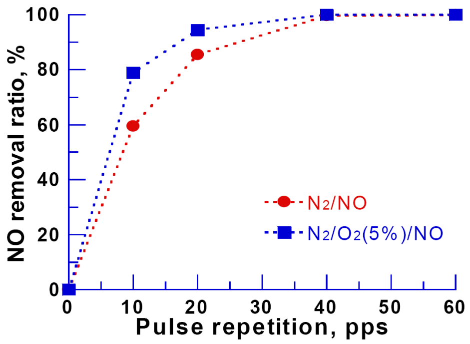

Fig. 3. Dependence of NO removal ratio on pulse repetition rate.

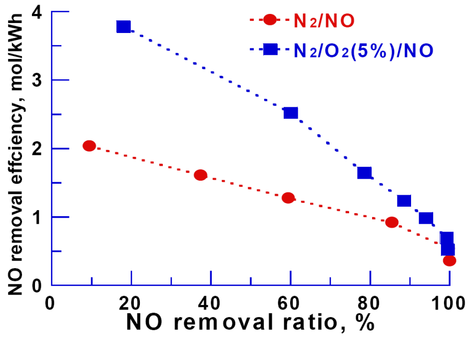

Fig. 4. Dependence of NO removal efficiency on NO removal ratio.

- Positive and high peak voltage was more effective for NO removal.
- The reactor was more effective when diameter was shorter and it was longer.
- O_2 and water vapor in the gas stream are more effective for NO removal.

3.2. O_3 production experiment result

In this experiment, the reactor having 76 mm in internal diameter and a length of 210 mm was used. Figure 5 shows the ozone concentration after discharge. With increasing pulse repetition rate, the ozone concentration increased. And in the same frequency, the ozone concentration increases as the applied voltage maximum value increases. This is because the injection energy increased. Figure 6 is a plot of the ozone generation yield vs. the ozone concentration after discharge. The ozone generation characteristic of the past work using short pulse (50 ns, 100 ns, 200 ns) voltage is also shown in Fig. 6 [3]. In ns pulse voltage, although maximum pulse repetition

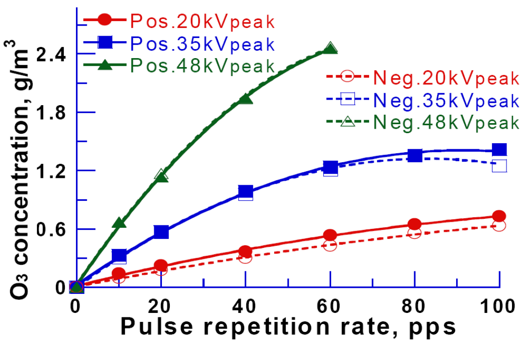

Fig. 5. Dependence of O_3 concentration on pulse repetition rate.

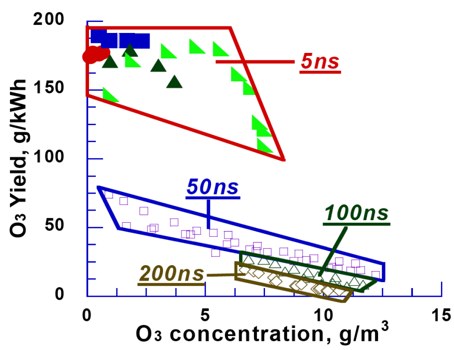

Fig. 6. Dependence of O_3 yield on O_3 concentration.

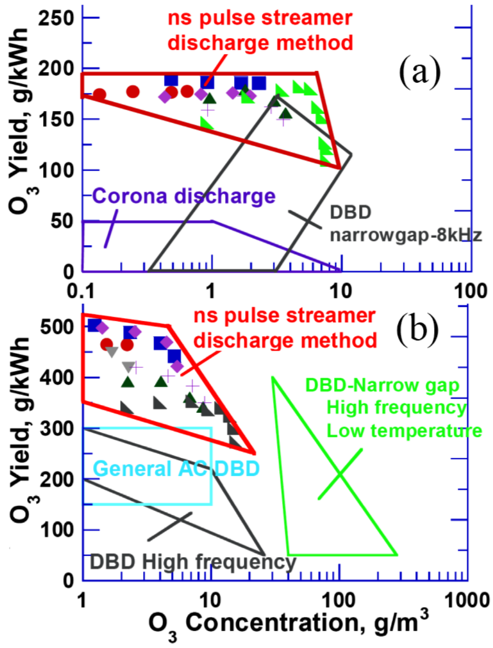

Fig. 7. Comparison with existing ozone generation method. (a) Dry air feeding. (b) Oxygen feeding.

frequency is 100 pps and the ozone generation was suppressed small, it was possible to obtain the very high ozone generation yield which is twice as high as at the short pulse voltage in the same area of the ozone concentration. This is because the ns pulse voltage suppressed the heat loss small compared with a short pulse voltage [4]. Finally, the result in the amount of the ozone generation and ozone generation yield that had been obtained by current research was compared with the other existing methods of generating ozone in Fig. 7. In terms of generation yield, it is thought that the ns pulse streamer method is superior to the other methods.

4. Conclusions

In this work, the nanosecond pulse generator was able to show very remarkable results in the NO removal efficiency and the ozone generation. In NO removal experiments, NO removal energy efficiency of 2.2 mol/kWh was demonstrated at 60 ppm of NO removal ratio. In ozone generation experiments, ns pulse generator demonstrated the superior generation yield. The utility of the ns pulse voltage in the plasma process was proven according to study results.

References

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