

The Effect of Superimposed Discharge on the Decomposition of NO_x in Exhaust Gas

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ABSTRACT

Silent Discharge is usually used for plasma reactor to decomposition of NO_x. A New type of plasma reactor for reduction of NO_x is proposed in this paper. This new type of plasma reactor has three electrodes arranged coaxially and cylindrically. Two type of discharge, silent discharge and surface discharge, were superposed in the same cylindrical air gap. The reduction rate of NO_x in the simulated model exhaust gas by means of this new system at particular phase difference condition was greater rate than other phase difference condition and at without superposed discharge condition. These experimental results confirms the synergistic effect at special condition on NO_x decomposition process. The most effective condition on NO_x reduction were found at inverse phase (180 degrees) of superimposed condition and at gap length larger than 3.5mm.

EXPERIMENTAL APPARATUS

A schematic outline of experimental system is shown in Fig.1. In this experiment, the simulated model gas, which exhausted from a diesel engine, was supplied from two gas cylinders. The mixing rate of two gases was able to controlled. The initial density of NO and NO_x (NO+NO₂) were fixed at 1700ppm and 1830ppm, respectively. Flow rate of model gas was changed from 0.2 l /min to 2.0 l /min. The densities of NO and NO_x (NO+NO₂) in model gas before and after passing through the reactor were measured by a NO_x analyzer, and the decomposition characteristics of NO_x were evaluated by calculating the reduction rate and the energy yield of reduction. The ingredient rate of model gas is as follows.

《 ingredient rate of model gas 》

gas cylinder A NO:5306 [ppm] as balance gas of N₂

gas cylinder B CO:0.217 [%]

CO₂:29.6 [%]

CH₄:0.833 [%]

CO₂:5.46 [%] as balance gas of N₂

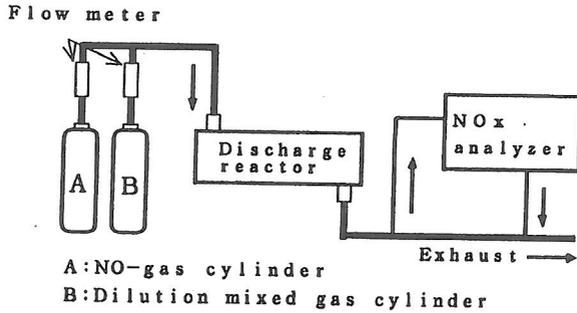


Fig.1 A schematic diagram of experimental system

The new type of plasma reactor is shown in Fig.2. Inner and outer tube were made of hard glass and ceramics respectively. The inner tube filled with electrolyte served as a so called central electrode. The outer tube seted slit type electrodes seted on inner surface of outer tube as so call surface electrode and coaxial metal film electrode immersed inside ceramic so call embedded electrode.

AC high voltage was applied to the embedded electrode and central electrode, and the surface electrode was used as a common ground electrode. In the experiment of superimposed discharges, a high voltage was applied such that the surface discharge current are fixed to equal to the silent discharge current. The discharge current and discharge power measured by Lissajous's figure method. Experiments were carried out at four discharge mode as follows. There

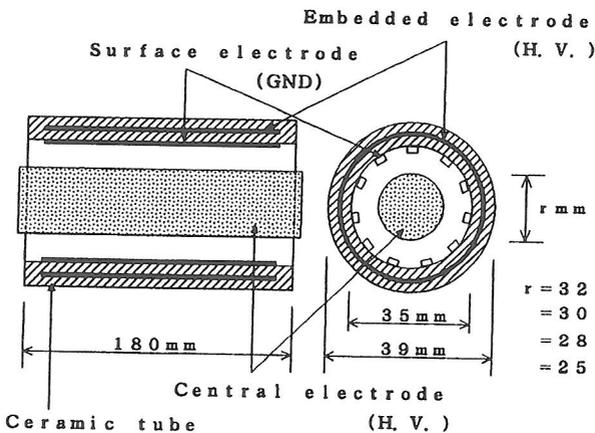


Fig.2 A schematic diagram of Electrode construction

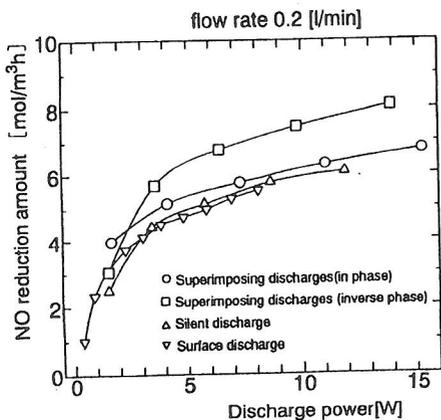


Fig.3 NO reduction amount as a function of discharge power

than the other modes. The NO reduction rate are measured for several gap length and gas flow rates. From these characteristics, NO reduction rate were calculated for several discharge modes. The NO reduction rate as a function of discharge power at four discharge modes shown in Fig.4 for 0.2 l /min flow rate. Figure 4 (a) indicates about same of the NO reduction rate characteristic at four discharge modes. On the other hand, Figures 4 (b),(c) and (d) indicate a clear different characteristic among four discharges modes under the range of low discharge power, however, as increasing the discharge power, the superimposed discharge for the inverse phase mode indicate a higher NO reduction rate than that of each single discharge mode. We presume that this higher NO reduction rate was caused by the synergistic effect on the NO reduction by superimposing surface and silent discharges.

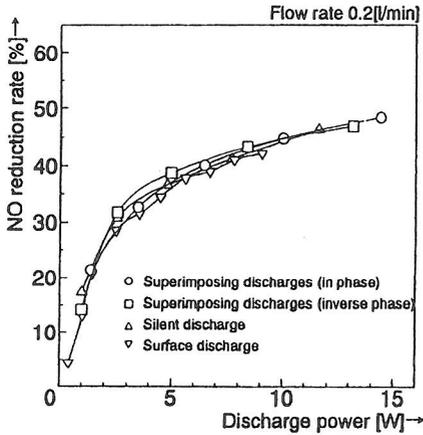
The NO reduction rate depend on various parameter stated above characteristics. The NO decomposition rate is shown in Fig.5 as function of the discharge current and the gas residence time. The gas residence time means that the time from gas inlet to outlet of the discharge gap. The NO reduction rate increase saturalely with the discharge current and the gas residence time. These characteristic shall be suggest that the NO decomposition rate depend on the collision rate of NO agents with the charge particles.

The reason of the synergistic effect of superimposed discharges for the

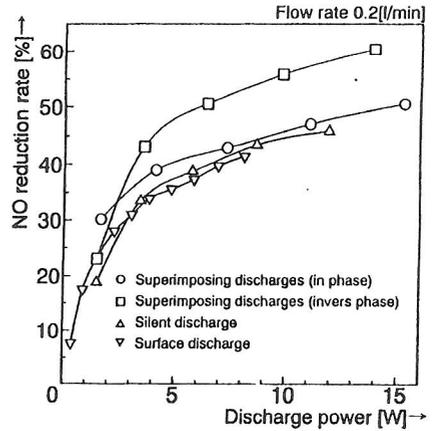
are the silent discharge or the surface discharge mode and the superimposed discharge mode (in phase and inverse phase : 180degrees). Also Experiments were carried out at four discharge gap lengths of 1.5mm, 2.5mm, 3.5mm, 5.0mm and at several discharge current condition.

Experimental Results and Discussion

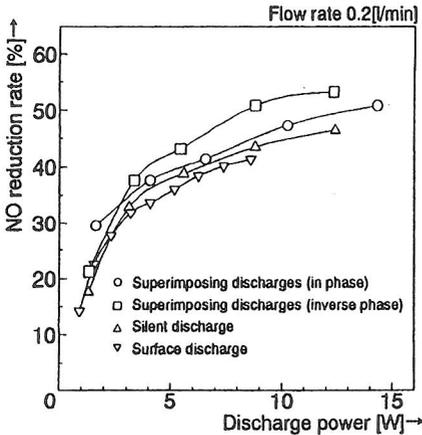
The NO reduction amount as a function of discharge power for superimposed discharge and inverse mode are shown in Fig.3 for gas flow rate of 0.2 l /min and gap length of 3.5mm. The NO reduction amount increase saturately with discharge power, however, the NO reduction amount is larger at the superimposed discharge mode of inverse phase



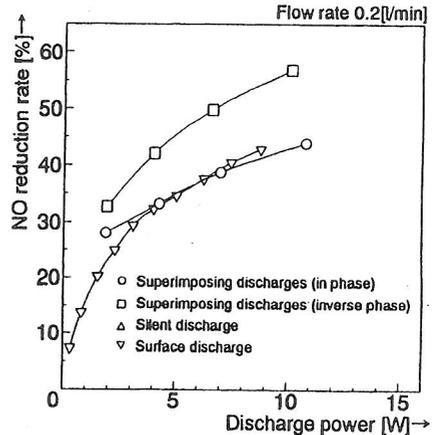
(a) Gap length : 1.5mm



(b) Gap length : 2.5mm



(c) Gap length : 3.5mm



(d) Gap length : 5.0mm

Fig.4 NO reduction rate as a function of discharge power

inverse mode were explained by the photographs of discharge luminosity. The photographs of discharge luminosity were taken by setting a CCD camera on the direction of axis of discharge reactor. Fig.6 show the discharge luminosity distribution at a case of nitrogen gas, flow rate of 0.5 l /min and gap length of 3.5mm.

Fig.6 (a),(b) indicates the luminosity for the silent discharge mode and

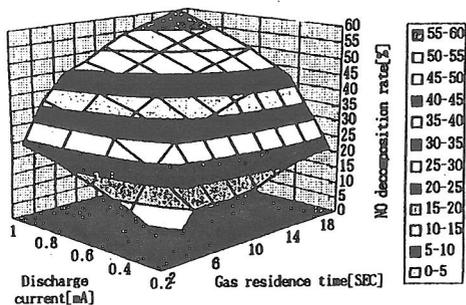


Fig.5 NO decomposition characteristics

surface discharge mode respectively. Under the silent discharge mode, the luminosity between the central electrode and surface electrode were observed, but not observed between each surface electrode. On the other hand, under the surface discharge mode, the luminosity around each surface electrode was observed, but not observed outside of the surface electrode. Fig.6 (c) (d)

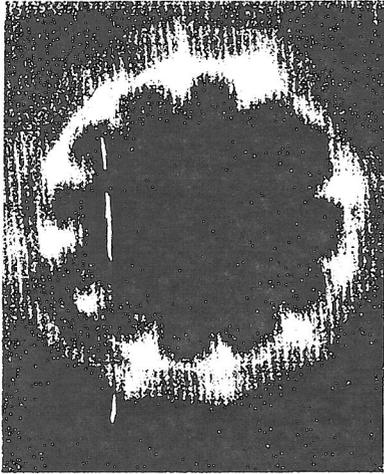
indicates the luminosity for the superimposed discharge of inverse phase and in phase mode respectively. For in phase mode, the luminosity was observed around each surface electrode same as surface discharge mode. However, the area of luminosity was a little larger and the intensity was stronger than the surface discharge mode. For the inverse phase mode, the luminous conditions were quite different from other discharge modes. The luminosity was observed uniformly all over the inside of the reactor. The luminescence is the largest volume among all four discharge modes. In this discharge mode, the intense luminosity was not concentrated at around the surface electrodes.

The difference of discharge area and intensity of luminosity depends on phase difference on superimposed discharges mode. These phenomena may be depend on the field distribution in the air gap and between the surface electrodes due to the superimposed discharge mode.

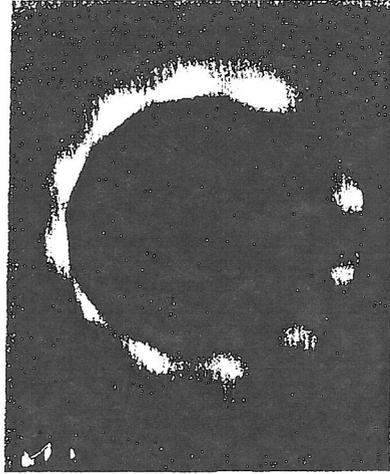
CONCLUSIONS

As a results of the NO reduction rate with the simulated exhaust gas by superimposed discharges, we can derive the following conclusions.

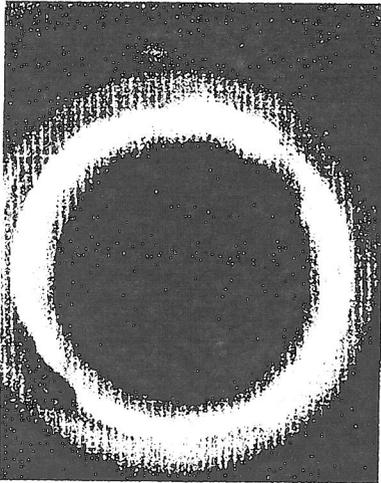
- (1) Experiment were caried out four discharge modes, surface discharge, silent discharge, superimposed discharges of in-phase and superimposed discharge of inverse phase. The reduction rate of NO at superimposed discharges at the inverse phase mode is higher than other discharge modes.
- (2) From the observation of discharge luminosity for four discharge modes, the area of luminosity at the superimposed discharge of inverse phase mode is the largest area among four discharge modes. The reduction rate of NO depend on remerkably the discharge area (volume).
- (3) The reduction rate of NO depend on the discharge current and the residence time.
- (4) The more effective conditions for the NO reduction are that the gap length is; more than 3.5mm and the phase difference is the inverse phase.



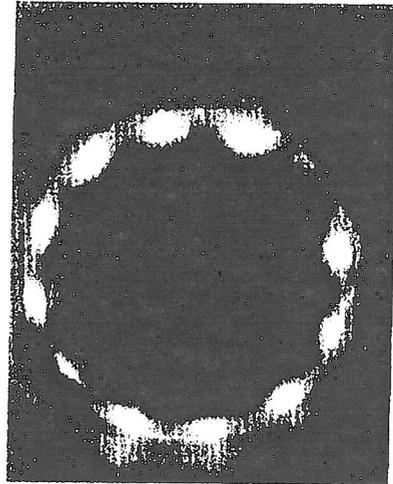
(a) Silent discharge



(b) Surface discharge



(c) Superimposing discharges for
inverse phase



(d) Superimposing discharges for
in-phase

Fig.6 Photographs of luminosity at four discharge modes
(Gap length:3.5mm,Discharge power:10W)