# 23E04

# Development of honeycomb discharge for catalyst activation
# 触媒活性化に向けたハニカム内放電技術の開発

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Atmospheric pressure discharge plasma has been studied and applied to environmental purification in recent years. We have been trying to clean diesel exhaust gas and we have verified that the combination of discharge plasma and honeycomb catalyst is quite effective for the removal of nitrogen oxides. However, complicated setup of high voltage power supplies and electrodes is required to generate stable discharge plasma inside the narrow capillaries of the honeycomb catalyst. Therefore, the generation of discharge plasma inside a ceramic honeycomb using a single high voltage power supply was investigated in this study. As a result, surface discharge was generated at both ends of the capillaries as primary discharge, and the discharge successfully expanded into the capillaries from both sides. In this study, NO oxidation using our this method is also demonstrated. The oxidation efficiency was improved by the combination of the honeycomb discharge and catalysts compared to that of surface discharge alone. Therefore, it was suggested that the effective discharge was generated inside the honeycomb.

## 1. Introduction

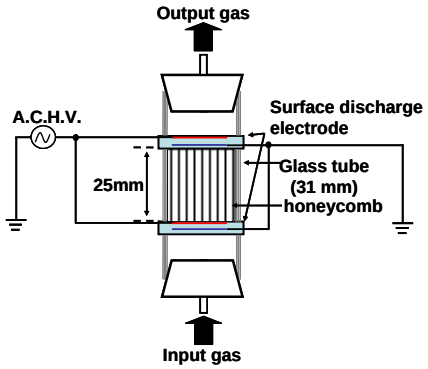
Diesel engines have been used in many industrial and transport fields due to their higher thermal efficiency and durability, as well as lower carbon dioxide emission compared to gasoline engines. However, removal of nitrogen oxides ($NO_x$) and particulate matter (PM) is a major problem with diesel engines. For gasoline engines, three-way catalysts are used to reduce $NO_x$. Since the catalysts require higher temperature and lower concentration of oxygen, however, this conventional method is not suitable for diesel engines. Therefore, it is very important to develop the techniques to remove NOx in diesel exhaust. For example, urea-SCR, the selective catalytic reduction using urea as reducing agent, has been investigated for about ten years in detail and today is a well-established technique for DeNOx of stationary diesel engines. However, urea-SCR has the problem of low catalytic activity at low temperatures. In the present study, effective NOx removal method by using SCR catalyst together with honeycomb discharge plasma at low temperature was examined. We have already demonstrated that atmospheric pressure discharge plasma can activate the catalyst [1, 2]. However, complicated setup of high voltage power supplies and electrodes is required to generate stable discharge plasma inside the narrow capillaries of the honeycomb catalyst. To cope with this problem, we investigated a novel and simplified method to generate the plasma inside the honeycomb using a single power supply. Primary discharge was generated by using surface discharge at both ends of honeycomb structure and it was expanded from both sides to form sliding discharge inside the narrow capillaries [3].

## 2. Experimental setup and method

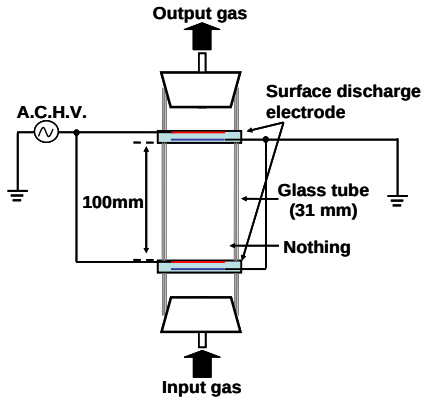
Fig. 1 shows schematic illustrations of the experimental setup with a single power supply. The honeycomb discharge generator and the discharge generator without honeycomb are shown in (a) and (b), respectively. For reactor (a), two surface discharge electrodes were installed at both ends of a ceramic honeycomb (length: 25 mm) inside a glass tube (inner diameter: 31 mm, length: 25 mm). As for reactor (b), only two surface discharge electrodes were installed inside a glass tube (inner diameter: 31 mm, length: 100 mm). To ignore the oxidation effect by sliding discharge, and to evaluate that by surface discharge alone, the distance between the two electrodes was set to 100 mm for reactor (b). The outer electrodes and the inner electrodes of the two surface discharge electrodes were connected to AC high voltage power supply and ground, respectively. The applied voltage was 8-13 $kV_{P-P}$ and frequency was 1 kHz.

In this study, to evaluate the effect of the honeycomb discharge, NO oxidation was demonstrated. 400 ppm of NO (dry air base) was

supplied to the reactor with 2.5 L/min flow rate. The output gas from the reactor was input into a Fourier transform infrared spectrometer (FT-IR) with 1 L/min flow rate and the concentration of the gas components was measured.




(a) Honeycomb discharge generator with a single electric power supply




(b) Reactor of only surface discharge

Fig. 1. Experimental Setup

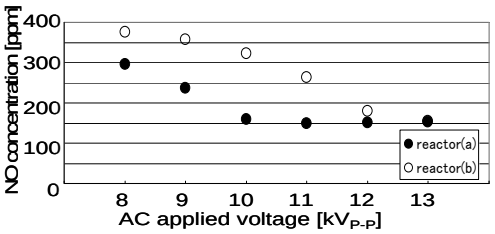
## 3. Results and Discussions

NO and $NO_2$ concentration versus AC applied voltage are shown in Fig. 2 (a) and (b), respectively. NO concentration decreased and $NO_2$ concentration increased with the increase of AC applied voltage. This suggested that NO was oxidized to $NO_2$. This result indicated that the oxidation ability of the reactor (a) was higher than that of the reactor (b).

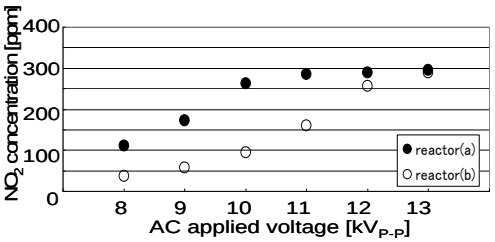
Table 1 shows the oxidation efficiency and the power consumption of both reactors. From this result, it was verified that the oxidation efficiency of the reactor (a) was higher than that of the reactor (b). This could be because the discharge space was successfully expanded in the reactor (a) and, therefore, the treatment space also became larger. Moreover, the power consumption of the reactor (a) was higher than that of the reactor (b). This indicated that honeycomb discharge took place in the reactor (a).

## 4. Conclusion

The oxidation efficiency was improved through using the honeycomb discharge, compared to the use of surface discharge alone. Therefore, it was suggested that the effective discharge for diesel exhaust was generated inside the honeycomb.




(a) NO




(b) $NO_2$

Fig. 2. NO and $NO_2$ concentration
(Simulated gas 2.5 L/min, NO 400 ppm, Air balance)

Table.1 Oxidation efficiency and power consumption of reactors

| | applied voltage[$V_{P-P}$] | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|
| (a) | oxidation efficiency [mmol / J] | 0.092 | 0.073 | 0.068 | 0.062 | 0.052 | 0.048 |
| | power consumption [W] | 1.1 | 2.2 | 3.6 | 4.3 | 5.2 | 5.7 |
| (b) | Oxidation efficiency [mmol / J] | 0.050 | 0.047 | 0.034 | 0.050 | 0.052 | 0.046 |
| | power consumption [W] | 0.7 | 1.1 | 2.7 | 3.0 | 4.6 | 5.9 |

## Reference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[2] S. Sato and A. Mizuno, “$NO_X$ Removal of Simulated Diesel Exhaust with Honeycomb Discharge”, International Journal of Plasma Environmental Science and Technology, vol.4, 18-23, 2010

[3] C. Louste, G. Artana, E. Moreau and G. Touchard, “Sliding discharge in air at atmospheric pressure: electrical properties”, Journal of Electrostatics, vol.63, 615-620, 2005