NO_x treatment using DBD plasma applied by high frequency AC power supply

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Abstract: A adsorption-discharge process was investigated using a packed-bed non-thermal plasma reactor for NO_x treatment. The NO_x could be adsorbed on the activated carbon after NO in the feed gas was completely oxidized into NO_2 by ozone which was generated by ozone generator. The NO_x adsorbed on the adsorbent could be efficiently decomposed. The NO_x removal efficiency was investigated with changing the applied voltage. As a result, the removal efficiency was increased as the applied voltage increased.

Keywords: DBD, NO_x treatment, adsorption, regeneration, desorption

1. Introduction

NO_x emitted from the diesel engines of marine transport and heavy machinery and power plants, have an effect on not only the human health but also environment. Therefore, NO_x emission regulations have recently become stricter. To reduce the NO_x emissions from the exhaust gases, the technologies of NO_x treatment have been continuously developed such as exhaust gas recirculation (EGR), selective non-catalytic reduction (SNCR) [1], and selective catalytic reduction (SCR), etc. Among many treatment technologies, the SCR method is used in many industries because the NO_x reduction reaction can occur at the relatively low temperature in the presence of oxygen [2]. However, there are some disadvantages in this method; (i) high temperature is still required to activate the catalyst, (ii) it needs always the urea solution, (iii) the large space is required to store the urea solution (iV) the process is expensive. Meanwhile, some researchers have studied a non-thermal plasma (NTP) technology for NO_x treatment [3]. It has some advantages, which are the NO_x reduction reaction can occur at the low temperature even room temperature [4] and any solution is not required. It is considered as a very simple and highly efficient technology. However, the presence of oxygen inhibits the NO_x reduction reaction. Since the exhaust gas contains about more than 5% of oxygen, the plasma technology cannot achieve the high efficiency alone. Therefore, it is necessary to develop a method of the NO_x decomposition process for solving a problem in the presence of oxygen. In this study, the NTP combined with activated carbon as an adsorbent was used for NO_x treatment to separate the oxygen in a feed gas. The NO_x removal efficiency was investigated at the various applied voltage.

2. Experimental

Fig. 1. shows a schematic diagram in this study. The experiment was composed of two processes. The first process was an adsorption stage. In the first stage, the ozone was generated by ozone generator and oxidized NO to NO_2 which is easily adsorbed on the activated carbon than NO. The discharge region of the reactor was filled with the 2g of activated carbon. The NO_2 was adsorbed during 10 min. The total gas flow rate was 4 litter per minute (LPM) constantly and the initial concentration of NO_2 was set as 1100 ppm. The second process was a discharge stage. The NO_2 adsorbed on the activated carbon was directly decomposed by the plasma without the desorption stage during 10 minutes in the N_2 atmosphere. The cylindrical Dielectric Barrier Discharge (DBD) plasma reactor was used for it. The NO and NO_2 concentration were measured by a NO_x analyzer and the amount of NO_x remaining on the activated carbon was analyzed during the desorption process by an electric furnace. The CO and CO_2 concentration were measured by a Fourier Transform Infrared spectroscopy (FT-IR).

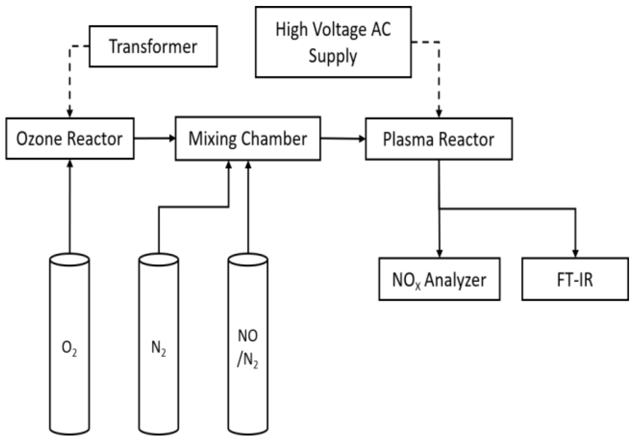

Fig. 1. Schematic diagram of the experimental setup.

3. Results and discussion

In the adsorption stage, we confirmed the amount of NO_2 generated during the oxidation of NO to NO_2 because the reaction between N_2 and O_3 would generate the excess NO_2. These excess NO_2, also, couldn't be completely adsorbed on the activated carbon. These problems should be further studied to improve the removal efficiency. In terms of the reduction of adsorbed NO_2, the recombination and the desorption were unavoidable. Thus, we introduced a special packed-bed DBD reactor to solve these problems. Fig. 2. shows the fluctuation of NO_x concentration at the applied voltage of 6 kV, 7 kV, and 8 kV, respectively. At the discharge stage, the NO_x adsorbed on the activated carbon was decomposed, and was simultaneously desorbed. It was confirmed that the maximum concentration of desorbed NO_x during discharge process were 330 ppm, 550 ppm and 580 ppm at 6 kV, 7 kV and 8 kV, respectively.

Because of the plasma discharge, the adsorbed NO_x was instantaneously desorbed at the initial step of discharge. Also, the concentration of the emitted NO_x gradually decreased as the discharge time increased. It could be considered that the NO_x adsorbed on the surface of the activated carbon was desorbed more quickly at the higher applied voltage because the more energy was instantaneously applied.

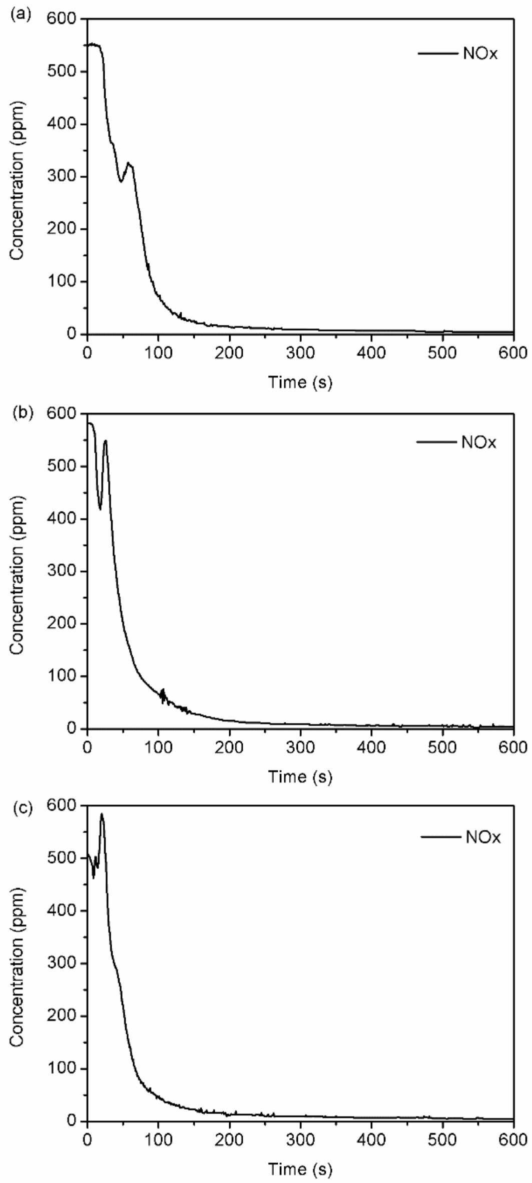

Fig. 2. The fluctuation of NO_x concentration at the different applied voltage; (a) 6 kV, (b) 7 kV, and (c) 8 kV.

Fig. 3. shows the fluctuation of CO and CO_2 concentration at 8 kV. When the plasma was turned on after the adsorption process, the adsorbed NO_x was converted into N_2 and O_2 by the plasma. A variety of reactions would take place during this decomposition process. One of them was the reaction of O atom react with the carbon to form CO and CO_2. It could be detected by FT-IR. At the beginning of discharge, the concentration of CO_2 was increased, but decreased gradually as the time went on. It could be considered that the NO_x could be decomposed into N atom and O atom, and only this O atom is considered to contribute to the generation of the CO and CO_2 in N_2 discharge process. It implies that the NO_x was decomposed. The similar trend was observed at 6 kV and 7 kV.

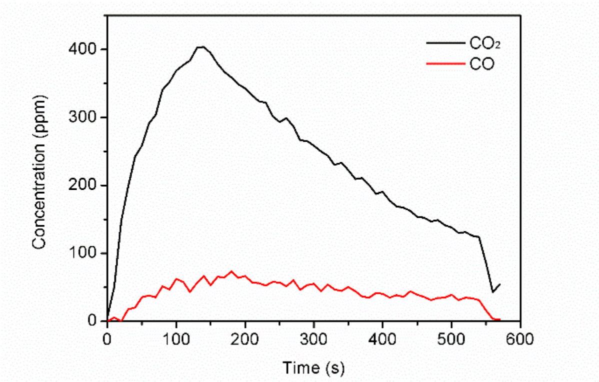

Fig. 3. The fluctuation of CO and CO_2 concentration when the applied voltage was at 8 kV.

Fig. 4. shows the effect of the applied voltage on NO_x removal efficiency. The removal efficiency of NO_x increased as the applied voltage increased. The amount of the recombination and the desorption of NO_x decreased greatly, but it was also confirmed that the similar amount of NO_x was still desorbed from the surface of the activated carbon during the discharge regardless of the applied voltage. Also, it was found that the largest amount of NO_x remaining on the surface of active carbon was desorbed at 6 kV by the furnace. It is because the energy consumed for the decomposition of the adsorbed NO_2 during the discharge stage was not enough high to decompose NO_2 instantly.

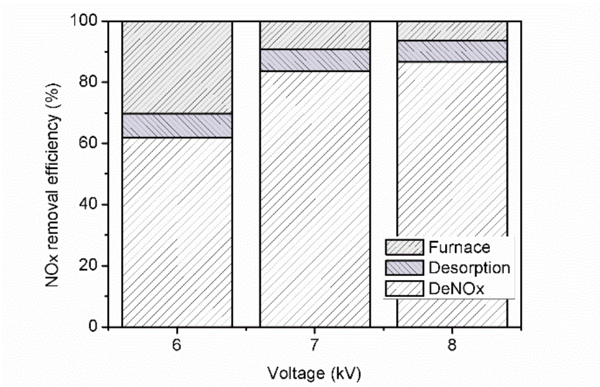

Fig. 4. Effect of the voltage on NOx removal efficiency in the DBD plasma.

4. Conclusions

In this study, the NTP combined with the adsorption method was used for the NO_x decomposition to treat the NO_x in the presence of oxygen. As the applied voltage increased, the NO_x adsorbed on the activated carbon was desorbed rapidly, so the NO_x removal efficiency could increase. CO and CO_2 were generated while the adsorbed NO_x was decomposed. When the low voltage was applied, it was difficult to decompose the adsorbed NO_2 due to the lack of energy supply.

5. References

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