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Environmental Applications of Non-thermal Plasmas
非平衡プラズマを用いた環境応用技術

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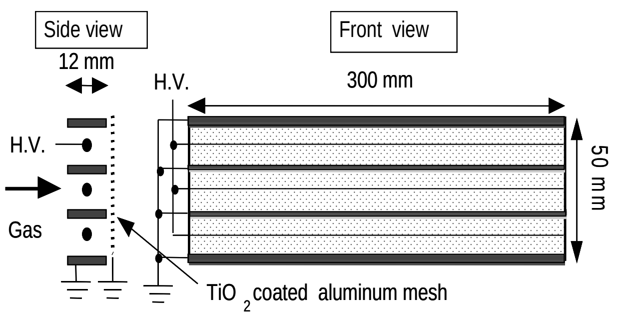
Non-thermal discharge-plasma is effective for abatement of gaseous pollutants, and commercial products have been introduced recently. Indoor air cleaners have been mass-produced. Non-thermal plasma is also effective to decompose volatile organic compound (VOC) or cleaning of diesel exhaust. Combination of plasma and catalysts will further improve efficiency and selectivity. Generation of non-thermal discharge plasma, its application in gas cleaning will be presented.

1 Introduction

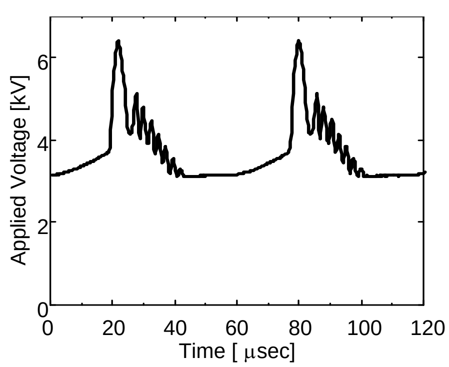
Non-thermal discharge plasma in atmospheric air produces reactive radicals (O, OH, etc.) that promote chemical reactions [1-2]. Non-thermal plasma has been applied for removal of odor/allergen in indoor air, VOCs in factories, etc. These applications require high energy efficiency, low cost and reduced size. To improve the energy efficiency, combination of non-thermal plasma with various catalysts has been investigated, and has been applied in several commercialized products for indoor air cleaning and VOC decomposition. DeNOx of diesel exhaust can be made, and is potentially an important application. There are several types of non-thermal discharge to be used for gas cleaning, such as pulsed streamer discharge[3], packed-bed[6], etc. In air, or flue gas, O and OH radicals are produced at first, then these radicals react with gaseous pollutants. Chemical reactions on catalyst surface exposed to plasma are very important for improvement of energy efficiency and selectivity of plasma chemical processes. In this paper, several commercialized applications are introduced, together with possible applications such as diesel exhaust cleaning, etc.

2 Indoor air cleaning using discharge plasma with titanium dioxide catalyst

As a pioneering commercial product, TiO_2 catalyst was used, combined with positive streamer discharge[3] generated by dc with ac superposition. Fig.1 shows the reactor, consisting of the parallel plate with the wire discharge electrode, follolwed by a TiO_2 catalyst. The gas residence time was 10msec. One pass performance is about 70 % for dust removal, and 27 % for 1 ppm acetaldehyde removal. TiO_2 can be activated by photons having more than 3.2eV. In this reactor, the TiO_2 catalyst may possibly be activated by energy exchange of high energy particles produced by the plasma[3].



(a) Electrode and catalyst



(b) Voltage waveform

Fig.1 Indoor air cleaner using pulsed discharge with TiO_2 catalyst

3 Cleaning of diesel exhaust

Cleaning of diesel engine exhaust is potentially an important application of non-thermal plasma. Reduction of NOx to N_2 and O_2 is the most attractive way, especially for vehicles. The combination of discharge plasma with catalysts or chemical scrubbers has been emerged as a potential method [4-5]. Fig.2(a) shows the 2-stage plasma process. NO is oxidized to NO_2 and entering to the ccatalyst, where low temperature reduction of NO_2 can be made by adding reductive agent such as ammonia. Fig. 2(b) is an example of the NOx removal in the two-stage system with Co-ZSM-5 catalyst at 150 C[5]. NO was completely oxidized to NO_2 with 27kJ/Nm^3 of specific input energy in the plasma reactor, and introduced to the catalyst section.

To assist the oxidation of NO to NO_2 in the discharge plasma reactor, 1200ppm of ethylene was added. At the inlet of the catalyst section, 200 or 400 ppm of ammonia was added. At 150 C, continuous reduction of NO_2 can be made. No powder formation was observed in this operation. Carbon soot could be used as a reductant agent for NOx when the soot layer absorbing NO_2 is exposed to discharge plasma[6].

4 Concluding remarks

Non-thermal discharge plasma has been utilized for cleaning of indoor air and flue gas. In order to improve the energy efficiency, appropriate combination with catalysts is effective. The mechanism, however, has not been clarified. Further understanding of surface, gas and liquid phase plasma chemical reactions will provide more effective means to improve the efficiency, and more wide industrial applications such as sterilization, chemical synthesis, surface modification, thin film deposition at atmospheric pressure, water purification, etc.

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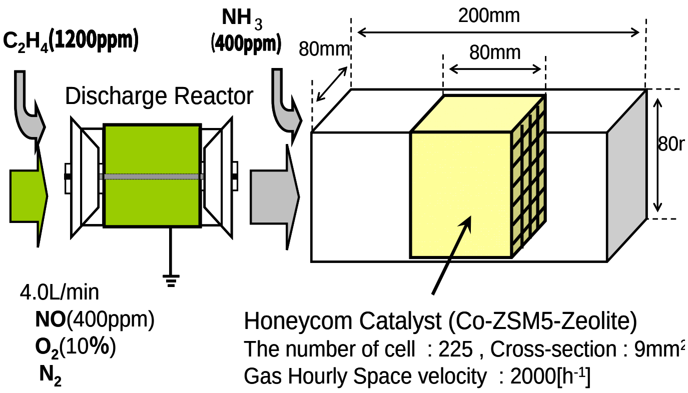
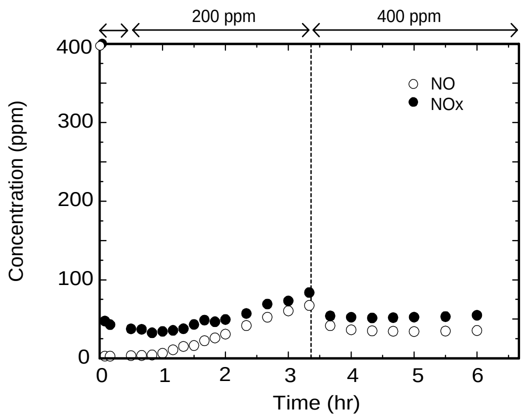


(a) 2-stage reactor



(b) NO removal performance

Fig.2 NOx removal in the two stage process with Co-ZSM-5 catalyst.
(SIE: 27kJ/Nm^3, GHSV: 1820hr^{-1}, Temperature: 150 C, C_2H_4: 1200ppm,