

Plasma Catalytic Reactor for the Destruction of Diluted VOC at Low Temperatures

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Introduction

The emission of industrial exhaust gases containing diluted Volatile Organic Compounds (VOCs) into the atmosphere is an important source of air pollution and an environmental concern. Abatement of VOCs needs highly efficient low cost processes. Conventional techniques for the abatement of VOCs mainly include thermal and thermo-catalytic oxidation. However, at low VOC concentrations (< 1000 ppm), these techniques demand a high energy supply. Among the alternatives, non-thermal plasma (NTP) generated at atmospheric pressure seems to be advantageous from the point of energy saving. The specific advantage of NTP is that it selectively produces high energy electrons at ambient temperature without heating the flue gas. The NTP has been tested for the destruction of various VOCs, but the low selectivity to total oxidation (0.3 to 0.5) limits its application. Among the alternatives to improve the efficiency of NTP technique, plasma combined with a heterogeneous catalyst seems to be advantageous. In practice the catalyst can be either placed in the discharge zone (in-plasma catalytic reactor) or after the discharge zone (post-plasma catalytic reactor). However, both methods have limitations due to the deactivation of the catalyst caused by carbonaceous deposits on the catalyst surface. The present study deals with the design and performance evaluation of a novel dielectric barrier discharge (DBD) catalytic reactor during the destruction of model VOCs. Influence of various parameters like the nature of the VOC, selection of the catalyst, voltage, and frequency will be also discussed.

Materials and Methods

A novel dielectric barrier discharge (DBD) reactor with catalytic electrode was developed during the present study (Fig.1). The novelty of present DBD configuration is that the metallic catalyst made of sintered metal fibers (SMF) also serving as the inner electrode. The dielectric discharge was generated in a cylindrical quartz tube with an inner diameter of 18.5 mm. A silver paste painted on the outer surface of the quartz tube acts as the outer electrode, whereas, a modified stainless steel filter SMF was used as the inner electrode. The SMF was modified by supporting Mn, Ti and Co oxides. Typical discharge length was 10 cm and discharge gap was varied between 1.0 to 3.5 mm. The specific input energy (SIE) in the range 165-1650 J/l was applied by varying the AC high voltage (12.5-22.5 kV) and frequency (200-350 Hz). The V-Q Lissajous method was used to determine the discharge power (W) from which SIE was calculated. Destruction of model VOCs (toluene, isopropanol (IPA) and trichloroethylene (TCE)) was carried out in the DBD reactor designed.

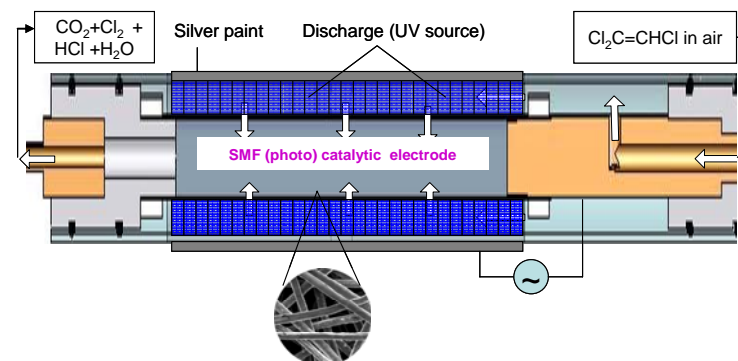


Fig. 1. Schematic representation of the novel catalytic DBD reactor

Results and Discussion

It was observed that MnOx and CoOx supported SMF catalytic electrodes shifted the product distribution towards total oxidation. At a fixed initial concentration of the VOCs studied, it has been observed that total oxidation of an alcohol (IPA) can be achieved at low SIE compared to a hydrocarbon (toluene) followed by chlorinated hydrocarbon (TCE). The better performance of MnOx/SMF might be due to the formation of active oxygen atoms by the *in-situ* decomposition of ozone on the catalyst surface.

The selectivity to CO₂ during TCE destruction was further improved to ~ 85 % at 650 J/l by modifying MnOx/SMF with TiO₂ coating at a discharge gap of 1.0 mm. This improvement was assigned to the synergy between plasma excitation of the TCE molecules and their photocatalytic oxidation since TiO₂ absorbs the UV light produced by the NTP. These innovative SMF catalytic electrodes were characterized by x-ray photo-electron spectroscopy (XPS) and transmission electron microscopy (TEM) confirming the formation of titania anatase, whereas the emission spectrum of plasma showed the presence of ultraviolet light.

Significance

Novel Non-Thermal Plasma-Catalytic reactor is designed and tested for the destruction of different VOCs demonstrating high efficiency at relatively low specific input energy as compared to thermo-catalytic methods.

References

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