

Novel Catalytic Non-Thermal Plasma Reactor for the Destruction of Volatile Organic Compounds

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Summary

A novel dielectric barrier discharge (DBD) reactor has been designed and tested for the abatement of diluted volatile organic compounds (VOCs) of different nature. The novelty of the DBD reactor is that a metallic catalyst made of sintered metal fibres (SMF) also acts as the inner electrode. The SMF electrodes modified with oxides of Ti, Mn and Co were efficient during the destruction of toluene, isopropanol (IPA) and trichloroethylene (TCE). During the abatement of 250 ppm of VOC, total oxidation of IPA was achieved at lower specific input energy (SIE) compared to toluene and TCE. Among the catalysts studied, MnO_x/SMF showed the best performance, probably due to the formation of active oxygen species by *in-situ* decomposition of ozone on the catalyst surface. The SMF electrode modified with MnO_x and TiO₂ catalyst effectively destroys TCE due to the synergy between plasma excitation of the TCE molecules and their catalytic oxidation. The latter process was observed to be further enhanced by photocatalysis, since TiO₂ absorbs the UV light produced by the NTP.

Introduction

The emission of industrial exhaust gases containing diluted Volatile Organic Compounds (VOCs) into the atmosphere is an important source of air pollution and a social 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 an energy saving approach. The specific advantage of NTP is the selective production of high energy electrons at ambient conditions without heating the flue gas. However, 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 [1,2]. 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 of different nature. Influence of various parameters like the nature of the VOC, selection of the catalyst, voltage, and frequency will be also discussed.

Results and Discussion

A novel dielectric barrier discharge (DBD) reactor with catalytic electrode was developed during the present study. The novelty of present DBD configuration is that a metallic catalyst made of sintered metal fibers (SMF) also serves 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 SMF was used as the inner electrode (Fig. 1). The SMF was modified by supporting Ti, Mn and Co oxides. Typical discharge length was 10 cm and discharge gap was varied between 1.25 to 3.5 mm. The specific input energy (SIE) in the range 160-1650 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.

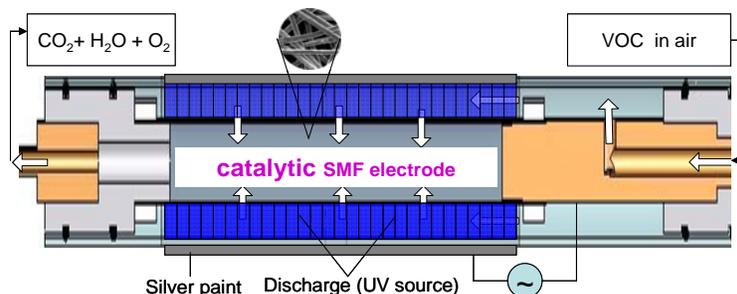


Fig.1. Schematic representation of the novel DBD reactor with catalytic SMF electrode

The results indicate that close to 100% conversion of VOC can be achieved at $SIE < 250$ J/l [2,3]. Metal oxide supported on SMF catalytic electrode shifted the product distribution towards total oxidation (CO_2 and H_2O without solid deposit). The total oxidation of an alcohol (IPA) was achieved at lower SIE compared to a hydrocarbon (toluene) followed by chlorinated hydrocarbon (TCE). Among the catalysts studied, MnO_x/SMF showed better performance to total oxidation, which was attributed to the formation of atomic oxygen by *in-situ* decomposition of ozone on the catalyst surface. The selectivity to CO_2 during TCE destruction at a discharge gap of 1.25 mm was improved up to $\sim 80\%$ at 1100 J/l by modifying MnO_x/SMF with TiO_2 . This improvement was assigned to the synergy between plasma excitation of the TCE molecules and their catalytic oxidation, which was further enhanced by photocatalysis, since TiO_2 absorbs the UV light produced by the NTP. The NTP destruction of TCE can be achieved at lower consumption of energy compared to thermocatalytic methods, but it still needs to be improved in view of achieving total oxidation at low SIE. The innovative SMF catalytic electrodes were characterized by X-ray photoelectron spectroscopy (XPS) and transmission electron microscopy (TEM) confirming the formation of TiO_2 anatase. The emission spectrum of plasma showed the presence of ultraviolet light [3].

Conclusions

A novel Catalytic Non-Thermal Plasma reactor has been designed and tested for the destruction of VOCs of different nature demonstrating high efficiency to CO_2 and H_2O at relatively low specific input energy as compared to thermo-catalytic methods.

References

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