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Application of Atmospheric Non Thermal Plasma-Catalysis Hybrid System for Air Pollution Control in HCMC-Vietnam

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Introduction

Atmospheric Non Thermal Plasmas (ANTP) has been extensively investigated in NO_x removal, decomposition of VOCs, and indoor air cleaning. Compared to other technologies such as adsorption and catalytic oxidation, ANTP chemical processing is advantageous in achieving high decomposition efficiencies of VOCs at short residence time and low temperature. Simultaneous treatment of multiple hazardous substances is also possible due to the large magnitude of acquired electron energy and the variety of active species generated such as oxygen atoms, hydroxyl radicals, and ozone.

ANTP driven catalysis is expected to be a promising technology for air pollution control, waste gas treatment characterized by high energy efficiencies, high pollutant conversion rate, and low by-products formation.

In this work, atmospheric dielectric barrier discharge (DBD) combined to various catalytic materials at low temperature was used. Reported results concern the plasma effect and the plasma-catalyst effect on the conversion rate of C₇H₈, H₂S, and NH₃. Catalyst position regarding the DBD was also studied for better conversion efficiency.

Experimental

The experimental system consists of a laboratory-scale plasma-catalyst hybrid system, a continuous flow gas generation system, and a gas detection system. The plasma reactor we used is a dielectric-barrier discharge (DBD) reactor in a cylindrical configuration. The DBD reactor was powered by a homemade high voltage AC generator: 18 kV - 1.5 Hz.

Various catalytic materials based on Ag, Au, Cu, Co, Mn, Nb, La, supported by Al₂O₃ and CeO₂ (in powder form, 200 mg), has been tested to design the catalyst that present the highest activity at low temperature (30°C).

The combination of catalysts with ANTP can be operated in two configurations: positioning the catalyst in the discharge zone (*in-plasma* catalysis) or downstream the discharge zone (*post-plasma* catalysis). The experiments were carried out with and without catalysts at total flow rates up to 4 L/h in air polluted by C₇H₈ (800 ppm), NH₃ (3 ppm), and H₂S (60 ppb).

The experimental plasma-catalyst (*post-plasma* catalysis, catalyst: γ -Al₂O₃) hybrid reactor was scaled up to semi-pilot system operating at gas flow rate up to 20 000 L.h⁻¹.

The outlet gas was analyzed online and quantified using GC (FID and SE 30 10% Column) and could sampled to be analyzed by GC-MS. Adsorption method is used to measure the H₂S and NH₃ concentrations.

Results and discussions

Systematic investigations were carried out with various catalysts introduced in the plasma reactor. An overview of the results, given toluene abatement in “*post-plasma*” and “*in-plasma*” catalyst positions compared with non-catalytic plasma oxidation, is showed in Table 1. Only one criterion was considered: maximum toluene efficiency.

In the absence of catalyst material, the toluene conversion rate does not exceed 60%. Both “*in-plasma*” and “*post-plasma*” positions increased toluene removal efficiency whatever the nature of the catalyst used. As example, adding 200 mg of 1%Au/Al₂O₃ or Nb₂O₅ catalyst in plasma zone increased this removal rate to 95% and 96%, respectively. However, when these catalysts were positioned in the post discharge region, lower toluene removal was measured. The products of toluene oxidation are CO₂, CO, benzyl alcohol, and benzoic acid.

Tab. 1. C₇H₈ conversion efficiencies (%): Initial C₇H₈ concentration: 800 ppm.

Catalyst	Post-Plasma catalysis	In-Plasma Catalysis
No Catalyst		60
γ-Al ₂ O ₃	70	74
5%Co ₂ O ₃ / Al ₂ O ₃	-	75
1-2% Ag/Al ₂ O ₃	70-74	75-80
1%Au/Al ₂ O ₃	80	95
OMS-2	65	70
10%CuO/OMS-2	70	78
10% Co ₂ O ₃ /OMS-2	66	76
CeO ₂	62	75
1%Au/CeO ₂	80	90
LaMnO ₃	70	85
LaMnO ₃ /Al ₂ O ₃	65	78
La _{0.7} Ag _{0.3} MnO ₃	73	92
La _{0.7} Ag _{0.3} MnO ₃ /Al ₂ O ₃	71	88
Nb ₂ O ₅ (From LCP-INPE (Brazil))	89	96

The experiments with air samples polluted by ammonia and hydrogen sulfide show that NH₃ and H₂S removal efficiencies reach 60% and 93%, respectively, after 1 minute of plasma treatment. Products of NH₃ and H₂S oxidation are NH₄NO₃ and H₂SO₄, respectively.

Conclusion

ANTP-Catalysis Hybrid System is used for the abatement of toluene, hydrogen sulfide, and ammonia. Toluene removal rate strongly increased using in-plasma catalyst position. Best removal rates, 95% and 96% respectively, were obtained when using 1%Au/Al₂O₃ and Nb₂O₅ catalyst. The products of the C₇H₈ oxidation are CO₂, CO, benzyl alcohol, and benzoic acid. The plasma-catalyst system was scaled-up to semi-pilot system operating at gas flow rate up to 20 000 L.h⁻¹.

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