Warm air plasma for nitrogen fixation coupled with heterogeneous catalysis

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Fixation of nitrogen due to naturally occurring electrical discharges (i.e., lightning) is well known. Based on the same principle, reactive nitrogen produced from N_2 and O_2 by the electrically-powered non-thermal air plasma has been recently proposed as an alternative technology for nitrogen fixation. The main barrier to this technology is the relative energy inefficiency of the plasma that converts air and water to nitric acid using electrical power.

This report has provided considerable insights into the potential of catalyst to enhance the energy efficiency of NO_x production in pin-pin DC glow discharge and air plasma jet systems [1-5]. A significant reduction in energy costs, up to 45%, is realized when the γ-Al_2O_3 catalyst is employed in the DC glow discharge system at lower gas flow rates. Despite being located away from the plasma zone, the catalyst sees a notable increase in NO_x production, with neutral species like N, O, and electronically excited N_2* likely contributing to this enhancement. Additionally, a significant boost in NO_x production correlates with an increase in oxygen content in the nitrogen gas mixture, suggesting that O_2 or O atoms play a vital role in NO_x formation on the catalyst surface.

The results highlight the importance of understanding gas flow and catalyst positioning within plasma-based NO_x production systems. An innovative approach was also explored in the study - the use of an air plasma jet infused with floating γ-Al_2O_3 powder for NO_x production as shown in Figure 1. Although the floating catalyst did sometimes destabilize the plasma discharge, this was effectively mitigated by employing a neodymium magnet ring, which enhanced the uniformity and stability of the plasma jet. The floating catalytic particle approach did significantly increase energy efficiency at higher discharge currents. The lowest recorded energy cost for NO_x production using this approach was 2.9 MJ/mol, the lowest value observed across our discharge types and heterogeneous catalyst coupling methods studied.

The study demonstrates the remarkable potential of floating γ-Al_2O_3 catalysts in magnet-stabilized air plasma jet systems for energy-efficient NO_x production. The research underscores the need to maximize the interaction between plasma and catalysts for efficient NO_x production, suggesting that future studies should investigate the positioning of catalysts as close to the plasma zone as possible and explore the use of floating catalytic particles.

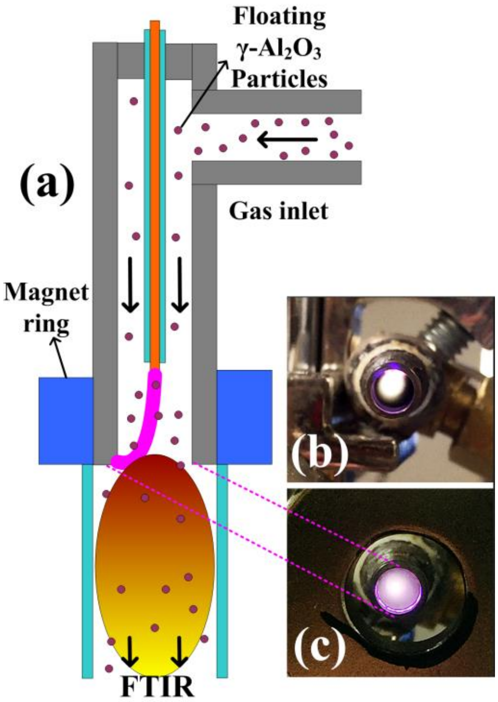

Figure 1. Experimental setup of the air plasma jet powered by floating γ-Al_2O_3 within the gas stream. (b) Overhead view of the plasma jet nozzle without magnetic stabilization. (c) Overhead view of the plasma jet nozzle with magnetic stabilization applied.

References

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