In-situ measurements of nitric oxide (NO) decomposition in a helium radio frequency (RF) atmospheric pressure plasma jet

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Abstract: Plasmas have great potential for mitigating NO_x emissions. We report NO density profiles obtained by laser induced fluorescence in 1 mm capillary tubes and investigate the mechanisms of plasma-enabled NO dissociation in He. The results are consistent with a dominant role of helium metastable species. A strong effect of non-homogeneous NO decomposition in radial direction of the capillary was found.

1. Introduction

Plasma catalysis has the potential to mitigate the cold start responsible for a large percentage of the total NO_x emissions in car engines. While NO oxidation reactions have been studied, the underlying mechanism for NO decomposition by plasma particularly in a non-oxidizing environment in capillary tubes akin to honeycomb catalysts remains unexplored. In many cases the benefits of plasma-catalyst interactions are explored by trial-and-error.

We focus on 1-D Laser Induced Fluorescence (LIF) measurements of NO [1] for *in situ* analysis of both gas phase and surface kinetics in a capillary tube to probe NO decomposition mechanisms. Breakdown of plug flow model due to inhomogeneous dissociation of NO was observed.

2. Methods

LIF on NO was performed in a He-NO radio frequency plasma in a 1 mm capillary tube at atmospheric pressure to study the plasma-induced decomposition of NO. He gas streams with NO concentrations ranging from 20 ppm to 200 ppm and H_2 ranging from 0.01% to 1.2%. The flow rate and plasma power (time-averaged) were varied in the range from 1.12 to 4.5 slm and 0.95 W to 3.4 W respectively.

3. Results and Discussion

Fig. 1 shows the NO density profile as a function of the axial position in the capillary tube for different gas flow rates. The axial NO density profiles show significant dissociation of NO in the active plasma zone reaching values more than 50% for the lowest gas flow rates. We also observe an unexpected recovery in the afterglow, particularly pronounced for the highest gas flow rates. The recovery is on the timescale of radial diffusion and can be explained by the inhomogeneous dissociation of NO by metastable species mostly concentrated at the center of the capillary. The resulting radial diffusion of the NO from the edges of the capillary to the center homogenizes the NO density in the far afterglow leading to an effective

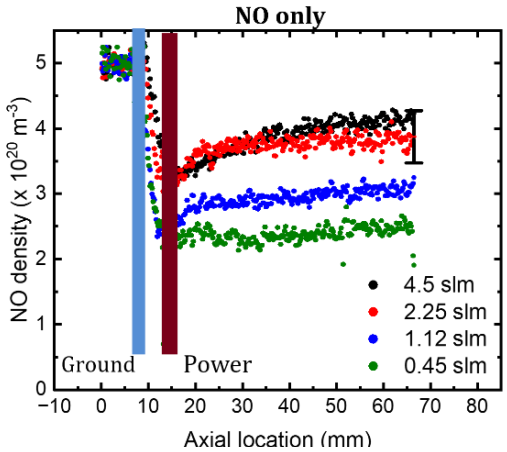

Fig. 1. Comparison of NO dissociation for different gas flow rates of helium with 20 ppm NO feed gas at the constant plasma power 0.95 W.

increase along the measured laser beam. The results suggest that the plug flow approximation for discharges in capillaries breaks down, particularly in capillaries with diameters not much larger than the typical sheath thickness.

To confirm the role of He metastable species in the dissociation, we showed that upon addition of hydrogen to the gas feed, the NO conversion decreased due to the preferential reaction of He metastable species with H_2 instead of NO.

4. Conclusion

Helium metastable species inside an RF plasma enable significant dissociation of NO at near ambient temperatures. Recovery of NO densities in the afterglow can ascribed to inhomogeneous dissociation of NO in capillary reactors and transport of remnant NO near the capillary wall to the bulk fluid suggesting that a breakdown of the plug flow approximation in microreactors.

Acknowledgement

This work was supported by the National Science Foundation under award CBET 2234270.

References

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