Numerical investigation of NO reduction in an RF He plasma at atmospheric pressure in a confined geometry

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Abstract: A plug flow model for He/NO plasma in an RF discharge at atmospheric pressure has been developed to study a RF plasma jet operated in a confined space. Both volume and surface processes are taken into account. The modeling results demonstrate that metastable He atoms are dominantly responsible for a degradation of NO radicals between the electrodes. Heavy species interaction is of major importance out of the discharge.

1. Introduction

NO is a combustion product that inevitably contributes to environmental pollution. While NO_x in the effluent of internal combustion engines is effectively removed by catalytic after treatment, alternatives remain needed to mitigate emission during cold start. Nonthermal plasmas can be effective for NO_x removal treatment.

In this work, we explore the mechanisms of NO decomposition by an RF plasma discharge generated in a confined capillary geometry. We established a plug flow model to explore the dominant species and reactions for NO degradation in a He – NO mixture and investigate the spatial and time evolution of the key species and reactions. The numerical investigation provides us with detailed insights in the key species and processes responsible for NO degradation.

2. Methods

Low temperature He plasma containing small admixtures of NO (20 ppm) is investigated by modelling and experiments. The RF plasma jet is operated in a capillary with a diameter of 1 mm at atmospheric pressure at a power of a few watts. A global model [1-4] describes the plasma chemistry and the gas heating. The model is extended to a plug flow model, which converts the temporal evolution of a volume element flowing with the gas into a spatial distribution. A power density profile is defined in the active region between the RF electrodes. This model provides the species densities, the mean electron energy, and the gas temperature. Laser induced fluorescence enables the experimental determination of the density of NO radicals.

3. Results and Discussion

Fig. 1 lists the dominant reactions responsible for NO degradation in the RF discharge with a capillary radius of 0.5 mm, power of 0. 95 W, and a flow rate of 1.12 slm. The gray shadow region in Fig. 1 represents the interelectrode region of the capillary corresponding to the ionizing plasma zone. Apparently, metastable He atom-induced dissociation of NO is the dominant process and is almost completely restricted to the active region. Additionally, the N atom, as the product of this process, serves as the reactant of the second most important reaction, further contributing to the degradation of NO. Within the plasma region, excited states of N also contribute to the loss of NO,

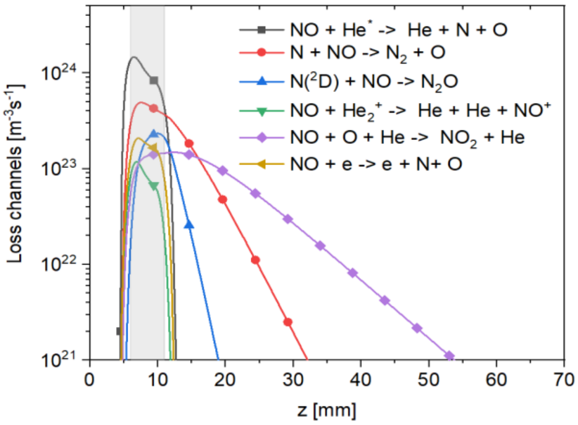

Fig. 1. Dominant NO loss channels and the spatial evolution of their reaction rates

while in the afterglow region, heavy species (N and O) enabled dissociation and recombination dominates.

4. Conclusion

A plug flow model of an RF plasma jet in a He/NO mixture at atmospheric pressure was developed, including 34 species and 294 reactions, providing a comprehensive view of chemical processes. Electron energy loss channels and NO loss and gain channels were analyzed. The influence of NO degradation depending on gas flow or input power have been investigated. Reasonable agreement is obtained between the measured NO density and the model predictions.

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