Conversion of CH_2O in a wet He plasma propagating through a micro-capillary at atmospheric pressure

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Abstract: In this study, we investigate the conversion of Formaldehyde (CH_2O) in a non-equilibrium wet Helium plasma in a micro capillary tube created using a DC-pulsed micro dielectric barrier discharge (µDBD). We follow the concentration of CH_2O throughout cold plasma experiments with real-time mass spectrometry Fourier Transform Ion Cyclotron Resonance with Chemical Ionization (CI-FTICR).

1. Introduction

Volatile Organic Compounds (VOCs) have an important impact on the atmosphere and therefore on our everyday-life environment [1], making the conversion of VOCs a significant research subject. Non-equilibrium plasmas allow efficient VOCs removal and are often used to treat polluted gases like Formaldehyde (CH_2O) [2]. Among VOCs, this molecule is a significant concern due to its prevalence in indoor and outdoor air and its toxicity that can cause serious health issues such as cancer [3]. This study aims to determine the impact of a micro-capillary wet He cold plasma in the conversion of CH_2O depending on the deposited energy in the discharge.

2. Methods

Using a DC-pulsed micro–Dielectric Barrier Discharge (µDBD), we ignite a non-equilibrium plasma inside a micro-capillary tube with an inner diameter of 800 μm in Helium at 1 ln/min flow with 1% of H_2O and CH_2O at an inlet concentration of 180 ppm. A stainless-steel needle is inserted inside the tube, playing the role of the high voltage electrode, while a copper tape is wrapped around the tube, used as the counter electrode. The plasma is ignited with different voltage applied to the µDBD, varying from 2 kV to 5 kV at a frequency of 10 kHz and pulse duration 3 µs.

In order to follow the conversion of CH_2O and potential by-product generated during the experiment, a real-time high sensitivity mass spectrometer CI-FTICR is set up at the exit of the tube. This method allows to detect VOCs down to concentration around tens of ppb [4].

3. Results and Discussion

Figure 1 shows the concentration of CH_2O exiting from the tube while varying the voltage applied to the µDBD during the experiment, highlighting the impact of the plasma in the conversion of CH_2O. As the energy deposited in the plasma increases with the applied voltage, more efficient reactions occur thus increasing the conversion rate. We observe a conversion rate of 14% at 2 kV, 37% at 3 kV, 57% at 4 kV, and 73% at 5 kV. This suggests that CH_2O is not only removed but also transformed into other products, potentially including H_2, CO, or even HCOOH. Further analysis would be needed to confirm the exact nature of these by-products.

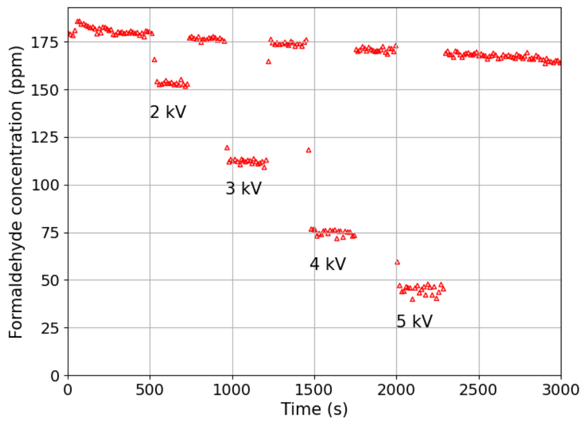

Fig. 1. Evolution of CH_2O concentration while varying the voltage applied to the µDBD, for 2, 3, 4, and 5 kV.

Figure 1 also shows a continuous decrease in the concentration of CH_2O likely due to external factors and not consequences of the discharge.

4. Conclusion

The applied voltage in the µDBD plays a major role in CH_2O conversion, with higher voltages leading to increased energy deposition in the plasma and consequently a higher conversion rate. Our results show that CH_2O conversion reaches up to 73% at 5 kV, highlighting the efficiency of the micro-capillary wet He plasma in VOCs removal. Further studies will optimize the process and elucidate reaction pathways to enhance conversion rates and identify by-products.

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