Time and spatially resolved OH density in a nanosecond pulsed discharge in atmospheric pressure He-H_2O mixtures

T. Verreycken(*), R. M. van der Horst, A. H. F. M. Baede, E. M. van Veldhuizen, P. J. Bruggeman

Department of Applied Physics, Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, The Netherlands
(*) t.verreycken@tue.nl

Time and spatially resolved laser induced fluorescence (LIF) of OH is accomplished on a nanosecond pulsed filamentary discharge in He-H_2O mixtures at atmospheric pressure. Together with the OH density the main plasma properties (electron density n_e, gas temperature T_g, electron temperature T_e) are determined to explain the observed OH dynamics. Depending on the voltage two different modes are observed. In the mode at high voltage (> 3 kV) a chemical model shows that charge exchange and subsequent dissociative recombination can explain the production of OH. The discharge chemistry is dominated by H_2O at water vapour concentrations higher than 1000 ppm.

In view of biomedical and environmental applications, recently a lot of attention is spent on atmospheric pressure plasmas [1, 2]. These plasmas are characterized by a low temperature (down to room temperature) which makes them very appropriate to treat heat-sensitive surfaces like skin. Because of the strong non-equilibrium nature of atmospheric pressure plasmas some highly reactive particles are created. One of the reactive particles that are of high importance for applications is the OH radical.

In this work time and spatially resolved LIF of OH is perfomed on a filamentary discharge in a pin-to-pin electrode configuration in He-H_2O mixtures. The water vapour concentration is varied from 500 ppm H_2O to 27000 ppm H_2O. The discharge is created by applying dc nanosecond pulses of 170 ns with a frequency of 1 kHz. High-voltages up to 10 kV are investigated. At voltages less than about 3 kV the discharge is somewhat diffuse (ø 0.3 mm) and is spreading along the lower, negative electrode. At voltages higher than 3 kV a more constricted discharge (ø 0.2 mm) is created between the electrode tips [3]. As the diameter of the laser beam (250 μm) is approximately equal to the plasma diameter, the OH density can be investigated with a high spatial resolution. To explain the measured OH dynamics the main plasma parameters (n_e, T_g, T_e) are obtained using optical emission spectroscopy.

The measured electron density is of the order 10^{21} m^{-3} and 10^{22} m^{-3} for the mode at low and high voltage respectively. The gas temperature remains below 1000 K. When the water vapour density is of the same order of magnitude as the electron density or higher (> ≈ 1000 ppm), it is observed from time resolved optical emission that water (and its ions) play an important role. In the low-voltage mode the observed OH density has its maximum in the core of the discharge filament, while in the high-voltage mode the core of the discharge filament is highly depleted and the maximum OH density is found at the edge of the discharge [3]. An estimate of the absolute OH density is obtained using a chemical model and using a calibration with Rayleigh scattering in N_2. The obtained OH density is of the same order of magnitude as the electron density. The time resolved OH density of the mode at high voltage (after the discharge pulse) can be modelled by taking into account only the production mechanisms of OH related to charge exchange and dissociative recombination and the chemical loss processes of OH producing H_2O and H_2O_2.

References

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