Helium ns-pulsed atmospheric pressure discharges and the key role of Rydberg molecules

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Non-thermal atmospheric pressure micro plasmas have seen an amazing renaissance in recent years, both in research and application. These discharges are often operated in a pulsed mode and in helium. The physics and chemistry of helium discharge has been the subject of intense investigations in the past but many aspects remained a mystery, especially in the afterglow. Here a ns-pulsed discharge is investigated experimentally by a variety of diagnostics and the results are compared to a chemistry model. It is shown that long living helium molecules in highly excited Rydberg states play a key role in the dynamics. The formation of these Rydberg molecules is not correlated with the optical emission observed from lower excited molecular states [1,2].

The temporal evolution of the electron velocity distribution function, the plasma density, and the electron temperature are measured by Thomson scattering. A new technique based on Thomson scattering is developed that allows for the first time quantitative measurement of the Rydberg state population. Laser absorption measurements provide the evolution of the absolute number of the metastable atomic triplet state. The temporal and spatial evolution of excited atomic and molecular states (lower than the Rydberg states) is recorded by various spectrometers and detectors, including a streak camera. The rotational spectrum of the molecular transitions allows an estimate of the gas temperature which is in good agreement with an energy balance. Current and voltage measurements provide further insight into the ignition behavior and the power coupled to the plasma.

The ab-initio chemistry model is based on a critical review of the literature on theoretical and experimental cross sections and rate coefficients and uses the experimental electron data at the time of power termination as an input. The dynamics of free and bounded electron densities in various atomic and molecular states is calculated. Excellent agreement is found throughout which allows drawing of a rather complete picture of the kinetics.

[1,2] Plasma Sources Science and Technology 25, 054003 and 054004 (2016)