Spatio-temporal dynamics of excited species and electrons in a pulsed argon microwave discharge

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In this contribution, a detailed investigation of the spatio-temporal dynamics of excited atoms and electrons in pulsed microwave plasma is presented. The repetitively pulsed plasma is ignited inside a 6 mm diameter dielectric tube at 1 up to 100 mbar pressures, with pulsing rates from 200 Hz up to 500 kHz. Thomson scattering is used to obtain the local electron density and mean electron energy at different positions. The temporal evolution of the two resonant and two metastable argon 4s states are measured by laser diode absorption spectroscopy. Nanosecond time resolved imaging of the discharge allows to observe the discharge formation and propagation inside the quartz tube. Finally, the temporal evolution of argon 4p and higher states is measured by optical emission spectroscopy.

The combination of these various diagnostics techniques allows to obtain a deeper insight in the plasma dynamics. The effects of the pulse repetition frequency on the plasma ignition dynamics are discussed and the plasma-off time is found to be the relevant parameter for the observed ignition modes. Depending on the delay between two plasma pulses, the dynamics of the ionization front are found to be changing dramatically [1]. This is also reflected in the dynamics of the electron density and temperature and plasma induced emission of argon lines. On the other hand, the (quasi) steady state properties of the plasma are found to depend only weakly on the pulse repetition frequency and the afterglow kinetics present an uniform spatio-temporal behavior.

The use of an ultrafast pulsed microwave power supply does not show any significant difference in the ignition and afterglow behaviors compared to a more conventional microwave power supply [2]. New insights in the propagation mechanism of the ionization wave are obtained. The effective electron temperature at the tip of the ionization front is higher than in the bulk of the plasma. In the case of steady state conditions, it was found experimentally that the tail of the electron energy distribution function is depleted [3] but the situation is less clear during plasma breakdown. Moreover, under some plasma and pulsing conditions, the ionization front is no more homogeneous. A self-consistent fluid hybrid (2 or 3D) time dependent model would be needed to bring more light on the mechanisms responsible for the microwave plasma propagation.

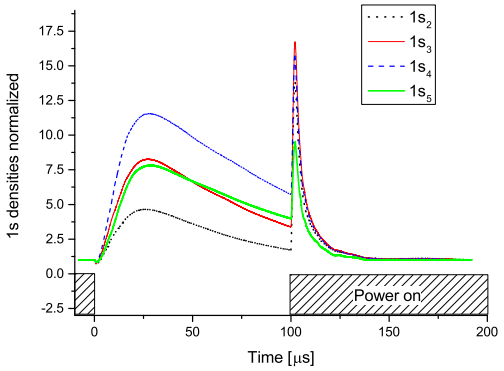

Fig. 1: *Temporal evolution of the resonant (1s4 and 1s2) and two metastable (1s5 and 1s3) states of argon in power on and afterglow periods. The peak microwave power is 50 W, the pressure 20 mbar and the pulsing rate 5 kHz, with 50% duty cycle. The densities are normalized to their steady state value which is at t=0 s.*

Figure 1 shows an example of the time variation during the plasma-on and afterglow periods of argon atoms density in the four lowest excited metastable and resonance states. In the afterglow, large amounts of argon atoms are produced in the metastable and resonant states. The production rates of excited atoms in the afterglow are analyzed and attributed to the recombination of electrons with Ar^+ and Ar_2^+ ions. Depending on the pulse repetition frequency and duty cycle, the kinetics in the post-discharge also influences the re-ignition of the discharge.

References

[1] E. Carbone, S. Nijdam. Plasma Sources Sci. Technol. (2014) **23** 012001.

[2] E. Carbone, et al. Plasma Sources Sci. Technol. (2015) **24** 015015.

[3] E.A.D. Carbone, et al. J. Phys. D: Appl. Phys. (2012) **45** 475202