Tunable diode laser absorption spectroscopy of all four Ar*($3p^54s$) states in a pulsed-operated single-filament dielectric barrier discharge at atmospheric pressure

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Abstract: In this contribution, we report on density measurements of all four lowest energetically excited states of argon (Ar*($3p^54s$)) in a pulsed-operated single-filament dielectric barrier discharge in argon at atmospheric pressure. Time-resolved density measurements in combination with electrical characterisation and optical diagnostics allow to elucidate the role of argon excited species on the discharge dynamics of DBDs.

1. Introduction

Dielectric Barrier Discharges (DBDs) are applied for plasma enhanced chemical vapour deposition, i.e. of thin functional films [1]. Excited argon species play an important role as they have sufficient energy to dissociate or ionise molecular species and influence the discharge dynamics. The ability to determine the number density of all four Ar*($3p^54s$) states as a function of the operating parameters, such as the gas flow or the characteristics of the applied high-voltage (HV) pulse, is required for the benchmarking of numerical models, see e.g. [2].

2. Methods

A two-sided DBD consisting of a half-spherical powered stainless steel electrode in contact with a planar dielectric (Al_2O_3, thickness 0.6 mm, $\varepsilon_r \approx 9$) and a second dielectric on top of a grounded planar stainless steel electrode, separated by a gas gap distance of 3 mm is investigated. Operating the DBD with HV square-wave pulses leads to the ignition of an individual discharge event during both slopes of the HV pulse in this single-filament arrangement similar to [3]. The spatial position of the filament in the gas gap is monitored with two, synchronised iCCD cameras, capturing its emission parallel and perpendicular to the gas flow direction. Tunable diode laser absorption spectroscopy is utilised to measure absolute number densities of all four Ar*($3p^54s$) states, i.e., the resonance states ($1s_2$, $1s_4$) and the metastable states ($1s_3$, $1s_5$).

3. Results and Discussion

In Figure 1 an example of the temporal evolution of the densities of all four Ar*($3p^54s$) states for a HV pulse with an amplitude of 6 kV, a repetition frequency of 1 kHz, and a pulse width of 1 µs, measured in pure argon at a flow rate of 4 slm at atmospheric pressure is shown. For the density determination an effective absorption length of 100 µm was assumed. The number densities reach their maximum shortly after the discharge is ignited, indicated by the peak of the discharge current. The number densities in the back discharge on the falling slope of the HV pulse are reduced. The short pulse width of 1 µs results in a higher pre-ionisation in the discharge gap during the breakdown phase of the back discharge, which leads to a weaker discharge,

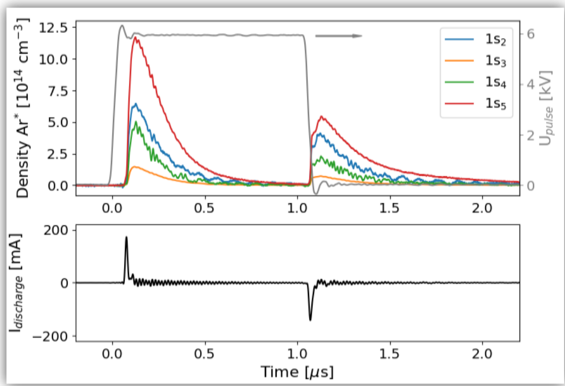

Fig. 1. Temporal evolution of Ar* densities for a HV pulse with an amplitude of 6 kV, a repetition frequency of 1 kHz, a pulse width of 1 µs, measured at a flow rate of 4 slm argon at atmospheric pressure.

indicated by a slightly smaller maximum current, and thus lower densities of excited species [3]. The relative number densities (n_{1si}/n_{1s5}) follow approximately the ratios of their statistical weights, which suggests an equilibrium-like population distribution of the 4s states.

4. Conclusion

Time-resolved density measurements in combination with electrical characterisation and optical diagnostics allow to elucidate the role of argon excited species on the discharge dynamics of single-filament DBDs. The measured densities can be used to compare and benchmark numerical models.

Acknowledgement

This work is funded by the Deutsche Forschungs-gemeinschaft (DFG) – Project number 504701852.

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