Understanding a "in principle rather old gas discharge”: Plasma diagnostics on barrier discharges

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Abstract: The contribution intends to provide an overview of the methods for diagnostics of barrier discharges. The focus is on techniques with a high spatial and temporal resolution, which make it possible to record the electrical breakdown phenomena at high pressures.

Although barrier discharge (or dielectric barrier discharges, DBDs) as nonthermal atmospheric pressure plasma sources were first described more than 150 years ago and are still widely used in plasma technology, it is still a highly interesting object of research. In his 2003 review article [1], Ulrich Kogelschatz described a “renaissance of an in principle rather old gas discharge” since the 1990s, which continues to this day. In addition to the classic use in ozone generators and surface activation, applications can now be found in medicine, exhaust air purification, light sources and analytical devices [2]. DBDs are frequently used in research and development, particularly in the rapidly growing fields of surface deposition, gas conversion, plasma-catalysis and plasma-agriculture. However, the barrier discharge is still a challenge for plasma diagnostics and simulation, with research and development into new applications constantly raising new fundamental questions. The formation of filamentary or diffuse discharges, the local charging of electrically insulating interfaces and the behavior of surface charges or the coupling between discharge physics and plasma chemistry are just a few examples. Data on fundamental plasma parameters such as electron densities, electric field strength or temperatures are not yet available to a sufficient extent for many operation conditions.

This contribution will provide an overview of the methods used to diagnose barrier discharges. The focus is on techniques with high spatial and temporal resolution, which make it possible to record the electrical breakdown phenomena at high pressures. However, aspects for monitoring the discharge operation are also touched upon and, the application of tunable laser absorption spectroscopy to measure absolute number densities of the four lowest energetically excited states of argon will be introduced.

Like most nonthermal plasmas at elevated pressure, DBDs also show a transient character with discharge dynamics often down to the sub-nanosecond range. To study the discharge, e.g. the streamer development with sufficient spatial and temporal resolution can be mastered by fast electrical measurements in combination with synchronised high-end optoelectronic devices such as ICCD and streak cameras or with time-correlated single photon counting. The application of this approach is demonstrated for pulsed (see fig. 1) and sinusoidal operated single filaments in nitrogen with admixtures of oxygen or nitrous oxide [3].

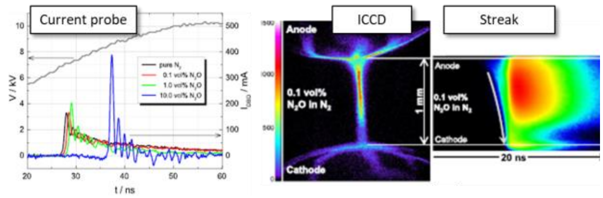

Fig. 1. Electrical measurements, ICCD and streak camera recordings of pulsed operated single DBD filaments in N_2/N_2O gas mixtures (Unipolar square wave pulses with 10 kV amplitude, 10 kHz repetition frequency and a pulse width of 10 µs), taken from [3].

For discharge operation monitoring electrical characterization, based on the simple equivalent circuits is established. In this case, DBDs are described by some overall quantities such as the applied frequency, the applied voltage amplitude and the so-called discharge voltage. The extension of this approach to more sophisticated discharge geometries (e.g. single filament arrangements, surface discharges or packed bed DBDs) or high voltage power supplies will be briefly discussed in the lecture.

The experimental techniques presented are an important prerequisite for ensuring that the “renaissance of the DBD” continues.

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References

[1] U. Kogelschatz, Plas. Chem. Plas. Proc., 23, 1-46 (2003).
[2] R. Brandenburg, K.H. Becker, K.-D. Weltmann, Plas. Chem. Plas. Proc., (2024).
[3] H. Höft et al., J. Phys. D: Appl. Phys., 53, 025203 (2020).