Topic number: 10

Experiments on and simulation of a thin cathode discharge

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The atmospheric pressure microhollow cathode discharge (MHCD) was first investigated by Schoenbach in the mid-nineties [1, 2]. The MHCD consists of two electrodes separated by a thin dielectric layer. The discharge burns in a hole drilled through this setup. The dimensions of the electrodes, the dielectric layer and the hole are usually of the order of some 100 µm. It was quickly discovered that, depending on the pressure and the applied supply voltage, the MHCD can be operated in different modes. One of these modes is the so called self-pulsing, which was thoroughly investigated by Rousseau [3, 4]. This self-pulsing is characterized by periodically occuring voltage drops and current peaks which are explained by a periodic extension of the discharge onto the surface of the cathode which cannot be sustained and thus collapses. However, at very high pressures of several 100 hPa another kind of self-pulsing occurs (fig.1). Compared to the self-pulsing investigated by Rousseau, it shows higher voltage drops down to zero and much higher current peaks. A study of the electrical characteristics of this self-pulsing mode showed that this self-pulsing is caused by a periodic ignition of an arc discharge which instantly decays. The ignition of an arc discharge is possible because of the thinness of the cathode (in our case 100 µm) which enables the cathode to heat quickly, thus we chose to call it thin cathode discharge (TCD) instead of microhollow cathode discharge.

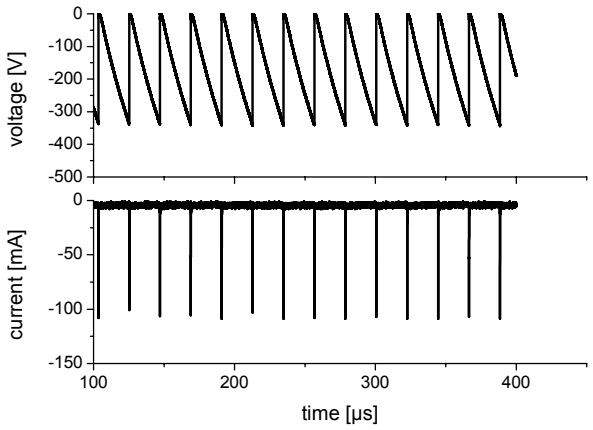

Fig. 1: self-pulsing of the TCD at a pressure of 900 hPa and a supply voltage of 1200 V.

During our investigations, we concentrated on the TCD-mode. So far, emission spectroscopic measurements, both time-averaged and temporally resolved, were made additionally to the electrical measurements. We obtained the electron density by adding 1% hydrogen to the discharge and using the Stark broadening of the H-Beta line based on the model by Gigosos et al.

[5]. These measurement yielded electron densities of several 10^{16} cm^{-3} which can be maintained over a period of about 200 ns in a mixed argon-hydrogen discharge. However, temporally resolved measurements of the emission intensities of several argon lines in a pure argon discharge showed that the afterglow has an even longer lifetime of 600-700 ns, which is surprisingly long, since at these high pressures the electrons should cool much faster. Furthermore, an attempt to measure the electron temperature by line intensity ratios led to the assumption that the electron energy distribution function (EEDF) is non-Maxwellian with a high concentration of high energy electrons as high energy states of argon are very densely populated.

In order to identify the mechanisms responsible for the long-living afterglow, a kinetic model of the afterglow was developed. Since we expect a non-Maxwellian EEDF, the electron energy distribution dunction was explicitly calculated. A special emphasis was also put on processes involving excited states, especially metastable ones. In detail, these are super-elastic collisions, Penning-ionization and the formation of excimers which can also be ionized or be subject to super-elastic collisions. The inclusion of these processes leads indeed to a long-living afterglow (fig. 2) and a non-Maxwellian EEDF due to the inelastic nature of the heating mechanims. The super-elastic collisions with excited argon atoms heat the electrons very efficiently, while the Penning-ionization is mainly an efficient electron source. Excimers play only a minor role in the early afterglow but once a sufficient density is reached, they heat the electrons more efficiently than the metastables and dominate the electron kinetics over the majority of the afterglow.

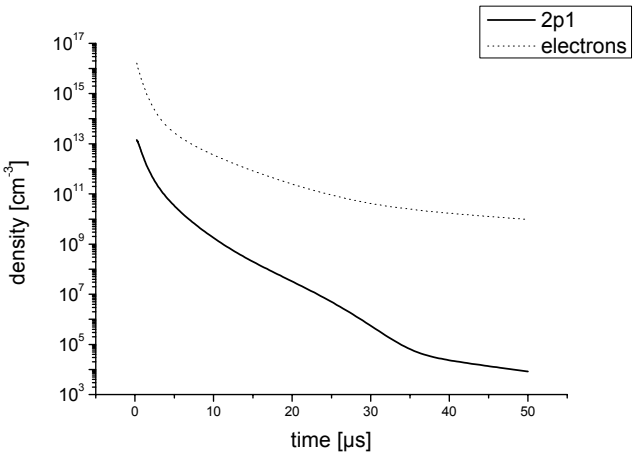

Fig. 2: simulated electron density and population density of the argon $2p_1$-state in the afterglow

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