Temporal and spatial resolved density of the metastable $N_2(A^3\Sigma_u^+)$ molecule in barrier discharges

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The density of the metastable $N_2(A^3\Sigma_u^+)$ molecule has been measured by laser induced fluorescence spectroscopy (LIF) in an asymmetric barrier discharge at 500 mbar in the filamentary mode. The absolute density calibration is based on a comparison of the LIF signal with the signal from Rayleigh scattering. Time dependent measurements in front of the dielectrics have been performed and axial profiles of the density distribution in the gap for fixed times have been measured.

Barrier discharges usually operate in the filamentary mode, characterized by numerous randomly distributed microdischarges over the entire dielectric surface. Under special conditions, a diffuse discharge mode exist covering homogeneously the dielectric surface. For the diffuse mode, the electron density at the beginning of the breakdown must be sufficient large enough to avoid the generation of large electric fields. In nitrogen, these initial electrons are caused by Penning ionization within the discharge volume or exoemission of electrons from surfaces. Both processes are initiated by long living $A^3\Sigma_u^+$ metastables from previous discharges.

To clarify the role of these processes and the importance of the $A^3\Sigma_u^+$ state a new discharge configuration has been developed to measure metastables, surface charges and the optical emission in one identical discharge configuration. As shown in figure 1 it consists of a glass plate on top and a bismuth silicon oxide (BSO) crystal at the bottom as dielectrics. The gap between both is one millimeter. Below the BSO, a grounded aluminium mirror works as one electrode and on top a needle like electrode is used to fix the microdischarge position in the centre of the discharge configuration.

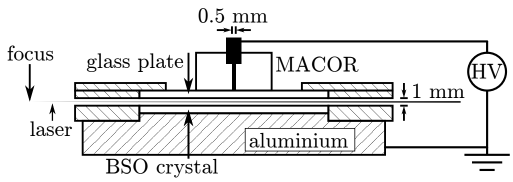

Fig. 1: Cross section of the discharge cell along the laser axis. The laser diverges in the gap due to its focus in front of the discharge cell.

The discharge was ignited in pure nitrogen with a sufficient large voltage to force the filamentary mode (500 mbar, 2 or 5 kHz, 10.5 to 12.5 kV_{pp}). The detection of metastables was done by laser induced fluorescence (LIF) spectroscopy. To pass the discharge gap, the laser was focused by a cylindrical lens (300 mm focal length). Its focus was in front of the discharge cell and diverges within the gap. It has a vertical extend of about 0.15 mm in the centre of the discharge cell. The laser wavelength was tuned to 687.44 nm to hit the band head of the transition from the $A^3\Sigma_u^+, v = 0$ state to the $B^3\Pi_g, v = 3$ state. The fluorescence from the transition to the $A^3\Sigma_u^+, v = 1$ state was measured perpendicular to the laser beam by a monochromator at 762 nm and a photomultiplier tube. This conventional setup allowed to record temporally resolved signals by a fast oscilloscope (ns-resolution). The comparison of the time dependent LIF signal with the signal from Rayleigh scattering was the basis of the absolute density calibration [1, 2].

Two examples of the obtained results are presented in figure 2. Both diagrams show the time dependence of the density of the metastable $A^3\Sigma_u^+, v = 0$ state of nitrogen. The vertical position of the central laser axis was about 0.2 mm in front of the glass plate and the needle-like electrode on top of the glass

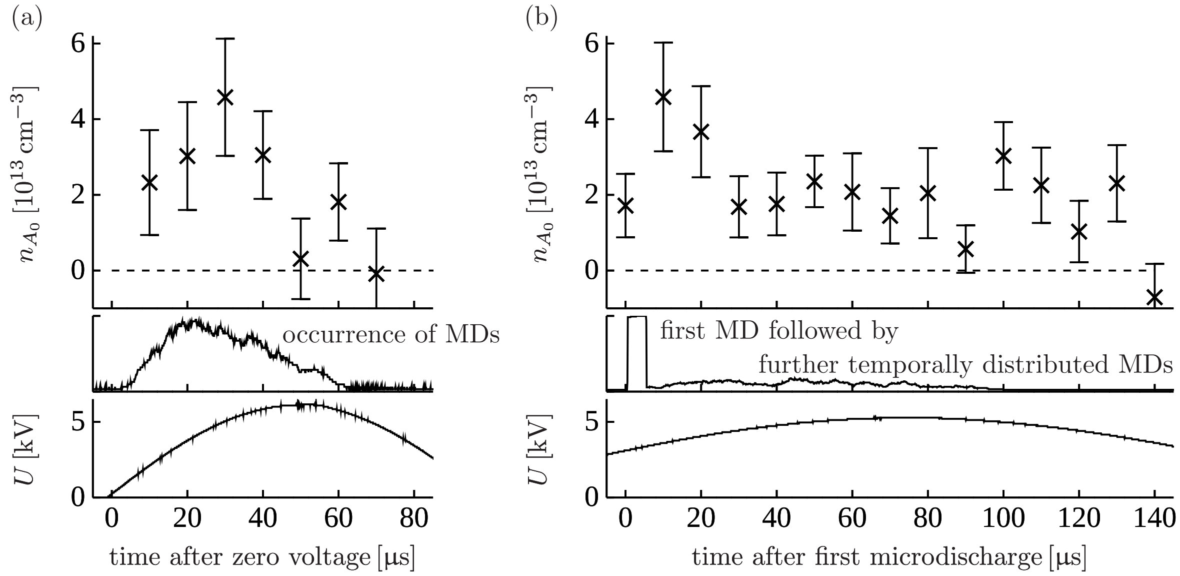

Fig. 2: Density of metastable $N_2(A^3\Sigma_u^+), v = 0$ molecule in front of the glass plate (=anode) depending on time (a) in the positive half cycle (500 mbar, 5 kHz, 12.5 kV_{pp}) and (b) after the first microdischarge (500 mbar, 2 kHz, 10.5 kV_{pp}).

plate was positive. In figure 2 (a) the time dependence of the density in the positive half cycle at 5 kHz and 12.5 kV_{pp} is shown. The density of metastables increases steeply and reaches a maximum at 30 µs. This is about 10 µs after the maximum of the occurrence of microdischarges. The delay of several microseconds of the metastable density with respect to the maximal discharge current is typical for diffuse discharges [3, 4]. After the maximum, the density decreases fast within 40 µs to zero. In this measurement, it is not clear how many microdischarges cross the laser beam and contribute to the measurement. Therefore, a lower frequency of 2 kHz and discharge voltage of 10.5 kV_{pp} has been chosen in figure 2 (b) to measure the time dependence in the afterglow of one single microdischarge. The influence of further discharges can be neglected due to their rarer occurrence and their delay of about 50 µs on average with respect to the first microdischarge. Looking at the time dependence, the maximum of the density is 10 µs after the microdischarge. The decrease of the density after the maximum is as fast as in figure 2 (a), but remains on a nearly constant level between 30 and 80 µs. In the end, strong fluctuations appear caused by the large measurement error. The same measurements have been performed for the negative half cycle and show a slower increase of the density after the microdischarge. Furthermore, time dependent measurements in front of the BSO crystal have been performed. They show a lower density as in front of the glass plate which is probably the result of the asymmetric setup of the electrodes. Besides the time dependent measurements, axial profiles of the density for fixed positions in the half cycles have been done.

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