Spatio-temporally resolved investigation of surface charges, $N_2(A^3\Sigma_u^+)$ metastables and the discharge development in diffuse N_2 barrier discharges

M. Bogaczyk[1], S. Nemschokmichal[1], G. B. Sretenović[2], J. Meichsner[1], H.-E. Wagner[(*)1]

[1] *Institute of Physics, University of Greifswald, Felix-Hausdorff-Str. 6, 17489 Greifswald*
[2] *Faculty of Physics, University of Belgrade, Studentski trg 12, 11000 Belgrade, Serbia*
[(*)] wagner@physik.uni-greifswald.de

The correlation of volume processes in diffuse barrier discharges and their interaction with an insulated surface has been studied by three different diagnostics at ONE discharge configuration. It enables the detection of surface charges on one optoelectronic dielectric BSO crystal by the Pockels effect as well as the measurement of the metastable $N_2(A^3\Sigma_u^+)$ state by laser induced fluorescence spectroscopy (LIF). Both diagnostics have been compared to the discharge development measured by cross-correlation-spectroscopy (CCS) and electrical discharge characteristics.

Barrier discharges are found in many applications, e.g. for the ozone synthesis, surface treatment and excimer lamps [1] and hey still have a high technological potential. For a detailed understanding of the mechanisms (ignition, discharge mode, stability, etc.), the investigation of the elementary processes in the discharge volume as well as the interaction with dielectric surfaces is necessary. One important process is the exoemission of electrons from charged surfaces by metastables. Here, the combination of surface charge measurements with the detection of metastables in one discharge configuration should give a better insight.

The used discharge cell consists of two parallel dielectrics, namely a glass plate on top and a lower BSO ($Bi_{12}SiO_{20}$) crystal. The gap distance between the two dielectrics is 1 mm. The lower electrode is a grounded aluminum mirror. An ITO layer covers the glass plate as the driven transparent electrode. This configuration enables the investigation of the surface charge development on the BSO crystal from top via a CCD high-speed camera. The working gases are pure helium and nitrogen. The sinusoidal voltages vary from 1 kV (helium) to 4 kV (nitrogen) to sustain a diffuse discharge.

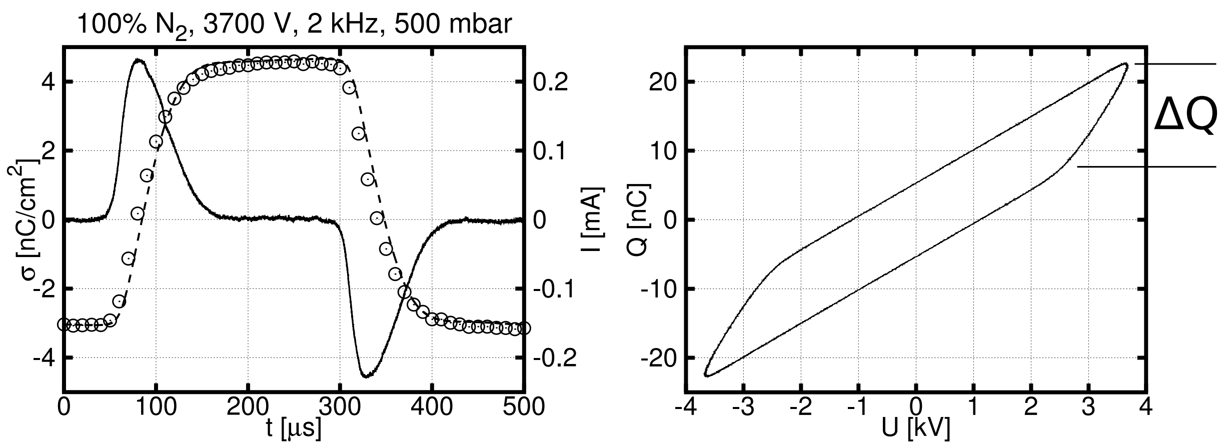

Fig. 1: Left: Discharge net current (solid line), integrated net current (dashed line), and surface charges (circles) in diffuse nitrogen discharge. Right: Corresponding Lissajous figure.

The surface charge measurement is based on the optical birefringence of light passing the BSO crystal when a voltage is applied across the crystal. This voltage is given by surface charges deposited on the crystal which enables the recalculation of these surface charges from the measurement of intensity changes of elliptically polarized light. The intensity change is well correlated with the sign and value of the surface charges [2, 3]. The detection of the metastable $N_2(A^3\Sigma_u^+)$ state is performed by laser induced fluorescence spectroscopy (LIF) and an absolute calibration by the comparison with the Rayleigh scattering [4]. The discharge development can be characterized by the cross-correlation spectroscopy [5] and electrical measurements.

In figure 1 the discharge net current (solid line) in combination with the measured surface charges (circles) are shown for pure nitrogen. The low discharge current indicates the Townsend-like mode which is the typical discharge mode in pure nitrogen at atmospheric pressure. The corresponding spatio-temporally resolved emission shows a maximum in front of the anode. Looking at the surface charges, they remain constant until the current pulse appears. During the current pulse, the surface charge changes its sign and remains again constant until the next current pulse of the next half period. For a quantitative comparison, the discharge current is temporally integrated and also plotted in figure 1 (dashed line). Besides, the corresponding Lissajous figure is also plotted in figure 1 to show the transported charge ΔQ within one current pulse. The accordance of the surface charge measurement with the temporal integrated net current and the transported charge is excellent.

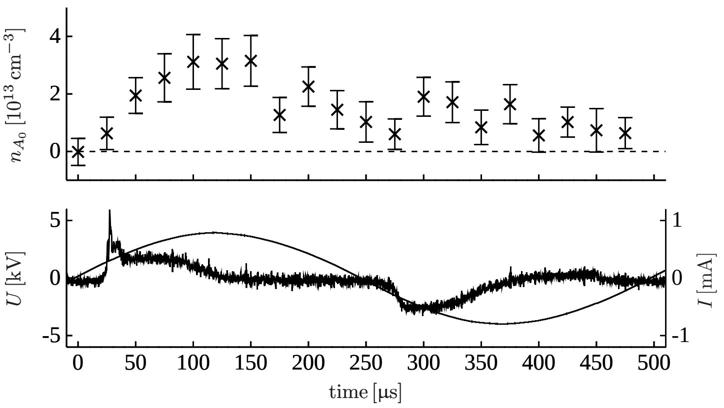

Fig. 2: Time dependence of the density of $N_2(A^3\Sigma_u^+, v = 0)$ in the centre of the discharge gap in pure nitrogen in comparison with the applied voltage and discharge current. Conditions: 500 mbar, 2 kHz, 4 kV

The time dependence of the $N_2(A^3\Sigma_u^+, v = 0)$ density in the center of the discharge gap is shown in figure 2 in comparison with the applied voltage and the discharge net current. In the positive half period, the discharge current shows a peak at the beginning of the pulse. This indicates the transition from the diffuse to the filamentary mode. In the negative half period, this effect is not visible. The density of metastables increases strongly in the positive half period, but only weakly in the negative half period. The reason might be a different distance of the laser beam to the different dielectrics or an effect caused by the dielectrics which is correlated to the discharge current. Further measurements in front of the dielectrics and axial profiles of the density in the gap are necessary to clarify this.

References

[1] U. Kogelschatz, *Plasma Chemistry Plasma Process.* **23** (2003) 1

[2] A. Yariv, *Quantum electronics*, Viley New York (1989)

[3] L. Stollenwerk, J. G. Laven, H.-G. Purwins, *PRL* **98** (2007) 255001

[4] S. Nemschokmichal, F. Bernhardt, B. Krames, J. Meichsner, *J. Phys. D: Appl. Physics* **44** (2011) 205201

[5] H.-E. Wagner, K. V. Kozlov, R. Brandenburg, vol. 1, 385 in R. Hippler, H. Kersten, M. Schmidt, K.H. Schoenbach (Eds), WILEY-VCH Weinheim (2008)