Laser-photodetachment of negative ions in He/O_2 barrier discharges

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1. Introduction

Barrier discharges operating in rare gases with small admixtures of oxygen are well established for the treatment of temperature-sensitive biological samples. The rare gas serves as a buffer gas requiring low power, whereas oxygen provides an effective source of radicals. Since oxygen is strongly electronegative, attachment processes generating negative ions might significantly change the discharge properties. To quantify the influence of negative ions, laser-photodetachment is applied to barrier discharges in helium with small oxygen admixtures.

2. Experiment

The experiment is performed in helium with oxygen admixtures of up to 1000 ppm at a pressure of 500 mbar. The barrier discharge configuration contains two 0.7 mm thick glass plates ($\varepsilon_r = 7.6$) as dielectrics separated by a 3 mm gap. A power supply operates the discharge by means of a sine wave feeding voltage at a frequency of 2 kHz. For the discharge characterization, the gap voltage and discharge current are derived from the measured transported charge across an external capacitance. The photodetachment of negative ions is performed using a Nd:YAG laser at its fundamental and second harmonic wavelength. The different wavelengths enable the distinction of different negative oxygen ions.

3. Results

In figure 1, the influence of the laser on the discharge in pure helium and helium with 400 ppm oxygen is shown. The discharge current and gap voltage of the laser-disturbed discharge are plotted in red and blue, respectively. The electrical quantities of the undisturbed discharge are added by gray lines. To be sure that the laser alignment is well done, a control measurement in pure helium is performed. As expected, it reveals no laser-induced change in the discharge properties. This is different for the helium oxygen discharge. As visible, the discharge current pulse starts earlier and its maximum is also shifted to earlier times. The discharge ignites at a lower gap voltage and the voltage drop during the discharge pulse is smaller. Furthermore, it is remarkable that the laser firing time is during the discharge pre-phase, whereas no effect can be observed when firing during the discharge current pulse. This behavior lets us assume that the electron attachment is important during the pre-phase of the discharge, but not during the discharge breakdown.

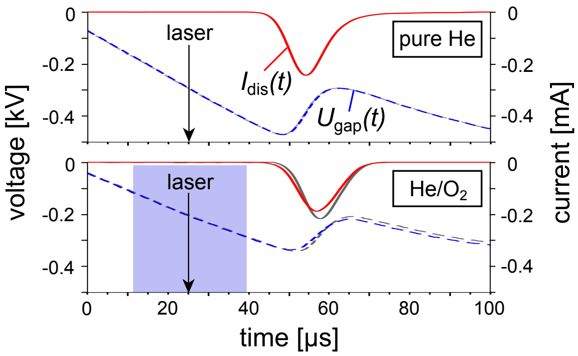

Fig. 1: *Gap voltage and discharge current of the control measurement in pure helium (top), and of the photodetachment effect in He/O_2 (bottom).*

The strength of the photodetachment effect depending on the laser pulse energy is shown in figure 2. As it is expected, the effect reaches saturation, since for large laser pulse energies all negative ions are detached. The saturation energy can be used to determine the negative ion species. The figure suggests that mostly O_2^- ions should be present, but measurements with the fundamental laser wavelength show no effect as it should be in the case of O_2^- ions. Hence, probably a mixture of O^- and O_3^- ions is present during the pre-phase of the discharge.

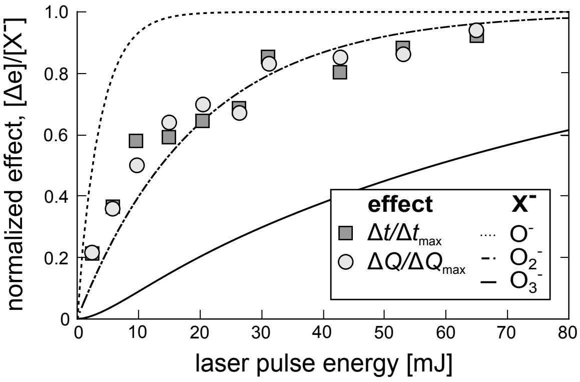

Fig. 2: *Photodetachment effect depending on the laser pulse energy in comparison to theoretical curves.*

4. Outlook

To clarify the actual composition of negative ion species in the pre-phase of the discharge a 1D fluid modeling is planned. This should also explain why the laser-photodetachment during the discharge pulse has no influence on the discharge.