EFFECTS OF PHOTO- AND BACKGROUND IONIZATION ON POSITIVE STREAMERS

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1. INTRODUCTION

Positive streamers need a continued source of free electrons in front of them in order to propagate. Because of the electronegativity of molecular oxygen, free electrons in air quickly attach to oxygen. If this is the case, a high field is needed to detach the electrons. The detached free electrons can form avalanches that feed the front of the streamer head and enable it to propagate. The density of the electrons influences the morphology of the streamers as was demonstrated in [1].

In most streamer models the medium is air and the major source of electrons in front of the streamer head is taken as photo-ionization. In air, this occurs when a UV photon in the 98 to 102.5 nm range, emitted by an excited nitrogen molecule, ionizes an oxygen molecule, thereby producing a free electron. We tested effects of photo-ionization by using nitrogen with oxygen concentrations ranging from less than 0.1 ppm (ultra pure N_2) to 20% (artificial air).

Besides photo-ionization, there is another source that can provide free electrons in front of a positive streamer head: background ionization. Background ionization is ionization that is already present in the gas before the streamer starts, or at least it is not produced by the streamer. It can have different sources. In ambient air, radioactive compounds (e.g. radon) from building materials and cosmic rays are the most important sources of background ionization. They lead to a natural background ionization level of 10^9 -10^{10} m^{-3} at ground level (Pancheshnyi [2] and references therein). Another source of background ionization can be leftover ionization from previous discharges. This is especially important in repetitive discharge types like DC corona discharges or repetitive pulsed discharges. Background ionization can also be created by other sources like radioactive compounds. We have added traces of radioactive ^{85}Kr to pure nitrogen to increase background ionization levels and we have varied the pulse repetition rate.

The measurements have been performed in a set-up designed for pure gas handling. Discharges are created by applying a voltage pulse on a sharp tungsten tip, placed inside the vacuum vessel 16 cm above a grounded plane. Two different pulsed power supplies have been used to make this pulse: a so-called C-supply (see [3]) and a Blumlein pulser (see [1]). More information about the circuit, discharge vessel and imaging system can be found in [1, 4, 5].

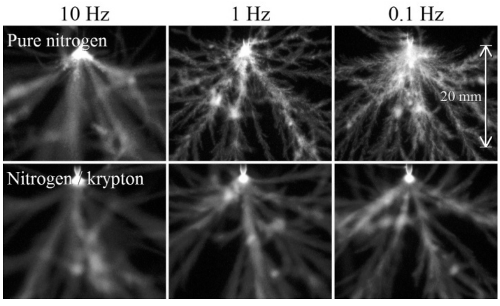

Fig. 1. Zoomed images around the cathode tip of repetitive streamer discharges created with the Blumlein pulser (pulse length 130 ns) at 25 kV at three different pulse repetition rates in pure nitrogen and the nitrogen/krypton mixture.

2. RESULTS

From overview images of streamer discharges in three different gasses (air, pure nitrogen and nitrogen with added ^{85}Kr) we observe that there are some differences in appearance between the gasses, but they are limited. Even with a change of more than six orders of magnitude in oxygen content between pure oxygen and air, streamer length and appearance remain more or less the same.

The effect of repetition rate on streamer morphology in pure nitrogen is shown in the top row of figure 1, where there is a distinct difference between streamers in pure nitrogen made with the same pulse shape but at 10, 1 and 0.1 Hz pulse repetition rate. At higher repetition rates, the streamers are smoother and fewer or no feather-like structures are visible (see [6]). Streamers in the nitrogen/krypton mixture show a somewhat similar trend, although in this mixture the streamers remain much smoother at 0.1 and 1 Hz than the ones in pure nitrogen.

3. CONCLUSIONS

The background ionization levels left by previous discharges at 200 mbar and 1 Hz in pure nitrogen are estimated at about 10^{11} m^{-3}. This is just below the estimate of the background ionization from radioactive decay in the nitrogen/krypton mixture ($4{\cdot}10^{11}$ m^{-3} at 200 mbar). This fits well with the observed behaviour that shows differences in streamer morphology between pure nitrogen and nitrogen/krypton at 1 Hz and lower repetition rates, but no differences at 10 Hz. At the lower repetition rates the (fixed) radioactive ionization source dominates over the ionization from previous discharges, while at 10 Hz the leftover ionization is dominant.

In general we do not observe large differences in streamer properties between air, pure nitrogen and the nitrogen/krypton mixture or between repetition rates. Minimal streamer diameters and propagation velocities are very similar even though photo- and background ionization vary by many orders of magnitude. This confirms that streamers are very insensitive for the exact value of ionization levels as was already discussed in [1, 7]. The observations also confirm the explanation of feather-like structures given in these papers. Again, it is found that higher ionization levels (photo or background) lead to smoother streamers and less feathers. This supports the theory that the feathers are caused by the stochastic nature of the ionization distribution that occurs at low ionization levels and that the feathers may be visible remnants of single avalanches.

4. REFERENCES

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