# Positive Streamers in Ambient Air and a $N_2 : O_2$ Mixture (99.8 : 0.2)

T. M. P. Briels, E. M. van Veldhuizen, and U. Ebert

*Abstract*—**Photographs show distinct differences between positive streamers in air or in a nitrogen–oxygen mixture (0.2% $O_2$). The streamers in the mixture branch more frequently, but the branches also extinguish more easily. Probably related to that, the streamers in the mixture propagate more in a zigzag manner, whereas they are straighter in air. Furthermore, streamers in the mixture can become longer; they are thinner and more intense.**

*Index Terms*—**Corona, gas discharges, photoionization.**

STREAMERS are narrow rapidly growing ionized channels. They can be created when a high voltage is applied to a nonconducting medium [1]. They are used, for example, in gas and water cleaning [1], [2]. In nature, they are observed as the so-called sprite discharges in the atmosphere at 40–90-km altitude [3]. Streamers are often investigated in ambient air since this is the most commonly used gas in applications, experiments, and nature. However, air is a compound gas in which many processes can occur. To understand the physical mechanisms, it is useful to perform experiments in simple gases as well. $N_2$ is a good candidate because it is the main component of air, and it is a simple single molecular gas. Note, however, that small impurity concentrations can be essential and can never be fully suppressed. Therefore, in this paper, we present experiments where the $O_2$ concentration in $N_2$ is varied by a factor of 100, i.e., the gases used are ambient air and a nitrogen–oxygen mixture with 99.8% $N_2$ and 0.2% $O_2$ (abbreviated to $N_2 : O_2$ hereafter). This mixture is taken from a bottle. Comparable studies [4], [5] report different pictures.

High-voltage pulses are created by using a switched capacitor supply [6], [7]. The voltage pulse is intentionally given a long rise time so that only thin streamers are created [6], [7]. Photographs are taken with a 4QuikE intensified charge-coupled-device camera from Stanford Computer Optics.

Fig. 1 shows positive streamers in a 160-mm point-plane gap in $N_2 : O_2$ and air at 400 mbar and 30 kV. The discharge starts at the needle tip (top of photographs, which is indicated by 0 mm) and propagates toward the plate (bottom, which is 160 mm). The discharge in air is clearly not fractal. The discharge in $N_2 : O_2$ forms many more branches and zigzags than the one in air. Furthermore, the many side branches in $N_2 : O_2$ die out after a much shorter distance than in air. The discharge in $N_2 : O_2$ branches roughly every 7.5 ± 2.5 mm, whereas in air, it branches roughly every 10 ± 4 mm. The discharge in $N_2 : O_2$ is more intense; therefore, the intensity level of the figures was reduced relatively to those in air. Streamers in $N_2 : O_2$ are thinner, show a better contrast between in- and out-of-focus, and have diffuser tips. Other observations show that the streamers in $N_2 : O_2$ propagate further in space and have longer current pulse durations than the streamers in air under similar conditions [7].

The difference in current pulse duration can be explained by the electronegative character of $O_2$ in air which attaches the electrons that are necessary to maintain a discharge. The discharge in air therefore will die out sooner because of an electron shortage. The difference in branching statistics can most likely be ascribed to photoionization. In addition, simulations [8], [9] in a fluid model show that branching can be delayed by photoionization. However, this should be reinvestigated in a particle model with its inherent particle density fluctuations [10]. The average electron energy in the streamer head is deduced from the electric field [11], and the field is obtained via the ratio of the spectral lines of $N_2$ [12]. The obtained results show higher average electron energy for $N_2$ which can explain the observed difference in intensity [7]. The experiments will be discussed in more detail in [13].

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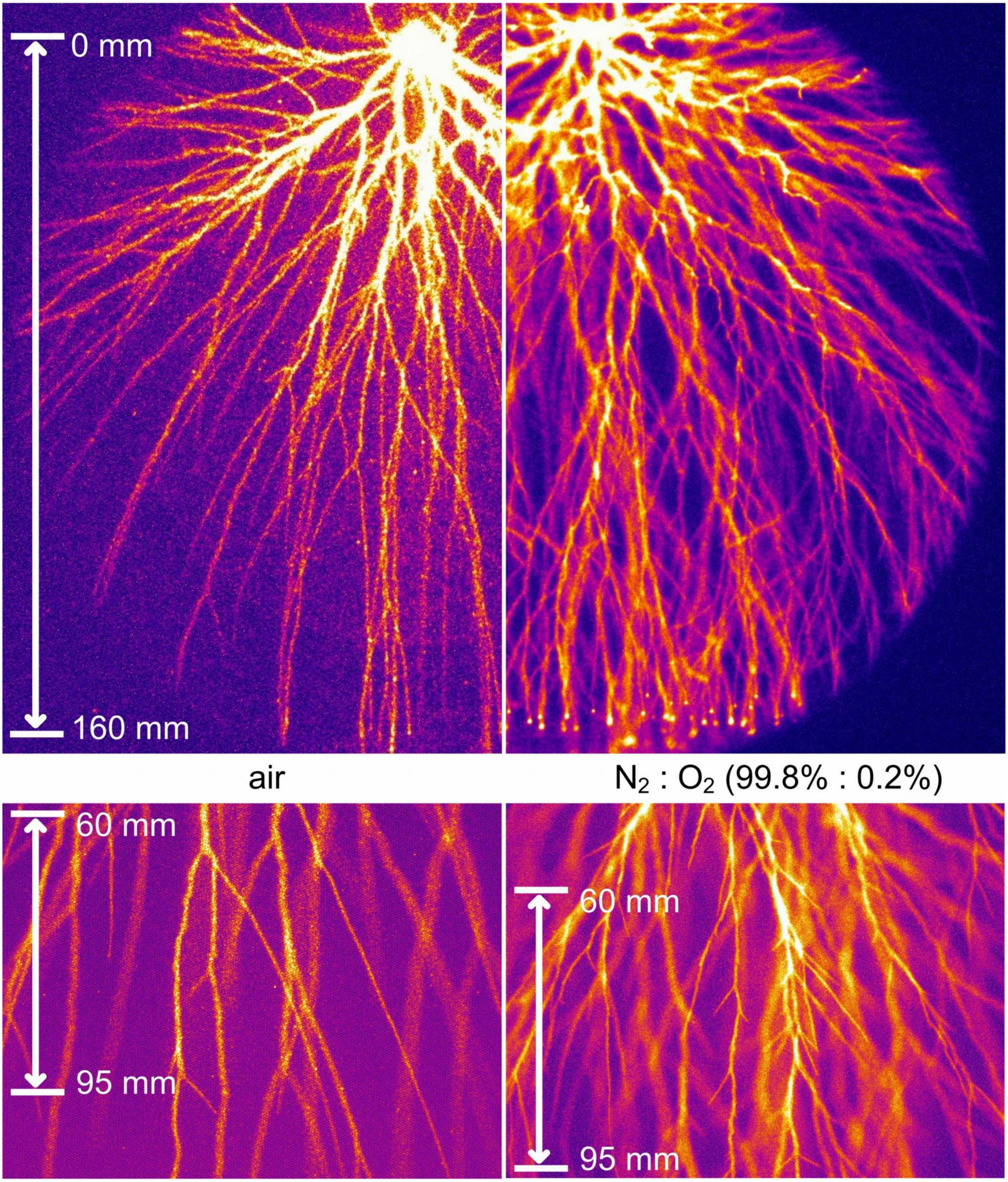

Fig. 1. Positive streamers at 400 mbar and 30 kV in (left) a 160-mm gap in air and (right) 99.8% $N_2$:0.2% $O_2$. The top photographs show the complete discharge. The dark ring around the photographs is the edge of the viewing port of the setup. The gate delay and the gate width (cf. [6]) are 0 and 70 $\mu$s in air and 0 and 5 $\mu$s in $N_2 : O_2$, respectively. The bottom photographs zoom into the middle region of the 160-mm gap at a position of 60–95 mm from the anode tip. The gate delay and the gate width are 0 and 4 $\mu$s in air and 1 and 3 $\mu$s in $N_2 : O_2$, respectively. Note that the photographs cannot be compared in intensity since the streamers in $N_2 : O_2$ are much more intense and, thus, recorded with different camera settings.