

Branching of Positive Discharge Streamers in Air at Varying Pressures

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Abstract—The formation of positive streamers in a 17-mm gap in air is studied at pressures varying in the range from 1010 to 100 mbar. An intensified charge coupled device camera is used to image the discharge. At high pressures, the discharge shows many branches, while at low pressure, fewer branches arise. The structure is not simply determined by the ratio of voltage over pressure.

Index Terms—Corona, gas discharges, optical imaging, sparkgap.

STREAMERS are narrow rapidly growing channels, which arise when a high voltage is applied to a nonconducting medium like air. They form the early stages of sparks of all sizes. Recently, they have been observed at low-pressure in the atmosphere at ~ 40 to 90 km altitude; here, they are called sprite discharges [1]. Since streamers are also used in industry, e.g. in water cleaning or photocopiers, a better understanding of the phenomena is desirable. Therefore, at Eindhoven University of Technology, The Netherlands, experiments are performed on streamers [2], [3], while at the Center for Mathematics and Computer Science The Netherlands, analytical research [4] and simulations [5] are done. We aim at a quantitative comparison between theory and experiment of different streamer parameters.

The measurements are performed in a 17-mm point-plane gap in air. A high-voltage power supply charges a 250-pF capacitor via a 5-M Ω resistor. This capacitor discharges over the point-plane gap when the electric circuit is closed via a switch. There are two types of switches that can be used, a semiconductor switch and a sparkgap [2]. In the present measurements, a sparkgap is used, which leads to a voltage pulse at the anode with a rise time of 10 ns.

The pictures are made with a fast intensified charge coupled device (ICCD) camera (Andor DH534-18), which has a minimum optical gate of 0.8 ns and a spatial resolution of 21 μm . Here, a long illumination time of 10 μs is used. For compar-

ison, typical streamer propagation times at 1 bar are ~ 100 ns. Furthermore, the images are made with different gains to obtain the clearest patterns and not to overexpose the camera. The relative intensities shown in Fig. 1 are corrected for the different gains.

Fig. 1 shows pictures of positive discharges at a pressure of (a) 1010 mbar, (b) 400 mbar, (c) 200 mbar, and (d) 100 mbar at different voltages. The left column shows the lowest voltage at which discharges occur at the respective pressure.

When comparing the pictures, it is observed that at high pressure, the discharge forms more and thinner streamers than at low pressure. At 1010 mbar, their number also increases with voltage while at lower pressures their number remains constant, i.e. four streamers at 400 mbar, two at 200 mbar, and one at 100 mbar. Furthermore, at 1010 mbar, streamers at low voltages do not bridge the gap, while at lower pressures they always do.

The pictures also show that the structures are not simply determined by U/p . If this would be the case, the picture at 20 kV and 1010 mbar should be comparable to the one at 8 kV and 400 mbar, which is not the case, or to a discharge at e.g. 4 kV and 200 mbar, which does not exist. This nonlinearity is also found when comparing [3] and [6]. In [3], a discharge is found in argon at 1000 mbar and a lowest voltage of 3.5 kV. In [6], measurements are done on argon at 4.65 mbar and 410 V. Hence, the pressures differ a factor of ~ 200 and the voltage only a factor of ~ 10 .

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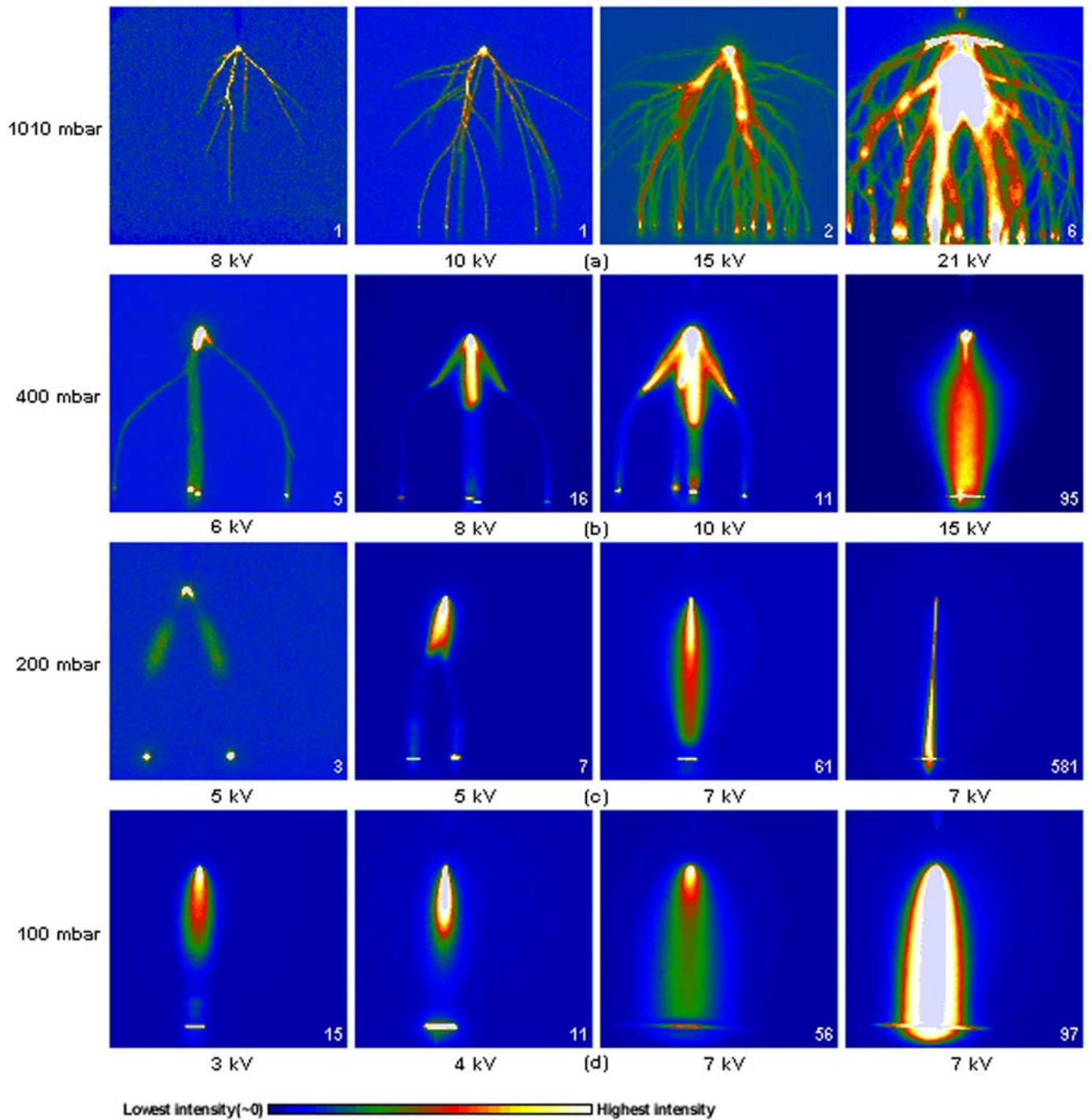


Fig. 1. ICCD images are time integrated pictures ($10 \mu\text{s}$) of the gas discharge at different pressures and voltages. Discharge starts at the positive anode tip and ends at the negative cathode plate, 17 mm below the tip. Relative intensities in a picture are indicated by the color bar, which has a linear scale. Relative intensity between pictures is indicated by the number in the lower right corner of each picture. Last picture of (b) and the last two pictures of (c) and (d) are sparks and are visible by naked eye. Other images are streamers.