The “cometary” discharge, a possible new type of DC electric discharge in air at atmospheric pressure, and its bactericidal properties

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Abstract. A new type of electric discharge was observed during studies of a DC discharge of the point-to-point type in air at atmospheric pressure. Some of its properties were studied with respect to its bactericidal properties.

1. Introduction
In previous papers we described the design of a simple setup generating a negative corona discharge in the point-to-plane arrangement [1, 2] and the microbicidal properties of the low-temperature plasma generated by this discharge in air [3, 4]. In so far unpublished works, we also attempted to employ other discharge types and arrangements, namely the positive corona of the point-to-plane type and the discharge of point-to-point type. The overall physical properties of various known types of DC discharge, namely the negative and positive corona, were previously described in details in several works, e.g. Sigmond et al. [5]. However, studying the point-to-point discharge, we observed a new phenomenon, which we provisionally called the “cometary” discharge in view of its shape; some of its properties are described below.

2. Experimental arrangement
We used the simple electric circuit drawn schematically in figure 1(a). An HT 2103 apparatus (Útes Brno, Czech Republic) was used as the source of variable high voltage, with maximal voltage 10 kV and current up to 0.5 mA. The electrodes were arranged in parallel; the positive one was tilted approximately 30° from the vertical. Ordinary medical injection needles served as electrodes, but very similar results were obtained with electrodes made from tailor’s pins. The setup was used to study the microbicidal effects of low-temperature plasma generated the between electrodes in samples placed below electrodes. The detailed results of this research will be published elsewhere as soon as they will be compiled.

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3. Generation of the “cometary” discharge

The ordinary point-to-point discharge is shown in figure 2, where the ellipsoid of low-temperature plasma between the electrodes can be seen. A new type of discharge is formed if the positive electrode tip is lifted 1 to 2 mm above the tip of negative one, figure 1(b), and the voltage and the inter-electrode distance (see below) are maintained within the values specified in table 1. Under these conditions, an additional cloud of plasma arises, streaming not from the positive to the negative electrode, but rather into the space below the electrodes. This cloud, resembling the tail of a comet, is shown in figure 3.

Figure 1. Schematic diagram of the setup for generation of low-temperature plasma by the common point-to-point (a) and “cometary” (b) discharges.

Figure 2. An ordinary point-to-point discharge between the positive (at right) and the negative electrode (at left).

Figure 3. A “cometary” discharge streaming from the positive electrode (at right) below the negative electrode (at left).
This “cometary” discharge is formed if the inter-electrode distance is greater than 4 mm and is sustainable up to a distance of 12 mm. The voltage applied $U$ must be kept within the minimal and maximal limiting values given in table 1 for the various inter-electrode distances $d$. The common point-to-point discharge appears at the lower $U$ value and is extinguished at the higher one. The values of the corresponding DC current $I$ are also given in table 1 and plotted in figure 4. Under these conditions, the burning of discharge is temporally steady. The current has a direct component without a superposed alternating one with a frequency lower than 20 kHz. Nevertheless, the presence of higher frequencies cannot be excluded. The plateau and the consecutive decrease of the current values at higher $d$ are caused by the limits of the source used, which cannot deliver more than 10 kV.

### Table 1. Distance – voltage – current conditions necessary to sustain the “cometary” discharge. The “cometary” discharge only burns between the minimal and maximal voltage and current values. The maximal voltage and current values for distances over 9 mm were not measured due to the 10 kV voltage limit of the source used.

| $d$ /mm | $U$ /kV | $I$ /μA | $U$ /kV | $I$ /μA |
|---------|---------|---------|---------|---------|
| 4       | 4.4     | 50      | 6.0     | 200     |
| 5       | 6.2     | 50      | 7.0     | 270     |
| 6       | 6.2     | 50      | 8.1     | 330     |
| 7       | 6.3     | 30      | 8.2     | 360     |
| 8       | 6.5     | 30      | 9.8     | 400     |
| 9       | 7.7     | 30      | > 10    | 400     |
| 10      | 8.8     | 30      | > 10    | 300     |
| 11      | 9.0     | 30      | > 10    | 250     |
| 12      | 9.2     | 30      | > 10    | 250     |

4. Comparison of bactericidal effects

The bactericidal effects of the common point-to-point and the “cometary” discharge were assessed on cultures of *Staphylococcus epidermidis* and *Escherichia coli* bacteria. The agar plates were inoculated with bacterial suspensions and exposed to both discharges generated at 10 kV and acting for 15 minutes. After incubation of the plates, inhibition zones appeared in the bacterial cultures. The shape of the zones differs markedly: after action of the common point-to-point discharge, a divaricating zone appeared resembling a butterfly. On the contrary, the “cometary” discharge yielded elliptical zones occupying a larger area and no divarication was apparent. Images of the inhibition zones of both discharges with the position of electrodes indicated are shown in the figure 5.

In the next experiments, we placed a drop of bacterial suspension onto an inert surface and exposed it to the common point-to-point and to the tip of the “cometary” discharge. The complete sterilization of the liquid occurred within about 2 minutes in both cases. These effects were of comparable magnitude with those observed after action of other DC discharges described in our previous works [1, 3 and 4].
5. Conclusions
The “cometary” discharge represents a new type of electric discharge producing low-temperature plasma and displaying bactericidal effect. We still have no theoretical explanation of its origin and we continue to investigate its properties and compare them with those of other discharge types.

Acknowledgments
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