Plasma Jetlike Point-to-Point Electrical Discharge in Air and Its Bactericidal Properties

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***Abstract*—A new type of point-to-point plasma jetlike electric discharge at atmospheric pressure in air without outsource gas flow was observed. Some of its properties were studied, including its bactericidal properties.**

***Index Terms*—Corona, gas discharges, microorganisms, plasma torches.**

I. Introduction

LOOKING FOR NEW types of devices generating the low-temperature plasma used for decontamination or sterilization is still actual; for review, see, e.g., [1] and for new plasma devices, see, e.g., [2], [3]. In our previous papers, we described the construction of a simple apparatus generating plasma by the negative corona discharge in air and its microbicidal properties in the point-to-plane arrangement [4]–[7]. Studying the point-to-point discharge, we observed a new phenomenon, provisionally called the "cometary" discharge. This discharge resembles the plasma jet torch, induced by RF not only in the stream of a noble gas, usually argon [8], but also in the stream of the room air [9]. According to its appearance, either the term plasma jetlike point-to-point or cometary discharge should be coined for this new type of discharge. Some of its properties are documented further.

II. Experimental Arrangement

The simple electric circuit is drawn in Fig. 1(a). The HT 2103 apparatus (Utes Brno, Czech Republic) was used as the source of the variable dc voltage, giving the maximal voltage of up to 10 kV and a current of up to 0.5 mA. The electrodes were arranged in parallel. The positive one was tilted ca. 30° from the vertical line. Common medical injection needles served as the electrodes, but similar results were obtained with electrodes made from tailor pins.

III. Appearance of the Jetlike Discharge

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

This cometary discharge is formed if the interelectrode distance is greater than 4 mm and is sustainable up to the distance of 12 mm. At various distances d, the applied voltage U and corresponding dc current I must be kept within minimal and maximal boundary values given in Table I. At a lower U, the common point-to-point discharge appears, and at the higher one, the discharge extinguishes. Under these conditions, the burning of the discharge is steady in time. The plateau and consecutive decrease of the current values at a higher d are

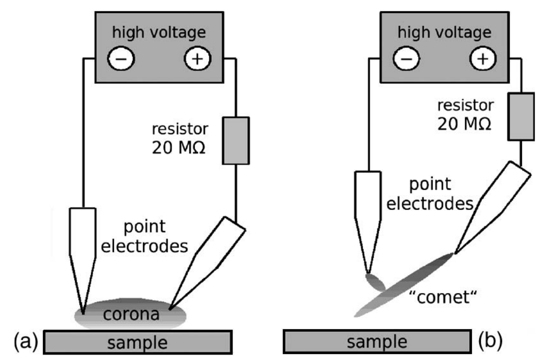

Fig. 1. Scheme of the apparatus for the generation of low-temperature plasma by (a) common point-to-point and (b) cometary discharges.

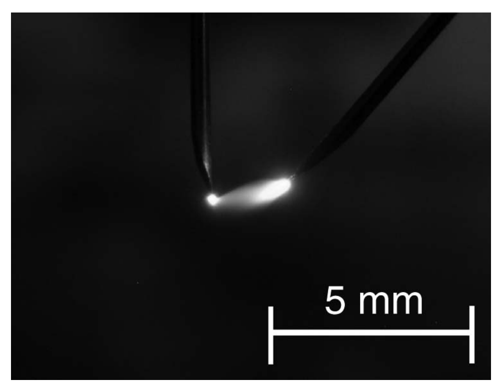

Fig. 2. Appearance of the ordinary point-to-point discharge between the (at the right) positive and (at the left) negative electrodes.

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TABLE I
DISTANCE–VOLTAGE–CURRENT CONDITIONS FOR THE COMETARY DISCHARGE BURNING

	minimal		maximal	
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

The "cometary" discharge burns between the minimal and maximal values of voltage and current only. The values of maximal voltage and current for the distance over 9 mm are unmeasurable due to the 10 kV voltage limit of the used source.

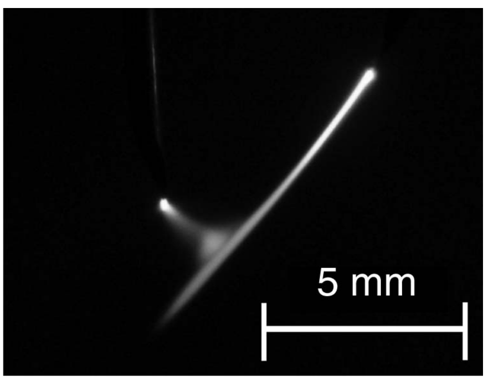

Fig. 3. Cometary discharge streaming from (at the right) the positive electrode below (at the left) the negative electrode.

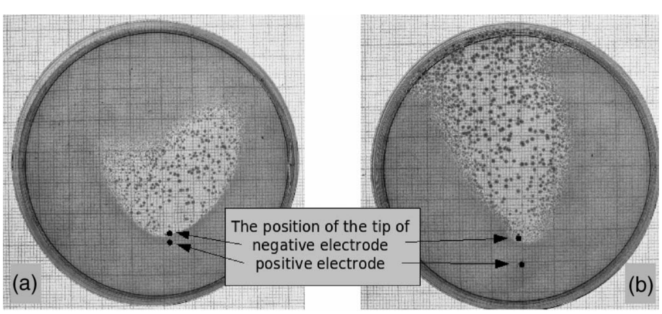

Fig. 4. Inhibition zones of *Escherichia coli* bacteria of (a) ordinary point-to-point and (b) cometary discharges with the position of electrodes indicated.

caused by the limits of the used source, which cannot deliver more than 10 kV.

Due to the appearance of this discharge, its characteristics seem to be similar to the common positive or negative corona discharge, i.e., the density of the charged particles about $10^9 - 10^{13}$ cm^{-3} and the electron temperature about 5 eV [10]. More accurate investigation is still in progress.

IV. COMPARISON OF BACTERICIDAL EFFECTS

The bactericidal effects of the common point-to-point and cometary discharges were assessed on cultures of *Staphylococcus epidermidis* and *Escherichia coli* bacteria. The agar plates were inoculated with bacterial suspensions and exposed to both

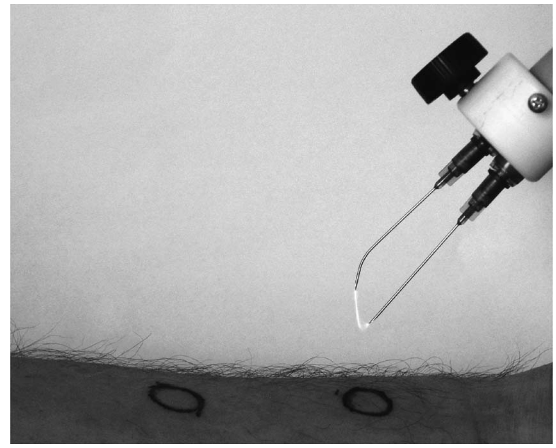

Fig. 5. Exposition of human forearm to the cometary discharge.

discharges generated at 10 kV and acting for 15 min. After the incubation of the plates, the inhibition zones appeared in the continual growth of bacterial cultures. The shape of the zones differs markedly: After the action of the common point-to-point discharge, the divaricating zone appeared resembling a butterfly. On the contrary, the cometary discharge yielded elliptical zones taking a larger area, and no divarication was apparent. The shape of the inhibition zones with the position of electrodes indicated are shown in the Fig. 4.

In the next experiment, we placed a drop of bacterial suspension onto the inert surface and exposed it to the common point-to-point discharge and to the tip of the cometary discharge. The complete sterilization of the liquid occurred within ca. 2 min for both bacteria. These effects were comparable with those observed after the action of other dc discharges described in our previous works [4]–[7].

To demonstrate the bactericidal ability of the cometary discharge in natural conditions, we also applied it directly on human skin. A smear was taken from 1 cm^3 of untreated skin using a cotton swab, eluted in 1 ml of physiological saline, and inoculated onto Mueller-Hinton agar, and colonies were counted after the incubation. The same procedure was repeated for the skin irradiated for 10 min by the cometary discharge, where a certain lowering of the bacterial colonization was observed. The arrangement of this preliminary experiment is documented in Fig. 5.

V. CONCLUSION

The cometary or plasma jetlike discharge represents a new type of electric discharge producing the low-temperature plasma and displaying bactericidal effects. We still have no theoretical explanation of its origin, and we continue to investigate its properties and compare them with other discharge types.

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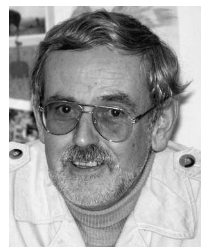

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