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Two Hollow Needles-to-Plate Electrical Discharge at Atmospheric Pressure

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Introduction

Electrical discharges at atmospheric pressure have many applications - starting from ozone generation, electrostatic precipitation, electrostatic charging of aerosols particles and in environmental applications such as cleaning of flue gases, decomposition of volatile hydrocarbons, destruction of toxic gases etc. Among different types of non-thermal plasma devices the multipoint-to-plate discharge electrode configuration is used. Usually the discharges are generated in gases flowing around the needles.

Problems concerning electrical discharge from two or more interacting needles were studied in [1-6]. All these works were however devoted to the study of the discharge in a still air [1-4] or to the study of the discharge with the external gas flow around the needle electrodes [5-6]. Thus in [1-3] was found that when the needles are brought together the onset voltage increases with a subsequent decrease of the corona current for the same applied voltage. Following results presented in [3] discharge with negative needle polarity results in higher corona current. It was also found [5] that for the negative needle corona the currents are more dependent on interpoint distances than for the positive corona. For the both polarities of needle the total current from multipoint electrode increases with the increasing interpoint distance. Electrical parameters of different types of multicorona discharge reactors and production of ozone for the flow of oxygen through the discharge chamber is studied in [6]. It was found that the type of electrode system weakly influences ozone production.

However in all these papers the discharge is enhanced by a flow of gas around the needle electrodes. For the purpose of plasmachemical reactor it was proposed in [7] multineedle-to-plate electrode configuration in which needles are hollow and gas is supplied through the needles.

In this paper the results of experimental work of interaction of two hollow needle-to plate discharges are presented. The discharge is enhanced by the flow of air through needles.

Experimental arrangement

The experimental set-up is shown in Fig.1. Two stainless needles *N* of outer diameter 1.2 mm and inner diameter 0.7 mm were placed in the middle of a rectangular channel of the height h=14.4 mm, width w=20 mm and the length l=80 mm.

The tips of the needles were sharpened at the angle 15° in such a way that the openings of needles were oriented downstream the discharge chamber. Both needles were through ballast resistors R=0.92 MΩ attached to the same potential. Currents of the fixed and movable needle were measured by ammeters I_f and I_m respectively. Position of the first needle was fixed. Second needle was attached to a micrometric screw so that it can be moved in a precise way with respect to the first fixed needle downstream or upstream the channel. The distance between fixed and movable needle is denoted as *s*.

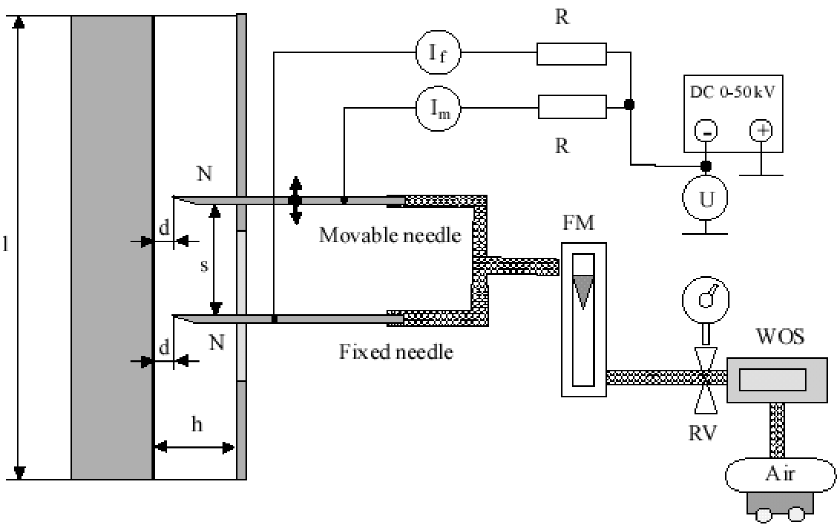

Fig.1. Experimental set-up

Steel wall of the channel opposite to the needles was used as a second electrode. Experiments were carried out with a dry air that was supplied through water and oil separator WOS by a compressor. The flow of air through needles was measured by a flowmeter FM.
DC power supply provided voltage up to 50 kV. Polarity of needles could be changed.

Experimental results

Results presented in following figures were obtained for the distance between the tip of the needle and the plane electrode d=3,2 mm and for the air flow rate through each needle Q=10 l/min.
V-A characteristics of the fixed and movable needle are shown in Fig.2 for needles positive and in Fig.4 for needles negative. From Fig.2 can be seen that for the separation between needles $s \geq 11mm$ these characteristics are identical and the same as for the single isolated needle.

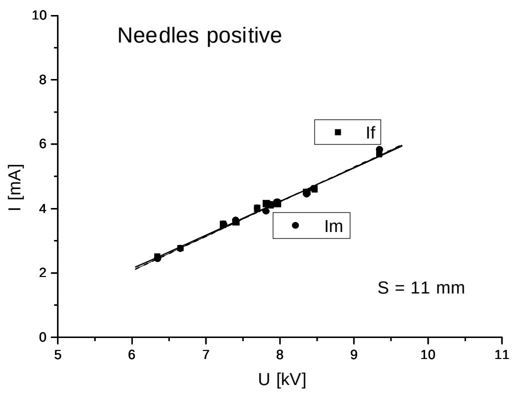

Fig.2. V-A characteristics

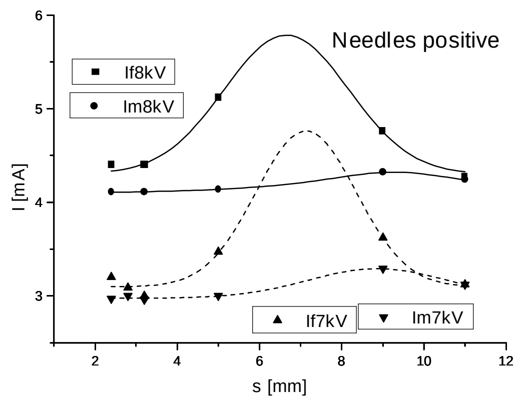

Fig.3. Current of needles versus distance

On the other hand if the movable needle approaches to the fixed needle, the current of the fixed needle for particular voltage increases - see Fig.4. This figure is for the distance between needles s=9 mm.

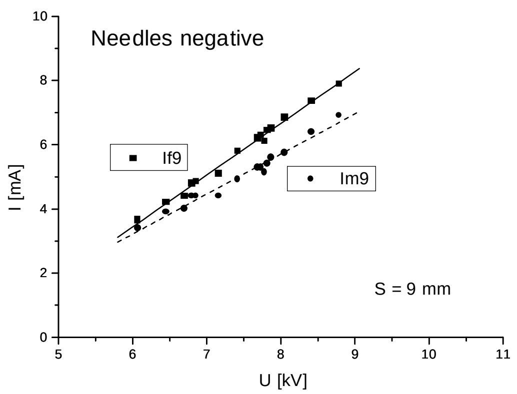

Fig.4. V-A characteristics

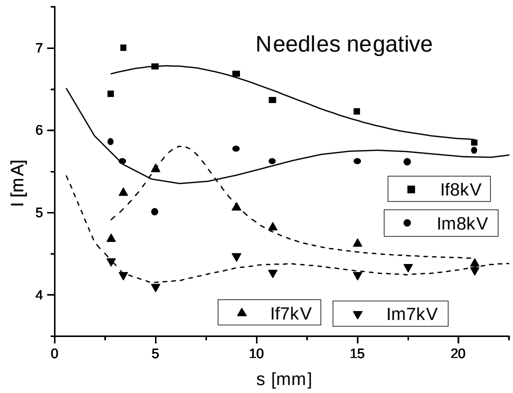

Fig.5. Current of needles versus distance

Finally current of the fixed and movable needles as a function of separation *s* between them for positive and negative polarity of needles and discharge voltages 7 and 8 kV are shown in Fig.3 and in Fig.5. From these two figures following conclusions can be taken:

1. For both polarities of needles increasing voltage causes increased current of each needle.
2. Current of the fixed and movable needle is higher for negative polarity of the needles than for positive polarity.
3. Current of the fixed needle is higher than the current of the movable needle.
4. Distance between needles influences more significantly current of the fixed needle than the current of the movable needle.
5. Currents of the needles positive reach the same value for smaller distances between them than for negative polarity of the needles ($I_f \sim I_m$ for s about 11 mm for the needle positive and $I_f \sim I_m$ for s about 20 mm for the needle negative).
6. From the comparison of the maximum current of the fixed needle as a function of the distance s for voltage 7 and 8 kV it is seen that the distance between needles s_{max} for which is obtained the maximum current of the fixed needle slightly decreases with increasing voltage. This dependence is more expressed for needles positive.

Discussion

Experimental results can be explained taking into account interaction between adjacent discharges.

Significant change especially of the current of the fixed needle as a function of the distance between needles can be caused by two effects. First of all space charges generated by adjacent needles interact and affect the ionization processes near each needle. As far as the fixed needle is situated downstream from the movable needle the flowing gas blows out the space charge downstream, changing additionally the space charge distribution of the fixed needle and thus affecting discharge characteristics. Current of the fixed needle is therefore more influenced by the proximity of the movable needle than the current of the movable needle is affected by the proximity of the fixed needle. The second effect that can affect current of the fixed needle can be caused by ozone. Hollow needle to plate electrical discharge enhanced by the flow of the gas through the needle is an efficient source of ozone [8]. Due to the dissociative attachment of electrons to ozone molecules the number of free electrons is

reduced and thus the discharge current is decreased [9]. The change of the fixed needle current is probably combined result of these two effects.
From the obtained results a certain optimum distance between needles for which the current of the fixed needle reaches maximum value can be found. Results presented in this paper can be used for design of electrode configuration of efficient multineedle to plate plasmachemical reactor for environmental applications.

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