

# NEEDLE-TO-PLATE ELECTRICAL DISCHARGE AT ATMOSPHERIC PRESSURE FOR ECOLOGICAL APPLICATIONS

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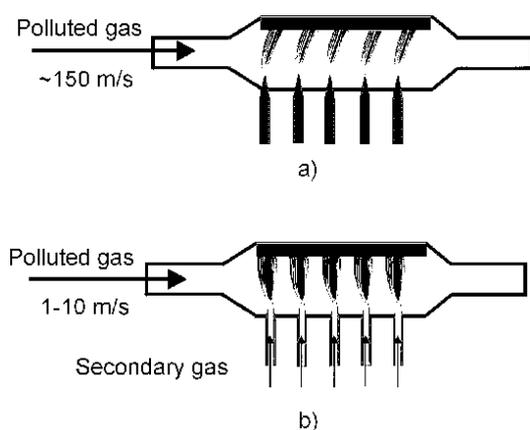
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## 1. Introduction

Non-thermal plasma at atmospheric pressure can promote favourable conditions to destroy hazardous chemicals. Electrical energy directed into the process chemistry creates highly reactive free radicals that oxidise/reduce pollutants, fragments pollutants directly or promote excited state chemistry. The most frequent way to produce a non-thermal plasma are electrical discharges.

Generally an atmospheric pressure electrical discharge is difficult to stabilise and it rapidly changes to a spark. To avoid transition to a spark discharge different methods are used: inter-electrode distance is changed so that the discharge is periodically interrupted, it is used a power source with a frequency of over kHz, it is used a dielectric covering of one or of both electrodes and finally it is used a gas medium flowing around electrodes.

In plasmachemical reactors for cleaning of polluted gases as a medium flowing around electrodes is frequently used the polluted gas itself. The use of a fast gas flow for a gas processing was presented in [1]. The gas flowed through a rectangular channel, the top wall of which was the anode plate and the multi-pin cathode was built into the bottom wall of the channel, see Fig. 1a. To prevent transition to the spark the velocity of the gas must be about 100 - 200 m/s. This requirement causes the problems when this method is supposed to be used for example for cleaning of the fuel gases from incinerators, hospitals, etc. Acceleration of all polluted gas to these high velocities requires, among others, additional energy that decreases energetic efficiency of the cleaning process. One of the ways how to avoid this problem and to stabilise needle-to-plate electrical discharge is to use except of external flow of the polluted



**Fig. 1.** Plasmachemical reactor

gas around the electrodes, the electrodes in the form of hollow needles through which flows secondary gas (air or other medium) see Fig. 1b. The main advantage of this arrangement is that all the polluted gas need not be accelerated to high velocities, and to stabilise the

channel, see Fig. 1a. To prevent transition to the spark the velocity of the gas must be about 100 - 200 m/s. This requirement causes the problems when this method is supposed to be used for example for cleaning of the fuel gases from incinerators, hospitals, etc. Acceleration of all polluted gas to these high velocities requires, among others, additional energy that decreases energetic efficiency of the cleaning process. One of the ways how to avoid this problem and to stabilise needle-to-plate electrical discharge is to use except of external flow of the polluted

discharge relatively small amount of gas flowing through the needles is required. In this work the results of electrical parameters investigations of the basic pixel of future plasmachemical reactor - a single needle-to-plate discharge - are given.

## 2. Experimental study

The experimental set-up, similar to that presented in [2], is shown in Fig.2. A stainless hypodermic needle  $N$  of the outer diameter 1,2 mm and inner diameter 0,7 mm was situated in the middle of a rectangular channel of the height  $h=14,4$  mm, width  $w=20$  mm and the length  $l=80$  mm. As a second electrode it is used the wall of the channel opposite to the needle. As a cooling medium was used a dry air which was supplied through water and oil separator WOS by a compressor. The airflow through the needle, measured by a flowmeter FM, could be changed up to 35,6 l/min.

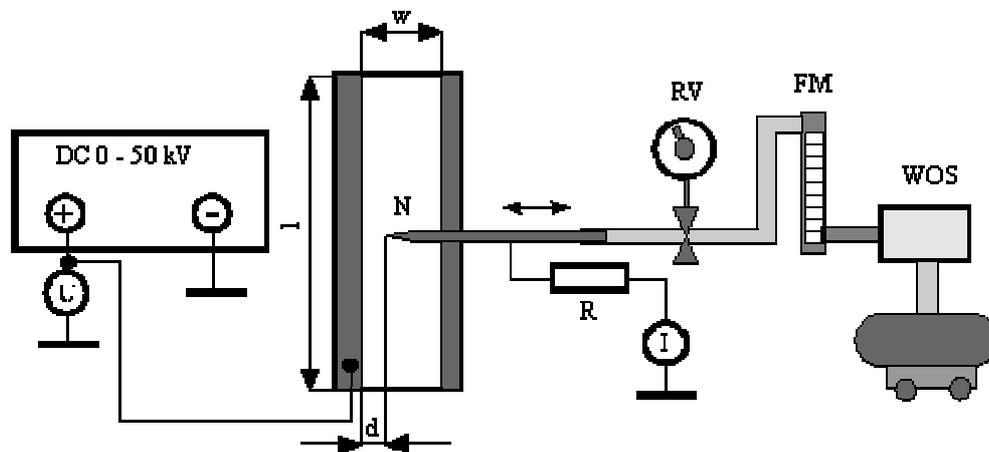


Fig. 2. Experimental set-up

DC power supply provides voltage up to 50 kV. Polarity of the needle as well as the separation  $d$  between the tip of the needle and the plane electrode could be changed. The needle was ballasted by a resistor  $R=1M\Omega$ . Experiments were devoted to the study of the basic electrical parameters of the discharge on the polarity of the needle, needle-to-plate separation and on values of the airflow. Results of experiments are shown in Figs. 3 - 6.

First experiments were devoted to the study of the distance  $d$  between electrodes on the V-A characteristics. As it was expected it was found that for both polarities of the needle for a given current with increasing needle to plate separation discharge voltage increases. This conclusion was obtained for all values of airflow as well as for both polarities of the needle.

Polarity of the needle influences the discharge stability. Thus for the negative polarity of the needle the discharge was more difficult to control, with sparking occurring frequently.

Except of it the discharge with positive polarity of the needle requires, for the same current, a higher voltage, see Figs. 3 and 4. This conclusion has been obtained for all values of the airflow.

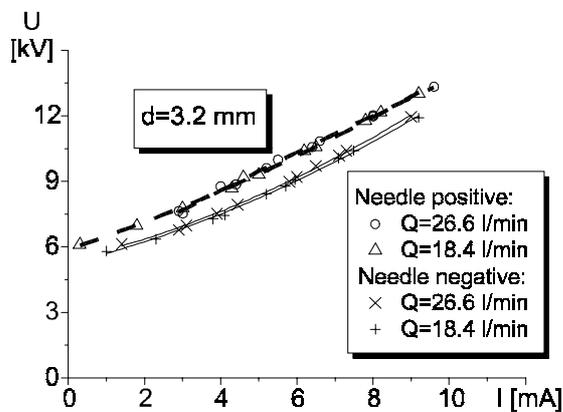


Fig. 3. V-A characteristics

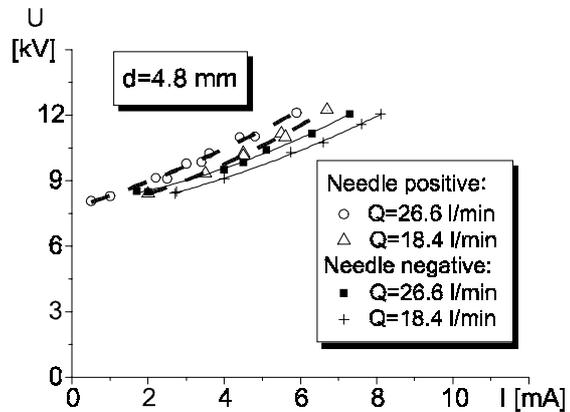


Fig. 4. V-A characteristics

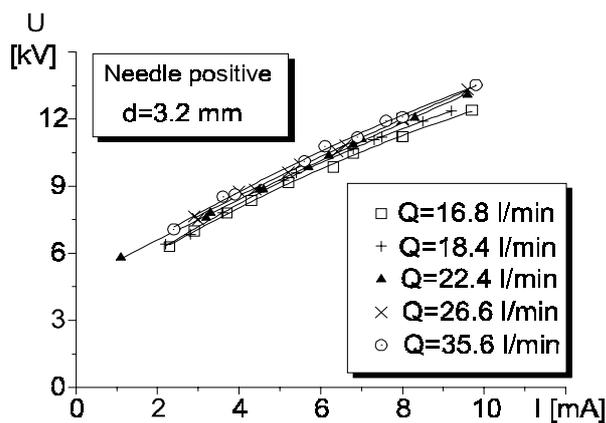


Fig. 5. V-A characteristics

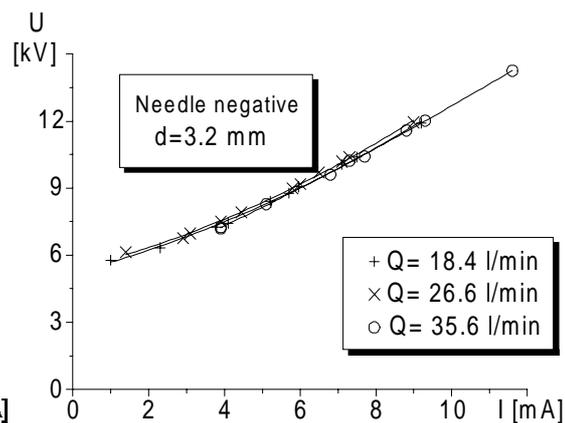


Fig. 6. V-A characteristics

Following results presented in Figs. 5 and 6 the effect of airflow is different for positive and for negative polarity of the needle. Thus for the positive polarity of the needle, see Fig.5, the change of the airflow through the needle from 16,8 to 35,6 l/min increases for a given current the discharge voltage. However for the same electrode separation and for the negative polarity of the needle, see Fig. 6, no influence of the airflow on the volt-ampere characteristics of the discharge was observed. This result is in agreement with those presented in [5] for electrodes with external gas flow.

### 3. Conclusions

Effect of an airflow on parameters of the discharge with active electrode in the form of hollow needle through which flows the air has not been up to now studied. For electrodes with external flow of the gas similar experiments are described in [3, 4 and 5].

As it is seen from our results V-A characteristics of an atmospheric pressure electrical discharge with airflow through the active electrode depend, among other, on the distance between electrodes, on the polarity of the active electrode and in the case of the positive needle also on the airflow.

The airflow influences the distribution of the space charge around the active electrode. If the direction of the external electric field coincides with the vector of the velocity of the airflow (as in the case of positive needle) then the motion of negative ions against the direction of the external electric field is slowed down. When the velocity of the airflow is higher than velocity of negative ions, it is even possible that these ions will be stopped and will be cumulated in the discharge gap. On the contrary if the external electric field acts opposite to the vector of the velocity of the air flow (as in the case of negative needle) then the motion of negative ions in the direction of the external electric field will be accelerated. Thus the shape of the volt-ampere characteristics will be different for different polarities of the needle.

For the negative polarity the discharge current does not depend on the airflow (see Fig.6). It is probably due to the fact that the main component of the current is electronic, the electrons possess high mobility and flow to the anode with higher velocities as compared with velocity of flow of air. Thus the gas flow had only a weak effect on the discharge current.

The complex nature of the studied phenomena requires further comprehensive experimental and theoretical work.

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