Impact of the pre-deposited surface charge on the breakdown in a dielectric barrier discharge in the air

Y Akishev1,2, V Karalnik1, A Petryakov1, T Shao3, C Zhang3
1 JSC «SRC RF TRINITI», Moscow, Troitsk, Pushkovykh Str., 12, 108840, Russia, 2 NRNU MEPhI, Moscow, Kashirskoe shosse, 31, 115409, Russia, 3 Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing 100190, China

E-mail: akishev@triniti.ru

Abstract. The electrical charge deposited on a dielectric barrier of dielectric barrier discharge (DBD) changes markedly the configuration and strength of the local electric field both on the barrier and in the gas gap. In turn, a change in the local electric field affects the rate of ionization multiplication of electrons in this area and, accordingly, influences the breakdown conditions providing the appearance of microdischarges in a barrier discharge. The features of the DBD breakdown in the presence of the pre-deposited charge on a dielectric barrier were investigated by the example of the plane-to-plane DBD operating in the ambient air at atmospheric pressure. The electric charge deposition on the barrier was performed in advance with the use of the pulsed pin-to-plane barrier corona. Corona discharge allows one to control both the amount and location of the pre-deposited charge. The slow increasing voltage of the needed polarity was used to initiate the breakdown in the plane-to-plane DBD. The slow increasing applied voltage provides the multiple breakdowns forming the “one by one” sequence of MDs. The analysis of the obtained results was performed on the base of the conception of the necessary and sufficient conditions for the MDs formation.

1. Introduction

The monopulse or periodic dielectric barrier discharges (DBDs) are widely used in various scientific researches and numerous practical applications [1-8]. In many cases, these discharges exist in the form of a large number of the spatially separated thin current filaments – microdischarges (MDs) randomly distributed within the interelectrode gap [9-15]. Each MD corresponds to the local breakdown of the gap when the voltage drop across the gap reaches the threshold magnitude. In fact, all MDs exist only a short time because the MD is the self-quenching discharge in principle. A reason is that the electric current of each MD provides deposition of the electric charges on dielectric barriers. These surface charges create the electric field $E_s$ directed conversely to the $E$-field formed in the gap by the external power source. The $E_s$-field magnitude quickly grows that leads to diminishing the resultant electric field down to low magnitude which is not able to support the MD existence. Eventually, it results in the MD decay. This is a reason why many publications on DBD are devoted to the investigation of the surface charge itself and different aspects associated with this charge as well [16-22].

In the case of periodical DBD, one of the important questions is the influence of the surface charge deposited in the previous half-cycle on the MD appearance in the subsequent half-cycle. According to the most popular opinion, the emergence of every MD in the next half-cycle happens at the same place...
where the surface charges have been deposited by MD during the previous half-cycle. A reason is that the Es-field in the next half-cycle coincides with the E-field created by the power source. It means, the Es-field will promote the new MD formation just at the same place and even under the lower magnitude of the applied voltage [21]. This effect is called in literature a spatial memory of MD. If assume that each MD has a strong spatial memory, one may conclude the MD will always happen at the same place and under the same applied voltage magnitude. Indeed, under some experimental conditions in DBD of the plane-to-plane configuration, the MDs exhibit sometimes such behavior and form on the barriers nice stationary patterns regularly repeated from cycle to cycle [23-27]. In reality, the regular spatial-temporal behavior of MDs is rather an exception than a rule. This statement especially is true for DBD in electronegative gases like the air at atmospheric pressure.

Indeed, the experiments performed by [10,28] revealed the MDs formed by sinusoidal plane-to-plane DBD in the air do not keep constantly their location on the barrier but slowly and chaotically migrate over its surface. This phenomenon proves the MD spatial memory is not strong. A possible reason of that can be attributed to the absence of exact repeatability in the spatial distribution of the surface charges being deposited in different half-cycles. The surface charges location is determined by the configuration of surface streamers being formed by each MD on the barriers. The absence of the spatial repeatability of the surface streamers’ configuration is proved by Fig.1. This figure presents a set of streamer images taken at different half-cycles of barrier discharge in Ar. One may clearly see the configurations of the surface streamers in different half-cycles are not similar to each other. The surface streamers formed by MDs in DBD in air demonstrate the same behavior. Due to that, the “centers of gravity” of the deposited surface charges will slightly and stochastically change their position from one half-cycle to another. It leads to the slight displacement in the next half-cycle the position of the maximum electric field strengthened by the surface charges. Therefore, the next MD will develop along a few another direction compared to the previous MD.

![Negative half-cycle](image1.png)  ![Negative half-cycle](image2.png)  ![Positive half-cycle](image3.png)

**Figure 1.** Images (top view) of negative and positive surface streamers forming the configuration of the charges deposited onto the barrier. Sinusoidal pin-to-plane DBD, F=20 kHz, U=3 kV, Argon, P=1 atm, exposure time is 25 μs, the average diameter of the area occupied by streamers is 75-85 mm.

There is another feature of the MDs formed in the periodical DBD in its steady-state operating regime. The total charge transferred onto each barrier by all MDs over one cycle is equal to zero, i.e. \( Q_+ + Q_- = 0 \), where \( Q_+ \) and \( Q_- \) are the total charges transferred by MDs in the negative and positive half-cycles. However, this equality is satisfied on average over total barrier area. In fact, the charges \( Q_+ \) and \( Q_- \) are the sums of the charges transferred by individual MDs: 

\[
Q_- = \sum_{i}^{N_-} q_i^- \quad \text{and} \quad Q_+ = \sum_{k}^{N_+} q_k^+ ,
\]

where \( q_i^- \) and \( q_k^+ \) are the surface charges deposited by the \( i \)-th and \( k \)-th MDs in the negative and positive half-cycles; \( N_- \) and \( N_+ \) is the total amount of MDs. In general, due to various stochastic reasons, the charges transferred by different MDs in each half-cycle may be not equal to each other, i.e. \( q_i^- \neq q_j^- \) and \( q_k^+ \neq q_m^+ \). Moreover, these charges can vary from cycle to cycle.

Thus, in each half-cycle, the local electric field strengthened by the surface charges can appreciably vary over the barrier surface. It follows from this that in the course of half-cycle, the threshold voltage for the MDs appearance will form not simultaneously for all MDs on the barrier but at different times...
for every isolated MD. This effect was described in [10, 28] by the example of the sinusoidal (F=100 kHz) DBD in ambient air. In the experiment, the non-simultaneous appearance of MDs in a half-cycle was observed by the fast camera through the transparent plane barrier (see Fig.2). One may see in Fig.2 the MDs appear on the barrier at different places and different time moments of the half-cycle. Besides, MDs do not appear twice at the same place during a half-cycle. A possible reason is that the applied voltage amplitude used in this experiment was not enough for the repeated MD formation in a half-cycle. In principle, the new MD can arise again at the same place after decaying the previous one if the applied voltage continues to increase and the resultant electric field in this place will reach again the breakdown magnitude.

![Figure 2](image)

**Figure 2.** The typical characteristics of sinusoidal plane-to-plane DBD in the air in the steady-state regime. a) The current-voltage oscillograms before and after MDs appearance. F=100 kHz; [t]=4 μs/div; [V]=5.2 kV/div; [I]=100 mA/div. b) Series of the current pulses in a single positive half-cycle, [t]=0.2 μs/div; markers 1-4 point the time position of the images presented below. 1, 3, 4 - Images of instant “fingerprints” of MDs on the barrier (top view through the transparent barrier). The total image composed of images 1, 3, 4 shows that MDs do not appear twice at the same place during a half-cycle. (This figure is taken from [10] with the permission of Eur. Phys. J. D)

At last, plasma has been formed in the gap by previous MD also influences the development of the subsequent MD. This influence is clearly pronounced in the case of DBD operating in gas flow oriented perpendicularly to the MD current direction. The flow transports the plasma "frozen-in" the gas but not drags the surface charges located within the boundary layers. Thus, if suppose the MD formation is determined only by the deposited surface charges location, MDs would not move by gas flow. In fact, the experiment shows [10, 28-34] the MDs are transported by the flow. It means the MDs appear in downstream barrier areas where the surface charges were absent.

One may conclude from the above that both the surface charges enhancing the local E-field and the volume plasma giving seed electrons are key factors influencing the MD initiation. However, studying the relative role of these factors in real periodical DBD with numerous MDs is not a simple task. The main reason is the mentioned above stochastic behavior of MDs in the time and space within each half-cycle and from cycle to cycle as well. Therefore, we have implemented this search by the example of the monopulse DBD in the plane-to-plane configuration in ambient air at atmospheric pressure and with the use of the surface charge deposited on the barrier in advance. The charge deposition was a separate procedure and performed in advance by pin-to-plane barrier corona. This type of discharge allows us to control both the amount and location of the pre-deposited charge on the barrier. Besides, the variation of the voltage magnitude applied to the monopulse DBD allowed us to
study the MDs behavior in the multi-breakdown regime when several successive MDs may appear at the place of the pre-deposited charge.

2. Experimental setup

In the experiments, we have used two setups the electrical schemes of which are shown in Fig.3. One of them (Fig.3a) represents the pin-to-plane barrier corona served to deposit the needed amount of electric charge onto the dielectric barrier. High-voltage (HV) electrode (the pin) in Fig.3a is the stainless steel wire with a diameter of 1 mm, the end of which was sharpened to a cone with a radius of 100 μm. The metallic pin can be also seen as a simulator of the MD plasma channel being formed in the plane-to-plane DBD. The distance between the wire tip and the dielectric barrier (quartz) is varied from 0 to 0.3 mm. The barrier DB1 serves as the barrier electrode for the barrier corona and as the bottom barrier electrode for the plane-to-plane DBD as well. An electric charge Q was deposited due to a short-term transient surface discharge happening on dielectric barrier after connection of the pin to the capacitor C1 through thyatron T. Important, before each deposition of a new pre-deposited charge Q, the dielectric barrier surface was being "cleaned" from any residual charges of the previous experiment. This procedure was performed with the use of the grounded soft brush made of many thin copper wires. Variation of the magnitude and sign of the pre-deposited charge Q was performed due to changing the amplitude and polarity of the DC voltage applied to capacitor C1. The amount of the charge Q was being determined from the measured voltage on the capacitor C2.

![Figure 3](image)

**Figure 3.** a) Setup for pre-deposition of the Q charge on a dielectric barrier. DB1 is the plane dielectric barrier of quartz disk; DC is the pre-deposited charge Q; T is the thyatron 1000 A/25 kV; R1 = 10 MOhm; R2 = 100 kOhm; R3 = 1, 10 and 300 kOhm; R4 = 0.75 Ohm, C1 = 50 nF, C2 = 1 μF. b) Setup for studying the breakdown in plane-to-plane DBD with the pre-deposited charge Q on the bottom dielectric barrier. DB1 is the bottom dielectric barrier; DB2 is the upper dielectric; the interelectrode distance h = 1 mm. T is the thyatron 1000A/25kV, R1 = 0.75 Ohm, R2 = 1MOhm, R3 = 240MOhm, R4 = 200kOhm, R5 = 10MOhm, C1 = 1μF, C2 ≈ 15 pF is the stray capacitance, C3 = 1.57nF, C4 = 10nF. c) The electric field strength radial distribution in DBD gap (h=1 mm) in the case of the pre-deposited charge amount Q = 0 (red curve) and Q = 5.5 nC (black curve). The applied voltage U=12.5 kV.

Another scheme (Fig.3b) depicts the plane-to-plane DBD served to study the influence of the pre-deposited charge on the DBD breakdown voltage (i.e. on the MD appearance), the number of breakdowns and the distribution of MDs on a barrier in presence of the pre-deposited charge Q. The feature of our approach is that the Q is deposited only onto a single (bottom) barrier DB1. It allows us to diminish twice the Q influence on the total E-field in DBD and to get several MD re-breakdowns happening one after another. The bottom dielectric barrier is a quartz disk (diameter of 40 mm and thickness of 2.4 mm, ε = 4) covered with metallic foil on the back side over the area with a diameter of 30 mm. The upper dielectric barrier (disk of glass ceramic with a diameter of 30 mm, thickness of 3.75 mm, ε ≈ 10) with metallic foil on the back side over the area with a diameter 20 mm.

Note, at the chosen parameters of the plane-to-plane DBD, the capacitance of the air gap between barriers and the total capacitance of the barriers are equal to each other with magnitude approximately 4.4 pF. It means the applied voltage is shared equally between capacitances of the barriers and the air gap in between two barriers. Next, the non-charged dielectric barrier was placed above the pre-charged barrier (Fig.3b). The interelectrode distance was equal to 1 mm. The chosen difference in the
diameters of metallic foils attached to the upper and bottom barriers leads to the radial inhomogeneity of the electric field strength in the DBD gap (see Fig.3c). In the case of the absence of the pre-deposited charge, this circumstance creates the preferential conditions for happening the MD around the axis of the DBD. However, the pre-deposited charge (as well as the charges deposited by DBD itself) shifts the E-field maximum to the peripheral area of the barriers.

At last, the relatively slow increasing voltage $U(t)$ of the needed polarity and amplitude was applied to the upper non-charged dielectric barrier. A long rise-time (several hundreds $\mu$s) of the applied voltage provides the wanted multiple breakdowns forming the “one by one” sequence of MDs in the air gap between two barriers. The discharge current and voltage were registered with the low-inductive current shunt $R = 1$ Ohm and the compensated voltage probe PINTEK HVP-39 (1000:1, 40 kV, 200 MHz), respectively, signals from which were recorded by a digital oscilloscope Tektronix DPO 2024. The breakdown moments were attributed with the appearance of sharp pulses on the current waveforms. An integrated visual picture of the MDs formed by the breakdowns was being captured by Canon EOS 550 and CASIO-EX-F1 digital cameras.

3. Experimental results

3.1. The surface charge deposition by the pulsed pin-to-plane barrier corona.
The pulsed pin-to-plane barrier corona deposits the surface charge on the barrier by the surface streamers. Therefore, a transversal size of the area occupied by the surface charge correlates with the area occupied by the surface streamers. This area was estimated by processing the surface streamer's images. As a result, the typical diameter of the area occupied by the charge deposited by corona is approximately equal to 2.5 mm.

3.2. The breakdown voltage measurement in the plane-to-plane DBD.
a) The pre-deposited surface charge on the barriers is absent. At the beginning, we have done the experiments with the applied voltage of negative and positive polarity in the absence of the pre-deposited surface charge on the barriers ($Q=0$). The typical examples of the obtained results reflecting the general behavior of the MDs are shown in Figs.4a and 4b. As it turned out, the absolute values of the breakdown voltages were practically the same ($U_b \approx 12.6$ kV) for both polarities. This magnitude corresponds to the very first breakdown (i.e. to the appearance of the very first MD) and will be used further as a reference value. In fact, the second, third, etc. breakdowns at $U(t) > U_b$ can also happen. However, their number is only a few and their current amplitudes are lower compared to that for the first one.

![Figure 4](image_url)

**Figure 4.** Typical DBD current pulses attributed to the first and others breakdowns under slowly increasing applied voltage $U(t)$: a) negative polarity, b) positive polarity. The typical duration of each current pulse is about 10 ns.

b) The pre-deposited surface charge on the barriers there is. The experiments with DBD at the presence of the pre-deposited surface charges on the bottom barrier were implemented. The aim was to search the influence of the pre-deposited charges on local breakdowns forming the MDs in the gap. We have studied two combinations: 1) a positive pre-deposited charge $+Q$ and negative polarity of the monopulse applied voltage $-U(t)$, and 2) a negative pre-deposited charge $-Q$ and positive polarity of
the monopulse applied voltage $+U(t)$. From the formal point of view, one may wait the E-field distributions within the DBD gap are mirror-symmetric for combinations $(+Q, -U(t))$ and $(-Q, +U(t))$, if $Q = \left| -Q \right|$ and $U = \left| -U \right|$ (here the sign $\left| \right|$ means the modulus). In such a case, the breakdown parameters for these combinations may be also close to each other.

In the case of the negative polarity of the applied voltage, the typical examples of the obtained data are presented in Fig.5. One may see, in contrast to Fig.4, there is a long sequence of many breakdowns (i.e. MDs) in the course of slowly increasing applied voltage. We have to emphasize despite our hard efforts to keep the same experimental conditions with high accuracy, a great statistical scatter of the results from one driving monopulse to another was revealed. The scatter can be clearly seen by the comparison of Figs.5a and 5b.

![Figure 5](image)

**Figure 5.** Two typical waveforms of the current pulses in DBD under slowly increasing voltage $U(t)$ at the presence of the same pre-deposited positive charge $Q = +11 \, \text{nC}$. The pulses are attributed to local breakdowns forming the MDs in the gap. The waveforms and amplitudes of the applied monopulse voltages are the same.

For happening the next breakdown, the additional increase $\Delta U$ in the applied voltage is required. In the case of the pre-deposited positive charge $Q = +11 \, \text{nC}$, the proper data are presented in Fig.6a (black curve). Note the data are averaged over many monopulses of the applied voltage. As a result, the current amplitudes in the successive breakdowns diminish monotonically from one pulse to another (Fig.6a, red curve). The additional voltage $\Delta U$ exhibits practically the same behavior. Important to note the diminishing both the current amplitude and the additional voltage $\Delta U$ in the successive breakdowns means that the surface charge deposited by each MD diminishes from one pulse to another. It is also interesting to trace the general behavior of the very first breakdown voltage $U_b$ with increasing the pre-deposited charge $Q$. This information is presented in Fig.6b for two combinations $(+Q, -U(t))$ and $(-Q, +U(t))$. Expectedly, the $U_b$ magnitude decreases with growing the pre-deposited charge. Recall, as mentioned above, the real breakdown voltage $U_g$ in the gas gap is twice lower compared to the measured applied magnitude $U_b$: $U_g = U_b/2$.

One should be noted the following main features in the MDs behavior induced by the pre-deposited surface charge. On the one hand, in different driving monopulses, there is no rigid reproducibility of such parameters as the breakdown voltage and the current amplitude of the emerging MDs and of their quantity as well. On the other hand, the pre-deposited charge appreciably diminishes the breakdown voltage for the very first and all next MDs and strongly increases the number of secondary breakdowns at $U > U_b$. 


Figure 6. a) The average current amplitudes (red curve) in the successive breakdowns and the additional voltage $\Delta U$ required for the next breakdown (black curve) in the course of the applied voltage growth. Pre-deposited positive charge $Q = +11 \text{ nC}$. b) The modulus of the applied voltage $U_b$ corresponding to the very first breakdown vs the modulus of the pre-deposited charge for two combinations: $(+Q, -U(t); \text{full circles})$ and $(-Q, +U(t); \text{open boxes})$.

There is a question about the appearance of MDs at the higher voltages $U > U_b$: if they happen only in the area with the pre-deposited charge or not. We have answered this question. To do that we have taken two pictures presented in Fig.7. One of them (Fig.7a) is the image of the pulsed barrier corona depositing the surface charge $Q = +8.0 \text{ nC}$ on the bottom barrier. The second one (Fig.7b) is the image of the monopulse DBD with this pre-deposited charge. So, at the higher voltages $U > U_b$, the conclusion is that the MDs happen also far from the area with the pre-deposited charge. Indeed, one may see in Fig.7b, the diameter of the area (20 mm) occupied by MDs is equal to the diameter of the metallic foil on the upper barrier backside. It means the transversal size of the area with the MDs exceeds appreciably the initial size of the pre-deposited charge.

Figure 7. Evidence of the MDs formation on the peripheral barrier area far outside the pre-deposited charge area. a) Image (side view) of the surface streamers (in red) formed by pin-to-plane barrier corona. The visual diameter of the area with streamers providing the charge pre-deposition is about 2.5 mm. The voltage amplitude is $+15 \text{ kV}$. b) Image (side view) of the area (in blue) occupied by all MDs being happened in the plane-to-plane DBD in the course of the slowly increasing the applied voltage up to $-17 \text{ kV}$. c) The radial distribution of the light intensity (in a.u.) emitted by the surface streamers. $Q = +8.0 \text{ nC}$.

4. Discussion

The development of local breakdowns forming the MDs in the barrier discharges has much in common with the development of streamers. Therefore, we will use the existing ideas on the streamers’ development in the air to explain qualitatively the obtained experimental results.

The necessary condition for streamer development in the electric field is the fulfillment of the Raether-Meek criterion: $\int (\alpha_l - \alpha_d) \, dl \cong M$, here $M=20$ is the empirical parameter determining quantitatively the electron avalanches multiplication needed for the streamer formation. Integration is
performed over an area where the Townsend ionization coefficient $\alpha_i$ is greater than the electron attachment coefficient $\alpha_a$: $(\alpha_i - \alpha_a) > 0$. In the ionization area, an intensive detachment of electrons from negative ions happens as well. However, important to note, the fulfillment of the Raether-Meek criterion, in itself, does not yet guarantee the streamer development.

The sufficient condition for the breakdown development (if the necessary condition is fulfilled) is the existence of seed electrons in the gap. In our case, the applied voltage increases slowly, and the all natural background charge particles leave the gap due to their drift to the barriers long before reaching the necessary breakdown condition. In fact, the small number of the natural negative ions are always adsorbed at the barrier surfaces. Because of the narrow interelectrode gap (1 mm), the necessary breakdown condition in DBD is realized at very high electric field strength in the gap (see Fig. 3c). At the $E/N > 200$ Td, the adsorbed negative ions can be desorbed and due to fast detachment processes in a strong electric field they will give seed electrons.

The analysis of the obtained results was performed on the base of the conception of the necessary and sufficient conditions for the MDs formation. To do that, the numerical calculations of the electrostatic electric field distributions in the DBD gap under different experimental conditions were performed. Based on these calculations, the radial distribution of the ionization multiplication coefficient $M(r) = \int (\alpha_i - \alpha_a) dl$ was determined at different pre-deposited charges. Besides, the charges deposited by the MDs themselves following one by one was taken into consideration as well and their influence on the general behavior of the $M$ magnitude was also studied. The obtained numerical results on the $M$ behavior were used to explain qualitatively the experimental results.

Figure 8 presents the typical examples of the numerical results reflecting the general behavior in the DBD gap of the $E$-fields and the $M$ magnitude. Figure 8a gives a general impression of the radial distribution of the $M$-magnitude with an increase in the applied voltage in the absence of the pre-deposited charge. The charges deposited by MDs at higher voltage were not taken into account. One may see in this figure, the Raether-Meek criterion is fulfilled at $U > 12$ kV predominantly in the central area of the barriers. It agrees with the experiment that the very first MD appears at the applied voltage $U \approx 12.5$ kV.

Figure 8b demonstrates the $M$-behavior in the gap in the presence of the pre-deposited negative charge $Q = -2.5$ nC on the bottom barrier playing the role of the cathode. The number at each curve corresponds to the ordinal number of MD in the sequence of MDs happening in the course of the growth of the applied voltage $U(t)$. Number 1 corresponds to the situation before the very first breakdown with the pre-deposited charge on the bottom barrier. Each MD deposits itself the charges on the upper and bottom barriers (see Figs. 8c and 8d). It results in the redistribution of the $E$-field in the gap and consequently in change the radial distribution of the $M$-magnitude (Fig.8b). In total, the charge deposition by MDs leads to the neutralization of the pre-deposited charge followed by a decrease the $M$-magnitude in the center and its increase in the peripheral area of the barriers. Eventually, the $M$-magnitude in the peripheral area reaches the value corresponding or exceeding the Raether-Meek criterion. Therefore, the several last MDs happening at the maximum of the applied voltage will appear at the peripheral area. This numerical result agrees with the experimental fact presented in Fig. 7b that MDs spread over the barriers far away from the area occupied by the pre-deposited charge. Fig.8c presents two color pictures for the $E$-distribution in the gap. The upper picture shows the $E$-distribution for the initial situation with the pre-deposited charge on the bottom barrier, the bottom picture shows the $E$-distribution corresponding to curves 10 when the pre-deposited charge is practically neutralized.
Figure 8. a) and b) The typical radial distribution of the $M = \int (\alpha_i - \alpha_a) \, dl$ in the gap in the absence and presence of the pre-deposited charge. The number at each curve corresponds to the ordinal number of MD in the sequence of MDs happening in the course of the growth of the applied voltage $U(t)$ up to $U \approx 16 \text{kV}$. Number 1 corresponds to the situation before the very first breakdown with the pre-deposited charge. c) and d) Radial distribution of the surface charges on the upper and bottom barriers with taking into account the charges deposited by MDs themselves. e) The $E$-distribution in the gap.

The upper picture shows the initial situation with the pre-deposited charge, the bottom picture corresponds to curves 10 when the pre-deposited charge is practically neutralized.

In the case of the pre-deposited charge absence, the E-field strength in the peripheral area can reach the same high magnitudes as those shown in Fig. 8b when the pre-deposited charge presents. However, the experiment revealed the multiple breakdowns under the applied voltage $U > U_b$ were not observed (see Fig.4). One may conclude therefore the multiple breakdowns produce some amount of reactive species (for instance, O-atoms and O$_3$-ozone) influencing the appearance of seed electrons in the peripheral area. It means the MDs can promote the formation of other MDs at new locations. It follows from that the surface charges only partially provide the spatial memory MDs. This remote influence on the appearance of new MDs eventually erodes the effect of the MD spatial memory based on the surface charges. One may say therefore - if the distant MDs can affect each other, there is no full additivity in characteristics of DBD in relation to MDs, i.e., in general, the total property of the large amount of MDs cannot be reduced to the sum of properties of the isolated MDs.

5. Conclusion
The experiments were performed with the plane-to-plane DBD operating in the air at atmospheric pressure. The DBD was driven by the monopulse voltage with slowly growing magnitude. The work
was aimed to clarify the role of the surface charges in the development of microdischarges formed between dielectric barriers. In particular, we investigated the influence of the surface charge on the so-called memory of MDs. To do that we locally deposited in advance the preset amount of the charge onto the one (bottom) barrier of the DBD. Under regime with slowly increasing applied voltage, two important things were revealed. First, the pre-deposited surface charge induces the local formation of many MDs happening in the “one by one” sequence. Second, these MDs promote the formation of many new MDs located far outside the area with the pre-deposited charge. The mentioned effect is not associated with the deposited surface charges but very likely with the volume processes like generation of reactive species (O, O₃) or photoionization of the air surrounding each MD. Both the reactive species and photoionization can produce seed electrons forming the new MDs in the area far from that occupied already with MDs. The total outcome related to DBD is the following: the surface charges deposit from that occupied already with MDs. The total outcome related to DBD is the following: the surface charges destroy this memory. To do that we locally deposited in advance the preset amount of the charge onto the one (bottom) barrier of the DBD. Under regime with slowly increasing applied voltage, two important things were revealed. First, the pre-deposited surface charge induces the local formation of many MDs happening in the “one by one” sequence. Second, these MDs promote the formation of many new MDs located far outside the area with the pre-deposited charge. The mentioned effect is not associated with the deposited surface charges but very likely with the volume processes like generation of reactive species (O, O₃) or photoionization of the air surrounding each MD. Both the reactive species and photoionization can produce seed electrons forming the new MDs in the area far from that occupied already with MDs. The total outcome related to DBD is the following: the surface charges destroy this memory.

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