Light emission of Dielectric Barrier Surface Discharge in Air formed by High Voltage of Different Form

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Abstract: Results of experimental investigation of light emission of surface discharge in dried Air from the edge of a strip electrode under impulse high voltage of different parameters and ac voltage are presented. Different microsecond impulse duration and different nanosecond wave front duration are used. Measured distribution of discharge light emission along the Alumina barrier surface and perpendicular to it is used to evaluate the length and the thickness of the plasma layer formed near the electrode edge during the surface discharge.

Keywords: surface discharge, atmospheric Air, light emission, plasma layer dimensions.

1. Introduction

The aim of the present work was to get additional information regarding the surface discharge physics in normal conditions of ambient Air. The main attention was paid to the dimensions of the plasma layer formed by the surface discharge near the electrode edge under periodic high voltage of different form (ac voltage and periodic impulse voltage of different impulse parameters). The promising application of plasma systems to flow control has raised an interest in the investigations of the surface discharge in Air. The results of experimental investigation of DBSD presented in [1] show strong dependence of the discharge area dimensions on the Air pressure, applied nanosecond impulse voltage amplitude and its frequency. The investigations described in the present work were done for atmospheric Air pressure, low gas humidity, constant gas flow up to 1.5 l/min and different form of the applied high voltage: ac and impulse voltage of the same frequency f = 3.5 kHz. The aim of the present investigation was to evaluate the influence of the ac voltage amplitude, impulse amplitude, impulse duration and impulse front duration on the parameters of the plasma layer developed near the electrode edge. Such characteristics as the spatial dimensions of the plasma layer, distribution of light emission of DBSD and the distribution of the charge left on the barrier surface are measured and analyzed.

2. Experimental

All results given below were achieved in accurately defined following conditions. The electrode configuration seen in fig. 1 includes a strip electrode of Ni 50 µm of thickness placed on one side of an Alumina dielectric plate (barrier) 48x60 mm of dimensions and 1.1 mm of thickness. The length of the strip electrode opened to the discharge formation was 14 mm. The strip electrode was grounded whereas the other electrode of copper foil 40x50 mm in dimensions that has been placed on the back side of the barrier was connected to the output of the high voltage source. All sides of the high voltage electrode had been covered by an epoxy layer to prevent possible surface discharges.

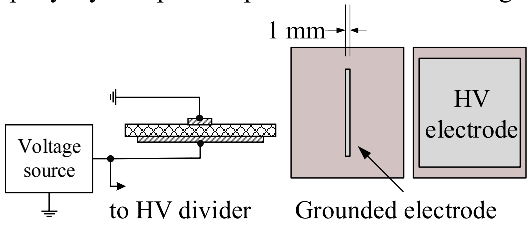

Fig.1. The electrode arrangement

The electrode system had been placed into a cell made of Plexiglas in such a way that the strip electrode with the discharge was vertical and perpendicular to the optical axis of the system. Two Quartz windows in two sides of the cell permit to measure the light intensity of the discharge in two directions: as a front view (face view fig.2a) or as a side view (profile view fig.2b) without opening the cell and changing the position of the electrode system. To change the position of the electrode system relative the optical axis the cell in a whole could be turned by 90^0.

The high voltage impulse amplitude was 6 kV throughout all measurements with impulse front duration τ_{fr} in the range of 60-250 ns and impulse duration τ_{imp} in the range 5-132 µs. The ac voltage value used was 2.5 and 2.8 kV (RMS values). The frequency in most experiments was 3.8 kHz for ac and for impulse voltage. Voltage probe P6015 and Tektronix 2012 oscilloscope were used to measure the voltage form.

The light emission of the discharge has been measured using the device developed in Moscow State University to analyze the time-spatial characteristics of a barrier discharge [2]. The block scheme of the device is given in fig. 2. The measuring element of the device is a photomultiplier.

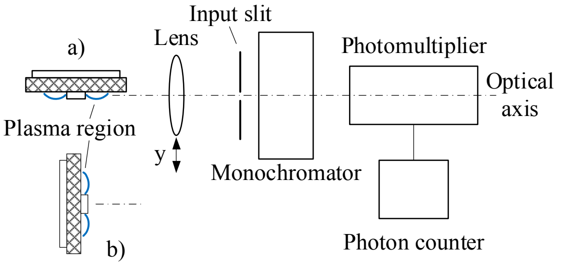

Fig.2. Optical scheme of the measurements with top view of different electrode positions relative the optical axis of the measuring system. a) Profile view. B) Face view

Together with a Monochromator it permits to register light emission with different wave lengths. All measurements were done for λ = 337.1 nm that is for second positive system of Nitrogen. The light signal registered by the photomultiplier was transformed by a special device (photon counter) to an amount of photons per second. The integral light flow from a certain part of the discharge was focused by means of a lens placed at middle point between the discharge and the entrance of the Monochromator (fig. 2). The whole distance between the electrode system and the slit was about 50 cm. The light intensity was limited by a vertical slit installed at the Monochromator entrance. All measurements were carried out with the slit aperture equal to 14 µm to prevent the damage of the photomultiplier.

The movement of the lens in horizontal (X direction) or vertical (Y direction) direction permits to scan the emission flow in space with a certain step. All measurements of the emission flow density distribution in space in both directions along x axis and along y axis as it is shown in fig.2, were done with steps equal to 100 µm. Throughout all measurements the slit was parallel to the electrode edge.

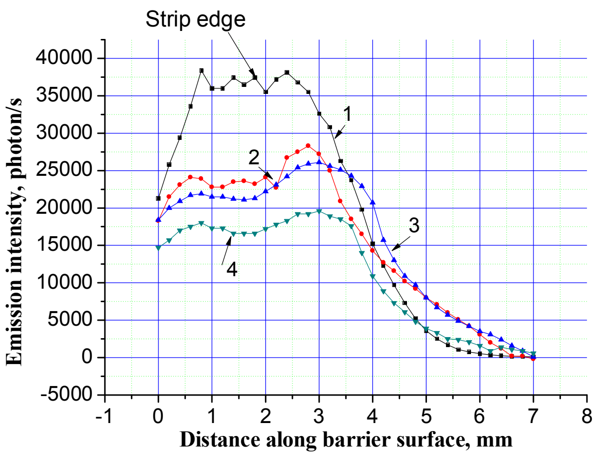

Fig.3. Distribution of light emission of the surface discharge from the electrode edge along the barrier surface (front view, X direction, Fig.2b).

Fig. 3 shows the distribution of intensity I(x) of light emission coming from a certain part of the discharge at different distances x from the electrode edge along the barrier surface in the direction perpendicular to the electrode edge.

The curves in fig. 3 are for different values of high voltage impulse duration τ_{imp} and for different impulse front duration $\tau_{fr.}$ Curve 1 is for AC voltage with U = 2.8 kV (RMS value). Curve 2 is for impulse voltage with τ_{fr} = 135 µs and τ_{imp}= 5 µs. Curve 3 is for τ_{fr}= 60 µs and τ_{imp}= 5 µs, curve 4 is for τ_{fr}= 60 µs and τ_{imp}= 132 µs. These measurements were done as a front view of the discharge when the barrier was placed perpendicular to the optical axis of the device (Fig. 2b). The lens was moved parallel the barrier surface with a step l = 100 µm and at each position the integral emission coming from a certain part of the discharge was measured as a quantity of photons per second. The measured signal is an integral one and includes the light from all microdischarge channels that appear from the electrode edge. The measured values describe the width X of the plasma layer of the surface discharge.

The distribution of light emission in the direction perpendicular to the barrier surface I(y) was measured as a side view of the discharge when the barrier surface was parallel to the optical axis (fig.2 a). The measured values are given in fig.4 and describe the thickness Y of the plasma layer for different form of impulse voltage (different τ_{imp} and τ_t) and different values of ac voltage. The numbers in the legend give values of τ_t and of τ_{imp}.

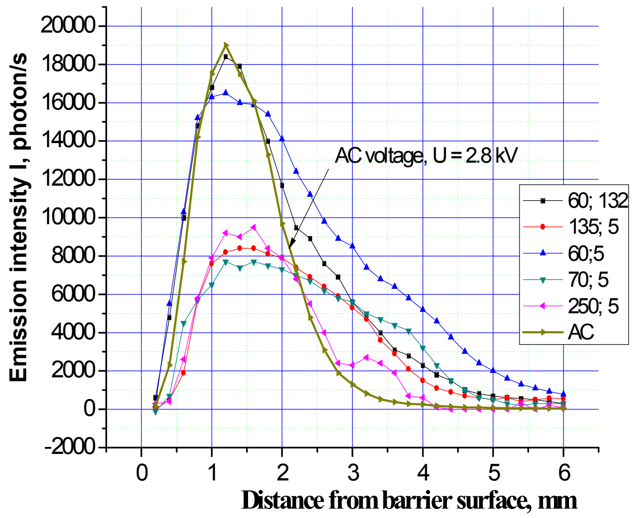

Fig.4. I(y) distribution perpendicular to the barrier surface

The curves in Fig.4 describe the withdrawal of micro discharge channels from the barrier surface as a result of repulsive effect of the charges left on the barrier after during previous discharges. As it is seen the maximal value of the withdrawal corresponds to the same distance from the electrode edge, but the measure of this withdrawal depends on the parameters of the applied voltage.

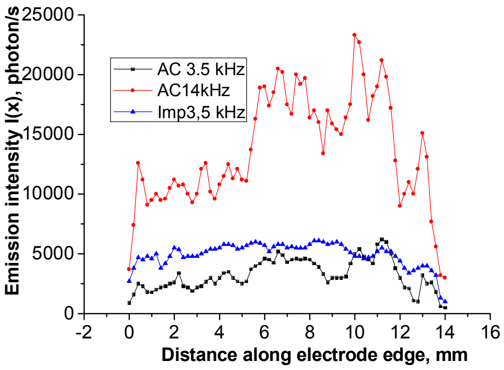

Fig.5. Distribution of light emission along the electrode edge (emission of individual micro channels).

Distribution of light emission intensity along the electrode edge (face view) is given in fig.5. All measured signals correspond to the same distance from the electrode edge (about 1 mm) and are found by the movement of the lens parallel the barrier surface. The results are for two different frequencies of AC voltage with U = 2.8 kV (RMS) and impulse voltage with τ_{fr}= 60 µs and τ_{imp}= 132 µs.

Although the aperture of the slits was the same for all three cases the measured emission intensity of microdischarges, more powerful and contours of individual microdischarge channels could be seen in case of the high voltage frequency. Contrary to it the emission signals from individual channels merge together and nearly uniform plasma layer density is seen for ac voltage and impulse voltage of low frequency.

Additional measurements have been done to compare the character of light emission distribution with distribution of the charges left on the barrier surface after the discharge. To get the pictures of the charge distribution over the barrier surface dust figures were developed using well known dust technique. Fig.6 shows an example of a dust figure that corresponds to situation after 10 subsequent discharges under positive impulse voltage with τ_{imp} = 5 µs and τ_t = 60 ns and U_m = 6 kV.

Fig. 6 Dust figure of the charge on the barrier surface after 10 subsequent discharges.

It is clearly seen that the highest charge density is in the region lying at a distance about 3-4 mm from the electrode edge. The position of this region corresponds to the position of the region where the highest light emission intensity is seen (fig. 3).

3. Conclusions

Analysis of the light emission measurements of the surface discharge makes it possible to make several conclusions concerning the influence of the applied voltage parameters on the characteristics of plasma layer of the surface discharge.

- The emission intensity is up to 30% higher for sine voltage of the same frequency and the same voltage amplitude than the corresponding emission for impulse voltage. The width X of the plasma layer of the discharge under impulse voltage is visibly bigger than for the discharge under ac voltage (5-6 cm instead of 3.5 cm). In its turn this width depends on the impulse duration τ_{imp} and impulse front duration τ_f as it is seen in fig. 3. The measured X values for impulse voltage are of the same order as the values measured in [1] for atmospheric Air.
- The dependence of the thickness Y of the plasma layer on the applied voltage form has the same character as the dependence on U of the plasma width X. The character of the distribution of the light emission above the barrier surface is the same for different values of the applied AC voltage (fig 4), whereas there is seen evident influence of the impulse parameters in case of impulse applied voltage.
- The distribution of emission intensity along the electrode edge is very near to a uniform one if the frequency of the applied periodic voltage is in the range of several kHz. With higher frequency the emission from micro channels becomes much more intensive and the contours of individual channels can be seen.
- In a whole the results achieved indicate that the change in the form of the applied high voltage makes it possible to change the parameters of the plasma layer near the electrode edge.

References

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