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Partial discharge emission characteristics in the UV range

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Abstract. In the work, UV radiation of the completed partial discharge involving the electrolyte, which is mainly located in the region of 280–315 nm, is recorded. UV radiation of incomplete partial discharge was not recorded. It has been shown that the radiation power of the completed partial discharge is sufficient to ignite ethyl alcohol vapors at their equilibrium concentration under normal conditions.
Keywords: UV radiation, completed partial discharge, incomplete partial discharge, breakdown voltage, ignition.

1. Introduction

This work is a continuation of the studies carried out in [1], devoted to the study of the optical characteristics of the radiation of the completed and incomplete partial discharge with the participation of the electrolyte in the visible area. An incomplete partial discharge in our conditions was called a weak glow that occurs in the electrode region at some small voltage value on this electrode, which, with a further increase in voltage, turned into a bright flash accompanied by a strong sound effect, which, by analogy with a high-voltage discharge on the surface of the dielectric [2], is called a complete partial discharge. A number of works [2, 3] show that radiation of partial discharge is significant in the UV region. In this regard, it is of interest to study the optical characteristics of partial discharge involving electrolyte and in the UV region.

In addition, in work [3], it is shown that UV radiation occurs not only during the passage of the completed partial discharge, but also at incomplete partial discharge. Since UV radiation can act as a factor in facilitating breakdown of the discharge gap [2], it is also of interest to study the radiation of incomplete partial discharge in the UV region.

Thus, the purpose of the work is to fix UV radiation both in the case of a completed and incomplete partial discharge in the presence of an electrolyte and to study the dependence of its characteristics on discharge parameters.

2. Equipment and experimental setup

As the plasmatron in which the discharge was carried out, a spark plug without an upper electrode, a diameter of the central electrode of 2 mm, a discharge gap value of 3 mm, was used. The space between the central and outer electrodes 10 mm deep was filled with 1.5% NaCl solution. In the course of experiments, the polarity of the central electrode (CE) changed. The plasmatron was powered by a pulse RC-generator, the scheme of which is also given in [1]. To record UV radiation, a combined device of the TKA-PKM series was used, designed to measure energy illumination (E, mW/m^2) in three regions of the spectrum: 200–280 nm (UV-C zone), 280–315 nm (UV-B zone) and 315–400 nm (UV-A zone). The device screen also displays the calculated parameters: the maximum (peak) energy illumination value E_{max} and energy exposure in the corresponding regions of the spectrum. The transition from one part of the spectrum to another is carried out by changing the receiving optical heads.

Since the duration of the discharge is 10^{-3} s, and the time constant of the device is 1 s, to obtain real illumination values, the readings of the device were recalculated according to the formula $E_{calc} = (t_2/t_1)\, E_{meas}$, where t_2 is a doubled time constant (the response time to the appearance of an outbreak and its failure was taken into account), t_1 is the lifetime of the discharge [1].

Since the measuring heads have a limited angle of view (10°), they were located at a distance (0.09 m) so that the emitting area completely falls into this angle.

3. Experiment and results

Energy illumination was measured for discharges occurring at different values of voltage *U* applied to the discharge gap. The polarity of the applied voltage also changed. When the value of the applied voltage increased, the discharge type changed. The incomplete partial discharge passed into the completed one, which was accompanied by a bright flash.

During the experiments, UV radiation from incomplete partial discharge was not recorded, most likely due to its low intensity. Also, UV radiation was not recorded in the region of 200–280 nm, due to its absorption by the atmosphere. However, visible radiation is observed to the eye when partial discharge is incomplete. It can be assumed that there is also weak UV radiation, which is not recorded by the device due to its low sensitivity. At 675V, the instrument detects UV radiation from the already completed partial discharge.

The data obtained from the experiments are shown in Table 1. Ballast resistance in the supply circuit is zero.

Table 1. Peak values of energy illumination in the UV range at the completed partial discharge

Polarity of CE	Discharge type	Range, nm	U, V	$E_{maxmeas}$, mW/m^2	$E_{maxcalc}$, mW/m^2
minus	incomplete	315–400	600	0	0
minus	incomplete	280–315	600	0	0
minus	completed	315–400	675	5.56	11120
minus	completed	280–315	675	9.18	18360
plus	completed	315–400	630	8.36	16720
plus	completed	315–400	900	6.06	12120
plus	completed	280–315	600	29.5	59000
plus	completed	280–315	900	23.3	46600

As can be seen from Table 1, UV radiation is mainly concentrated in the range 280–315 nm.

To study the question of the initiating effect of partial discharge radiation, experiments were carried out on the ignition of ethyl alcohol vapors by partial discharge. To do this, the candle was placed in a plasma chemical reactor (volume 60 ml), similar to that used in our work [4]. As a source of ethyl alcohol vapors, a cotton swab impregnated with ethyl alcohol was placed in the reactor. The equilibrium concentration of ethyl alcohol vapors at room temperature and atmospheric pressure lies within the concentration limits of ignition of ethyl alcohol vapors (50–363 g/m^3). The cotton swab was placed either at the end of the plasma chemical reactor (option A) or on the side of the spark plug (option B), as shown in Fig.1.

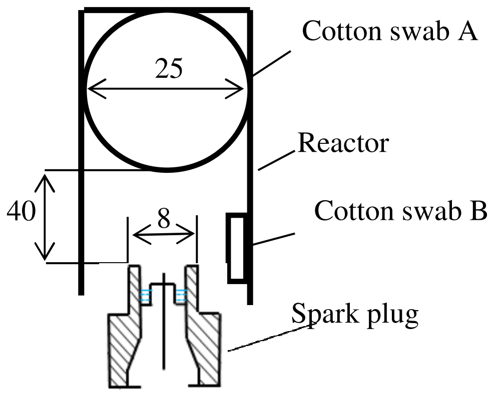

Fig.1. Scheme of experiment on ignition of ethyl alcohol vapors.

In the case of option A, ignition did not occur in most cases due to the powerful shock wave (SW) that occurs during discharge. Excessive pressure p in the shock wave reached tens of kilopascals [4] in the absence of ballast resistance in the power supply circuit of the plasmatron. The use of ballast resistance of 30 Ohms allowed to reduce overpressure to units of kilopascals. In this case, ignition occurred in all cases. If the option of placing tampon B was used, ignition occurred both in the presence and absence of ballast resistance. In this case, the shock wave propagated tangentially to the cotton swab. Results of experiments are given in Table 2.

Table 2. Results of ignition experiments

***U*, B**	**R_b, Ohm**	***p*, Pa**	**Vapor combustion time, s**	**Note**
950	0	86750	no	Frontal SW (var. A)
950	30	5740	1	Frontal SW (var. A)
950	0	86750	5	Tangent SW (var. B)
950	30	5740	5	Tangent SW (var. B)

Visible burning was observed near the surface of the cotton swab. No wave of combustion propagation from the discharge gap was observed. The absence of such a combustion wave is apparently explained by its damping by a shock wave. Thus, the ignition of alcohol vapors near the surface of the cotton swab is most likely carried out under the influence of partial discharge radiation. At the same time, since ultraviolet radiation has a significantly higher energy than visible, it seems justified to assume its initiating role in igniting ethyl alcohol vapors.

4. Conclusion

1. The completed partial discharge generates sufficiently powerful UV radiation in the range of 280–315 nm.

2. UV radiation of incomplete partial discharge was not recorded. Therefore, the question of its initiating action remains open.

3. The radiation power of the completed partial discharge is sufficient to ignite ethyl alcohol vapors.

5. References

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