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# Study of radiative characteristics of a completed partial discharge

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**Abstract.** The work is devoted to the study of the optical and electrical characteristics of a completed partial discharge burning in the presence of an electrolyte (1.5% NaCl solution). The possibility of using optical sensors that are part of smartphones such as Xiaomi for research is shown. The dependence of the radiation intensity of the completed partial discharge on the value of the ballast resistance in the discharge circuit and the material of the grounded electrode (anode) is studied. The dependence of the breakdown voltage on the size of the discharge gap is also studied. It is shown that it has a nonlinear character at a significantly lower (up to 20 times) breakdown voltage in comparison with the case of the absence of an electrolyte.

## 1. Introduction

The object of research in this work is a completed partial discharge along the surface of a dielectric coated with an electrolyte, burning in a pulsed plasmatron. In contrast to a completed partial discharge over the surface of a dielectric without an electrolyte, the breakdown of the discharge gap occurs at a significantly smaller potential difference [1]. In general, in electrical engineering, a partial discharge is considered as a harmful phenomenon in power transmission lines [2], however, we have made attempts to use a completed partial discharge on a surface covered with an electrolyte for other purposes, in particular as a plasma generator in plasma chemistry.

Investigations, in particular, high-speed photographing of a partial discharge (PD) in the presence of an electrolyte, have shown that with a completed partial discharge, a bright flash occurs with a lifetime of 0.001 s. In contrast to the classical partial discharge, i.e. without electrolyte, the brightness of the discharge is comparable to the brightness of the welding arc.

To characterize the radiation intensity of a completed partial discharge, the illumination created by this discharge at a certain distance was used.

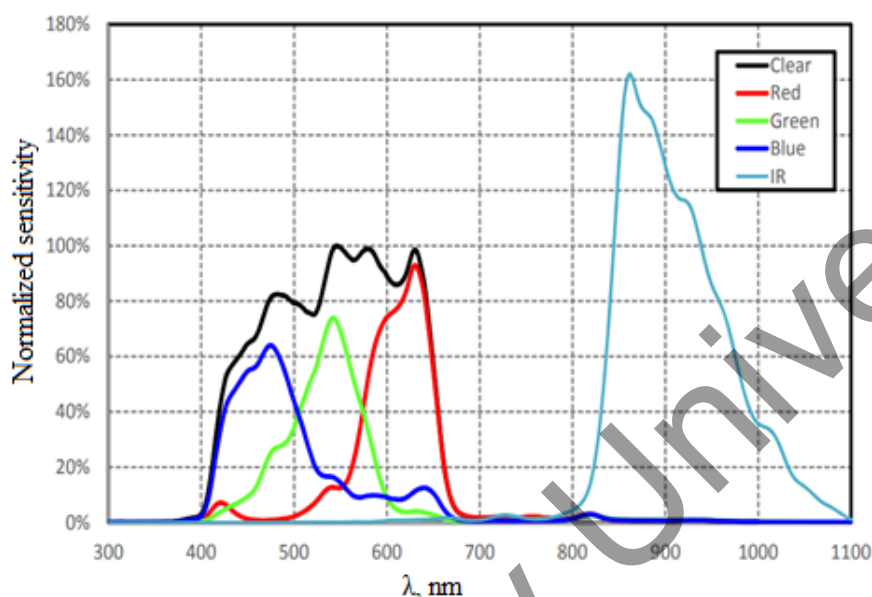
The concept of illumination is closely related to the optical characteristics of the human eye. The measurement of illumination, according to [3], can be performed with instruments with measuring transducers of radiation having a spectral error of no more than 10%, defined as the integral deviation of the relative spectral sensitivity curve of the measuring transducer of radiation from the curve of the relative spectral luminous efficiency of monochromatic radiation for daytime vision (human). Thus, by



measuring the illumination, we can judge the intensity of the radiation from the source in the visible region of the spectrum.

## 2. Equipment and installation

In this work, the TMD 4903 optical sensor, which is part of the equipment of the Xiaomi smartphone, was used as a radiation receiver. To register the sensor readings, the program "Luxmeter" for the Android OS was used. Data on the characteristics of the radiation receiver are given on the official website of the manufacturer [4]. Spectral characteristic of radiation receiver is given in figure 1.



**Figure 1.** Spectral characteristic of TMD 4903 radiation receiver.

The IR region of the spectrum is trimmed by a corresponding built-in filter.

The dynamic range of the illumination sensor is up to 60000 lx and the dependence of the signal on illumination in this range is linear [4].

A comparison of the spectral characteristics of the radiation receiver with the curve of the relative spectral light efficiency of monochromatic radiation for daytime vision [5] shows that they differ significantly only in the red region of the spectrum. The indications in this area are overestimated. Thus, this radiation receiver can be used to measure illumination if there is no or little red radiation in the spectrum.

To power the pulsed plasmatron, the scheme shown in figure 2 was used.

Significantly, a negative potential was applied to the central electrode of the pulsed plasmatron. According to article [1], this allowed to reduce the ignition voltage of the completed discharge by 15% (120 V) compared to the supply of positive potential to the central electrode.

## 3. Experiment

In this work, the illumination generated by the radiation of the partial discharge at different values of the ballast resistance in the discharge circuit was measured.

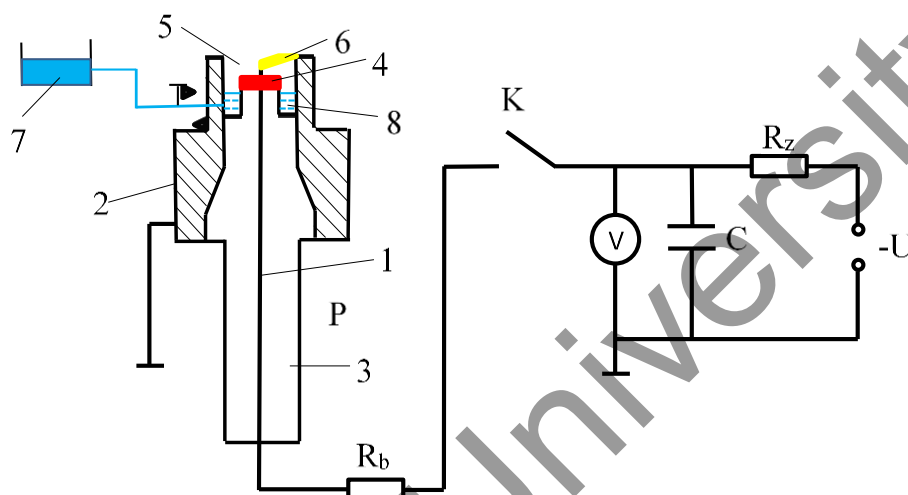
Since the time constant of the radiation receiver given in [4] is significantly longer than the time of the discharge and is about 1 s, it is necessary to take this factor into account when calculating real illumination values based on the measured values.

Using the approach described in [6], to obtain real illumination values, the readings of the illumination sensor were recalculated according to the formula

$$E_{\text{calc}} = (t_2 / t_1) E_{\text{meas}} \quad (1)$$

The parameter  $t_2$  is defined as the doubled time constant of the radiation receiver, since it is necessary to take into account the response time both to the leading edge of the discharge flash and to the trailing edge (that is, to the extinction of the discharge). Based on the manufacturer's data [4],  $t_2$  was estimated at 2 s. The parameter  $t_1$  is the lifetime of the discharge, which was determined from the data of high-speed shooting of the discharge and the electrical characteristics of the capacitor discharge circuit in the power supply circuit [1], and  $E_{\text{meas}}$  is readings of the device.

Naturally, this formula can only be used for estimation and does not take into account losses in the registration scheme.



**Figure 2.** Diagram of the pulsed plasmatron.  $-U$  - DC voltage source 0 – 1000 V,  $R_z$  - charging resistance,  $R_b$  - ballast resistance, V - digital voltmeter, K - low-voltage commutator, P - plasmatron, 1 - central electrode, 2 - grounded electrode, 3 - dielectric, 4 - ignition point of incomplete partial discharge (I stage), 5 - discharge gap, 6 - ignition point of completed partial discharge (II stage), 7 - electrolyte tank, 8 - electrolyte (1.5% NaCl solution).

In previous experiments [1], it was found that the lifetime of the completed partial discharge was 0.001 s with zero ballast resistance in the discharge chain and 0.004 s with a ballast resistance of 68  $\Omega$ .

Table 1 shows measured and recalculated values of illumination generated by completed partial discharge at different distances from pulse plasmatron at different values of ballast resistance. A plasmatron with a steel anode (grounded electrode) was used.

**Table 1.** Values of illumination generated by completed partial discharge in a plasmatron with a steel anode in the presence of electrolyte (discharge gap 3 mm,  $U = 950$  V).

$R_b$ ( $\Omega$ )	$r$ (mm)	$E$ (measured) (lx)	$E$ (calculated) (Mlx)
0	150	354	0.71
0	850	14	0.028
68	150	19	0.0095
68	850	4	0.002

Similar measurements were made for the aluminum anode plasmatron (table 2).

The very high value of calculated illumination at short distances from the discharge significantly exceeds the range of illumination measurement by the TMD 4903 sensor, in which the linearity of the

sensitivity characteristic is maintained (up to 60000 lx). Therefore, the distance from the discharge for measurements shall exceed 400 mm (based on tables 1 and 2).

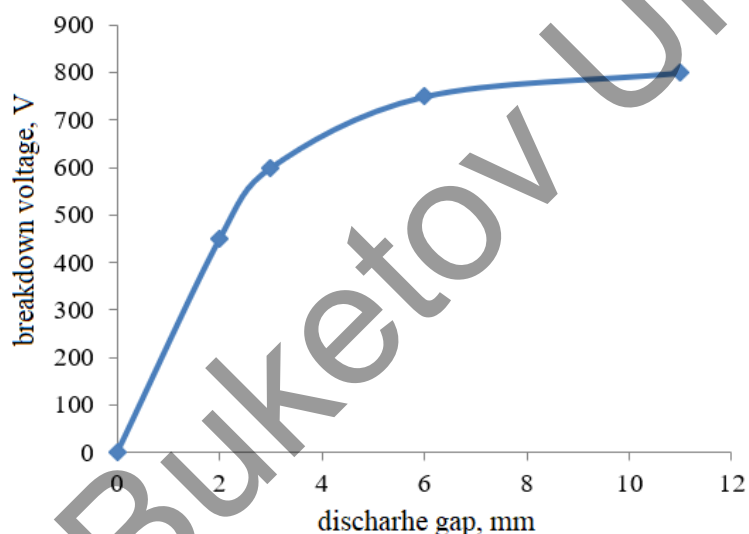
**Table 2.** Values of illumination generated by completed partial discharge in a plasmatron with an aluminum anode in the presence of electrolyte (discharge gap 3 mm,  $U = 950$  V).

$R_b$ ( $\Omega$ )	$r$ (mm)	$E$ (measured) (lx)	$E$ (calculated) (Mlx)
0	150	390	0.78
0	850	14	0.028
68	150	101	0.05
68	850	4	0.002

As can be seen from the data in tables 1 and 2, there is a slight increase in the intensity of discharge radiation when using an aluminum anode.

#### 4. Discussion

According to various experiments, the intensity of radiation (or so-called optical output) depends significantly on the value of the discharge gap [7]. The dependence of the value of the breakdown voltage on the value of the discharge gap for a conventional static discharge has a linear character with a large coefficient. For a partial discharge, this dependency is non-linear. The experiments we conducted yielded the results shown in figure 3.



**Figure 3.** Dependence of breakdown voltage on the value of discharge gap in the presence of electrolyte.

The nature of the dependence is similar to that given in [7], but with significantly smaller (up to 20 times) values of the potential difference at which the breakdown occurs. Such a significant difference in the value of the breakdown voltage is due to the presence on the surface along which the partial discharge (sliding, in terminology [7]) of the electrolyte occurs.

The weak dependence of the breakdown voltage on the size of the discharge gap at its values above 3 mm makes it possible to increase the internal diameter of the plasma torch to 24 mm, which contributes to increasing the efficiency of plasma generation and increasing its volume [8].

In addition to recording the illumination generated by the completed partial discharge, we have attempted to capture the radiation from the incomplete partial discharge, which is the first stage of the completed partial discharge and initiates it. The incomplete partial discharge does not go to the completed one at the value of the potential difference insufficient to breakdown the discharge gap.

Unlike the completed partial discharge, which under our conditions (when used as an electrolyte of an aqueous solution of NaCl) has a bright yellow color, the radiation of the incomplete partial discharge is visually shifted to the blue region of the spectrum. However, the intensity of this radiation is not enough to record it with our devices.

In many works, including [7], the initiating effect of the incomplete partial discharge is explained by the presence of sufficiently powerful ultraviolet radiation in its spectrum. However, under our conditions, we did not have the opportunity to register it.

The yellow tint of the completed partial discharge in the presence of electrolyte (solution NaCl) is determined by the radiation of excited Na atoms.

## 5. Conclusions

1. For optical research, it is possible to use fairly common radiation receivers included in smartphones.
2. Data were obtained on the radiation intensity of a completed partial discharge on the dielectric surface covered with electrolyte, which reaches a value of 0.7 Mlx, corresponding to the radiation of an arc discharge with a power of 1 MW at a distance of up to 1 m from the source.
3. The nonlinearity of the dependence of the breakdown voltage on the size of the discharge gap for a partial discharge along the surface of a dielectric coated with an electrolyte is shown at significantly lower (up to 20 times) values of the breakdown voltage compared to the discharge along a dry surface.
4. The design of a pulsed plasmatron using a partial discharge with a higher plasma generation efficiency has been developed.

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