CONDITIONS FOR OBTAINING UNIFORM PLASMA IN ATMOSPHERIC ELECTRICAL DISCHARGE WITH DOUBLE BARRIER (D-DBD)

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Abstract

Constructive solutions are presented for a double barrier for plasma-chemical reactor designed to treat multiple: fluid, thin planar dielectric materials etc. In order to obtain a uniformly distributed plasma workload considering the nature of the barrier, the geometric structure of the floating electrode (contact surface, the inner surface), the distance between the electrode voltage. In each case, D-DBD plasma uniformity appreciate the RGB colorimetric analysis, average power, lighting.

Key words: plasma D-DBD, electrodes, barrier, gap, colorimetric

The accumulated findings in PhD theses [1-34] and our own research outcomes [35-41] enabled the preparation of the present paper which focuses on obtaining D-DBD plasma uniformly distributed in the gap between electrodes. In agriculture, D-DBD plasma is applied in treating soil, seeds, packaging liquids, meat products, etc., being highly effective in terms of agricultural output and shelf life.

MATERIAL AND METHOD

Electrodes. Geometric characteristics

The base (marked as E0, *table 1*), fixed electrode is made of 10-mm thick aluminum and is covered in 3-mm glass. The glass barrier extends over the margins of the electrode to prevent peripheral electric discharges (air penetration).

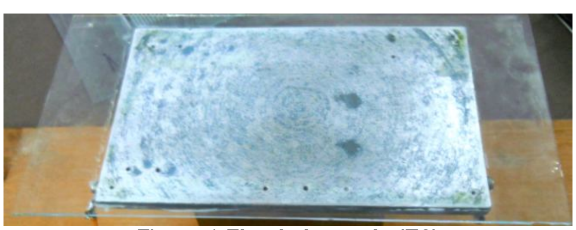

Figure 1 **Fixed electrode (E0)**

Experimental findings can be expressed as follows: U1 [V] - I1 [A], U2 [kV]- I2 [mA] or in other potential combinations, such as: I1 [A]-U2 [kV]. During experiments, the average power supply values were measured (U1 [V], I1 [A]), including for reasons related to work safety and protection.

Table 1

Geometric characteristics (E0- fixed base electrode; E1...E5 – floating electrodes)

Characteristic	Electrode					
	E_0^a	E_1	E_2^b	E_3^c	E_4	E_5
Length, [mm]	400	215	225	228	120	120
Width, [mm]	250	90	58	100	50	55
Heigth, [mm]	10	38	22	1.5	40	30
Inner surface, [mm^2]	NaN	10425	128700	NaN	NaN	6000
Discharge surface, [mm^2]	100000	4590	2025	22800	600	3078
Capacity, C_{Ei} [pF]	NaN	2,43	1,29	NaN	NaN	7,21

a – base electrode; b- consisting of 3 modules; c - non-coplanar surface

Characteristic volt-ampere curves

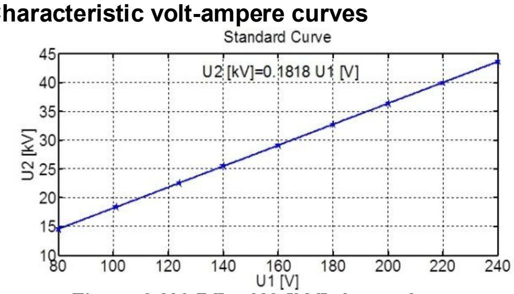

Figure 2 **U1 [V] – U2 [kV] dependence**

Based on the standard curve of the electrical-technical system, the voltage of the power supply is measured based on well-known ratio:

$$U1I1=U2I2,$$

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RESULTS AND DISCUSSION

Influence of the gap between the electrodes

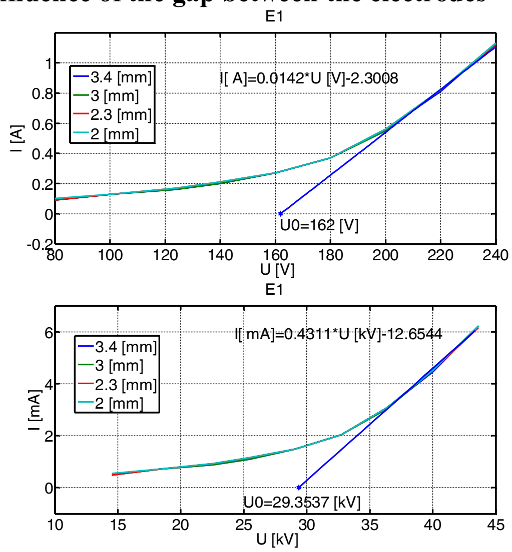


Figure 3. **Volt-ampere curves (U1 [V] - I1 [A], U2 [kV] – I2 [mA]) for various gaps between electrodes E0 and E1**

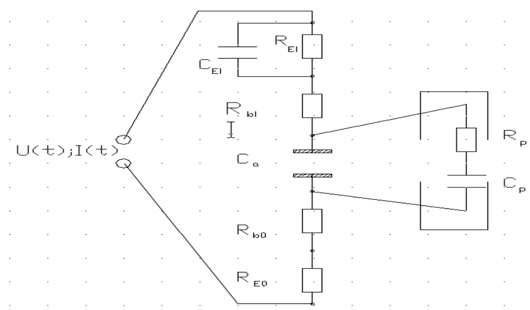


Figure 3 **Equivalent blueprint of a plasma-chemical cell**
R – resistance; C – capacity; indices: E_0 – base electrode; E_i – floating electrode; b_0 – base electrode barrier; b_i – floating electrode barrier; a – air; p – plasma;

Influence of the nature of the electrode

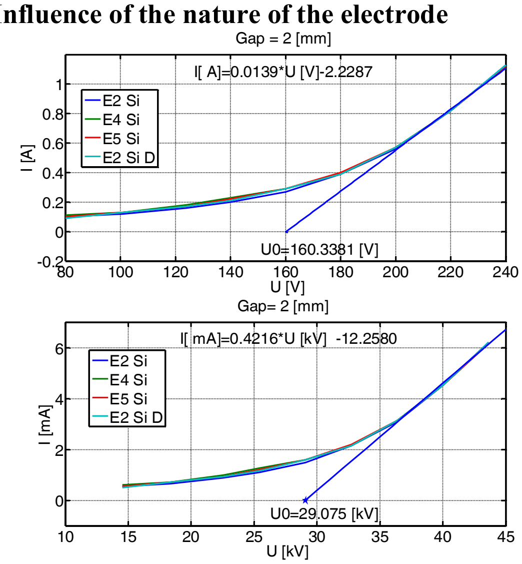


Figure 4 **Volt-ampere ratios characteristics of electrodes with a 2 [mm] gap**

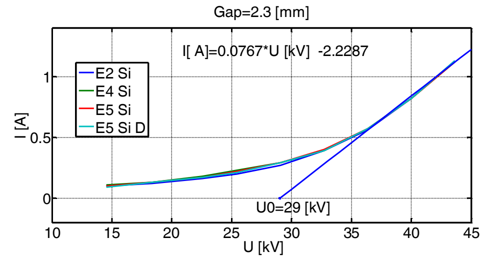
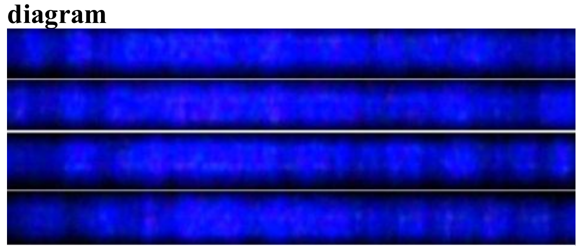
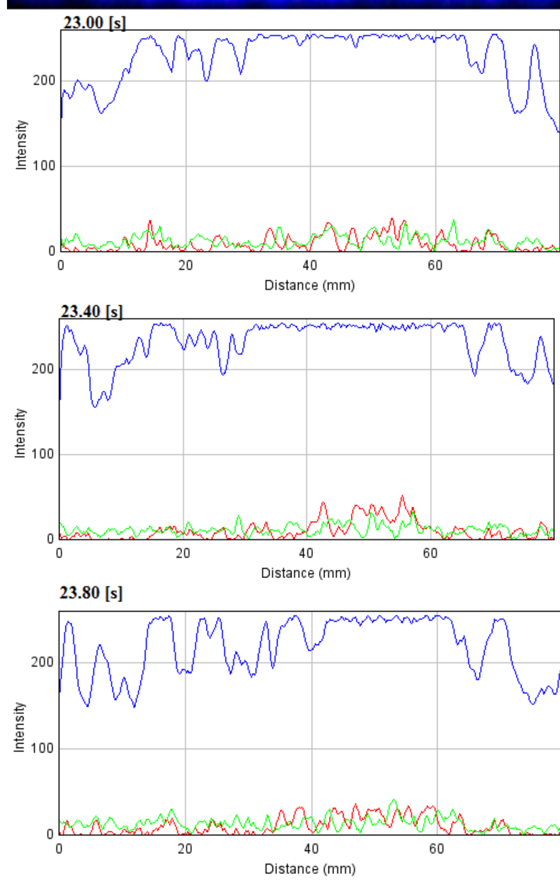


Figure 5 **Volt-ampere ratio characteristics of electrodes with a 2,3 [mm] gap**

For the electrical-technical system with the base electrode presented above, expressed in various forms, the size of the gap between the electrodes and the nature of the higher electrode do not have a major impact on the volt-ampere characteristic.

The locus of D-DBD plasma in the CIE xy diagram





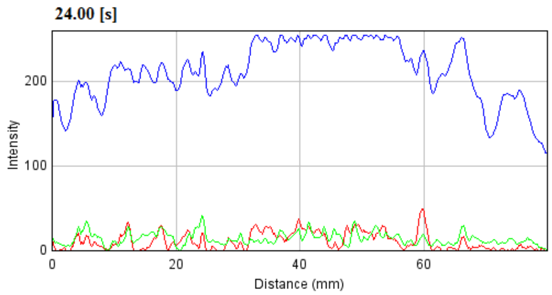


Figure 6 **Discharges at various time intervals (from 23 seconds onwards); R,G,B values**

Table 2

RGB analysis from 23 seconds onwards

RGB/t[s]	Red	Green	Blue
Linear analysis			
23.00	11.0367	14.5746	231.2738
23.40	12.5528	13.6413	230.8059
23. 80	10.0294	13.5368	222.9191
24.00	8.9432	12.1185	212.5210
Average	10.6405	13.4678	224.3799
Std	1.5349	1.0133	8.7861
Surface, transversal analysis			
23.00	8.7540	12.4300	201.4000
23.40	10.8000	11.4100	196.1000
23.80	8.3230	11.7700	192.5000
24.00	7.4220	10.8300	178.2000
Average	8.8247	11.6100	192.0500
Std	1.4290	0.6699	9.9306

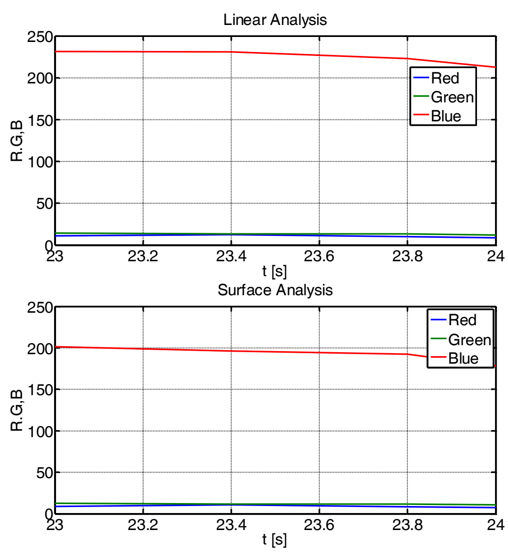


Figure 7 **Variation of R,G,B values at 23 seconds**

There results the need to analyse plasma using the blue (B) sensitive component with values in the [0…255] range.

In the visible spectrum, the colour palette for D-DBD plasma is located in the area of short wavelengths (blue-purple).

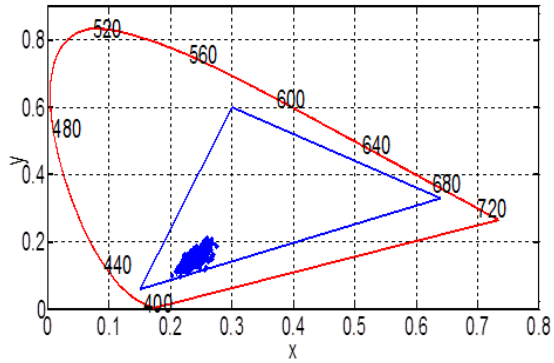


Figure 8 **Position of D-DBD air plasma at atmospheric pressure in the CIE xy colour space**

Light intensity

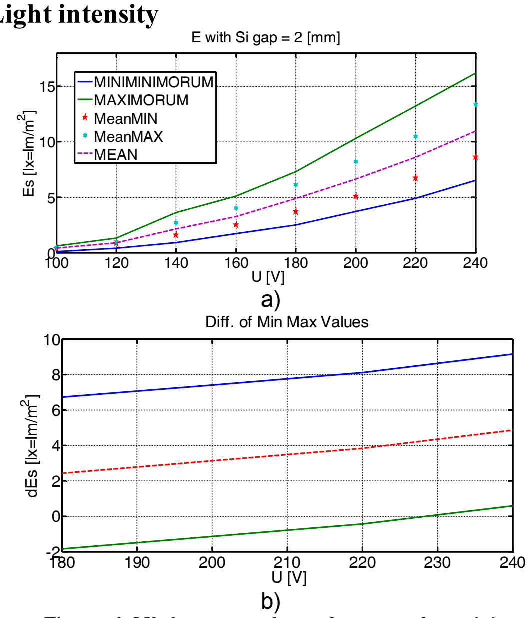
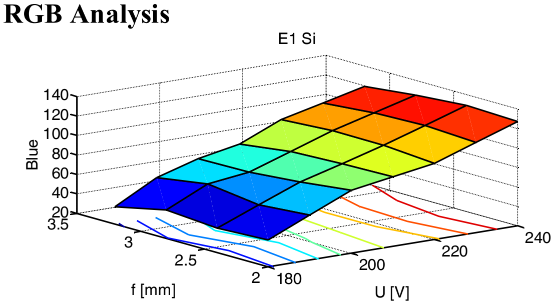


Figure 9 **Minimum and maximum values (a) and differences (b) for light intensity in voltage ratio (E_1, E_2, E_4, E_5, electrodes, with glass or glass-textolite barrier)**

RGB Analysis



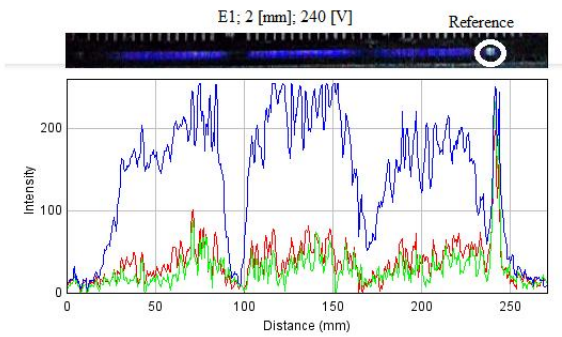


Figure 10 **RGB analysis for the floating electrode E1-glass (3 serial modules)**

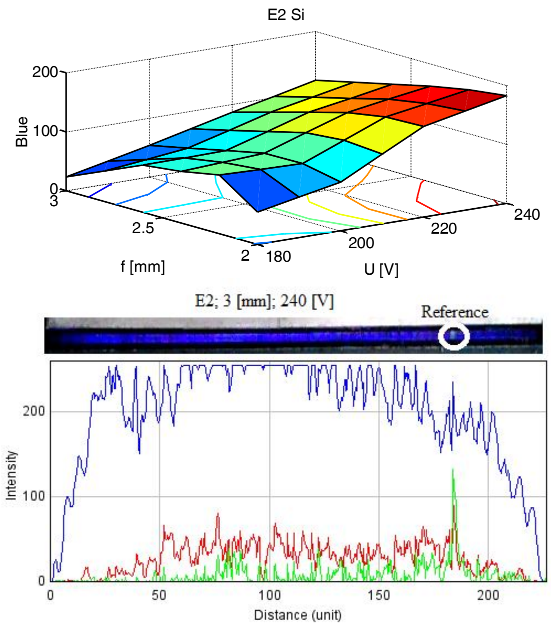


Figure 11 **RGB analysis for the floating electrode E2-glass**

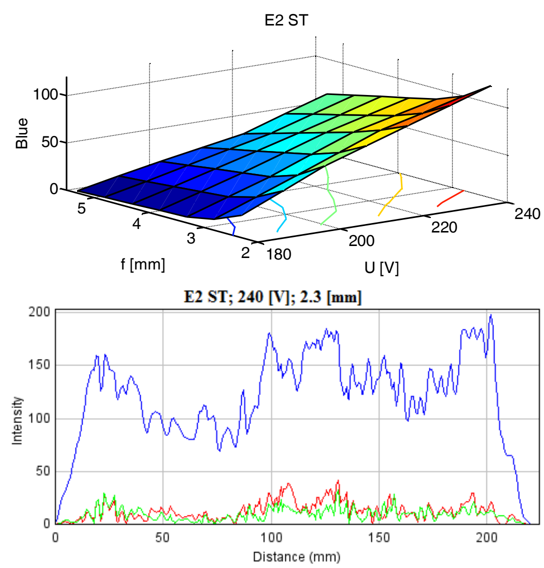


Figure 12 **RGB analysis for the floating electrode E2-glass –textolite**

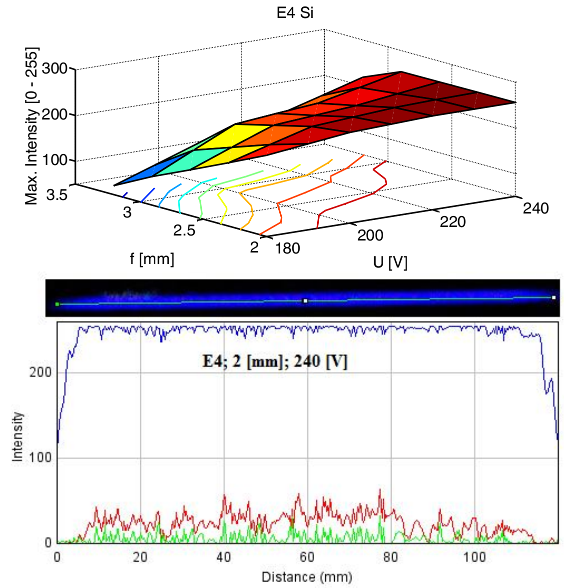


Figure 13 **RGB analysis for the floating electrode E4-glass**

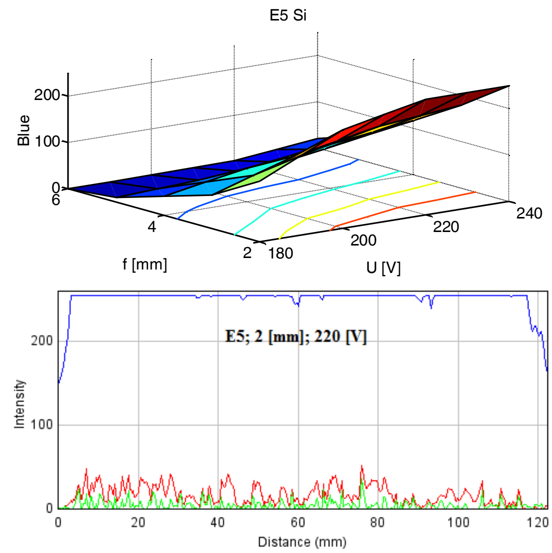
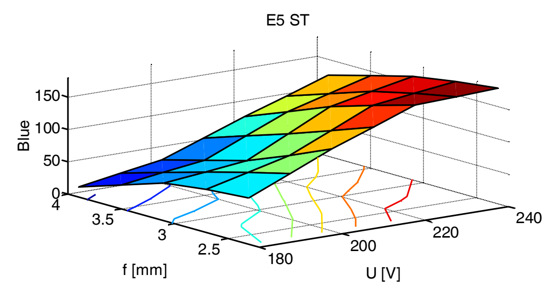


Figure 14 **RGB analysis for the floating electrode E5 - glass**



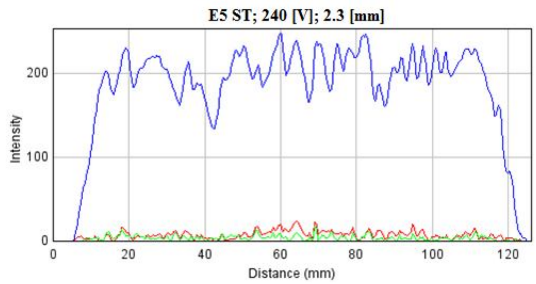


Figure 15 **RGB analysis for the floating electrode E5 – glass-textolite**

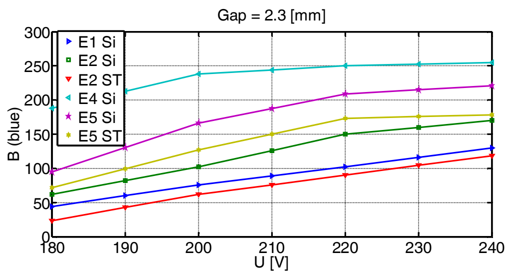


Figure 16 **B (blue) analysis for various electrode systems**

Table 3

Mathematical description
(B=Blue; U– voltage [V]; b – free term)

No	Electrode/barrier	Polynomial coefficients B= a*U - b
1	E1 Si	1.4100 -207.8929
2	E2 Si	1.9214 -282.3571
3	E2 ST	1.5572 -253.2121
4	E4 Si	123 -1159.8
5	E5 Si	2.1086 -267.9643
6	E5 ST	1.8553 -250.3571

x: Si – glass; ST – glass-textolite; thickness of barrier on the floating electrode 2 [mm]

CONCLUSIONS

Papers [42, 43] specify 40 kV as the voltage required to obtain uniform D-DBD plasma. According to the audiogram, the equilibrium state of uniform plasma is achieved in approx. 100 seconds.

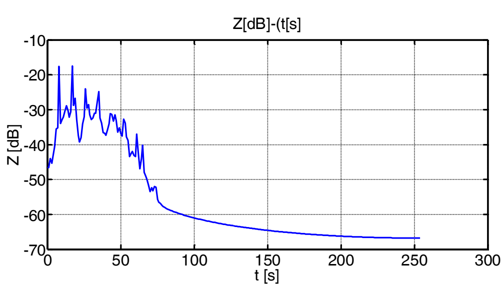


Figure 17 **Audiogram for D-DBD plasma**

The base electrode, E0 – Figure 1, according to the equivalent graph – Figure 3, constitutes the determinant of the discharge processes in D-DBD plasma, also reflected through single volt-ampere curves – figures 3, 5, 6.

In the kinetic time of development of D-DBD plasma from 23 seconds onwards, figure 6, the system dominant is the B (blue) component with values in the [0 – 255] range, figure 8. The standard deviation presents largely similar values in linear analysis and surface analysis, *table 2*.

In colorimetric analysis terms, the colour palette of the D-DBD plasma is located in the blue-purple area of the CIE xy diagram, figure 8.

Regardless of the mobile electrode, the mini-minimorum and maxi-maximorum values for the light intensity of plasma are in a limited range – figure 9, not conducive to a high level of discharges.

The RGB analysis of D-DBD plasma, Fig. 10-16, for various structures of the floating composite electrode, provides the conditions for obtaining uniform plasma for various gaps. E4 with glass barrier, fig. 13, provides a wide range for obtaining uniform plasma: voltage: 200-240 V (or 36-44 kV) and gap between electrodes 2-3 mm.

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