

PAPER • OPEN ACCESS

Charge transferred in brush discharges

To cite this article: M Talarek and R Kacprzyk 2015 *J. Phys.: Conf. Ser.* **646** 012022

View the [article online](#) for updates and enhancements.

Recent citations

- [Direct ignition tests of brush discharges for explosive methane-air and propane-air gas mixtures](#)
Marcin Talarek and Ryszard Kacprzyk



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

Charge transferred in brush discharges

M Talarek¹, R Kacprzyk²

¹- KOMAG Institute of Mining Technology, Gliwice, Poland
E-mail: mtalarek@komag.eu

²- Wrocław University of Technology, Wrocław, Poland

Abstract. Electrostatic discharges from surfaces of plastic materials can be a source of ignition, when appear in explosive atmospheres. Incendivity of electrostatic discharges can be estimated using the transferred charge test. In the case of brush discharges not all the energy stored at the tested sample is released and the effective surface charge density (or surface potential) crater is observed after the discharge. Simplified model, enabling calculation of a charge transferred during electrostatic brush discharge, was presented. Comparison of the results obtained from the simplified model and from direct measurements of transferred charge are presented in the paper.

1. Introduction

Electrostatic discharges from plastic materials, which are mostly brush type discharges, can be incendiary if appear in an explosive atmosphere. Charge transferred test method [1], which is described in Standards [2, 3], allows assessing if the discharge will be incendiary for the specific gas mixture. The idea of the test is to measure charge Q transferred in a single discharge, as the ball electrode approaches the tested sample. Standard [2] allows using three different apparatus for charge transfer measurement (von Pidoll, Schnier, Chubb). Obtained result is compared with the criterion for the specific gas mixture, for example for the methane-air mixture acceptable transferred charge is 60 nC. However, results for charge transferred test have a strong statistical scatter [4], which is the test method disadvantage.

In the case of brush discharges, not all the energy stored in the tested sample is released and the effective surface charge density (or surface potential) crater is observed after the discharge [5,6]. Assuming the ball electrode as the closest earthed element in the vicinity of the tested sample, one can estimate the energy released W from the approximated formula (1):

$$W \cong \frac{1}{2} \cdot \frac{Q^2}{C_E} \quad (1)$$

where: Q – charge transferred during discharge, C_E – capacitance between ball electrode (on the earth potential) and surface of the sample tested just before the discharge. It is worth to emphasize, that the total energy W accumulated in the dielectric (sample) – ball electrode system changes itself with position of the electrode which determines its capacitance C_E . Total charge Q transferred in a discharge can be estimated using the following equation:

$$Q = \int_{S_{CE}} \Delta q_s ds \quad (2)$$



where: Δq_s – change of the effective surface charge density value measured for the pre- and after-discharge states; S_{CE} – part of investigated dielectric surface covered by brush discharges (surface exhibiting change of Δq_s value due to discharges).

The main task of this work was to observe real distributions of surface charge density after the discharge and to propose a simplified model describing it and allowing to assess the total charge Q transferred in brush discharges. Distribution of surface charge density was determined indirectly, using the measurements of surface potential, U_Z which depends on the local surface charge density as follows:

$$U_Z = \frac{q_s \cdot d}{\epsilon_0 \cdot \epsilon_r} \quad (3)$$

where: q_s – local value of the surface charge density, d – thickness of tested sample, ϵ_0 – dielectric permittivity of a free space and ϵ_r – relative electric permittivity of the tested sample.

Determination of the C_E capacitance, which changes with a distance between the ball electrode and tested sample is a different problem, not considered in the paper.

2. Test set-up and experimental procedure

Test set-up using in the experiments is shown in Figure 1. It consists of: HV source, 100-needles fakir-electrode, non-contact electrostatic voltmeter with compensative probe, capacitor, discharge probe and voltmeter. Electrostatic voltmeter, Trek Model 341B, with compensative no-contact probe, operating in the measurement range ± 20 kV was the main instrument in this test stand.

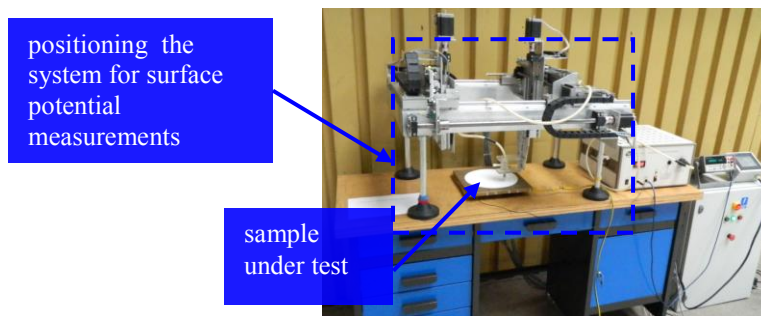


Figure 1. General view of the test stand for surface potential measurements.

Plastic, high resistivity samples of dimensions (150 x 150 x 6) mm and PTFE disc of diameter 250 mm and 6 mm thickness were the test objects. Before the measurements the samples were cleaned with isopropyl alcohol. Climatic conditions of the tests were as follows: temperature $T=23^\circ\text{C}$ and relative humidity $RH \leq 30\%$. Multi-needle electrode was used for corona charging, to have satisfactory repeatability of the electrification process. Corona electrode was supplied with negative high voltage - 30 kV dc. Freshly charged samples were submitted to transferred charge measurements. Electrostatic discharge was provoked by approaching ball electrode to the tested sample, which was lifted about 100 mm above the metal earthed plate. Ball electrode was connected to the standard capacitor, across which the voltage was measured to determine the transferred charge [3]. Surface potential, U_Z was measured using contact-less method with compensative probe placed in a distance of 5 mm above the tested sample surface.

3. Results and discussion

Typical result of surface potential distributions observed after discharge provoked on the tested PTFE sample is shown in Figure 2. Some results for other samples are presented in Figure 3, with the information about transferred charge obtained from the simplified model.

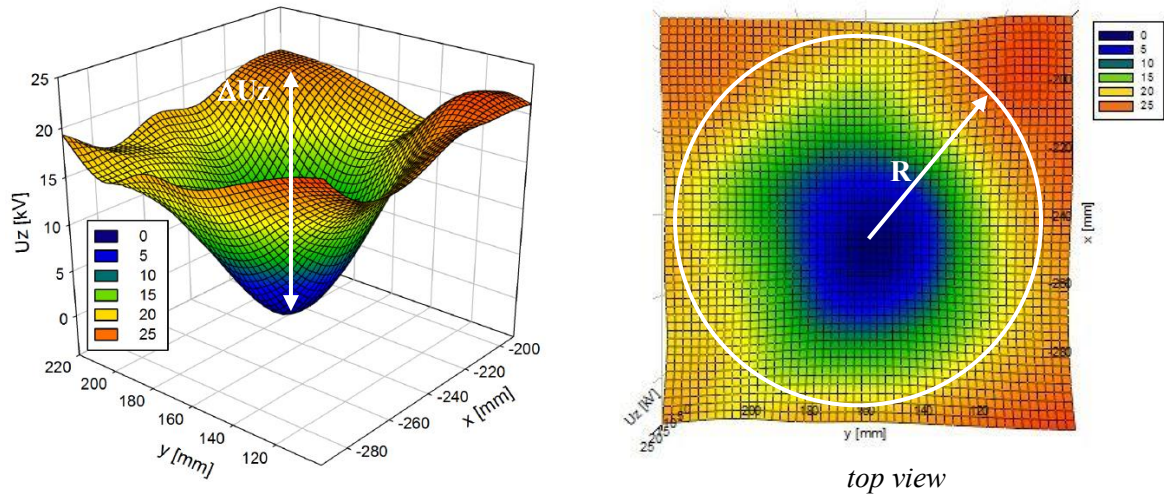


Figure 2. Example of surface potential distribution after discharge at PTFE sample.

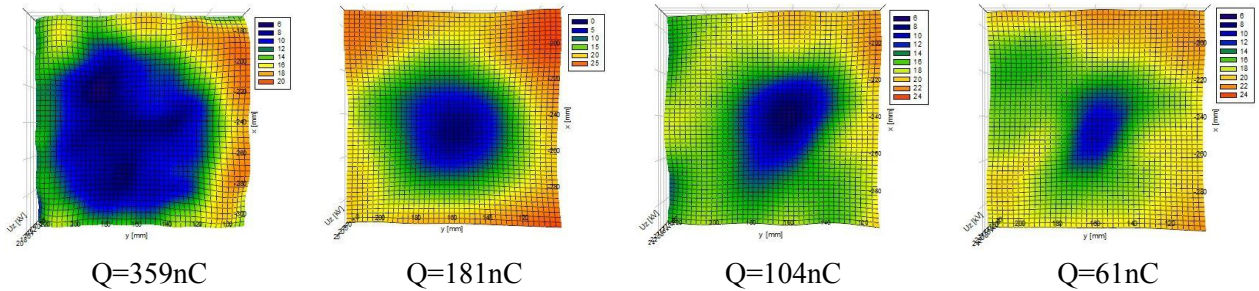


Figure 3. Some results of surface potential distribution after discharge.

The real potential distributions were modelled by a cone-type distributions using ΔU_Z and R parameters shown in Figure 2 and defined as follows:

$$\Delta U_Z = U_{Z \max} - U_{Z \min} \quad (4)$$

where: $U_{Z \max}$, and $U_{Z \min}$, - maximum and minimum values of surface potential, U_Z measured for the same “crater”, respectively - determining “crater” depth. The “crater” equivalent radius R was estimated from the following equation:

$$R = \sqrt{\frac{S_C}{\pi}} \quad (5)$$

where: S_C was area of a cross-section (limited by an equipotential line) of the voltage “crater” for the level of $0,8 U_{Z \max}$. It should be noted, that $S_C \leq S_{CE}$.

The proposed simplified model has the following assumptions:

- 1) The sample is electrically and geometrically uniform – exhibits constant electrical permittivity and thickness;
- 2) Uniform distribution of surface charge density along the surface of the whole sample before the discharge;
- 3) Cone type distribution of effective surface charge density occurs in the “crater” region - after the discharge;
- 4) Probe-to-surface separation distance does not influence the surface potential results.

Transferred charge Q value was calculated on the basis of a surface charge density change in the “crater” region using (in the first approximation) eq. (2).

The equation can be transformed, for the assumptions given above, to the following form:

$$Q = \frac{\pi}{3} \cdot \frac{\Delta U_z \cdot \epsilon_0 \cdot \epsilon_r}{d} \cdot R^2 \quad (6)$$

Some results of comparison between measured transferred charge and the charge obtained from the simplified model are presented in Table 1.

Table 1. Transferred charge. Values measured and estimated from the model

Tested sample	Q [nC]		k k=SM/DM
	Simplified model (SM)	Direct measurements (DM)	
Plastic sample 1	61	66	0.93
Plastic sample 2	104	108	0.96
PTFE disc	133	164	0.81
Plastic sample 3	184	217	0.85
PTFE disc	181	260	0.70
Plastic sample 4	359	397	0.90

4. Conclusions

Surface charge density craters observed after discharge were previously reported for thin dielectric layers [4,5]. Similar phenomenon was observed for dielectric (plastic) samples, 6 mm thick and with total area equal to 225 cm² (according to the requirements of samples for charge transferred test method [2]).

Simplified model, which is used to assess the value of transferred charge, assumes conical shape of the charge density crater. Real surface charge density craters have more complex shape than the conical one. However, relationship between value of transferred charge obtained from the model and the measured value, k is about 0.7 to 0.9 which gives an error in the range from 10% to 30%.

The model simplicity is its advantage. This might be useful in the test method, which is to be developed in future research work.

References

- [1] U. von Pidoll, E. Brzostek, H. R. Froechtenigt, Determining the incendivity of electrostatic discharges without explosive gas mixtures, IEEE Transactions on Industry Application, 40 (2004), 1467-1475
- [2] IEC 60079-32-2:2015 Explosive atmospheres – Part 32-2: Electrostatics hazards – Tests
- [3] EN 13463-1:2010 Non-electrical equipment for use in potentially explosive atmospheres – Part 1: Basic method and requirements
- [4] M. Talarek, L. Orzech, Results of an interlaboratory comparison on the measuring of transferred charges, Electrostatics 2013 proceedings
- [5] T. Oda, Y. Ito, Studies of electrostatic surface discharges on corona-charged polymer surfaces, IEEE Trans. Ind. Appl. 26 (4) (1990) 22-27
- [6] J.L. Davidson, T.J. Williams, A.G. Bailey, Electrostatic discharges between charged insulators and grounded spheres, Journal of Electrostatics 56 (2002) 29-42