Electrical charge relaxation on a dielectric surface

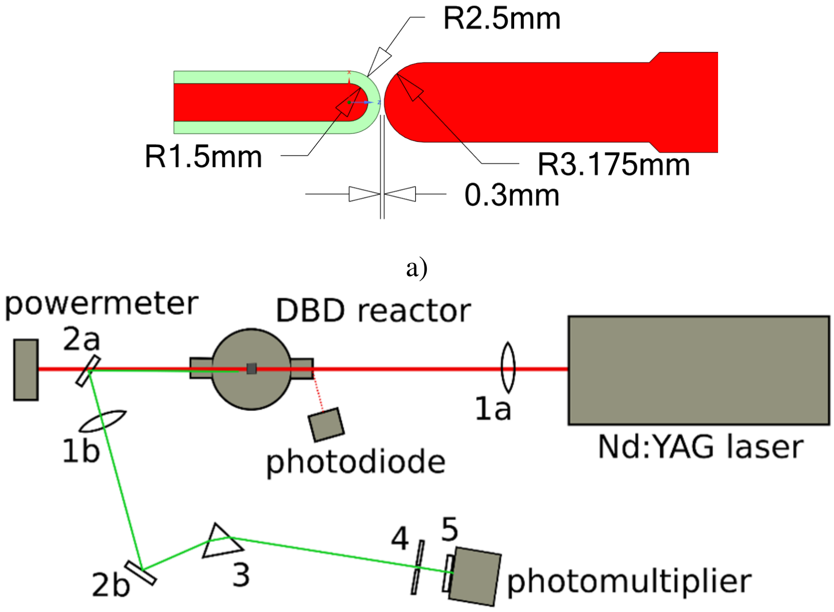
D. Prokop(*)[1], M. Mrkvičková[1], J. Tungli[2], P. Dvořák[1], S. Kadlec[2] and T. Hoder[1]

[1] *Department of Plasma Physics and Technology, Masaryk University,*
Kotlářská 2, 611 37 Brno, Czech Republic
[2] *Eaton European Innovation Center, Bořivojova 2380, 252 63 Roztoky, Czech Republic*
(*) david.prokop@mail.muni.cz

Electrical charge deposited on a dielectric surface by gas discharges is a phenomenon occurring in many situations connected to fundamental as well as applied fields of low-temperature plasma physics. It is common to find charging effects both in the field of barrier discharges and their application in surface treatment or thin film deposition and in the field of electrical engineering utilizing the gas/solid insulation.

One of the motivations for this work is the development of an ultra-fast gas-filled sealed miniaturized relay carrying high currents of tens to hundreds of amps to be used in novel AC and DC hybrid circuit breakers. The relay can be filled with various gases - air, nitrogen, SF_6, or in mixtures of its alternative gases, such as C_4F_7N. The relay contacts are fully open to a gap of the order of 0.1 mm after a given semiconductor bypass time (of the order of 0.1 ms). The dielectric strength of the filling gas is of high importance, as well as the effects of the electrical charge deposited on nearby dielectric surfaces.

The studies of surface charges on dielectrics started already by Lichtenberg and his famous dust figures in 1778 [1]. Recently, the amount of the deposited charge was quantified under different conditions using complex methods [2, 3]. It was found that the surface charge can relax and slowly disappear [4] and an analytical model was reported as well [5].



a)

b)

Fig. 1: Experimental setup for barrier discharge, part a), and of the EFISH method, part b).

In this contribution, we investigate a charge deposition and relaxation on a dielectric surface by measuring the residual electric field in the gap above the surface using the electric field induced second harmonic generation (EFISH) method, see [6, 7]. In this method we assume that the intensity of the EFISH signal depends quadratically on the applied electric field. This attribute can be then used to assess the dependence of the EFISH signal in time. The experimental setup is displayed in Fig.1. Single breakdown was initiated by powering a hemispherical electrode (radius 3.175 mm) against another

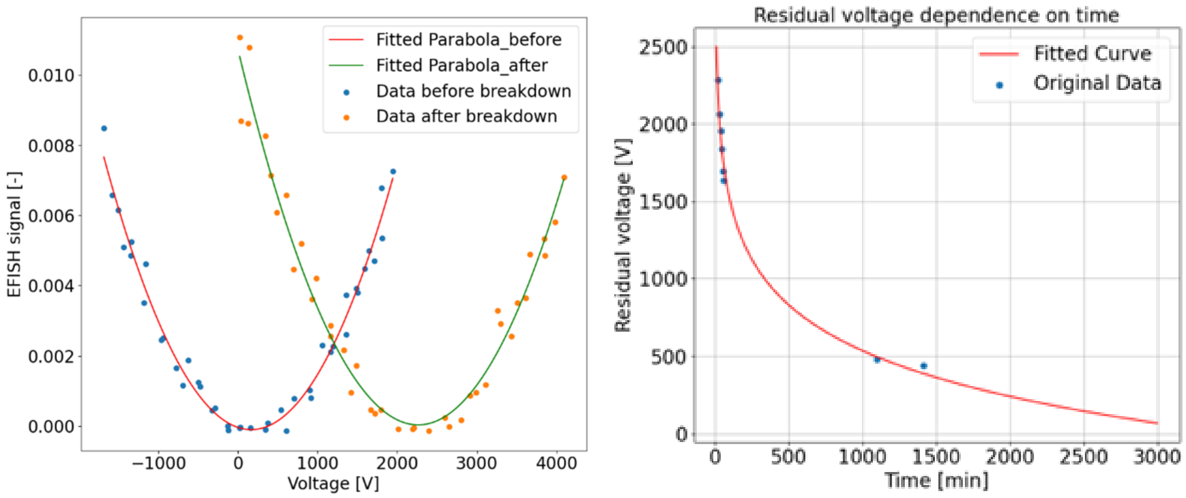


Fig. 2: Dependence of the EFISH signal on the applied voltage and change of the residual voltage in time.

electrode covered by Al_2O_3 ceramic (inner radius 1.5 mm, outer one 2.5 mm). The shortest gap was 0.3 mm. A DC power supply (FuG Elektronik GmbH, HCP 1400-20000 MOD) was utilized as a voltage source. The measurements were performed in a closed reactor filled with atmospheric pressure nitrogen and also in a nitrogen mixture with C_4F_7N. Measurements of the EFISH signal were obtained using high-definition oscilloscope Keysight Infiniium (20 GSa/s).

We conducted several experiments using the setup shown in Fig.1(b) to measure the EFISH signal at different time delays after charge deposition. As a result, we determined a voltage shift of the zero point of the EFISH signal (residual voltage) corresponding to the relaxation of the charge deposited on the dielectric surface. Preliminary results for pure nitrogen are displayed in Fig.2. The results obtained will serve as data for the validation of numerical models.

[1] G. C. Lichtenberg, *Novi commentarii Societatis Regiae Scientiarum Gottingensis* (1778) 168–180.
[2] L. Stollenwerk, J. G. Laven, H. G. Purwins *Phys. Rev. Lett.* **98** (2007) 255001.
[3] A. Kumada, S. Okabe, K. Hidaka *J. Phys. D: Appl. Phys.* **42** (2009) 095209.
[4] R. Brandenburg et al. *J. Phys. D: Appl. Phys.* **46** (2013) 464015.
[5] O. Emelyanov, M. Shemet *Journal of Electrostatics* **81** (2016) 71–75.
[6] A. Dogariu, B. M. Goldberg, S. O'Byrne, and R. B. Miles *Phys. Rev. Appl.* **7** (2017) 024024.
[7] M. Mrkvičková et al. *Plasma Sources Sci. Technol.* **32** (2023) 065009.

This research has been supported by the Technology Agency of the Czech Republic within the project TK04020069: *Streamers and surface flashover discharges on insulators in alternative gases to SF6*.