Electric Field Measurement in Multipeak Mode of DBD in Helium-Hydrogen Mixture

S. S. Ivković, B. M. Obradović*, and M. M. Kuraica

University of Belgrade, Faculty of Physics Studentski trg 12, 11000 Belgrade, Serbia
(*) obrat@ff.bg.ac.rs

Time–space resolved optical emission spectroscopy was used for investigation of diffuse dielectric barrier discharge (DBD) in 95% He + 5% H_2 gas mixture. The DBD in the gas mixture operated in diffuse mode only in the regime with more than three current peaks. Using Stark polarization spectroscopy technique based on He I 492.19 nm line and its forbidden counterpart, the electric field distribution was measured in the cathode region of the DBD at 200 mbar pressure. In the multiple current peak mode of the DBD, electric field distribution was measured during each of the four current peaks.

Dielectric barrier discharge (DBD) is a high pressure plasma source widely applied in plasma chemistry, surface modification, and thin film deposition. It is a low frequency AC discharge in a narrow gap between two electrodes of sufficiently large area covered by a dielectric barrier. At certain conditions DBD at near atmospheric pressure is homogeneous in the electrode plane what is very suitable for applications in plasma technologies, especially in surface treatment. In helium, DBD is characterized by the narrow current pulses of large amplitude of several tens of milliamperes. In this mode of the discharge, the spatial structure containing the cathode fall region, Faraday dark space and positive column, develops in the phase of maximal current [1]. This circumstance allowed referring to this mode of the discharge as the atmospheric pressure glow discharge. Using the Stark polarization spectroscopy of He I 447.15 nm and He I 492.19 nm lines and their forbidden counterparts we have measured electric field in near atmospheric pressure DBD in helium [2, 3]. Although these measurements represent mean values of electric field strength for a period of a current pulse, they have shown that electric field linearly decreases in the direction from the cathode forming a cathode fall region with length of ~ 1 mm, typical for subnormal mode of the DBD discharge in helium.

This paper is focused on investigating the DBD in helium-hydrogen mixture (95% He + 5% H_2), in which difuse disharge is obtained only in multipeak current mode. The object is to investigate a change of electric field distribution (EFD) from peak to peak in a multipeak discharge sequence. Measurements were made at 200 mbar - the highest pressure at which a diffuse discharge can be established in the gas mixture.

The DBD source consist of two parallel metal electrodes (50 x 50mm) covered by a 0.65 mm thick alumina layer at a fixed distance of 2 mm. Radiation from the DBD was polarized in electric field direction using a plastic polarizer and detected using 1m Spectometer equiped with a 2-dimensional ICCD triggered with a time delayed pulse, generated initially by the power supply. Recorded images consist of 50 accumulations each made of 50 000 gates per exposure. Time duration of the ICCD gate was chosen to cover the duration of the entire single current peak and was 1 μs. Following the procedure described in [2], electric field in the cathode sheath region of the DBD is obtained for 200 mbar gas pressure.

Electric field distributions which belong to the current peaks are represented on Fig. 1. Inserted graphs shows the gas voltage U_g (U_g is calculated using formulas given in [3]) signal and current peaks in the DBD. Each current peak is marked with 1μs time intervals which are exposition times for the helium line recording. Analyzing Fig. 1 we have concluded that EFDs in the vicinity of the cathode are fitted quite well with linear functions, what is typical for DC glow discharge structure, with a high electric field in a cathode layer. Accuracy of our measurements is confirmed by comparison of U_g with $U_c = \int E dx$, where integration is performed over the cathode length. Agreement between U_c and U_g is fairly good, see Fig. 1. Further analysis of Fig. 1 shows that from the first to the third current peak the space distribution of electric field is almost unchanged. At fourth current peak there is a small decrease of the electric field at the cathode surface with simultaneous extension of the cathode fall length. This change of the electric field distribution from first to fourth current peak qualitatively agrees with results of model proposed in [4]. Namely, numerical calculations and analyses done in [4] for a DBD in helium, powered by 5 kHz sinusoidal voltage, have shown that for a second current peak which decreased for 50%, the electric field at the cathode surface decreased 30%. Although our discharge is different (helium-hydrogen mixture, pulse voltage), we expected larger change of the electric field value at the cathode surface because the current decreases for 80 % from the first to the fourth peak. As can been seen, change of only 10% of the electric field values is observed.

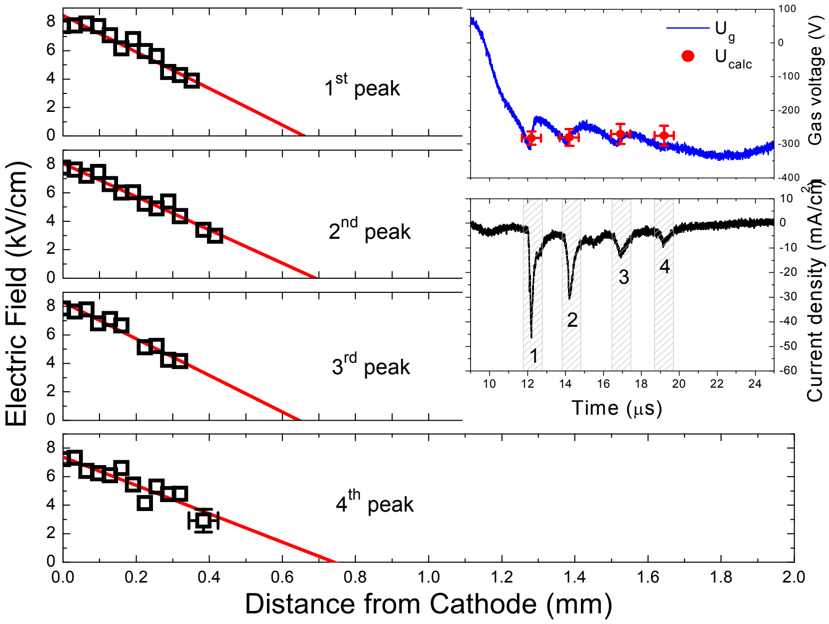

Fig. 1: Electric field distributions in DBD in 95%He + 5%H_2 obtained at 200 mbar pressure. Inserted graphs are current and gas voltage signals.

References

[1] F. Massines, A. Rabehi, P. Décomps, R. Ben Gadri, P. Ségur, C. Mayoux, *J. Appl. Phys.*, 83 (1998) 2950 – 2957.

[2] B. M. Obradović, S. S. Ivković and M. M. Kuraica, *Appl. Phys. Lett.*, 92 (2008) 191501.

[3] S. S. Ivković, B. M. Obradović, N. Cvetanović, M. M. Kuraica and J. Purić, *J. Phys. D: Appl. Phys.*, 42 (2009) 225206.

[4] D. Wang, Y. Wang, C. Liu, *Thin Solid Films*, 506– 507 (2006) 384 – 388.