Spatial structure of the low-pressure discharge in nitrogen – influence of surface conditions

S. R. Gocić (*)1, N. Škoro 2, D. Marić 2 and Z. Lj. Petrović 2

1 Department of Physics, University of Niš, P.O.Box 224, 18001 Niš, Serbia
2 Institute of Physics, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia

(*) gsasa@pmf.ni.ac.rs

We present comparisons of electrical properties and structure of the discharges in nitrogen, established with two different cathode surfaces. One of the cathodes was significantly and inhomogeneously conditioned by a constricted dischage over a long period of measurements, while the other had polished and homogeneous surface. Results reveal that inhomogenities in secondary electron yields over the cathode surface can lead to considerably different discharge properties – even positive volt-ampere characteristics at low currents and deformation in spatial structure of the discharge.

Secondary electron emission is one of two key mechanisms for controlling the breakdown and operation of non-equillibrium dc discharges. Studies of the influence of different processes of secondary emission [1] emphasized the importance of the state of cathode surface for discharge properties. In our earlier contribution [2] we analized volt-ampere (*VI*) characteristic of the discharge established in the system with the cathode that was severely conditioned by the discharge that operated in constricted glow regime over extended period of time. Exposure to such extreme conditions created visible inhomogenities at the electrode surface, which led to anomalous volt-ampere characteristics (positive slope in the low-current range). In this paper we extend our analysis by comparisons of our previous results with results for the discharge established in identical chamber, but whith new, homogeneous, cathode surface. Our aim was to demonstrate significance of the quality of the cathode surface i. e. secondary electron yield over the surface to the properties of the dishcarge.

We studied dc discharge in nitrogen, in parallel-plate electrode system, where both electrodes were made of copper. The diameter of the electrodes was D = 2.2 cm and the electrode gap was fixed at 0.8 cm. The discharge tube was filled with research grade nitrogen at a pressure of 2 Torr. We have measured *VI* characteristics by the experimental procedure that is described in detail in [3,4]. At the same time, 2D side-on profiles of emission were recorded by ICCD camera.

Figure 1 shows *VI* characteristics for the discharge realized with two different cathode surfaces. Upper set of images coresponds to selected caracteristic points on *VI* characteristics for significantly conditioned cathode (red symbols). Lower set of images coresponds to selected points for new, polished electrodes (blue symbols). In the case of significantly conditioned surface, as reported in our previous paper [2], we observe a non-standard increase of voltage in the low-current region, where negative slope is expected. In the range of discharge currents from ~100 μA to ~ 1000 μA, the slope is negative leading to a shallow minimum. At higher currents, characteristics is positive again, as expected for the abnormal glow discharge. 2D profiles of emission show that in low-current region, the discharge is limited to a small area at the center of the cathode which is visibly conditioned by earlier discharge operation. Staying within this area, discharge goes from Townsend discharge (label 1) to glow discharge (label 2). A drop in voltage coincides with spreading of the discharge to a wider area, with different surface conditions (different secondary electron yield) (labels 3-4). Radial profile appears skewed towards the cathode. This transition occurs when the current density in conducting channel increases enough for the charge particles, diffused outside the conditioned area, to induce a space charge sufficient to ignite the discharge at that position and for the given voltage [4]. Further development of the discharge structure is in agreement with the standard behaviour of low-pressure non-equilibrium discharges – gradual radial spreading of the profile in the abnormal glow. On the other hand, with non-conditioned cathode, we can observe typical structure of the discharge starting from low currents, with diffuse Townsend discharge (labels A and B); significant decrease of voltage with development of space charge; followed by constricted normal glow (labels C, D); and again diffuse abnormal glow (E) that covers entire electrode area. Over the entire current range, the discharge with homogeneous cathode surface conditions is more efficient – lower voltages are required for the discharge operation.

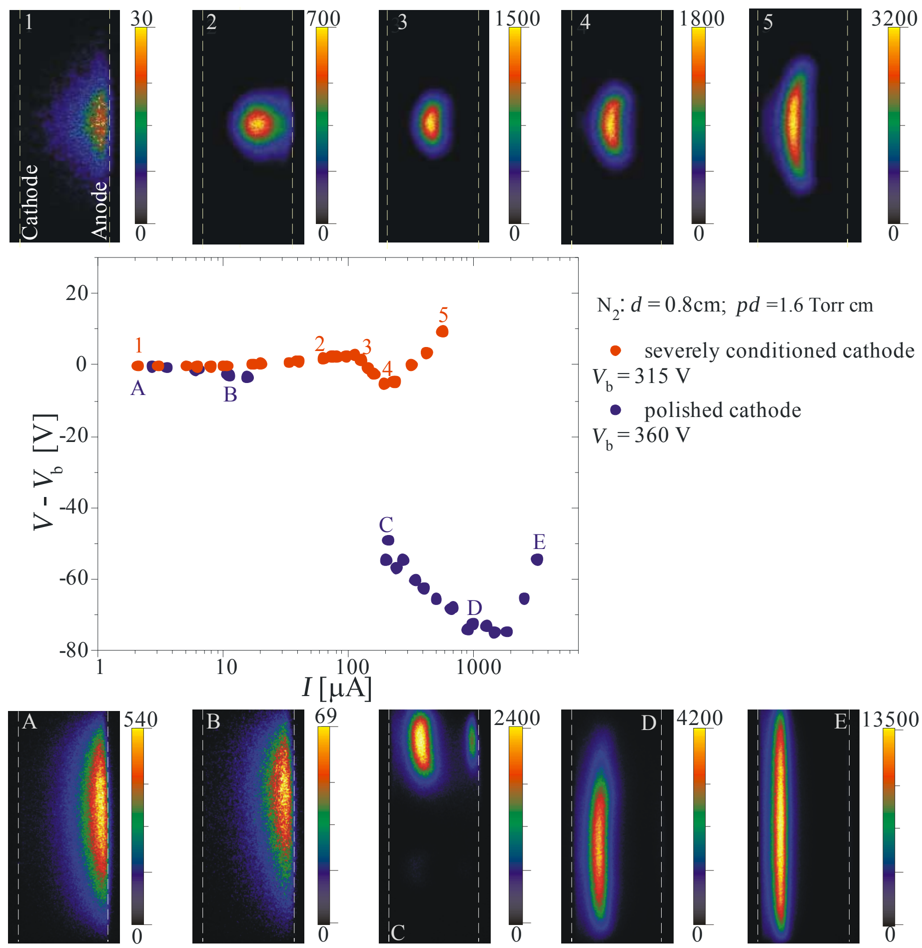

Fig. 1: Volt-ampere characteristics for: the discharge established by using cathode that was significantly conditioned by glow discharge in the central area of its surface (red circles) and by using new polished homogeneous cathode (blue circles). Upper row of images coresponds to selected points labeled by 1-5. Lower row shows images of discharge taken for points labeled by A-E. Position of electrodes is indicated by white dashed lines. Gap between electrodes is 0.8 cm and electrode diameter is 2.2 cm.

Presented results lead to several important conclusions: (*i*) long pre-conditioning of the cathode surfaces can lead to variable secondary emission over the surface and misinterpreting of the results; (*ii*) in applications that operate under the constricted normal glow conditions, voltage required for operation may increase over time; (*iii*) even in the low-current Townsend discharge, where it is assumed that radial distribution can be described by the Bessel function that spreads over the electrode diameter, structure of the discharge may appear constricted under certain conditions. This has also been observed in micro discharges [5].

The authors acknowledge support by MES of Serbia (projects ON171037 and III41011).

References

[1] A. V. Phelps and Z. Lj. Petrović, 1999 *Plasma Sources Sci. Technol.* **8** R21
[2] S. R. Gocić, N. Škoro, D. Marić, Z. Lj. Petrović, 20th ESCAMPIG (Novi Sad, Serbia, 2010) P3.17
[3] I. Stefanović and Z. Lj. Petrović, 1997 *Jpn. J. Appl. Phys.* **36** 4728
[4] D. Marić, G. Malović and Z. Lj. Petrović, 2009 *Plasma Sources Sci. Technol.* **18** 034009
[5] Z. Lj. Petrović, N. Škoro, D. Marić, C. M. O. Mahony, P. D. Maguire, M. Radmilović-Rađenović and G. Malović 2008 *J. Phys. D: Appl. Phys.* **41** 194002