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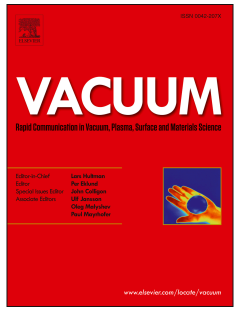

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Electric field non-uniformity effect on dc low pressure gas breakdown between flat electrodes

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This paper presents the results of studying the gas breakdown in a non-uniform direct current electric field. The breakdown curves have been measured in nitrogen between flat electrodes of 6 mm in radius spaced 3 to 300 mm apart and placed inside the discharge tubes of 6.5 mm and 28 mm in radius.

The effects of the non-uniform distribution of the electric field inside the inter-electrode gap and of the diffusion loss of charged particles to the discharge tube walls on the gas breakdown have been studied separately. A conclusion is drawn from the experimental data that the general form of the gas breakdown criterion must be as follows $U = f\left(pL, L/R_{el}\ , L/R_{tube}\right)$ in which the L/R_{el} ratio of the inter-electrode gap value to the electrode radius describes the electric field nonuniformity inside the discharge tube whereas the L/R_{tube} ratio characterizes the diffusion loss of electrons on the discharge tube walls.

It has been found that the breakdown curves for different electrode radius values and a fixed gap L value intersect at such value of the gas pressure that corresponds to the location of the inflection point of the breakdown curve for a uniform electric field.

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Introduction

Direct current glow discharge is widely applied in a multitude of technological processes and devices, e.g. for pumping gas discharge lasers [1, 2], for plasma nitriding [3–5], in xenon and mercury high pressure lamps [6, 7], in surge protectors / transient voltage surge suppressors [8, 9], for plasma sterilizing medical tools and equipment [10, 11], in dc diode sputtering systems [12, 13] etc.

A breakdown curve is one of the important discharge characteristics because it determines the conditions for plasma production in a given research or technological chamber. Therefore for many years a great attention has been devoted to gas breakdown in discharge chambers of different design. Actually all monographs devoted to low temperature plasma outline the Paschen's law describing the ignition of the direct current discharge. This law has been established by Paschen in the course of preparing his thesis (under August Kundt as a supervisor) devoted to studying the gas breakdown in the dc electric field [14]. In his experiments Paschen has employed the spherical electrodes with variable spacing L and measured the breakdown voltage U at different gas pressure values as well as at different spacing values. He has demonstrated that the breakdown voltage U depends not on pressure p and spacing L separately but it is a function of the pL product. In order to preserve historical justice one should remark that the $U(pL)$ dependence was first observed by De La Rue and Müller [15] 9 years before Paschen.

Actually Paschen's law means the following. Let us measure the breakdown curves $U(p)$ for any two different distance L_1 and L_2 values. These curves possess a U-shape with the minimum pressure values of $p_{\min1}$ and $p_{\min2}$, respectively, for which the minimal breakdown voltage values $U_{\min1}$ and $U_{\min2}$ have to be close to each other. When we now plot these breakdown curves to the $U(pL)$ scale, they would match each other. Under such plotting not only minima values $U_{\min1}$ and