SIMULATION OF STREAMERS AND SPARKS IN AIR

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Abstract. The paper discusses two topics on streamer discharges: relation between streamer parameters at the stage of streamer propagation and dynamics of controlled streamer-to-spark transition.

1. INTRODUCTION

Streamer-induced pulsed discharges in high-pressure gases are actively studied now as an efficient means of production of non-thermal plasma. In this paper two topics related with the discharge dynamics are discussed. The first one deals with the stage of streamer propagation and concerns the relation between streamer parameters – radius and propagation velocity. The second topic concerns the stage of streamer-to-spark transition occurring after streamer bridges the discharge gap and forms a conducting plasma channel. The energy input to the channel during this stage may be controlled by changing in time the voltage applied to the gap [1,2]. In the paper a model of the controlled streamer-to-spark transition is described and the results of numerical simulation are presented that demonstrate the effects of various parameters of the electric circuit on the spark characteristics.

2. STREAMER VELOCITY AND MINIMUM STREAMER DIAMETER

Both experiments and simulations show that streamer diameter may vary in a wide range, depending on gas pressure, applied voltage, gap length, etc. Recently a set of experiments has been performed in order to reveal the minimum value $d_{\min}$ of diameter of positive streamer propagating in point-plane gap at pulsed applied voltage [3]. It has been obtained that in room-temperature air at pressure ranging from 0.013 to 1 bar the minimum diameter is related with the normalized gas number density $\delta = n/n_0$ (where $n_0 = 2.5\text{x}10^{19}$ cm^{-3} is the gas number density at room temperature and atmospheric pressure) as $d_{\min}\delta = 0.02$ cm. Below it is shown that the existence of minimum diameter for positive streamers follows from analytical consideration of streamer head structure.

Results of numerical simulation [4] show that the electric field E in front of the streamer head decreases steeply in the direction z of streamer propagation, from the maximum value E_h at $z = 0$, nearly as $E(z) = E_h l_f/(z+l_f)$, the length l_f being about twice smaller than the streamer radius. It allows one to evaluate the distribution of the electron number density n_e along z in front of the head in the framework of one-dimensional approximation. In the reference system moving with the streamer head the balance equation for n_e has the form

$$-V\frac{dn_e}{dz} \mp \frac{d(n_e V_e)}{dz} = \nu_i n_e, \tag{1}$$

Here V is the streamer velocity, V_e is the absolute value of the drift velocity of electrons, ν_i is the effective ionization rate. The upper and lower signs in (1) correspond to positive and negative streamers, respectively. Integration of equation (1) in the region ahead of the field maximum, at $z > 0$, gives for the electron number density n_{eh} at $z = 0$ the expression

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