Unified model of the streamer initiated gas breakdown

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A common feature of the discharges at near-atmospheric pressures is that the most important physical processes leading to the formation of non-equilibrium plasmas occur on the time scales of 10^{-9}s in regions of characteristic size of 0.1 mm. The reasons for the unsatisfactory understanding of such phenomena are both experimental and computer simulation constraints. They are given by the ultra-fast changing basic plasma parameters on given extremely small areas. Based on experimental study and computer simulations of the cathode spot formation for a wide range of electrode geometries and materials, an integrated model describing a wide range of streamer micro-discharges and pre-breakdown phenomena will be presented.

1. Introduction

Since ”the development of atmospheric–pressure plasma sources to replace plasma processing in vacuum systems is a current trend in industrial plasma engineering” [1] in the last two decades the centre of both experimental and theoretical study of the gas discharge ionisation phenomena has been shifted from the low-pressure gas discharges to the discharges generated at near-atmospheric pressures [2].

A common feature of the discharges at near-atmospheric pressures is that the most important physical processes leading to the formation of non-equilibrium plasmas occur on the time scales of 10^{-9}s in regions of characteristic size of 0.1 mm. This is result of the fact that the discharge formation in such conditions is usually associated with the formation of fast and narrow ionization waves, termed ”primary streamers” and consequently, such discharges are now frequently referred to as micro-discharges.

The arrival of a primary streamer to the cathode forming an active cathode spot/region marks an important turning point in the development of micro-discharges and is a significant bottleneck in the understanding of the micro-discharge formation mechanism [3]. Similar phenomena occur also as streamer-like instabilities in the cathode region leading to the plasma filamentation and glow-to-arc transitions in various types of atmospheric-pressure glow discharges. The reasons for the unsatisfactory understanding of such phenomena are both experimental and computer simulation constraints: The main experimental difficulties are due to small size of the cathode spots, their random distribution on the cathode surface, and the nanosecond time scale of their formation. As a consequence, computer simulations are the essential tools that can be used to increase our understanding of the cathode spot formation. The simulations, however, are constrained by the fact that they typically fail as the streamer reaches the cathode due to instabilities introduced by numerical discretization.

Based on experimental study and computer simulations of the cathode spot formation for a wide range of electrode geometries and materials, an integrated theoretical model describing a wide range of streamer micro-discharges and pre-breakdown phenomena will be presented. Except for narrow-gap (< 5.10^{-6}m) and microwave breakdowns, the model is applicable to all high-pressure discharge types, serving as a necessary guide in the selection of cases for further study by experiment or computer simulation, as well as for the design of atmospheric-pressure sources of non-thermal plasmas.

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3. References

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