World Academy of Science, Engineering and Technology
International Journal of Electrical and Computer Engineering
Vol:12, No:12, 2018

Electro-Hydrodynamic Effects Due to Plasma Bullet Propagation

Authors : Panagiotis Svarnas, Polykarpos Papadopoulos

Abstract : Atmospheric-pressure cold plasmas continue to gain increasing interest for various applications due to their unique properties, like cost-efficient production, high chemical reactivity, low gas temperature, adaptability, etc. Numerous designs have been proposed for these plasmas production in terms of electrode configuration, driving voltage waveform and working gas(es). However, in order to exploit most of the advantages of these systems, the majority of the designs are based on dielectric-barrier discharges (DBDs) either in filamentary or glow regimes. A special category of the DBD-based atmospheric-pressure cold plasmas refers to the so-called plasma jets, where a carrier noble gas is guided by the dielectric barrier (usually a hollow cylinder) and left to flow up to the atmospheric air where a complicated hydrodynamic interplay takes place. Although it is now well established that these plasmas are generated due to ionizing waves reminding in many ways streamer propagation, they exhibit discrete characteristics which are better mirrored on the terms 'guided streamers' or 'plasma bullets'. These 'bullets' travel with supersonic velocities both inside the dielectric barrier and the channel formed by the noble gas during its penetration into the air. The present work is devoted to the interpretation of the electro-hydrodynamic effects that take place downstream of the dielectric barrier opening, i.e., in the noble gas-air mixing area where plasma bullet propagate under the influence of local electric fields in regions of variable noble gas concentration. Herein, we focus on the role of the local space charge and the residual ionic charge left behind after the bullet propagation in the gas flow field modification. The study communicates both experimental and numerical results, coupled in a comprehensive manner. The plasma bullets are here produced by a custom device having a quartz tube as a dielectric barrier and two external ring-type electrodes driven by sinusoidal high voltage at 10 kHz. Helium gas is fed to the tube and schlieren photography is employed for mapping the flow field downstream of the tube orifice. Mixture mass conservation equation, momentum conservation equation, energy conservation equation in terms of temperature and helium transfer equation are simultaneously solved, leading to the physical mechanisms that govern the experimental results. Namely, we deal with electro-hydrodynamic effects mainly due to momentum transfer from atomic ions to neutrals. The atomic ions are left behind as residual charge after the bullet propagation and gain energy from the locally created electric field. The electro-hydrodynamic force is eventually evaluated.

Keywords : atmospheric-pressure plasmas, dielectric-barrier discharges, schlieren photography, electro-hydrodynamic force
Conference Title : ICPPA 2018 : International Conference on Plasma Physics and Applications
Conference Location : New York, United States
Conference Dates : December 17-18, 2018