Simulation of Nanosecond Pulse Discharge in Air Using Advanced Plasma Models

Bernard Parent [1]

[1]Pusan National University, Korea, Republic of

The numerical simulation of non-neutral plasmas has so far been particularly challenging due to the large discrepancy of the wave speeds. Whereas ions and neutrals velocities travel at velocities generally not exceeding a few hundred meters per second, the electrons travel at velocities in excess of a million meters per second within the non-neutral sheaths where the electric field reaches high values. Because the stability conditions associated with the largest wavespeeds force the integration steplengths to be excessively small, a large number of iterations is needed to perform simulations of non-neutral plasmas. This effectively prevents the simulation of meshes with more than a few tens of thousands of cells.Such mesh sizes are too small to minimize the numerical error to a satisfying level, resulting in possibly substantial error often exceeding the error associated with the physical model. Recent progress in computational plasmadynamics has made it possible to overcome this hurdle. As was demonstrated in recent papers by the Author, the slow convergence of the drift-diffusion plasma model is not due to the discrepancy of the wave speeds but rather due to the potential equation based on Gauss's law amplifying the errors associated with the charged species concentrations. Thus, a new set of governing equations for non-neutral plasmas was devised that doesn't make use of Gauss's law but rather obtains the electric field from a potential based on Ohm's law. To ensure that Gauss's law is satisfied in the non-neutral sheaths,some source terms are added to the ion transport equations. Such a recast of the equations is performed while not altering the physical model. That is, the converged solution (on a fine enough mesh) is identical to the one obtained with the standard drift-diffusion model while resulting in a 10-1000 times decrease in computational effort for various problems. For a given computing hardware, this permits the use of finer meshes, and hence leads to reduced numerical error. In this presentation, we use the new computationally-efficient plasma model to obtain numerical results of a nanosecond discharge in air interacting with a boundary layer. The results obtained show that the new plasma model permits the use of meshes with millions of cells, hence leading to much reduced numerical error compared to the standard drift-diffusion model.

This research was sponsored by a grant from the National Research Foundation of Korea (NRF).