Application of Scientific Computing in Plasmas and Gas Discharge Physics

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Abstract: The present century is expected to be not only the century of informatics and biomedicine but also the century of plasma technologies, due to their significant advantages over traditional chemical technology widely used in the last century. As plasma is typically non-equilibrium, it is very difficult to describe it using standard theoretical and experimental methods, which is mostly because of high complexity of involved processes. In this regard, in past decades scientific computing has become widespread tool in low temperature plasma physics and technology. In some cases, when obtaining experimental data is extremely difficult or impossible, numerical simulations are a primary method of research.

Modeling approaches that are used in solving modern problems of gas discharge physics can be divided into kinetic, hydrodynamic and hybrid approaches. The most detailed and accurate among them is kinetic approach, which is based on the concept of plasma as a combination of large number of particles and uses statistical methods to describe the collisions between them. Due to the necessity of describing a large number of particles, this method is more time consuming and costly. In the fluid approach, the description of the plasma components is carried out using average macroscopic parameters (concentrations, fluxes, average energy of particles, etc.). Fluid balance equations together with macroscopic Maxwell equations, such as Poissons equation, which describes the effect of space charge on the electric field, give a complete, self-consistent description of the discharge. The hybrid approach combines the hydrodynamic and kinetic approaches.

Among the most important advantages of the fluid approach is relatively simple software implementation. Fluid models require significantly less computational resources compared with kinetic approach, and are flexible enough to adapt equations to a wide range of discharge conditions. Fluid approach is realized in software package Comsol Multiphysics. This approach allowed for obtaining models of different kind of discharges for scientific and technical purposes. Using this approach a detailed longitudinal structure of different types of glow discharges used in modern applications was obtained. Other discharges effectively simulated using fluid approach include CCP and ICP discharges, corona discharge, dielectric barrier discharge (DBD), atmospheric pressure microdischarge, etc.

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