Particle-in-Cell/Monte Carlo Collisions simulation of low pressure capacitively coupled plasmas

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Low-pressure capacitively coupled plasmas (CCPs) are widely used in the manufacturing of high-tech devices. CCPs are basic tools in applications such as plasma-enhanced chemical vapor deposition and plasma etching in the semiconductor industry, as well as in applications aimed at surface treatment in bio-engineering and medicine [1]. These applications are based on the interaction of plasma particles with the electrode surfaces: the plasma changes the nature of the surface exposed to particle bombardment; at the same time, the surface also influences the nature of the plasma via various surface processes such as particle absorption, reflection, and emission.

The Particle-in-Cell (PIC) approach combined with Monte Carlo (MC) type treatment of collision processes (known as the PIC/MCC method [2]) has become the prevailing self-consistent numerical method for the kinetic description of low-pressure CCPs. In this approach "superparticles", representing a large number of real plasma particles, are traced, and their interaction is handled via the electric field calculated at points of a computational grid. This efficient simulation technique makes it possible to follow the spatio-temporal evolution of discharge characteristics and to obtain information about various plasma parameters, e.g. densities and fluxes of different plasma species, particle heating rates, rates of different collision processes, etc.

In PIC/MCC simulations of low-pressure CCPs, the description of the interaction of plasma particles with the boundary surfaces is generally implemented in a simplified manner. For heavy particles, the assumption of a constant secondary electron (SE) emission coefficient is typical, independent of the incident particle energy and angle, the electrode material and its surface conditions. For electrons, a constant probability for the elastic electron reflection is generally set, while other electron-surface processes, e.g. the emission of SEs by electron impact, are completely neglected. By using our 1d3v electrostatic PIC/MCC code [3], we perform a systematic investigation of the effects of implementing realistic energy-dependent SE yields for heavy particles and electrons, and taking the surface conditions into account on the calculated discharge characteristics, under conditions relevant for plasma processing applications of surfaces [4, 5, 6].

References

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