Abstract

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This work presents results of the development of new 1D and 2D Particle-in-Cell/Monte Carlo Collisions (PIC/MCC) programs optimized for GPU hardware. We perform an in-depth analysis of gas discharge physics, as well as all basic and advanced aspects of the PIC/MCC method. Briefly, we present basic principles, concepts and definitions from the field of programming GPU hardware. In the context of PIC/MCC we perform an in-depth analysis of mathematical methods for solving numerical problems including solving the electrostatic Poisson equation in 1D and 2D, and we present a detailed analysis of the implementation of these numerical methods optimized for GPU hardware, as well as the implementation of the PIC/MCC programs. We use our 2D PIC/MCC program to study the influence of a non-planar, structured electrode on a plasma generated by a low-pressure radiofrequency discharge in helium gas. We show that our PIC/MCC programs efficiently utilize the GPU hardware, and that their results are in agreement with the theory as well as experimental measurements of discharges. From these results we make several conclusions relevant for modern practical applications of plasma such as plasma-assisted sterilization and plasma-assisted coating deposition in the presence of complex, structured electrodes.

Keywords: plasma, Particle-in-Cell/Monte Carlo Collisions, 1D/2D PIC/MCC, simulations, modelling, discharge physics, structured electrodes, GPU programming, GPU program optimization, 1D/2D Poisson equation, random number generation, Monte Carlo methods