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An advanced particle-in-cell simulation parallelized with GPUs for a capacitively coupled plasma reactor

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Many key aspects of low-temperature plasmas include nonlinear transient and kinetic effects related to the spatiotemporal variation of electron energy distribution function (EEDF) which cannot be treated in a fluid simulation model. The particle-in-cell (PIC) simulation calculates kinetic effects through the statistical representation of the EEDF using many particles and thus gives accurate results. However, the computational cost is very expensive to resolve all aspects in a plasma discharge with millions of particles as well as hundreds of thousand of grids during millions of time steps. Additionally, the simulation of discharge plasmas should handle the collision processes and the rapid increase of the total number of simulation particles. In this presentation, details of a two-dimensional PIC simulation parallelized with graphics processing units (GPUs) are explained for the improvement of computation speed. For the simulation of a capacitively coupled plasma reactor with a gas pressure from 10 mTorr to 3 Torr, various kinetic effects are analyzed with the GPU-PIC code by investigating the spatiotemporal variation of EEDFs and electron heating. Finally, the changes of ion energy and angle distribution functions on the substrate are presented with the increase in gas pressure.