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Kinetic and electromagnetic effects in technical plasmas

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There is an accumulating body of evidence that kinetic effects play a significant role in practically all kinds of technical plasmas. Such plasmas often exhibit several groups of electrons with disparate energies, where electrons from different groups exchange energy only through weak processes. The intrinsically non-Maxwellian charachter of the electron distribution function in this case invalidates the fluid-based approaches for description of the technical plasmas. Rather, a self-consistent kinetic treatment is frequently needed for capturing all the important physics features, whereas fluid models under such conditions can yield quantitatively or even qualitatively erroneous results. Despite this, the fluid-based numerical codes remain a popular tool for investigation of the technical plasmas due to the low computational cost of such codes compared to that of the kinetic ones. The proper description of technical plasmas becomes further complicated if in addition to the kinetic treatment one needs to consider electromagnetic effects, which gain in significance as the electrode size and driving frequency increase, which continues to be the tendency in many CCP industrial plasmas usually described under the electrostatic approximation. In this talk we discuss modern techniques of parallelization of self-consistent kinetic particle-in-cell/Monte-Carlo (PIC/MCC) numerical codes on graphics cards (GPUs), which make kinetic simulations a routine numerical tool for investigation of technical plasmas. Then, we will demonstrate for the plasmas spanning broad parameter range examples of simulations made with such codes, where kinetic effects are important and thus the fluid description is inadequate. Finally, we argue that in many situations the electromagnetic effects relevant to the technical plasmas can be described in the framework of Darwin (magneto-inductive) approximation, which can be implemented as a natural modification in an electrostatic PIC/MCC code, as all the field equations are elliptic. We give the examples of kinetic simulations with electromagnetic effects obtained with such Darwin code.