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Fully Electromagnetic PIC/MCC Simulation of Discharge in the Ion Thruster

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Due to their high efficiency, high specific impulse, long lifetime and high reliability, ion thrusters[1] have already become the research focus of the international electrical propulsion.

In the early 1990's, Arakawa and Yamada[2] developed a computational tool called PRIMA to model the primary electron trajectories using Monte Carlo and finite element methods. PRIMA considered the effects of magnetic fields, but not electric fields. In 2005, Wirz and Katz[3] proposed a two-dimensional hybrid model to study the effects of electrons, ions and neutral particles inside the discharge chamber. However, only primary electrons were tracked, and the ions and electrons were modeled using a diffusion approach based on the assumption of quasi-neutrality. Also the charge particles effects on electric fields were neglected. In 2010, Mahalingam and Menart[4] used a fully kinetic PIC/MCC model to calculate the dynamic electric field inside the discharge chamber, tracked five major types particle. They ignored the effects of the dynamic magnetic fields produced by the charged particles' movement. Mao and Sun[5] used PIC/MCC method to simulate the plasma flow inside the discharge chamber. Zhang and Chen[6] established a 2D axisymmetric PIC/MCC model to simulate the dynamic behavior of primary electrons. The collision probabilities between the electrons and neutral atoms, the loss rate of the electrons, and the effects of electromagnetic field were analyzed.

Up to now, the numerical simulation of the ionization characteristics of the ion thruster discharge chamber was mainly based on electrostatic model, which can't make research deeply on the electromagnetic radiation characteristics and the self-consistent interaction between charged particles and time-varying electromagnetic fields inside the discharge chamber. In this paper, the 2D-RZ PIC/MCC solver in the BUMBL- EBEE software was used to simulate the ionization process of the ion thruster. A 2D axisymmetric model showed in figure 1 was established to test the 2D-RZ PIC/MCC solver.

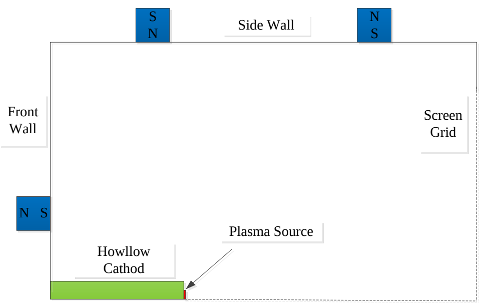

Figure 1. Schematic of discharge chamber model

Three major particle types including primary electron, secondary electron, and singly charged xenon ion were tracked. The neutral particles were treated as background gas and detailed particle ionization collisions between the charged particles and the neutral particles were simulated. The complete Maxwell's equations were solved and taken the effects of the magnetic fields on the charged particles into account in the self-consistent way. The spatiotemporal distribution of the charged particles and electromagnetic fields were obtained in detail.

Figure 2 shows the primary electron number density distribution results at 330ns. The maximum primary electron density value of $1 \times 10^{18} m^{-3}$ was observed near the cathode exit region. The primary electrons were well confined by the strong magnetic field lines. Also we can see that the number density values decrease rapidly for the regions close to the screen grid. More results and relative simulation discussions will be reported in future.

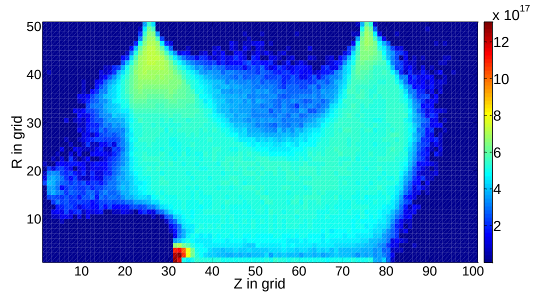

Figure 2. Electron number density results in R-Z plane

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