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Development of Plasma Fluid Model in Microwave Rocket Supported by Magnetic Field

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Discrete plasma were obtained at atmospheric pressure in the discharge experiments for a microwave rocket. However, the microwave plasma transitioned from discrete to diffusive patterns with decrease in an ambient gas pressure, while increasing the propagation speed of the ionization front. Thrust performance of a microwave rocket was degenerated at low pressures because of the high-speed propagation of the ionization front and the smaller energy-absorption rate of the plasma. An external magnetic field is applied to the breakdown volume to suppress the propagation speed of the plasma and increase the energy-absorption rate due to an electron cyclotron resonance heating. The one-dimensional particle-in-cell with Monte Carlo Collision simulation (PIC-MCC) is conducted to trace motions of the electron and ion under the magnetic field. The shock wave driven by gas heating is enhanced inside the rocket nozzle by applying the magnetic field, which results in improvement of the thrust performance at low pressures. However, the multi-dimensional breakdown dynamics is not discussed under the magnetic field using the fully kinetic model because of a huge computational load. The fluid model of the plasma transport under the magnetic field is constructed to reduce the computational load for the multi-dimensional simulation. The transport coefficients of the charged particles are evaluated based on swarm simulations using the PIC-MCC code, which are introduced into the fluid model to keep consistency between the fluid and particle models. The plasma pattern of the fluid model is in good agreement with that of the PIC-MCC model at 0.5 atm. Multi-dimensionality of the breakdown plasma is examined using the fluid simulation, and the discrete plasma structure is induced by reflections of the incident microwave from the overcritical plasma.

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