Paper ID: 78698
student

IAF SPACE PROPULSION SYMPOSIUM (C4)
Electric Propulsion (1) (5)

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COUPLED PARTICLE-IN-CELL AND DIRECT-SIMULATION MONTE-CARLO MODELLING OF GRID EROSION BY ION BOMBARDMENT IN RADIO-FREQUENCY ION THRUSTER GRIDS

Abstract

The high specific impulse ($2000 < I_{sp} < 3000\,s$), broad range of available thrust ($\mu N - N$) and reliability have made ion thrusters one of the standard electric propulsion devices for attitude control, orbital raising maneuvers and Deep Space missions. Determining the physical phenomena of grid erosion occurring in radio-frequency ion thrusters are crucial for determining and improving the lifetime of this type of electric propulsion system. The main cause for grid erosion are on one hand misaligned primary ions of the accelerated ion beam that collide with the accelerator grid during acceleration. On the other hand, fast moving ions may collide with neutral gas atoms from the discharge chamber within the grid, resulting in a charge exchange (CEX) event that produces a fast moving neutral atom and a slow secondary ion. If this occurs in proximity to the accelerator grid, the slow moving ion will be accelerated towards it, resulting in ion bombardment. The approach and results of modelling these processes for a μN RIT3.5 thruster using a coupled Particle-in-Cell (PIC) and Direct-Simulation Monte-Carlo (DSMC) approach are outlined. In contrast to the Monte-Carlo-Collision (MCC) technique, the DMSC method models all inter-species collisions directly. Chemistry between the interacting species is implemented with a cross-section based database from experimental data, where the collision probability is added to the DSMC collision probability each time step to reproduce the reaction rates. Results of the simulations are compared with experimental data and utilized to apply analytical formulas based on the time-averaged ion bombardment impact energy and temperature along the grid surfaces for a given simulation time in order to estimate and extrapolate the geometrical erosion on the grid surfaces.