Numerical Simulation of Two-Grid Ion Optics Using a 3D Code

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A three-dimensional ion optics code has been developed to model two grid ion optics systems. The computational domain extends axially from the discharge chamber through the screen and accelerator grid and several centimeters into the ion beam downstream of the accelerator grid. Perpendicular to the aperture pair axis the computational domain is a triangular wedge with a 30° angle extending from center of a hole to the midpoint between two holes; the entire aperture region can be covered by reflection and/or rotations of the triangular domain. The potential is specified on the upstream and downstream boundaries as well as at the grid surfaces, and the normal electric field is specified to be zero at the other computational domain boundaries. A discharge chamber plasma with specified electron temperature and number density exists in the region upstream of the screen grid. Positive ions flow from the discharge chamber through the screen and accelerator grid apertures into an ion beam downstream of the accelerator grid. The electron temperature is specified in the ion beam region and the electron density is that required to charge neutralize the ion beam. The neutral gas density is also specified in the discharge chamber and a background neutral gas density can be specified in the ion beam. Charge-exchange collision rates for beam ions interacting with neutral gas are determined. These charge exchange ion trajectories are then followed to determine where they strike the grid and how much sputter erosion they cause.

An iterative scheme is used to solve the ion optics problem. First the potential is obtained using a finite element approximation to solve Poisson's equation. Then beam ion trajectories are computed using the electric field determined from the potential solution. Over several iterations the positive beam ion charge is slowly incremented and blended with the charge from the previous iteration, until the desired beam current is obtained. On each iteration, the positive charge is assigned to the finite element nodes using the weighting from the finite element shape functions. The electron charge density is computed using the barometric law in the discharge chamber and in the ion beam downstream of the accelerator grid. Once the beam ion solution has been determined, charge-exchange ion production and trajectories are computed.

A comparison of code predictions with results from NSTAR ion thruster tests is presented. The code predicts the pits and grooves wear pattern observed on the downstream side of the NSTAR accelerator grid but over predicts the initial erosion rate by about 50%.