A 2-D Model of a Hollow Cathode Insert Plasma

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Hollow cathodes are critical components of most electrostatic and Hall effect ion thrusters. Proposed missions being studied under Project Prometheus, such as JIMO, may require hollow cathode life three or more times longer than presently demonstrated. The purpose of this work is to develop and validate physics based models of hollow cathode performance and life for such missions.

Hollow cathode performance and life are determined by the plasma processes in the insert region, along with thermionic emission from the barium rich emitter surface. Electrons are accelerated through a sheath potential and partially ionize the propellant gas. In turn, ions are accelerated back to the emitter surface, maintaining the temperature high enough to support the required current density. In this paper we present a new hollow cathode insert region model that combines bulk plasma processes, thermionic electron emission across a plasma sheath, and a simple thermal model.

In the insert region of a typical ion thruster hollow cathode, electrons transfer between neutral gas atoms and ionized propellant through resonant charge exchange (CEX). The charge exchange cross-section between Xe and Xe+ is so large at low ion energies and the gas densities are sufficiently high inside hollow cathodes, that ion mobility is diffusion limited. Using literature values for the cross section, at a cathode pressure of 10 Torr, the ion mean free path for resonant charge exchange is less than 5x10-6 meters, much less than cathode insert dimensions. The model described below builds upon the limited ion mobility to construct a set of fluid equations that describe the insert region plasma.

The model predicts sheath potentials, plasma temperatures, and the insert "emission zone", the limited area of the insert that accounts for most of the electron emission. It is found that bulk ionization of the propellant accounts for some of the cathode current, and that barium is ionized immediately.