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HIGH ENERGY ION PRODUCTION AND EROSION IN HOLLOW CATHODE MICROTHRUSTERS

Abstract

The current paper makes a study of the downstream ion energy distribution in hollow cathodes using a hemispherical energy analyser to determine the influence of high energy ion erosion in hollow cathode microthrusters. In recent years hollow cathodes have received interest as standalone microthrusters. Two forms of device have subsequently been developed based on the T5 and T6 hollow cathodes (HC). Indirect thrust measurements have shown that the T5 and T6 microthrusters are capable of propulsive performance of interests for both small spacecraft and all-electric spacecraft however the operating points are generally outside of the typical envelope of operation, most notably with much lower flowrates and higher discharge currents. Under these low flow conditions, cathodes transition into 'plume mode' type operation, synonymous with large discharge voltage oscillations and plasma instabilities. Hollow cathodes were originally suggested as standalone microthrusters based on observed downstream ion energy distributions, suggesting a reasonable fraction of energetic ions are accelerated downstream. These fast ions have also however been attributed to high rates of cathode erosion in ring cusp type GITs following long duration testing. Since then, their presence has been confirmed by many sets of experimental data. The majority of the data agree that these ions are emitted from a highly localized region either within or directly in front of the cathode orifice. The means by which ions are accelerated to such velocity has been debated for some time. Proposed mechanisms have included the formation of potential hills, charge exchange between ions and neutrals, double ionization, triple ionization, multiple collisions of ions with the cathode orifice wall, magneto-plasma-dynamic mechanisms and turbulent plasma oscillations. The current work shows that the ion energy distribution does describe the existence of a potential hill acceleration mechanism whereby a region of positive potential is formed downstream of the cathode, significantly in excess of the anode potential. This forms as a result of a double layer at the cathode exit which creates an intense ionization region significantly raising the local plasma potential. This region serves to accelerate ions back towards the cathode at high velocity which then impact and sputter the cathode. The data also shows however that the main source of high energy ions are local plasma potential oscillations caused by ion acoustic turbulence in plume mode. The work is of significance to all applications of hollow cathode including microthrusters, gridded ion thrusters and plasma contactors.