Paper ID: 10211
student

SPACE PROPULSION SYMPOSIUM (C4)
Electric Propulsion (4)

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PREDICTIVE CONTROL OF PLASMA KINETICS: TIME-RESOLVED MEASUREMENTS OF INERT GAS MIXING IN A HOLLOW CATHODE DISCHARGE

Abstract

Improved Hall-effect Thruster (HET) efficiency would enable more extensive cost-capped, Discovery class NASA missions such as robotic missions to Mars and near-Earth asteroids to perform round trip sample-returns. HET efficiency would be further improved if electrons with energies that contribute to ionization are increased, and those involved in transient processes are reduced. Therefore, control of the Electron Energy Distribution Functions (EEDFs) is needed. However, predictive tailoring of the EEDFs in plasma devices remains a challenging problem in plasma physics due to complex electromagnetic interactions that take place in the actual system that lead to the turbulent nature of these plasmas. Time-averaged diagnostics, which are currently the primary method for characterizing these systems, have not been able to explain dynamic mechanisms that may affect ionization efficiency such as the anomalously high electron cross-field transport. The High-speed Dual Langmuir Probe (HDLP) system, which is an in-lab-built diagnostic, has been developed to obtain time-resolved measurements of electron density, electron temperature, plasma potential, and the EEDF with an unprecedented 10 μs resolution [1].

The HDLP was used to obtain measurements in a hollow cathode xenon discharge operated in triode configuration. The hollow cathode was run in plume mode where the plasma exhibits an underlying periodicity inherent in HET plumes as well. Data was also obtained with the introduction of another inert gas, such as helium or argon, at various partial pressures. Detailed maps of the temporal and spatial evolution of various plasma properties were compiled from high spatial resolution data taken across a large portion of the plume. Inert gas mixing was shown to be an effective method for tuning electron temperature and density by as much as an order of magnitude. Also, when one of these gases is a small percentage of the mixture, its naturally present, small fraction of metastable states have a greater effect on the plasma; and the superelastic collisions that ensue create plateaus, holes and peaks in the EEDF. Additionally, higher cathode-to-keeper voltages reduced the magnitude of these effects. These results will be used to develop possible predictive control methods in HETs. The end goal is to obtain an understanding of the physical dynamics that govern how transients and ionization in a HET are affected by EEDF changes. With that knowledge, schemes to predictably tailor the EEDF in order to increase HET efficiency will be developed.

[1] R. Lobbia and A. Gallimore, Rev. Sci. Instrum. 81, 073503 (2010)