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MINIATURIZED ELECTRIC PROPULSION SYSTEM BASED ON HIGHLY EFFICIENT HALL-EFFECT THRUSTER TECHNOLOGY

Abstract

The significance of small satellites has grown across various applications, owing to their compact size, reduced costs, and enhanced accessibility. Electric propulsion systems present numerous advantages over traditional chemical propulsion systems, especially in terms of extending orbital lifetimes and ensuring precise spacecraft positioning. However, there is a challenge in developing powerful and miniaturized electric propulsion systems. Therefore, a small and highly efficient electric propulsion system would be suitable to open new opportunities for commercial, academic, and scientific small satellite missions. The German company BERLIN SPACE has developed a miniaturized electric propulsion system for small satellites, which uses innovative Hall-effect thruster technology to increase the thruster efficiency. A novel approach to enhancing propellant ionization in small-scale Hall-effect thrusters has been both theoretically investigated and empirically validated. This innovative method involves the integration of a high-frequency component into the thruster's discharge circuit, with a frequency corresponding to a multiple of the electron-drift frequency. The resulting increased electron velocity leads to an enhancement in propellant mass utilization and energy efficiency. Two technical implementations of this method were proposed and experimentally evaluated: one involving no modification to the existing design of the Hall-effect thruster, and the other incorporating additional elements into its structure. Test results indicated that the second approach achieved superior results. Based on the resulting high-efficient thruster, BERLIN SPACE has developed two different versions of the electric propulsion system that can be operated either with xenon or with krypton. The overall size of the propulsion system has a maximum dimension of a 3U CubeSat and features a specific impulse of up to 900 s and a power consumption of 65-80 W. With a tank volume of roughly one liter, a total impulse of several kilonewton-seconds can be achieved. Additionally, the Hall-effect thruster of BERLIN SPACE uses a special technology that reduces the erosion of the anode unit ceramics to such an extent that the lifetime of the thruster can be significantly increased. In conclusion, the development of a highly efficient and miniaturized electric propulsion system holds significant promises in advancing the capabilities of small satellites for diverse commercial, academic, and scientific missions.

Keywords: Electric Propulsion System, Hall-Effect Thruster, Small Satellites, Miniaturized, Advanced Micro-Propulsion for Small Satellites