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OPTIMIZED VAPORIZATION IN LIQUID-FED MICRORESISTOJETS USING PULSED HEATING

Abstract

The recent advancements in MEMS technology have allowed the development of secondary micro-propulsion systems for small satellites (total mass ¡ 10 kg) for Earth and Deep Space observation. Among them, vaporizing liquid microthrusters (VLMs) are an interesting choice thanks to their simplicity and the advantage in using lighter and smaller propellant tanks. VLMs provide thrust force ranging between 0.1 and 10 mN and have an estimated specific impulse (Isp) above 100 s for water. However, to reach such values, the liquid propellant is heated at a temperature much higher than its boiling temperature, inducing explosive boiling into the flow channels. This reduces the VLM lifetime and dramatically worsens its nominal performance leading to low thermal efficiency and thrust unsteadiness.

We have developed and manufactured a MEMS-based VLM consisting of an inlet chamber, multiple parallel microchannels as a heating chamber, and a planar convergent-divergent micronozzle. A sandwich structure defines the overall device layout: the inlet chamber, the heating chamber, and the micronozzle are fabricated using anisotropic wet etching of a silicon pad; a Pyrex pad is glued onto the silicon pad, ensuring optical access inside the microthruster. A Platinum resistive film placed on the bottom of the silicon pad provides the main heat source required for water vaporization. In addition, a set of thermistors and vapor quality capacitive sensors have been designed to equip the microthruster with local sensing capabilities.

The operational feasibility of the microthruster has been previously demonstrated. In the present work, we apply fast pulsed actively controlled heating to maximize the thermal efficiency and stabilize the thermal oscillations induced by boiling instabilities. Such control is based on the embedded micro-sensors, real-time management electronics, and the implementation of a PID controller acting on the pulse duty

cycle. An experimental campaign is conducted to build an experimental dataset capturing the dynamic response of the VLM at different operating conditions by varying the pulse frequency, the pulse amplitude, and the PID parameters. Therefore, the experimental dataset is used to define the optimal pulse law in combination with the PID control as a function of the operating conditions and the target setpoints. The entire optimization process is based on the minimization of response time, response overshoot (mostly related to the device safety), steady-state oscillations, and the maximization of the thermal efficiency. Therefore, the resulting optimal controls are experimentally validated, and the most relevant insights are discussed.