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FLOW REGIME CHARACTERIZATION OF A MEMS-BASED VAPORIZING LIQUID MICROTHRUSTER

Abstract

The spacecraft miniaturization has led to the reduction of the total expenditure of space missions and, hence, to the development of nanosatellites (total mass below 10 kg) for Earth and Deep Space observation. They usually require thrust forces from few micro-newtons up to some milli-newtons for attitude control and pointing requirements, in combination with constraints of the available power (usually ranging between 2.5 W and 20 W).Micro-resistojets represents a promising solution due to the simplicity of their working concept which well meets the Micro-Electric-Mechanical Systems (MEMS) manufacturing technology. When operating with liquid propellant, they are known as Vaporizing Liquid Microthrusters (VLM): they allow the storage of larger amount of propellant into lighter and smaller propellant tanks. Furthermore, the use of water as propellant meets the even more stringent requirements of safety in operation and non-toxic emissions. However, the behaviour of a VLM is intrinsically instable. In fact, flow boiling instabilities occur into inlet and heating chambers causing pressure-temperature-mass flow rate oscillations which dramatically affect the expansion process into the micronozzle, and hence the microthruster performance.

A MEMS-based VLM prototype has been designed and manufactured. The device composes of an inlet chamber, a set of parallel microchannels as 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 have been fabricated using anisotropic wet etching of a silicon pad; a Pyrex pad is glued onto the silicon pad, which allowed to optically 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. Different microchannel geometries and inlet chamber configurations have been designed in order to evaluate their impact on micro flow boiling instabilities and microthruster performance. In addition, a set of thermistors and vapor quality capacitive sensors have been designed to equip the microthruster with sensing capabilities for the flow instability control.

The operational feasibility of the microthruster has been previously demonstrated. Based on those findings, a deep flow regime characterization has been performed. To this purpose, micro-flow high-speed visualization has been performed in order to investigate the dynamics of the boiling flow into the inlet chamber and microchannels at different operating conditions. Schlieren imaging allowed to investigate the exhaust plume in presence of full vaporized flow condition. Results matched with data retrieved by means the embedded micro-sensors.