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Title

Heat Transfer Assessment in a Vaporizing Liquid Microthruster undergoing Dual Heating Control

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Abstract

Recent advancements in MEMS technology have enabled the development of secondary micropropulsion systems for small satellites (total mass < 10 kg), used for Earth and Deep Space observation. Among these systems, vaporizing liquid microthrusters (VLMs) are attractive due to their simplicity and the advantage of using lighter and smaller propellant tanks. VLMs provide thrust force ranging between 0.1 and 10 mN and an estimated specific impulse (Isp) above 100 s for water. However, in order to reach such values, liquid propellants must be heated to a temperature much higher than the boiling temperature, leading to detrimental explosive boiling into the flow channels. This reduces the VLM's lifetime and dramatically worsens its nominal performance leading to low thermal efficiency and trust unsteadiness [1]. We have successfully developed and manufactured a MEMS VLM that is fueled by water and based on a parallel microchannel system. [2]. The device has a sandwich structure that is created by using anisotropic wet etching on a silicon substrate, while a Pyrex substrate is fixed onto the silicon pad by adhesive bonding. Additionally, a set of thermistors and vapour quality capacitive sensors have been designed to equip the microthruster with local sensing capabilities. In our previous investigations [3][4], we have found that the optimization of the heat transfer process and, as a result, the maximization of the propulsive performance, is limited when using one single heating system and geometry. This is due to the high-density ratio of water, which makes it impossible to achieve both a high energy transfer and device safety simultaneously. To have a high energy transfer from solid walls to the fluid, we need to operate at device temperatures well above the threshold tolerated by adhesive bonding.

In this work, we propose a new VLM design where the flow vaporization is achieved in two steps using two different chambers equipped with their own heating systems, which actively separate the boiling and overheating processes. To this purpose, a quasi-1D steady-state numerical model has been developed to solve the flow into the VLM at constant heat flux boundary conditions. This model has been used to provide a preliminary performance assessment of dual heating control and demonstrate its benefit. Furthermore, an experimental assessment of the heat transfer process on a real device undergoing dual heating control is provided, and the most relevant insights are discussed with comparisons with numerical predictions.

References

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