

07/3108 ON A CHIP MICRO-DISCHARGE THRUSTER ARRAYS INSPIRED BY PHOTONIC DEVICE TECHNOLOGY FOR PLASMA TELEVISION

Type of activity: Medium Study (4 months, 25 KEUR)

Background and Motivation

Recent trends in the space community for smaller, cheaper and more frequent space missions are driving the development of micro- and nano-spacecraft which are considered for large constellations or swarm formations. Potential applications are, among others: distributed, simultaneous scientific measurements of the space environment and virtual, sparse apertures in space for high-resolution radar imagery of Earth, interferometry and high gain communications [1]. However, swarm formations tend to require a high degree of relative position control, thus driving the need for high thrust accuracy from on board micro-propulsion systems.

Nano-satellites (with mass between 1 and 10 kg) and pico-satellites (with mass of less than 1 kg) impose significant limitations on mass, power and volume available for all subsystems, including propulsion. In general, micro-propulsion devices will need to be more efficiently packaged than conventional systems in order to comply with the tight constraints [2], [3], and [4]. For micro-propulsion systems, MEMS fabrication processes can be used to integrate thrusters, valves, power conditioning and control electronics into a single device (so-called “Propulsion-on-a-chip”) in an attempt to achieve this [5], [6], and [7].

Hollow cathodes have been used for decades as electron emitters in various electric propulsion applications. The plasma is generated within a cylindrical cavity by the thermionic emission of electrons from a small insert [8]. The plasma then flows through an orifice and couples the cathode to the rest of the discharge. A hollow cathode was first tested as a stand-alone thruster in the early 1970’s using mercury as its propellant, and its performance was characterised [9]. Recently, a hollow cathode thruster has been again proposed for attitude control using noble gases such as argon or xenon, hence allowing the realisation of an all-electric spacecraft [10]. However, these devices are not suitable for nano-spacecraft.

A new generation of hollow cathode-based micro-discharge devices (extracting electrons and ions, in addition to photons) has been developed for optoelectronics applications in order to decrease the pixel size and hence increase the definition of flat-panel visual displays. Emitter arrays (comprising 30x30 single elements as small as 10 μm^2 in emitting area) have recently been fabricated using wet chemical etching processes and laser techniques to etch semiconductor and metal/polymer structures on a single chip module. These arrays are therefore highly scaleable for large television screens [11].

Preliminary assessments indicate that, if the technology used in the optoelectronic field for fabricating micro-discharge devices in arrays is applied to the development of a micro hollow cathode thruster array for “propulsion on a chip”, then suitable micro-propulsive performances may be achieved for enabling nano- and pico-satellite formation flying control and attitude control.

However, detailed assessments need to be performed in order to determine a more precise prediction of hollow cathode array “on a chip” thruster performance and interactions, so that the concept can be reliably compared against other possible

solutions. In particular, the thrust, efficiency and specific impulse must be evaluated. System-level issues such as on-chip integration of propellant storage and feed regulation, power electronics and control also need to be investigated in order to determine overall feasibility. Alternative configuration and integration solutions should be considered, assessed and a trade-off analysis should be performed.

Research and Study Objective

The following tasks shall be undertaken:

- Evaluate the application of the micro-fabrication technologies used in the aforementioned optoelectronic devices to a microchip hollow cathode array thruster concept; assess possible showstoppers, benefits and drawbacks of using such technologies.
- Based on the models developed to determine the characteristics of hollow cathodes used as a neutralizer [6], develop an analytical model and/or numerical simulation in order to evaluate the propulsive performance and operating characteristics of a microchip hollow cathode array thruster; in particular investigate the influence of the reduced orifice diameter and insert diameter on the overall performance. Identify the optimum design of a single-element microchip hollow cathode thruster.
- Produce conceptual designs of a microchip hollow cathode array propulsion system for different configurations and chip-level integration solutions of the system. Identify and consider the critical issues and principal showstoppers, if any, associated with the different conceptual design configurations (e.g. selection of suitable materials for hollow cathode operation and micro-fabrication processes, structural failure under thermal stress, discharge breakdown, propellant mass flow regulation etc.)
- Assess and trade-off the different system design configurations and integration solutions in order to attain a preliminary propulsion system design.

References

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