NASA facts

Film-Evaporation MEMS Tunable Array for PicoSat Propulsion and Thermal Control

The Film-Evaporation MEMS Tunable Array (FEMTA) concept for propulsion and thermal control of picosats exploits microscale surface tension effect in conjunction with temperature-dependent vapor pressure to realize compact, tunable and low-power thermal valving system. The FEMTA is intended to be a self-contained propulsion unit requiring only a low-voltage DC power source to operate. The microfabricated thermal valving and very-high-integration level enables fast high-capacity cooling and high-resolution, low-power micropropulsion for picosats that is superior to existing smallsat micropropulsion and thermal management alternatives.

Chemical micropropulsion options for small satellite systems are currently limited by feed system complexity and viscous losses, which dominate low Reynolds number flows, inhibiting efficient operation at low thrust levels. Electric propulsion, still in development, offers high Isp but with high power/thrust demands and require power supplies which are bulky, complex, and expensive. Off the shelf propulsion for a 1U CubeSat is currently limited to cold gas systems with propellant mass only about 10% of total system mass. Thus the overall micropropulsion systems size is the key challenge that is addresses by the FEMTA technology. The thermal valving concept is compatible with other micropropulsion options such as warm gas, microwave and ion thrusters.

The local vapor pressure is increased by resistive film heating until it exceeds meniscus strength in the nozzle inducing vacuum boiling which provides a stagnation pressure equal to vapor pressure at that point which is used for propulsion. The heat of vaporization is drawn from the bulk fluid and is replaced by either an integrated heater or waste heat from the vehicle serving as a thermal management component.

The valveless design allows the propellant storage to be integrated with the nozzle itself reducing mass and complexity. The nozzle and thermal valve system mass are less than 0.1 gram such that propellant could compose 80% of a 2 gram device.

The FEMTA concept utilizes advanced microfabrication techniques to integrate the propellant storage, feedthroughs and valving in a compact system. Using the MEMS fabrication process, the decoder and driver electronics can be integrated onto the FEMTA propulsion and thermal management chip itself. The power requirement is a low-voltage source in the range of 1 watt (W) or less. Thrust to power is approximately 300 μN/W. The entire FEMTA unit with 1 gram of propellant could be fabricated with a total mass of less than 2 grams and a volume less than 2 cm3 which makes it suitable for picosatellites.

The FEMTA concept provides both thrust and thermal control with the same process

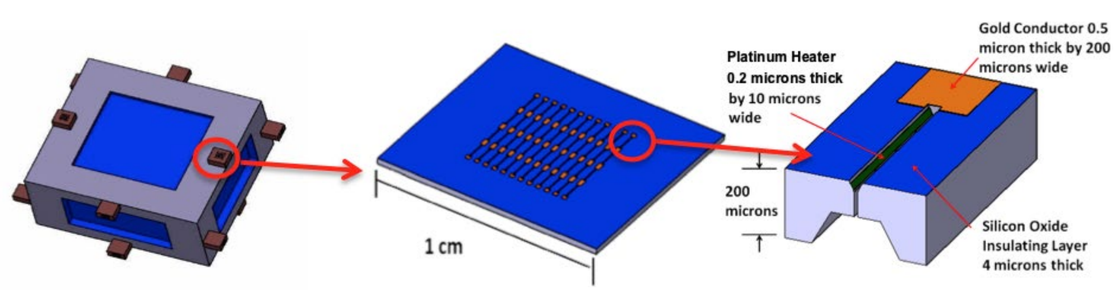

Figure 1. 2D slot type Film Evaporation Mems Tunable Array (FEMTA): (a) Schematic of 12 FEMTAs for 3-axis control on a CubeSat; (b) 4x12 FEMTA array; (c) close-up of a single element of FEMTA inlet side up showing 60 to 10 micron converging inlet and electrical connectors.

and a low mass/low power and inexpensive alternative to conventional reaction control systems. In addition to desaturating momentum wheels this device could provide high slew rates for fast realignment and tracking. FEMTA is conducive to integration with higher Isp micropropulsion options by providing compact thermal valve for propellant handling.

The development and demonstration program directly responds to the requirement for new smallsat technologies in propulsion and thermal management. The FEMTA subsystem enables picosat capabilities for orbital maneuvering, formation flying, proximity operations, rendezvous, docking and precision pointing.

Purdue University, School of Aeronautics and Astronautics and Birck Nanotechnology Center, and NASA Goddard Space Flight Center are collaborators on this project.

This project is funded through the SmallSat Technology Partnerships, a program within the Small Spacecraft Technology Program (SSTP). The SSTP is chartered to develop and mature technologies to enhance and expand the capabilities of small spacecraft with a particular focus on communications, propulsion, pointing, power, and autonomous operations. The SSTP is one of nine programs within NASA's Space Technology Mission Directorate.

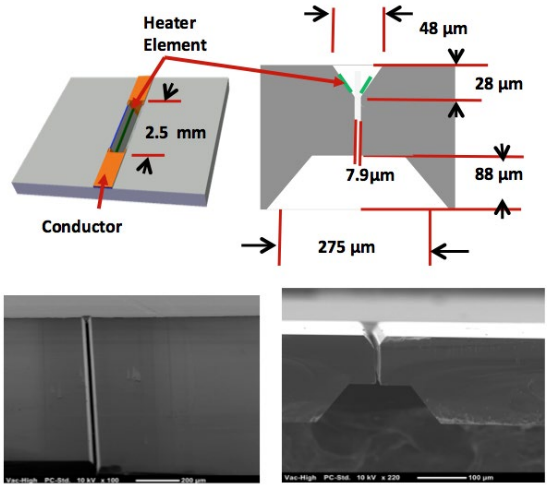

Figure 2. 2-D Prototype single FEMTA nozzle, schematic (top), SEM top view (lower left) and cross section (lower right)

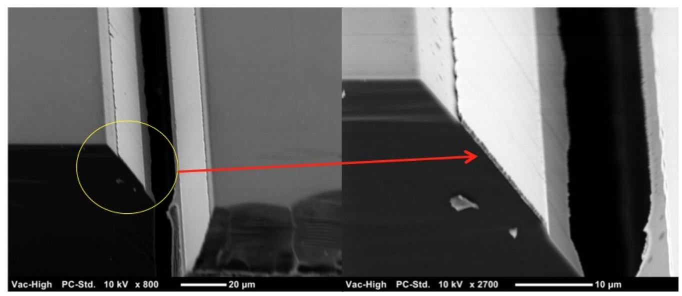

Figure 3. SEM view of nozzle inlet (left), close up on nichrome heater (right)

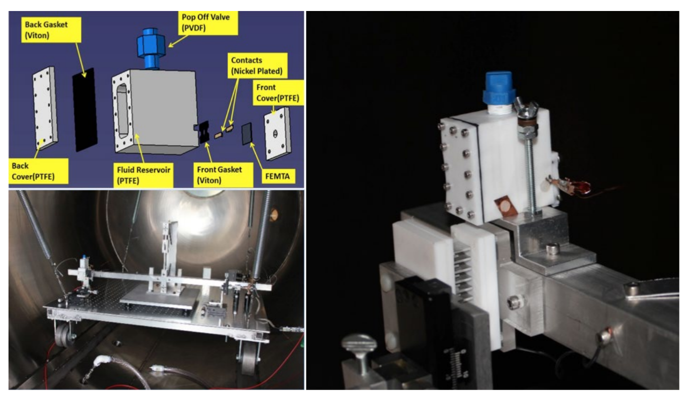

Figure 4. Test vessel schematic (top); mounted on a microNewton thrust stand (bottom); close-up (right)

For more information about the SSTP, visit:
http://www.nasa.gov/smallsats

For more information about this project, please contact:

Alina Alexeenko
Associate Professor
School of Aeronautics and Astronautics
Purdue University
alexeenk@purdue.edu

Eric Cardiff
Propulsion Engineer
Goddard Space Flight Center
eric.h.cardiff@nasa.gov

Andres Martinez
Small Spacecraft Technology Program Manager
Space Technology Mission Directorate
NASA Ames Research Center
Andres.Martinez@nasa.gov

Andrew Petro
Small Spacecraft Technology Program Executive
Space Technology Mission Directorate
NASA Headquarters
Andrew.J.Petro@nasa.gov

National Aeronautics and Space Administration

Ames Research Center
Moffett Field, CA 94035

www.nasa.gov