# ME – PhD Thesis Defense

## A capillary-fed evaporative microthruster for micro/nano satellites

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## ABSTRACT

Small satellites offer a unique platform for short-term and low-cost communications and surveillance missions. Despite their potential, small satellites face significant challenges, particularly in propulsion, due to their compact size, weight limitations, and restricted power availability. Addressing these challenges is crucial to unlocking their full potential and expanding their range of applications in the space industry.

The study explores the development, fabrication, and experimental characterization of a capillary-fed evaporative microthruster. Initially the microthruster was developed using MEMS based silicon device using standard photolithography technique in the cleanroom at CENSE, IISc. This MEMS-based vaporizing liquid microthruster utilizes microtextured silicon substrates for passive propellant (water) feeding via capillary force and subsequent thin film evaporation through localized heating. The generated vapor flows through a converging nozzle to produce thrust. The first part of the thesis details the microfabrication techniques employed in creating various generations of silicon devices, their experimental characterization, and the performance estimation of the microthruster using a developed numerical model. The numerical model presents a unique way of integration of evaporation characteristics at the liquid-vapor interface with compressible flow dynamics 3D micro-nozzle. The developed method can act as compressive technique for estimating performance of any kind of Silicon-Based Vaporizing Liquid Microthruster. The results show that the proposed device can generate a thrust of approximately 60 μN and an ISP of around 67 seconds with a power input of approximately 3W.

The second part of the thesis provides design, fabrication, and experimental characterization of a millimeter scale microthruster. The microthruster consists of a reservoir, evaporation chamber, and a capillary wick. The capillary wick enables passive transport of the propellant (deionized water) from the reservoir to the vapor chamber, where the water evaporates upon the application of electric heating. The generated vapor is expelled through a nozzle in the evaporation chamber to generate thrust. Pressure and temperature measurements in the evaporation chamber along with side-view imaging, facilitate real-time monitoring to understand the device's behavior at different input power under vacuum conditions (~ 50 Pa) of the ambient. We present the relevant design parameters of the microthruster device to mitigate issues such as two-phase boiling, water ejection or ice formation, which are detrimental to the performance of vaporizing liquid microthrusters. We show that the evaporative microthruster can achieve thrust ranging from approximately 200 μN to 820 μN, with a specific impulse of around 100 seconds, for power input of 0 W to 3 W.

The last part of this work focuses on the design, fabrication, and calibration of a torsional pendulum-type thrust stand. The calibration results reveal that the thrust stand can measure thrusts ranging from 30 μN to 340 μN. The thrust stand's measurement capability can be easily adjusted by changing the length of the cross-arm, making it scalable and suitable for both silicon and acrylic-based microthrusters.

## ABOUT THE SPEAKER

Akshay Sharma is a PhD student in the Department of Mechanical Engineering at IISc Bangalore. He completed his M. Tech in Thermal Science and Engineering from the IIT Bhubaneswar in 2018. He then joined IISc Bangalore as a PhD student in 2018 and got a Prime Minister's Research Fellow (PMRF) scholarship in 2020. His research interests include fluid mechanics, heat transfer and CFD. Currently he is working as Manager: Thermal Management of EV at Ola Electric.