FY24 Topic Areas Research and Technology Development (TRTD)

Advancing Electric Propulsion Technology with 3D Printing (AdEPT3D)

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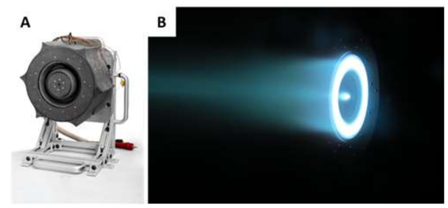
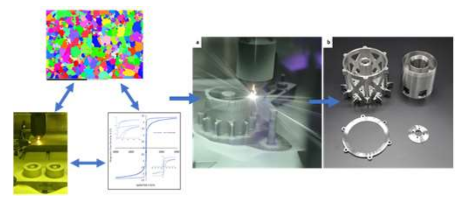
Strategic Focus Area: Additive Manufacturing, Multifunctional Systems

Objective: The objective of this work is to demonstrate integrated thermal management technologies to enable the H10 Hall thruster to operate at more than twice the power density of state-of-the-art (SOA) flight thrusters.

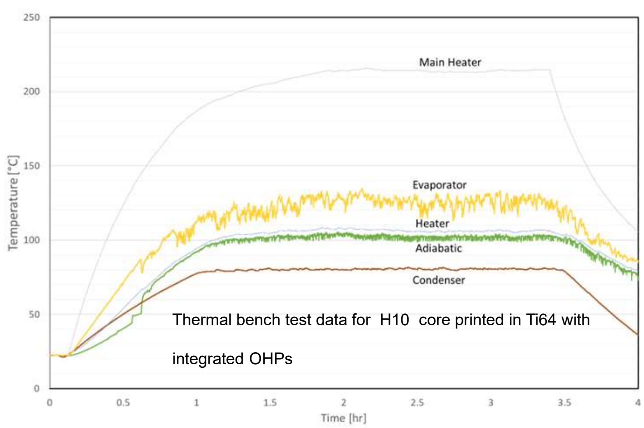


Photographs of (A) H10 Thruster and (B) H10 thruster test

Background JPL is developing a low-cost, low-mass, 10-kW (H10) Hall thruster that features deep power throttling (50:1), high specific impulse (Isp = 3000 s), and long-life magnetic shielding technology [1-2]. A key feature of the H10 thruster is operation at high power densities (2x SOA) which severely stress current thruster thermal management methodologies. Processes for additively manufacturing Hiperco®, the alloy used for magnetically shielded Hall thrusters, have recently been developed by this team [3,4]. Simultaneously, methods to integrate channels that can accommodate single or 2-phase thermal systems into structures via additive manufacturing have also been developed [5]. By combining these technologies, the low effective thermal conductivity of Hiperco® structures could be increased by at least a factor of 20, from 30 W/m-K to over 600 W/m-K.



Previous additive manufacturing development of Hiperco®, MaSMi Hall thruster components



Thermal bench test data for H10 core printed in Ti64 with integrated OHPs

Approach and Results: We developed and calibrated detailed thermal and magnetic models for the H10 thruster and performed trade studies to inform design and integration of OHPs into a thruster core, showing dramatic decreases in the operating temperature of critical components without compromising magnetic shielding performance. We also designed, printed and thermal bench tested a full scale H10 thruster core with integrated OHPs in Ti64 demonstrating effective thermal conductivities ~100 times higher than the base Ti64 material.

Significance of Results/ Benefits to NASA/JPL: This technology will enable ultra-compact, high-performance thrusters that expand the range of unique JPL propulsion capabilities that are needed to sustain JPL's competitive advantage in electric propulsion for our most ambitious missions.

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References:

[1] Hofer, R. R., "Development and Characterization of High-Efficiency, High-Specific Impulse Xenon Hall Thrusters," Ph.D. Dissertation, Aerospace Engineering, University of Michigan, Ann Arbor, MI, 2004.

[2] Mikellides, I. G., Katz, I., Hofer, R. R., and Goebel, D. M., "Magnetic Shielding of Walls from the Unmagnetized Ion Beam in a Hall Thruster," Applied Physics Letters 102, 2, 023509 (2013).

[3] Firdosy, S., et al "Processing-Microstructure-Property Relationships in a Laser-Deposited Fe-Co-V Alloy" Advanced Engineering Materials, 2021

[4] Firdosy, S., et al "Compositionally graded joints between magnetically dissimilar alloys achieved through directed energy deposition" Scripta Materialia, 2021

[5] Odagiri, K., et al "Three-dimensional heat transfer analysis of flat-plate oscillating heat pipes" Applied Thermal Engineering, 2021