Applied Ion Systems

AIS-TR-023

AIS ADAMANT Series Development

Preliminary Sublimation and Ionization Test #2 of Adamantane Fuel for Ultra-Low Power Micro-Ion Thruster Systems - 01/12/2021

Test Report and Summary

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I. BACKGROUND

The AIS ADAMANT Series thrusters leverages Adamantane, a diamandoid hydrocarbon which exhibits many unique properties allowing for the potential of extreme power and size miniaturization of conventional gas-fed electric propulsion systems, with significantly reduced toxicity and no known corrosion issues like its similar and highly explored cousin Iodine. Currently, the ADAMANT Series is focusing on the development of highly integrated and modular micro-Hall thrusters run purely on sublimated Adamantane fuel. Total system power depending on the thruster is currently aimed from 5W up to 20W for the smallest class systems, with the ability to scale up to more conventional 50W class systems. Despite its unique potential as an alternative molecular propellant for conventional gas-fed EP, little work has been done on Adamantane for use as a fuel in the field.

While Adamantane has been tested a couple of times in literature, this has only been done at much higher power levels in larger gridded ion thrusters at hundreds of watts to kW class systems. Despite successful operation at higher power levels, with performance similar to Xenon, Krypton, and Iodine, Adamantane has been largely dismissed in literature without custom modifications to the chemical composition to overcome some of the inefficiencies inherent to the fuel, and overall testing in the field has been practically non-existent otherwise. Due to its many attractive properties however, such as solid storage, ease of sublimation, high ionization cross-section, high molecular weight, low cost, non-corrosiveness, and low-toxicity, Adamantane has been identified as a key technical enabler in meeting the unique challenges being addressed and inherent limitations in funding and infrastructure at AIS, and fully embraced as the central focus of new development efforts at AIS through the ADAMANT Series, which leveraging the unique properties of Adamantane to overcome conventional scaling limitations in EP technology such as Hall thrusters.

II. OVERVIEW

The goal of this second preliminary sublimation and ionization test was to further continue simple low-power sublimation and ionization experiments from the first test, exploring just how low total power is required to sustain a stable plasma discharge, gauging the viability of this fuel for very low-power ion thrusters. In the prior test, heater power of 3.5W was applied to the fuel sublimator, with glow discharge initiated at 1.5kV using 2W of discharge power. However, prior to ignition, significant gas load was still observed from the Adamantane fuel even at low background chamber temperatures of around 12C. This test aimed to see if stable discharge could be initiated on purely passively sublimated Adamantane vapors without any additional heater power, and at similar discharge power levels at higher discharge voltage.

While Adamantane has been successfully tested a couple of times in the field prior, this has been only conducted at high power levels of hundreds of watts to several kW in conventional gridded ion thrusters. Looking at currently available limited data, and drawing extrapolations from these test results and basic principles of related EP systems and other alternative fuels, AIS proposes that Adamantane can allow for unprecedented scaling of conventional gas-fed EP technologies, allowing for low-power operation and unpressurized feed for the smallest class of satellites in the field. With significantly less toxicity, and no corrosion issues like Iodine, Adamantane has further potential for much greater total system cost reduction using conventional materials in the design of the Hall thruster, neutralizer, and propellant feed system. The first preliminary test has already confirmed the initial hypothesis that very low power is needed for a system to run fuel delivery and ionization of Adamantane. AIS is currently the first and only EP company in the world specifically developing Adamantane-fueled EP systems through its AIS ADAMANT Series development initiative.

III. PRELIMINARY SETUP

Preliminary setup for this test followed the same procedures as described in *AIS-TR-022*. >99% purity Adamantane was used, crushed into individual granules, and loaded up into the sublimation chamber.

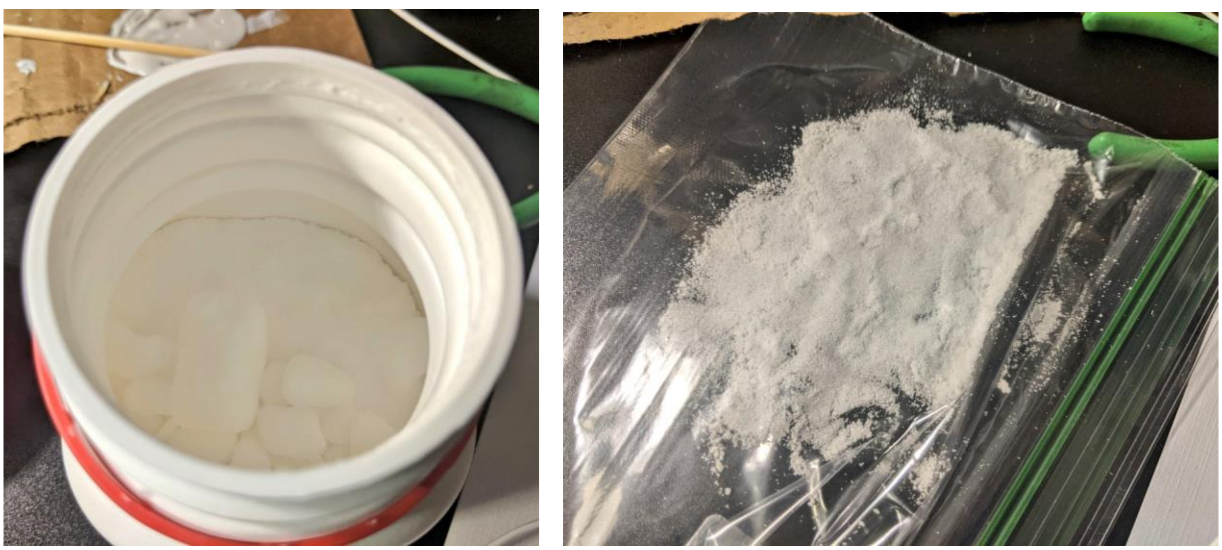

FIGURE 1: *Adamantane preparation for loading into the test cell*

The test cell assembly also remained the same as the prior test. See *AIS-TR-022* for further details on the build and setup of the sublimation and ionization cell.

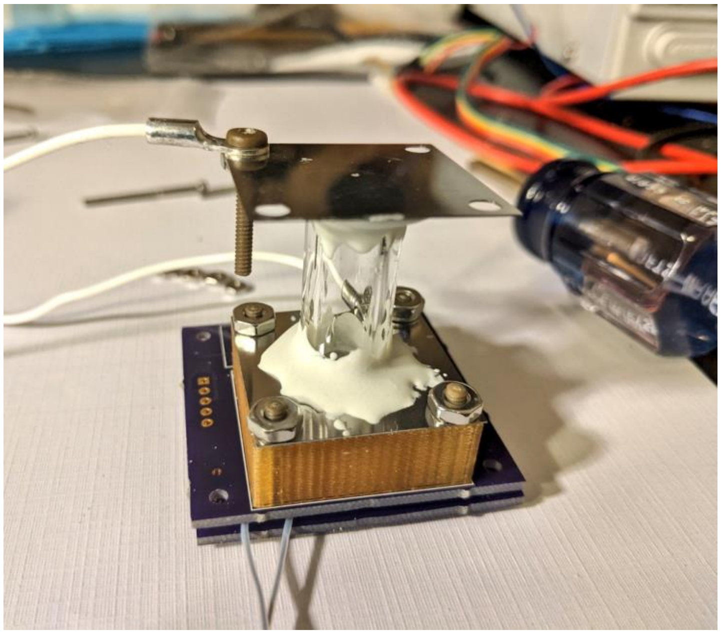

FIGURE 2: *Completed and assembled prototype sublimation and ionization test cell*

The original 2W, 1.5kV Pico supply that was used in the first test was switched out for a 2W, 3.5kV Pico supply. Electrode polarity remained the same, with the lower electrode held at ground potential, and the upper electrode at HV. The entire assembly was wired up and mounted in the chamber.

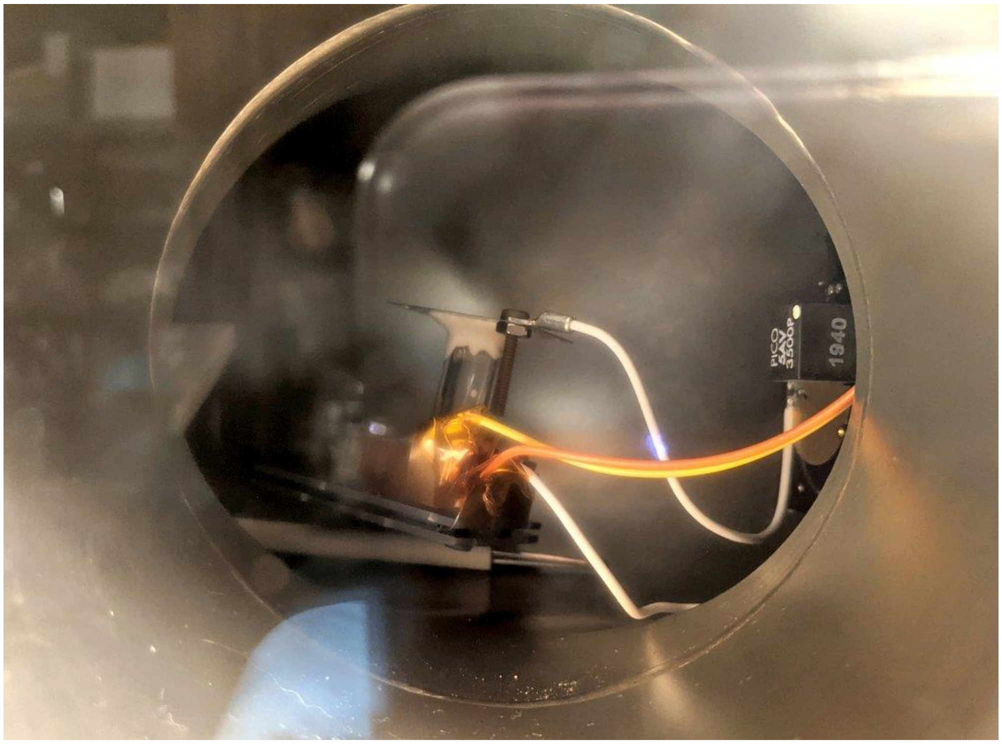

FIGURE 3: *Mounting of the test cell in the high vacuum chamber for testing*

IV. TESTING

Like the first test, pumpdown was slow and reached an ultimate vacuum level in the mid-10^-4 Torr range prior to ignition attempts. Once this ultimate vacuum was reached, the HV supply was turned on, and slowly brought up. At around 1.5kV, and a faint glow discharge was observed. Power at this point was only 0.75W, and the temperature of the chamber was only 11-12C. Since a very light glow discharge was established, power was further increased. At 2kV, power draw was around 0.97W, with the discharge increasing in brightness. Power was eventually raised to 2W, with the final measured discharge voltage at 2.3kV on the test cell, sagging down from the maximum 3.5kV rating of the power supply. Power was repeatedly cycled on and off, with smooth and reliable re-ignition on each cycle at full power.

The discharge was allowed to run until fuel depletion, evident by a decrease in vacuum levels in the chamber, as well as extinction of the plasma. Throughout the entire run, the plasma discharge was very stable. At the top aperture plate where the positive HV was applied for the plasma discharge, a very small plasma plume was observed like in the prior test. By the end of the test, ambient background temperature in the chamber had risen to 15C from its initial 11C starting point.

Video of operation of the test cell and successful ionization can be viewed on the AIS website and AIS YouTube page.

FIGURE 4: *Successful Adamantane plasma glow-discharge at 2W discharge power on purely passively sublimated Adamantane vapors from ambient background of 11-15C*

V. POST-TEST ANALYSIS

After the test, the test cell was removed from the vacuum chamber for inspection. Complete sublimation of the Adamantane fuel was confirmed, with similar levels of minimal buildup and fuel charring around the bottom electrode plate. The erosion pattern around the output aperture of the upper electrode plate had also not significantly changed from prior testing. See *AIS-TR-022* for further details and example pictures from the prior test.

VI. CONCLUSION AND FUTURE DEVELOPMENTS

The second preliminary sublimation and ionization test of Adamantane fuel in vacuum has been successfully completed. In this test, ionization was successfully demonstrated on purely passively sublimated Adamantane vapors at chamber background temperatures from 11-15C without any additional heater power applied to the fuel sublimator. In addition, successful glow discharge was initiated from 0.75W at 1.5kV, to 2W at 2.3kV.

The results of this test further validate the hypothesis that stable discharge can be initiated and maintained at not only very low discharge power, but very low total system power as well, with minimal temperature required to sublimate the Adamantane in vacuum to create enough gas load for discharge to occur. In addition to discharge stability, like in the prior preliminary test the Adamantane plasma has shown the ability to be easily and reliably reignited at very low power levels at reasonable voltages. This further exemplifies the fact that Adamantane is incredibly easy to sublimate for very low-power unpressurized fuel deliver, and can be readily ionized to create a discharge plasma for micro ion and plasma thrusters at minimal power levels, suitable for small Cubesats and even PocketQube class systems.

Based on this and the prior test results, AIS will be moving forward in full force on the development of the first Adamantane fueled micro-Hall thruster, as well as preparing for modified testing of the original test cell to explore the concepts of operation of a novel ultra-low-power glow-discharge hollow-cathode neutralizer.